(Revised final version)

National Cyclone Risk Mitigation Project (NCRMP)

National Disaster Management Authority (NDMA)

Consulting Services for Hazard, Risk and Vulnerability Assessment for 13 states and UT's in India

Exposure and Vulnerability Assessment Report for Andhra Pradesh and Odisha

October 2015

Submitted by

RMSI
A-8, Sector 16
Noida 201301, INDIA
Tel: +91-120-251-1102, 2101
Fax: +91-120-251-1109, 0963
www.rmsi.com

Contact: Pushpendra Johari
Team Lead
Email: pushpendra.johari@rmsi.com




For the attention of:

The Project Director
National Cyclone Risk Mitigation Project (NCRMP)
National Disaster Management Authority (NDMA)
A1, Safdarjung Enclave, NDMA Bhawan
New Delhi -110029

Company Information:	
Name	RMSI Private Limited
CIN	U74899DL1992PTC047149
Registered Office Address	SEATING 3, UNIT NO. 119, FIRST FLOOR, VARDHMAN STAR CITI MALL, SECTOR-7, DWARKA NEW DELHI Delhi-110075, INDIA
Corporate Office Address	A-8, Sector-16 NOIDA, 201 301,India Tel:+91 120 251 1102, 251 2101 Fax:+91 120 251 1109, 251 0963 E-mail: info@rmsi.com

Acknowledgements

We appreciate the special efforts put forth by the Project Management Office NCRMP, Mr. B. Pradhan, Joint-Secretary, NDMA,, Mr. S.S Jain Deputy Project Director, Mr. P.E. Narayanan, Project Manager, and Dr. S. Asta Lakshmi, Environmental Specialist in contacting the State Nodal officers and some of the key national organizations like Forest Survey of India (FSI), Survey of India (SOI), and National Hydrographic Office (NHO), Dehradun; India Meteorological Department (IMD) and Census of India, New Delhi; National Remote Sensing Centre (NRSC) and Indian National Centre for Ocean Information System (INCOIS), Hyderabad. We would also like to thank all the State Nodal Officers and other national organizations for providing required support and data for this assignment.

We extend our special thanks to Mr. Saurabh Dani, Senior DRM Specialist, the World Bank, Washington DC, and Mr. Deepak Singh, the World Bank, New Delhi for their kind help in providing official RDNA reports of Cyclone Hudhud and Phailin and useful discussions at different stages of this project.

Executive Summary

Exposure is a critical component of any risk model. Exposure constitutes the population, the built environment, the infrastructure, and/or any other elements present in hazard zones that are thereby subject to potential losses.

The initial steps in exposure development are data collection and processing of the collected data. The main elements of exposure in this study are population and households, residential buildings, and other non-residential buildings that include commercial, industrial, religious and cultural heritage sites. Apart from these, infrastructural facilities have been considered under five broad headings, namely essential facilities (schools and health facilities), public buildings (administrative headquarters, fire-stations, police stations and safe shelters), transportation system (roads, railways, bridges on roads and railways, airports and seaports), utility systems (waste water, potable water, electricity, communication, and oil and gas pipelines), and critical infrastructure (power plant and sensitive installation). Besides these, to assess the impacts of cyclone, storm surge, and cyclone induced rainfall flooding, a database of crops, coastal plantations, and mangroves has also been compiled as a part of exposure development.

The key data sources used in developing the exposure database are as follows:

- Survey of India (SOI) for administrative boundary and site specific data
- Census of India (2011 vintage) for population at ward/village level, housing tables in absolute numbers at city level in urban areas and at district levels for rural areas; housing tables in percentage at ward- and village-levels, and occupancy tables at city level in urban areas and at district levels for rural areas
- Forest Survey of India (FSI) for coastal plantations and mangroves data
- Department of Agriculture and Cooperation, Ministry of Agriculture for agriculture data
- State departments for state-specific data
- RMSI in-house data and online sources to fill the gaps in the existing data

This report also focuses on establishing a relationship between the potential damageability of critical exposure elements and different levels of hazard intensity for the perils of interest in this study through physical vulnerability analysis. Physical vulnerability refers to the degree to which an asset would undergo damage or be destroyed in a hazardous environment caused by catastrophic events. Physical vulnerability assessment involves quantifying the damage susceptibility of each asset class with respect to hazard parameters of each peril. On the other hand, social vulnerability refers to the incapability of people, organizations, and societies to endure adverse impacts from disasters to which they are exposed.

Damage susceptibility associated with a given level of hazard is measured in terms of a mean damage ratio (MDR) defined as the expected proportion of the monetary value of repair needed to bring back the facility to pre-event condition, over the replacement value of the facility, as a consequence of the hazard. The curve that relates the MDR to the hazard is called a vulnerability function. Vulnerability functions have been developed for various assets for different perils, using analytical/synthetic and statistical methods complemented with expert engineering or heuristic judgment based on local and/or international experiences.

Key Steps on Exposure Data Development

The important step in exposure development is to analyze the processed data for gaps and to use time-tested methods to fill the identified gaps. Based on the gaps identified, appropriate approaches are applied. The major gaps could be categorized into missing location information, missing building typology, missing replacement costs, and in certain cases, a complete lack of data regarding particular exposure types.

The demographic data is available at ward/village level. Using the population growth rate, the population data of 2011 is projected to year 2014 for urban areas at ward and city levels (however, due to non-availability of ward level boundaries, the analysis is restricted to city level) and at village level for rural areas.

Similarly, 2011 household information providing the details of number of households is also projected to 2014. Finally, all the data is compiled for developing the demographic exposure database.

RMSI's approach for quantifying building exposure is based on the "bottom-up" approach. This includes classifying the different types of buildings into different categories, estimating the number of buildings under each category, combining building counts with per unit built-up floor area, and applying costing information relevant to the conditions. The output of building exposure is the total monetary value by asset category.

Data provided by the Census of India (2011) based on occupancy type is limited to building counts at city/district level. As a result, the quantification of exposure data pertaining to buildings became a challenging and complex process mainly because of missing location information and unavailability of replacement costs of each of the identified typologies.

The building location information is derived mainly using satellite images as building clusters for residential, commercial, and industrial buildings. To delineate buildings based on structural details, the team considered the wall and roof material combinations derived from Census 2011 at city/village level. The Census (2011) provides 90 combinations based on the predominant materials of roof and wall. These combinations have been further grouped into 25 combinations based on the vulnerability of buildings to different hazards presented in Table 8-5 of Annex 8.1. Table E 1 presents the six predominant building structural classes that are mainly available in the study area of Andhra Pradesh and Odisha. All these structural classes have been validated through sample-field verification surveys and considered for customizing the vulnerability functions.

Table E 1: Predominant building structural categories by construction materials

Sl. No.	Building Category	Structural Types (combination of major wall and roof materials)
1	ST4	Grass/ thatch/ bamboo/ wood/ plastic/ polythene etc. used as roof material in combination of burnt brick/ stone packed with mortar/concrete as wall materials
2	ST6	Handmade tiles/ machine made tiles/burnt bricks/stone/slate/concrete used as roof material in combination of Grass/thatch/bamboo etc. as wall material
3	ST8	Handmade tiles/ machine made tiles used as roof material in combination of stone packed with mortar/burnt brick/concrete as wall material
4	ST16	G.I./Metal/Asbestos sheets used as roof material in combination of Stone packed with mortar/ burnt brick/ concrete as wall material
5	ST17	Concrete used as roof material in combination of Mud/unburnt brick/Stone not packed with mortar as wall material
6	ST18	Concrete used as roof material in combination of Burnt brick/Stone packed with mortar/Concrete as wall material

Based on the unit replacement cost provided by Central Public Works Department (2012) Andhra Pradesh Municipal Asset Methodology Valuation Manual (2012), National Municipal Asset Valuation Methodology Manual (2007) and inputs from RMSI field sample verification survey (2015), unit replacement cost of buildings for each occupancy type has been derived. Finally, after careful review and analysis by RMSI expert team, the average unit replacement costs for each type of buildings has been derived (Table 3-15).

The sources of police stations data in the study area are SOI and online sources. The data gaps are primarily in the areas of structural types, floor area, and replacement costs that were filled using literature survey, sample field-verification survey, and secondary data. The source of data for fire stations is the State Fire Service and emergency services. The data gap for fire stations is primarily in the area of replacement costs that are filled-in using literature survey, sample survey, and secondary data.

The data that could be collected for administrative headquarters and cyclone shelters is also patchy (lack geospatial location and building attributes). Using online sources, a list of administrative headquarters in the study area has been compiled for Andhra Pradesh. In the absence of exact spatial data for administrative headquarters, point data has been generated at city/town level. Similarly, using Revenue Disaster Management, Govt. of Andhra Pradesh[1] website, data for 1,000 shelters has been downloaded for Andhra Pradesh. Out of these, 234 cyclone shelters could be geocoded at village level. In Odisha, the data for cyclone shelter received from Odisha revenue and disaster management department. This data contains 134-cyclone shelters geospatial location. The data lack in structural details, floor area, capacity that were filled using literature survey, sample survey, and secondary sources including NDMA NCRMP website.

For transportation infrastructure, the prime source of data is SOI. The data gaps have been filled using RMSI in-house data, high-resolution satellite images, and online sources. In order to estimate the replacement costs, unit costs of various component of transport infrastructure were determined by taking inputs from the Pradhan Mantri Gramin Sadak Yojna (PMGSY)[2], National Highway Authority of India (NHAI)[3], Public Works Department (PWD)[4], International Railway Equipment Exhibition (IREE)[5], Indian Railways[6] website, and Planning Commission. In order to estimate the replacement costs of airports, unit cost of the built-up area as well as the unit cost of the runway was determined by taking inputs from online sources (Airport technology.com)[7]. For estimating the replacement costs of seaports, cost for developing one berth of the port was determined from online sources.

In the Utilities category, the spatial data for wastewater and potable water system is not available from any of the sources. Census (2011) provides village-level percentage of household having open and closed drainage systems and tap water from treated and untreated sources. Using these percentages, approximate lengths of wastewater and potable water systems has been estimated using the road network data assuming that drainage network is distributed along the roads.

In the case of communication infrastructure, city and village level data on the number of mobile and landline connections are available. The exposure value of communication systems has been estimated using the number of mobile and landline connections in the study area.

The electric line network has been received from SOI but it lacks continuity, and details of electric sub-stations, as well as having a bit older vintage of 2005 or earlier. Therefore, using data present in the open street map, gaps for electric transmission lines have been filled. In order to estimate the replacement cost of the electric power network, unit cost of the electric. line has been determined by taking inputs from the Western Electricity Coordination Council (WECC).

---

[1] http://disastermanagement.ap.gov.in/website/shelters.htm
[2] http://pmgsy.nic.in/achiev_bhanirm.htm
[3] http://www.nhai.org/completednh2.asp
[4] ttps://pwddelhi.com/UI/Home/SectorWiseReport.aspx?enc=9J3T0Ky+opEjCrT08q8UfA
[5] http://www.ireeindia.org/RE%20Booklet.pdf
[6] http://www.nr.indianrailways.gov.in/view_detail.jsp?lang=0&dcd=3265&id=0,4,268
[7]http://www.airport-technology.com/projects/indira-gandhi-international-airport-terminal-3/

None of the sources has provided data for oil and gas pipeline. Therefore, a map of India Energy Infrastructure[8] from online sources has been used as reference. This map has spatial distribution of the oil and gas infrastructure in India. The length of oil and gas pipelines has been estimated based on this map in the study area of Andhra Pradesh and Odisha. In order to estimate the replacement cost of the oil and gas pipeline network, unit cost of oil and gas pipelines has been determined by taking inputs from open source[9].

Critical infrastructure consists of power plants, sensitive installations, and hazardous industries. Data for power plants and sensitive installations have been developed using online sources[10]. Using high-resolution satellite images, power plants and sensitive installations have been captured as point locations. The list of major and hazardous industrial facilities has been taken from Andhra Pradesh pollution control[11]website. For Odisha, the list of major and hazardous industrial facilities has been taken from Ministry of Labour and Employment, Government of India website. Using high-resolution satellite images, major and hazardous industrial facilities, power plants, and sensitive installations have been captured as point locations. The exposure value of Critical infrastructure has been taken from a few online sources.

Data for major agriculture crops constitute one of the primary exposure elements. Due to unavailability of village-level crop data, district level crop data (source: Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India) are disaggregated at village level using Land Use Land Cover (LULC) maps of LISS III satellite data, available in-house. Fraction of agricultural area in each village with respect to district level total agricultural area is calculated and subsequently district-level total observed normal acreage is distributed among the villages as per this fraction.

GIS data for coastal plantations and mangroves has been received from FSI, which is of 2013 vintage.

Key Findings on Exposure Data Development

The Table E-2: provides details of estimated values for aggregated and site-specific exposures in the study area for Andhra Pradesh and Odisha.

Table E-2: Estimated exposure values for aggregated and site specific exposures

		Andhra Pradesh	Odisha
Sl. No.	**Exposure Layer**	**Total Replacement Cost (in crores)**	**Total Replacement Cost (in crores)**
1	Residential	695,804	77,387
2	Commercial	30,688	24,663
3	Industrial	33,440	17,663
4	Educational institutions	30,080	26,860
5	Health facilities	2,880	2,702
6	Religious places	1,950	2,229

[8] http://www.eia.gov/todayinenergy/detail.cfm?id=10611

[9] http://www.yourarticlelibrary.com/india-2/pipeline-6-major-pipelines-of-india/19721/

[10] http://www.apgenco.gov.in , http://www.gvk.com/ http://www.spgl.co.in/

http://www.meenakshigroup.com

[11] http://www.appcb.ap.nic.in/main/index_flat1.php

		Andhra Pradesh	Odisha
Sl. No.	Exposure Layer	Total Replacement Cost (in crores)	Total Replacement Cost (in crores)
7	Police Stations	218	39
8	Fire Stations	22	55
9	Administrative Headquarters	291	166
10	Cyclone Shelters	920	48
11	Airports	2,775	912
12	Bridges	24,803	18,227
13	Railway bridges	4,963	3,063
14	Railway Lines	19,169	4,592
15	Roads	37,587	24,175
16	Sea Ports	20,000	7,600
17	Oil and Gas	4,452	1,584
18	Potable Water	11,801	1,684
19	Waste Water	8,050	2,682
20	Communication System	6,048	4,087
21	Electric Power Network	18,434	10,906
Grand Total		954,375	231,324

The SoVI map shows high social vulnerability in Krishna, Vishakhapatnam, Vizianagaram and Srikakulam districts. Coastal villages of these districts are showing high index and is mainly attributes to high population density and low density of infrastructure - roads and hospitals. The West and East Godavari and Sri Potti Sriramulu Nellore districts has majority of the villages with medium SoVI and Prakasam and Guntur has villages mostly with low SOVI. Prakasam district interestingly has all the villages with low SoVI, which means having high resilience. This is mainly because of low population density and people are mainly depending on secondary and service sector for livelihood.

The SoVI map of Odisha shows a quite different pattern compared to that of Andhra Pradesh, which is highly influence by the population distribution. The northern part of the State – Mayurbhanj and south district - Puri and Cuttack districts has majority of the villages with high SOVI. Bhadrak and Ganjam have relatively less number of villages with high SoVI. Some of the coastal villages of Odisha particularly Bhadrak has coastal villages (villages with seacoast) with less population density and are showing low SoVI. Many of the villages in Odisha have poor road and health facilities and is a key reason for having high SoVI. North of Chilka Lake in Puri district has large number of village predominantly engaging in fisheries and has high SoVI.

Data Limitations

The objective of this section is to introduce the reader to the assumptions applied as part of exposure development and their impact. As discussed above data collected from various sources had gaps and RMSI team tried to fill these gaps in the source data by applying secondary data and data processing techniques. In this process, we had to make some assumptions and decisions that may affect the exposure quantification. It may be noted that limitations related exposure quantification and paucity of authentic replacement values in certain categories would affect the final risk values that are to be derived as part of this study. Following are the key assumptions for exposure and vulnerability function development:

- **Mismatch in village name and extent:** A significant issue encountered throughout the development of exposure information was mismatch in village name and extent. The village boundary information has been collected from various sources. There are differences in alignment and name of villages when each data set compared to the others. Since Census 2011 is the latest vintage data, hence Census 2011 Atlas is used as reference to modify SOI village boundary to attached census tabular data at village level.

- **Vintage of the Data:** The source of many exposure elements is SOI and their vintage dates back to 2005. Using online sources, SOI data sets have been updated based the availability of particular data set.
- **Geo-positional accuracy:** Since SOI and data from many sources are created at low-resolution maps so these data would not be located exactly on high-resolution map.
- **Data from alternative sources:** There are a few datasets, such as administrative headquarters, major and hazardous industries, power plants/sensitive installations and, oil and gas are not available from any of the authorized sources. In such cases, online available data has been used to estimate the exposure value. For these, RMSI team utilized online sources for their details.
  Similarly, spatial data for potable and waste water system is not available from any of the sources but census provides village level percentage of tap water connection and drainage system. Using this percentage, approximate length of potable and waste water system has been generated using the road network data assuming that potable and wastewater network is distributed along the road network.
- **Mapping of structural classes:** For building structural classification, this study relies on census data. Census provides percentage for roof and wall type separately at village level. To determine the structural type of buildings, both roof and wall percentage are combined. There is no detailed classification available for concrete building, which may be a reinforced cement concrete (RCC) frame structure or unframed structure etc. Based on the sample field verification checks and using high-resolution satellite images, further percentage of various categories of concrete buildings are defined.
- **Replacement costs:** Only for a few exposure elements, replacement cost is available from the authentic sources. To estimate the replacement cost of remaining exposure element information from online sources have been used with expert judgment.

It may be noted that limitations related exposure quantification and paucity of authentic replacement values of exposure assets in certain categories would affect the final loss values that are to be derived as part of this study.

As a way forward, for effective exposure data management it is important to have:

- The data archiving and sharing is very poor among various government agencies, which not only contributes to delays in completion of a study but also hampers its quality. All State/Central government agencies should be encouraged to share data freely for national interest. This warrants revision in the 'National Map Policy of 2005'
- There should be a 'GIS-based centralized national repository' of all the exposure data and can be align to the national initiatives of National Spatial Data Initiative (NSDI). It would not only help in Disaster Risk Management but also in holistic planning and development of infrastructure in the future and modification/retrofitting of existing infrastructure
- Updating of exposure data should be carried out at regular intervals, ideally every year or at least one in 5 years
- Building level data should be developed for major cities with key attributes like location, structural type, built-up area, replacement cost, use, height/number of stories, foundation type, basement, ground floor elevation. This will significantly improve the result of risk assessment process in future.

Table of Contents

List of Figures

List of Tables

Abbreviations Used

Abbreviation	Expanded Form
AHP	Analytical Hierarchy Process
APTD	Andhra Pradesh Transport Department
BHPV	Bharat Heavy Plate and Vessels Limited
BSNL	Bharat Sanchar Nigam Limited
CIA	Central Intelligence Agency
CPWD	Central Public Works Department
CT	Census Town
GDP	Gross Domestic Product
GI	Galvanized iron
GIS	Geographic Information System
GOI	Government of India
GPS	Global Positioning System
HVRA	Hazard Vulnerability and Risk assessment
IIR	India Infrastructure Report
IMD	Indian Meteorological Department
INCOIS	Indian National Centre for Ocean Information System
INR	Indian Rupees
IPHS	Indian Public Health Standards
IREE	International Railway Equipment Exhibition
ISO	International Organisation for Standardization
LISS	Linear Imaging Self Scanning Scanner
LULC	Land use/Land cover
MDR	Mean Damage Ratio
MHA	Ministry of Home Affairs
MSL	Mean Sea Level
NCRMP	National Cyclone Risk Mitigation Project
NDMA	National Disaster Management Authority
NHAI	National Highways Authority of India
NHO	National Hydrographic Office
NSSO	National Sample Survey Organization
OG	Outer Growth
OSDMA	Odisha State Disaster Management Solution
OSM	Open Street Map
PNDA	Post Damage Need Assessment
PCA	Principal component analysis
PMGSY	Pradhan Mantri Gramin Sadak Yojna
PWD	Public Works Department
RCC	Reinforced Cement Concrete
QA	Quality Assurance

Abbreviation	Expanded Form
QC	Quality Control
SOI	Survey of India
SoVI	Social Vulnerability Index
TRAI	Telecom Regulatory Authority of India
UID	Unique Id
UN	United Nations
USACE	U.S. Army Corps of Engineers
UT	Union Territories

Glossary of Terms

Terminology and Definitions

Capacity: The combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals.

Climate change: The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

Coping capacity: The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.

Critical facilities: The primary physical structures, technical facilities and systems, which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency.

Disaster: A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

Disaster risk: The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

Disaster risk reduction: The concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

Early warning system: The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.

Economic loss: The total monetary cost incurred, whether insured or not, because of a shock; total losses from a disaster that include direct and indirect losses as well as insured losses and those paid by all other sources (such as property owners and the public sector).

Emergency services: The set of specialized agencies that have specific responsibilities and objectives in serving and protecting people and property in emergency situations.

Exposure: People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

Hazard: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Mitigation: The lessening or limitation of the adverse impacts of hazards and related disasters

Probable Maximum Loss: A general concept applied in the insurance industry for defining high loss scenarios that should be considered when underwriting insurance risk.

Probabilistic Risk Model: A model that assesses the impact of a hazard and assigns probabilities to a whole range of possible outcomes.

Deterministic Model: A model that assesses the impact of a hazard by investigating the severity of a single possible outcome.

Return period: The expected length of time between recurrences of two events with similar characteristics.

Risk: The combination of the probability of an event and its negative consequences.

Risk assessment: A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

Risk Category: These are based on the estimated economic losses that have been divided into a few classes- very low, low, medium, high, and very high.

Structural measures: Any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structures or systems;

Non-structural measures: Any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education.

Susceptibility mapping: Spatial probability analysis using variables that are of influence.

Vulnerability: The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard

1 Introduction

1.1 Background

The Indian coast is highly vulnerable to natural hazards, particularly to severe cyclone and cyclone induced heavy rain and flooding. National Disaster Management Agency (NDMA) is taking initiatives to develop a proactive approach for the coastal states and UTs for integrating disaster mitigation in development planning.

The National Cyclone Risk Mitigation Project (NCRMP) is a pioneer project of the Ministry of Home Affairs (MHA), Government of India (GOI) and is being implemented through NDMA with the financial support of the World Bank. The aim of NCRMP is to create suitable physical infrastructure to mitigate/reduce the adverse effects of cyclones. Part of this involves the setting up of a web-based risk assessment system that will inform a risk management framework of decision makers in the States/UTs and the Central Government to take mitigation steps to protect the people and assets of the country.

This report is the 'Exposure and Vulnerability Assessment Report for Andhra Pradesh and Odisha' and has been prepared at the end of the exposure data development and vulnerability assessment phase.

1.2 Objectives of the Study

The objective of the study is to provide a robust scientific and practical basis for assessing qualitative and quantitative risk for cyclone hazard for the 13 coastal States/UTs of India. The main objectives of the study include:

- Develop standardized spatial databases, maps and a decision support framework for assessing the cyclone and related hydro-meteorological hazards, exposure, and vulnerability.
- Identify critical 'hot-spot' high vulnerability coastal areas for communities at-risk and develop detailed planning/mitigation and emergency response decision support mechanisms in 10 of the top identified "hot-spot" areas (enable support for land use planning, shelter locations, evacuation routing, and emergency and contingency planning within these hotspot communities).
- Developing a platform for dynamic risk assessment modeling functionalities that will be taken up subsequently under Phase II of the NCRMP Project. (Deterministic hazard and vulnerability data to risk modeling is being done for phase – I, Probabilistic risk modeling shall be done for phase – II).

1.3 Study Area

The study area includes the coastal stretches that lie up to 10m above Mean Sea Level (MSL) in the districts of the 13 States/UTs, which are vulnerable to cyclones. For the convenience of data access and subsequent project activities, we have considered all the talukas falling within the 10 m contours from the MSL. Even if only a portion of the taluka lies up to 10m above MSL limit, the entire taluka has been considered. The total number of talukas, which have land area up to the 10m above MSL limit, is 1,087; and the names of these selected talukas are provided in Table 8-35 in Annex 2 and are shown in the map below. The total area covered by these talukas is around 247,705 sq km.

These 13 States/UTs have been further grouped into two categories, based upon the frequency of cyclone occurrence, size of population, and the existing institutional mechanism for disaster management. The categories are as follows:

- Category I: Higher vulnerability coastal States/UTs, i.e., Andhra Pradesh, Gujarat, Orissa, Tamil Nadu, and West Bengal

- Category II: Lower vulnerability coastal States/UTs, i.e., Maharashtra, Goa, Karnataka, Kerala, Daman & Diu, Puducherry, Lakshadweep, and Andaman & Nicobar Islands.

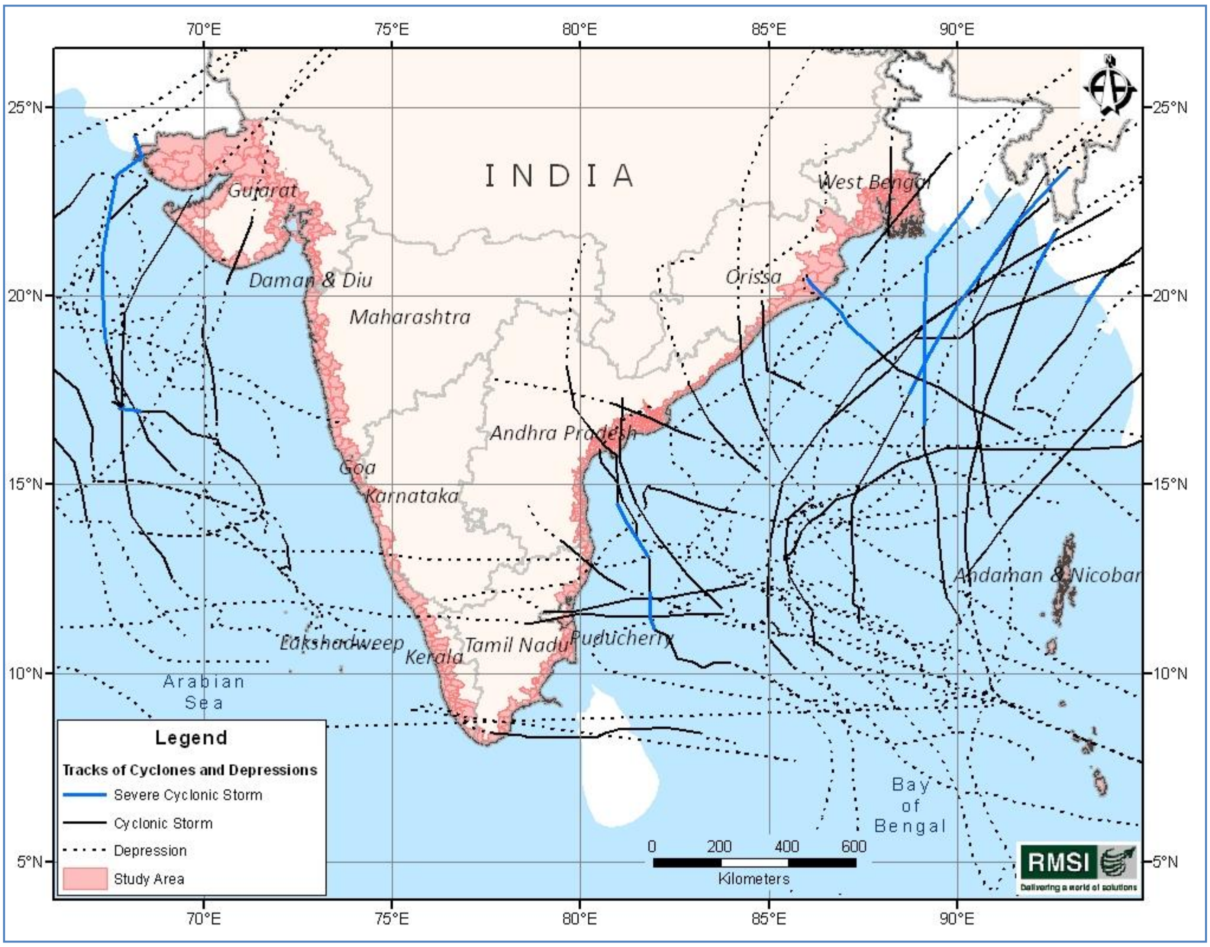


Figure 1-1: Coastal talukas of States/UTs with land area falling up to the 10m above MSL limit along with major cyclone tracks

1.4 Scope of this Report

This report is the fifth deliverable of the present study. It describes the exposure and vulnerability assessment carried out for Andhra Pradesh and Odisha states. The scope of this report includes:

- Development of exposure data
- Determination of replacement costs for assets
- Development of damage function for various exposure elements including agriculture assets
- Assessment of social vulnerability of population in the study area

1.5 Organization of this Report

The chapter wise synopsis of the report is presented below:

- Chapter 1 Introduction: (this section) provides an overview of the project and its objectives along with the scope of this report
- Chapter 2 Exposure and Vulnerability Data Sources: describes the data source used for exposure and vulnerability assessment

- Chapter 3 Methodology Adopted for Exposure and Vulnerability Assessment: describes the methodology followed for exposure data development and vulnerability assessment
- Chapter 4 Results and Findings for Andhra Pradesh: details the results and findings of exposure data and vulnerability functions for Andhra Pradesh
- Chapter 5 Results and Findings for Odisha: details the results and findings of exposure data and vulnerability function for Odisha
- Chapter 6 Progress on the Web Atlas Development and Testing: presents the work progress on Web Atlas development
- Reference: Key documents and website refered for this document
- Annex: provide detailed data used for various analysis and field survey photographs.

2 Exposure and Vulnerability Data Sources

The resolution of any risk assessment study largely depends on the availability and scale of exposure and vulnerability data preferably in geospatial format. The exposure data was collected and collated from various sources including State Government Departments, Central Government Departments, Public Sector Corporations, international funding agencies (World Bank, Asian Development Bank, etc.) as well as various private agencies working. The below sections present the data requirement for exposure and vulnerability assessment, data availability and sources, key data gaps, and alternate data sources used to fill those gaps.

2.1 Exposure Data Availability and Data Sources

The team has collected the required information for exposure data from key national and state agencies responsible for creation of a quality geospatial data for the study area (Table 2-1). The key data sources considered for the exposure data development include:

Table 2-1: Inventory of exposure data

Data -types	Key Data Sources/ Agencies Consulted	Vintages/ Publicati on dates	Resolutions	Remarks
Administrative Boundaries	Survey of India (SOI)	2004-2005	Village and town boundaries	Data available at District, Sub-district, village and town level
Land use/Land cover				No data received
Households	Census of India	2011, 2014	Village and ward level	
Demographic	Census of India	2011	Village and ward level	
Schools	Census of India, Educational department (Andhra Pradesh and Odisha)	2011, 2014	District and city level	
Health Centers	Department of Health and family welfare, Odisha, SOI	2011, 2014	District and city level	
Cyclone Shelters	Andhra Pradesh State Disaster Management Authority Odisha State Disaster Management Authority	2012	Village level	
Police Stations	SOI	2013	Site specific	
Fire Stations	Andhra Pradesh Fire Department MHA	2011-12	Site specific	
Govt. Offices/Others	Related Government Departments	Not available	Site specific	
Religious places	SOI	2013	Site specific location	Data on religious places available from SOI is updated using high resolution Pleiades satellite images (2014)

Data -types	Key Data Sources/ Agencies Consulted	Vintages/ Publication dates	Resolutions	Remarks
Cultural heritage sites	SOI	2013	Site specific locations	Data on Cultural Heritage Sites available from SOI is updated using high resolution Pleiades satellite images (2014)
Industry	Census of India		Village level	Database for List of Industries Provided
Power Plant				No data received
Roads	SOI Andhra Pradesh transport department	2013	Up to village roads	
Railways	SOI Andhra Pradesh transport department Odisha transport department	2013, 2014	Up to broad gauge railway network	
Bridges	SOI	2013, 2014	Site specific	
Airports	SOI	2014	Site specific location	The airport data has been updated using high resolution Pleiades satellite images (2014)
Seaports	SOI	2014	Site specific location	The seaport data has been updated using high resolution Pleiades satellite images (2014)
Crops	Department of Agriculture Andhra Pradesh, Department of Agriculture Odisha, Department of Economics and Statistics	2011-12	District level	
Livestock	Andhra Pradesh Animal Husbandry Department Department of Agriculture and Cooperation, India	2012	District level	
Electricity lines	SOI Odisha Electricity Department		Site specific	
Oil and Gas				No data received

2.1.1 Exposure Data Gaps and Alternative Data Sources

With the collected Exposure datasets, a detailed data inventory sheet has been prepared. This inventory includes required metadata information such as vintage, source, resolution, and other feature attributes etc and further reviewed and assessed by the team. The data with critical information gaps has been studied and appropriate sources/ methods were identified to fill any gaps for the remaining data sets. Table 2-2 below presents the data gaps and alternate data sources used for the exposure data development.

Table 2-2: Gaps in exposure data and alternate data sources used

Data Types	Data Sources/ Agencies Consulted	Data Gaps	Data Gaps Description	Alternate Data Sources	Remarks
Administrative Boundaries	SOI	Data has gaps	Village boundary was of old vintage, not matching with census data tables	Census of India digital maps(.pdf)	SOI data updated with Census village maps
Land use/Land cover (LULC)	None	Data has gaps	No data received	RMSI In-house data	LULC updated with latest vintage exposure data
Households	Census of India	No gap		Sample field survey	Sample field survey has been done to validate the structure type
Demographic Data	Census of India	No gap			
Schools	Census of India, Educational Department (Andhra Pradesh and Odisha)	Data has gaps	Structural and other infrastructure details (types, student enrolments, no. of rooms etc.) for each school is not available	Sample field survey	Sample field survey has been done to collect structural information.
Health Centers	SOI, Census of India, Department of Health and family welfare, Andhra Pradesh and Odisha	Data has gaps	Structural and other infrastructure details (types, beds, equipments etc.) of each hospital is not available	Sample field survey	Sample field survey to collect structural information. Department of Health (Odisha/Andhra Pradesh) has been approached to share required information (not received yet). Once updated information is received, the data layer would be validated and updated
Cyclone Shelters/ Safe Shelters	Andhra Pradesh state Disaster Management Authority Odisha state disaster management authority	Data has gaps	Structural details is not available for these structures	Sample field survey (interaction with officials and locals)	Sample field survey to collect structural information. Once updated information is received, the data layer would be validated and updated

Data Types	Data Sources/ Agencies Consulted	Data Gaps	Data Gaps Description	Alternate Data Sources	Remarks
Police Stations	SOI	Data has gaps	Structural and other infrastructure details (types, no. of vehicles etc.) of each police station is not available	State Police Departments, Sample field survey (interaction with officials)	Sample field survey to collect structural information. Once updated information is received, the data layer would be validated and updated
Fire Stations	Andhra Pradesh Fire Department, Ministry of Home Affairs (MHA)	No gaps			
Administrative Head quarters	None	Data has gaps	No data received	State Departments, Sample field survey (interaction with officials	Using online resources data for administrative HQ is finalized
Religious Places	SOI	Data has gaps	Structural details not available	Sample field survey (interaction with local persons)	Sample field survey to collect structural information.
Cultural Heritage Sites	SOI	Data has gaps	Structural details not available	Ministry of Tourism	Once updated information is received, complied cyclone shelter data layer would be validated and updated
Industry	Ministry of Commerce & Industry	Data has gaps	Structural details is not available	Sample field survey (interaction with officials)	Once updated information is received, the data layer would be validated and updated
Power Plants	None	Data has gaps	No data received	Online resources	Power plants have been developed using online resources Once updated information is received, the data layer would be validated and updated.
Roads	SOI, Andhra Pradesh transport department	Data has gaps	Road conditions, surface types, no. of lanes etc. not available	Open Street Maps RMSI in-house data Sample Field Survey	Sample field survey to collect information about road condition, length, lanes etc. Once updated information is received, the data layer would be updated

Data Types	Data Sources/ Agencies Consulted	Data Gaps	Data Gaps Description	Alternate Data Sources	Remarks
Railways	SOI, Andhra Pradesh transport department, Odisha transport department	Data has gaps	Conditions, type etc. details are not available. Also some internal portions of the railway lines missing	Open Street Map RMSI in-house data	
Bridges	SOI	Data has gaps	Conditions, surface type, no. of spans, type etc. details not available	High Resolution Satellite imagery Sample field survey	Sample field survey to collect detail level information of the bridges Recreation of new bridge layer over high resolution satellite imagery
Airports	SOI	Data has gaps	Shifting in location, structural details and other information not available	Airport Authority of India website, Google Earth	Once updated information is received, the data layer would be updated
Seaports	SOI	Data has gaps	Shifting in location, structural details and other information not available	Sample Field survey (interaction with officials), Port Authority of India website, www.ipa.nic.in	Once updated information is received, the data layer would be updated
Crops	Department of Agriculture Andhra Pradesh, Department of Agriculture Odisha, Department of Economic and Statistics	Data has gaps	Data is not available at village level		Using land use data, district level data brought to village level
Livestock	Andhra Pradesh animal husbandry department, Department of Agriculture and Cooperation, India	Data has gaps	Data is not available at village level		
Electricity lines	SOI, Odisha Electricity Department	Data has gaps	Incomplete network of electric network including high tension power lines	State Electricity Boards	Once updated information is received, the data layer would be updated
Oil and Gas	None	Data has gaps	No data received	RMSI in-house data	

2.2 Vulnerability Data

2.2.1 PHYSICAL VULNERABILITY

2.2.1.1 Data Availability and Data Sources

For physical vulnerability, the team has used a combination of primary and secondary data sets. While the structural vulnerability classes for buildings have been derived mainly from the Census 2011 housing data, the sample field verification survey has helped in improving the vulnerability curves.

2.2.1.2 Data Gaps and Alternative Data Sources

There are no major data gaps observed in this task. However, after identification of cyclone risk hotspots in the later phase of this project, the team would be collecting detailed site-specific structural details for different exposure elements through field survey in the select 10 hotspots in all the 13 states/UTs and consulting with state and central government departments.

2.2.2 SOCIAL AND ECONOMIC VULNERABILITY

2.2.2.1 Data Availability and Data Sources

For social vulnerability analysis and developing Social Vulnerability Index (SoVI), datasets from Census 2011 have been used. Moreover, for detailed social vulnerability analysis, a detailed field-survey would be taken up in the identified 10 hotspots in the study area of 13 coastal states/UTs.

2.2.2.2 Data Gaps and Alternative Data Sources

The data on Gross Domestice Product (GDP) is availabe only at district level and poverty data is based on NSSO and state level poverty statistics. The poverty level statistics has often been a controversial topic of discussion. The present data is based on Tendulkar Committee report (controversial due to lowering of calorie intake 1800 calorie) which constituted by planning commission at 2009-10. Tendulaker committee given its reports based on prices prevailing at that time and we are still using that value only without considering inflation. We didn't attempt to statistically interporate this poverty data to subdistrict or village level based on population as this will only give skewed result as there are several coastal villages which are thickly populated.

The data on female-headed household and disabled population was only avaiable at sub district level and was interpoliated statistically to village level as this is required for calcuating the SOVI and analysis of hotspots.

The geographical area of some villages in the Census 2011 data seems not correct and such instance this data was supplmented using area generated from GIS.

2.3 Database Validation and Quality Assessment

Data quality is an important aspect and is best achieved by preventing errors throughout the project life cycle. The Quality control system comprises of a set of routine technical activities, to measure and control the quality of the data divided into specific quality control stages. Therefore, the objective of the Quality Control (QC) and Quality Assurance (QA) processes is to ensure that the data is accurately captured, recorded, and saved. In the present study, the team tried to detect possible sources of errors linked to the data and their processing. As every error has some influence on the quality of the analysis, the detection of these errors has been considered as the first step in the present study.

The data QA/QC focus is mainly concentrated on areas of:

- Resolution of data
- Projection system
- Positional accuracy
- Topological error of the data
- Creation of Unique Id (UID)
- Essential attribute fields
- Standard unit in all dataset
- File naming convention and versioning
- Consistency in the data

2.4 Database Formats and Standards

The team is maintaining metadata for geospatial data layers following ISO 19139 standards. This includes the various data limitations and the assumptions RMSI made while processing the data. This metadata information will help NDMA understand the output data for future use.

2.5 Data Limitations

The following proxy and data assumptions were considered by RMSI while developing the exposure data and vulnerability functions. These steps we considerd based in industrial standards and based on our past experience working in various projects in India and similar geographies.

As discussed above in Table 2-2, the exposure data collected from various sources had gaps and RMSI team tried to fill these gaps applying secondary data and data processing techniques. The following are the assumptions considered for the exposure data development.

- **Mismatch in village name and extent**: A significant issue encountered throughout the development of exposure information was mismatch in village name and extent. The village boundary information has been collected from various sources. There are differences in alignment and name of villages when each data set compared to the others. Since Census 2011 is the latest vintage data, hence Census 2011 Atlas is used as reference to modify SOI village boundary to attached census tabular data at village level.
- **Vintage of the Data**: The source of many exposure elements is SOI and their vintage dates back to 2005. Using online sources, SOI data sets have been updated based the availability of particular data set.
- **Geo-positional accuracy**: Since SOI and data from many sources are created at low-resolution maps so these data would not be located exactly on high resolution map.
- **Data from alternative sources**: There are a few datasets, such as administrative headquarters, major and hazardous industries, power plants/sensitive installations and oil and gas are not available from any of the authorized sources. In such cases, online available data has been used to estimate the exposure value. For these, RMSI team utilized online sources for their details.
  Similarly, spatial data for potable and waste water system is not available from any of the sources but census provides village level percentage of tap water connection and drainage system. Using this percentage, approximate length of potable and waste water system has been generated using the road network data assuming that potable and waste water network is distributed along the road network.
- **Mapping of structural classes:** For building structural classification, this study relies on census data. Census provides percentage for roof and wall type separately at village level. To determine the structural type of buildings, both roof and wall percentages are combined. There is no detailed classification available for concrete building that may be a reinforced cement concrete (RCC) frame structure or unframed structure etc. Based on

the sample field verification checks and using high-resolution satellite images, further percentage of various categories of concrete buildings are defined.

- **Replacement cost:** Only for a few exposure elements, replacement cost is available from the authentic sources. To estimate the replacement cost of remaining exposure element information from online sources have been used with expert judgment.

It may be noted that limitations related exposure quantification and paucity of authentic replacement values of exposure assets in certain categories would affect the final loss values that are to be derived as part of this study.

As a wayforward, for effective exposure data management it is important to have:

- The data archiving and sharing is very poor among various government agencies, which not only contributes to delays in completion of a study but also hampers its quality. All State/Central government agencies should be encouraged to share data freely for national interest. This warrants revision in the 'National Map Policy of 2005'
- There should be a 'GIS-based centralized national repository' of all the exposure data and can be align to the national initiatives of National Spatial Data Initiative (NSDI). It would not only help in Disaster Risk Management but also in holistic planning and development of infrastructure in the future and modification/retrofitting of existing infrastructure
- Updating of exposure data should be carried out at regular intervals, ideally every year or at least one in 5 years
- Building level data should be developed for major cities with key attributes like location, structural type, built-up area, replacement cost, use, height/number of stories, foundation type, basement, ground floor elevation. This will significantly improve the result of risk assessment process in future.

3 Methodology Adopted for Exposure and Vulnerability Assessment

3.1 Exposure Data Development and Management

Developing exposure data is a critical component of any risk assessment study. Exposure data constitutes population, the built environment, systems that support infrastructure and livelihood functions, or other assets present in the hazard zones that are thereby subject to potential losses. Therefore, modeling vulnerability of a system to natural hazards involves establishing a relationship between the potential damageability of critical exposure elements and different levels of local hazard intensity for the hazard of interest.

Damage susceptibility associated with a given level of hazard is measured in terms of a Mean Damage Ratio (MDR), defined as the expected proportion of the monetary value of repairs needed to bring back the facility to pre-event condition, over the replacement value of the facility, because of the hazard.

The following sub-sections present a detailed overview of the development of the exposure database of population, buildings, infrastructure assets, and crops developed for the states of Odisha and Andhra Pradesh at taluka/mandal/city/town/village level.

3.1.1 Elements of Exposure

Inventory of vulnerable buildings, infrastructure, demographics and any other asset elements (e.g., agriculture, ecological assets (mangroves, coastal plantations)) present in hazard zones and thereby subject to potential losses constitute critical exposure elements that are considered for risk assessment. Figure 3-1 shows the broad categories of exposure elements that have been considered in this study. Details about these exposure elements have been presented in 4 and 4.6 sections.

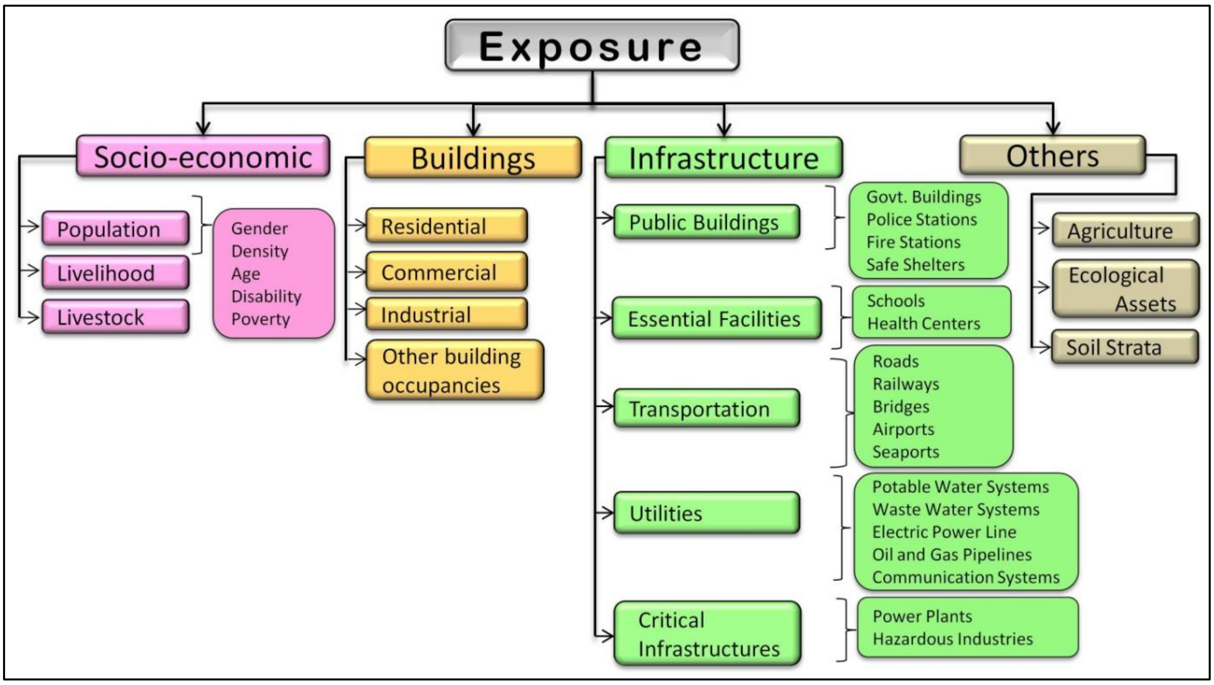


Figure 3-1 Categories of exposure elements

Before we move to the detailed methodology section below, it would be important to discuss the concept of 'site-specific' and 'aggregate' exposure types.

- **Aggregate exposure:** the area and replacement costs of exposure elements (e.g. building clusters, number of schools etc.) are summed/ combined at taluka/mandal/city/town/village level.
- **Site-specific exposure:** every feature has distinct location (latitude, longitude) on the earth's surface with a distinct replacement cost.

Categorizing the data into 'site-specific' and 'aggregate' level depends on the availability of location attributes and their accuracy. For hazards like flood, which are location specific, estimating risk based on aggregated data are not considered as the best solution. This is because when exposure is aggregated at any administrative unit, the assumption is that it is equally distributed across the entire aggregation unit like a district/taluka/mandal/city/town/village. However, in reality, it is observed that the whole exposure is only in one part of the administrative unit and the rest is devoid of it. To avoid this, RMSI team has used the cluster data to distribute the aggregate data over the built-up area at village level. Section 3.1.2 presents the data development process in more detail. It should be noted that the data for soil strata has been used in the flood model for the study area, and respective data sources and processing steps have been detailed in the hazard report ("4th deliverable 'Hazard Assessment Report for Andhra Pradesh and Odisha').

3.1.2 Methodology Adopted for Exposure Data Development

The methodology for exposure database development in this study has been formulated based on a "bottom-up" approach that includes classifying different types of buildings and infrastructure elements into different categories, estimating the count/ dimension under each category, and combining those building/ infrastructure counts/dimensions with per unit built-up floor area/ cost of construction. Thus, the output of exposure data is the total monetary value by asset category, called replacement cost.

The steps involved in exposure data development and management for buildings are presented below (Figure 3-2):

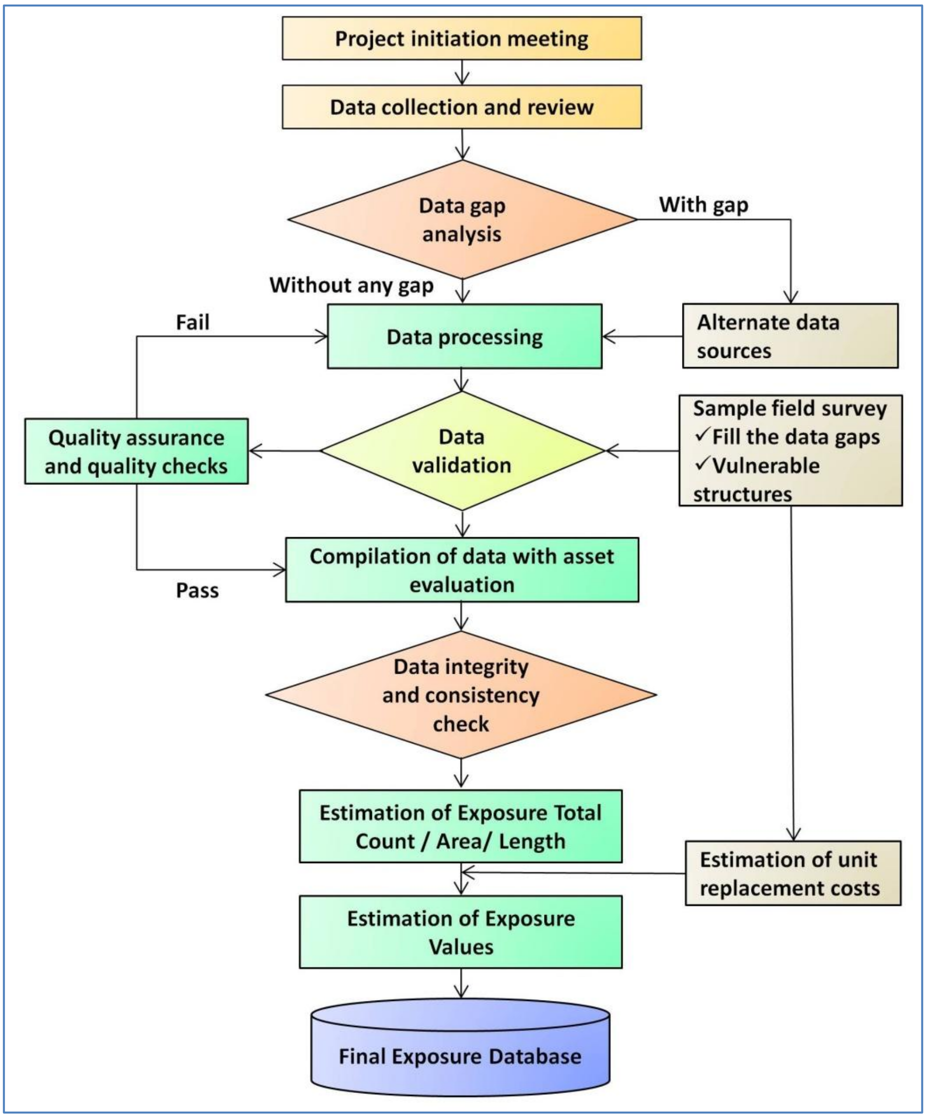


Figure 3-2: Approach for exposure data development

The team has adopted the methodology illustrated above to develop other types of exposure elements, at both site-specific and aggregate level. For example, to fill the gaps in essential facilities (educational and health centers), the team collected available data from concerned departments first and then filled and validated the data gaps using past studies, sample field verification surveys, published reports and high resolution satellite images (Google Earth, Bing images) for the present study. In addition to this, the sample field verification survey inputs and SOI toposheets have been used to develop site-specific bridge data layer. Such site-specific exposure data developed for the present study will enhance the outcomes of the risk assessment and help identify the exposure elements that need immediate attention at village/town/city and higher admin levels.

The following sub-sections present the four key steps involved in exposure data development namely data collection, data gap analysis, data processing, and data integration.

3.1.2.1 Data Collection

Data collection is an important step in exposure data development (Figure 3-2). The quality of exposure data developed depends on the kind of exposure information that is available.

Hence, the team emphasized on acquiring latest vintage data sets (as far as possible) for the present study.

Main steps in the data collection process include:

- Preparing a comprehensive list of data required
- Acquiring the required data with support from the NDMA team
- Creating a data inventory sheet
- Identifying data gaps and alternate sources

During the course of the project, with the support of Project Management Unit (PMU, NCRMP), the team interacted with various stakeholder agencies and collected available data from them. In addition, the team also made use of the data collected in sample field verification surveys in Andhra Pradesh and Odisha. Moreover, to make the study contemporary and precise, Landsat and Google Earth satellite imageries have been used to capture building clusters for the study area. Comprehensive details of this development are provided at the end of this section.

3.1.2.2 Data Processing

The collected data has been reviewed, assessed, and maintained in data inventory sheets with information about the vintage, source, resolution, and other feature attributes. While the data without any gaps are considered for processing, appropriate sources/ methods have been identified to fill any gaps for the remaining data sets. These processed datasets, after due quality checks, are used to estimate the exposure values by multiplying the total area/length/count with unit replacement costs. In this study, the data gaps identified and filled primarily in the areas of:

- **Missing location information:** to fill gaps in spatial location (latitude/ longitude) of features, sources such as Google Maps (after due verification) and data from past studies have been used. For example, the exposure data at aggregated level has been attached to taluka/mandal/city/town/village levels depending upon data availability and requirement.
- **Missing structure or classification details:** these data gaps have been filled through data collected from the sample field-verification surveys, databases available from past studies, and literature survey.
- **Missing replacement costs:** such gaps are filled using the historical event damage reports, technical papers, personal discussions with builders, and review of web sites. Based on this, suitable proxy values have been assumed to fill the data gaps.
- **No data available:** in such cases, data gaps are filled through use of appropriate literature and/ or GIS data available from open sources.

The team, during data processing, covered the following key aspects:

- Better data resolution
- Specified projection system
- Higher positional accuracy
- Standard naming convention and units
- Creation of Unique ID (UID)
- Essential fields
- Standard logical checks
- Metadata

Depending on the format of the data received, various data processing steps are applied, that include cleaning, data standardization, geo-referencing and data development. The positional accuracy and completeness of the data is also taken care in this activity.

The data outputs, after bridging the gaps, served as inputs for further processing (count estimation, area/length estimation, unit cost estimation) and finally the total exposure value for different features in the study area have been calculated. All the processing information is stored in metadata files that help stakeholders understand the output data for future use.

3.1.2.3 Compilation of Exposure Data and Generation of GIS Data Layers

Exposure categories described in Figure 3-1 can be organized into 'aggregate' or 'site specific' exposure to analyze the impact of hazards. A general rule for categorizing the data as aggregated or site specific is based on the level at which the location information is available.

3.1.2.4 Site-specific Exposure Data Processing

The site-specific exposure data are represented by a separate location (longitude, latitude) on the earth's surface for each feature with a separate replacement cost. This has helped the study to emphasize the building occupancies (residential, commercial and industrial) and infrastructural details with their specific occurrences at village level. Therefore, the developed exposure database clearly shows the depth of the study where an exclusive site-specific hazard risk assessment has been performed.

The land use classes with specific occupancy details were manually digitized from high-resolution satellite imageries (Google Earth, RMSI in-house data) by tracing polygons around the perimeter of building clusters using GIS tools. The team applied visual image interpretation techniques such as shape, size, color, tone, texture, and association etc. to capture the building clusters by land use classes. Next, the Census 2011 building structural details (wall and roof materials) were grouped into distinct structural classes and distributed over these building clusters. The information collected from the sample field-verification surveys was used for validation and calibration of these data. After compilation of exposure data, the exposure values were estimated based on the material of construction for the compiled data sets by applying per unit replacement costs. The unit replacement costs for various exposure elements were finalized using appropriate sources (i.e., Public Works Department, line ministries, published reports, and other relevant literature and web sites).

Similarly, the infrastructure data for essential facilities (schools, hospitals), transportation (roads, railways etc.), utilities (potable water, communication network) etc. have been developed at site-specific level. For transportation features (like roads, railways and bridges), the data have been processed as line/ poly-line features with essential attribute information attached to them. The location of public buildings (government offices, police stations, fire stations etc.) and critical infrastructure (power plants, hazardous storage etc.) has been processed as point features (site-specific) and associated with required attribute information to it.

The following table (Table 3-1) presents the list of exposure data layers that has been developed at site-specific level.

Table 3-1: Data layers by resolution for site-specific exposure

Sr. No.	Exposure Elements	File Types	Exposure Resolution
1	Residential	Polygon	Site Specific
2	Commercial	Polygon	Site Specific
3	Industrial	Polygon	Site Specific
4	Admin HQ	Point	Site Specific
5	Police Stations	Point	Site Specific
6	Fire Stations	Point	Site Specific
7	Cyclone Shelter	Point	Site Specific
8	Road Network	Polyline	Site Specific
9	Railway Line	Polyline	Site Specific

Sr. No.	Exposure Elements	File Types	Exposure Resolution
10	Bridges	Polyline	Site Specific
11	Airport	Polygon	Site Specific
12	Power Plant	Point	Site Specific
13	Electricity Line	Polyline	Site Specific
14	Oil and Gas Infrastructure	Polyline	Site Specific
15	Mangroves	Polygon	Site Specific
16	Coastal Plantation	Polygon	Site Specific
17	Seaport	Polygon	Site Specific
18	Cultural Heritage Sites	Point	Site Specific
19	Railway Stations	Polygon	Site Specific
20	Hospitals	Excel Sheet	Aggregate at Village
21	Schools	Excel Sheet	Aggregate at Village
22	Portable Water	Excel Sheet	Aggregate at Village
23	Waste Water	Excel Sheet	Aggregate at Village
24	Communication System	Excel Sheet	Aggregate at Village
25	Worship	Excel Sheet	Aggregate at Village
26	Village	Polygon	Aggregate at Village

3.1.2.5 Aggregated Exposure Data Processing

Aggregate data are those where area and replacement cost of exposure elements are summed by administrative units (district/taluka/city/village). In this case, the specific locations of occurance of the exposure elements are not known. Generally, the tabular data available from various agencies without latitude/ longitude details are aggregated by suitable administrative units. While calculating hazard losses, the loss figures are determined by percentage of adminstrative area affected by a hazard, and then multiplying these with the total aggregated exposure values considering the vulnerability of the structure to the hazard.

In the next step, city/village level population has been distributed over the building cluster based on the area of building clusters in each village. Such information is useful in estimating population affected due to cyclone (strong wind and storm surge) and cyclone induced flooding. The other demographic and socio-economic data like population (age, sex, density, literacy etc.), housing amenities, income, poverty, and crop details have been collected and used after required processing and analysis. Finally, all the tabular processed data with metadata information are attached with corresponding village/ city polygons for risk assessment.

3.2 Vulnerability Assessment

Modeling vulnerability of a system to natural hazards involves establishing a relationship between the potential damageability of critical exposure elements and different levels of local hazard intensity for the peril of interest.

Vulnerability can be divided into three broad classes:

- Physical vulnerability (vulnerability of structures and agricultural crops)
- Social vulnerability
- Economic vulnerability

Physical vulnerability refers to the degree to which an asset would undergo damage or destroyed in a hazardous environment caused by catastrophic events.

Social vulnerability refers to the incapability of people, organizations, and societies to endure adverse impacts from disasters to which they are exposed.

Damage susceptibility associated with a given level of hazard is measured in terms of a mean damage ratio (MDR) defined as the expected proportion of the monetary value of repair needed to bring back the facility to pre-event condition, over the replacement value of the facility, as a consequence of the hazard. The curve that relates the MDR to the hazard is called a vulnerability function. Vulnerability functions are developed for various assets for different perils, using analytical/synthetic and statistical methods complemented with expert engineering or heuristic judgment based on local and/or international experiences.

Figure 3-3 presents a flow chart indicating the interface between different components of vulnerability development.

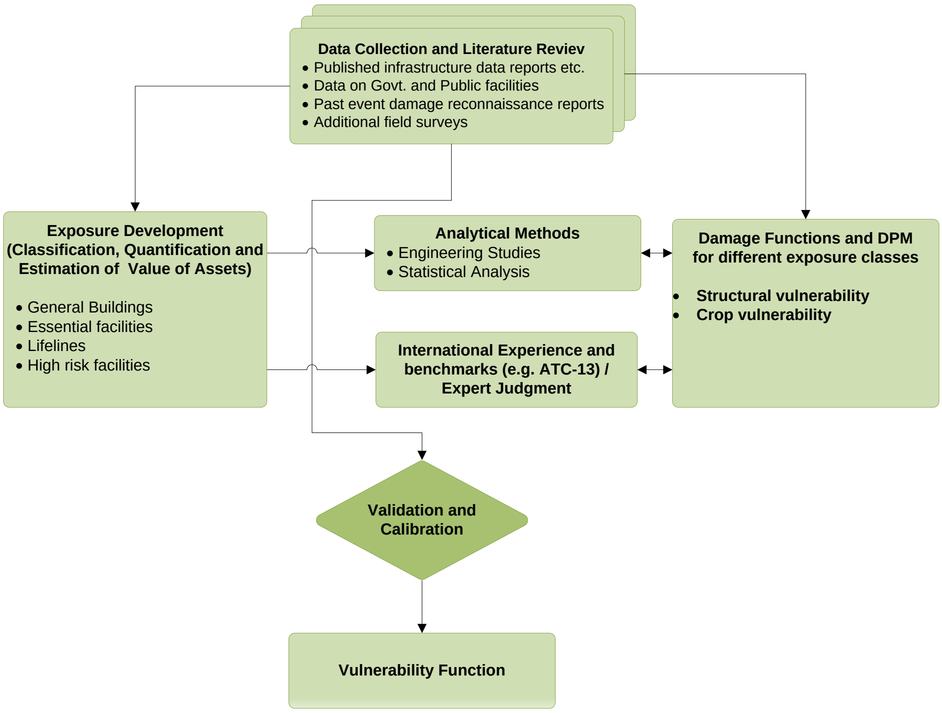


Figure 3-3: Methoddology for developing vulnerability functions

Development of physical and social vulnerability functions for all the 13 States/UTs is mainly, but not solely, based on damage data from historical events. Generally, an analytical approach complemented by engineering analyses along with expert judgment based on national/international experience helps in developing vulnerability functions.

For Cyclone hazard, there are three collateral hazards that can in isolation, or in combination happen:

- CP: Cyclone Pressure (measured by wind speed)
- CI: Cyclone induced Inundation (inland-flooding, by depth)
- Storm Surge- further decomposed into two components
  - SI: Surge Inundation (measured by depth)
  - SM: Surge Momentum (measured by velocity)

The final damage states are calculated per SRSS (Square Root of Sum of Squares), as follows: Dfinal = sqrt $\{(D^2_{CP} + D^2_{CI} + (D^2_{SI} + D^2_{SM})^{1/2}\}$

For each of the above collateral hazards, subsequent sections are given for respective damage functions.

3.2.1 Physical Vulnerability Assessment

3.2.1.1 Physical Vulnerability for Cyclone (wind effect)

This section focuses on development of methods for estimation of cyclone-induced damage to buildings, contents, and time element, due to exerting pressure from the wind hazard, given knowledge of the occupancy, building characteristics and its typical configuration, and wind speed.

The development starts with literature survey for related material to buildings performance in India. Due to scarcity of the literature specific to India, we have also resorted to material that, by our engineering judgment, can be related (not necessarily similar in performance) to India. This goes to damage functions (suggested for other regions) that have the expected configuration, mathematical form (polynomial versus exponential, stepwise or monotonic, etc.).

Some of the studies are brought as examples here.

3.2.1.1.1 Study 1 - Housing Damage in Windstorms and Mitigation for Australia

Ginger et. al.[12] from James Cook University, Australia has examined the vulnerability of domestic houses of Australia due to windstorms. Townships comprise a range of house types, with differences in shape, size, cladding type, window size, roof shape and slope, materials, method of construction, and age are considered as critical parameters for the damage function.

The wind classification is based on following four variables:

- Region (Figure 3-4),
- Terrain Category,
- Shielding Factor
- Topographic Classification.

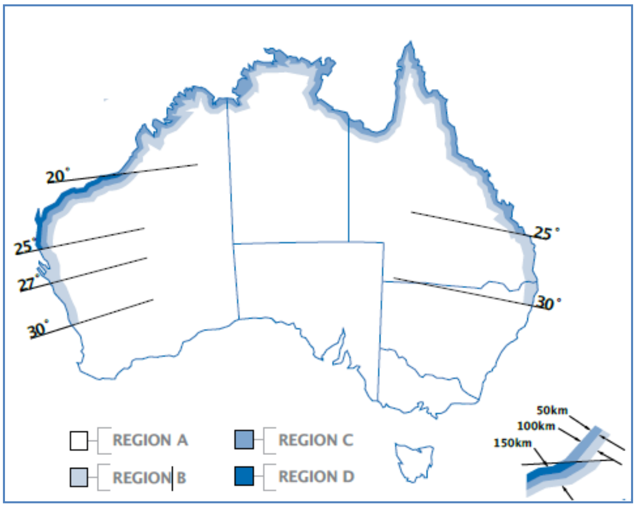


Figure 3-4: Wind classification regions

Table 3-2 below shows the wind classification and their respective wind speeds.

[12] Housing Damage in Windstorms and Mitigation for Australia; John Ginger, David Henderson, mark Edwards and John Holms; Cyclone testing Station, James Cook University (http://researchonline.jcu.edu.au/16337/1/Ginger_IGWRDRR_Aust_Final.pdf)

Table 3-2: Wind classification

Wind classification		**Wind speed**
Regions A and B	Regions C and D	meters per second
N1 (Non-Cyclonic)	N/A	W28
N2 (Non-Cyclonic)	N/A	W33
N3 (Non-Cyclonic)	C1 (Cyclonic)	W41
N4 (Non-Cyclonic)	C2 (Cyclonic)	W50
N5 (Non-Cyclonic)	C3 (Cyclonic)	W60
N6 (Non-Cyclonic)	C4 (Cyclonic)	W70

Based on above classification a series of six vulnerability curves representative of typical Australian construction types (roof and wall materials) and wind classification are developed drawing on the outcomes of a workshop attended by members of the Australian wind engineering community (Figure 3-5).

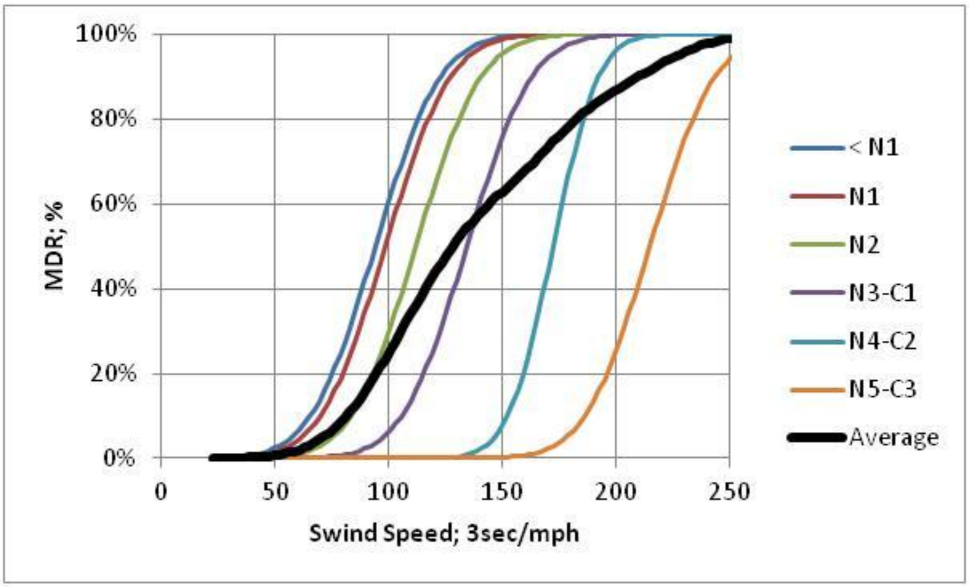


Figure 3-5: Reference curves for heuristic ranking process by expert group engaged through workshop activity

Note: The figure reconstructed through digitization of the pdf literature.

Responses were subsequently sought from eight recognized vulnerability experts in the Australian wind engineering community who could draw upon their experience in post-event activity. Each of the respondents were given a blank copy of the categorization and the suite of six vulnerability curves and asked to independently assign a curve (or intermediate curve) to each of the available fields in the categorization.

For each available field in the schema, the responses were analyzed to produce a heuristic vulnerability curve for each categorization. The process took account of the average curve (i.e. position left to right) and also the availability in responses that is reflected in the steepness of the curve. The results are expressed as an alpha and beta value for each field that describe the vulnerability curve by equation.

Although responses were sought from the insurance industry, none was received. An anecdotal response to Geoscience Australia indicated that the lower sections of the suite of six curves overestimated the damage at low gust wind speeds.

In this study, the building structures are defined per their components similar to this work. This study is especially useful for our study because of damage curves are based on combination of structures components.

3.2.1.1.2 Study 2: Assessing the Impact of Tropical Cyclones in Australia: using Tropical Cyclone (TC) Tracy as case

Tropical Cyclone (TC) Tracy[13] impacted Darwin early on Christmas Day, 1974, resulting in 71 deaths, the destruction of thousands of homes and the evacuation of over 35,000 people. Using Darwin as a test case, Craig Arthur, Anthony Schofield and Bob Cechet assessed the benefits of Geoscience Australia's Tropical Cyclone Risk Modeling tool in assessing the potential impact of a tropical cyclone.

They have estimated damage to residential structures by utilizing a suite of vulnerability curves, appropriately selected for the class of building present in the region of interest.

The residential structures are classified into four groups based on age (Figure 3-6). No classification on construction type was performed. These four classes are:

1. Pre-1974: these are structures, which survived effectively undamaged during TC Tracy. This is based on the behavior of timber-framed high-set fibro-clad housing;
2. Repaired and retrofitted: these are structures which survived TC Tracy with a low proportion of damage (≤40% Replacement Cost);
3. 1975—1980: this class includes all structures that sustained over 40% RC damage during TC Tracy, and are assumed to have been demolished and rebuilt prior to 1980, as well as new (additional) structures built between 1975 and 1980; and
4. Post-1980: buildings constructed after 1980.

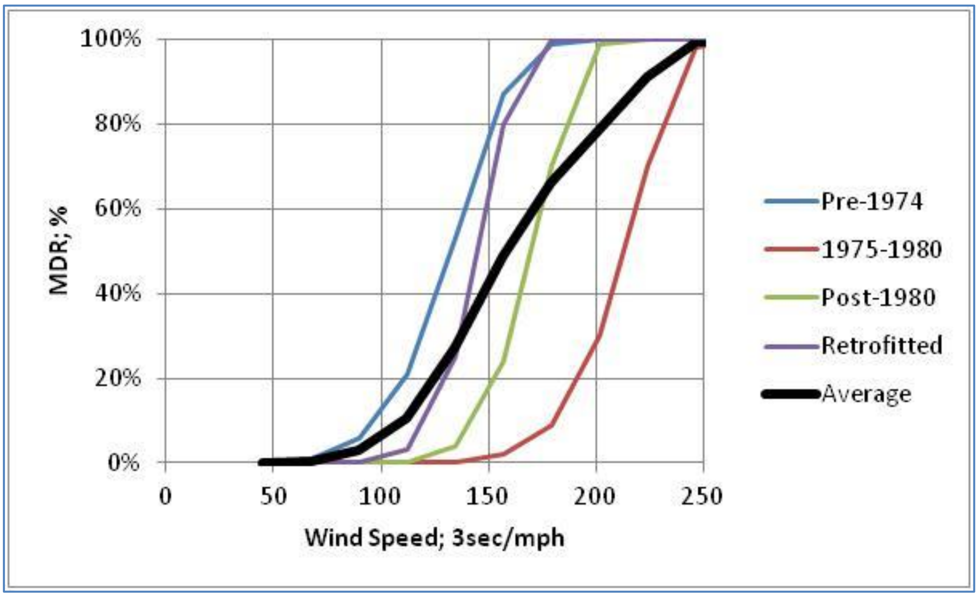


Figure 3-6: Comparative mean damage model curves for building ages

Note: Figure reconstructed through digitization of the pdf literature

Using the inventory of the Australian building stock, the above curves were weight-averaged so those can be used for our development.

13 Housing Damage in Windstorms and Mitigation for Australia - Craig Arthur, Anthony Schofield and Bob Cechet from Geoscience Australia. The Australian Journal of Emergency Management, Vol. 23 No. 4, November 2008. https://www.em.gov.au/Documents/AJEM_Nov08_Arthur.PDF

3.2.1.1.3 Study 3: Wind damage information related to India

In the paper "Wind damage information related to India" [14], a combination of local hazard intensity and vulnerability of existing house types were used for carrying out risk analysis given in the district-wise tables. This preliminary effort toward vulnerability assessment of buildings under cyclone intensities was made by Structural Research Engineering Center, Chennai. This information utilized to apply in the existing housing types available in each district (taken from Census of India, 1991) and categorized from vulnerability consideration. The vulnerability of these structural types to various intensities of the hazards was estimated by the group, and the damage risk in each district has been presented in Table 3-3.

Table 3-3: Distribution of Houses by Predominant Materials of Wall and Roof and level of Damage Vs Risk - Extract from a typical table in the Vulnerability Atlas

Housing details – as per census 1991				Level of Risk under Wind Velocity (m/s)			
Wall and Roof Combination	Type*	Number of Houses	(%)	55 &50	47	44&39	33
A1 Mud Wall All Roofs sloping	U	5,422,316	2.78	VH	H	M	L **
	R	57,104,950	29.28	VH	H	M	L
A2 Unburned Brick Wall (a) Sloping roof	U	1,937,714	0.99	VH	H	M	L
	R	9.951.794	5.10	VH	H	M	L
(b) Flat roof	U	119,042	0.06	VH	H	M	L
	R	161,492	0.08	VH	H	M	L
A3 Stone Wall (a) Sloping roof	U	2,111,574	1.08	VH	H	M	L
	R	12.445.497	6.38	VH	H	M	L
(b) Flat roof	U	2,308,017	1.18	H	M	L	L
	R	4.838.903	2.48	H	M	L	L

* U – Urban R - Rural

** Risk level: VH is very high, H is high, M is moderate and L is low

3.2.1.1.4 Study 4: Assessment of vulnerability to cyclones and floods in Odisha, India: a district-level

The study "Assessment of vulnerability to cyclones and floods in Odisha, India: a district-level"[15] published in current science provide district-wise relative vulnerability indices to assign vulnerability rank to each district according to its vulnerability level with regard to cyclones and floods. In doing so, an integrated approach, was adopted where vulnerability was the function of exposure, sensitivity and adaptive capacity. A number of proxy indicators, were considered in order to capture the determinants of vulnerability. Since the measurement unit for each indicator varies, a normalization procedure was used in order to aggregate them into a single value for comparison (Table 3-4).

[14] Structural Research Engineering Center, Chennai

[15] Assessment of vulnerability to cyclones and floods in Odisha, India: a district-level (http://www.currentscience.ac.in/Volumes/107/12/1997.pdf)

Table 3-4: Vulnerability score of various districts of Odisha

Vulnerability score	District
>0.5	Balasore, Bhadrak, Jajpur, Kendrapada, Malkangiri, Nabarangpur, Nuapada and Rayagada
0.4 – 0.5	Baragarh, Bolangir, Boudh, Cuttack, Deogarh, Dhenkanal, Gajapati, Ganjam, Jagatsinghpur, Kalahandi, Kandhamal, Keonjhar, Koraput, Mayurbhanj, Nayagarh, Puri and Sonepur
<0.4	Angul, Jharsuguda, Khurda, Sambalpur and Sundargarh

This is an interesting approach developed at a very coarse resolution (district level), however, it can't be used for loss estimation i.e. for vulnerability curves development as it is indexed based.

Procedure to develop India damage functions:

1. As result of the analyzing the studies from the literature, comparing them to Indian performance and workmanship, etc., the following curve has been developed to be used for the core curve.
2. Building in the inventory, here are decomposed into (assumed as integrated system of) four components of Roofing, Envelope, Configuration and Integration.
3. Based on engineering judgment, for each of the components, of each of the buildings in the inventory, a qualitative measure of vulnerability is assigned (Very Good, Good, Average, Bad, and Very Bad).
4. Based on judgment, quantitative values are assigned to each of the qualitative measure, to preserve their relativity in damage, overall damageability, etc.).
5. These values are combined to represent the relativity between buildings in the inventory.
6. The above Core Curve is then scaled by the above relativity.
7. An overall adjustment factor is used to make sure in overall the curves are within the expected range for India. This expectation comes from few (not direct) observation points, engineering judgment, and expert opinion.

Note that the X-axis represents the 3-second gust wind speed, in miles per hour. The Core curve (not the final curves per all buildings) goes as high as total damage, as it is developed for residential buildings for which there have been ample data collected (Figure 3-7). This curve, then, based on the quality and relativity of the four components (noted above) is scaled to meet the expectation for each and every buildings. In majority of cases, the final damage is not total, and part of the building is salvageable.

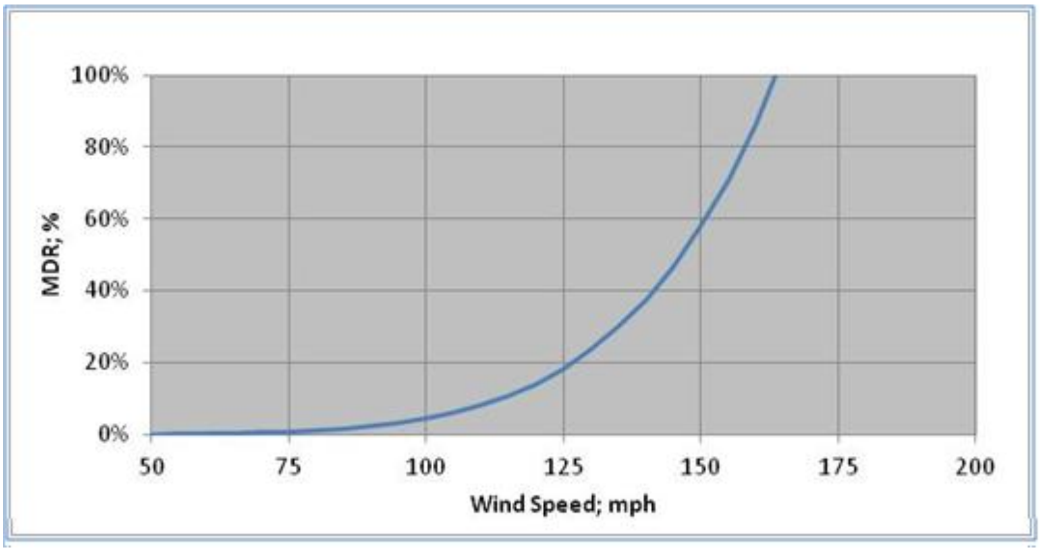


Figure 3-7: Core damage curve for cyclone (wind pressure impact)

3.2.1.2 Cyclone Inundation (inland-flooding, by depth)

This section focuses on development of methods for estimation of cyclone-induced flood damage to buildings, contents, and time element, given knowledge of the occupancy, building characteristics and its typical configuration, and depth of flooding throughout the area.

3.2.1.2.1 Study 1: Pan-European Flood hazard and Damage Assessment; evaluation of a new Digital terrain Model

Marco Rusmini 2009[16] in this study on flood hazard and damage assessment used two different strategies for extracting damage functions. The first consists of calculating the functions on the basis of historical flood damage data; the second is the calculation of functions from analysis based on LULC (Land Use Land Cover) classes, asset classes, questionnaire surveys, expert knowledge best estimations, etc (Figure 3-8).

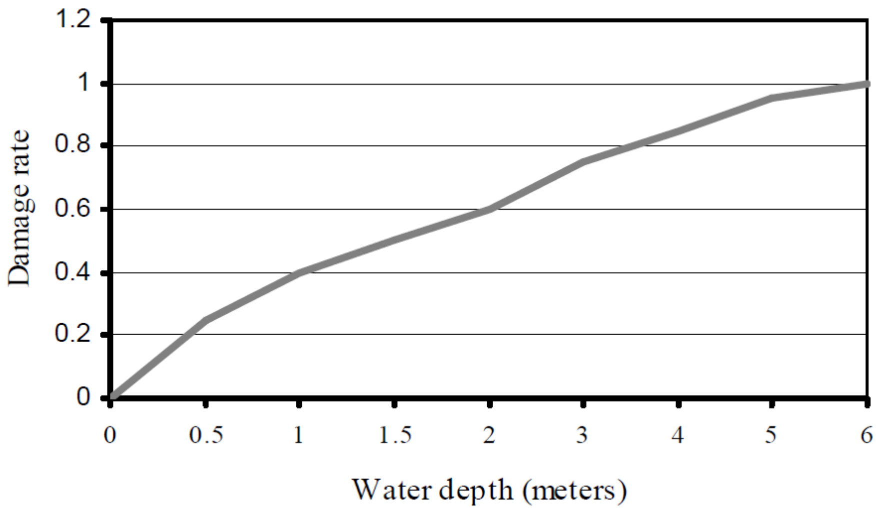


Figure 3-8: Damage functions for residential building

[16] Marco Rusmini 2009, Pan-European Flood hazard and Damage Assessment; evaluation of a new Digital terrain Model, International Institute of Geo-information and Earth Observation.

3.2.1.2.2 Study 2: Catalog of Residential Depth-Damage Functions used by the Army Corps of Engineers (USACE) in Flood damage estimations; Stuart Davis and Leigh Skagg

This work is completed under the Flood Mitigation, Formulation, Planning, and Analysis research work unit at the Corps of Engineers, Institute for Water Resources (IWR). It includes damage functions based on National data of flood damage records, and damage functions originally computed on a project-specific purpose (Figure 3-9).

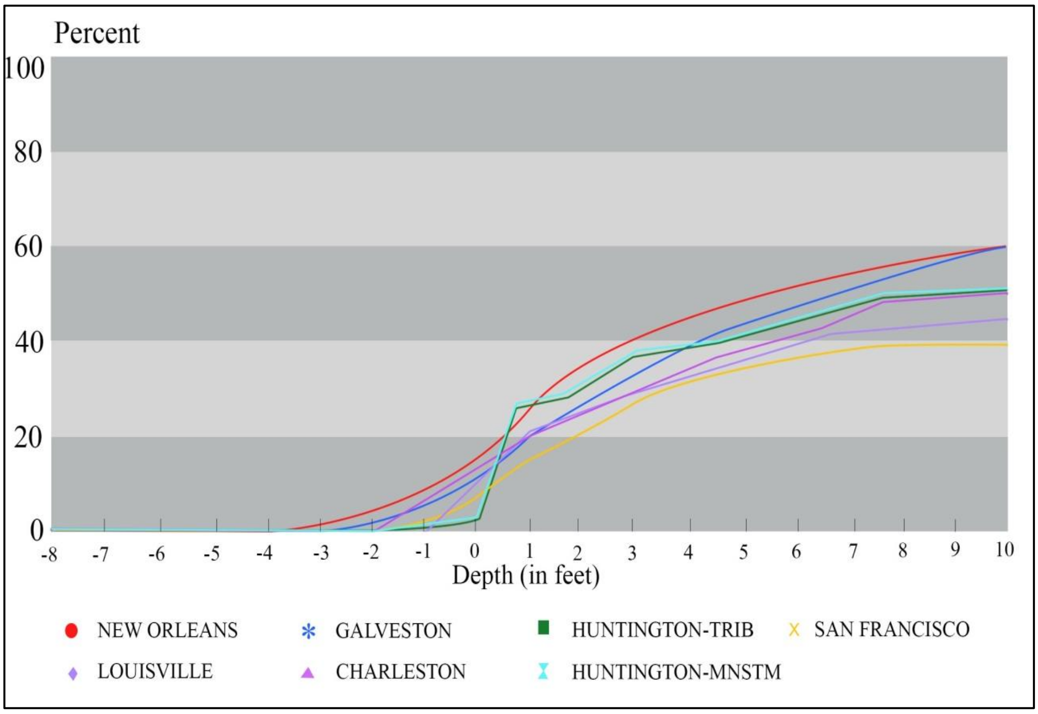


Figure 3-9: Example USACE depth – damage function- one storey no basement

3.2.1.2.3 Study 3: HAZUS Multi-Hazard Flood Loss Methodology

This study has demonstrated the damage and loss estimation capability of the HAZUS-MH Flood Model, which includes a library of more than 900 damage curves for use in estimating damage to various types of buildings and infrastructure in the United States. Based on estimated property damage, the model estimates shelter needs and direct and indirect economic losses arising from floods. Analyses for the effects of flood warning, the benefits of levees, structural elevation, and flood mapping restudies are also facilitated with the Flood Model.

The HAZUS-MH Flood Model uses the Federal Insurance Administration's FIA_ "credibility weighted" depth-damage curves and selected curves developed by various districts of the U.S. Army Corps of Engineers (USACE) for estimating damage to the general building stock, including Single-Story (no basement), Double-Story (no basement), Double-Story (with basement), Double-Story (Split-Level, no basement), Double-Story (Split-Level with basement), and Manufactured Housing (aka: Mobile Homes) (Figure 3-10).

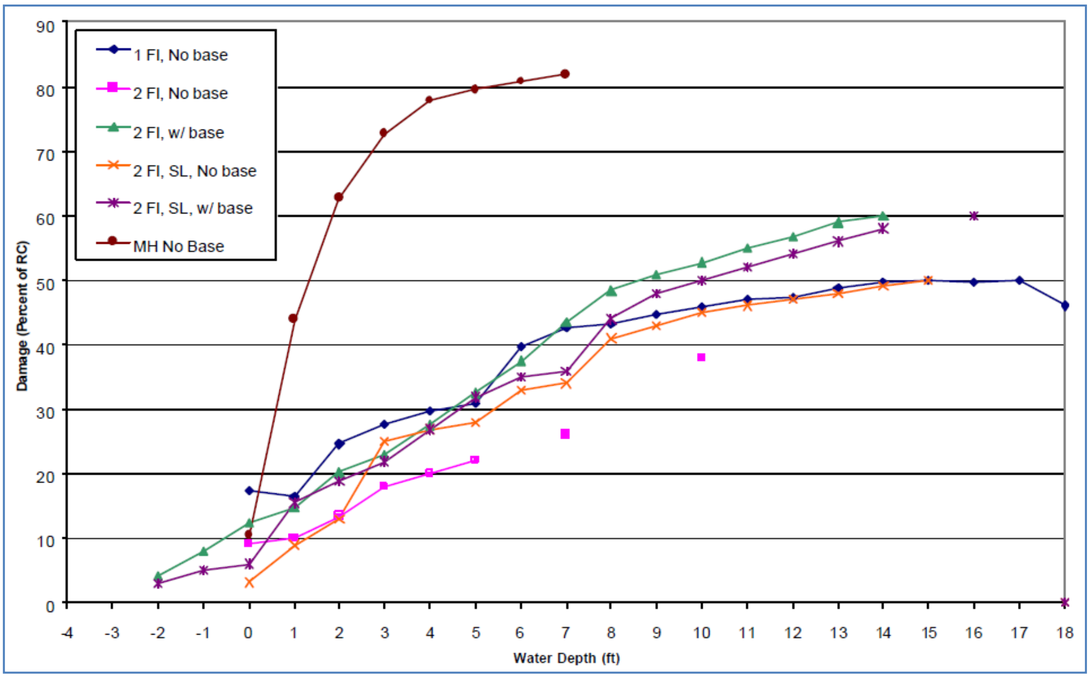


Figure 3-10: HAZUS – MH flood vulnerability functions

For building structures:

For a flood analysis, damage is estimated in percent and is weighted by the area of inundation at a given depth for a given building footprint. Default curves to estimate structural damage for the analyses have been deduced from equal weight averaging of Studies 1 through 3.

Damage functions for buildings are developed using the consensus form the following studies, adjusted for Indian building performance. The studies are selected so that they have had close relationships with Indian building and construction practice. If such is not met, factors (assigned subjectively and based on engineering judgment) were introduced to update (Figure 3-11).

Procedure to develop India damage functions:

1. As result of the analyzing the studies from the literature, comparing them to Indian performance and workmanship, etc., the following curve has been developed to be used for the core curve.
2. Building in the inventory, here are decomposed into (assumed as integrated system of) four components of Interior, Envelope, Foundation and Integration.
3. Based on engineering judgment, for each of the components, of each of the buildings in the inventory, a qualitative measure of vulnerability is assigned (Very Good, Good, Average, Bad, and Very Bad).
4. Based on judgment, quantitative values are assigned to each of the qualitative measure, to preserve their relativity in damage, overall damageability, etc.).
5. These values are combined to represent the relativity between buildings in the inventory.
6. The above Core Curve is then scaled by the above relativity.
7. An overall adjustment factor is used to make sure in overall the curves are within the expected range for India. This expectation comes from few (not direct) observation points, engineering judgment, and expert opinion.

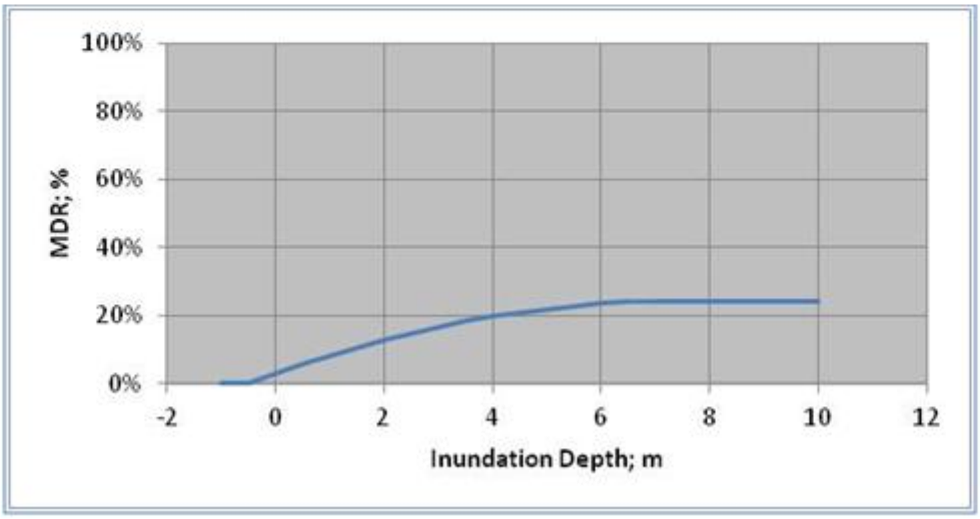
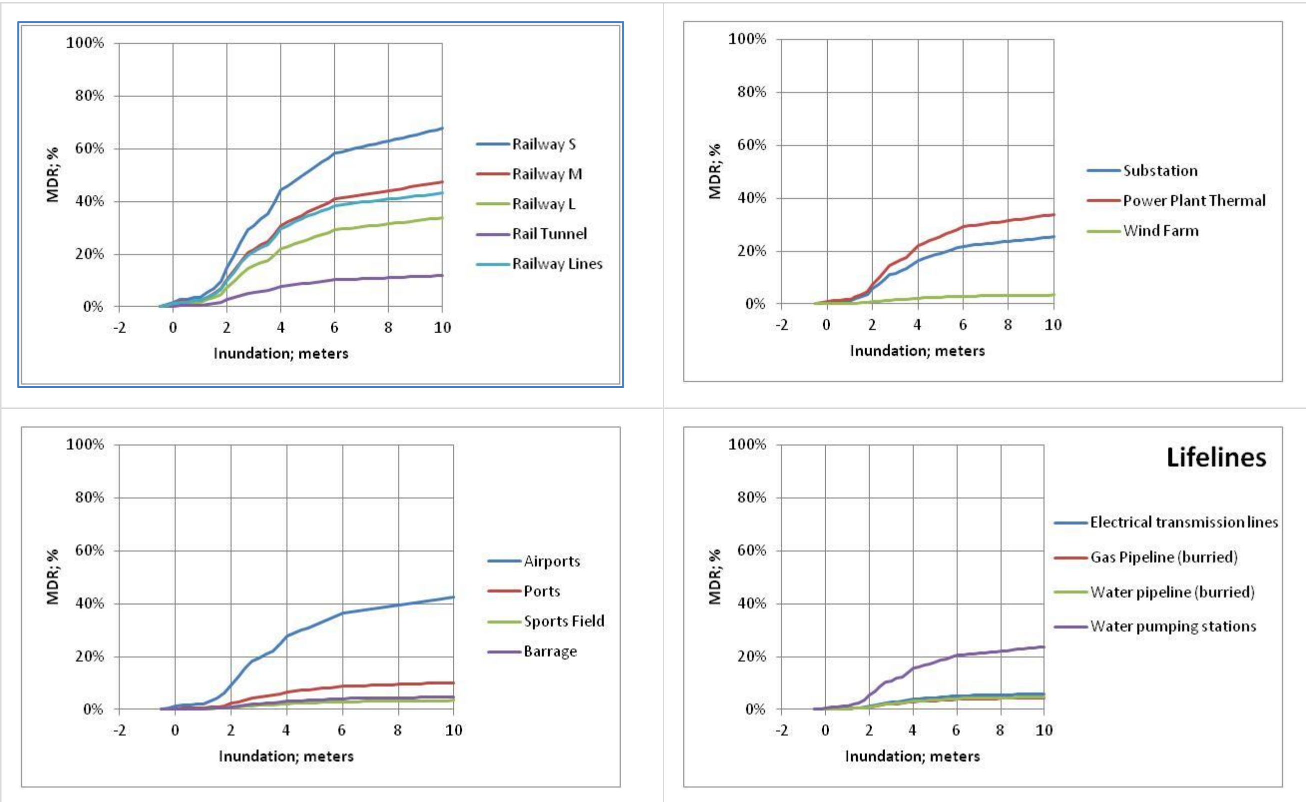


Figure 3-11: Core damage curve for cyclone inundation

For other-building structures:

For essential facilities, such as hospitals, schools, and fire stations, the damage is estimated by applying a default depth-damage curve, which is then editable by the user to create a specific function for the facility. Damage is estimated for lifeline systems with a separate set of damage functions that define the potential damage to components of the systems that are either uniquely vulnerable to inundation or are expensive to repair or replace.

The following curves (Figure 3-12) have been selected from HAZUS to meet with Other-Buildings (infrastructures, lifelines, etc.). Again, to bridge the gap between the US and Indian performance, based on engineering judgment, a scaling factor has been implemented.



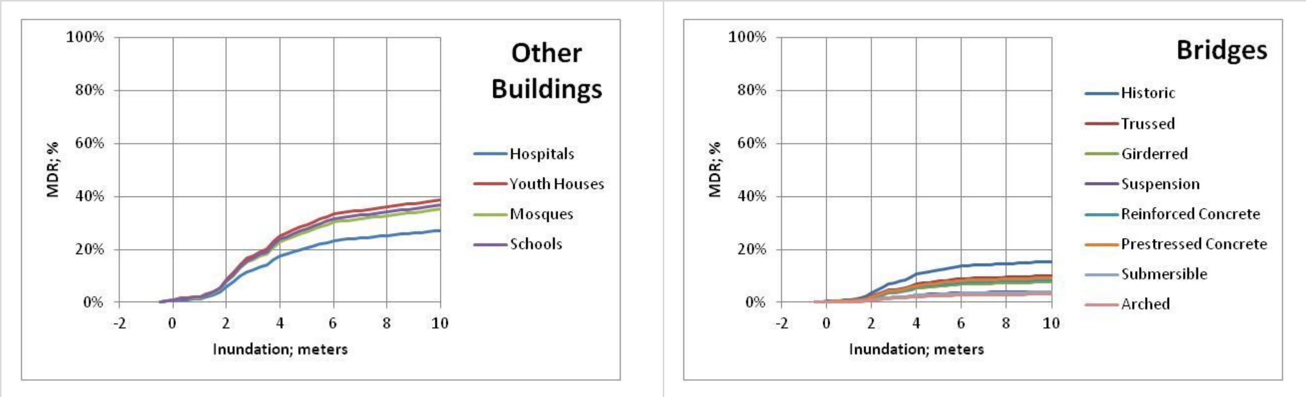


Figure 3-12: Inundation vulnerability models from literature for lifelines building and various infra-structures

Core Vulnerability Curves from Literature

Due to lack of available (and detailed) data regarding other structures, a subjective approach was implemented through which relative damageability, regarding inundation depth and current velocity, matrices were developed. Based on this matrix, individual curves were scaled based on Default Curves.

3.2.1.3 Vulnerability for Storm Surge (Inundation and Velocity)

Variety of factors are in play at the time of a storm surge, as shown in figure below; however, in practice the direct damage to a given building is at best defined as a function of the inundation depth and current velocity (Figure 3-13).

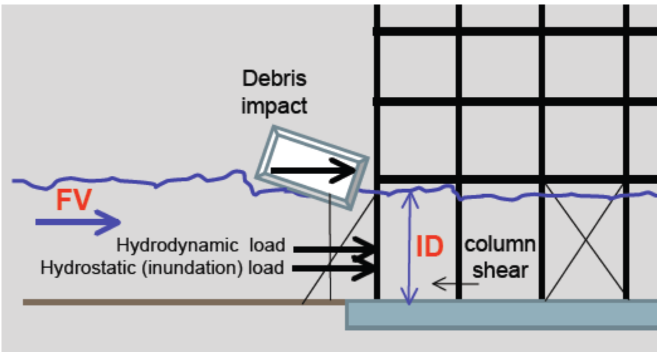


Figure 3-13: Damage to building due to storm surge

3.2.1.3.1 Study 1: Damage Assessment from Storm Surge to Coastal Cities: Lessons from the Miami Area

Damage Assessment from Storm Surge to Coastal Cities: Lessons from the Miami Area[17] simulated different storm surges were predicted using the computerized SLOSH1model. The flood risks were investigated with respect to current sea level, considering different hurricane parameters, e.g., storm category and direction, wind speed, and tide level. For each impact,

---

[17] Damage Assessment from Storm Surge to Coastal Cities: Lessons from the Miami Area
Elisabetta Genovese
Centre International de Recherche sur l'Environnement et le Développement (CIRED)
Stéphane Hallegatte
Ecole Nationale de la Météorologie, Meteo France
Patrice Dumas
Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)

a damage function has been applied which is the function of flood depth and mean damage ratio only (Table 3-5).

Table 3-5: Damage function for residential, commercial, and industrial structures

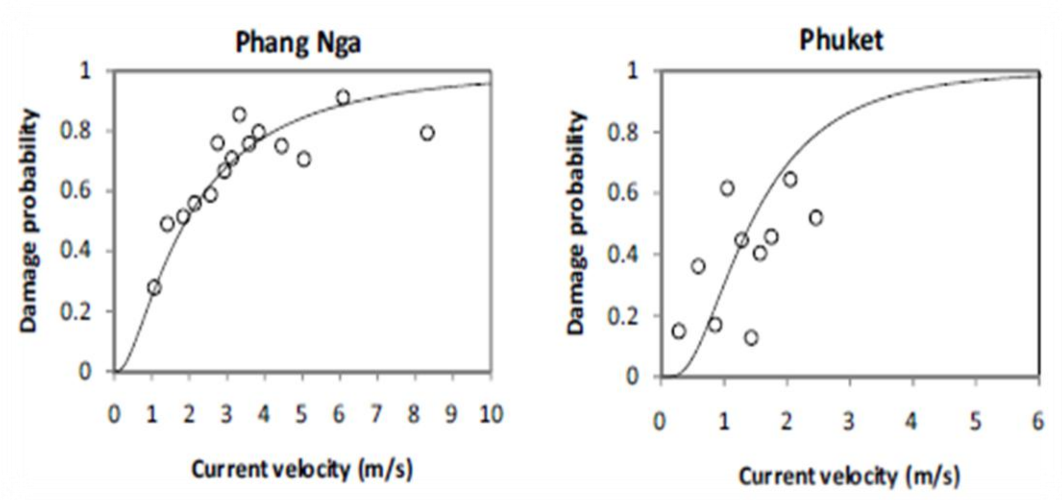
Elevation Range (m)	Residential (Structure) %	Commercial (Structure) %	Industrial (Structure) %	Residential (Contents) %	Commercial (Contents) %	Industrial (Contents) %
0	0	0	0	0	0	0
1	12	40	40	48	55	67
1.5	14	47	47	49	64	75
2	15	54	53	50	73	82
2.5	17	56	55	58	78	85
3	18	58	57	67	82	88
3.5	20	60	59	75	87	91
4	22	61	61	83	91	94
4.5	23	63	63	92	96	97
5	25	65	65	100	100	100

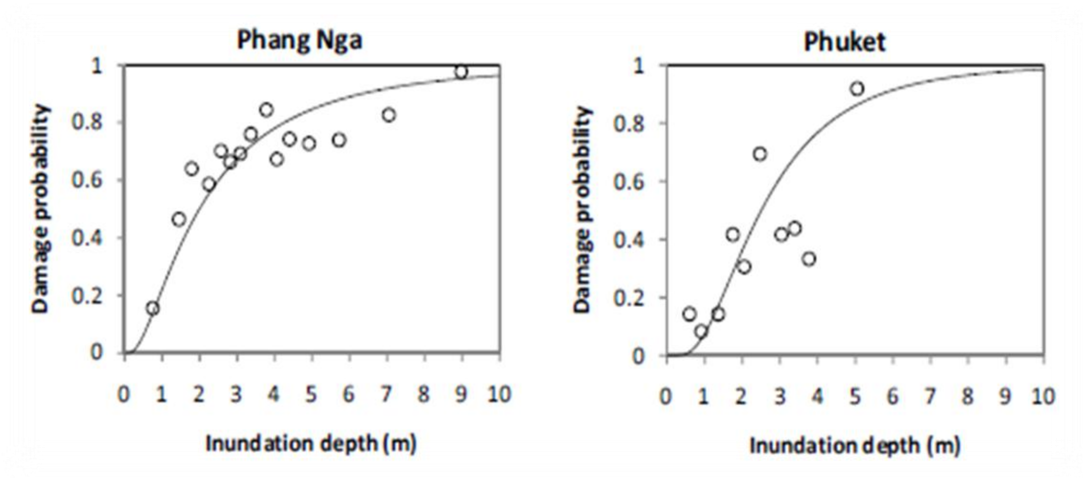
This study utilizes only one parameters of storm surge i.e, flood depth hence utilized only for developing curve for inundation depth.

3.2.1.3.2 Study 2: Developing Tsunami Fragility Curves Based on 2004 Indian Ocean Tsunami in Thailand; A. Supparsi, S. Koshimura, and F. Imamura; 2011

The reason we selected this study is that this is most recent study on coastal inundation, even though the hazard considered here is tsunami. Both tsunami and surge are similar in some ways and dis-similiar in other ways. In terms of similarities, both hazards are sea/ocean water based and the damage caused by them is a function of both both water volume and water velocity, even tough the volume of water in surge and tsunami is different.

In this study, the damage probabilities of buildings from two discrete sets (i.e., sets for Khao Lak, Phang Nga, and Kamala/Patong, Phuket) were calculated and shown against a median value within a range of about 100 buildings in Phang Nga and 50 buildings in Phuket. Linear regression analysis was performed to develop fragility functions:





From these results, all fragility functions with respect to inundation depth and current velocity are given by the standardized Log-Normal distribution functions with µ and *sigma*, forming least-square fitting of this plots. Consequently, two parameters were obtained by taking the intercept $(=\mu \text{ or } \mu')$ and the angular coefficient $(=\sigma \text{ or } \sigma')$ see below:

$$P(x) = \Phi\left[\frac{x-\mu}{\sigma}\right] \qquad P(x) = \Phi\left[\frac{\ln x - \mu'}{\sigma'}\right]$$

$$x = \sigma\Phi^{-1} + \mu$$

$$\ln x = \sigma'\Phi^{-1} + \mu'$$

Where the parameters, depending on sub-hazards, and per observation set are:

Khao Lak, Phang Nga					
X for fragility function $P(x)$	μ	σ	μ'	σ'	R^2
Inundation depth (m)	–	–	0.689	0.903	0.80
Current velocity ($\mathrm{m\,s^{-1}}$)	–	–	0.649	0.952	0.72
Hydrodynamic force per width ($\mathrm{kN\,m^{-1}}$)	–	–	1.748	1.937	0.75
Kamala/Patong, Phuket					
X for fragility function $P(x)$	μ	σ	μ'	σ'	R^2
Inundation depth (m)	–	–	0.917	0.642	0.62
Current velocity ($\mathrm{m\,s^{-1}}$)	–	–	0.352	0.675	0.32
Hydrodynamic force per width ($\mathrm{kN\,m^{-1}}$)	–	–	0.821	3.000	0.50

In this study study, authors have used the average of the two data sets; i.e., sets for Khao Lak, Phang Nga, and Kamala/Patong, Phuket:

For Inundation:
Mu = 0.803 meters
and Sigma = 0.773 meters

For velocity:
Mu' = 0.501 meters per second

and Sigma' = 0.814 meters per second

For this study, the information from most recent and relevant literature published for storm surge damage assessment have been referred. To adapt these curves to Indian conditions, engineering judgments was applied (Figure 3-14).

Folloing Procedure was used to adapt these damage functions for India:

1. As result of the analyzing the studies from the literature, comparing them to Indian performance and workmanship, etc., the following curve has been developed to be used as the core curve (Figure 3-14).
2. Buildings are assumed as a system of four components of Interior, Envelope, Foundation and Integration.
3. For each of the building components a qualitative measure of vulnerability is assigned (Very Good, Good, Average, Bad, and Very Bad) based on engineering judgment.
4. Based on judgment, quantitative values are assigned to each of the qualitative measure, to preserve their relativity in damage, overall damageability, etc.
5. These values are combined to represent the relativity between buildings in the inventory.
6. The Core Curve is then scaled by the above-derived relativity.
7. An overall adjustment factor is used to make sure that the curve developed is within the expected range for India. This expectation comes from a few (not direct) observation points, engineering judgment, and expert opinion.

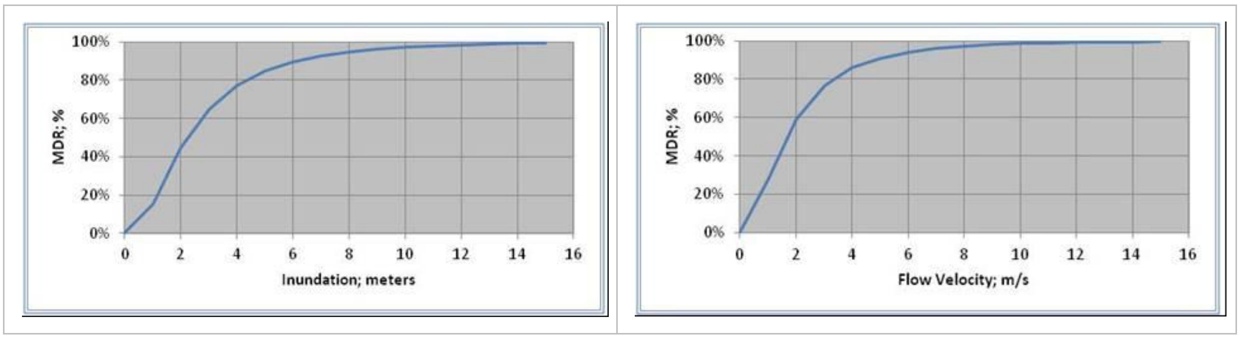


Figure 3-14: Core damage curves for Storm Surge for the inundation impact (left) and velocity impact (right)

3.2.1.4 Contents and Time Element

The core curves for Contents and Time Element are selected from the literature, and then modified (based on engineering judgment) to meet India performance and quality. In the process, the damage state to Building is used as input to calculate the damage states to Contents and Time Element (Figure 3-15). Note that, Time Element damage is given as percentage of Time Element Exposure (monetary); however, assuming the indemnity period to be 12 months, the percentages can also be interpreted as percent of year needed to bring the building back to function. This can be used for cases such as displacement and shelter need.

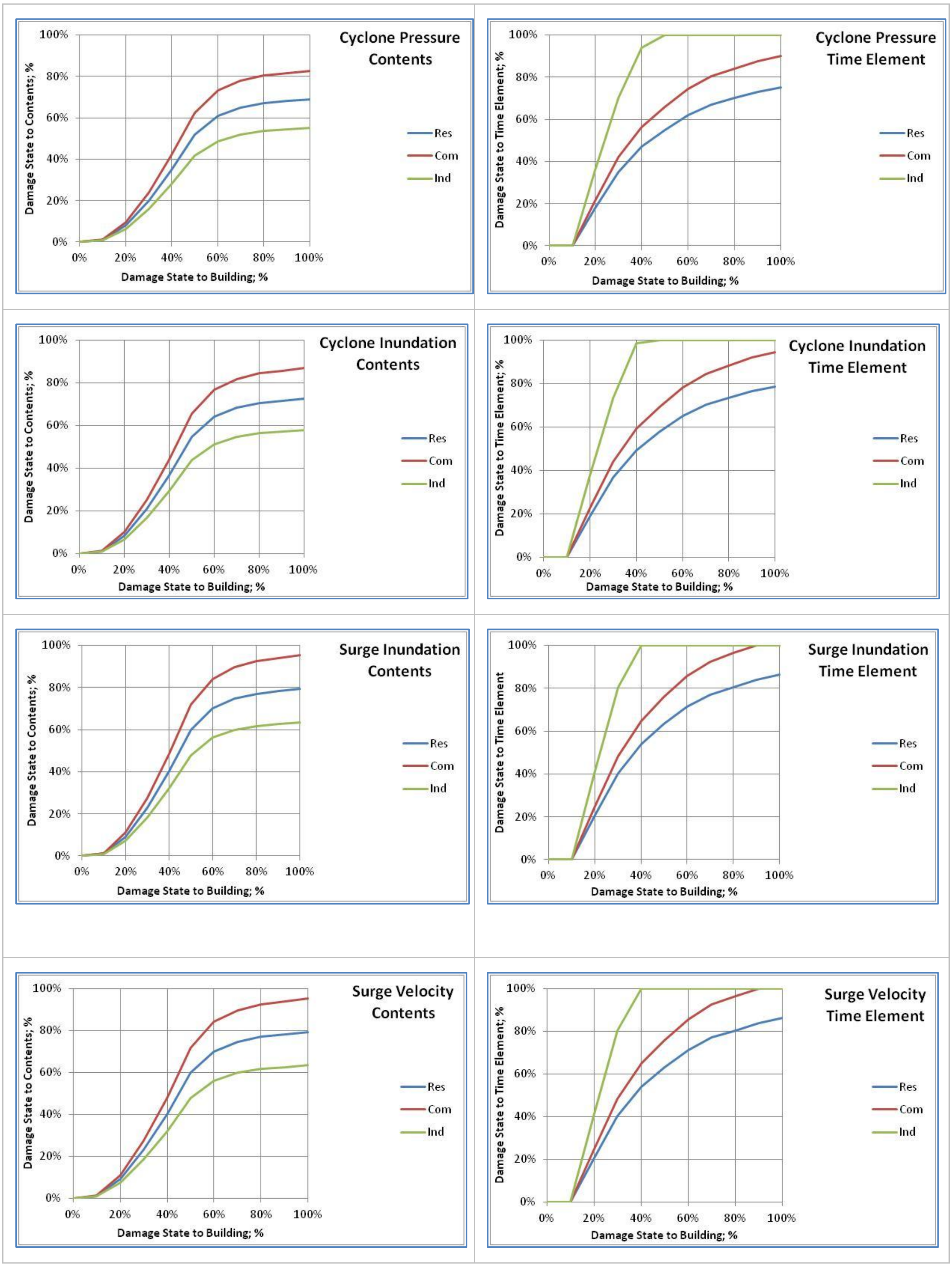


Figure 3-15: Damage functions for Contents and Time Element

Note: Dynamic vulnerability curves for various buildings and infrastructure elements would be part of the Web Risk Atlas and would be calibrated further during Risk Assessment.

3.2.2 UNCERTAINTY ASSESSMENT

The following plots represent the uncertainty around the building damage states. They are based on uncertainty proposed in ATC-13 [18] and adjusted to meet damageability in India. Figure 3-16 represent CoV (Coefficient of Variation = Standard Deviation normalized by MDR). Given the probability distribution modeled for this study, the CoV charts deduce standard deviations that, once coupled with the mean values (MDR), would construct the distribution that will be used in loss assessment (Ground-Up to Gross-Loss), per specific policy conditions.

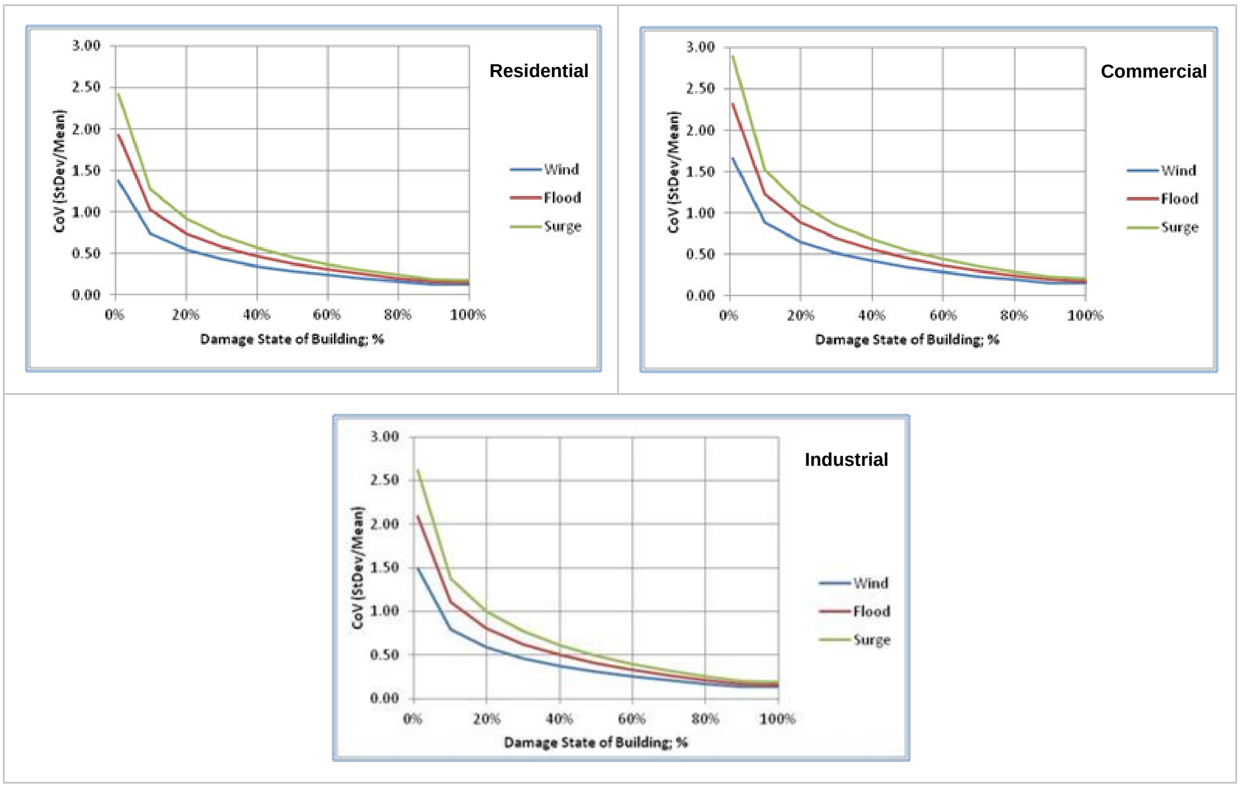


Figure 3-16: Coefficient of variation for residential, commercial, and industrial structures

3.2.3 VULNERABILITY FUNCTION FOR AGRICULTURE CROPS (FLOOD AND WIND)

In the event of a cyclone, crops get affected due to flooding and cyclonic wind. The impact of flooding and cyclonic wind on the various crops has been described in the below given sub-sections.

3.2.3.1 Crop vulnerability to flooding

Most crops grown in India are intolerant to flooding. However, the tolerance level of crops varies. Very susceptible crops include potatoes, pulses, and beans, which may succumb even if underwater for one day. In addition, it is critical for many crops at what growing stage they are under submergence condition. It should be noted that only Kharif crops were considered in this study for the cyclone induced risk assessment since the last 117 years database on cyclone events suggests that these storms occur in the months of May, June, October, and November only (Jain et al. 2010[19]). Hence, cyclones mainly cause damage to crops during the Kharif season crops. During Kharif season, rice accounts for about 70% of

[18] Applied Technology Council; California, 1985

[19] Jain, I., Rao, A.D., Jitendra, V., And Dube, S.K. (2010). Computation of expected total water levels along the east coast of India. Journal of Coastal Research, 26(4), 681–687. West Palm Beach (Florida), ISSN 0749-0208.

total acreage in the coastal districts of Andhra Pradesh and major crops cultivated in the remaining 30% area are groundnut, cotton (lint), maize, and pigeonpea. Similarly, in the coastal districts of Odisha rice accounts for about 85% of total acreage during Kharif season and major crops grown in the remaining 15% are green gram, black gram, horse gram, and pigeonpea.

Among the above-mentioned crops, rice can survive submergence conditions for up to 5-7 days whereas maize can survive flooding for 2-4 days. Major pulses, which are grown during monsoon season, are green gram, pigeon pea, and black gram. All the pulse crops are extremely sensitive to flooding when compared to cereal crops. Furthermore, research in flooded croplands has shown that the oxygen concentration approaches zero after about 24 hours (Weijun Z. et al., 1995[20]). Without oxygen, the plant cannot perform critical life sustaining functions, such as root respiration, and nutrient and water uptake due to impaired roots. Even if flooding does not kill plants completely, it may have a long-term negative impact on crop performance. Besides, submergence also leads to accumulation of compounds like CO2, which are toxic to plants in high concentrations (Ashipala, 2013[21]). For the present risk assessment exercise, flood damage functions at different flood depths for the crops have been developed using analytical approach (i.e., using field observations and crop simulation modeling techniques) and applying national/international field experiences. Table 3-6 shows the relationship between flood water heights and production losses for major crops grown in the coastal districts of Andhra Pradesh and Odisha.

Table 3-6: Flood hazard damage function for major crops grown in coastal districts of Andhra Pradesh and Odisha at different flood depths during early mid-season to late mid-season crop stage

Crop name	Damage function for flood hazard	
	Flood depth (m)	MDR
Rice	0.0	0.00
	0.5	0.35
	1.0	0.55
	1.5	0.75
	1.7	1.00
Maize	0.0	0.00
	0.5	0.45
	1.0	0.60
	1.5	0.80
	2.0	1.00
Cotton	0	0.00
	0.1	0.40
	0.2	0.60
	0.3	0.80
	0.4	1.00
Groundnut	0.0	0.00
	0.1	0.40

[20] Weijun Zhou, Linb X. 1995. Effects of waterlogging at different growth stages on physiological characteristics and seed yield of winter rape Brassica napus.
[21] Ashipala, S. N. (2013). Effect of climate variability on pearl millet (Pennisetum glaucum) productivity and the applicability of combined drought index for monitoring drought in Namibia. Department of meteorology, college of biological and physical science, University of Nairobi.

Crop name	Damage function for flood hazard	
	Flood depth (m)	MDR
	0.2	0.60
	0.3	0.80
	0.4	1.00
Sunflower	0.0	0.00
	0.5	0.45
	1.0	0.60
	1.5	0.80
	2.0	1.00
Green gram	0.0	0.00
	0.1	0.40
	0.2	0.60
	0.3	0.80
	0.4	1.00

3.2.3.2 *Crop vulnerability to wind speed*

High wind is the most common effect of cyclones. For the present risk assessment exercise, wind damage functions at different wind speeds for the crops have been developed using analytical approach (i.e., using field observations and crop simulation modeling techniques) and applying national/international field experiences. The relationship between wind speed and crop production loss in the coastal districts of Andhra Pradesh and Odisha due to cyclone induced winds is given in Table 3-7.

Table 3-7: Wind hazard damage function for major crops grown in coastal districts of Andhra Pradesh and Odisha at different flood depths during early mid-season to late mid-season crop stage

Crop name	Damage function for wind hazard	
	Wind speed (km/hr)	MDR
Rice	0	0.00
	50	0.15
	80	0.25
	110	0.50
	140	0.70
	160	0.90
	180	1.00
Maize	0	0.00
	30	0.10
	50	0.25
	70	0.40
	90	0.75
	110	0.80
	140	1.00
Cotton	0	0.00
	45	0.10

Crop name	Damage function for wind hazard	
	Wind speed (km/hr)	MDR
	60	0.20
	80	0.40
	95	0.60
	110	0.80
	115	1.00
Groundnut	0	0.00
	45	0.10
	60	0.20
	80	0.40
	95	0.60
	110	0.80
	115	1.00
Sunflower	0	0.00
	10	0.10
	15	0.25
	25	0.40
	40	0.75
	60	0.90
	70	1.00
Green gram	0	0.00
	45	0.10
	60	0.20
	80	0.40
	95	0.60
	110	0.80
	115	1.00

3.2.3.3 Validation of modeled loss with the reported crop loss due to Hudhud cyclone

Figure 3-17 shows reported rice and cotton crop production losses and modeled losses due to the Hudhud cyclone in four districts combined (Visakhapatnam, Vizianagaram, Srikakulam, and East Godavari). Variation between reported and model estimated rice and cotton crop production losses are 10% and -11% respectively which represent quite good agreement.

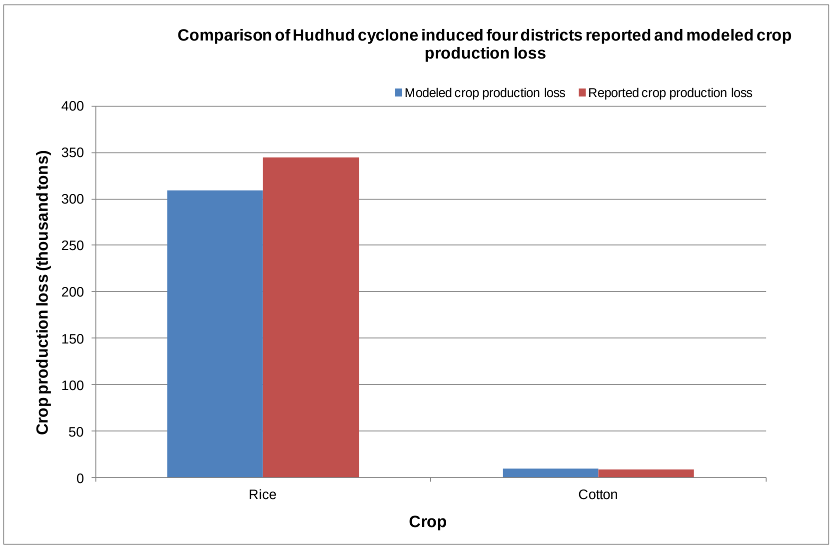


Figure 3-17: Comparison of Hudhud cyclone induced four districts combined (Visakhapatnam, Vizianagaram, Srikakulam, and East Godavari) reported crop production loss and modeled loss

It may be further noted that cyclone induced losses were estimated for each district and the combined to arrive at losses for the four districts to compare the reported losses and modeled losses as we received Hudhud cyclone induced reported crop production loss for aggregated four affected districts (Visakhapatnam, Vizianagaram, Srikakulam, and East Godavari). In this report, we show a comparison result only for two major crops (rice and cotton) grown in the coastal districts of Andhra Pradesh as Hudhud cyclone caused maximum damage to these two crops (about 80% of total affected acreage). Besides, there seems to be some issue in reported losses for other crops as reported acreage losses and reported production losses do not match. For example, normal yield of groundnut in these districts is about 0.9 t/ha but in case of reported yield loss it is only 0.28 although there has been damage to total cropped area. Another example is green gram, where normal yield is about 0.5 t/ha and reported yield loss is only 0.22 t/ha. This might be some error in the estimation of losses or in recording them. Some crops were not included in the validation exercise due to very minor reported losses due to the Hudhud cyclone (e.g. black gram, jowar, and bajra).

The team also compared Phailin cyclone induced reported crop production losses with modeled crop production losses. It is to be noted that Phailin cyclone reported crop production losses are given in terms of monetary values and not in terms of crop production. Hence, the team first estimated the crop production losses for the all crops and then multiplied the 2013 market prices of the respective crops. Subsequently, all crop losses were aggregated together for all three affected districts (i.e., Ganjam, Puri, and Khordha). Further, comparative results show that model estimated crop production losses are lower by about 26% of the reported crop production losses, which is a fairly good agreement in the context of so many approximations.

3.2.4 Social Vulnerability Assessment

Social vulnerability refers to the socio-economic and demographic factors that affect the resilience of communities. Studies have shown that in disaster events the socially vulnerable people are more likely to be adversely affected.

Social vulnerability is partly an outcome of aspects of social setup that influence or shape the susceptibility of various factions of the society to disasters and drive their ability to respond. It is, however, crucial that social vulnerability is not considered as a function of exposure to hazards alone, but also the sensitivity and resilience of the society to prepare, respond, and recover from disasters. Social vulnerability is a culmination of economic, demographic, and housing characteristics that influence a community's resilience to natural hazards. The major components of vulnerability are well being, livelihood resilience, skills awareness, social security, and social awareness.

An index-based approach has been used to assess the social vulnerability at mandal/tehsil level through development of social vulnerability index (SoVI).

3.2.4.1 Data Source

Social vulnerability analysis has been carried out based on social indicators like population, gender, children and aged, disabled population, literacy, and occupation, housing type, access to basic infrastructure like road and health care. Census 2011 data at village level has been used as the main source of social and economic data.

3.2.4.2 Methodology

Index based social vulnerability assessment is mainly used to quantify and analyze the distribution of vulnerability groups. Social indicators are identified based on its influence to vulnerability and a weighted ranking method is used for developing the index. SoVI was developed at village level, as this information is a key input variable for identifying the hotspots. For social vulnerability assessment, the selection of indicators varies even though most of the practitioners use some of the key demographic indicators including gender, age, disabled people, income (economic status), minority community, education, access to information, etc[22]. University of South Carolina has contributed substantially in developing methodologies SoVI and has developed social vulnerability for the whole of US using census data. The SoVI index developed in US is widely used from local administration for mitigation and planning during natural hazards – particularly hurricane and flood. SoVI indexing will help in prioritizing mitigation and planning to reduce social impact due to cyclones that could be predicted ahead of time.

In the present assignment, we followed the broad SoVI framework of Cutter et al and the social indicators were selected based on understanding the socio economic characteristics of the study area, historical hazard events, review of past vulnerability and risk assessment studies, review of post damage need assessment (PDNA) major events in India to understand the social issues and through expert opinion based on field experience working in coastal India. Basically, the social indicators that influence community's well being have been selected and analyzed using Analytic Hierarchy Process (AHP) method. The following socio-economic variables (Table 3-8) are selected for developing the SoVI.

Table 3-8: Indicators used for social vulnerability analysis

Sl No.	Indicators	Description	Normalization	Increases (+) or decreases (-) SV
1	Population density	Higher population density makes evacuation harder and increases risk of casualties	Population per sq km	Higher the density increase SV
2	Gender (Female headed household)	Women and women headed households impact more during disaster and recovery due to family responsibilities and lower incomes compared to men	Ratio of female headed households to total households	(-) Higher female headed HH increase SV
3	Population age <06 and >60	Dependant population - children and old people need support during any emergency	Ratio of population with age <6 and > 60 to total population	(-) Higher number of dependant population increase SV

[22] *Cutter et al., 2003, Satu Kumpulainen, 2006, Barry E. Flanagan et al 2011*

Sl No.	Indicators	Description	Normalization	Increases (+) or decreases (-) SV
4	Disabled Population	Disabled population struggle more during disaster and recovery due to their disability	Ratio of disabled population to total population	(-) Higher number of disabled population increase SV
5	Literacy	Education is linked with socio economics and access to information, which is important for prevention as well as support in relief and recovery	Ratio of literate population to total population	(+) Higher literacy decrease SV as they have better access to information
6	Primary sector (livelihood)	Livelihood mainly primary sector - agriculture and fisheries impacted lot during any disaster events and take more time to recover	Ratio of primary work to total workers	(-) Higher number of population in primary sector increase SV
7	House type	Consider kutcha house which is an indicator of economic status as well as kutcha houses are more vulnerable structures	Ratio of kutcha houses to total houses	(-) Higher number of kutcha house income lower income group and structure type are vulnerable
8	Access to roads	Access to road is important during rescue and evacuation	Road density (ratio of road to area)	(+) Higher road access decrease SV as this help rescue, evacuation and relief
9	Access to health facilities	Access to health facilities is important during rescue and evacuation	Health facilities density	(+) Higher health facilities decrease SV as this help rescue, evacuation and relief

Note: Most of these indicators are used by several authors elsewhere.

Instead of age <15 we have considered age <6 for the social vulnerability analysis considered this age group need support during evacuation and special care facilities during relief operations.

Social indicators were selected and reviewed to understand their relationships in the context of the coastal regions of India. The indicators that have significant correlation were selected and ranked using AHP techniques.

The stepwise process carried out for SoVI analysis is:

1. Secondary data on the identified indicators pertaining to Census 2011 are tabulated and analyzed at taluka/mandal/tehsil level and are used to derive input variables to calculate SoVI.
2. The variables are normalized on a scale of 1 to 10 as percentages in AHP tool.
3. Accuracy of the data sets is verified using descriptive statistics. Weightage assigned through AHP method is applied to the social indicators and cumulative score is derived, which is the SoVI for the taluka/mandal/tehsil.
4. SoVI is mapped using natural breaks method of GIS in classification illustrating areas of high, medium, and low social vulnerability.

The weights assigned to the social indicators through AHP are presented in Table 3-9.

Table 3-9: Weights assigned to the social indicators through AHP

Sl. No	Indicators	Weights (%)
1	Population Density	29
2	Gender (Female Headed Household)	9

Sl. No	Indicators	Weights (%)
3	Age < 06 and > 60	10
4	Disabled Population	6
5	Literacy	6
6	Primary sector (livelihood)	13
7	House type	14
8	Access to roads	6
9	Access to health facilities	6

SoVI prove valuable during prioritization of interventions in addition to planning and decision-making as it portrays the geographic variations in community resilience. This also indicates the differential ability of recovery across the geographical units. SoVI map was generated at village level categorizing SoVI into high, medium, and low. The SoVI results of both the states are provided in the subsequent sections.

3.2.5 ECONOMIC VULNERABILITY

Economic aspects (income and occupation) have been considered in social vulnerability analysis, as social resilience is highly influence by economic status or capacity to recover. For economic vulnerability primary occupation groups – people engaged in agriculture and fisheries sector were considered. Census 2011 data is used for generating the livelihood (primary sector) group and the working population is grouped into primary sector, secondary and service sector and non-workers. As per Census classification, working population is group broadly into main workers, marginal and non-workers. Detailed occupation classification of census data help in segregating occupation group as per our present requirement. Poverty level data is based on NSSO and state level poverty statistics. The data is only available at district level.

The following economic related data is further furnished in the subsequent section separately for Andhra Pradesh and Odisha.

1. Livelihood: for livelihood mainly we have considered the primary livelihood which is fisheries and agriculture
2. Major occupational groups: the occupation classes is grouped into primary sector, secondary and service together and non-workers
3. Poverty: percentage of people below poverty line to total population is considered here.
4. GDP: District level GDP and growth rate available is presented here.

Livelihood and source of livelihood are key factors determining the economic vulnerability of a community. Economic resilience helps community to recover from shock faster, which in turn help to reduce social vulnerability. This becomes more critical in the event of any natural hazards. Even though almost all livelihood activities get impacted in the event of cyclone, storm surge and cyclone induced flood, primary activities – fisheries and agriculture are the key livelihood sector than impacted lot and to a good extend for longer duration compared to secondary and tertiary sector.

The Census has considered economic activities and classified occupation by primary, secondary and service sector. The primary sector include fisheries, forestry and agriculture and in the case of coastal district this with be mostly fisheries and agriculture. For the present livelihood analysis, also we are considering primary occupation and have generated a livelihood (primary sector) map of the study area.

For occupational analysis, census data was used. The occupational data is grouped in primary sector (agriculture and fisheries), secondary and service sector together and non-workers. The occupational pattern maps for both the states are presented in the analysis section.

For GDP, district level data is considered and growth trend is presented over the year. Sub district GDP data is not available for the study area.

3.3 Developing Building Agglomeration (Cluster) Data by Land Use Classes Using Satellite Imageries/ Statistical Techniques

As the present study deals with cyclonic winds, storm surge, and cyclone induced rainfall flooding, which are mostly localized in nature, it becomes pertinent to know the spatial distribution of building exposure within the city/village. The land use data is the base for developing building agglomeration data at cluster level. The land use data for Andhra Pradesh and Odisha includes distinct occupancy classes (residential, commercial and industrial) based on specific building uses. In order to fulfill the above-mentioned requirement, in-house available land use data at 5.8-meter resolution for cities and at 25 meter for rural areas have been used. Further, there are occupancy sub-classes in the data based on building density and building heights assigned to every cluster. While developing the data at cluster level, the team has captured and updated the available land use data using Google Earth and RMSI in-house satellite imageries. In this process, special attention has been given in capturing clusters for coastal villages that are more vulnerable to cyclone and related hazards.

The building cluster data developed has then been used to distribute building occupancy and structural classes applying appropriate GIS and statistical techniques.

3.4 Development of Building Classification Schema

3.4.1 BUILDING TYPOLOGY

The function of a building is strongly influenced by its design and construction. In this study, first the buildings are categorized based on their structure (primarily, wall and roof materials) keeping in view their physical vulnerabilities and then these structural classes are distributed over the occupancy types (based on building usage such as residential, commercial, industrial etc.).

3.4.1.1 Structural Classes

The vulnerability of buildings to cyclone, cyclone induced flooding, and storm surge primarily depends on the construction materials used for wall and roofs, their designs, age, maintenance, and height of the buildings.

These are therefore the key parameters considered while organizing the buildings into different structural classes. These classes represent the categories that are distinctly vulnerable to the same level of hazards.

To delineate buildings based on structural details, the team considered the wall and roof material combinations derived from Census 2011 at city/village level. The Census (2011) provides 90 combinations based on the predominant materials of roof and wall. These combinations have been further grouped into 25 combinations based on the vulnerability of buildings to different hazards presented in Table 8-5 of Annex 8.1. Table 3-10 presents the six predominant building structural classes that are mainly available in Andhra Pradesh and Odisha. All these structural classes have been validated through sample field verification surveys and considered for customizing the vulnerability functions.

Table 3-10: Predominant building categories by construction materials and structural types

Sl. No.	Building Category	Structural Types (combination of major wall and roof materials)
1	ST4	Grass/ thatch/ bamboo/ wood/ plastic/ polythene etc. used as roof material in combination of burnt brick/ stone packed with mortar/concrete as wall materials
2	ST6	Handmade tiles/ machine made tiles/burnt bricks/stone/slate/concrete used as roof material in combination of Grass/thatch/bamboo etc. as wall material
3	ST8	Handmade tiles/ machine made tiles used as roof material in combination of stone packed with mortar/burnt brick/concrete as wall material
4	ST16	G.I./Metal/Asbestos sheets used as roof material in combination of Stone packed with mortar/ burnt brick/ concrete as wall material
5	ST17	Concrete used as roof material in combination of Mud/unburnt brick/Stone not packed with mortar as wall material
6	ST18	Concrete used as roof material in combination of Burnt brick/Stone packed with mortar/Concrete as wall material

3.4.1.2 Occupancy Classes

The primary source of defining the occupancy classes in the study area is Census 2011. It classifies the occupancy classes into four categories namely residential, commercial, industrial, and others (Table 3-11). The class named as others comprises of occupancy classes such as schools and colleges, hospitals and dispensaries, and places of worship etc. These data are available at a resolution of city level for urban areas and at district level for rural areas. The team has brought these data at city/village level using appropriate statistical techniques. Finally, after applying growth rates, the data has been projected to 2014 estimates.

Table 3-11: Building occupancy classes

Sl. No.	Occupancy category	Sub-Category
1	Vacant census houses	
2	Occupied census houses	Residential
3		Commercial
4		Industrial
5		Others (Educational institutes, health centres, religious places etc.)

3.5 Sample Field-Verification Survey

Sample field-verification survey not only helps in filling missing information but also helps in validation of exposure data being developed. In the present study, the field survey has been carefully designed and administered by experts to bridge the data gaps in the field of local construction practices (construction materials and structural types) for residential, commercial, industrial building use, as well as for religious buildings and infrastructural elements such as roads, bridges, power lines, irrigation systems, and airports etc. The RMSI field survey teams have carried out the survey through four distinct steps, namely, preparation of field survey questionnaires, delineation of sample size by administrative units, planning and execution of actual survey, and collation of surveyed data into exposure database. These steps are briefly detailed in the following sub-sections:

3.5.1 PREPARATION OF FIELD SURVEY QUESTIONNAIRES

The team has prepared the field survey questionnaires for various exposure elements in consultation with structural and vulnerability experts. This has been drafted keeping in view the information collection through both interactions with the building occupants as well as through field observations. To achieve better results, before the start of actual field survey, the team has carried out pre-tests of the questionnaire in 1-2 locations in each state under consideration. This has helped to incorporate necessary modifications in the field questionnaires and to avoid illogical entries into the data.

3.5.2 DELINEATION OF SAMPLE SIZE

The team has adopted a stratified random sampling method to select the representative sample size. The sample size for each type of predominant building categories (Table 3-10), has been calculated at 99% confidence level and the margin error of 3.5 according to the following formula[23]. Total number of households of all coastal districts in the study area has been considered from Census 2011.

Formula:

$$n = \frac{X^2 * N * P * (1-P)}{(ME^2 * (N-1)) + (X^2 * P * (1-P))}$$

Where:

n = required sample size

X2= Chi-square for the desired confidence level at 1 degree of freedom

N= population size

P= population proportion (0.50 for this table)

ME= desired margin of error (expressed as a proportion)

Sample size for each structure type has been calculated using the above formula. The relationship between sample size and total population is illustrated in Figure 3-18. It should be noted that as the population increases, the sample size increases at a diminishing rate and remains relatively constant at slightly more than 380 cases.

[23] Krejcie, et al 1970, Xu, Gang, 1999

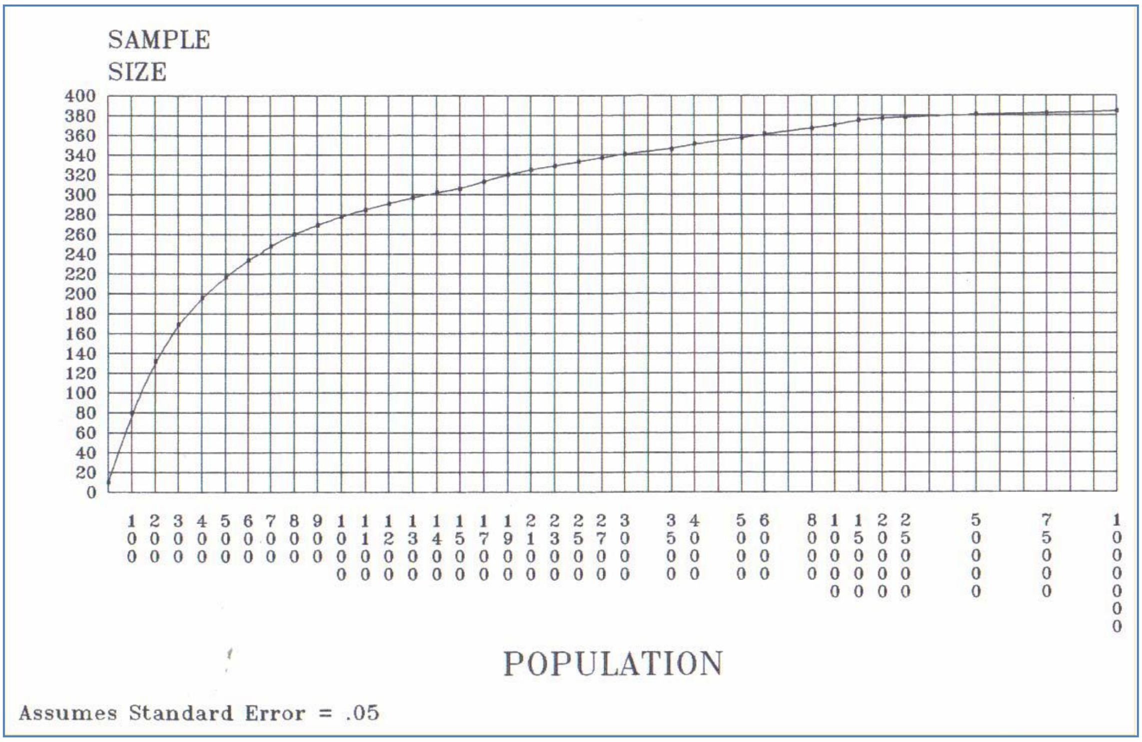


Figure 3-18: Relationship between sample size and total population

To select the district to be surveyed, household types for each district falling under the area of interest have been considered. In addition, the proneness of these districts to cyclone as per IMD has also been considered.

Using Analytical Hierarchy Process (AHP), weights for type of structure and proneness to cyclone have been defined. Higher weights have been given to temporary structures and more cyclone prone districts.

A matrix has been derived by multiplying the weights of types of structures and proneness to cyclone determined by AHP. Using this matrix, the number of households have been derived in each district by structural type and vulnerability to cyclone. In the next step, the number of households in each district has been normalized by the sample size derived by using the above mentioned formula for each structure type.

To select the district to be surveyed, all those districts that had all the roof and wall material combinations were selected. Out of these selections, all those districts were selected which were highly vulnerable to cyclones according to IMD[24]. Based on this, total sample size came to around 1,120 distributed in four districts (Ganjam, Puri, Srikakulam, East Godavari) across Andhra Pradesh and Odisha. However, the field-verification survey team has also covered Visakhapatnam district because of the recent Cyclone Hudhud 2014 that made landfall near Visakhapatnam city and caused massive socio-economic losses in the city.

3.5.3 Planning and Execution of Actual Surveys

The team has planned the sample field-verification surveys considering the city/village locations and building typologies. Sample field-verification surveys for the above-mentioned districts have been planned considering vulnerability of the area. Odisha has been selected on first priority as it is the most vulnerable state of India for cyclone hazards when considered for coastal disasters and has a lower elevation of coastal plains when compared to other coastal states on the East Coast of India.

[24] G.S. Mandal and M. Mohapatra (2010). Cyclonne Hazard prone districts of India: A Report, IMD, 44 pp.

Starting with Ganjam district of Odisha, team moved downwards towards Andhra Pradesh covering the selected districts for field survey. Figure 3-19 represents the area covered during the field survey.

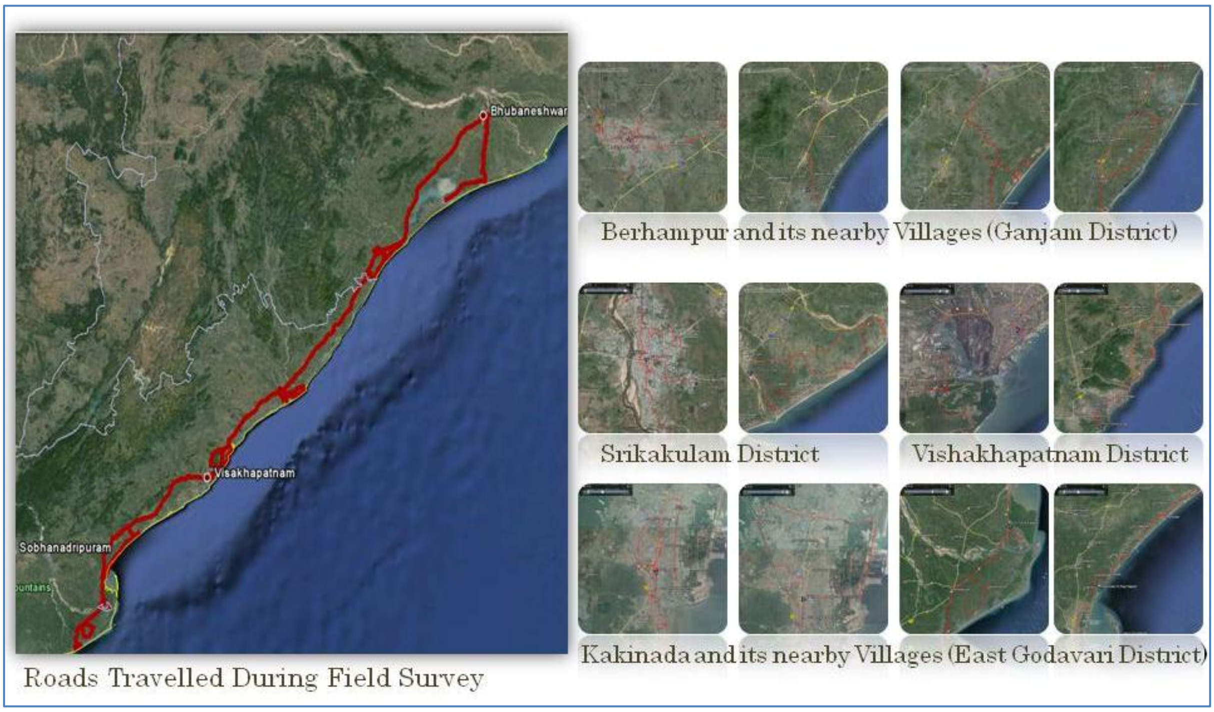


Figure 3-19: Area covered during sample field verification survey for Andhra Pradesh and Odisha

Major areas covered during the survey are as follows:

- Coastal villages to understand the impact of disasters on the living standard, which included location of the houses, building structures, relief funds received from government, building construction costs (replacement costs) etc.
- Cyclone shelters, if available, in the villages to monitor the condition, capacity, and other facilities.
- Public health centers to check the capacity of doctors and beds for better understanding the ratio of population with the health facilities to total population of the village.
- Education centers like primary, secondary, upper secondary, and colleges to collect information about the number of students, classrooms etc. and to check whether the same are being used as cyclone shelters at the time of disasters or not.
- Industrial facilities to collect information related to the product, capacity, structure, and location (distance between the industry and settlement villages and between coast and industry).
- Police and Fire and Emergency Stations building areas, building structures, conditions, and capacity
- Seaports and airports to find the material used for building structures and other infrastructure details.
- Roads and bridges to know condition and surface material.
- State and District departments to gather information about overall distribution of amenities across the state or district, their replacement costs and to collect information about their disaster management plans.

Data was captured using high accuracy GPS and tracks were recorded for the survey areas so that it helped in analyzing the portion of villages surveyed and quantifying the survey area. Approximately 60 villages were visited to collect different types of information such as building structure type, total number of houses, total population, availability of facilities like schools, hospitals, cyclone shelters etc. Approximately 1,500 km of road was travelled during this survey. Field photographs of some of the residential and commercial buildings has been presented from Figure 3-20, Figure 3-21, Figure 3-22 and Figure 3-23.

Figure 3-20: Samples of residential buildings in Andhra Pradesh and Odisha

Figure 3-21: Samples of residential buildings in Andhra Pradesh and Odisha

Figure 3-22: Samples of commercial buildings in Andhra Pradesh and Odisha

Figure 3-23: Under construction buildings provide insight into the construction materials and structural types

NOTE – Team collected information regarding the construction cost for buildings from builder, government approved construction companies for computing the replacement costs

3.5.4 COLLATION OF SURVEYED DATA INTO EXPOSURE DATABASE

After completing the field survey, the collected data was first converted into usable format and then reviewed and analyzed for inaccuracies pertaining to locations and attributes. The data, which passed through all logical checks, was used for filling the gaps and validation of available exposure attributes. Finally, the validated data, after necessary processing, was collated with the already composed exposure datasets.

3.6 Estimation of Exposure Values

In risk assessment, value of an exposure element is defined by its replacement cost as on today. The key steps to calculate the replacement cost is presented below.

3.6.1 Estimation of Built-up Areas

3.6.1.1 Residential, Commercial and Industrial buildings

Built-up areas are the total constructed area of a building or an infrastructure element. As presented earlier, building types in the study area have been categorized into 25 pre-dominant structural types (Table 8-5). Subsequently, based on construction materials, these structural types are further grouped into three categories; pucca, semi-pucca and kutcha houses. The team has conducted sample field verification surveys to collect information about various housing types for their structural details, occupancies and constructed areas. In addition, the team has collected information about building construction practices and their unit cost estimates from local builders and/or real-estate websites / other online references. The data from all these sources were used to estimate the average per unit built-up areas for different structure types. These information has further been validated with reference to India Infrastructure Report (IIR), 2007 [25]. (Table 3-12) and state level average area provided by NSSO 2013 [26]reports (Table 3-13).

Table 3-12: The average floor area and cost of various building types

Average Floor Area (square meter) and Average Cost (Rs thousand) per completed house construction during 1997–2002						
Structure type	New building		Addition to floor space		Repair/alteration	
	Floor area (sq m)	Cost (Rs thousand)	Floor area (sq m)	Cost (Rs thousand)	Floor area (sq m)	Cost (Rs thousand)
Pucca	42	113	21	46	29	21
Semi-pucca	29	22	16	13	29	6
Kutcha	20	8	12	4	21	2

Source: India Infrastructure Report, 2007 (NSSO.2004)

Table 3-13: State level average floor area of rural and urban dwellings

Average floor area (sq. m.) of the dwellings		
State/UT	Average floor area (sq. m.) of the dwelling	
	Rural	Urban
Andhra Pradesh	29.85	32.75
Odisha	31.27	34.04

Source: Key Indicators of Drinking Water, Sanitation Hygiene and Housing condition in India, Dec.2013, NSSO

To estimate the projected number of Census for 2014, decadal growth rate (2001-2011) was first determined to arrive at average annual growth rate, which was applied, to 2011 data. Next, the projected number of households (2014) is multiplied with the average per unit built-up area to estimate the total built-up area at village level for 2014. By using a similar

[25] http://www.iitk.ac.in/3inetwork/html/reports/IIR2007/10-Rural%20Housing.pdf
[26] *NSS KI (69/1.2): Key Indicators of Drinking Water, Sanitation, Hygiene and Housing Condition in India*

methodology, the total built-up areas for commercial and industrial buildings are also estimated.

3.6.1.2 Other Types of Structures

For other types of structures, the team has calculated the total area or, total length using GIS tools. For example, linear features, such as roads, railways, bridges, and electric lines, the total length of the features are calculated. Similarly, for schools and health centers, the area corresponding to the building coverage has been estimated.

3.6.2 ESTIMATION OF UNIT REPLACEMENT COSTS

To estimate the replacement cost (per square meter), the team has first collected the unit replacement values for each exposure element from various sources such as state and central Government websites, concerned state government departments, field verification survey, past studies and reports for Andhra Pradesh and Odisha as well as the information collected from local builders/ real-estates websites (Table 3-14).

Table 3-14: Replacement cost of typical buildings collected from various sources (cost per sq m in INR)

Building Types	RCC Framed Structure up-to six stories	RCC Framed Structure over six stories up-to nine stories		Sources
Residential	14,500	15,060		http://cpwd.gov.in/newsitem/latestnewspdf/PAR2012.pdf
Offices /Colleges/ Hospitals	19,000	19,560		
Schools	15,200	15,760		
Hostels	15,000	15,560		
Building Type	**Pucca**	**Semi-Pucca**	**Kutcha**	**Sources**
Residential	2,690	759	400	http://www.iitk.ac.in/3inetwork/html/reports/IIR2007/10-Rural%20Housing.pdf
Primary schools	10,978			Ministry of Education (Civil Engineering Department)
Building Type	**RCC frame structure building**			**Sources**
Residential	25,000-30,000			PWD Building Department
Building Type	**RCC framed structure with red oxide flooring and Jungle wood doors and windows**	**Madras terrace/Mangalore tiles/AC sheet roof brick/stone masonry walls and red with oxide flooring and Jungle wood doors and windows**		**Sources**
Residential	5,000	3,200		National Municipal Asset Valuation Manual

Building Type	RCC framed - posh structure	RCC framed - ordinary structure	Madras terrace/ Mangalore tiles/ AC sheet roof	Sources
Residential	6,200	5,000	3,200	http://www.cgg.gov.in/publicationdownloads2a/Asset%20Valuation%20manual.pdf
Building Type	**Single storey-multi- storey**	**Tile Buildings/AC Shed**	**Commercial/Hospitals/Schools**	**Sources**
	1,2000 -1,4000	6,000	10,000	Vizag Builders Association

Based on the unit replacement cost provided by Central Public Works Department (2012) Andhra Pradesh Municipal Asset Methodology Valuation Manual (2012), National Municipal Asset Valuation Methodology Manual (2007) and inputs from RMSI field sample verification surveys (2015), unit replacement cost of buildings for each occupancy type has been derived. Finally, after careful review and analysis by RMSI expert team, the average unit replacement costs for each type of buildings/ infrastructures has been derived (Table 3-15).

Table 3-15: Unit replacement cost on various exposure elements

Building Types	Types of Structures	Average Unit Replacement Costs per sq m (in INR)	
Residential Buildings	Kutcha	Rural	2,000
		Urban	2,500
	Semi-Pucca	Rural	4,000
		Urban	6,000
	Pucca	Rural	8,500
		Urban	12,000-14,000
Commercial Buildings	Kutcha	Rural	2,000
		Urban	25,000
	Semi-Pucca	Rural	4,000
		Urban	6,000
	Pucca	Urban	12,000-16,000
Industrial Buildings			15,000
School	Primary	Rural	10,000
		Urban	12,000
	Secondary		13,000-14,000
Hospital	Primary Health Centre		14,000
	Community Health Centre		16,000
	Major Health Centre		16,000
	Other Hospitals		10,000-12,000
Religious Buildings		Rural	8,500
		Urban	10,000
Police Stations		Rural	10,000
		Urban	12,000
Fire Stations	Kutcha		10,000
	Semi-Pucca		12,000
	Pucca		14,000
Administrative Headquarter	District HQ		14,000
	Tehsil HQ		12,000
Airport Buildings			240,000
Transportation	**Types**	**Average Unit Replacement Costs Per km (in crores)**	
Road	National Highway	9.7	
	State Highway	5.51	
	Major Road	5	
	Minor Road	0.25	

	Other Road	0.37
Railway Line	Single Line	6.3
	Double Line	9.45
Bridge		0.19
	Runway	3.04
Seaport	Per berth	400
Utilities	**Types/units**	**Average Unit Replacement Costs (in INR)**
Waste water	Per meter	5,000
Potable water	Per meter	5,000
Electric line	Main Power Line/ meter	620
	Power Line Other/ meter	443
Oil and Gases	Per km	80,000,000
Communication lines	Mobile Connection	730
	Landline Connection	4,960

3.6.3 Calculation of Exposure Values

The total estimated exposure value for each types of exposure has been calculated by:

$$Total\ exposure\ values = Total\ built - up\ area * Unit\ replacement\ cost$$

In this study, the replacement cost is expressed in Indian Rupees (INR).

4 Results and Findings for Andhra Pradesh

There are 9 districts, 192 sub-districts, and 3,623 villages in Andhra Pradesh, which fall in the study area. Detailed analysis of each exposure element as described in Figure 3-1 is presented in the following subsections.

4.1 Demography

As per Census 2011, the total population of the study area in Andhra Pradesh is about 1.72 crores. To estimate 2014 population, the decadal growth rate at district level (Census 2011 and 2001) was used to arrive at annual average growth rate, which was applied, to Census 2011 population to arrive at city/village level population for 2014. After applying the growth rate, the projected population for 2014 is estimated at 1.76 crores. Table 4-1 presents the distribution of population by gender at district level.

Table 4-1: Population distribution by gender at district level

District	Male Population	Percentage of male population	Female Population	Percentage of female population	Total Population
East Godavari	19,59,399	49.88	19,68,690	50.12	39,28,089
Guntur	9,33,279	49.63	9,47,228	50.37	18,80,507
Krishna	8,92,822	50.10	8,89,283	49.90	17,82,105
Prakasam	6,33,552	49.93	6,35,284	50.07	12,68,836
Sri Potti Sriramulu Nellore	9,77,048	50.35	9,63,504	49.65	19,40,552
Srikakulam	8,10,059	49.59	8,23,536	50.41	16,33,595
Vishakhapatnam	12,61,172	50.30	12,46,344	49.70	25,07,516
Vizianagaram	92,287	50.28	91,256	49.72	1,83,543
West Godavari	12,49,370	49.85	12,56,986	50.15	25,06,356
Grand Total	88,08,988	49.96	88,22,111	50.04	1,76,31,099

Table 4-1 indicates that East Godavari district has the highest population, about 39.28 lakhs (about 22% of the total[27]), whereas Vizianagaram has the least population, i.e., about 1% of the total. In terms of urban/rural distribution of population, majority of the population (64%) lives in rural areas and about 36% lives in urban areas (Figure 4-1).

[27] % of total population of study area

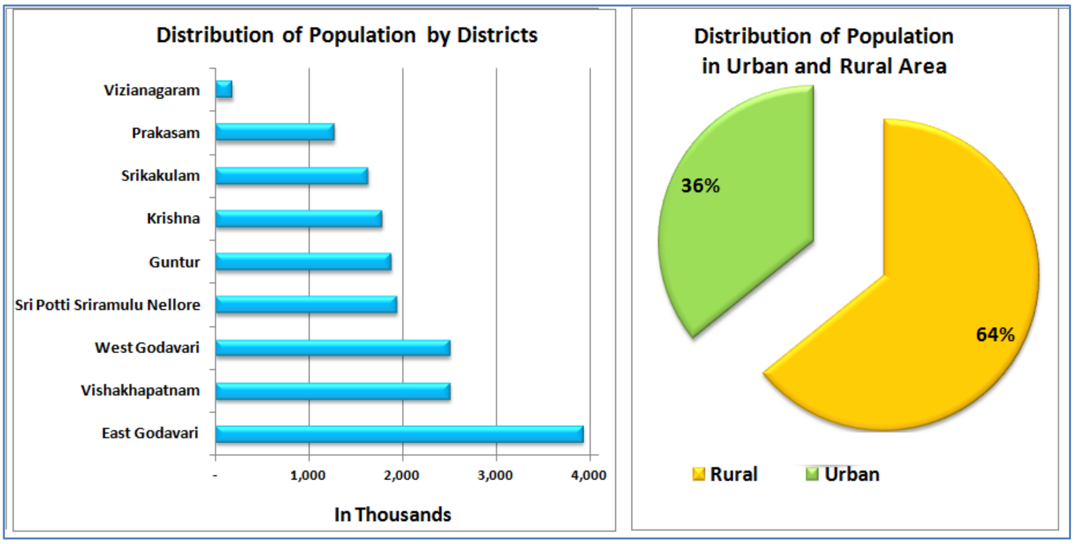


Figure 4-1: Distribution of population by districts (left) and in rural and urban area (right)

Of the total study area population, about 57% is non-working population residing across various villages. The non-working population comprises of about 64% females and about 36% males (Figure 4-2). East Godavari district has the highest number of non-working male and female population followed by Visakhapatnam and West Godavari districts. Vizianagaram district has the least number of working male and female population (about 1%), whereas East Godavari district has the highest number of working population (about 20%).

Figure 4-2 shows that the percentage of child population (<15 Years) to total population of study area is 24% (42.61 lakhs). Of this, about 66% lives in rural areas and 34% in urban areas. About 11% of total study area population comprises old age population (>60 years). Of this, 69% lives in rural areas and 31% in urban areas. Table 8-2 presents the district-level distribution of children and old age population.

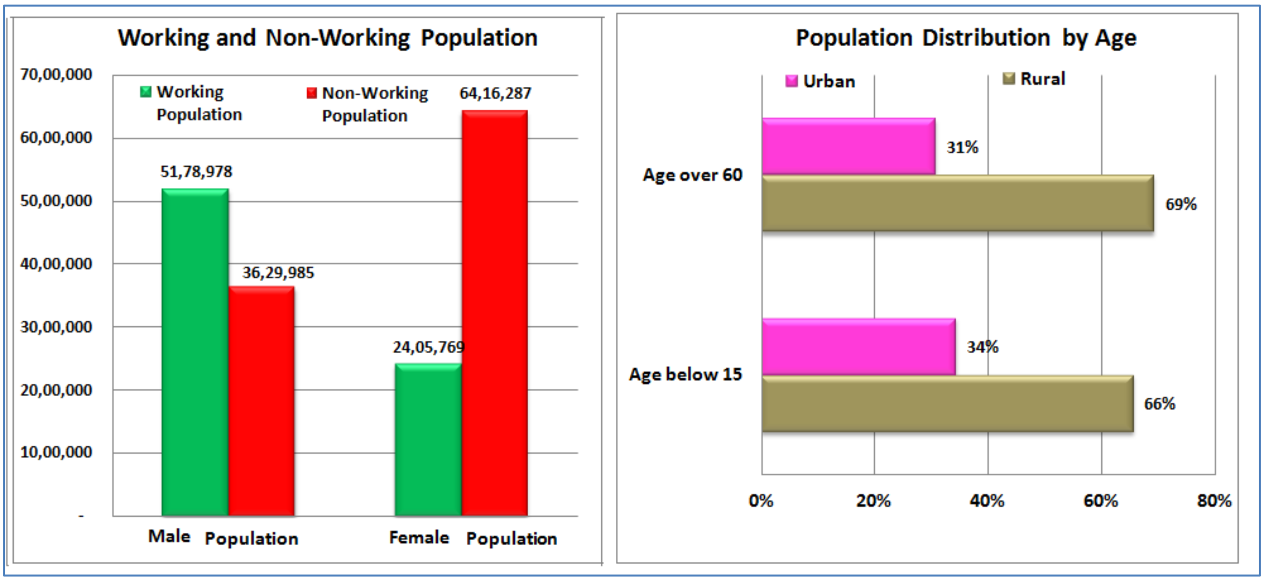


Figure 4-2: Total working and non-working population (left); and urban/rural distribution of child and old age population (right)

Figure 4-3 presents the population density at sub-district level. Rajahmundry (urban) sub-district in East Godavari district has the highest population density of more than 10,000 whereas Tada sub-district in Sri Potti Sriramulu Nellore district has the least population density of 100 amongst all the 192 sub-districts. At village/city level, Nellore (M.Corp. and OG) city in Nellore tehsil of Sri Potti Sriramulu Nellore district has the highest population density of more than 32,000 whereas Santhosha Puram village in Nandigam tehsil of Srikakulam district has least population density of two (2) persons/ sq. km.

.

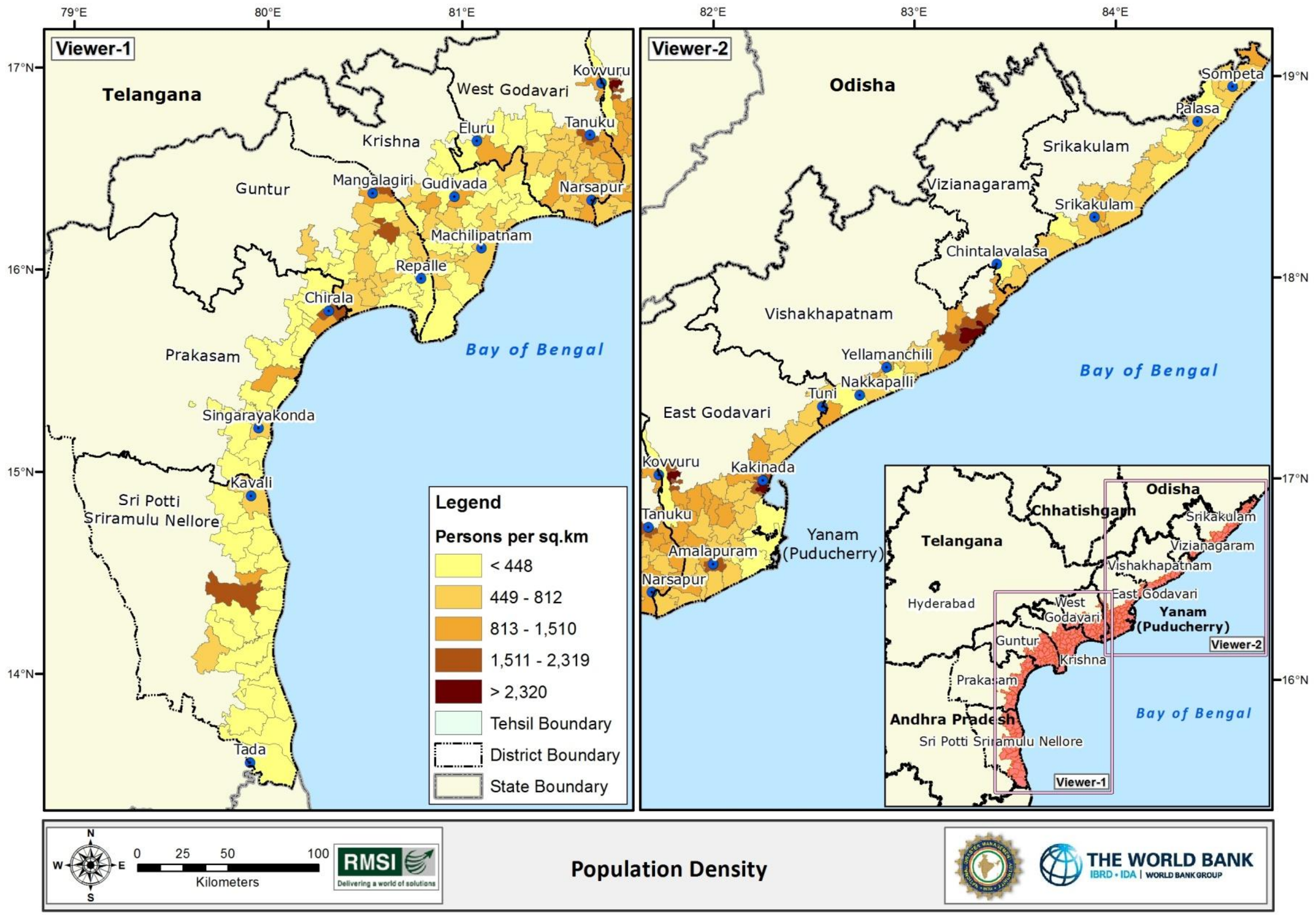


Figure 4-3: Tehsil level density of population

4.2 Building/Housing

4.2.1 Building Occupancy

About 59 lakh Census houses have been estimated for 2014, out of which about 93% are occupied and the remaining 7% are vacant (Figure 4-4). The occupancy based distribution of housing shows that about 87% of the houses are used for residential purposes; whereas, about 5% are used for commercial or residential-cum-commercial use and about 1% houses are used for industrial use. The remaining (7%) houses are used for other uses that include social and public uses, viz., schools, colleges, hospitals, dispensaries, religious places etc. Figure 4-4 provides the distribution of houses based on their occupancy. The district-wise distribution of houses based on their occupancy is given in Table 8-3. For better understanding, the educational institutes (about 0.7% of the total houses) has been presented separately in the below diagram (right).

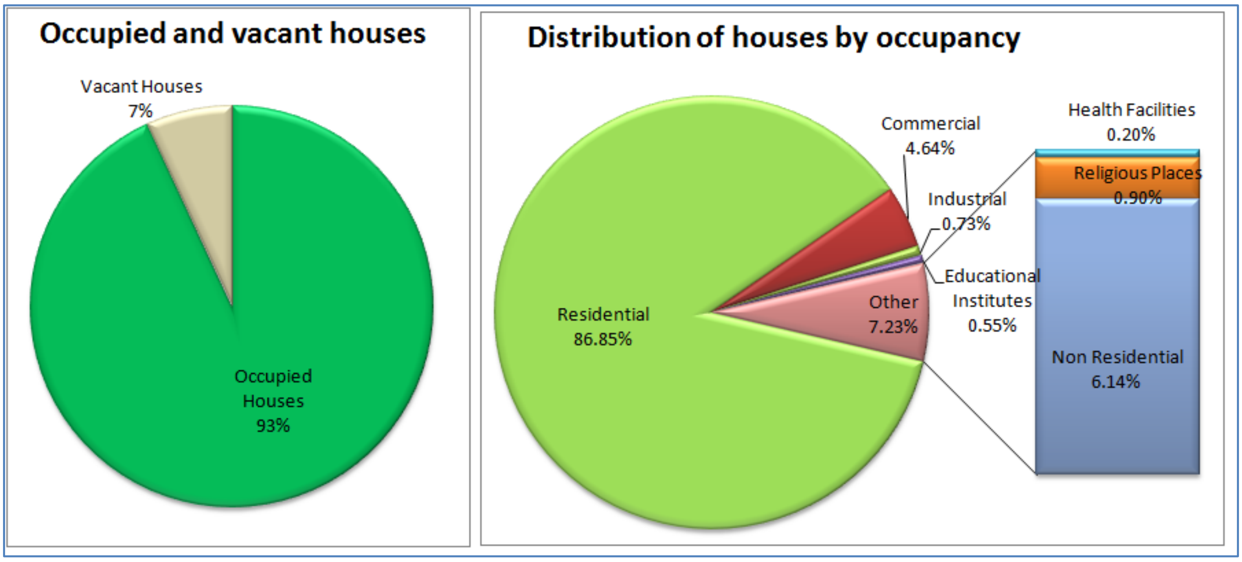


Figure 4-4: Percentage distribution of occupied and vacant houses (left), and distribution of the Census houses based on occupancy (right)

Census 2011 data for various occupancy types are in tabular format, which lacks the spatial distribution of residential, residential-cum-commercial, commercial, industrial, and other buildings within each district. In building agglomeration data, buildings are clustered based on the occupancy type. For cyclonic wind, storm surge, and cyclone induced rainfall hazards (mostly localized in nature), it is important to know the spatial distribution of building exposure within each district. In order to fulfill the above-mentioned requirement, building agglomeration data are derived from satellite LISS IV images. Figure 4-5 presents the building footprints delineated from satellite images for the study area. The classifications are done based on the tone, texture, shape, size, pattern, and associations between buildings as present on satellite images.

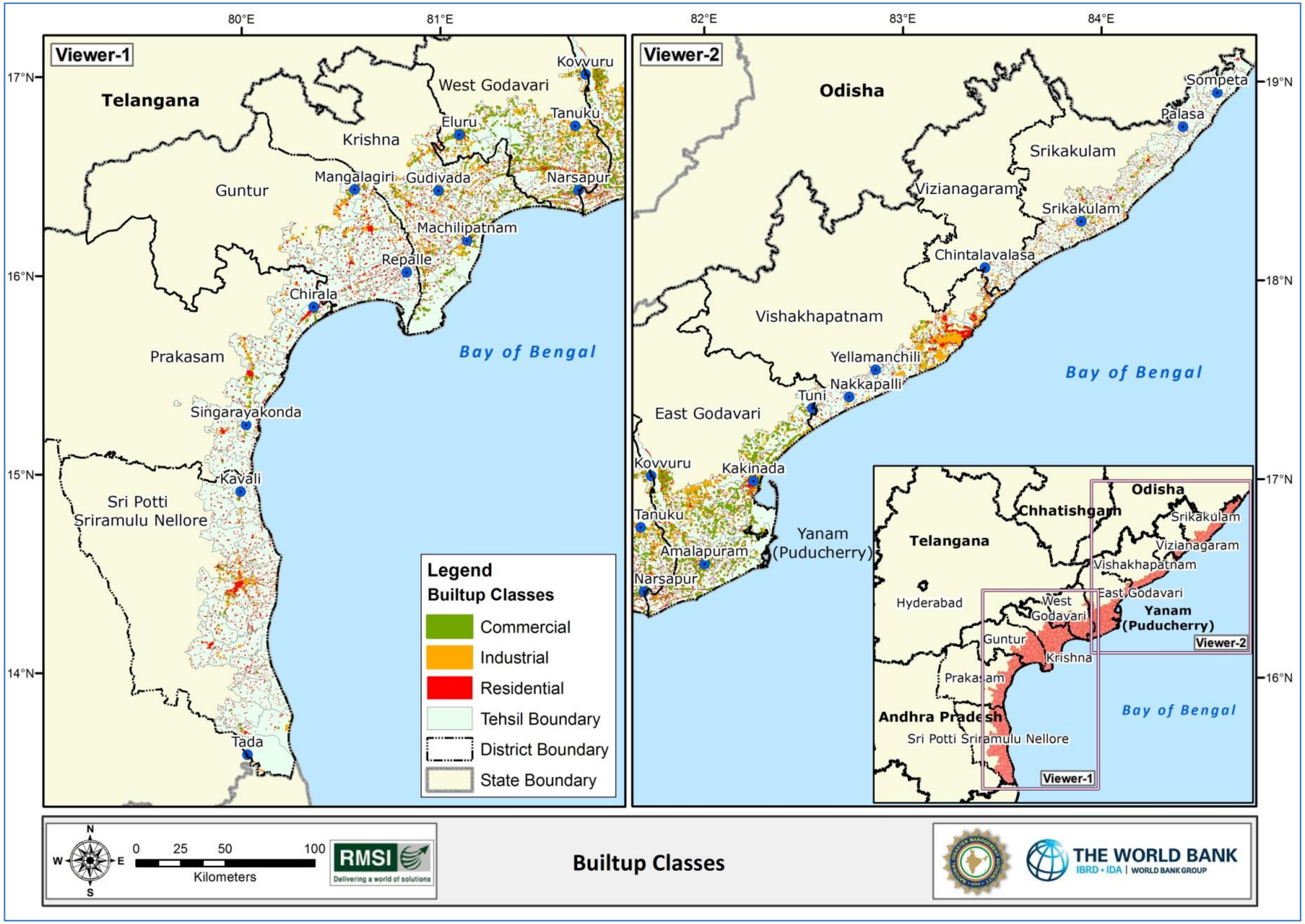


Figure 4-5: Distribution of built up area based on Occupancy

4.2.2 BUILDING STRUCTURE CLASSES FOR VARIOUS OCCUPANCIES

The building structure categories with respect to various occupancy types are described in the following subsections.

4.2.2.1 Residential

The general residential houses in Andhra Pradesh are classified as villas, apartments, chawls (row houses), and huts. Sample photographs of each category are provided in Figure 4-6. In terms of total residential building use, about 99% houses are being used as residential while only 1% is being used as residential-cum-other use.

Figure 4-6: Different types of residential houses

Out of the total estimated 58.88 lakh Census houses, about 48 lakh residential census houses in the study area of Andhra Pradesh are distributed across 9 districts. Out of these, about 17 lakh (36% of total residential houses) residential houses are located in urban areas. East Godavari district has the highest number of residential houses in rural areas (25% of total residential rural houses) and Vishakhapatnam has the highest number of residential houses in urban areas (33% of urban houses). The spatial distribution of rural and urban residential houses among nine districts is given in Figure 4-7.

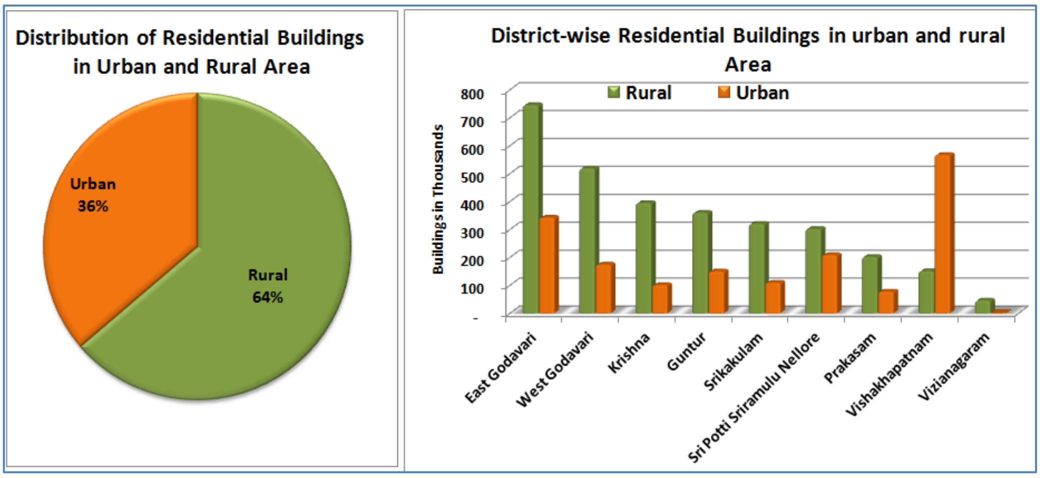


Figure 4-7: Percentage distribution of residential buildings in urban and rural areas (left) and district-level distribution (right)

Based on the census data, the residential buildings in Andhra Pradesh has apartments and villas covering substantial share. Structure type ST18 comprises about 22 lakh buildings (about 46% of the total residential buildings). ST4 and ST8 buildings are the next dominant classes that consist of about 6 lakhs and 4.7 lakhs of the total residential buildings respectively (13% and 10%) Figure 4-8, left). When we consider the building areas under different structural classes, residential buildings collectively covered about 632 sq.km area in the study area (Table 4-2, Figure 4-8, right). ST18, and ST8 are the top two classes that collectively account for more than 24% of the total residential area, where as ST15, ST21, ST22 and ST16 are the next major classes, which collectively covered 20% of the total residential area. Count of residential buildings and their areas based on the major structure types is presented in Table 4-2.

Table 4-2: Residential building counts and built-up area by structural types

Structure type	ST4	ST6	ST8	ST16	ST17	ST18	All Others	Total
Count of Houses	476,083	168,745	600,835	394,147	334,748	2,233,943	548,086	4,756,587
Area in Sq Km	18.41	6.44	66.40	51.09	44.78	415.71	29.0	631.91

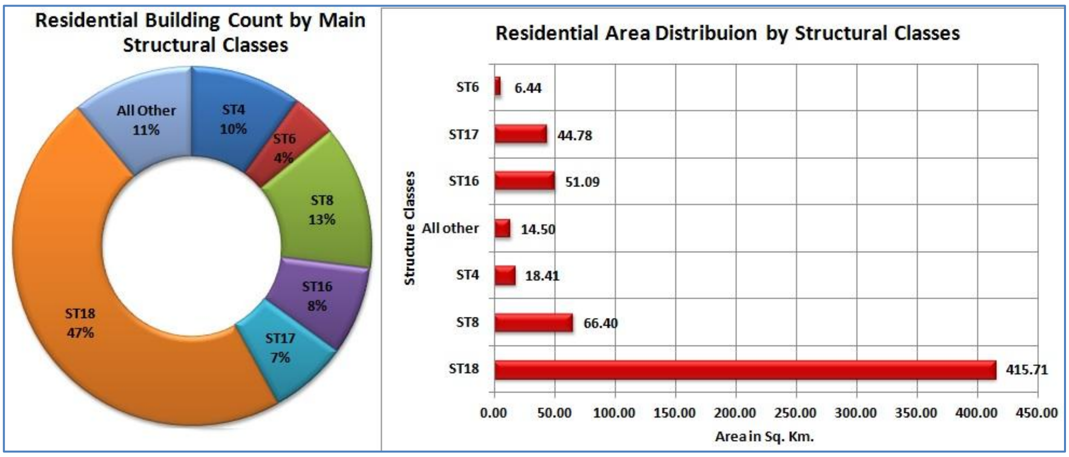


Figure 4-8: Percentage distribution of residential buildings by structure types (left) and their respective areas (right)

4.2.2.2 Commercial

The base data for number of commercial houses at city/district-levels was taken from the Census of India (2011). These numbers were further estimated for year 2014 by applying annual growth rates. The Census provides number of shops and offices, hotels, lodges, guesthouses, residence-cum other uses and other non-residential houses at tehsil level. All these categories of data were combined together to get the total number of commercial houses in the study area. It was further distributed over the village/ward, based on the household number available at each village/ward level in the demographic data. Sample photographs of some of the commercial buildings are provided in Figure 4-9.

Note: commercial buildings do not include schools and colleges, hospitals and dispensaries, places of worship, and industries.

Commercial

Figure 4-9: Different types of commercial buildings/centers

A total of 5.9 lakh commercial buildings were estimated, which cover a total built-up area of about 93 sq. km. East Godavari district has the highest percentage of commercial built-up area (about 30% of total commercial built-up area), followed by Vishakhapatnam (about 19%). Figure 4-10 below presents the distribution of main structural classes for commercial buildings. ST18 is the dominant structural type for commercial buildings (24% of total commercial built-up area) in the study area.

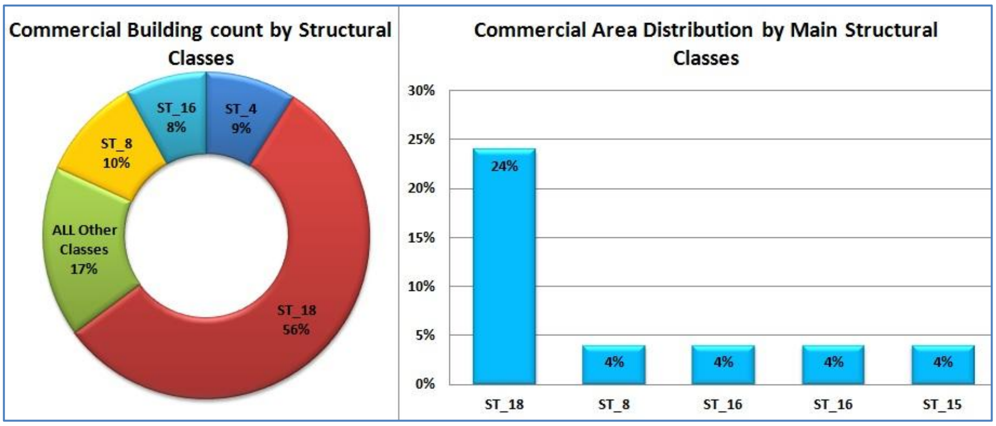


Figure 4-10: Percentage distributions of commercial building counts by structural types and by area

4.2.2.3 Industrial

Census 2011 provides number of industries at district and town levels. Using building agglomeration data of industries, district and town level number of industries were distributed over the villages.

Out of a total of 44,586 industries in the study area, majority of industries are located in East Godavari (19% of total industries) and Vishakhapatnam (12%) districts. The most prominent industry in the study area is Visakhapatnam Steel Plant popularly known as "Vizag Steel Plant. Another important industrial unit headquartered in Visakhapatnam is Bharat Heavy Plate and Vessels Limited (BHPV). Sample photographs of some industries are presented below in Figure 4-11.

Figure 4-11: A snap shot of industrial buildings in Visakhapatnam and Vizianagaram districts

Total industrial built-up area in the study area is estimated at about 4.8 sq. km In terms of percentage distribution of industrial built-up area by district, East Godavari district has the highest percentage of industrial built-up area (about 26% of total industrial built-up area), followed by Vishakhapatnam (about 25%), West Godavari districts (sharing about 17 as presented in Figure 4-12.

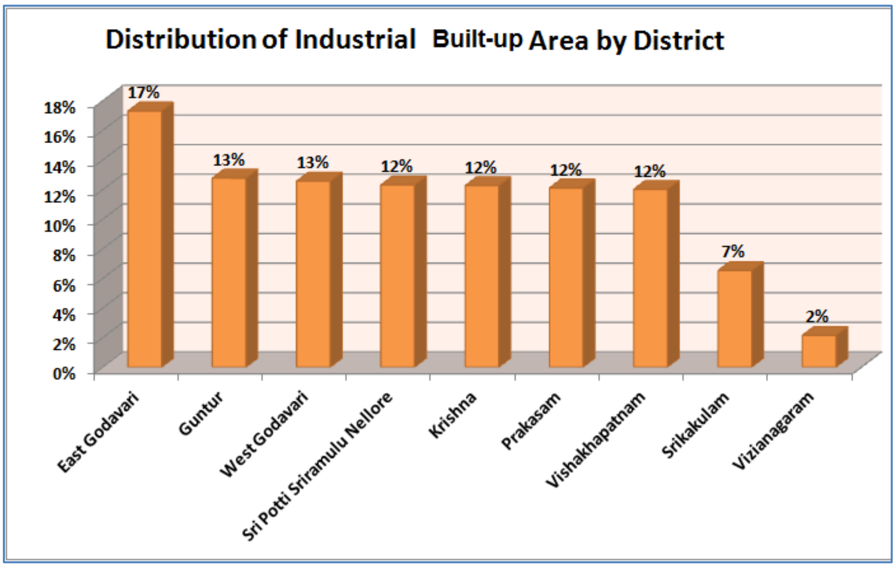


Figure 4-12: Percentage distribution of industrial built-up area by district

4.2.3 OTHERS

4.2.3.1 Religious Places

Places of worship are important from the disaster management point of view. During times of disasters, these can be used as temporary shelters. The sources of religious building data are SOI, Census of India (2011), and RMSI sample field verification survey. Although, SOI provided locations for 10,375 religious places, the vintage of this data is 2005. Therefore, Census of India (2011) data available at district/city level is considered as the primary source of data for religious buildings in the study area, which is further estimated for year 2014.

For 2014, the estimated number of religious places is 49,266 in the study area, which covers about 2.38 sq km of built-up area. East Godavari district has the maximum number of religious places about 11,000 and West Godavari district has the least number of religious places estimated at 473 (Figure 4-13).

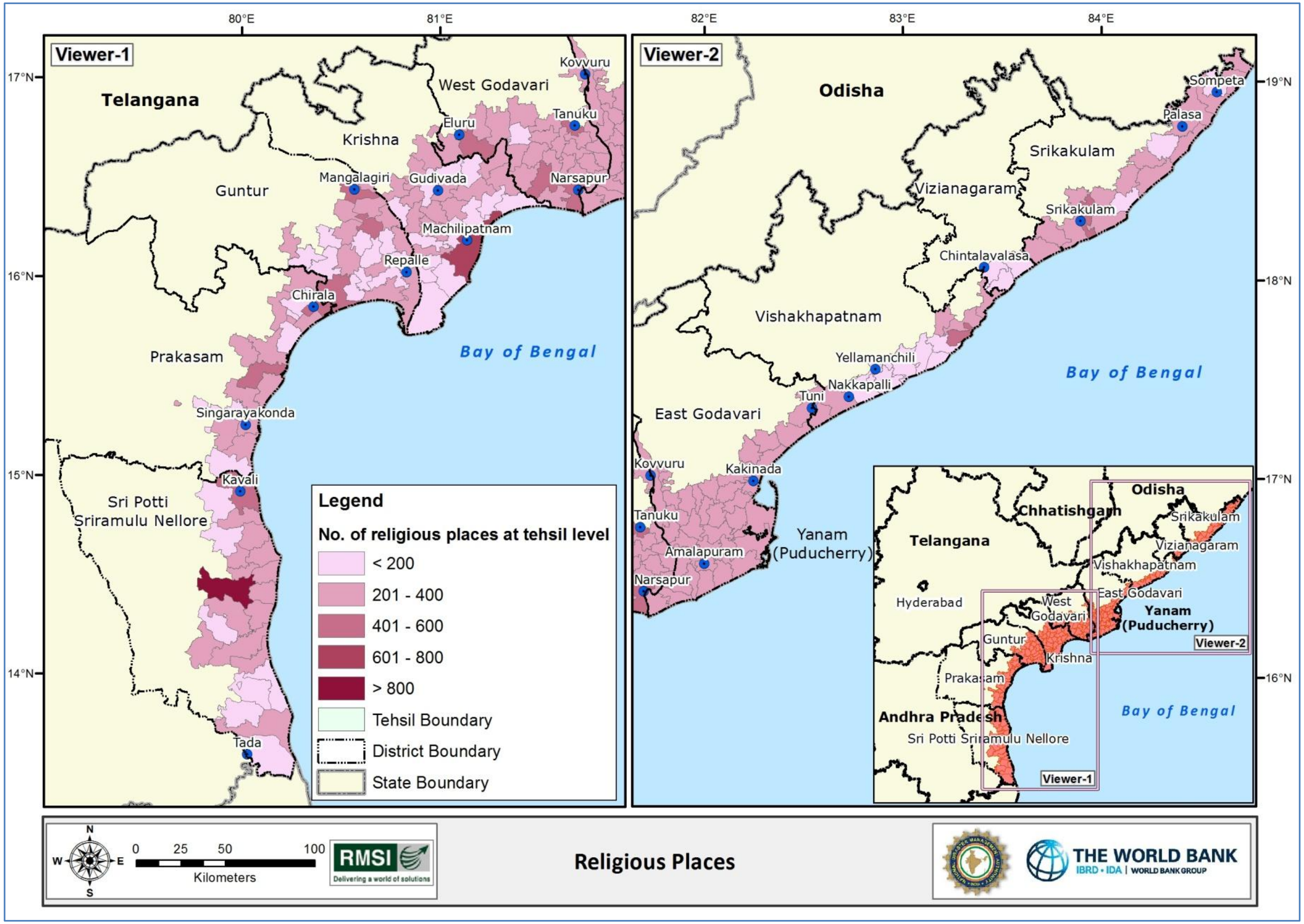


Figure 4-13: Distribution of religious places

4.2.3.2 Cultural Heritage Sites

Cultural heritage comprises of the sources and evidence of human history and culture regardless of origin, development, and level of preservation, and the cultural assets associated with this. Because of their cultural and historic value, cultural heritage sites need to be protected and preserved.

Cultural heritage conservation helps a community not only protect economically valuable physical assets, but also preserves its practices, history, and environment, and a sense of continuity and identity. These are invaluable, so the losses cannot be calculated in terms of monetary terms. However, the impact of hazards on these assets would be considered in risk assessment. The important cultural heritage sites are presented in Figure 4-14.

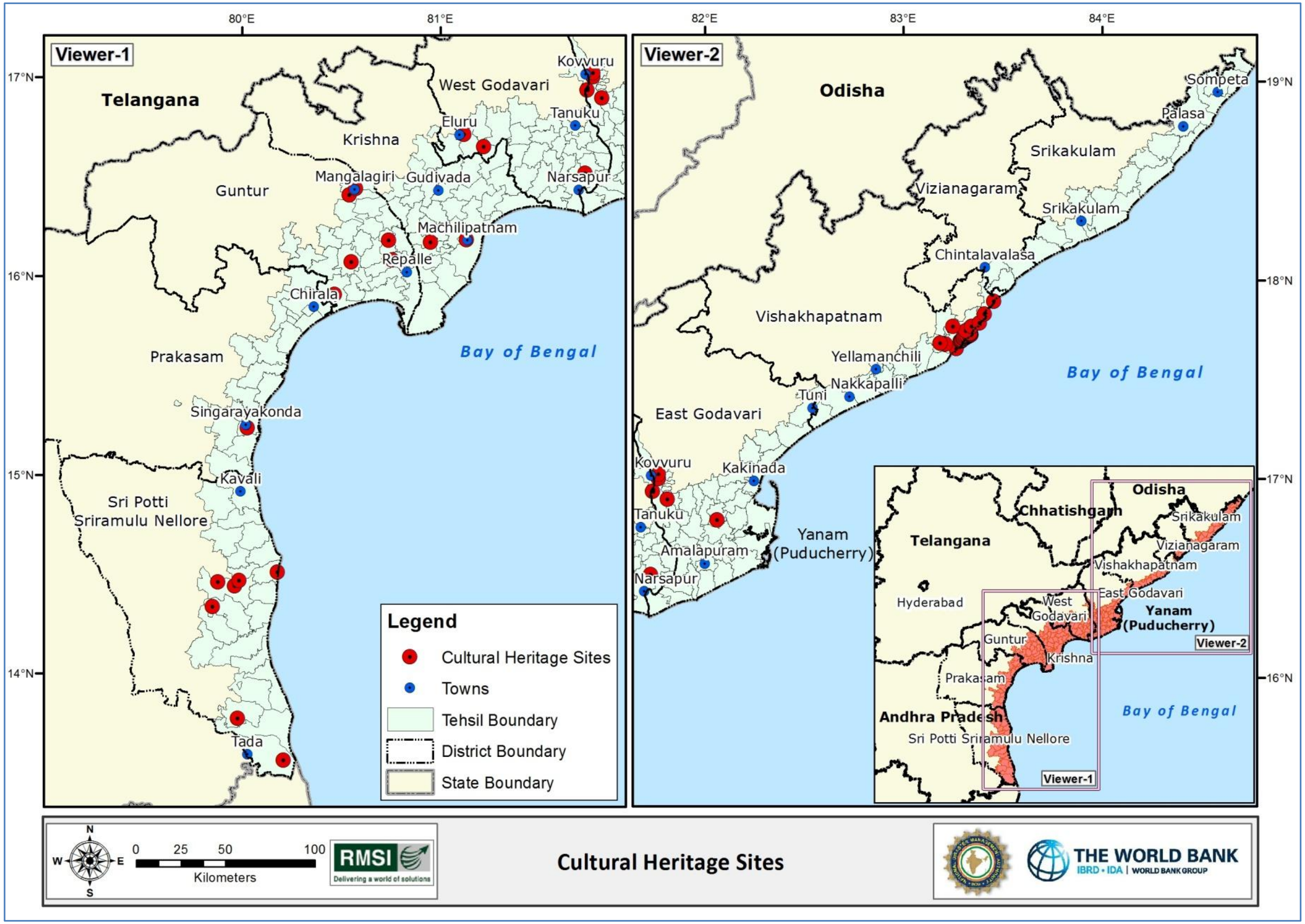


Figure 4-14: Location of cultural heritage sites

4.3 Infrastructure Data

4.3.1 Essential Facilities

School buildings (educational facilities) and hospital buildings (health-facilities) have been included under Essential Facilities. These play a critical role in mitigation, response, and recovery operations before, during, and after disasters. The following sections discuss the quantification of exposure values for these essential facilities.

4.3.1.1 Educational Facilities

Educational institutes play a critical role in mitigation and recovery operations during and after disasters as these are generally used as shelters. Data for educational institutes at village level has been collected from Census 2011 which has further been projected to 2014

There are 26,526 educational institutions located in the study area of Andhra Pradesh that comprise of schools, colleges, universities, and other educational institutes. Together they cover about 20.94 sq.km. of built-up area. The highest number of educational institutions are located in East Godavari district (4,453 institutions) followed by Srikakulam and Krishna districts (2,723 and 2,614 respectively). The data also indicates that the maximum number (about 98%) of educational institutions are located in rural areas, whereas about 2% educational institutes are in urban areas. Figure 4-15 (right) shows district-level percentage distribution of number of educational institutions located in rural and urban areas. Figure 4-16 presents the distribution of educational institutions at sub-district level.

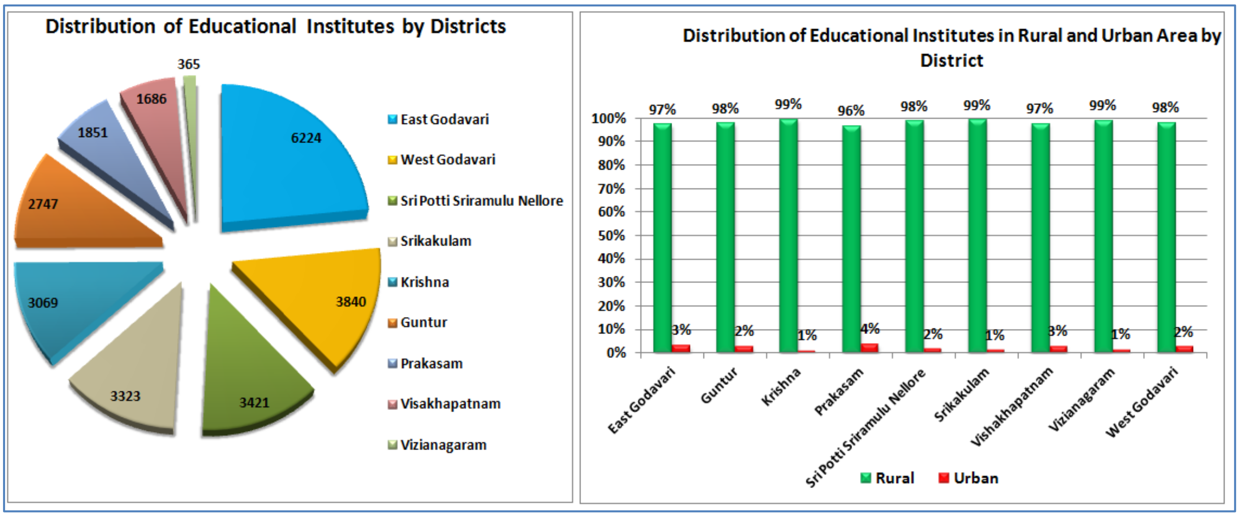


Figure 4-15: Distribution of educational institutes by districts (left) and district-level percentage distribution in urban and rural areas (right)

The village-wise estimated areas of different structure-types were multiplied with the per unit replacement costs of respective structure types. Based on this, the total estimated exposure value for educational institutions is estimated at INR 30,080 crores.

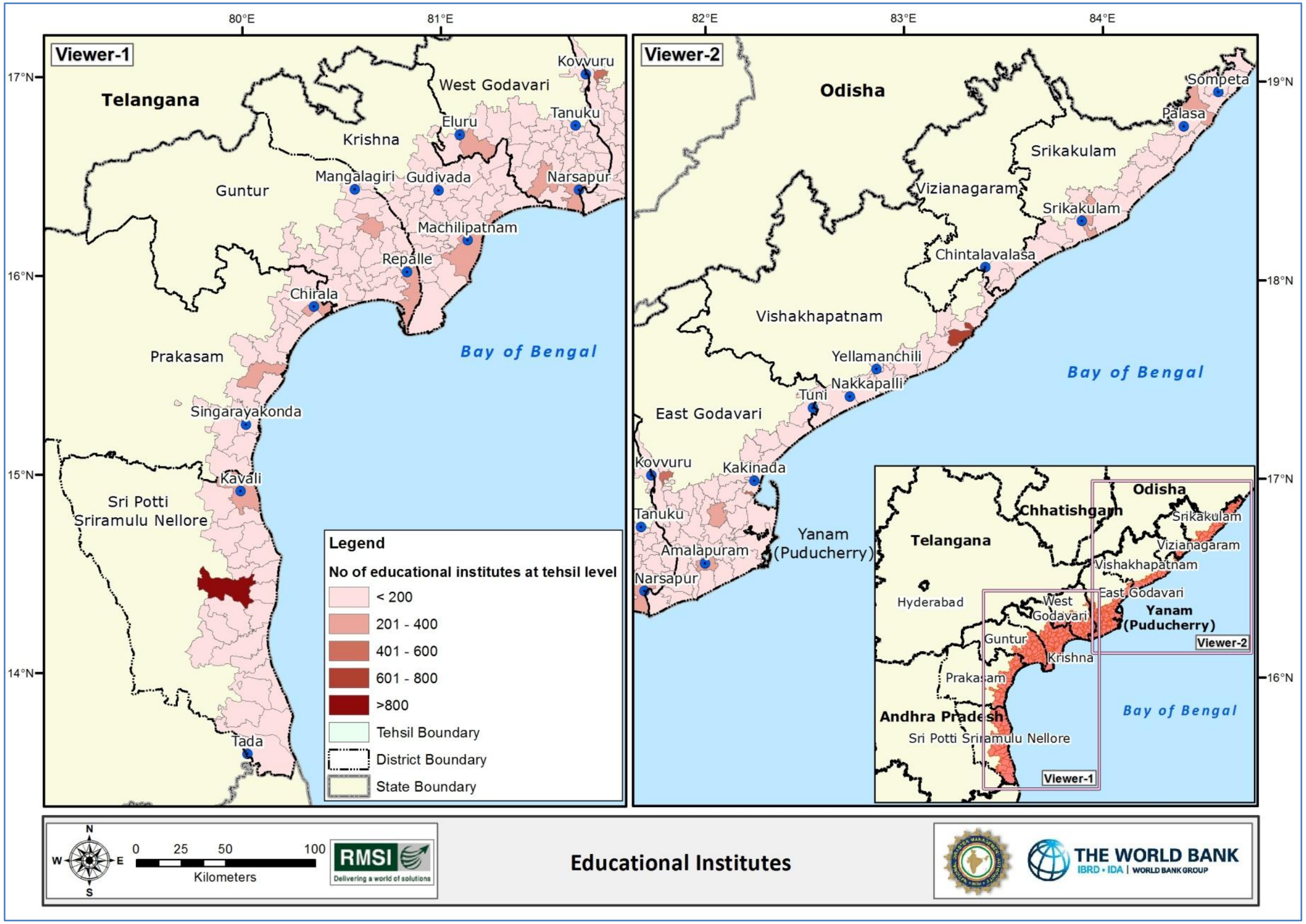


Figure 4-16: Distribution of educational institutions in study area

4.3.1.2 Health Facilities

The health facilities play a critical role in mitigation and recovery operations during and after disasters. Data for health facilities was available from the Census (2011), SOI, and was also collected through the sample field survey. As SOI data is of old vintage, data for health facility at village level has been collected from Census 2011, which has further been projected to 2014.

There are 11,708 health centers located in the study area in Andhra Pradesh. In order to estimate the area and type of the health centers, a standard defined by the Directorate General of Health Services, Ministry of Health & Family Welfare, Government of India has been used. Based on the guidelines provided in this document, number of beds, type of health centers, and average area of each type has been estimated. The unit replacement cost for each type has been defined based on the guidelines given in the Indian Public Health Standards (IPHS) document.

The village-level estimated areas of health facilities of different structural types were multiplied with the per unit replacement costs of the respective structure types. Based on this, the total estimated exposure value for health facilities is estimated at INR 2,880 crores. The locations of health facilities are presented in Figure 4-17 below.

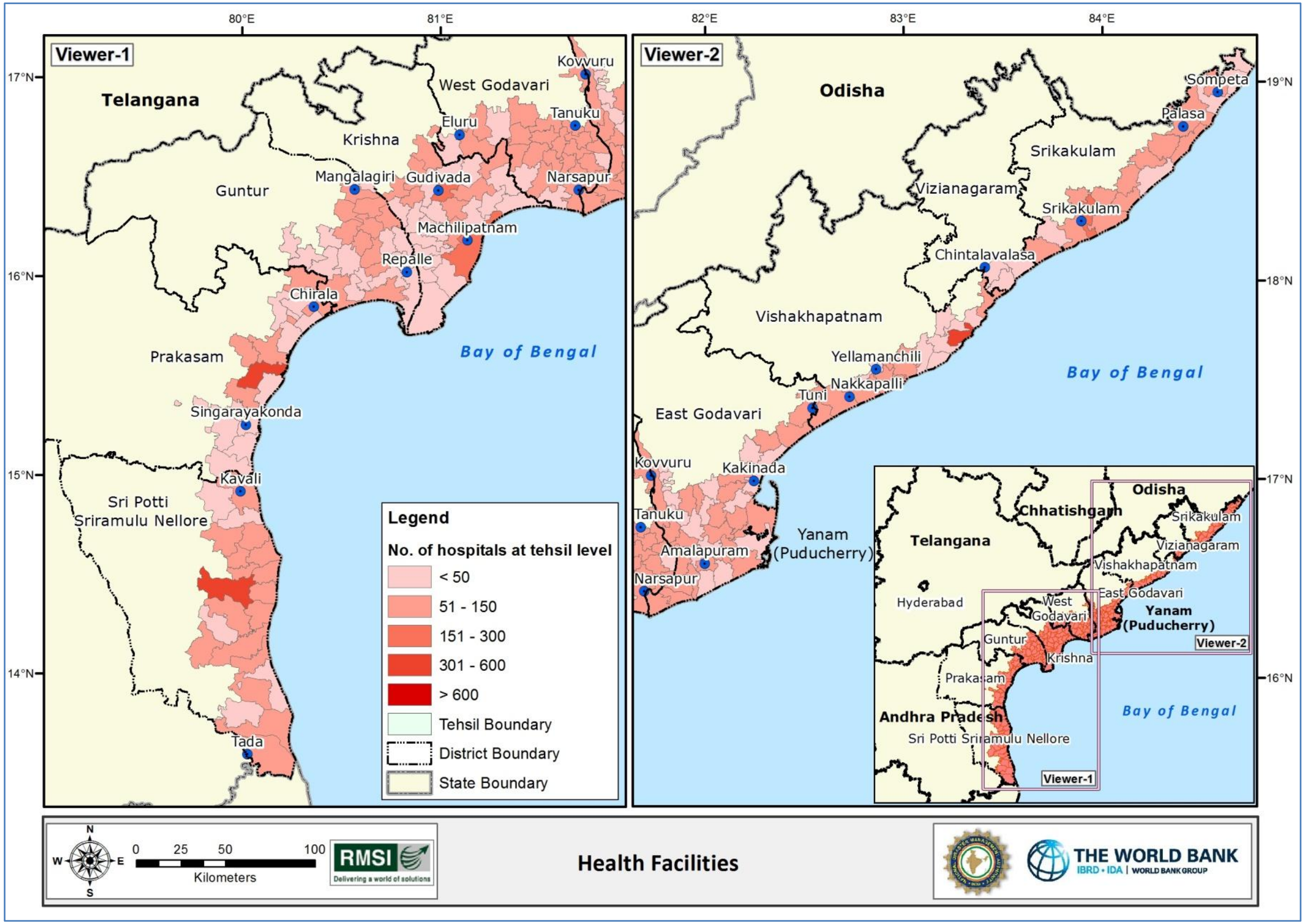


Figure 4-17: Distribution of Health Facilities

4.3.2 GOVERNMENT/PUBLIC BUILDINGS

This section presents exposure data development and analysis of public buildings (police stations, fire stations, administrative headquarters, and cyclone shelters) in Andhra Pradesh.

4.3.2.1 Police Stations

The team received data for police stations in the study area of Andhra Pradesh from SOI and online sources, which indicate that there are 221 police stations distributed across the nine districts within the study area (Figure 4-18). The total estimated area for police stations was estimated at about 0.083 sq.km (83,426 sq m). Accordingly, the total replacement cost is estimated at around INR 101.9 crores.

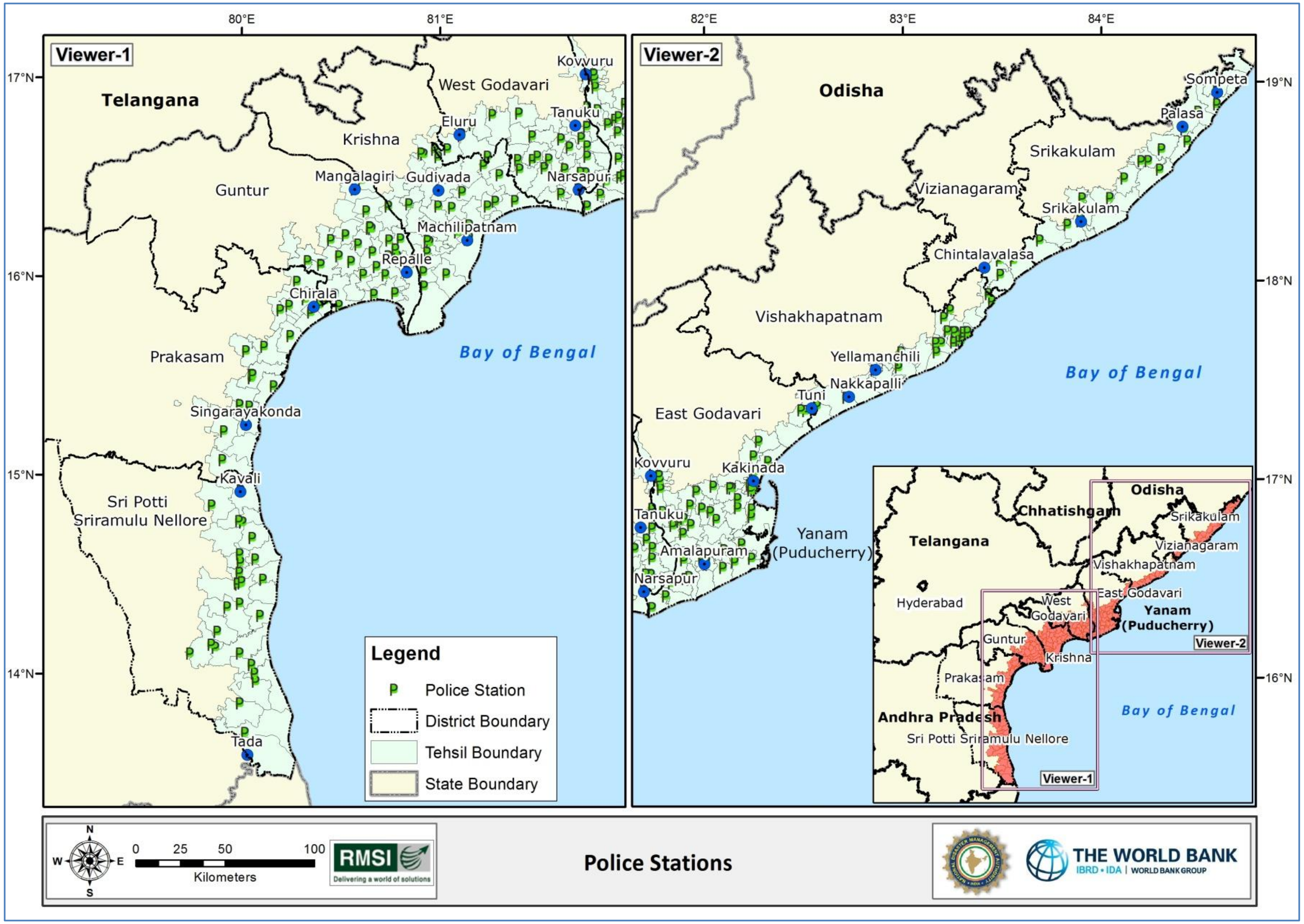


Figure 4-18: Distribution of police stations in study area

4.3.2.2 Fire Stations

Fire services in India are the first responders to any kind of emergency and play a critical role in risk mitigation. The source of data for fire stations is the Andhra Pradesh State Fire Service Department. There are 57 fire stations located in the study area. East Godavari has the maximum number of fire stations, whereas Krishna, Srikakulam, and West Godavari districts have 9 fire stations each. Guntur, Nellore, and Visakhapatnam have five fire stations each and Prakasham district has four fire stations (Figure 4-19).

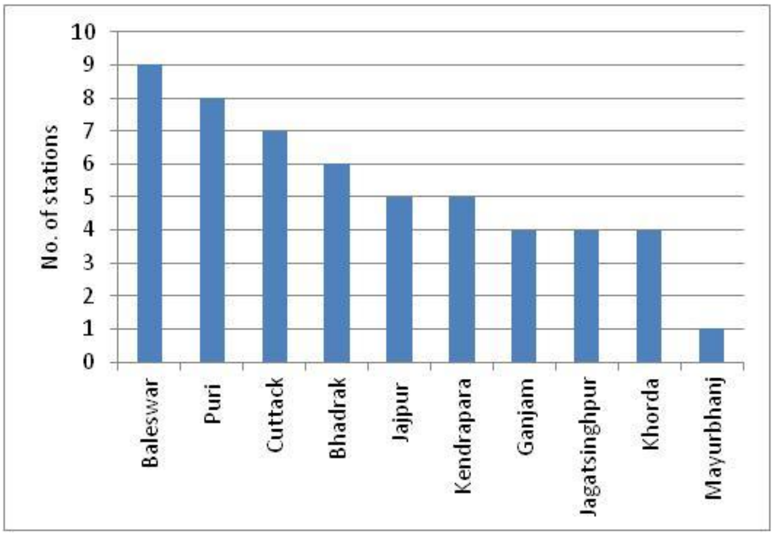


Figure 4-19: Distribution of fire stations across districts

In terms of availability of vehicles in fire stations, East Godavari has the highest number of fire vehicles within fire stations (19%), where as Prakasam district has the least number of fire vehicles about 7% (Figure 4-20). Further, in terms of bay systems in fire stations, it was found that the majority of fire stations were twin bay systems (49%), whereas about 44% of the fire stations were single bay systems. Only 2% fire stations had four bay systems associated with them. Figure 4-21 presents the spatial distribution of fire stations in Andhra Pradesh.

The total estimated area for fire stations was estimated at about 0.0159 sq km (15,907 sq m.) Accordingly, the total replacement cost is estimated at around INR 22.01 crores.

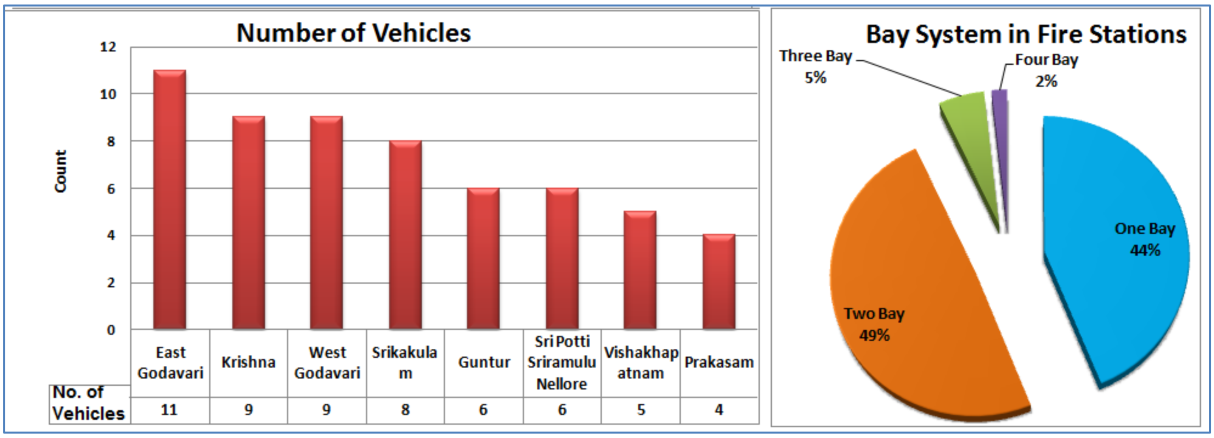


Figure 4-20: Distribution of fire vehicles (left); and percentage distribution of fire stations by number of bay systems (right)

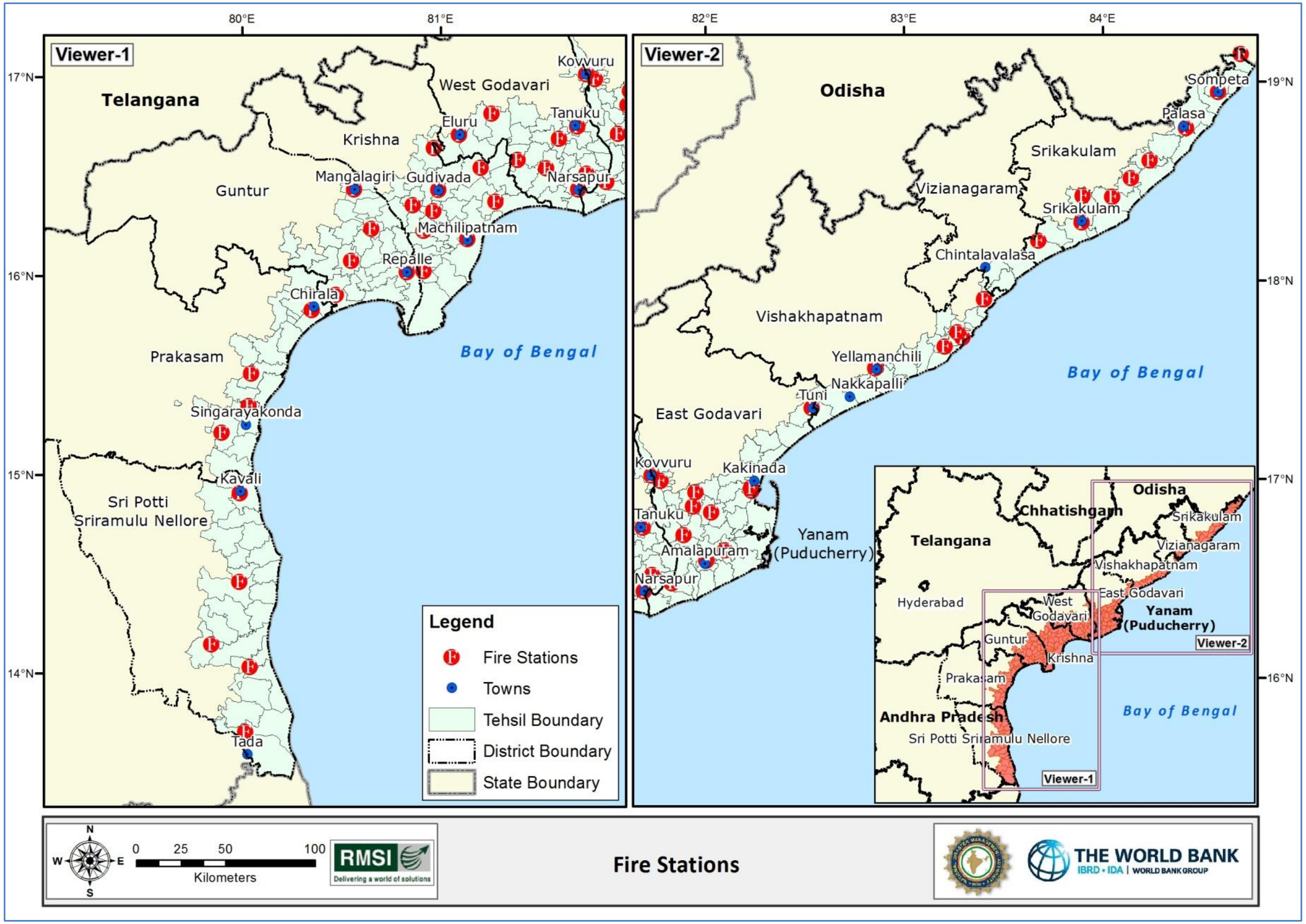


Figure 4-21: Distribution of fire stations

4.3.2.3 Administrative Headquarters

All the important government offices for the concerned districts are located in the administrative headquarters. In the absence of exact spatial data for administrative headquarters, point data has been generated at city/town level. Out of nine districts, there are seven district headquarters and 192 mandal headquarters are present within the study area (Figure 4-22).

The total estimated area for administrative headquarters is estimated at 0.22 sq.km (23,803 sq m). Accordingly, the total replacement cost is estimated at around INR 291.1 crores.

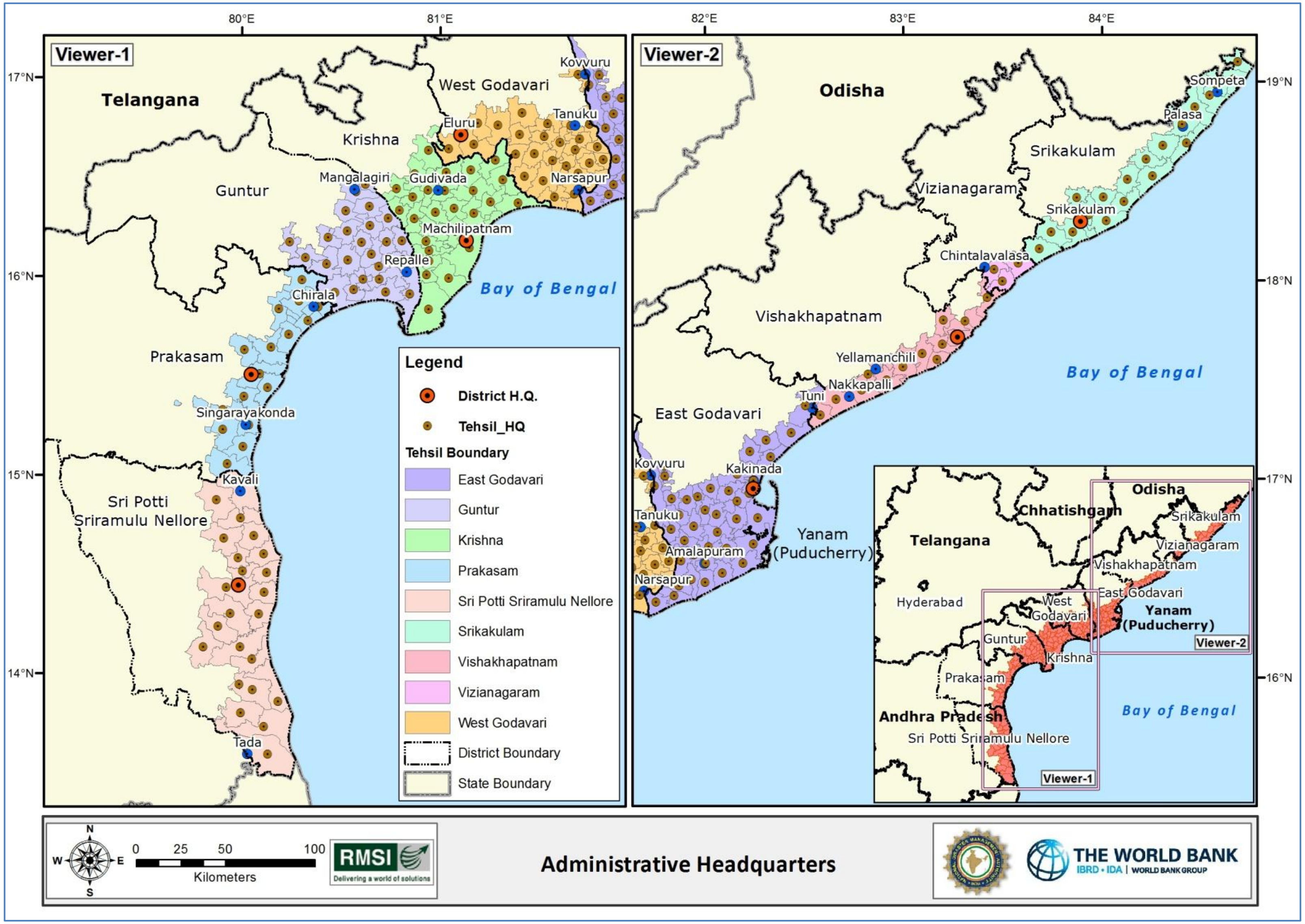


Figure 4-22: Location of administrative headquarters

4.3.2.4 Cyclone Shelters

Cyclone shelters are an important component of disaster risk management and evacuation planning. Data for 1,130 shelters has been collected using disaster management sites. Out of these, only 234 cyclone shelters have been geocoded at village level. However, various attribute data for cyclone shelters is missing. There are details of the distance of cyclone shelters from the coast, year of construction, and plinth area.

As per collected information, Sri Potti Sriramulu Nellore has the highest number (about 17%) of cyclone shelters, whereas Vizianagaram district has only 4% of the total cyclone shelters. East Godavari and Krishna districts have equal number of cyclone shelters (about 15% each). Among the other districts, Visakhapatnam has 13%, Guntur has 11%, Prakasham district has 8%, and West Godavari district has 6% of the total cyclone shelters.

The total estimated area for cyclone shelters is estimated at 7.6 sq.km (712,373 sq m). Accordingly, the total replacement cost is estimated at around INR 920 crores

4.3.3 TRANSPORTATION

During disasters, transportation systems play an important role in rescue and recovery operations. Roads, bridges, railways, airports, and seaports are considered for exposure analysis in the sections presented below.

4.3.3.1 Roads

The road data received from SOI and Andhra Pradesh Transport Department has been collated for this study. This data has been improved further using RMSI in-house data and high-resolution satellite images. The data provides information regarding the various types of roads as well as their respective lengths. The available data classifies roads into five categories, namely, national highways, state highways, major roads, and minor and other roads. Village-level total lengths of various categories of roads are calculated to compute the exposure value. In order to estimate the replacement cost of roads, unit costs of various road categories were determined by taking inputs from the Pradhan Mantri Gramin Sadak Yojna (PMGSY)[28], NHAI[29] , PWD[30], and the Planning Commission[31].

The study area has a total road network of about 41,998 km spread across various villages. The road network comprises of about 1,362 km of national highways, 630 km of state highways, 1,621 km of major road, 11,681 km minor roads, and remaining 26,704 km of other roads (Figure 4-23). The district-level road lengths of different road-types and their exposure values are given in Table 8-7 of Annex 8.1.

[28] http://pmgsy.nic.in/achiev_bhanirm.htm
[29] http://www.nhai.org/completednh2.asp
[30] https://pwddelhi.com/UI/Home/SectorWiseReport.aspx?enc=9J3T0Ky+opEjCrT08q8UfA==
[31]http://www.business-standard.com/article/economy-policy/nhai-plancom-differ-on-cost-of-4-lane-highways-110081000072_1.html

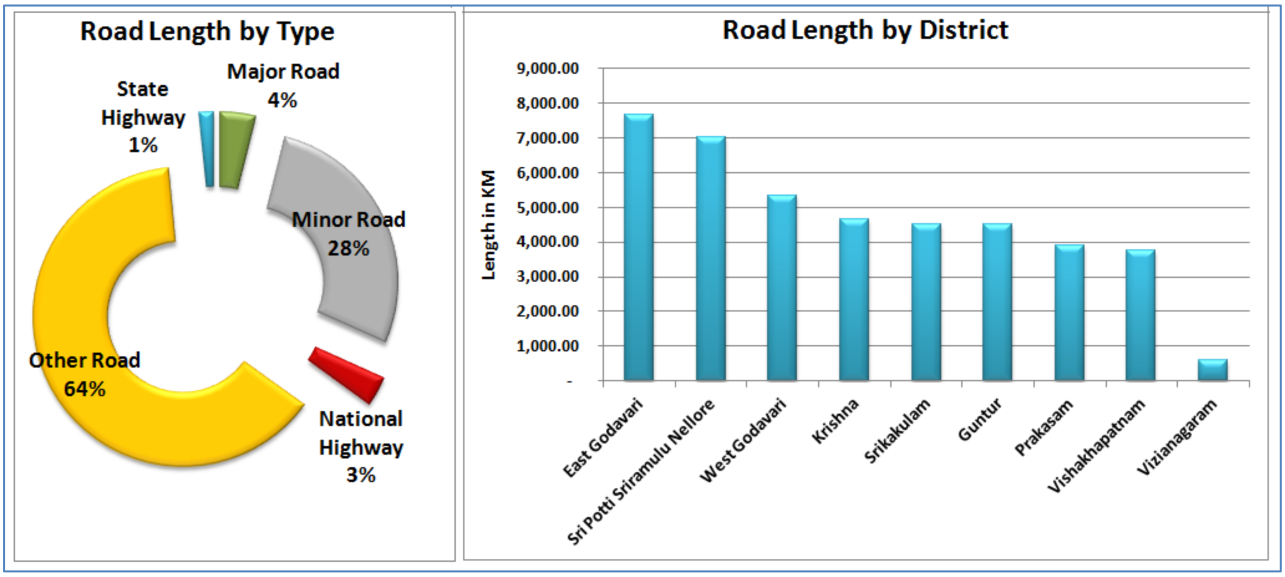


Figure 4-23: Percentage distribution of road network by type (left) and district-level road length (right)

The village-wise estimated length of different types of roads were multiplied with the per unit replacement costs of the respective road types. Replacement costs taken in this study are INR 9.7 crores per kilometer for national highways (four/ six lanes), INR 5.5 crores per kilometer for state highways (two/four lanes), INR 5 crores per kilometer for major roads (two lanes), INR 0.37 crores per kilometer for other important roads and INR 0.25 crores for minor roads. Based on this, the total estimated exposure value for the road network is estimated at INR 37,587 crores. Figure 4-24 presents the road network of Andhra Pradesh in the study area.

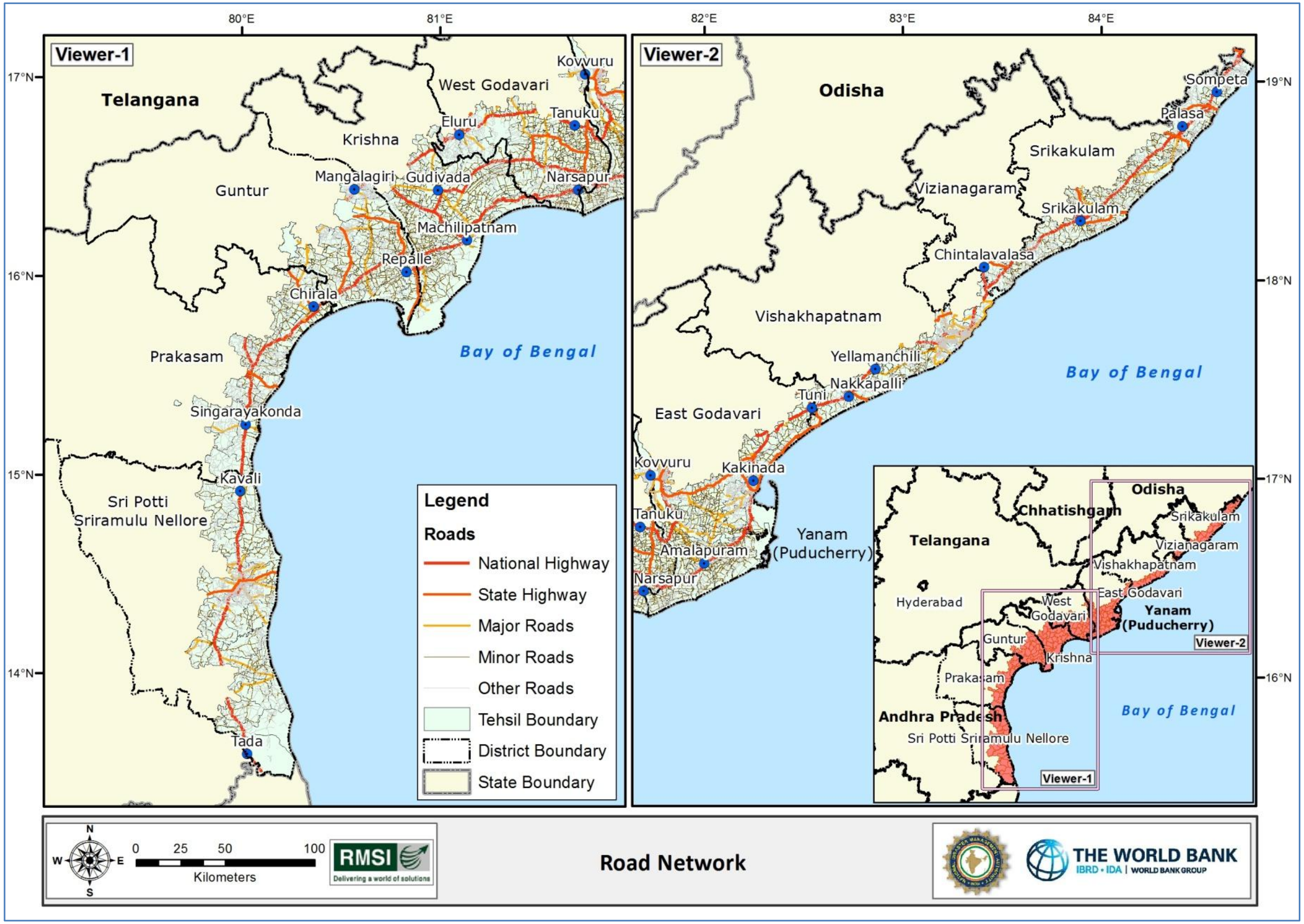


Figure 4-24: Road network in the study area

4.3.3.2 Railways

The data on the railway network was received from the SOI and Andhra Pradesh Transport Department. This data has been improved further using RMSI in-house data and high-resolution satellite images. In order to estimate the replacement cost of the railway network, unit cost of the railway network is determined by taking inputs from International Railway Equipment Exhibition[32] (IREE), and Indian railways[33] websites.

The total length of the rail network in the study area is about 2,280 km. The length of the railway network is multiplied with per unit replacement costs of the railway network i,e INR 6.3 crores per km for single line and INR 9.4 crores per km for double line. Based on this, the total estimated exposure value for the railway network is estimated at INR 19,169 crores.

Annex 8.1 (Table 8-9) provides the district-level estimated lengths and exposure values for the railway network in the study area. Figure 4-25 shows the railway network in the study area of Andhra Pradesh.

[32] http://www.ireeindia.org/RE%20Booklet.pdf
[33] http://www.nr.indianrailways.gov.in/view_detail.jsp?lang=0&dcd=3265&id=0,4,268

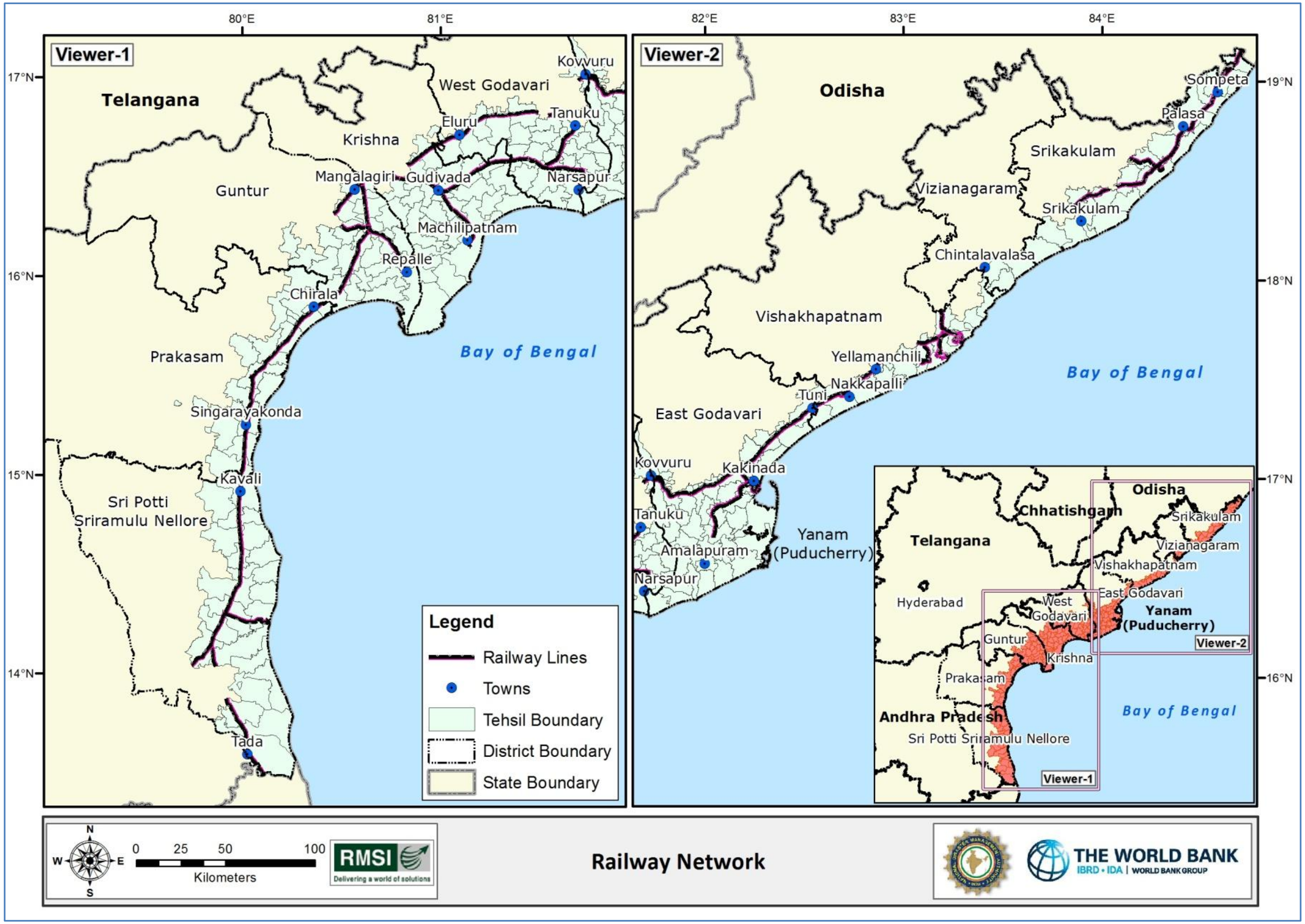


Figure 4-25: Railway network in study area

4.3.3.3 Bridges

The data for bridges for the study area in Andhra Pradesh is obtained from SOI, which is further validated with field survey data and high-resolution satellite images. Village level total lengths of bridges are calculated to compute the exposure value. In order to estimate the replacement cost of bridges, unit cost is determined by taking inputs from various web sources and previous similar case studies.

The village-level estimated length of bridges was multiplied with the per unit replacement cost of bridges i.e. INR 19 lakhs per meter. Based on this, the total estimated exposure value for bridges was estimated at INR 29,766 crores. Table 8-10 of Annex 8.1 provides the district-level estimated lengths and exposure values of bridges in the study area in Andhra Pradesh. Figure 4-26 shows bridges, which come under the study area.

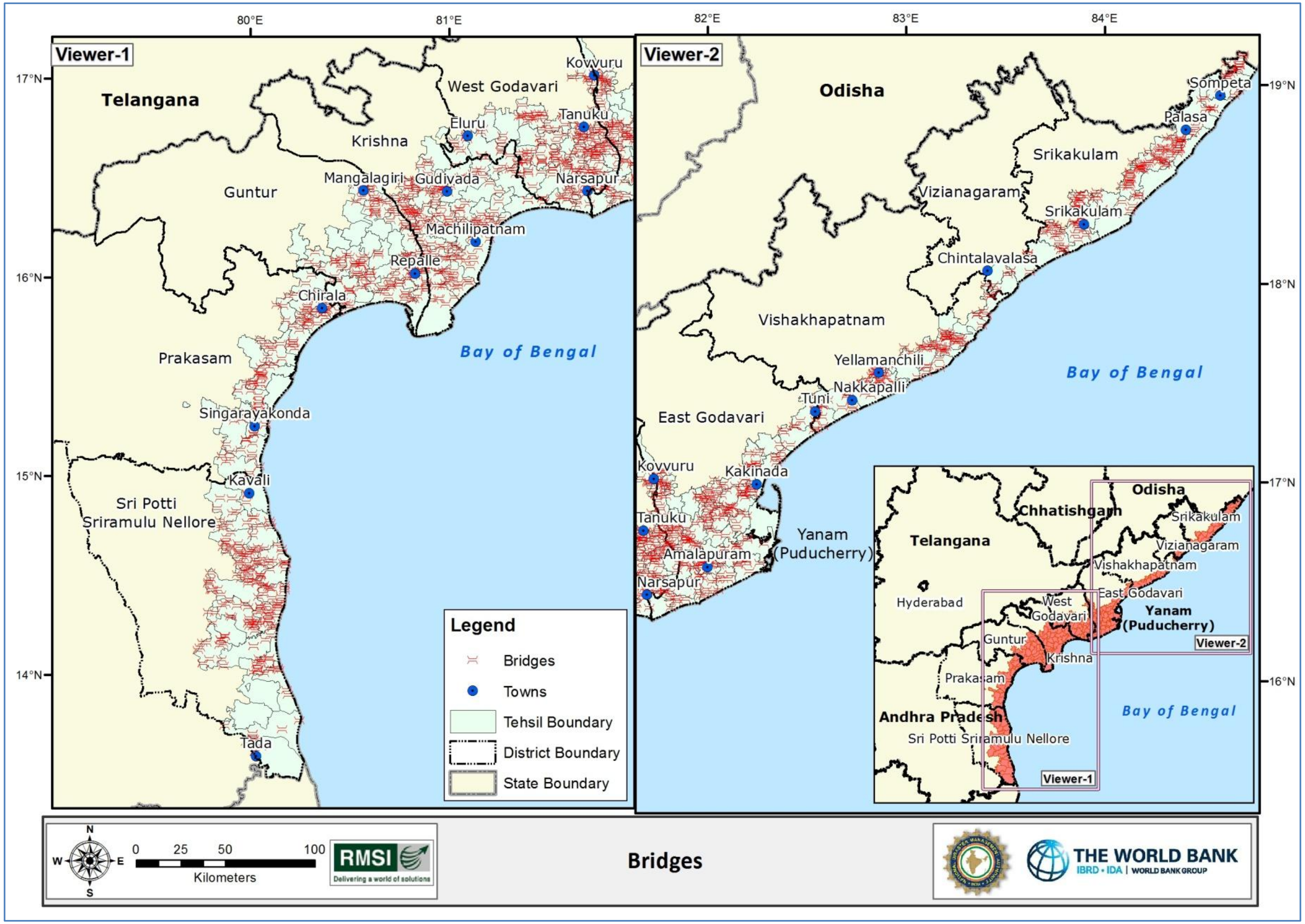


Figure 4-26: Bridge locations in Andhra Pradesh

4.3.3.4 Airports

Only one airport, located in Visakhapatnam district, is within the study area of Andhra Pradesh. Information related to the covered built-up area and length of runway of the airport has been captured using high-resolution satellite images. In order to estimate the replacement cost of the airport, unit cost of the built up area as well as the unit length of runway was determined by taking inputs from the web (Airport technology.com)[34].

The total covered area of the built up area and the runway of the airport were multiplied with their respective per unit replacement costs i.e. INR 25,833 per sq m for built-up and INR 52,334 per sq m for runway. Based on this, the total estimated exposure value for the airport was estimated at INR 2,775 crores. Figure 4-27 shows the location of the airport. Table 8-10 of Annex 8.1 provides the total area of the airport and its exposure value.

[34] http://www.airport-technology.com/projects/indira-gandhi-international-airport-terminal-3/

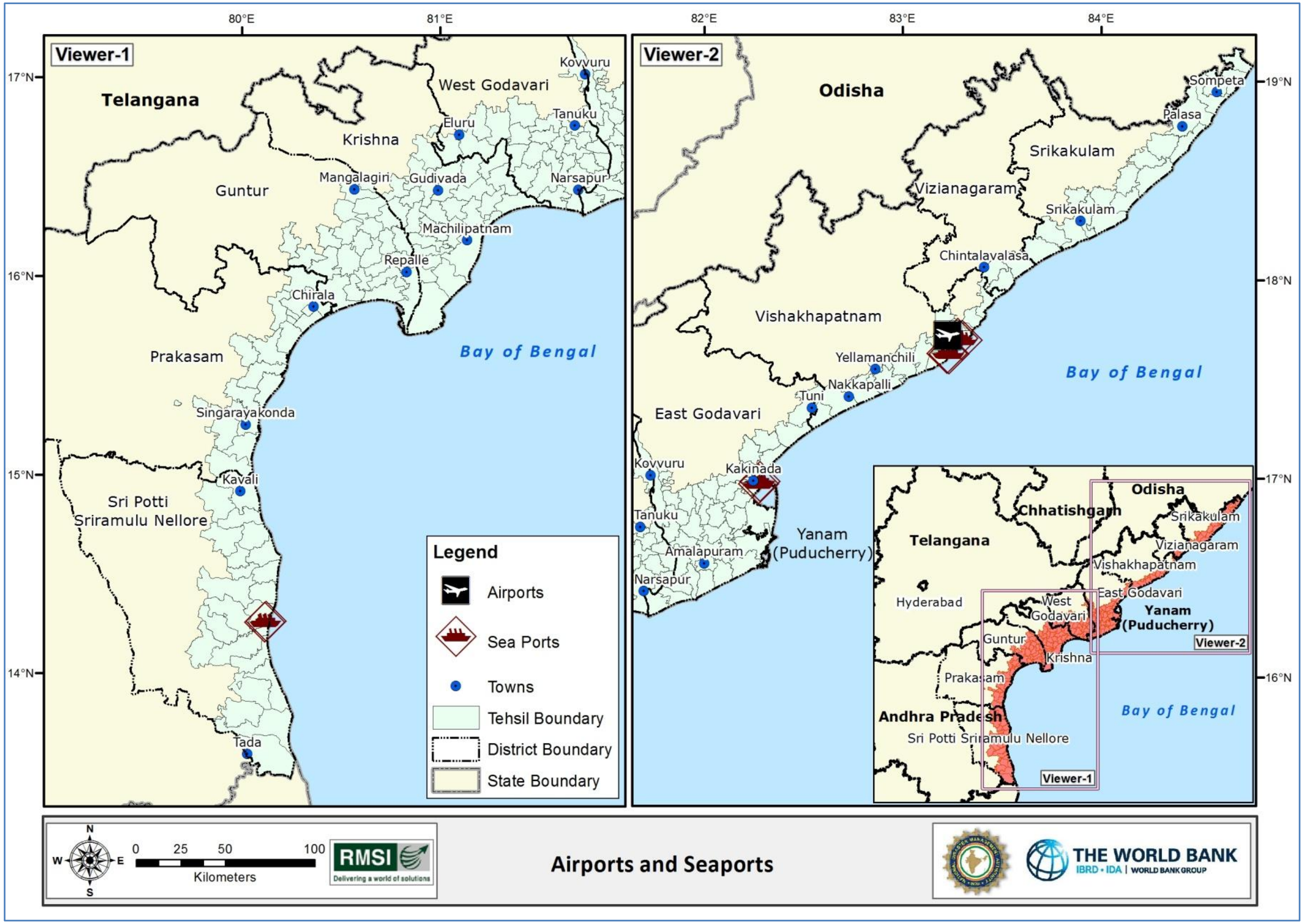


Figure 4-27: Locations of airports and seaports

4.3.3.5 Seaports

There are four ports located in the study area, namely, Visakhapatnam Port, Gangavaram Port, Kakinada Port, and Krishnapatnam Port. The Port of Visakhapatnam is one of the major ports of India and is located on the east coast midway between Kolkata and Chennai. The port has three harbors viz., outer harbor, inner harbor, and the fishing harbor. The port caters to key industries like the petroleum, steel, power, and fertilizers besides other manufacturing industries and plays a catalyst role for the agricultural and industrial development of its hinterland spreading from the south to the north.

In order to estimate the replacement cost of seaports, cost for developing one berth of the port has been determined from internet search (http://www.essar.com/) which is INR 400 crores per berth. There are to total berths in all the ports of which 24 berths are in Visakhapatnam port. This number is multiplied with the unit replacement cost of a berth to get the total exposure value. Based on this, the total estimated exposure value for seaports has been estimated as INR 20,000 crores. Figure 4-27 shows the seaports in study area of Andhra Pradesh.

4.3.4 UTILITIES

Utilities are essential facilities that include electric power, waste water systems, communication systems, and systems that supply potable water. Any disruption in these services due to physical damage not only cause direct economic losses, but it also has indirect impacts in terms of disrupting livelihoods as well as slowing or disrupting post-disaster relief work.

4.3.4.1 Waste Water

The spatial data for wastewater is not available from any of the sources. Census (2011) provides village wise percentage of open and closed drainage systems. Using this percentage, approximate length of waste water system has been generated using the road network data assuming that drainage network is distributed along the road network. The estimated total drainage network is about 16,099.6 km. Multiplying the unit cost with length provides the total replacement cost of about INR 8,049 crores.

District wise approximate wastewater drainage network lengths and their replacement values have been provided in the Table 8-13 of Annex 8.1.

4.3.4.2 Potable water

The spatial data for potable water is not available from any of the sources. Census (2011) provides village wise percentage of household having tap water connection from treated and untreated sources. Using this percentage, approximate length of potable water system has been generated using the road network data assuming that potable water network is distributed along the road network. The estimated total potable water network is about 23,601.5 km. Multiplying the unit cost with length provides the total replacement cost of about INR 11,800 crores.

District wise approximate potable water network lengths and their values have been provided in the Table 8-13 of Annex 8.1.

4.3.4.3 Oil and Gases

The oil and gas infrastructure consists of pipelines, refineries, pumping plants, and tank farms. The inventory data required for oil and gas infrastructure includes the geographical locations and classification of various system components. The analysis also requires the replacement costs for facilities and pipelines.

None of the sources has provided data for oil and gas pipelines. Therefore, using online sources, a map of India Energy Infrastructure[35] has been downloaded as reference. This map has spatial distribution of the oil and gas infrastructure of India. The length of oil and gas pipelines has been estimated based on this map.

In order to estimate the replacement cost of the oil and gas pipeline network, unit cost of oil and gas pipeline has been determined by taking inputs from open source[36]. The length of the oil and gas pipeline network was multiplied with the per unit replacement cost i.e. INR 8 crores per kilometer. Based on this, the total estimated exposure value for the oil and gas pipeline network has been estimated at INR 4,452 crore. Table 8-12 of Annex 8.1 shows district wise estimated lengths of the oil and gas pipeline network and their exposure values.

4.3.4.4 Electric Power Network

The data for electric line network has been received from SOI, which lacks continuity. Therefore, using data present in the open street maps, gaps between the electric lines have been filled. In addition, number of substations, transmission towers, transformers and electric poles at village level have been estimated based on the information collected from literature survey and sample field survey.

The replacement cost of the electric power network has been determined by taking unit cost of the electricity line from the Western Electricity Coordination Council. The replacement costs for the remaining components of electric power network have been estimated by taking inputs from sample field survey.

The length of the electric line network was multiplied with the per unit replacement cost i.e. INR 620 per meter for main power lines and INR 443 per meter for other power lines. Similarly, the replacement costs for other components of electric power network have been estimated. Based on this, the total estimated exposure value for the electric lines has been estimated at INR 18,434 crores. Table 8-11 of Annex 8.1 shows district-wise estimated lengths of the electricity line network and their exposure values.

[35] http://www.eia.gov/todayinenergy/detail.cfm?id=10611

[36] http://www.yourarticlelibrary.com/india-2/pipeline-6-major-pipelines-of-india/19721/

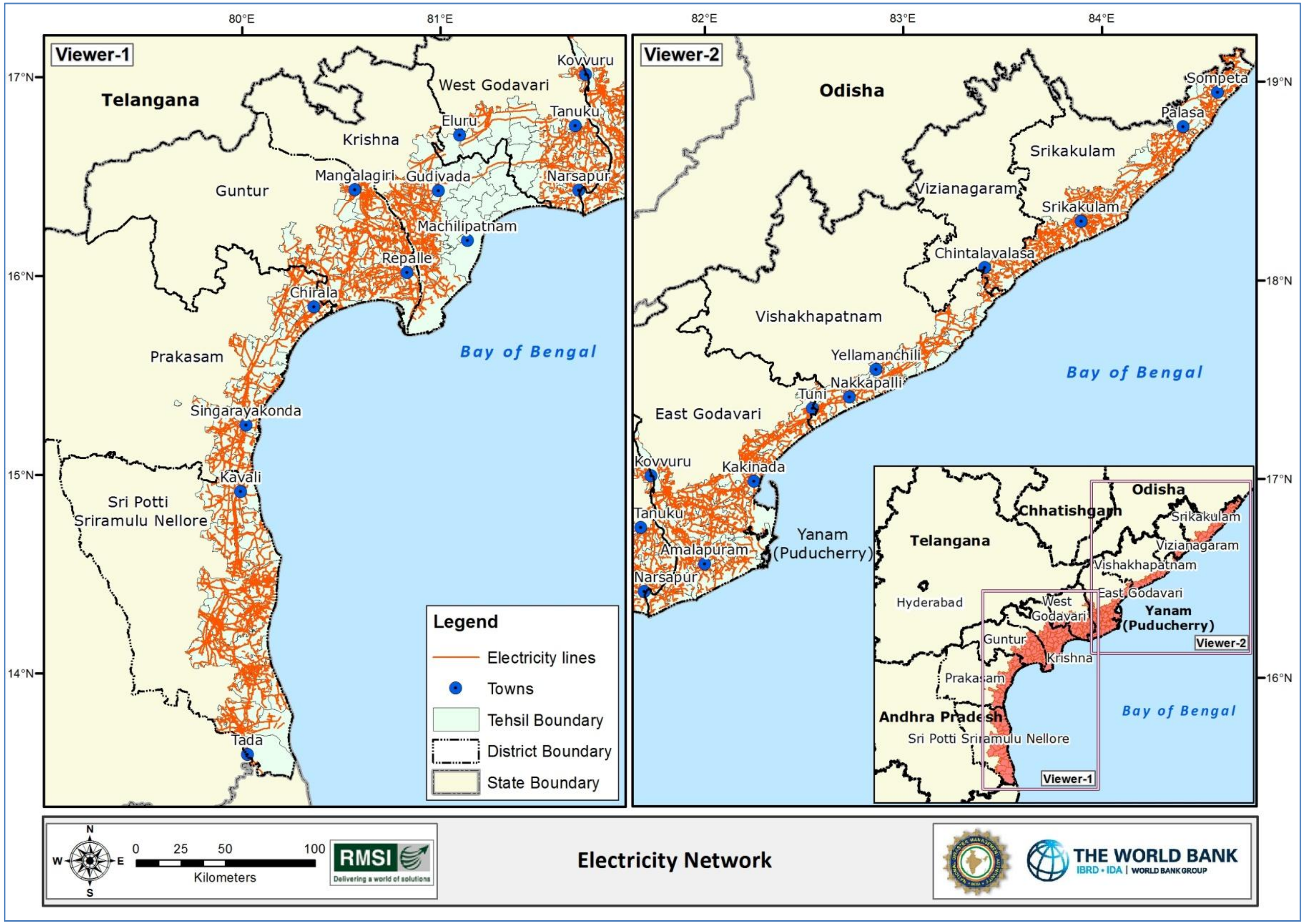


Figure 4-28: Electric line network in the study area of Andhra Pradesh

4.3.4.5 Communication lines

The estimation of communication systems requires detailed information on the number of communication towers, the length of optical fiber cables, the number of communication stations, and the unit cost of each of them. However, except for village level data on the number of mobile and landline connections, no other information is available on communication systems. In addition, number of telecommunication towers at village level have been estimated based on information collected through the sample field survey.

In order to estimate the total exposure value of the communication infrastructure, the cost per subscriber for mobile and landline connections in India has been utilized. As per data collected from the Telecom Regulatory Authority of India (TRAI) and Bharat Sanchar Nigam Limited (BSNL), the values of infrastructure per subscriber for mobile and landline connections are INR 730 and 4,960 respectively. The total estimated replacement cost of the communication system is INR 6,048 Crore. The district level estimated exposure values is provided in Table 8-14 of Annex 8.1.

4.3.5 CRITICAL INFRASTRUCTURE

4.3.5.1 Power Plants and Sensitive Installation

Data for power plants and sensitive installations have been developed using online sources[37]. Using high-resolution satellite images, power plants and sensitive installations have been captured as point locations. There are 14 major power plants and sensitive installations in the study area, which have been presented in Figure 4-29. Average value has been applied for calculating the total replacement costs for a few installations for which no reference exposure value was available.

[37] http://www.apgenco.gov.in , http://www.gvk.com/ http://www.spgl.co.in/

http://www.meenakshigroup.com

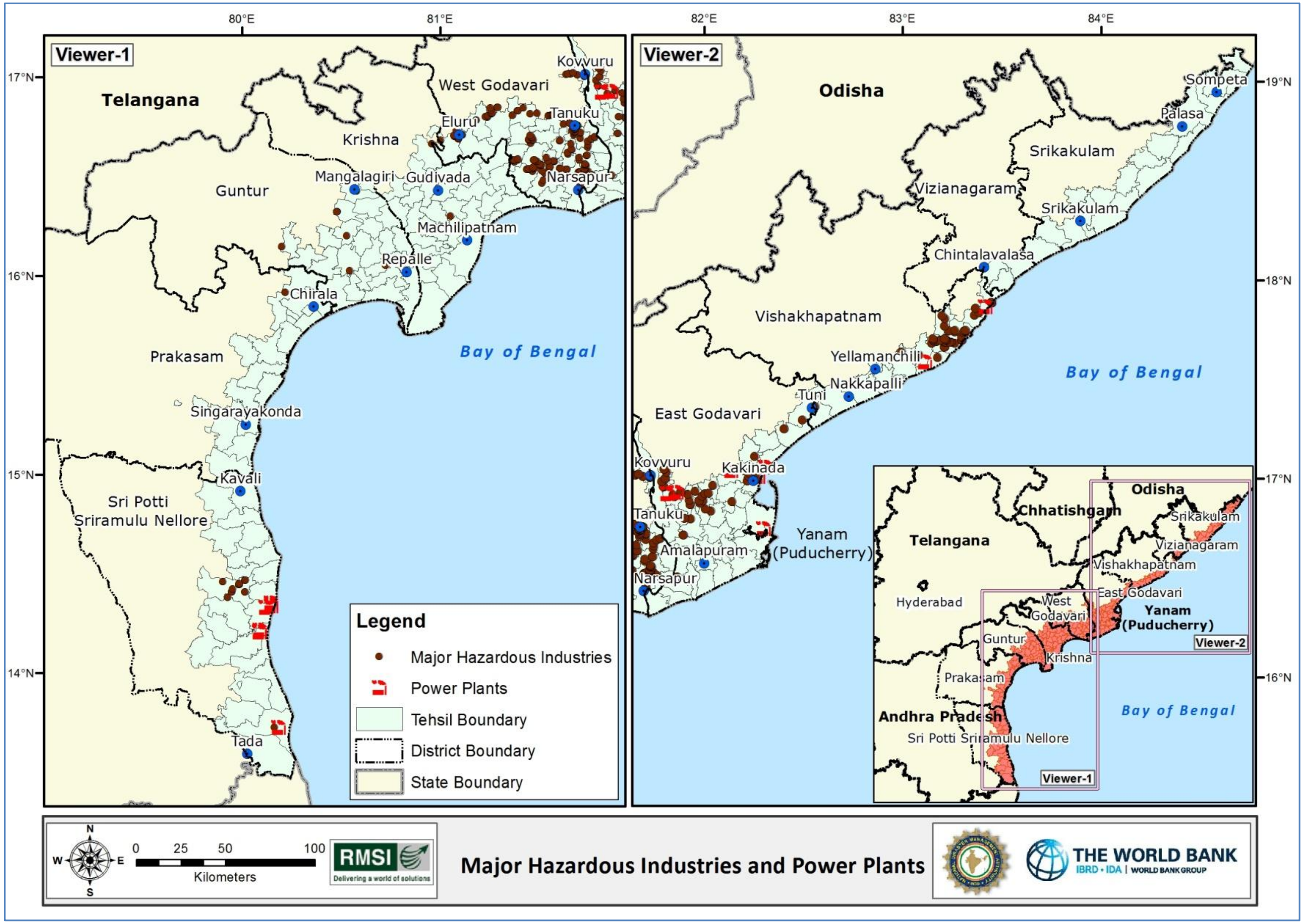


Figure 4-29: Location of major industries and power plants

4.3.5.2 Major and Hazardous Industries

The list of major and hazardous industrial facilities for Andhra Pradesh was collected from Pollution Control[38] website. The geographical location of the industrial facilities were captured using high-resolution satellite images. The unit replacement costs of these facilities were compiled from various online sources. Average value has been applied for calculating the total replacement costs for some of the installations for which no reference exposure value is available.

4.4 Others

4.4.1 AGRICULTURE

Data for agricultural crops constitute one of the primary exposures while studying the cyclone hazard. Since village level crop data is not available, district level crop data (source: Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India) are disaggregated at village level using Land Use Land Cover (LULC) map of LISS III satellite data. For this, Satellite data was classified into various land use classes. After this, other land use classes were eliminated from the land use layer and agriculture was retained for further analysis. Next, the district boundary layer was overlaid on the land use layer and total agricultural area in a particular district was clipped using Spatial Analyst tool embedded in the ArcGIS software. The village boundary layer was overlaid on the district level clipped agricultural area and subsequently available agricultural area was calculated for each village. Then fraction of agricultural area in each village with respect to district level total agricultural area was calculated and subsequently district level total observed normal acreage was distributed among the villages as per this fraction. Table 4-3 shows the district level total cultivated area in Andhra Pradesh.

Table 4-3: District level total cultivated area

District	Total cultivated area in Hectare
East Godavari	1,97,717
Guntur	1,62,7636
Krishna	2,00,6045
Nellore	22,252
Prakasam	93,6465
Srikakulam	1,52,1948
Visakhapatnam	58,158
Vizianagarm	31,850
West Godavari	1,70,951
Grand Total	10,90,136

Figure 4-30 shows that rice occupies about 69% of the total acreage in the study area. Cotton, lentil, and pigeonpea account for 8%, 3%, and 3% respectively of the total acreage. Rice accounts for highest acreage in East Godavari district followed by Srikakulam district. Guntur district has the highest acreage under coconut plantation in the study area. Figure 4-32 exhibits the spatial distribution pattern of cultivated areas among the tehsils in the study area. Detailed crop distribution patterns at district level is given in Table 8-15 of Annex 8.1

[38] http://www.appcb.ap.nic.in/main/index_flat1.php

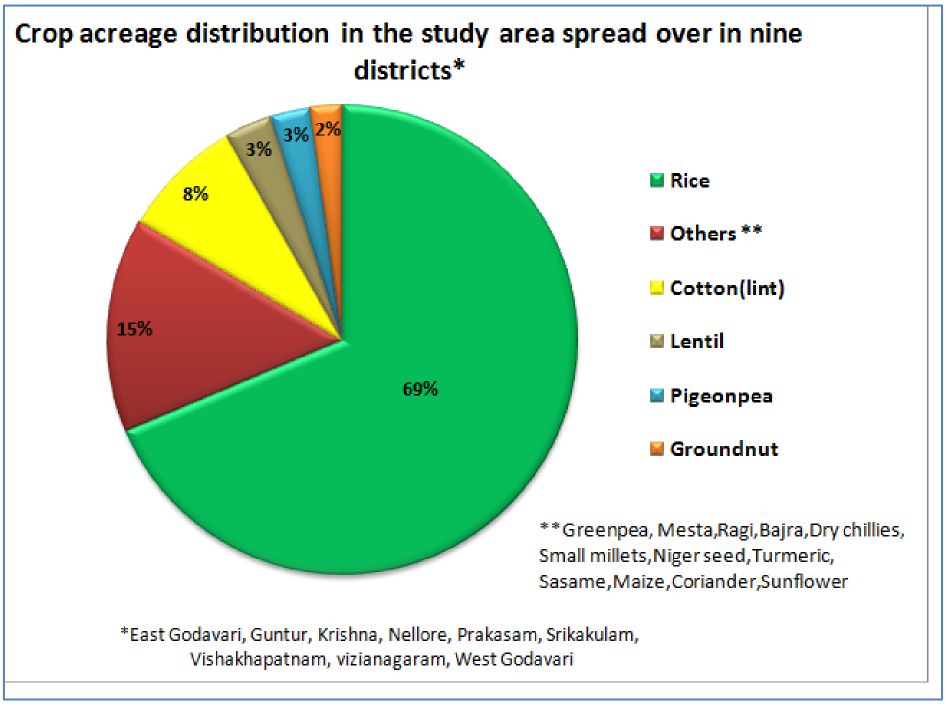


Figure 4-30: Crop acreage distribution in the study area of Andhra Pradesh

In case of crop production distribution among the villages, district level crop yield has been multiplied with the total acreage of respective crop of the particular village falls in the district. The total production value estimated for the study area in Andhra Pradesh is about 24.7 lakh ton for all types of crops.

In order to estimate the total exposure value of the crops at village level, the unit cost per ton at market price values was used along with production quantity for each crop. The total estimated replacement cost of agricultural crops is INR 15,292 Crore.

4.4.2 LIVESTOCK

Livestock play a vital role in the agricultural and rural economies of the developing country. Livestock provide nutrient rich food products, draught power, dung as organic manure and domestic fuel, hides & skin, and are a regular source of cash income for rural households.

Since village level livestock data is not available, district level livestock data (source: Department Of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India) are disaggregated at village level for the study area. The 19th Livestock Census (2012) data is used for the analysis. According to Livestock Census-2012, the total livestock population for the study area in Andhra Pradesh is 154.42 lakhs, excluding poultry. Total Livestock covers cattle, buffalo, sheep, goat, pig, horses& ponies, mules, donkeys, camels, mithun and yak. Andhra Pradesh stands number one in the country in sheep population, the state also stands third in buffalo population, and in total livestock population[39].

Figure 4-31 shows the distribution of livestock population at district level. Prakasam district has the highest number of livestock population about 19% of the total population whereas, Vizianagaram has the least livestock population about 7% of the total population in the study area.

[39] All India Report on 19th Livestock Census,2012

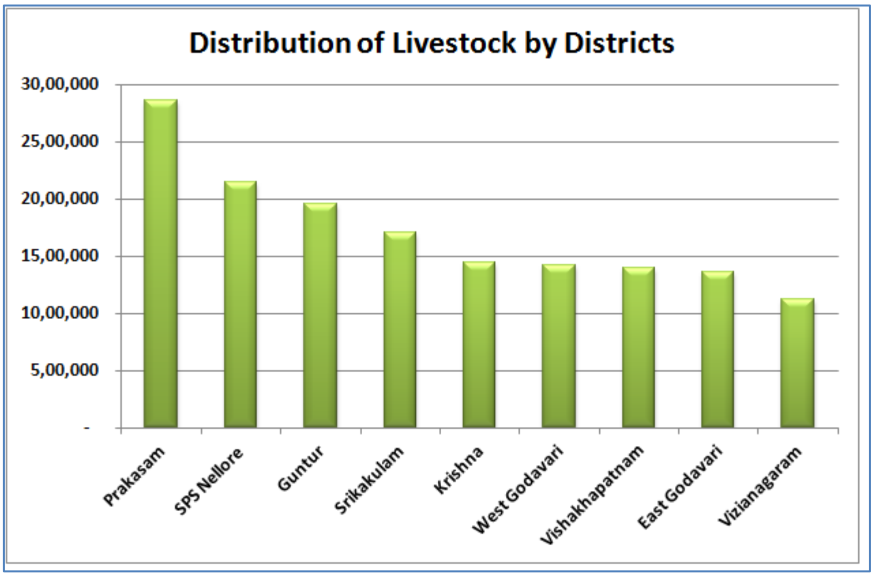


Figure 4-31: Distribution of Livestock population by District

Table 4-4 presents the Livestock population as per 2012 Census (Provisional) on the five major livestock population.

Table 4-4: Livestock Population as per 2012 Census (Provisional)

Sl. No.	Districts	Cattles	Buffaloes	Sheeps	Goats	Pigs
1	Srikakulam	7,90,026	1,26,328	5,75,046	2,12,300	4,725
2	Vizianagaram	3,85,119	1,33,056	4,23,123	1,73,751	10,151
3	Visakhapatanm	5,04,947	3,06,265	2,52,610	3,24,024	7,938
4	East Godavari	3,75,247	6,42,208	2,46,722	2,92,201	32,153
5	West Godavari	2,15,112	6,22,578	4,43,717	2,04,016	10,184
6	Krishna	79,420	6,96,118	5,08,061	1,51,118	10,187
7	Guntur	1,10,071	10,07,942	6,21,122	2,13,249	9,222
8	Prakasam	74,845	9,70,366	14,06,578	4,06,239	10,076
9	SPS Nellore	1,15,968	6,24,664	10,51,938	3,51,426	5,364

Source: http://www.ap.gov.in/socio/Annexure.pdf (Socio Economic Survey 2014-2015)

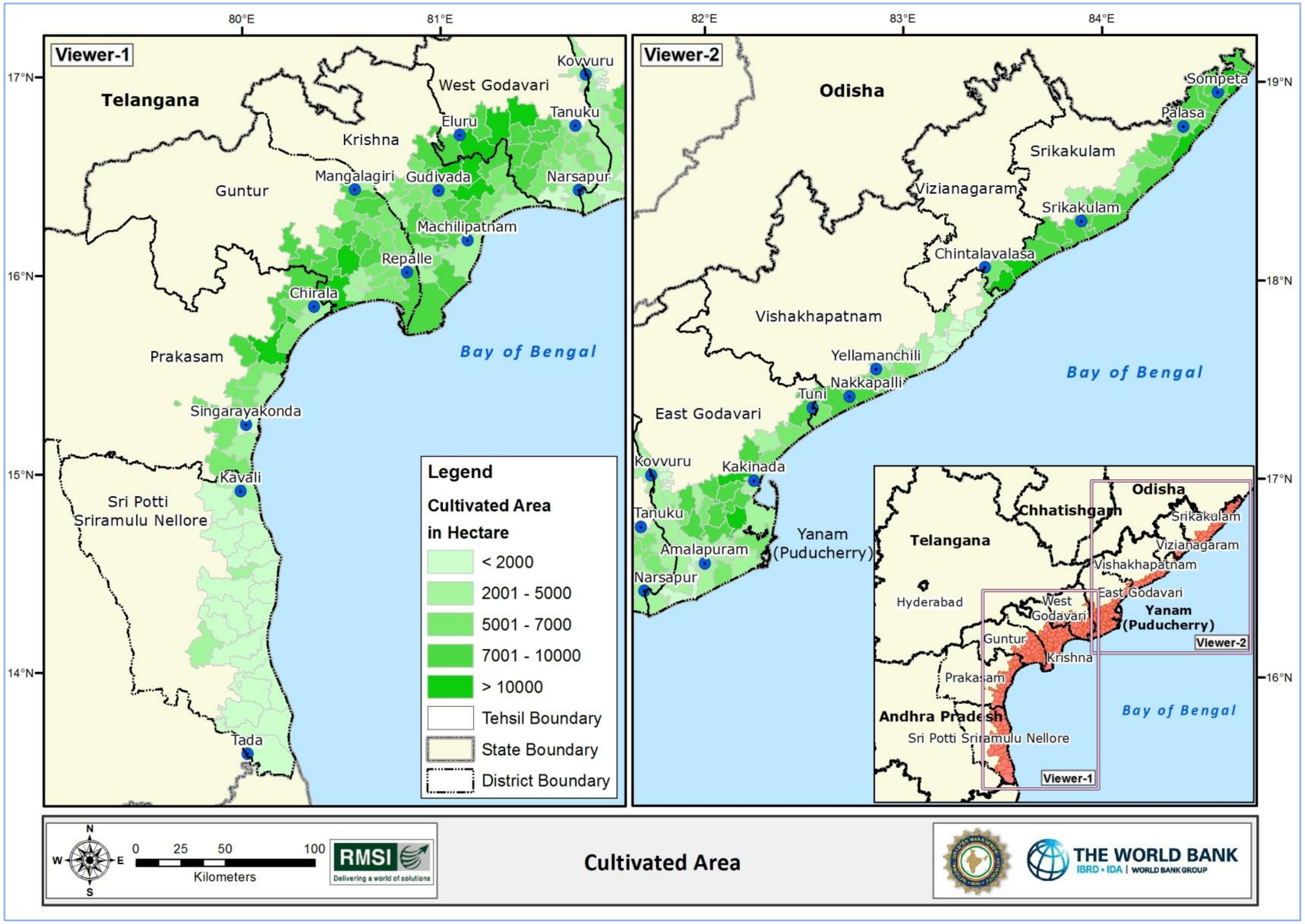


Figure 4-32: Spatial distribution of cultivated area among the tehsils of the study area

4.4.3 ECOLOGICAL ASSETS

Mangroves and coastal plantations are critical coastal ecological assets particularly for reducing the impact of storm surge and cyclonic wind. The data for mangroves has been collected from the Ministry of Forests, while the coastal plantations from SOI. Both these datasets have been further updated using high-resolution satellite images. In Andhra Pradesh, East Godavari district has the highest percentage of mangroves (70%) followed by Krishna (19%), Guntur (10%), and Sri Potti Sriramulu Nellore districts (1%). On the other hand, Vishakhapatnam, Vizianagaram, West Godavari, Srikakulam, and Prakasam districts have no mangrove cover within the study area. For other coastal plantations, East Godavari district has the highest percentage of plantations (22%), whereas Krishna district has the least coastal plantation (2%) within the study area. Table 8-17 presents district-level area of mangroves and coastal plantations. Figure 4-33 presents spatial distribution of mangroves and coastal plantations in the study area of Andhra Pradesh.

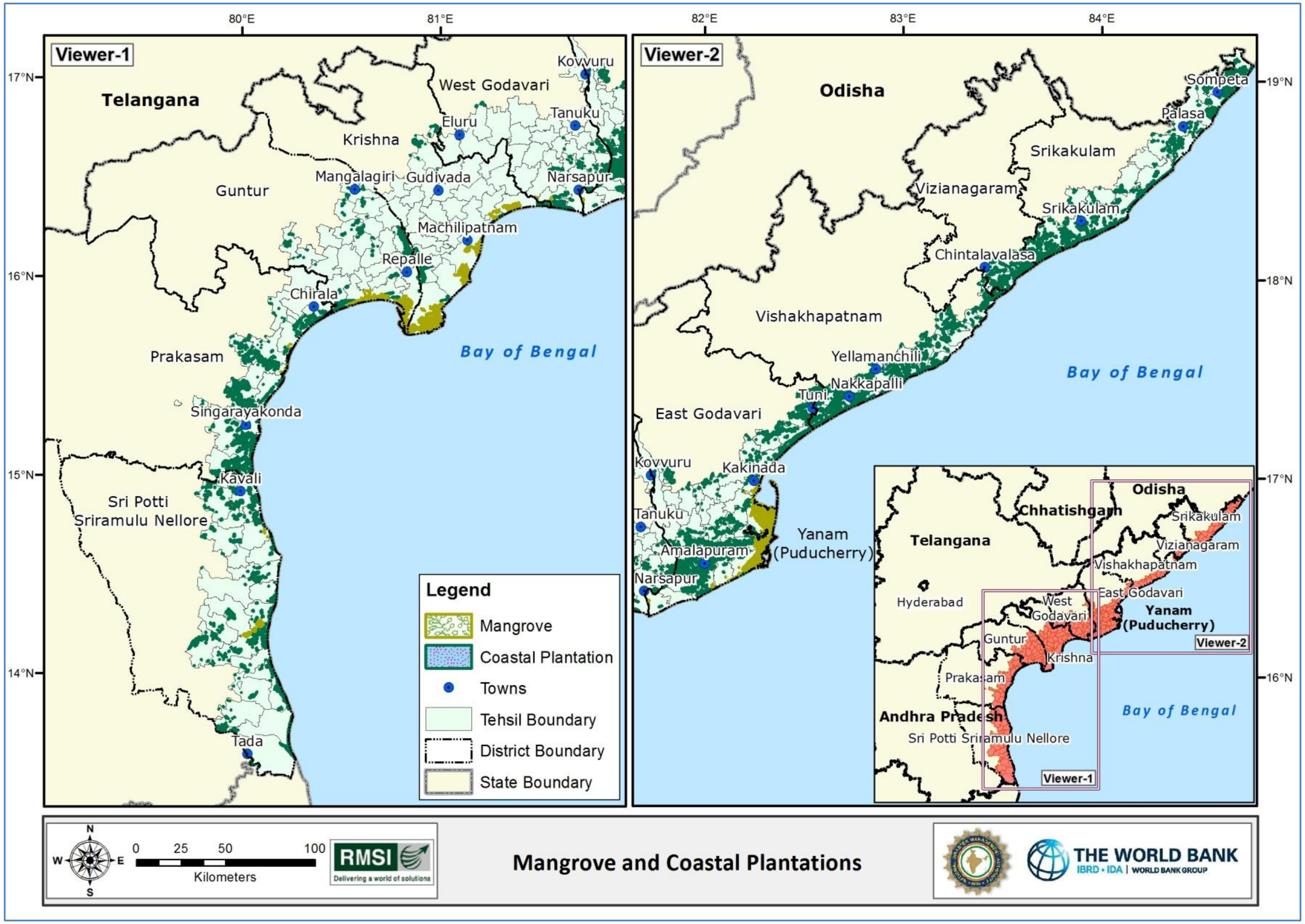


Figure 4-33: Mangroves and Coastal Plantations

4.5 Exposure Values

The total exposure values have been estimated for each type of exposure element. This estimation has been carried out by multiplying the unit replacement cost with corresponding asset length/area to get the total replacement cost for each exposure type. Detailed exposure data tables for districts in Andhra Pradesh are presented in Table 8-6 of Annex 8.1 of the report.

4.5.1 Housing, Public Buildings and Essential facilities

Figure 4-34 below presents the total exposure value for housing, public buildings and essential facilities in INR. The total estimated value of different buildings present in the study area is more than INR 795,256 crores, out of which residential buildings account for about 87% of the total value, industrial buildings for about 4%, commercial buildings for about 3.9% and educational institutes for about 3.8%.

Figure 4-34, Figure 4-35 and Figure 4-36 provide the total exposure values for building occupancy classes, transportation assets and utility assets, respectively.

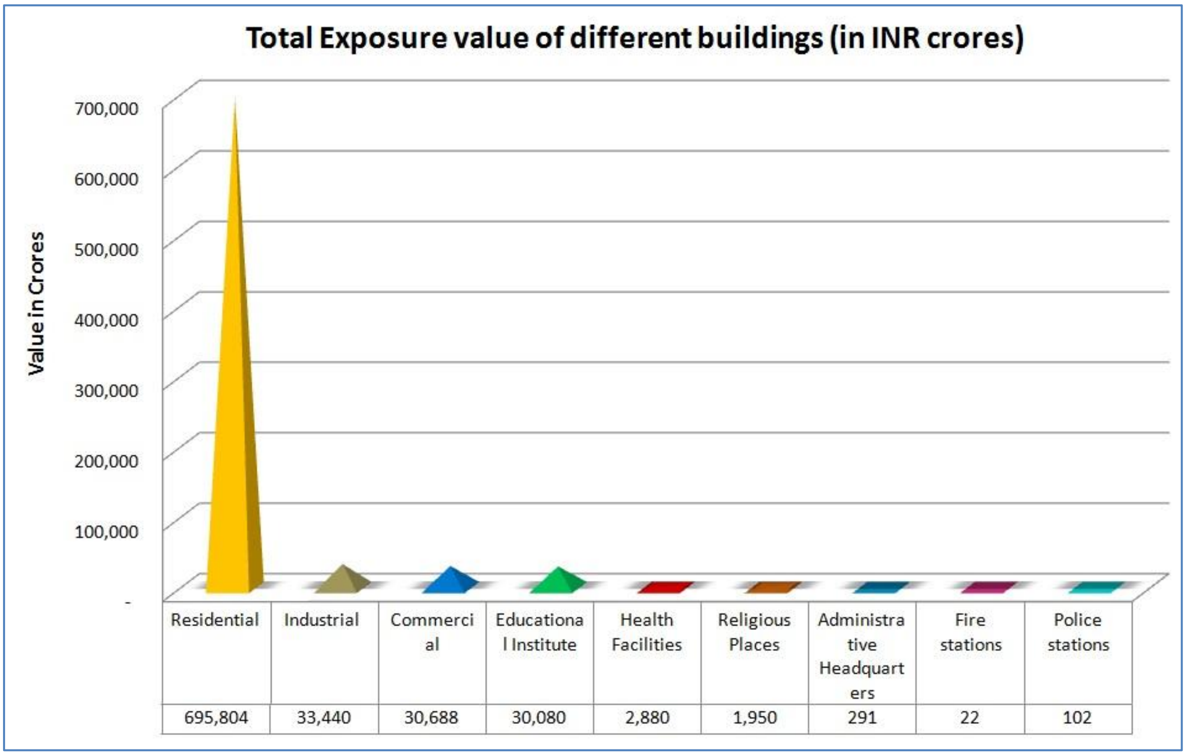


Figure 4-34: Total exposure value of different buildings

4.5.2 Transportation

Figure 4-35 below presents the total exposure value for different transport assets in INR. The total estimated value of exposure in all categories present in the study area is more than INR 109,297 crores, out of which road network exposure value accounts for about 34% of the total value, Bridges for about 27%, seaports and railway network for about 18% each, and the single airport for about 3%.

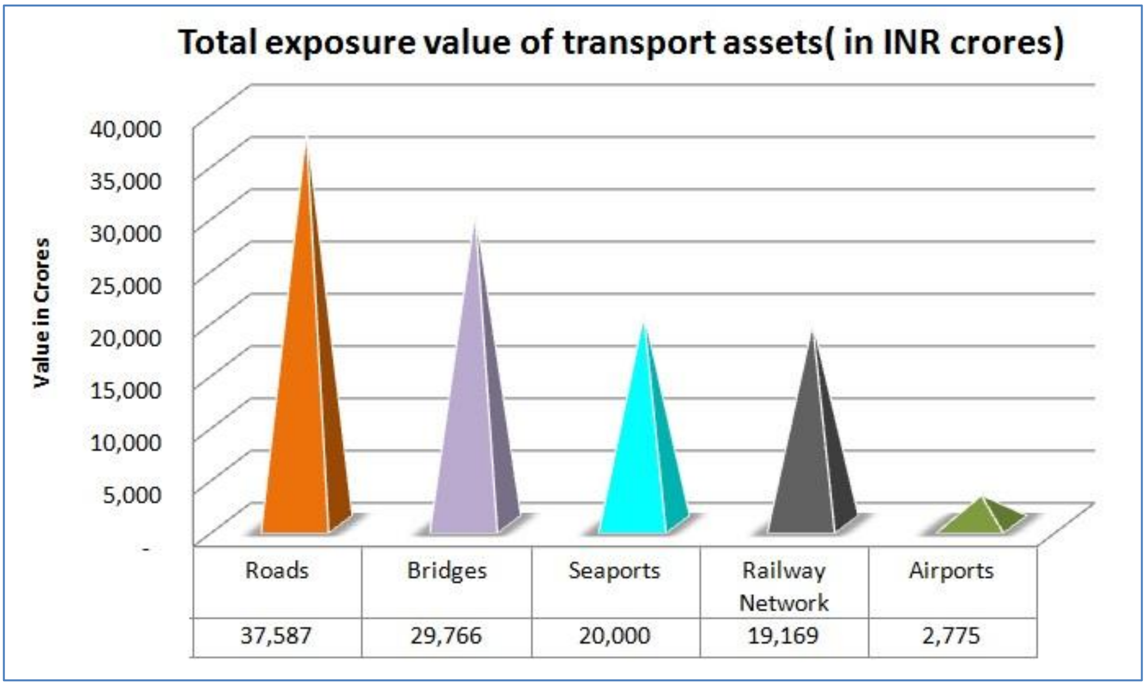


Figure 4-35: Total exposure value of transport assets

4.5.3 UTILITIES

The total estimated value of exposure for all utility categories present in the study area is more than INR 48,785 crores (Figure 4-36), out of which electric lines exposure value accounts for about 38% of the total value, potable water for about 24%, waste water for about 17%, communication systems for about 12% and oil and gases for about 9%.

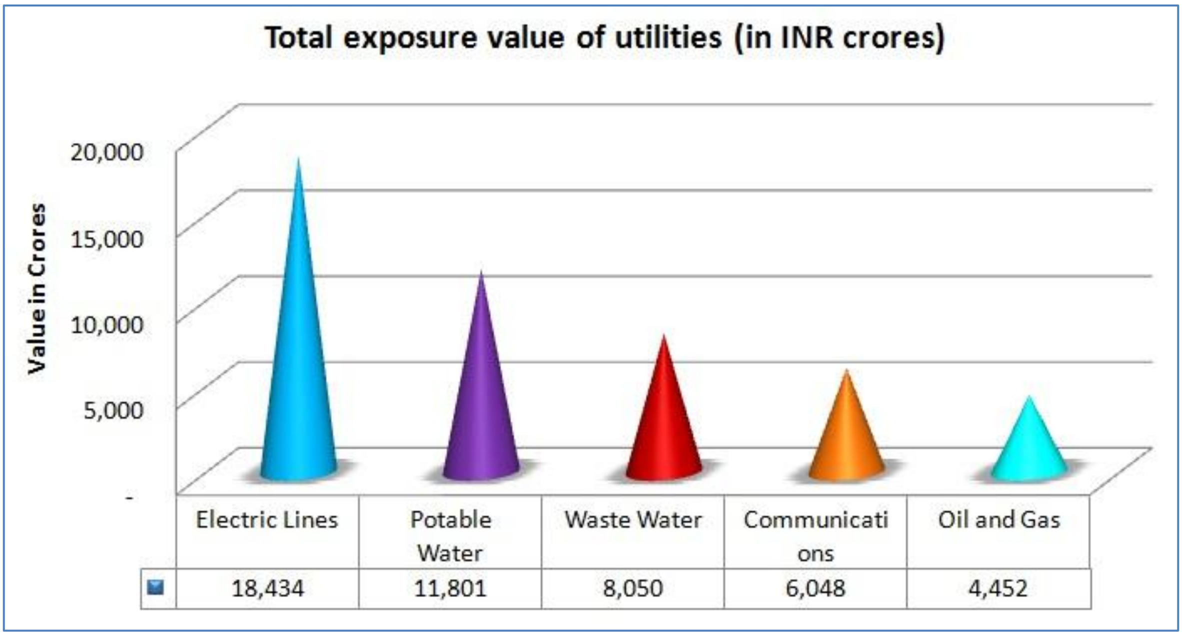


Figure 4-36: Total exposure value of utilities

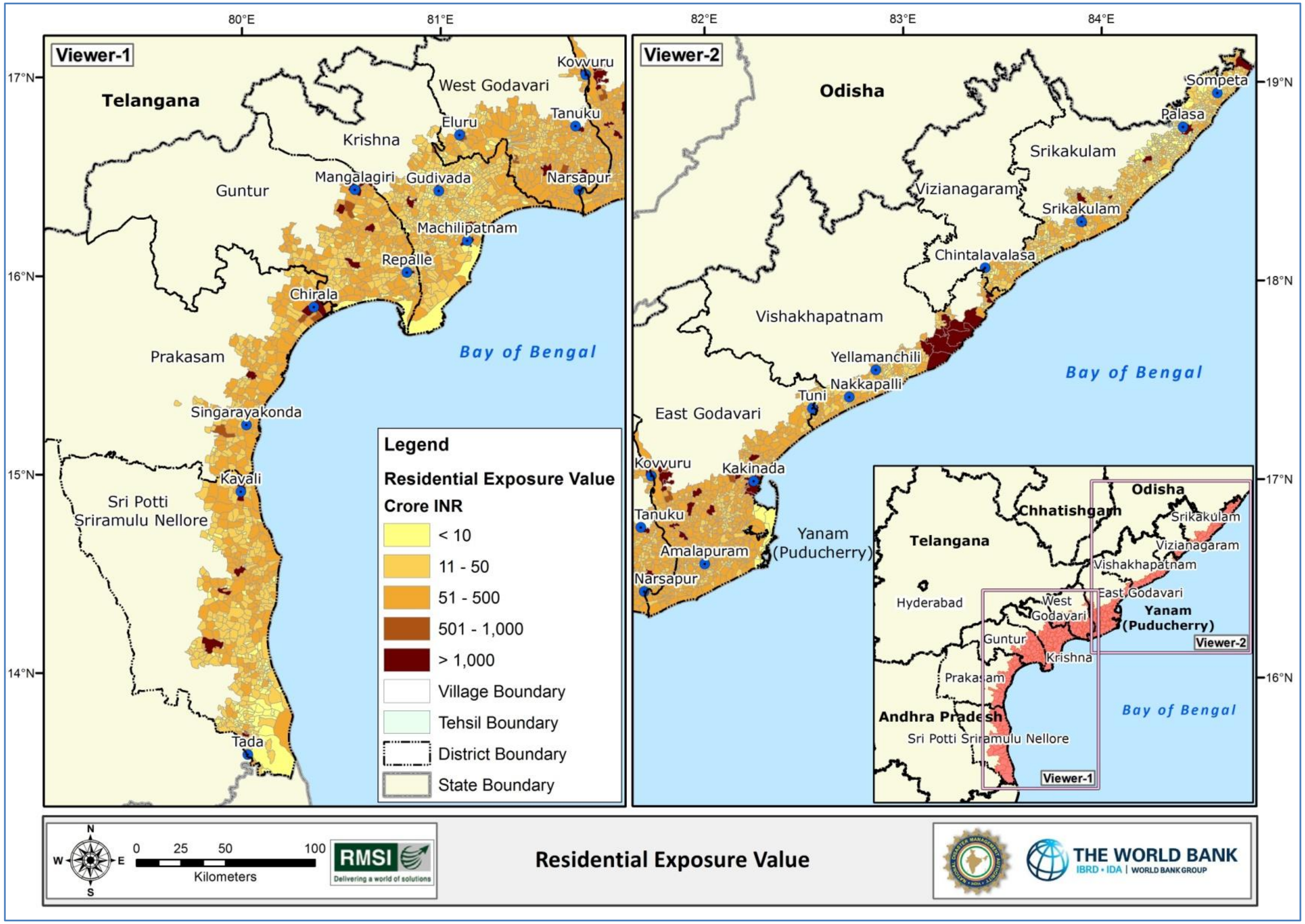


Figure 4-37: Distribution of total estimated exposure values for residential buildings at village level

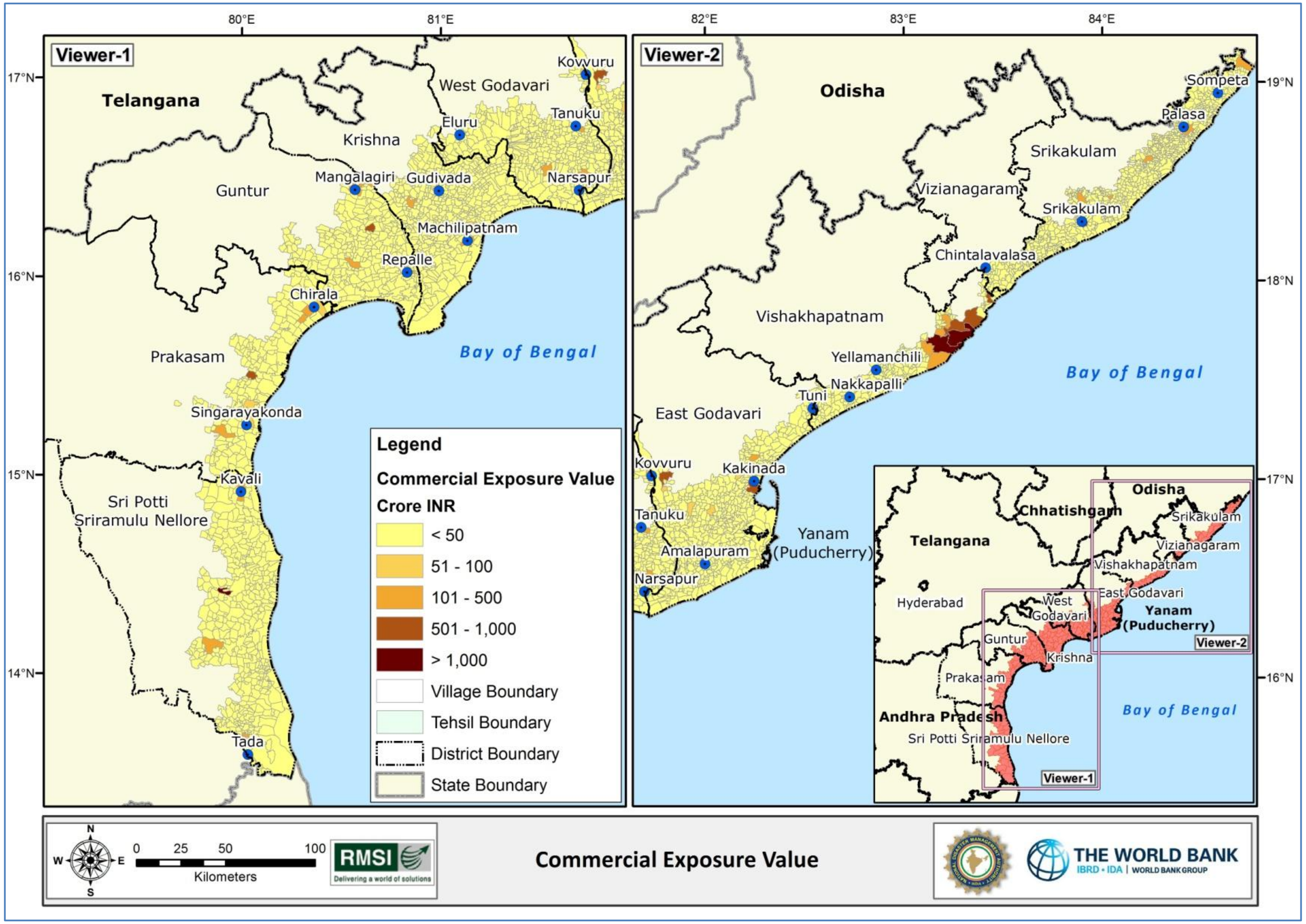


Figure 4-38: Distribution of total estimated exposure values for commercial buildings at village level

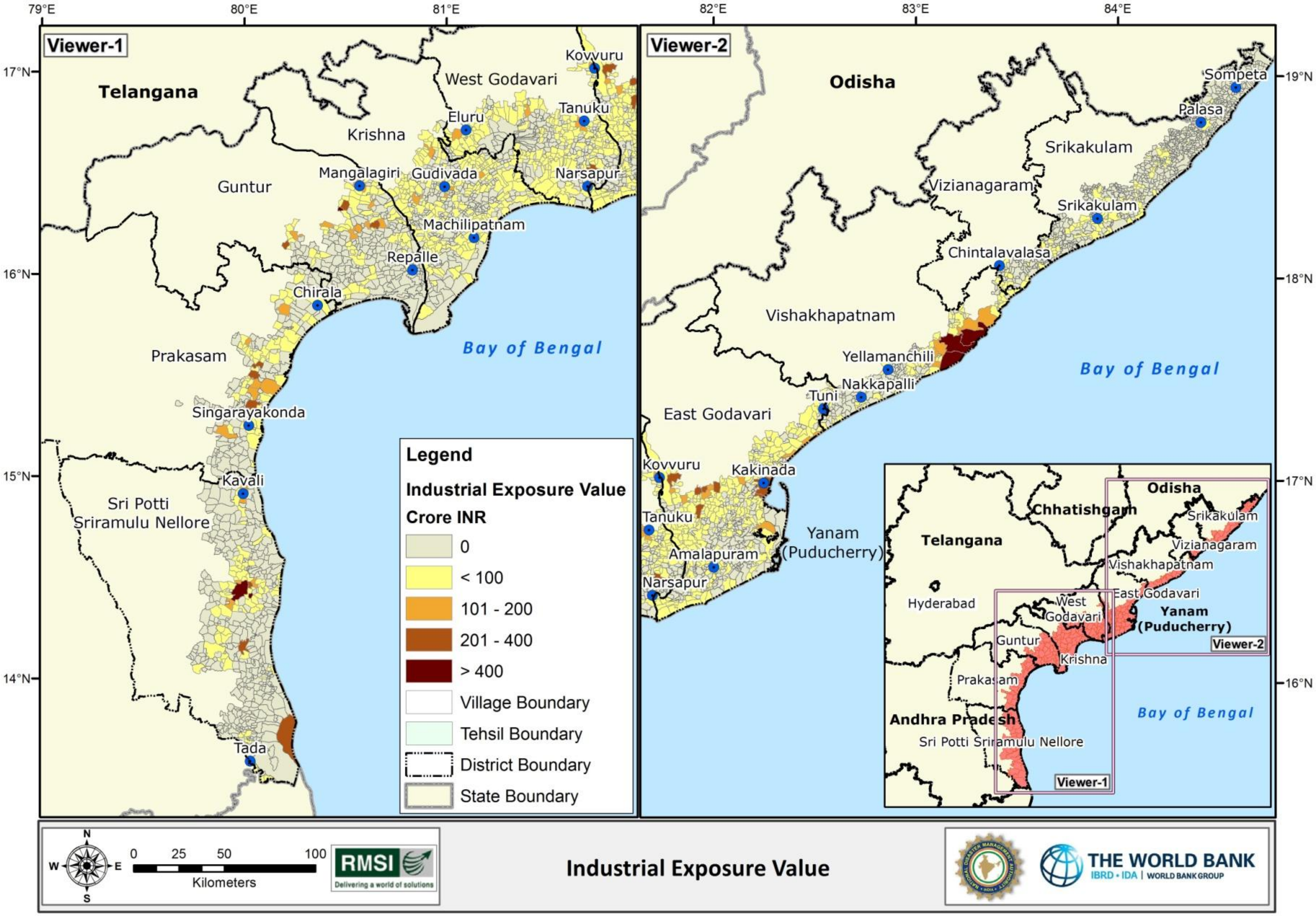


Figure 4-39: Distribution of total estimated exposure values for industrial buildings at village level

4.6 Social and Economic Vulnerability Assessment

4.6.1 Social Vulnerability Assessment of Coastal Districts of Andhra Pradesh

The SoVI map generated (Figure 4-40) for Andhra Pradesh shows high social vulnerability in some districts - particularly Krishna, Vishakhapatnam, Vizianagaram and Srikakulam districts. Coastal villages of these districts are showing high index and is mainly attributes to high population density and low density of infrastructure - roads and hospitals. The West and East Godavari and Sri Potti Sriramulu Nellore districts has majority of the villages with medium SoVI and Prakasam and Guntur has villages mostly with low SOVI. Prakasam district interestingly has all the villages with low SoVI, which means high resilience. This is mainly because of low population density and occupational structure. Substantial share of the population are involved in secondary and service sector. This is explicit in the Figure 4-42 presented in the subsequent section (Section 3.2.5 Economic vulnerability).

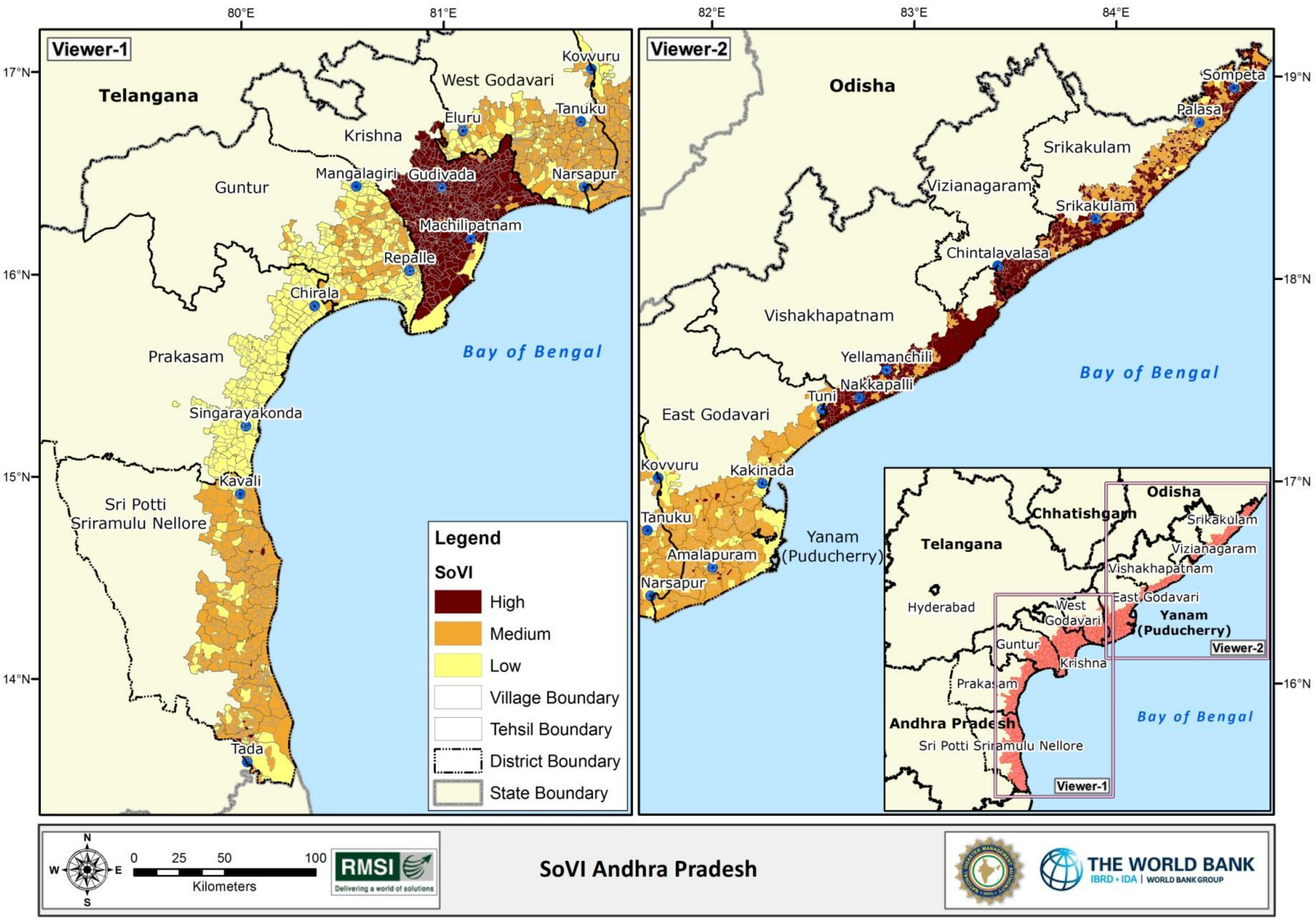


Figure 4-40: SoVI map of coastal districts of Andhra Pradesh

4.6.2 ECONOMIC VULNERABILITY

4.6.2.1 Livelihood and occupational pattern

The livelihood and occupational pattern of coastal Andhra Pradesh is provided in the Figure 4-41, Figure 4-42 and Figure 4-43. The key livelihood of majority of the population in the coastal stretch is related to agriculture and fisheries. The southern part of the state – Sri Potti Sriamulu Nellore, Prakasam, Guntur, Krishna and West Godavari has higher concentration of population depending on primary sector. Vishakhapatnam district has relatively less agriculture and fisheries population and more population engaged in secondary and service sector. Non-workers are relatively more in Vishakhapatnam and East Godavari districts.

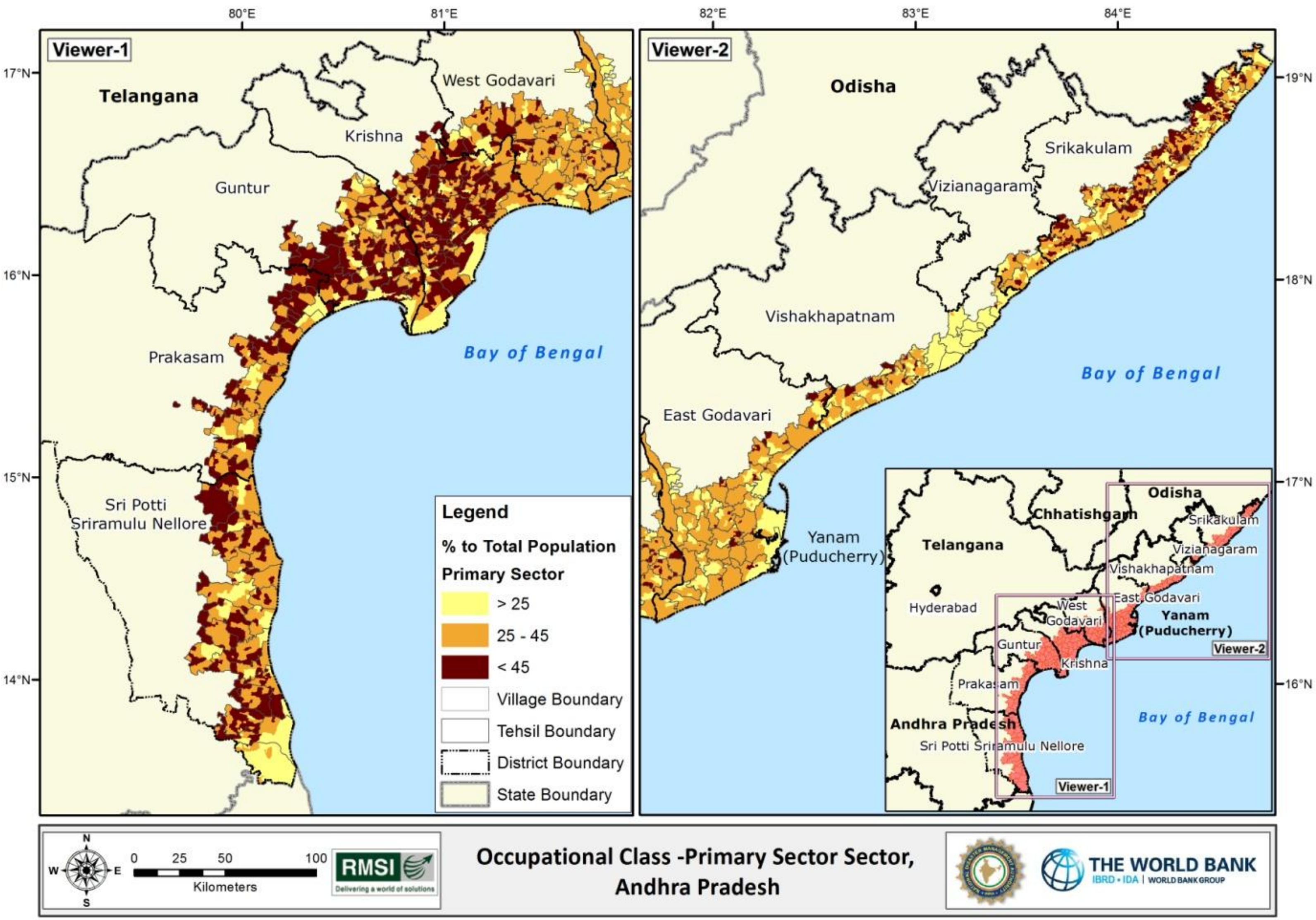


Figure 4-41: Occupational group: Primary sector (agriculture and fisheries), Andhra Pradesh

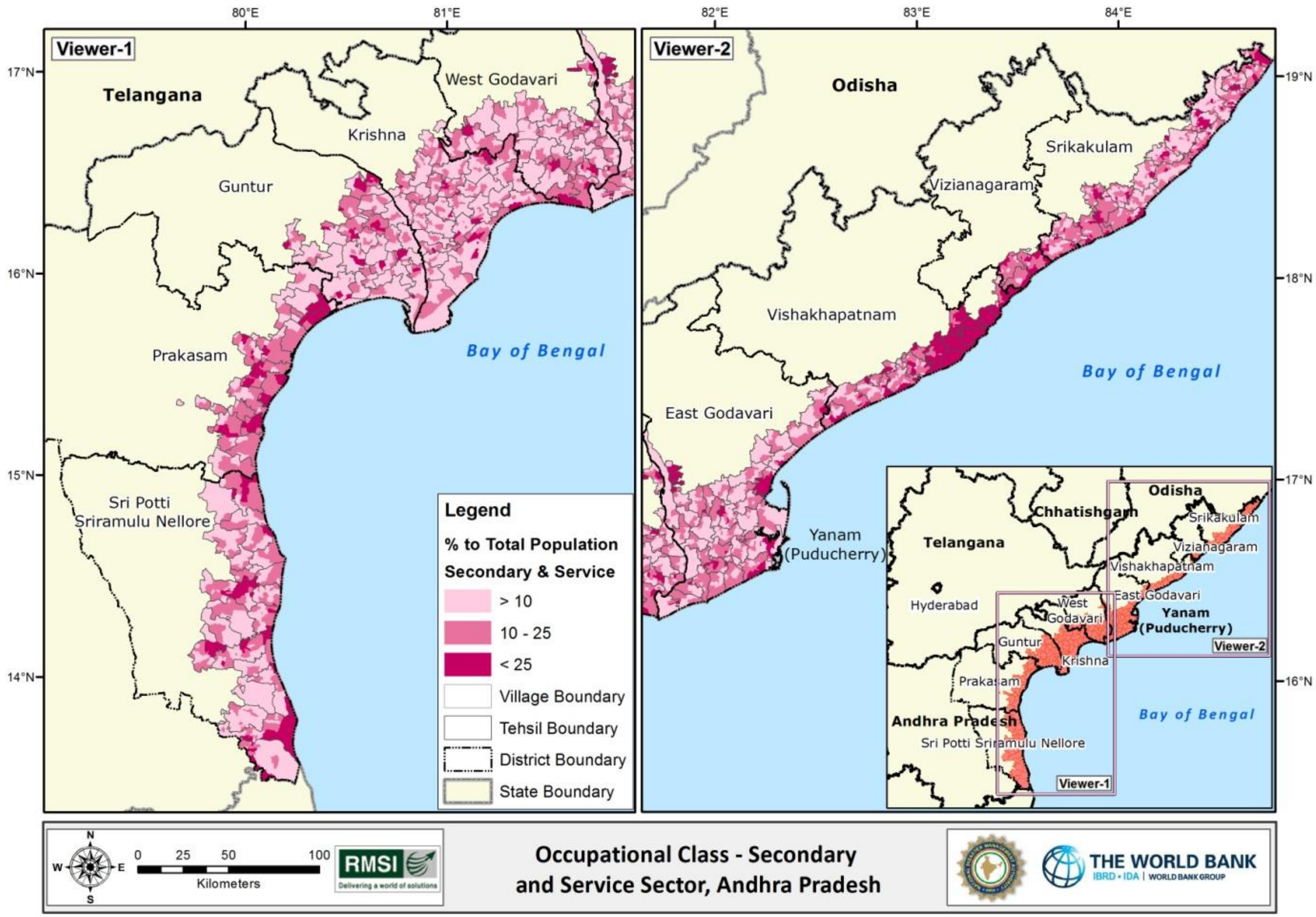


Figure 4-42: Occupational group: Secondary and service sector, Andhra Pradesh

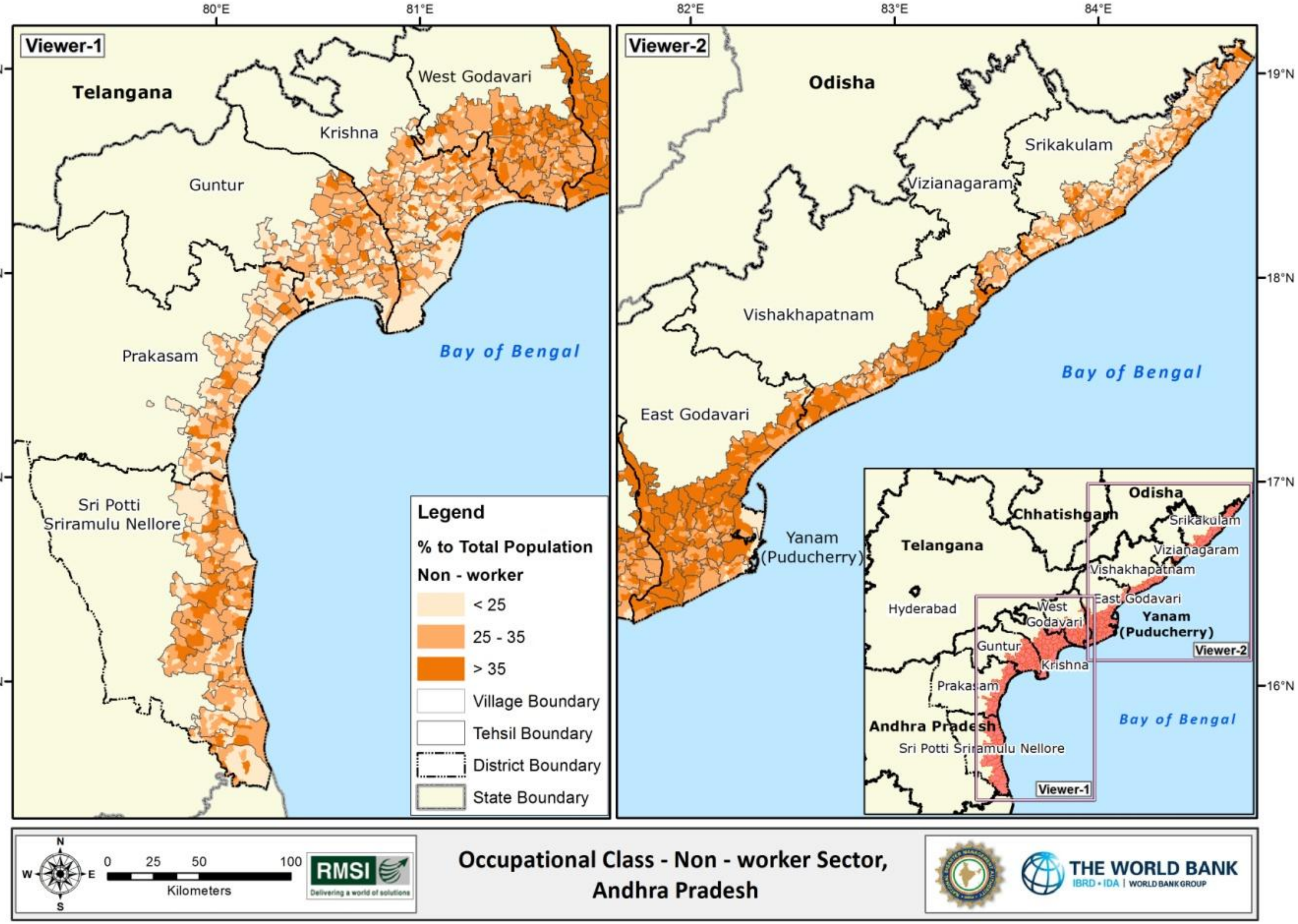


Figure 4-43: Occupational group: Non-workers, Andhra Pradesh

4.6.2.2 People below poverty line

The Figure 4-44 presents the distribution of poverty level among various coastal districts of Andhra Pradesh. Vishakhapatnam, Vizianagaram and East Godavari have the highest percentage of people below poverty line. The social vulnerability map Figure 4-40 also confirm this as those are the districts, which are having high SoVI; social vulnerable. These districts have substantial percentage of population engaged in primary sector activities.

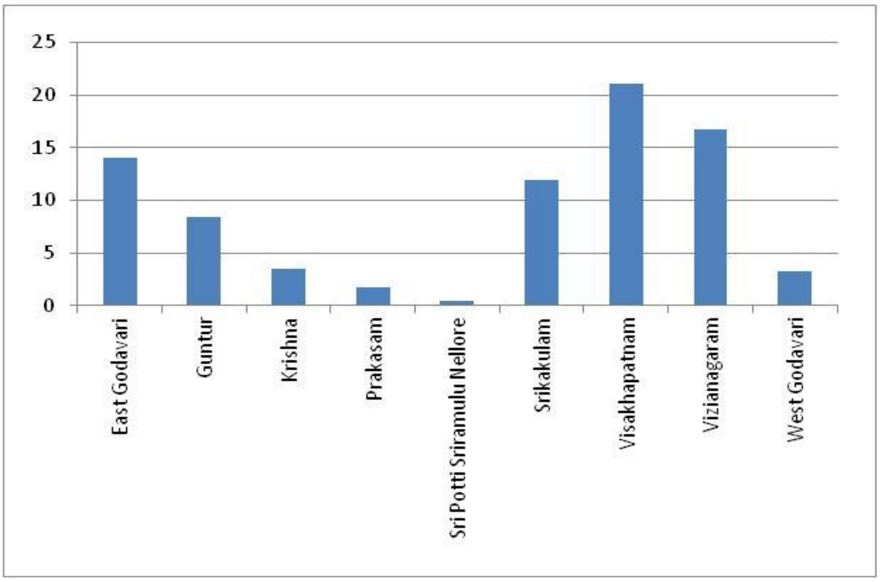


Figure 4-44: Poverty level – percentage to total population, Andhra Pradesh

4.6.2.3 District level GDP

The district GDP shows a steady growth over the last 8 years in most of the districts (Figure 4-45) and Figure 4-46). Three districts have experienced negative growths - Visakhapatnam (in year 2008-09) and East and West Godavari (in year 2004-05 and 2008-09).

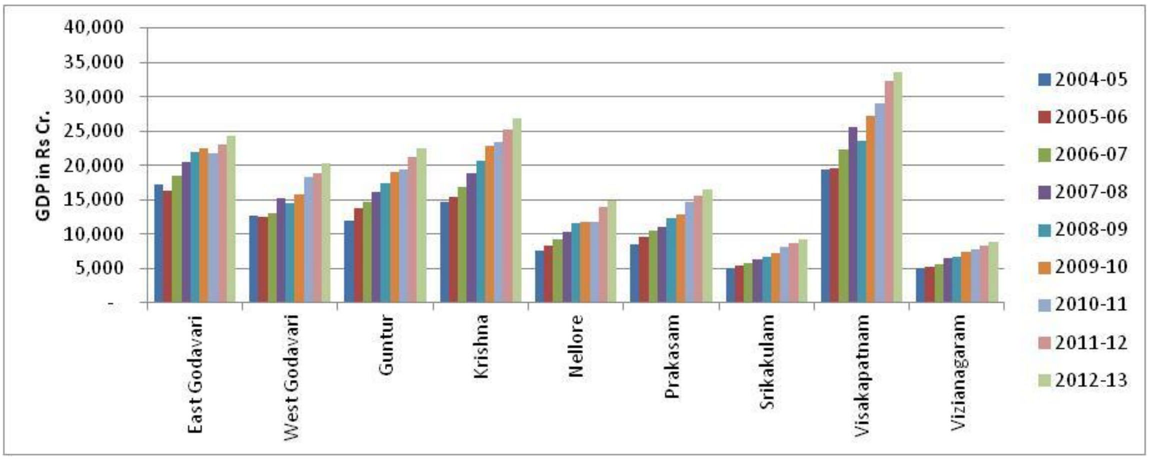


Figure 4-45: District level GDP of coastal district of Andhra Pradesh (2004 to 2012)

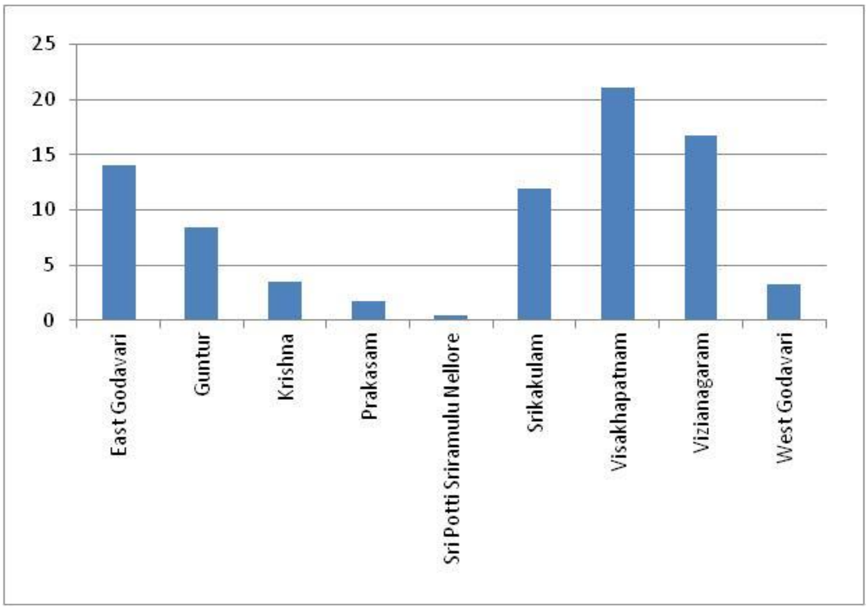


Figure 4-46: District level average GDP growth, Andhra Pradesh

5 Results and Findings for Odisha

There are 10 districts, 105 sub-districts, and 11,369 villages in the Odisha, which come under the study area. Detailed analysis of each exposure element as described in Figure 3-1 is presented in the following subsections.

5.1 Demography

As per Census 2011, the total population of the study area in Odisha is about 1.27 crores. To estimate 2014 population, the decadal growth rate at district level (Census 2011 and 2001) was used to arrive at annual average growth rate which was applied to Census 2011 population to arrive at village level population for 2014. After applying the growth rate, the projected population for 2014 is estimated at 1.32 crores. The male and female population are found to be almost equally distributed among various districts. Table 5-1 presents the distribution of population by gender at district level.

Table 5-1:- Population distribution by gender at district-level

District	Male Population	Percentage of male population	Female Population	Percentage of female population	Total Population
Baleshwar	11,17,810	51.18	10,66,229	48.82	21,84,039
Bhadrak	7,26,270	50.47	7,12,826	49.53	14,39,096
Cuttack	8,02,298	51.36	7,59,779	48.64	15,62,077
Ganjam	6,68,694	50.87	6,45,867	49.13	13,14,561
Jagatsinghpur	5,90,934	50.83	5,71,731	49.17	11,62,665
Jajpur	5,94,839	50.45	5,84,216	49.55	11,79,055
Kendrapara	7,40,939	49.84	7,45,831	50.16	14,86,770
Khordha	4,52,870	51.04	4,34,447	48.96	8,87,317
Mayurbhanj	1,14,600	50.39	1,12,804	49.61	2,27,404
Puri	8,99,679	50.94	8,66,393	49.06	17,66,072
Grand Total	67,08,933	50.9	65,00,123	49.20	1,32,09,056

Table 5-1 indicates that Baleshwar district has the highest population, about 39.28 lakhs (about 21.84 of the total[40]), whereas Mayurbhanj has the least population, i.e., about 2% of the total. In terms of urban/rural distribution of population, majority of the population (83%) lives in rural areas and about 17% lives in urban areas (Figure 5-1).

[40] % of total population of study area

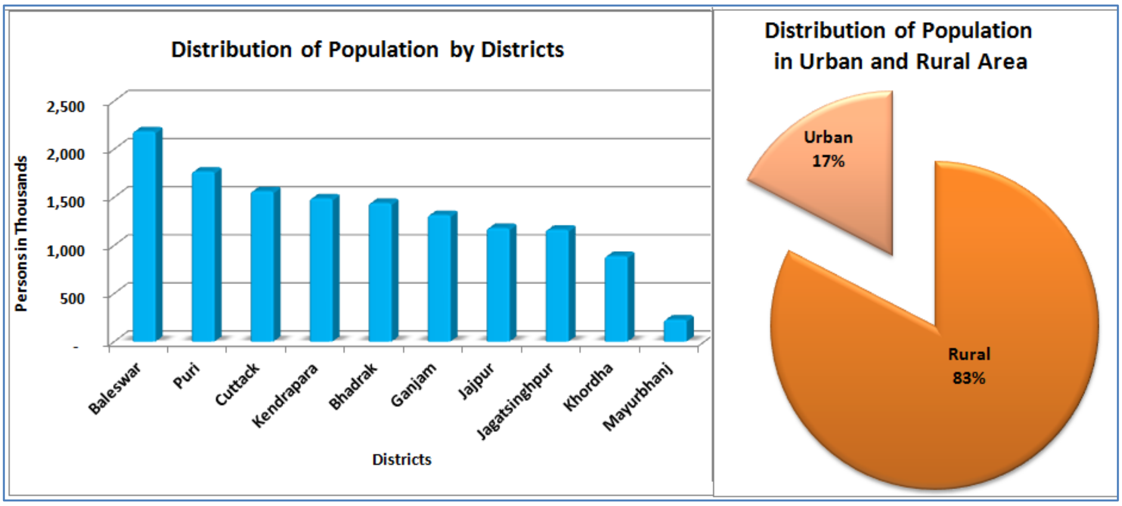


Figure 5-1: Distribution of population by districts (left) and urban and rural area (right)

Of the total study area population, about 65% is non-working population and about 35% is working population residing across various villages. The non-working population comprises of about 65% females and about 35% males (Figure 5-2). Baleshwar district has the highest number of non-working male and female population followed by Puri and Kendrapara districts. Mayurbhanj district has the least number of working male and female population (about 2%), whereas Baleshwar district has the highest number of working population (about 19%).

Figure 5-2 shows that the percentage child population (<15 Years) to total population of study area is 26% (34.66 lakhs). Of this, about 84% lives in rural areas and 16% in urban areas. About 10% of total study area population comprises old age population (>60 years). Of this, 85% lives in rural areas and 15% in urban areas. Table 8-19 presents the district-level distribution of child and old age population.

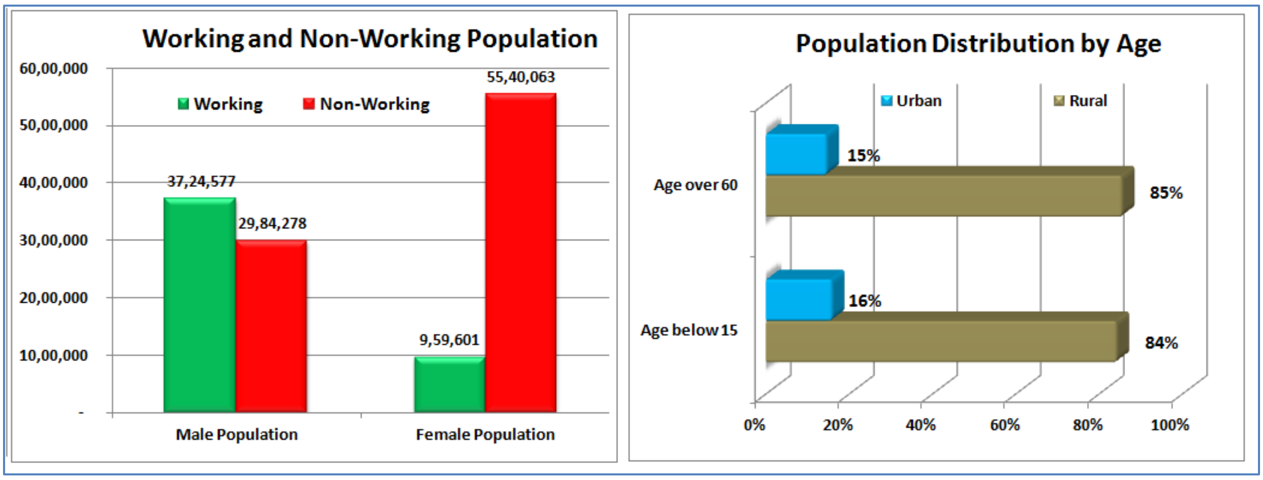


Figure 5-2: Distribution of working and Non-working population (left) and by age (right)

Figure 5-3 presents the population density at tehsil level. Puri (M) has the highest population density of more than 11,000 whereas Krushnaprasad tehsil has the least population density of 63 persons/ sq. km amongst all the 105 tehsils. At village/city level, Pathar (CT) in Khallikote tehsil of Ganjam district has the highest population density of more than 31,000 whereas Narayanpur village in Aali tehsil of Kendrapara district has least population density of less than one person/ sq. km.

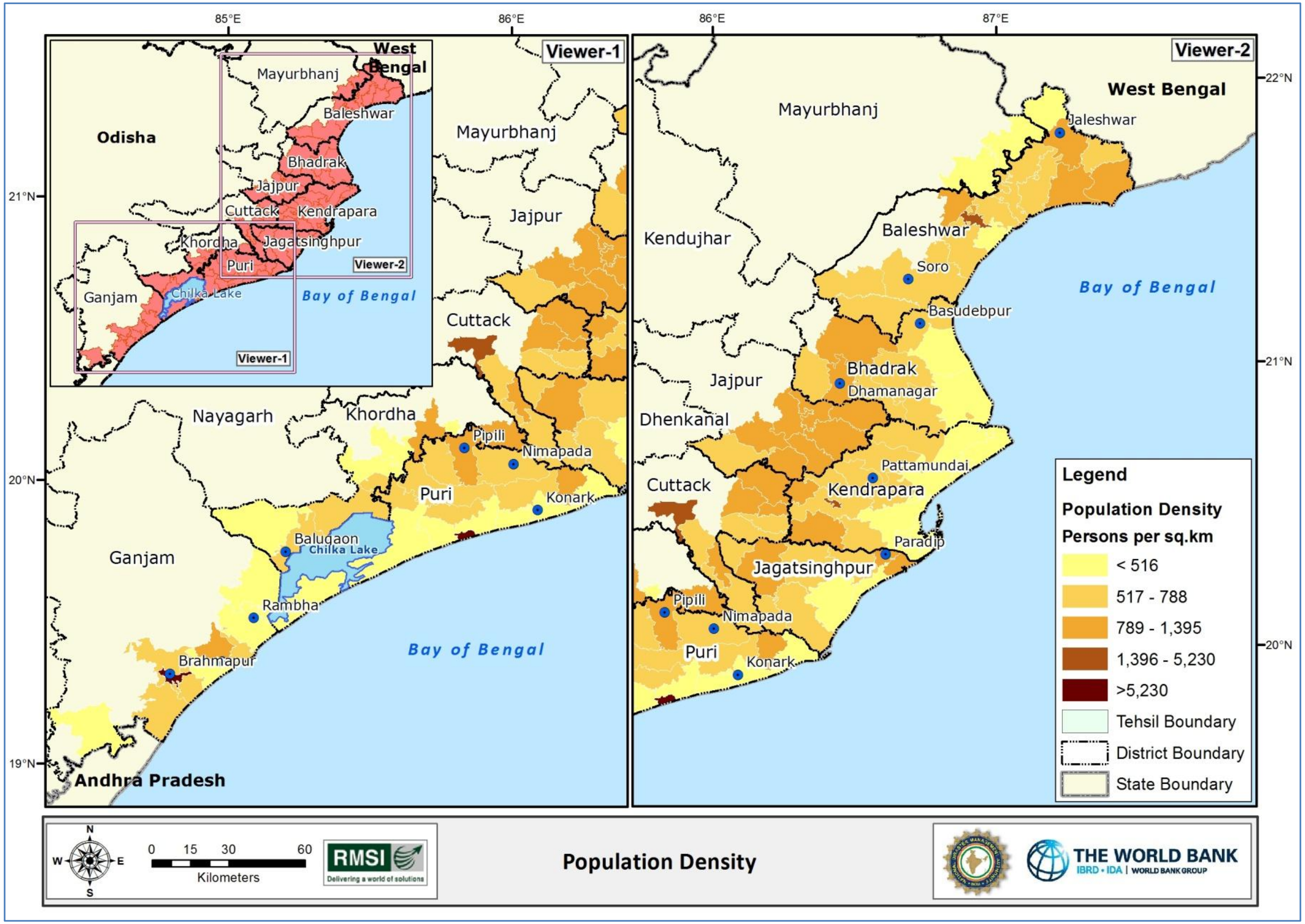


Figure 5-3: Population density in the study area at tehsil level

5.2 Building/Housing

5.2.1 Building Occupancy

About 40 lakh Census houses have been estimated for 2014, out of which about 95% of the total houses are occupied and the remaining 5% are vacant (Figure 5-4). The occupancy based distribution of housing shows that about 75% of the houses are used for residential purposes; whereas, about 8% are used for commercial or residential-cum-commercial use, and about 0.6% houses are used for industrial use. The remaining (16.4%) houses are used for other use that include social and public uses, viz., schools, colleges, hospitals, dispensaries, place of worship etc. Figure 5-4 provides the distribution of houses based on their occupancy. The district-level distribution of houses based on their occupancy and the respective uses for which they are deployed is given in Table 8-20. For better understanding, the educational institutes (about 0.7 % of the total houses) has been presented separately in the below diagram (right).

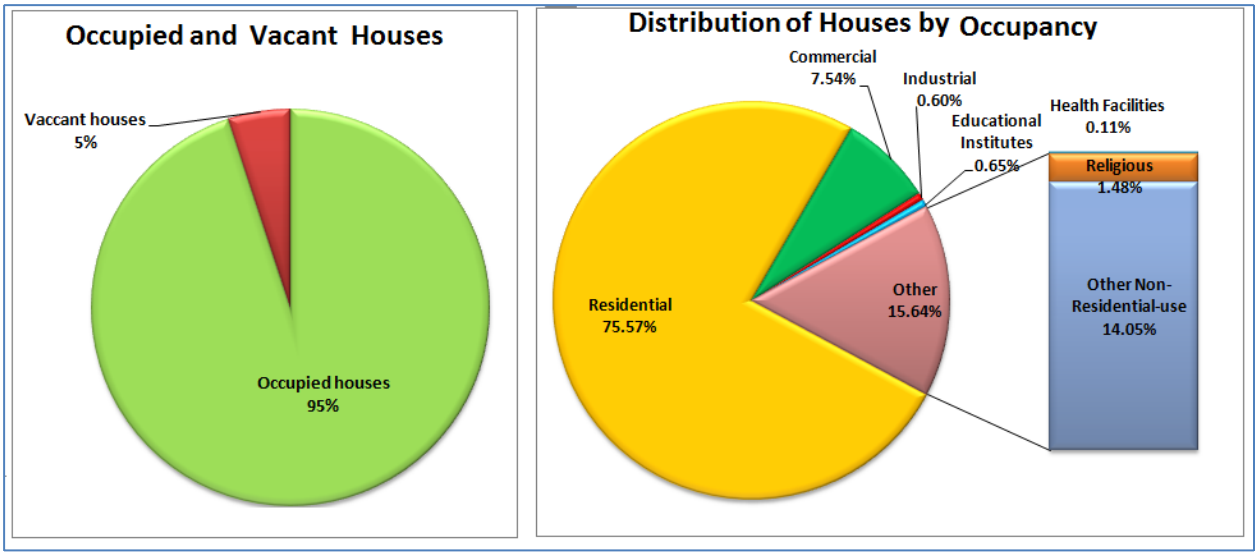


Figure 5-4: Percentage distribution of occupied and vacant houses (left) and percentage distribution of Census houses based on occupancy (right)

Census 2011 data for various occupancy types are in tabular format, which lacks the spatial distribution of residential, residential-cum-commercial, commercial, industrial and other buildings within the district. In building agglomeration data, buildings are clustered based on the occupancy type. For cyclonic wind, storm surge, and cyclone induced rainfall hazards (mostly localized in nature), it is important to know the spatial distribution of building exposure within the district. In order to fulfill the above-mentioned requirement, building agglomeration data are derived from satellite LISS IV images.

Figure 5-5 presents the building footprints delineated from satellite images for the study area. The classifications are done based on the tone, texture, shape, size, pattern, and associations between buildings as present on satellite images.

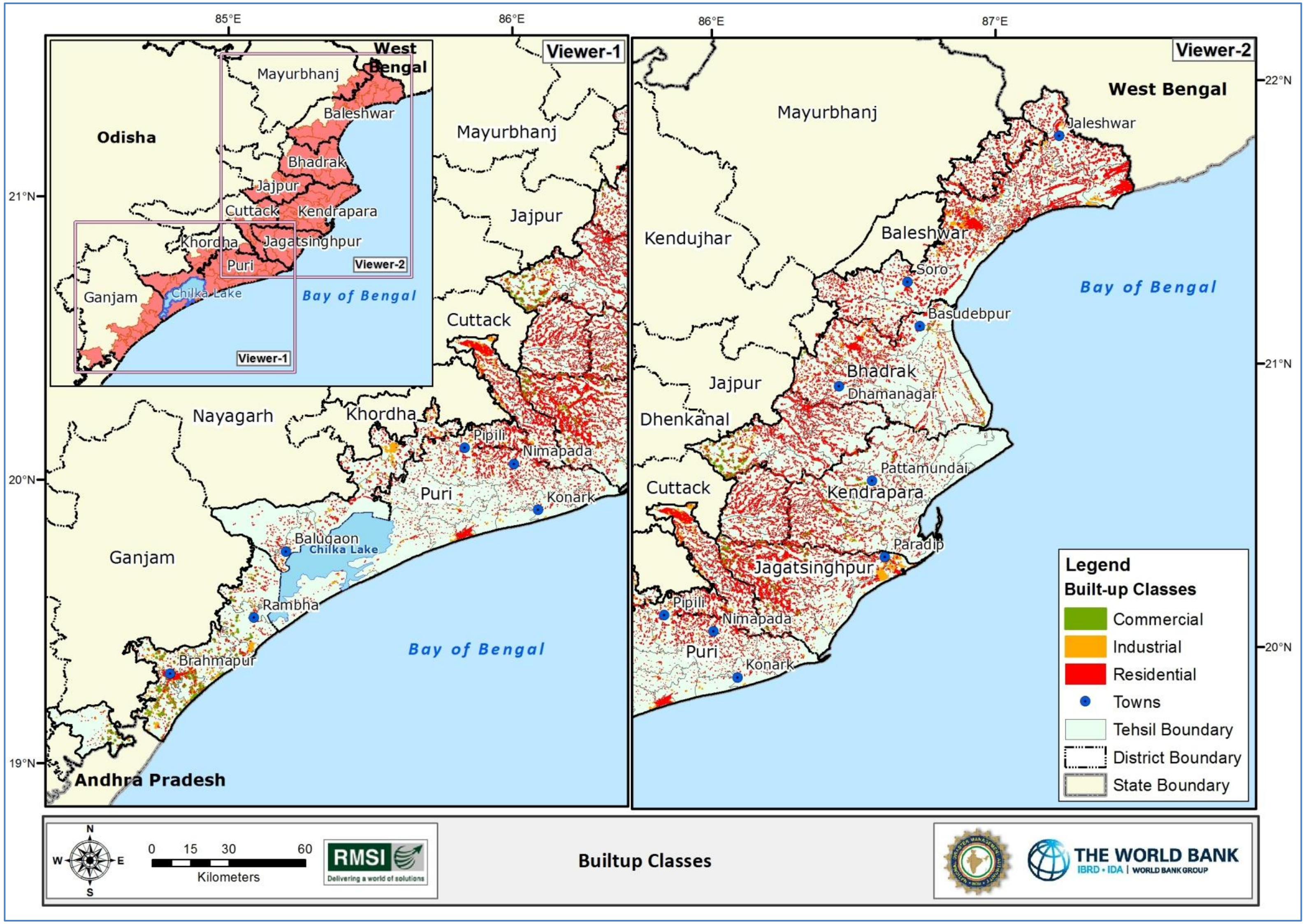


Figure 5-5: Distribution of built-up area based on occupancy

5.2.2 Building Structure Classes for various occupancies

The building structure categories with respect to various occupancy types are described in the following subsections.

5.2.2.1 Residential

The general residential houses in Odisha are classified as independent houses, apartments, row houses, and huts. Sample photographs of some of the residential buildings in Odisha are provided in Figure 5-6. In terms of total residential buildings, about 99% houses are being used as residences while only 1% is being used for residence-cum-other use.

Figure 5-6: Different types of residential houses

Out of the total estimated 40.20 lakh Census houses, there are about 29 lakh residential census houses in the study area of Odisha are distributed across 10 districts. Out of these, about 4.92 lakh (17% of total residential houses) houses are located in urban areas whereas about 23.95 lakh (83% of total residential houses) houses are located in rural areas. Baleshwar district has the highest number of houses in rural areas (18% of total rural houses) and Cuttack has the highest number of urban houses (25% of total urban houses). The spatial distribution of rural and urban houses among ten districts is given in Figure 5-7.

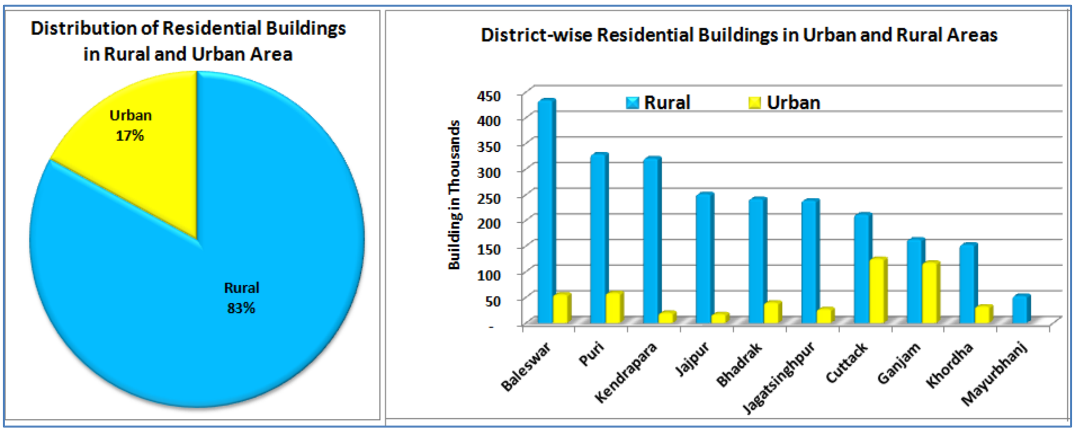


Figure 5-7: Percentage distribution of residential houses in urban and rural areas (left) and district-level distribution (right)

Based on the Census data, the residential buildings in Odisha are dominated by Structure type ST18 and ST 2 comprising about 6.7 lakh buildings in each category. ST4 type buildings is the next dominant class that consists of about 4.7 lakhs of the total residential buildings (16%). When we consider the building area under different structural classes, residential buildings covered about 100 sq.km area in the study area (Table 5-2, Figure 5-8). ST18, ST4, and ST2 are the top three classes that collectively account for more than 62% of the total residential area, whereas ST13, ST16, and ST17 are the next major classes, which account for 25% of the total residential area. Count of residential buildings and their areas based on the major structure types is presented in Table 5-2.

Table 5-2:- Residential houses and built-up area by structural types

Structure type	ST2	ST4	ST13	ST16	ST17	ST18	All Others	Total
Count of Houses	674,111	468,909	145,685	244,509	333,895	666,369	352,121	2,885,599
Area in Sq Km	11.64	11.96	3.89	10.44	9.27	35.86	9.93	92.99

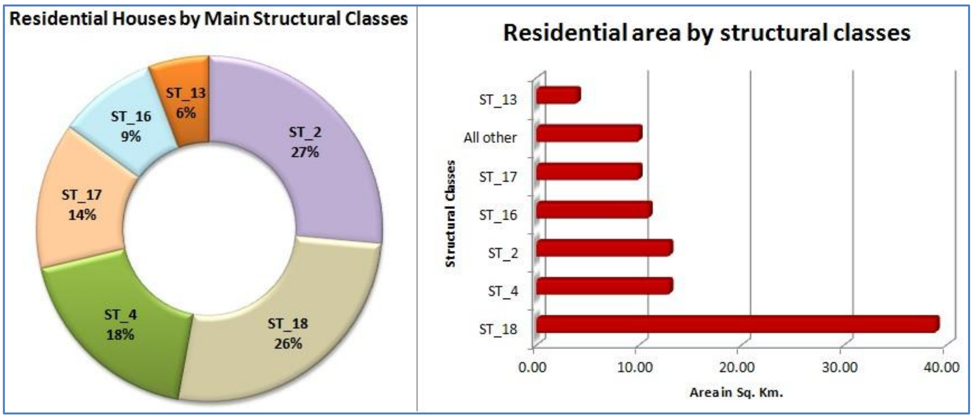


Figure 5-8: Distribution of residential areas by structural classes

5.2.2.2 Commercial

The base data regarding the number of commercial houses available at city/district -level was taken from the Census of India (2011). These numbers were further estimated for year the 2014 by applying annual growth rate. The Census provides number of shops and offices, hotels, lodges, guesthouses, residence-cum other uses, and other non-residential houses at tehsil level. All these categories of data were combined together to get the total number of commercial houses in the study area. It was further distributed over the village/ward, based on the household numbers available at each village/ward level in the demographic data. Sample photographs of some of the commercial buildings are provided in Figure 5-9.

Note: commercial buildings do not include schools and colleges, hospitals and dispensaries, places of worship, and industries.

Figure 5-9: Different types of commercial buildings/ centers

A total of 8.2 lakh commercial buildings were estimated, which cover a total built-up area of about 26.05 sq. km. Bhadrak district has the highest percentage of commercial built-up area (about 19% of total commercial built-up area), followed by Jagatsinghpur (about 16%). Figure 5-10 below presents the distribution of main structural classes for commercial buildings. ST18 is the dominant structural type for commercial buildings (19% of total commercial built-up area) followed by ST8, ST15, ST21, ST22, ST16 (17% each) in the study area.

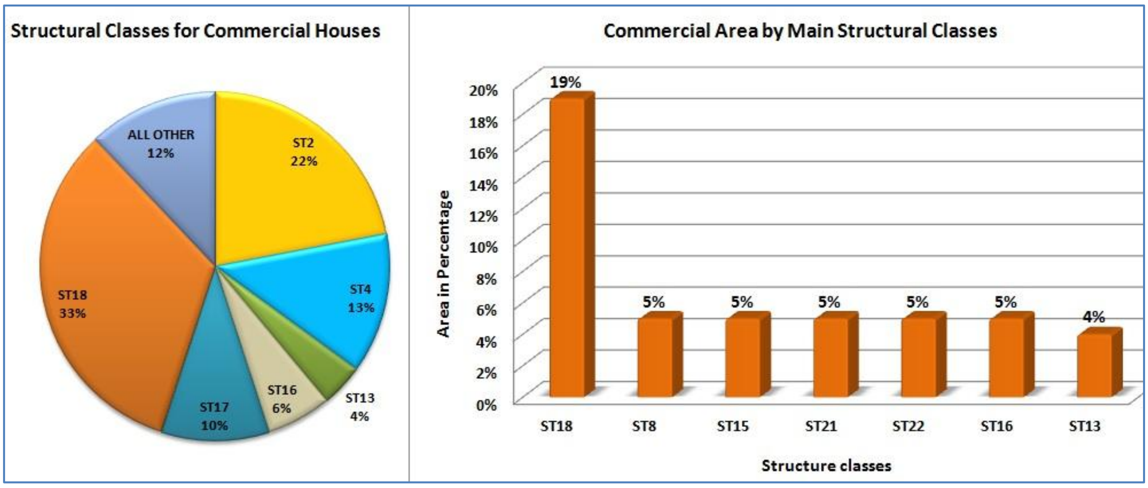


Figure 5-10: Percentage distributions of commercial building counts by structural types (left) and by area (right)

5.2.2.3 Industrial

Census 2011 provides number of industries at district and town levels. Using building agglomeration data of industries, district and town level number of industries were distributed over the villages.

Out of a total of 23,551 industries in the study area, majority of industries are located in Ganjam (25%) and Baleshwar (16%) districts. The RMSI team visited some industries in Ganjam district including United Chemicals Ltd. Suntech Industries Ltd., and Jayshree Chemicals Ltd. Sample photographs of some of these industries are presented below in Figure 5-11.

Figure 5-11: A snap shot of industrial buildings in Ganjam district

Total industrial built-up area in the study area is estimated at about 10.93 sq. km. In terms of percentage distribution of industrial built-up area by district, Ganjam district has the highest percentage of industrial built-up area (about 25% total industrial built-up area), followed by Baleshwar and Puri (about 16% and 15% respectively).

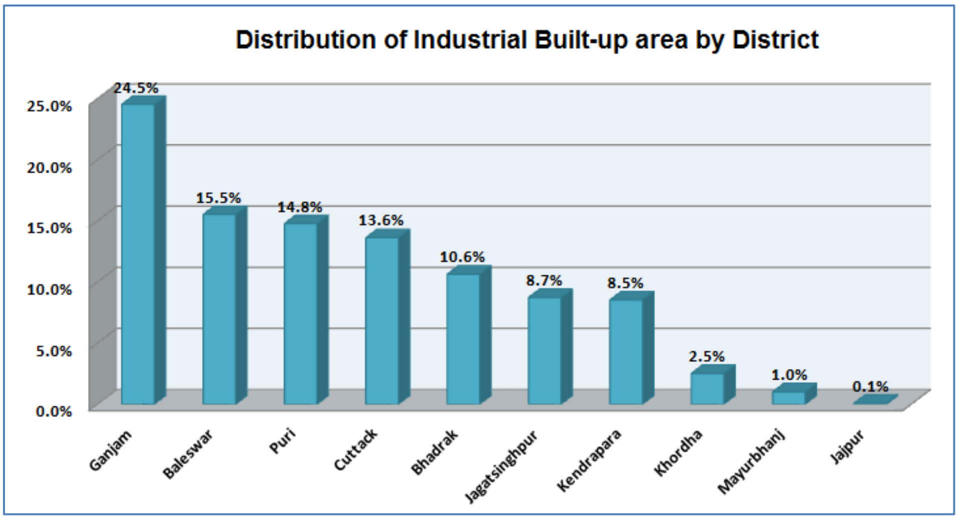


Figure 5-12: Percentage distribution of industrial built-up area by district

5.2.3 OTHERS

5.2.3.1 Religious Places

The sources of religious buildings data are received from SOI, Census of India (2011), and RMSI sample field verification survey. Although, SOI provided locations for 11,803 religious places (Figure 5-13), the vintage of this data is 2005. Therefore, Census of India (2011) data available at district/city level is considered as the primary source of data for religious buildings in the study area, which were further estimated for year 2014.

For 2014, the estimated number of religious places is 56,680 in the study area, which covered about 2.38 sq km of built-up area. It is observed that Puri district has the maximum number of religious places (9,000) and Mayurbhanj district has the least number of religious places (278).

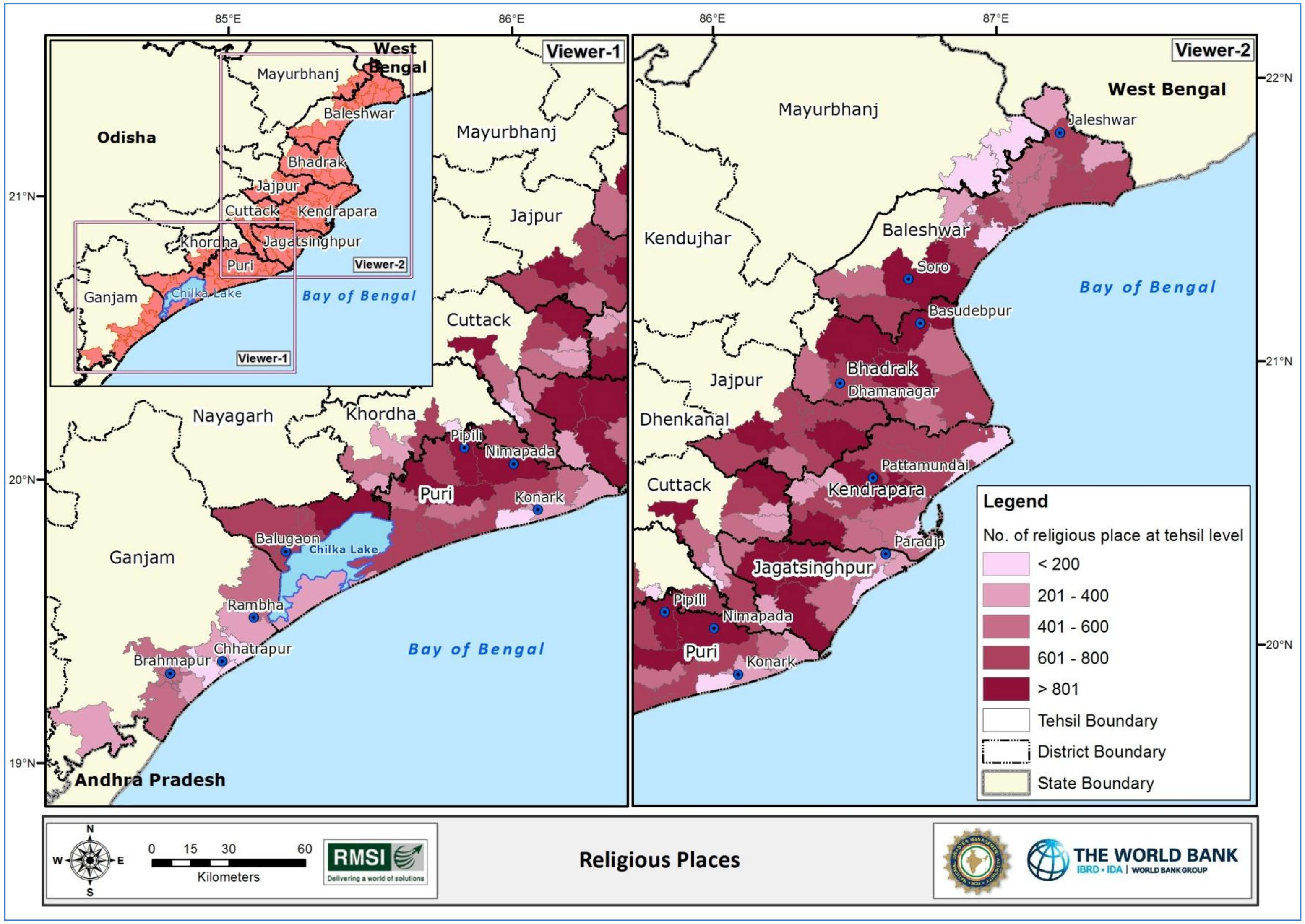


Figure 5-13: Distribution of religious places

5.2.3.2 Cultural Heritage Sites

Cultural heritage sites are invaluable, so the losses cannot be calculated in terms of monetary terms. However, the impact of hazards on these assets would be considered in the risk assessment. The important cultural heritage sites are presented in Figure 5-14.

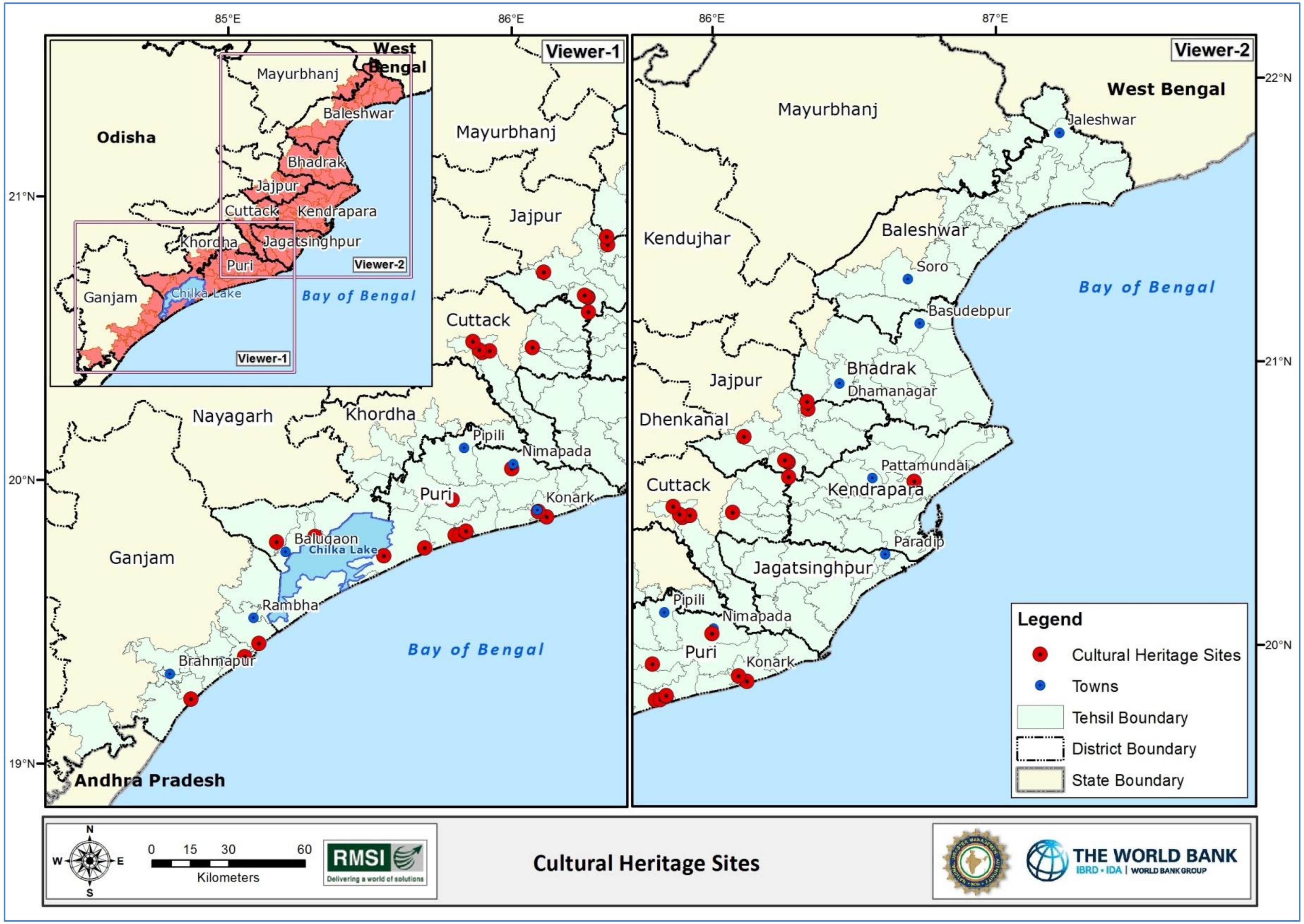


Figure 5-14:- Location of cultural heritage sites

5.3 Infrastructure Data

5.3.1 Essential Facilities

School buildings (educational facilities) and hospital buildings (health-facilities) have been included under Essential Facilities. These play a critical role in mitigation, response, and recovery operations before, during, and after disasters. The following sections discuss the quantification of exposure values for these essential facilities.

5.3.1.1 Educational Facilities

Educational institutions play a critical role in mitigation and recovery operations during and after disasters as these are generally used as shelters. Data for educational institutes at village level have been collected from Census 2011 that has further been projected to 2014.

There are 27,347 educational institutions located in the study area of Odisha that comprise of four main categories, viz., schools, colleges, universities and other educational institutes. Together they cover about 18.94 sq km of built-up area. The highest number of educational institutions are located in Baleshwar districts (5,026) followed by Puri and Kendrapara (3,469 and 3,165 respectively). The data also indicates that out of total educational institutions, the maximum number (about 89%) of educational institutions is located in rural areas, whereas about 11% educational institutes are in urban areas. Figure 5-15 (right) shows district-level percentage distribution of number of educational institutions located in rural and urban areas. Figure 5-16 presents the spatial distribution of educational institutions .at sub-district level.

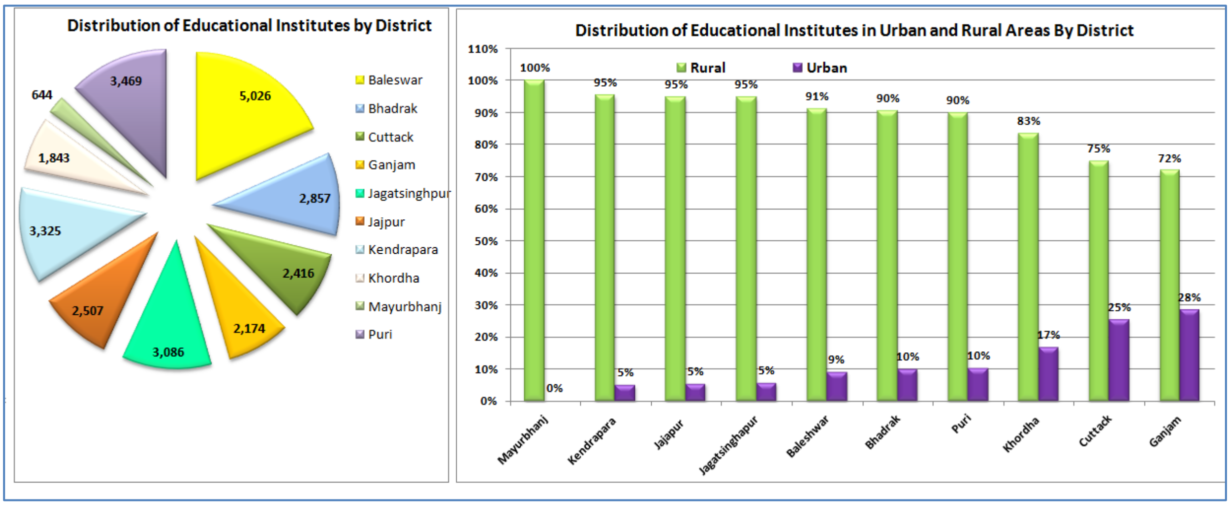


Figure 5-15: Distribution of educational institutions by districts (left) and district wise percentage distribution in urban and rural areas (right)

The village-wise estimated areas of different structure-types were multiplied with the per unit replacement costs of respective structure types. Based on this, the total estimated exposure value for educational institutions is estimated at INR 26,860 crores.

.

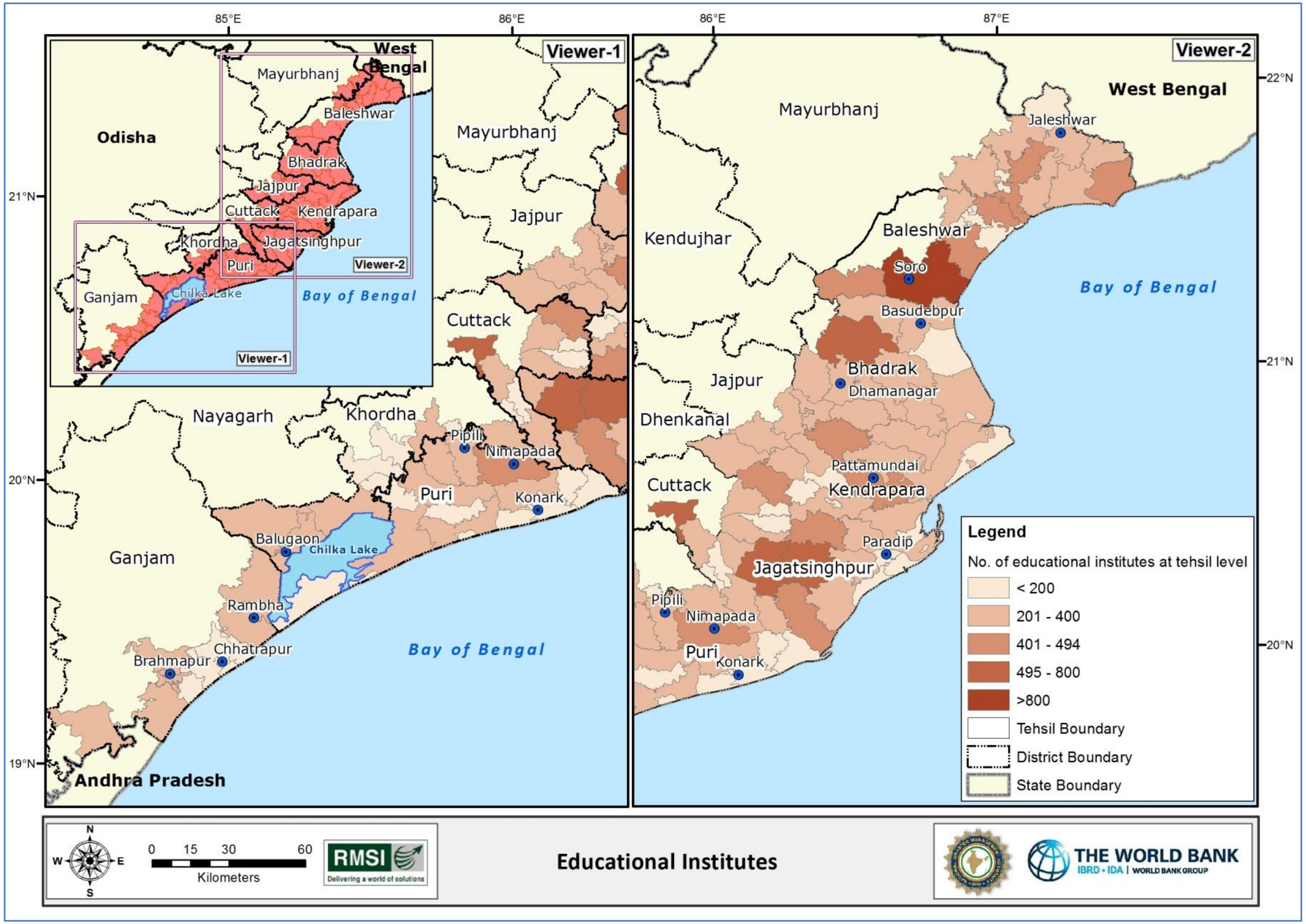


Figure 5-16: Distribution of educational institutions in study area

5.3.1.2 Health Facilities

Data for health facilities was available from the Census (2011), SOI, and also collected through the sample field survey. As SOI data is of old vintage, data for health facilities at village level have been collected from Census 2011 which has further been projected to 2014.

There are 5,353 health facilities present in the study area in Odisha. In order to estimate the area and type of the health centers, a standard defined by the Directorate General of Health Services, Ministry of Health & Family Welfare, Government of India has been used. Based on the guidelines provided in this document; number of beds, type of health centers, and average area of each type has been estimated. The unit replacement cost for each type has been defined based on the guidelines given in the IPHS document.

The village-wise estimated area of different types of structures was multiplied with the per unit replacement costs of the respective structure types. Based on this, the total estimated exposure value for health facilities is estimated at INR 2,702 crores. The location of health facilities are presented in Figure 5-17.

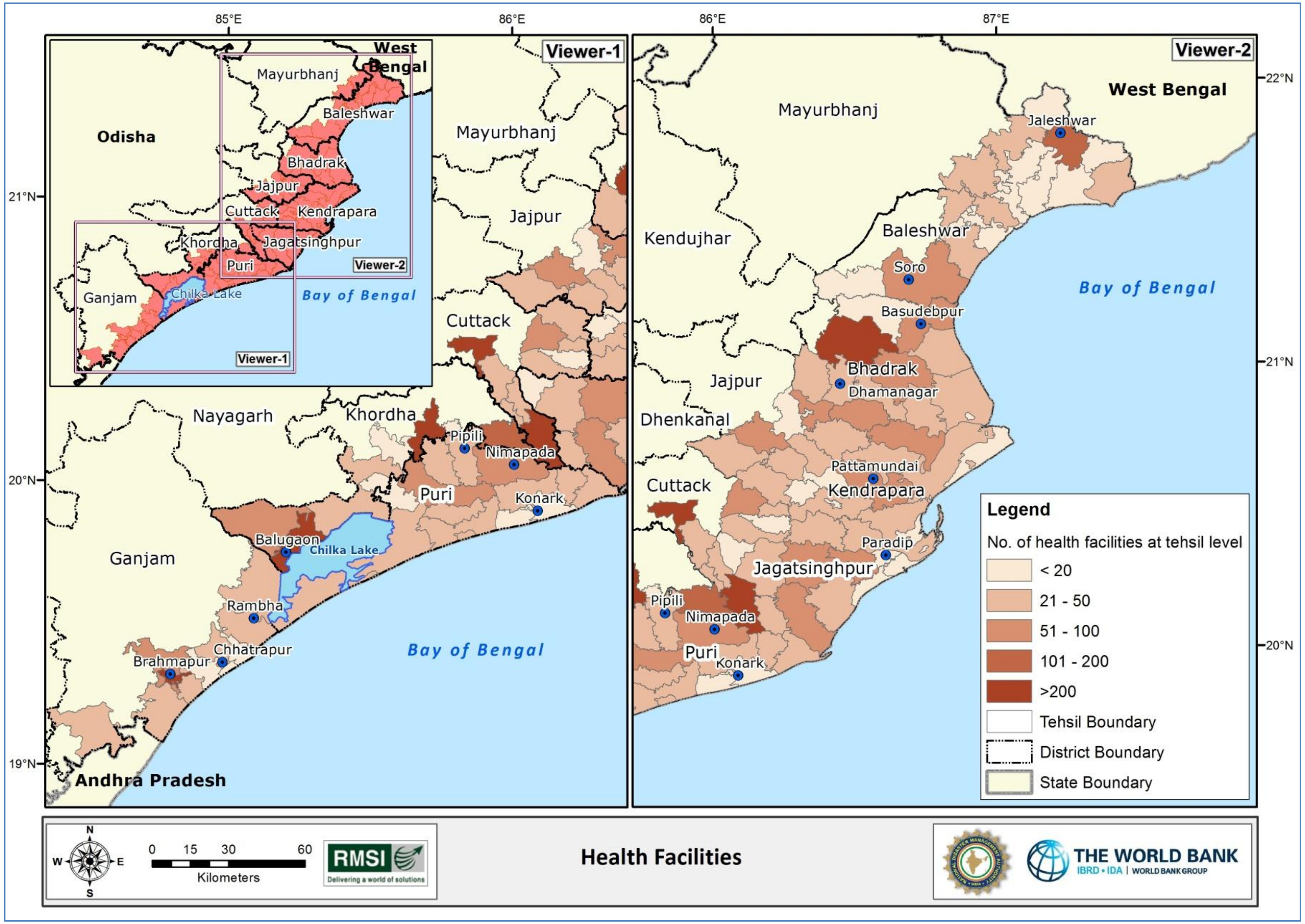


Figure 5-17: Distribution of health facilities

5.3.2 GOVERNMENT/PUBLIC BUILDINGS

This section presents exposure data development and analysis of public buildings (fire stations, police stations, administrative headquarters, and cyclone shelters) in Odisha.

5.3.2.1 Police Stations

The team received data for police stations in the study area of Odisha from SOI and online sources, which indicate that there are 108 police stations distributed across the ten districts (Figure 5-18). The total estimated area for police stations was estimated at about 0.032 sq.km (32,887 sq m). Accordingly, the total replacement cost is estimated at around INR 39.08 crores.

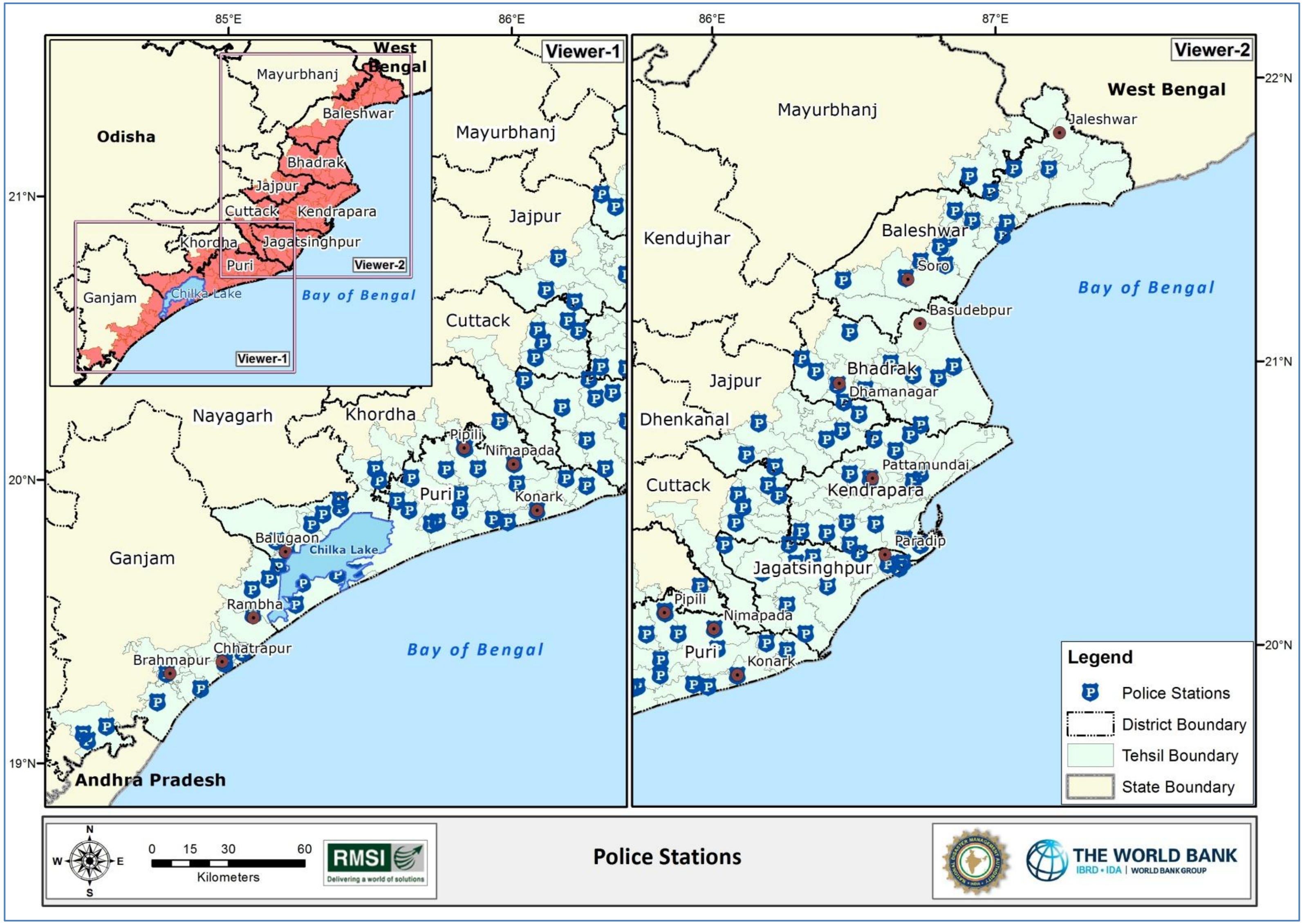


Figure 5-18: Distribution of police stations

5.3.2.2 Fire Stations

The source of data for fire stations is the Odisha State Fire Service Department. There are 53 fire stations located in the study area. Baleshwar district has the maximum number of fire stations followed by Puri and Cuttack district, which have 8 and 7 fire stations respectively. Bhadrak district has 6 fire stations whereas Jajpur and Kendrapara districts have 5 fire stations each. Ganjam, Jagatsinghpur, and Khorda have 4 fire stations each and Mayurbhanj has 1 fire station (Figure 5-19).

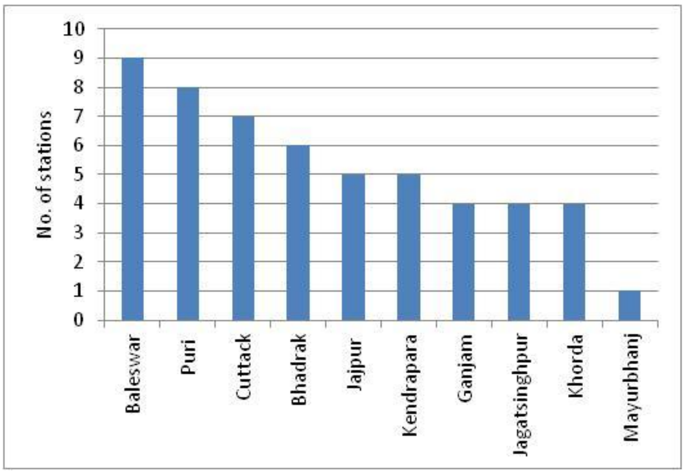


Figure 5-19: Distribution of fire stations across districts

In order to know the number of vehicles in Fire stations at district level, it was observed that Cuttack district has the highest number of fire vehicles (15%) whereas in Mayurbhanj district has the least number of fire vehicles (Figure 5-20). Further, in terms of bay systems in fire stations, it was found that the majority of fire stations were twin bay systems (74%), whereas about 9% of the fire stations were three bay systems. Only 6% fire stations have more than four bay systems associated with them. Figure 5-21 presents the spatial distribution of fire stations in Odisha.

The total estimated area for fire stations was estimated at about 36,480 sq m. Accordingly, the total replacement cost is estimated at around INR 54.67 crores

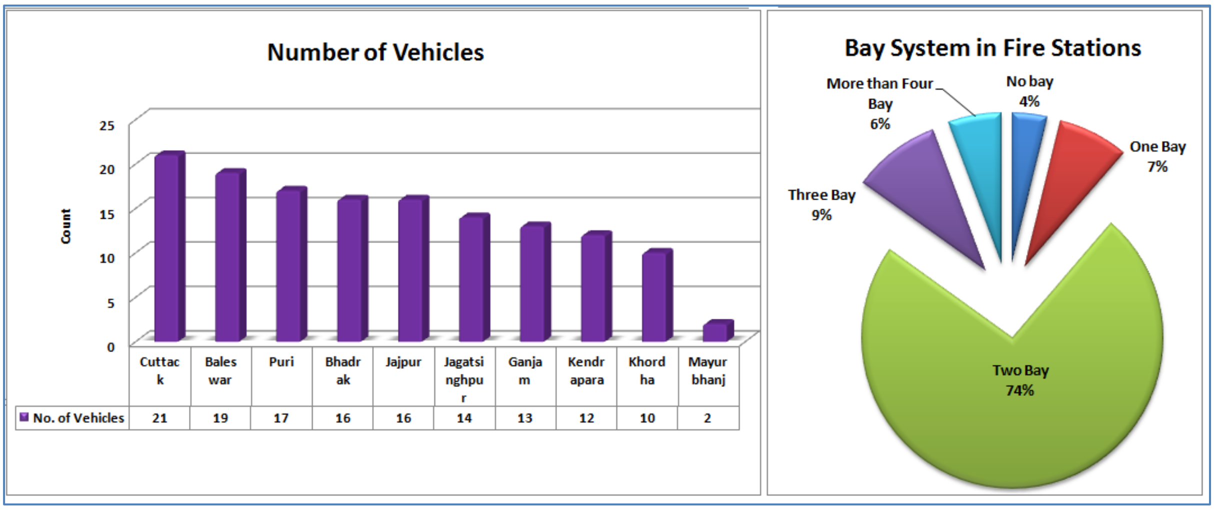


Figure 5-20: Distribution of vehicles by condition (left) and by bay systems (right)

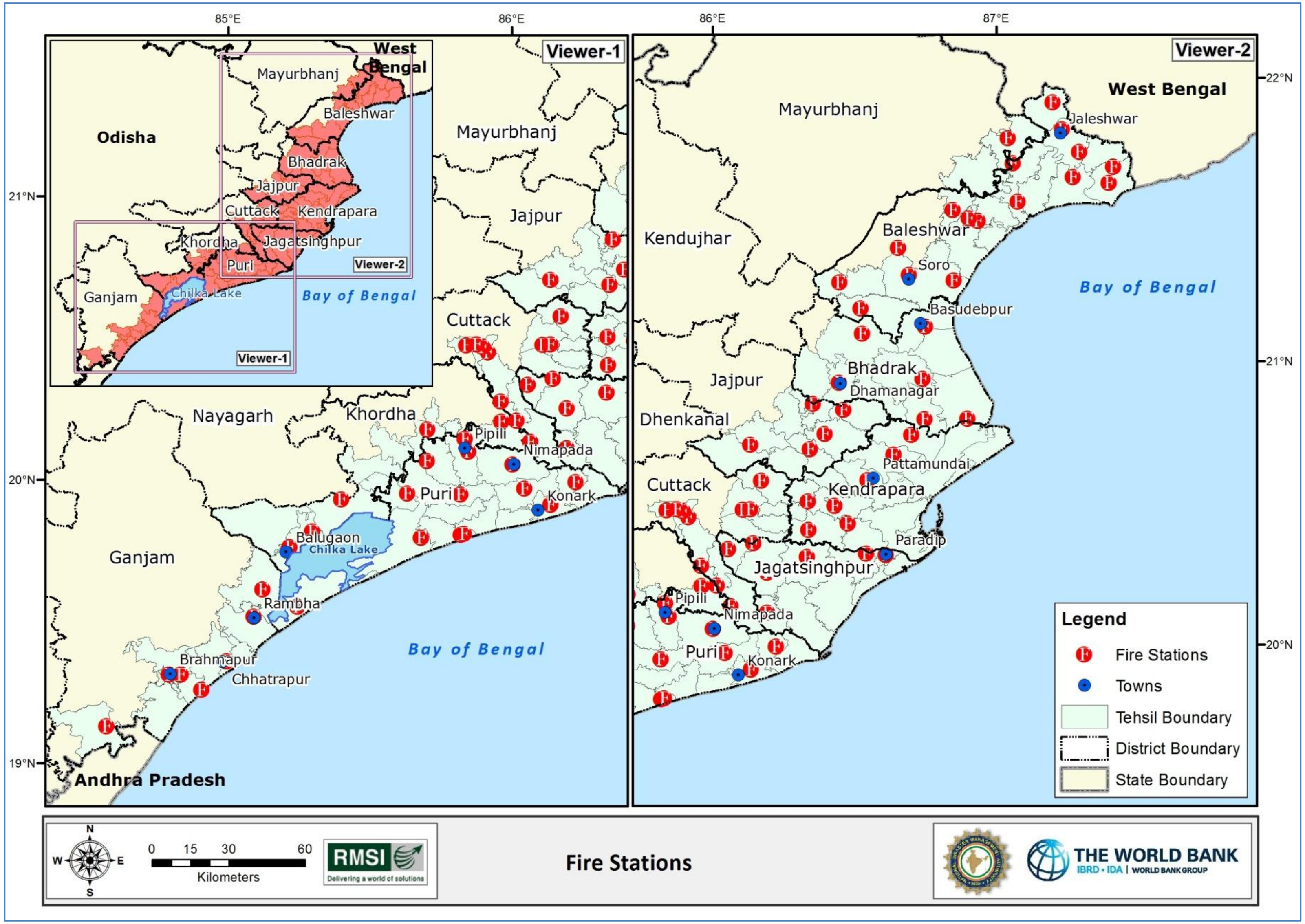


Figure 5-21: Location of fire stations

5.3.2.3 Administrative Headquarters

All the important government offices for the concerned districts are located in the administrative headquarters. In the absence of exact spatial data for administrative headquarters, point data has been generated at city/town level. Out of ten districts, 7 district headquarters and 105 tehsil headquarters are located within the study area (Figure 5-22).

The total estimated area for administrative headquarters is estimated at 0.12 sq. km. (1,26,812 sq m). Accordingly, the total replacement cost is estimated at around INR 165.9 crores.

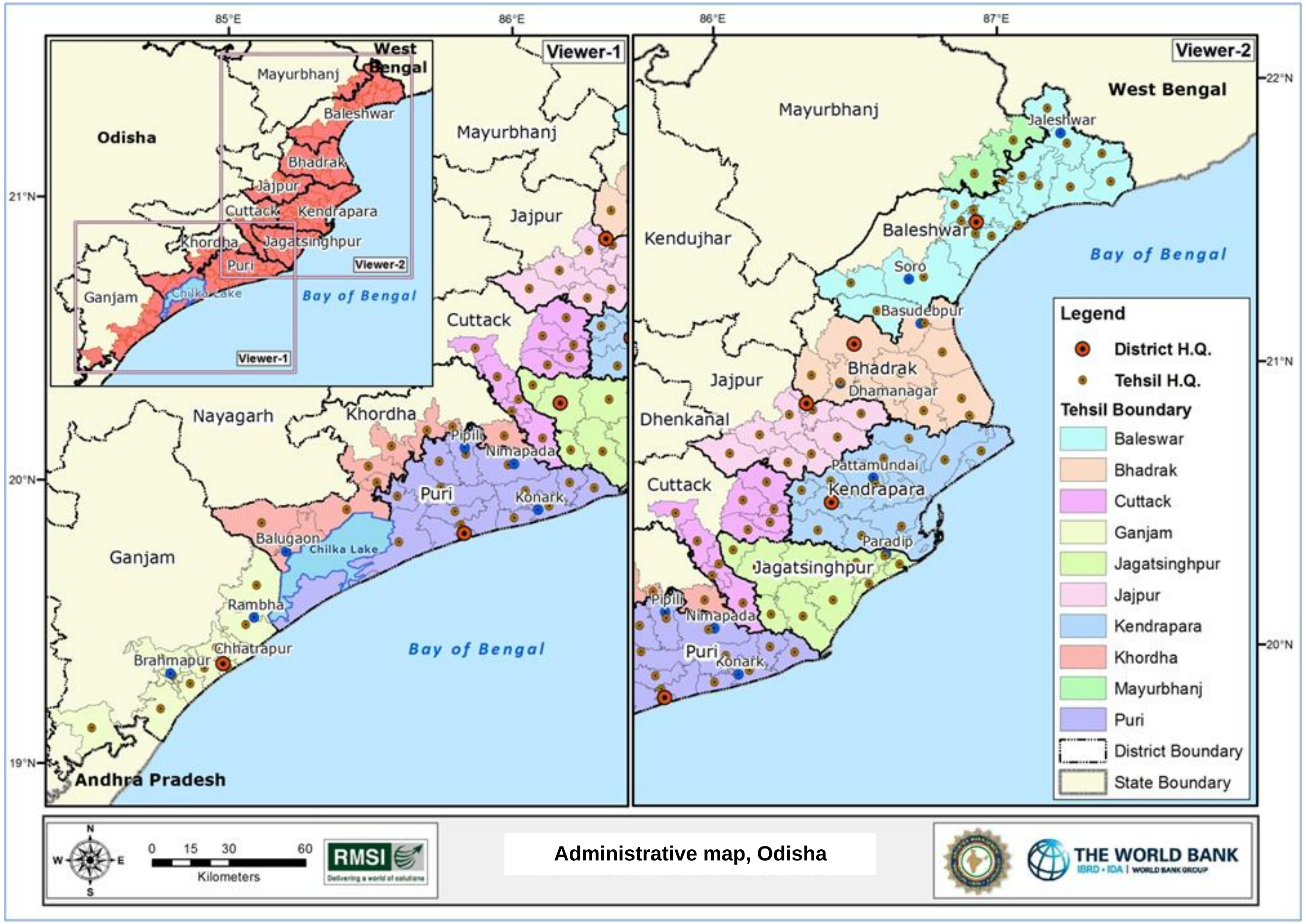


Figure 5-22: Administrative map showing district and tehsil headquarters

5.3.2.4 Cyclone Shelters

The data for cyclone shelters was received from Odisha Revenue and Disaster Management Department. This data contains 134 cyclone shelters located in six districts. The distribution of cyclone shelters in the study area of Odisha is presented in (Figure 5-23). However, various attribute data for cyclone shelters is missing.

Kendrapara district has the highest number of cyclone shelters (41), whereas Jagatsinghpur district has the least number (10). Among the other districts, Bhadrak has 31, Baleshwar has 21, Puri has 16, and Ganjam district has 15 cyclone shelters respectively.

The total estimated area for cyclone shelters is estimated at 0.40 sq.km (37,347 sq m). Accordingly, the total replacement cost is estimated at around INR 48 crores

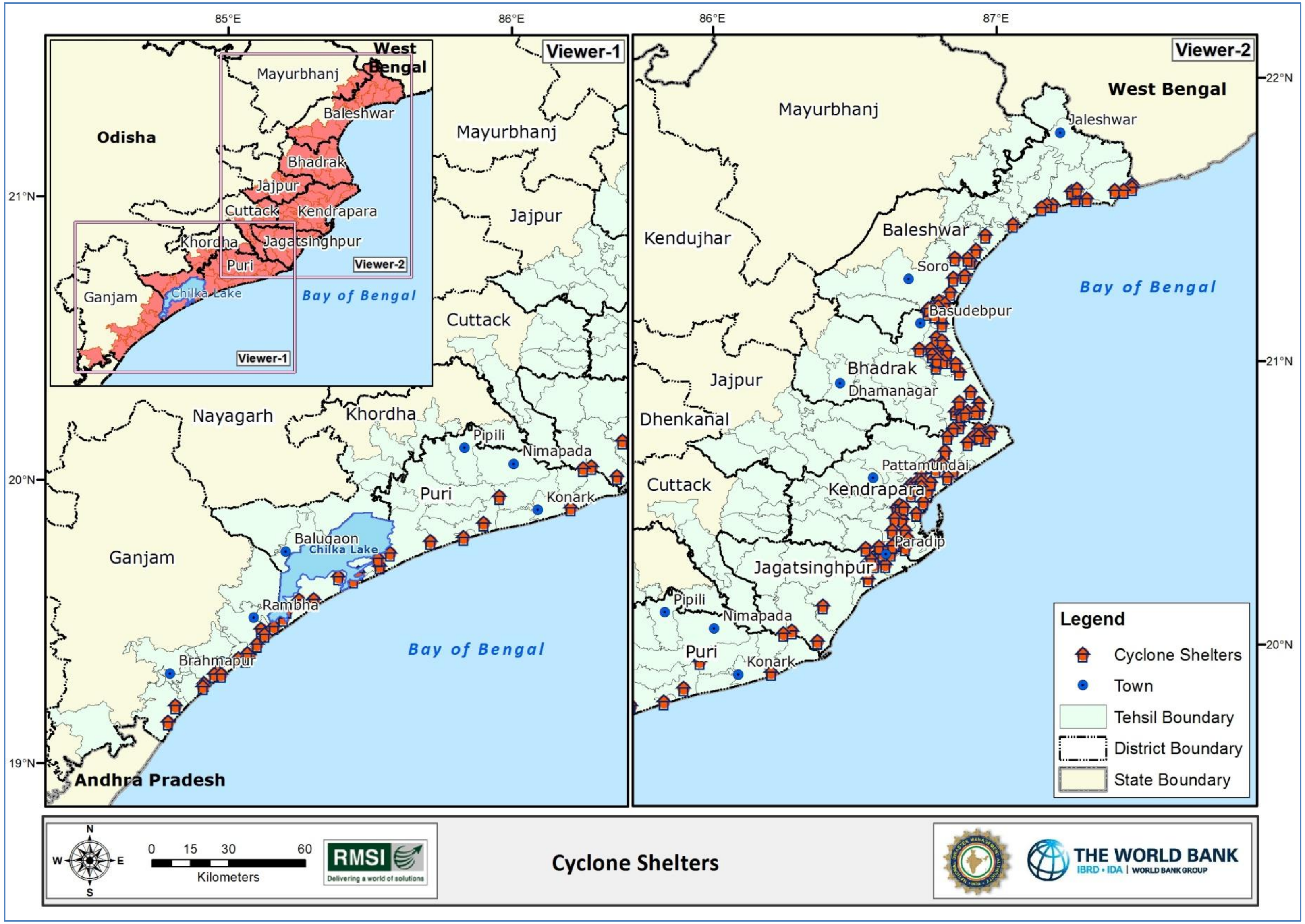


Figure 5-23: Distribution of Cyclone Shelters, Odisha

5.3.3 Transportation

Roads, bridges, railways, airports, and seaports are considered for exposure analysis in the sections.

5.3.3.1 Roads

The road data was received from SOI. This data has been improved further using RMSI in-house data and high-resolution satellite images. The data provides information regarding the various types of roads as well as their respective lengths. The available data classifies roads into five categories, namely, national highways, state highways, major roads, and minor and other roads. Village-level total lengths of various categories of roads are calculated to compute the exposure value. In order to estimate the replacement cost of roads, unit costs of various road categories were determined by taking inputs from the Pradhan Mantri Gramin Sadak Yojna (PMGSY) [41], NHAI[42] , PWD[43], and the Planning Commission[44].

The study area has a total road length of about 30,684 km spread across various villages. The road network comprises of about 653 km of national highways, 884 km of state highways, 893 km of major road, 16,315 km minor roads, and remaining 11,937 km of other roads (Figure 5-24). The district-level road lengths of different road-types and their exposure values are given in Table 8-24 of Annex 8.2.

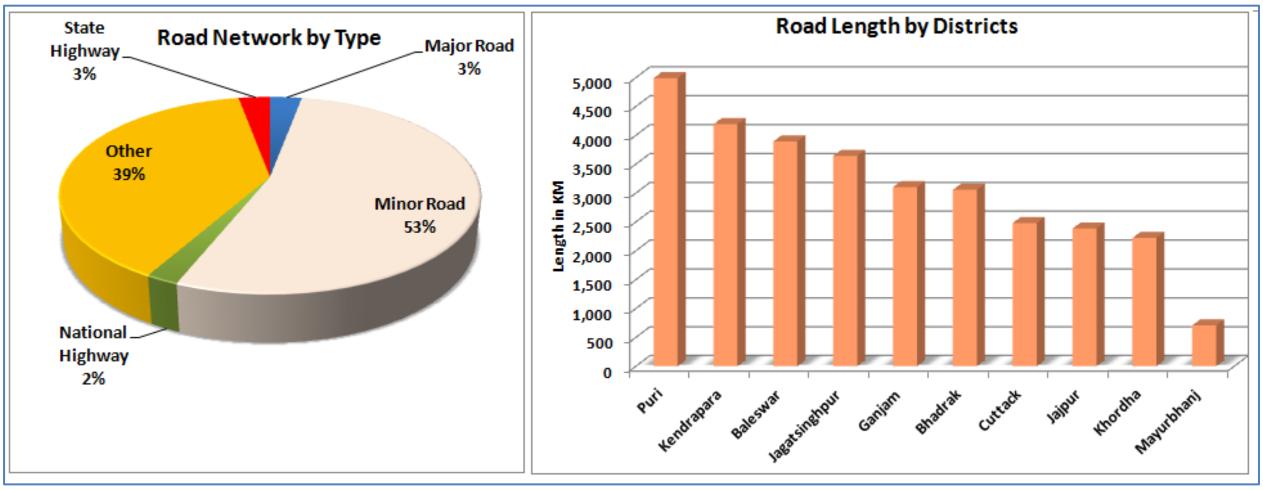


Figure 5-24: Percentage distribution of road network by type (left) and Length of roads by districts (right)

The village-wise estimated lengths of different types of roads were multiplied with the per unit replacement costs of the respective road types. Replacement costs taken in this study are INR 9.7 crores per kilometer for national highways (four/ six lanes), INR 5.5 crores per kilometer for state highways (two/four lanes), INR 5 crores per kilometer for major roads (two lanes), INR 0.37 crores per kilometer for other important roads, and INR 0.25 crores for minor roads. Based on this, the total estimated exposure value for the road network is estimated at INR 24,174 crores. Figure 5-25 presents the road network of Odisha in the study area.

---

41 http://pmgsy.nic.in/achiev_bhanirm.htm
42 http://www.nhai.org/completednh2.asp
43 https://pwddelhi.com/UI/Home/SectorWiseReport.aspx?enc=9J3T0Ky+opEjCrT08q8UfA==
44 http://www.business-standard.com/article/economy-policy/nhai-plancom-differ-on-cost-of-4-lane-highways-110081000072_1.html

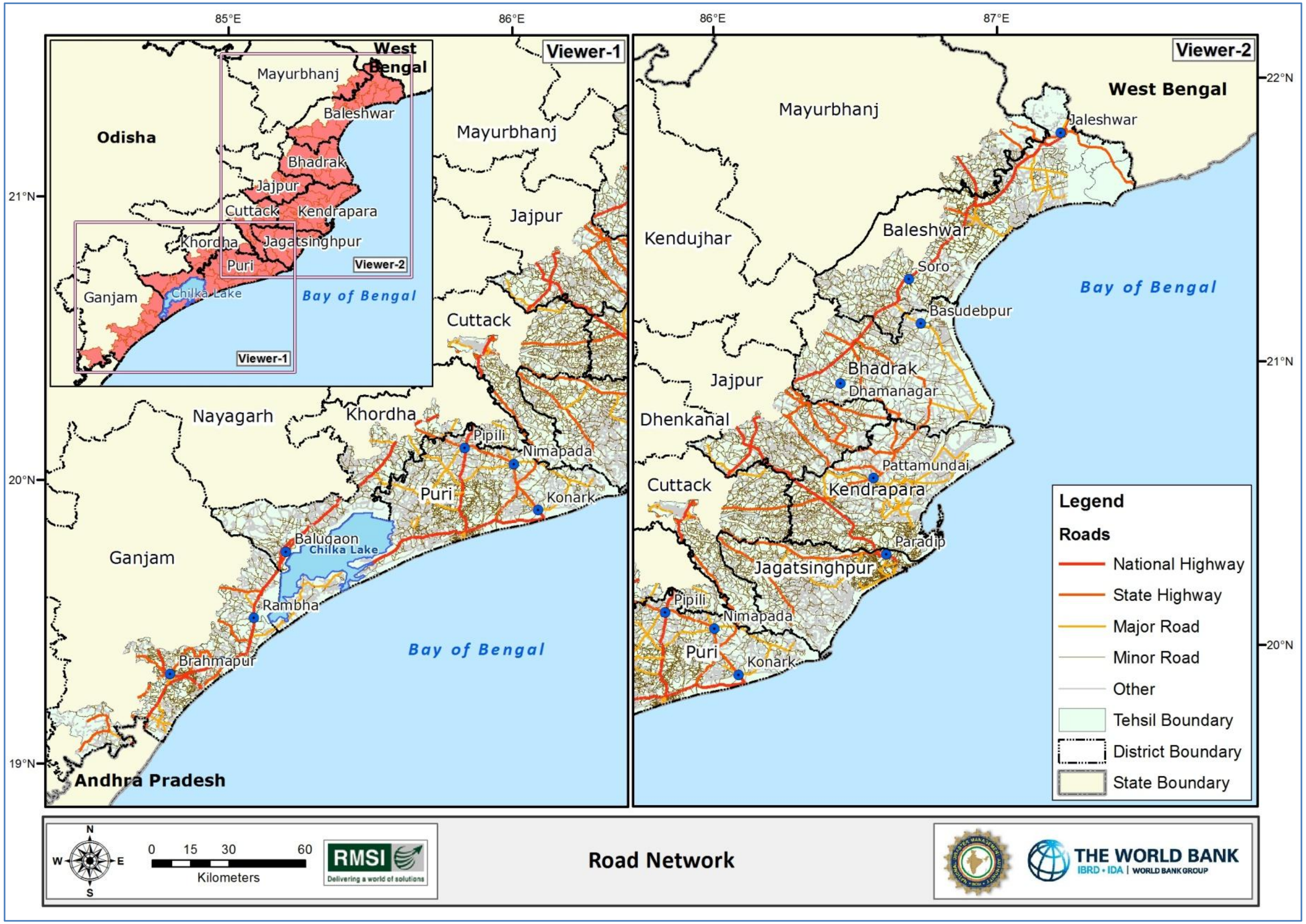


Figure 5-25: Road network, Odisha

5.3.3.2 Railways

The data on the railway network was received from SOI. This data has been improved further using RMSI in-house data and high-resolution satellite images. In order to estimate the replacement cost of the railway network, unit cost of the railway network is determined by taking inputs from IREE[45] and Indian railways[46] websites.

The total length of the rail network in the study area is about 502 km. The length of the railway network is multiplied with per unit replacement costs of the railway network i.e. INR 6.3 crores per km for single line and INR 9.4 crores per km for double line. Based on this, the total estimated exposure value for the railway network is estimated at INR 4.8 crores.

Annex 8.2 (Table 8-26) provides the district-wise estimated lengths and exposure values for the railway network in the study area. Figure 5-26 shows the railway network in the study area of Odisha.

[45] http://www.ireeindia.org/RE%20Booklet.pdf
[46] http://www.nr.indianrailways.gov.in/view_detail.jsp?lang=0&dcd=3265&id=0,4,268

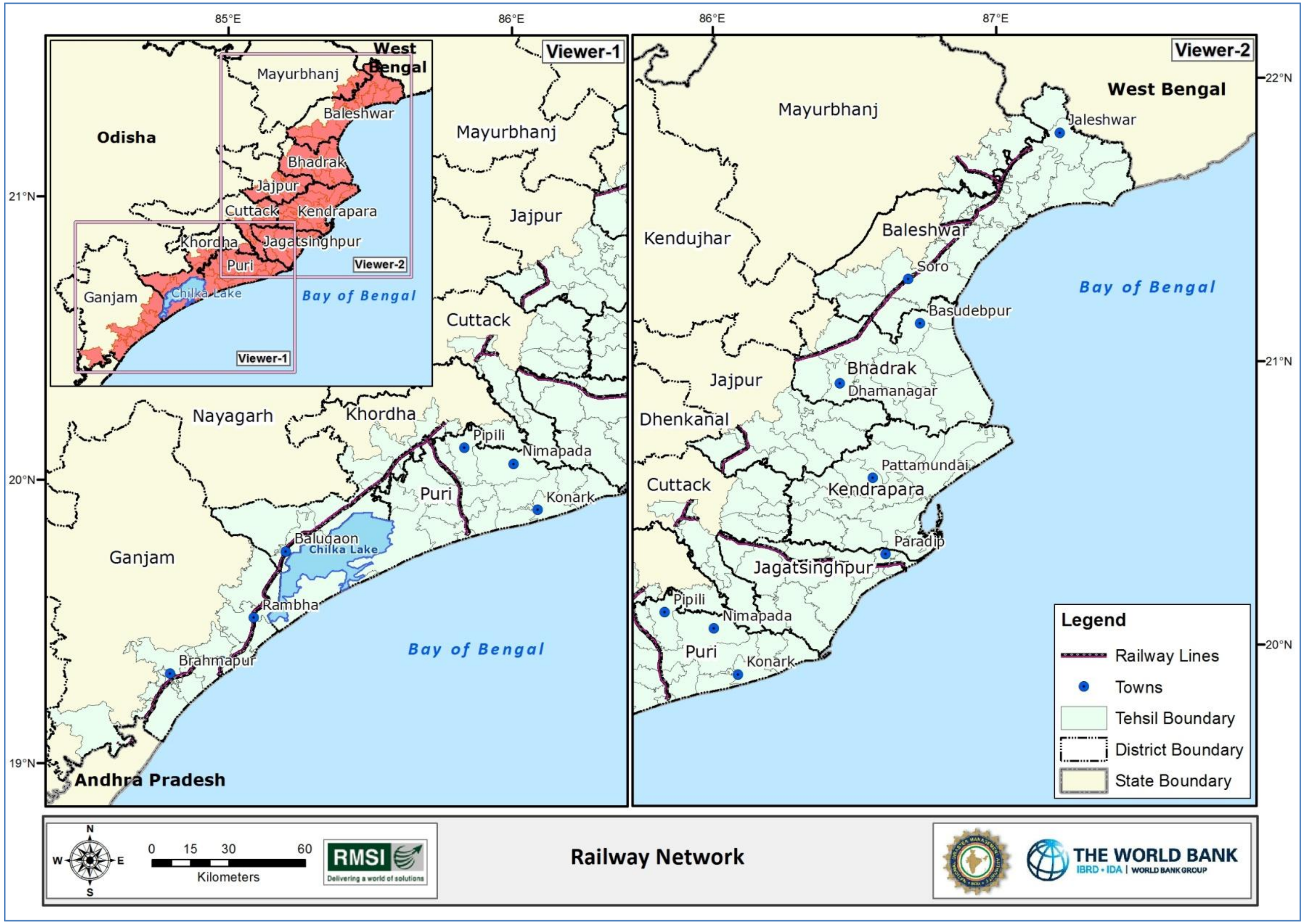


Figure 5-26: Railway network, Odisha

5.3.3.3 Bridges

The data for bridges for the study area in Odisha is obtained from SOI, which is further validated with field survey data and high resolution satellite images. Village level total lengths of bridges are calculated to compute the exposure value. In order to estimate the replacement cost of bridges, unit cost is determined by taking inputs from various web sources and previous similar case studies.

The village-wise estimated length of bridges was multiplied with the per unit replacement costs of bridges i.e. INR 19 lakhs per meter. Based on this, the total estimated exposure value for bridges was estimated at INR 21,290 crores. Table 8-27 of Annex 8.2 provides the district-wise estimated lengths and exposure values of bridges in the study area in Odisha. Figure 5-27 shows bridges which come under the study area.

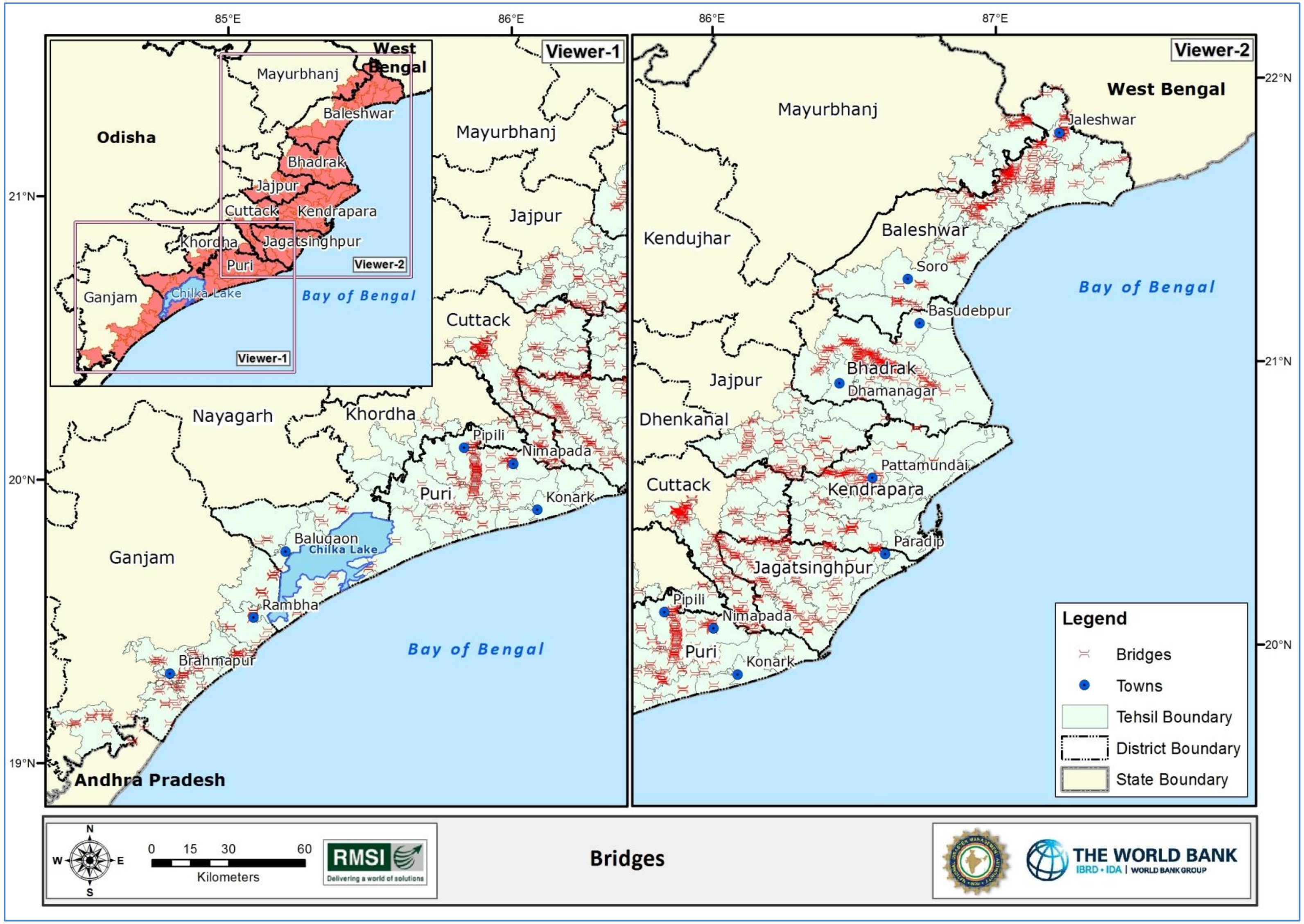


Figure 5-27: Bridge locations, Odisha

5.3.3.4 Airports

Berhampur runway and Rasgovindpur airstrip are present in the study area. Information related to the constructed length of runway of the airport has been captured using high-resolution satellite images. In order to estimate the replacement cost of the runway/airstrip, unit cost of unit length of the runway is determined by taking inputs from the web (Airport technology.com). [47]

The total length of runway is multiplied by the unit replacement costs i.e. INR 52,334 per sq m for runway. Based on this, the total estimated exposure value for the runways was estimated as INR 912 crores. Figure 5-28 shows the locations of airports. Table 8-27 of Annex 8.2 provides the total area of the runways and their exposure values.

[47]http://www.airport-technology.com/projects/indira-gandhi-international-airport-terminal-3/

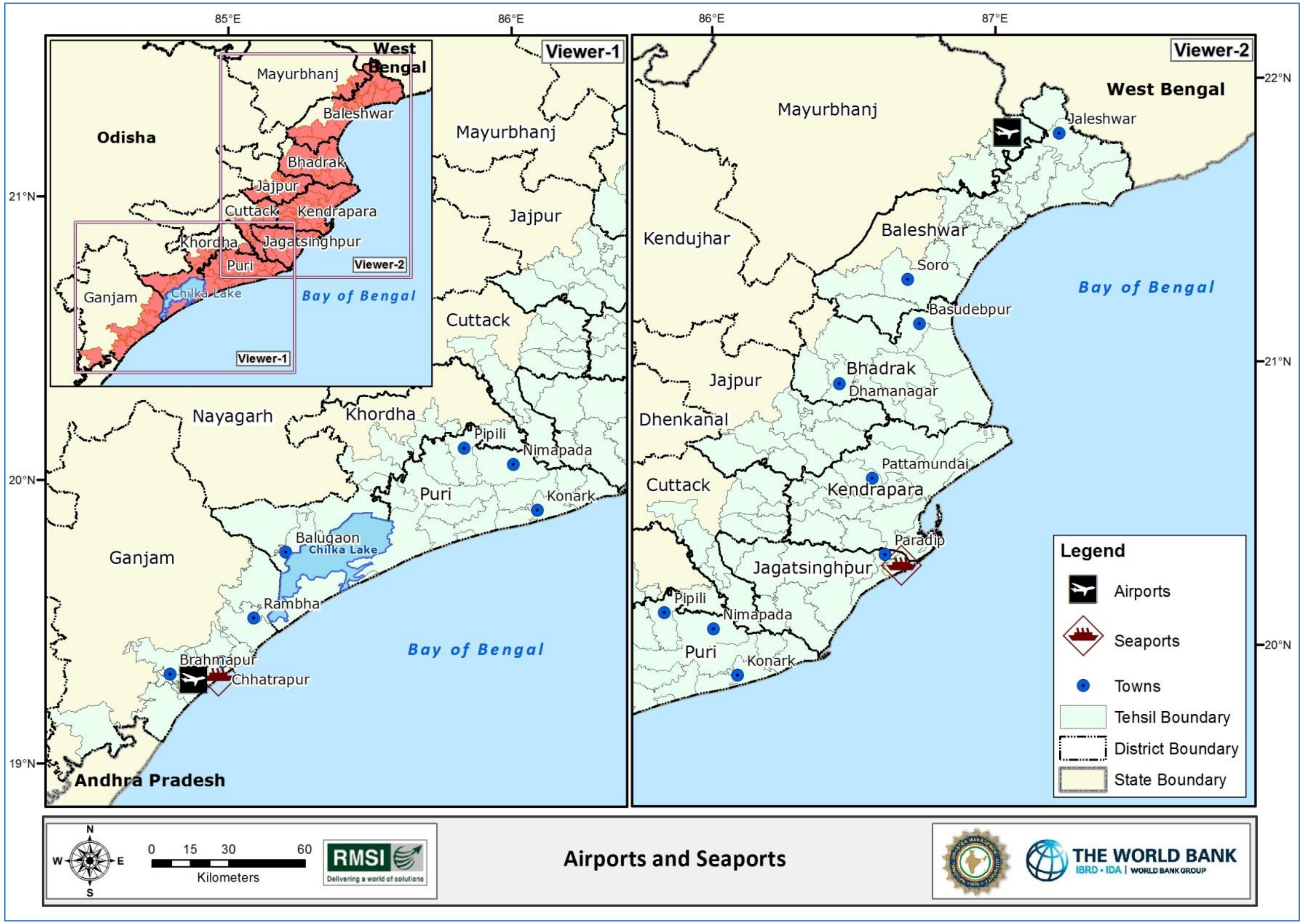


Figure 5-28: Locations of airports and seaports, Odisha

5.3.3.5 Seaports

There are two ports located in the study area, namely, Paradip and Gopalpur ports. In order to estimate the replacement cost of seaports, the cost for developing one berth of the port has been determined from internet search (http://www.essar.com/) and is estimated at INR 400 crores per berth. The total berths in both ports are 19 of which 5 berths are in Gopalpur port and 14 berths are in Paradip port. This number is multiplied with the unit replacement cost of a berth to get the total exposure value. Based on this, the total estimated exposure value for the seaport has been estimated at INR 7,600 crores. Figure 5-28 shows the seaports in study area of Odisha.

5.3.4 UTILITIES

Utilities are essential facilities that include electric power, waste water systems, communication systems, oil and gas, and systems that supply potable water.

5.3.4.1 Waste Water

The spatial data for waste water is not available from any of the sources. Census (2011) provides village wise percentage of open and closed drainage systems. Using this percentage, approximate length of the waste water system has been generated using road network data assuming that the drainage network is distributed along the road network. The estimated total drainage network is about 5,365 km. Multiplying the unit cost with length provides the total replacement cost of about INR 2,682 crores.

District wise approximate waste water drainage network lengths and their replacement values have been provided in the Table 8-30 of Annex 8.2.

5.3.4.2 Potable water

The spatial data for potable water is not available from any of the sources. Census (2011) provides village wise percentage of household having tap water connection from treated and untreated sources. Using this percentage, approximate length of potable water system has been generated using the road network data assuming that potable water network is distributed along the road network. The estimated total potable water network is about 3,367 km. Multiplying the unit cost with length provides the total replacement cost of about INR 1,684 crores.

District wise approximate potable water network lengths and their values have been provided in the Table 8-30 of Annex 8.2.

5.3.4.3 Oil and Gas

The oil and gas infrastructure consists of pipelines, refineries, pumping plants, and tank farms. The inventory data required for oil and gas infrastructure includes the geographical locations and classification of various system components. The analysis also requires the replacement costs for facilities and pipelines.

None of the sources has provided data for oil and gas pipelines. Therefore, using online sources, a map of India Energy Infrastructure[48] has been downloaded as reference. This map has spatial distribution of the oil and gas infrastructure of India. The length of oil and gas pipelines has been estimated based on this map.

In order to estimate the replacement cost of the oil and gas pipeline network, unit cost of oil and gas pipeline has been determined by taking inputs from open source[49]. The length of the

[48] http://www.eia.gov/todayinenergy/detail.cfm?id=10611

[49] http://www.yourarticlelibrary.com/india-2/pipeline-6-major-pipelines-of-india/19721/

oil and gas pipeline network was multiplied with the per unit replacement cost i.e. INR 8 crores per kilometer. Based on this, the total estimated exposure value for the oil and gas pipeline network has been estimated at INR 1,584 crores. Table 8-29 of Annex 8.2 shows district wise estimated lengths of the oil and gas pipeline network and their exposure values.

5.3.4.4 Electric Power Network

The data for electric line network has been received from SOI, which, lacks continuity. Therefore, using data present in the open street map, gaps between the electric lines have been filled. In addition, number of substations, transmission towers, transformer and poles at village level have been estimated based on information collected through literature survey and sample field survey. The replacement cost of the electric power network has been determined by taking unit cost of the electricity line from the Western Electricity Coordination Council.

The length of the electric line network was multiplied with the per unit replacement cost i.e. INR 620 per meter for main power lines and INR 443 per meter for other power lines. The replacement costs of the remaining components of electric power network have been estimated by taking inputs from the sample field survey. Based on this, the total estimated exposure value for the electric power network has been estimated at INR 10,906 crores. Table 8-28 of Annex 8.2 shows district-wise estimated lengths of the electricity line network and their exposure values.

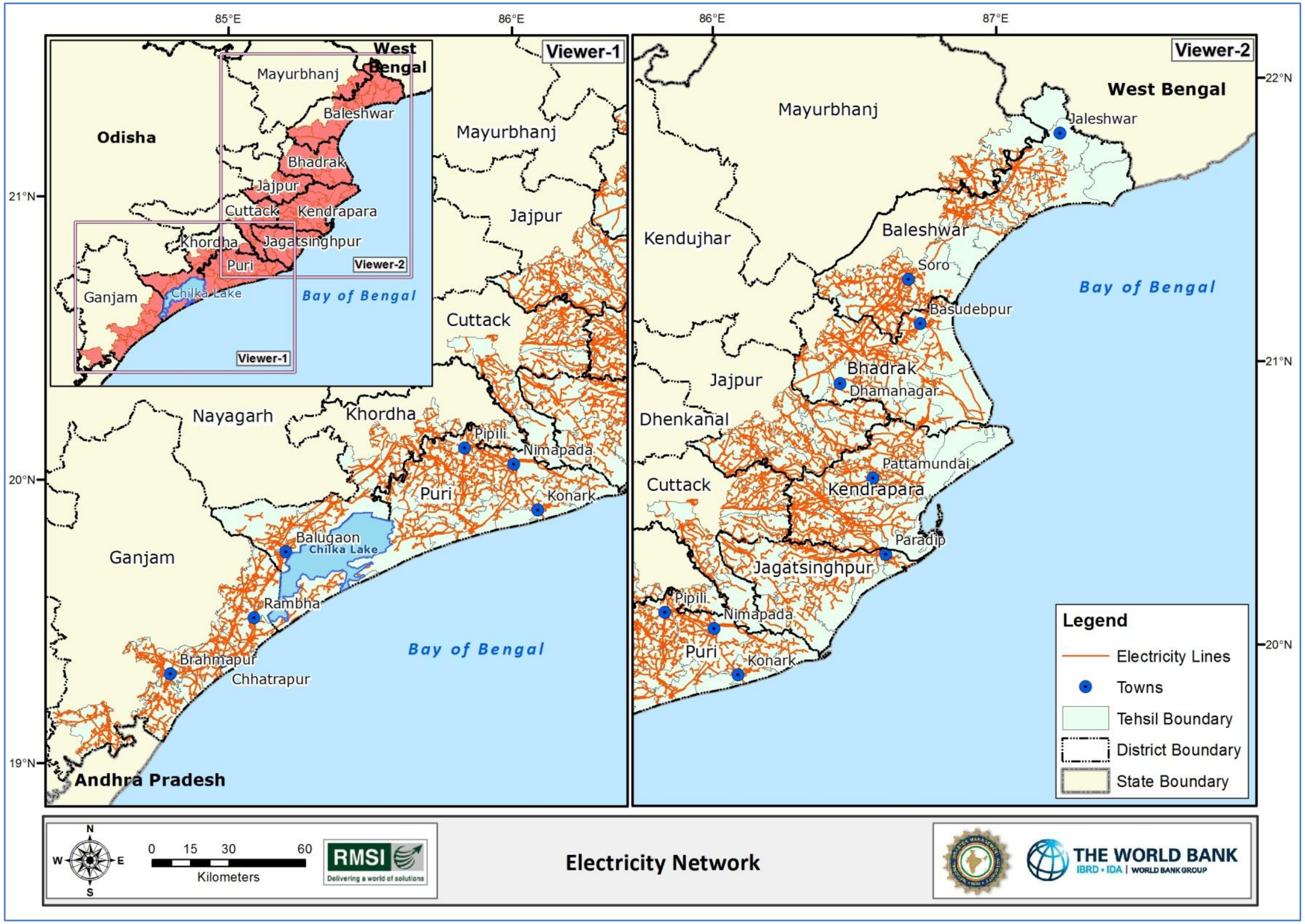


Figure 5-29: Electric line network, Odisha

5.3.4.5 Communication lines

The estimation of communication systems requires detailed information on the number of communication towers, the length of optical fiber cables, the number of communication stations, and the unit cost of each of the above-mentioned components. However, except for village level data on the number of mobile and landline connections, no other information is available on communication systems. In addition, the number of telecommunication towers at village level has been estimated based on information collected through sample field survey.

Thus, the exposure value of communication systems has been estimated using the number of mobile and landline connections, and the telecommunication towers in the study area. Census provides the percentage of number of mobile and landline connections for 2011 at village level. This data has been projected to 2014.

In order to estimate the total exposure value of the communication infrastructure in study area, the cost per subscriber for mobile and landline connections in India has been utilized. As per data collected from the Telecom Regulatory Authority of India (TRAI) and Bharat Sanchar Nigam Limited (BSNL), the values of infrastructure per subscriber for mobile and landline connections are INR 730 and 4,960 respectively. The total estimated replacement cost of the communication system is INR 4,087 crores. The district level final estimated exposure values have been provided in Table 8-31 of Annex 8.2.

5.3.5 CRITICAL INFRASTRUCTURE

5.3.5.1 Power Plants and Sensitive Installation

No power plants and sensitive installations are present in the study area

5.3.5.2 Major and Hazardous Industries

The list of major and hazardous industrial facilities has been taken from the Ministry of Labour and Employment, Government of India. Using high-resolution satellite images, major and hazardous industrial facilities have been captured as point locations. The unit replacement costs of major and hazardous industrial facilities have been taken from online sources. Average value has been applied for calculating the total replacement costs for a few installations for which no reference exposure value is available.

5.4 Others

5.4.1 AGRICULTURE

Data for agricultural crops constitute one of the primary exposures while studying the cyclone hazard. Since village-level crop data is not available, district level crop data (source: Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India) are disaggregated at village level using Land Use Land Cover (LULC) map of LISS III satellite data. For this satellite data was classified into various land use classes. After this, other land use classes were eliminated from the land use layer and agriculture was retained for further analysis. Next, the district boundary layer was overlaid on the land use layer and total agricultural area in a particular district was clipped using Spatial Analyst tool embedded in the ArcGIS software. The village boundary layer was overlaid on the district level clipped agricultural area and subsequently available agricultural area was calculated for each village. Then fraction of agricultural area in each village with respect to district level total agricultural area was calculated and subsequently district level total observed normal acreage was distributed among the villages as per this fraction. Table 5-3 shows the district level cultivated area and Figure 5-32 shows the sub-district level cultivated area in Odisha.

Table 5-3: District level total cultivated area

Districts	Total cultivated area in Hectare
Mayurbhanj	21,907.29
Baleshwar	1,97,057.66
Bhadrak	1,44,982.38
Kendrapara	1,44,307.07
Jagatsinghpur	1,03,108.60
Cuttack	79,440.87
Jajpur	98,727.43
Khordha	83,131.11
Puri	1,60,234.33
Ganjam	84,758.29
Grand Total	11,17,655.03

Figure 5-30 shows that rice occupies about 87% of the total acreage in the study area. Green bean and black gram account for 6% and 3% of the total acreage respectively. Rice accounts for highest acreage in Baleshwar district followed by Puri district. Jagatsinghpur district has the highest acreage under green bean cultivation in the study area. Figure 5-32 exhibits the spatial distribution pattern of cultivated areas among the tehsils in the study area. Detailed crop distribution patterns at district level are given in Table 8-32 of Annex 8.2

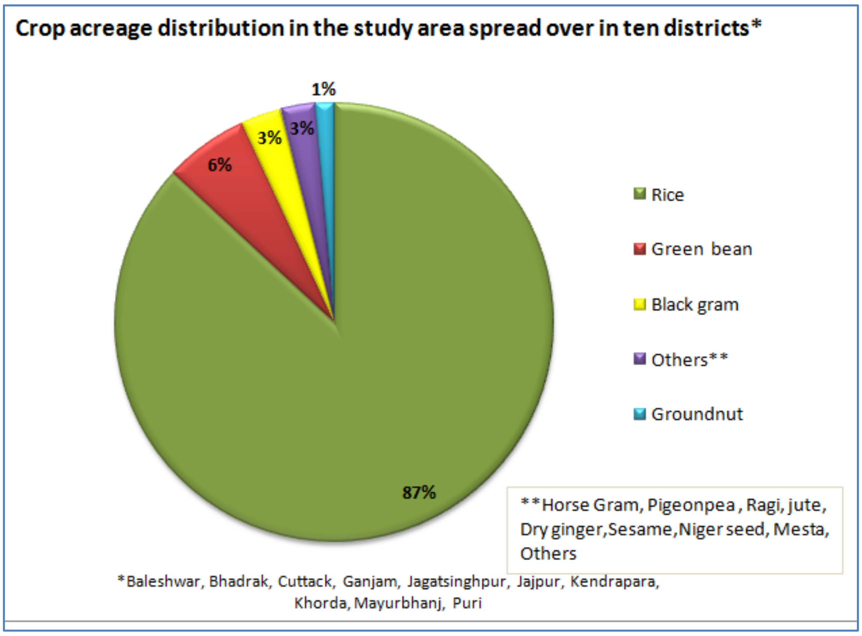


Figure 5-30: Distribution of major crops in the study area of Odisha

In case of crop production distribution among the villages, district level crop yield has been multiplied with the total acreage of respective crop of the particular village falls in the district. The total production value estimated for the study area in Odisha is about 14.8 lakh ton for all types of crops.

In order to estimate the total exposure value of the crops at village level, the unit cost per ton market price values has been multiplied with the production quantity for each crop. The total estimated replacement cost of agricultural crops is INR 4,768 Crore.

5.4.2 LIVESTOCK

Livestock play a vital role in the agricultural and rural economies of the developing country. Livestock provide nutrient rich food products, draught power, dung as organic manure and domestic fuel, hides & skin, and are a regular source of cash income for rural households.

In Odisha, around 80 percent of rural households depend on livestock and draw about 30 percent of their annual income or sustenance from livestock50.

Since village level livestock data is not available, district level livestock data (source: Department Of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India) are disaggregated at village level for the study area. The 19th Livestock Census (2012) data is used for the analysis. According to livestock census-2012 the total livestock population for the study area in Odisha is 87.31 lakhs, excluding poultry. Total Livestock covers cattle, buffalo, sheep, goat, pig, horses& ponies, mules, donkeys, camels, mithun and yak.

Figure 5-31 shows the distribution of livestock population at district level. Mayurbhanj district has the highest number of livestock population about 26% of the total livestock population whereas, Jagatsinghpur has the least livestock population about 5% of the total livestock population in the study area.

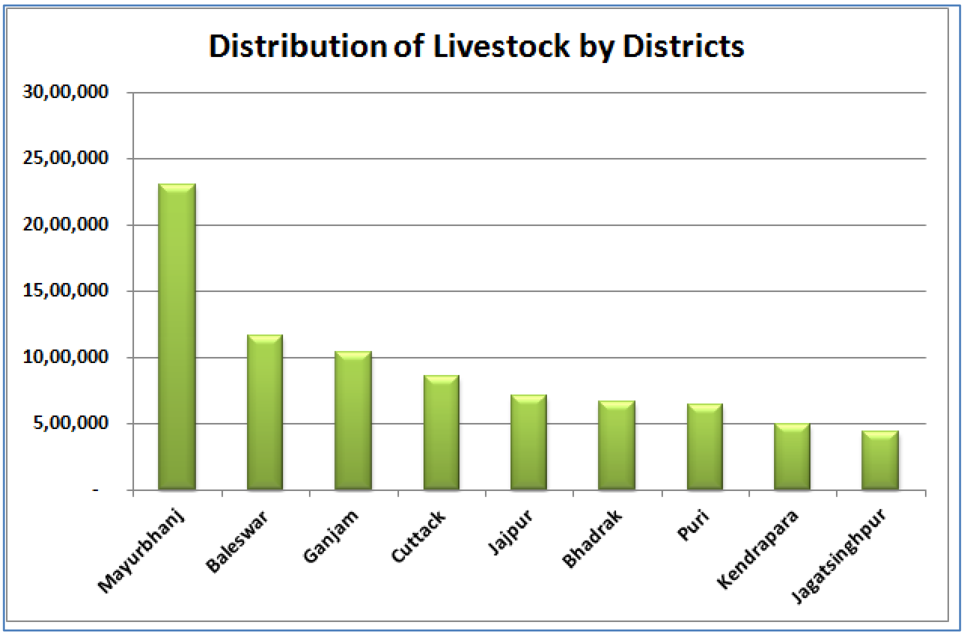


Figure 5-31: Distribution of Livestock population by District

[50] Economic survey 2012-13 Planning & Coordination Department, Govt. Of Odisha http://www.odisha.gov.in/pc/Download/Economic_Survey_2012_13.pdf

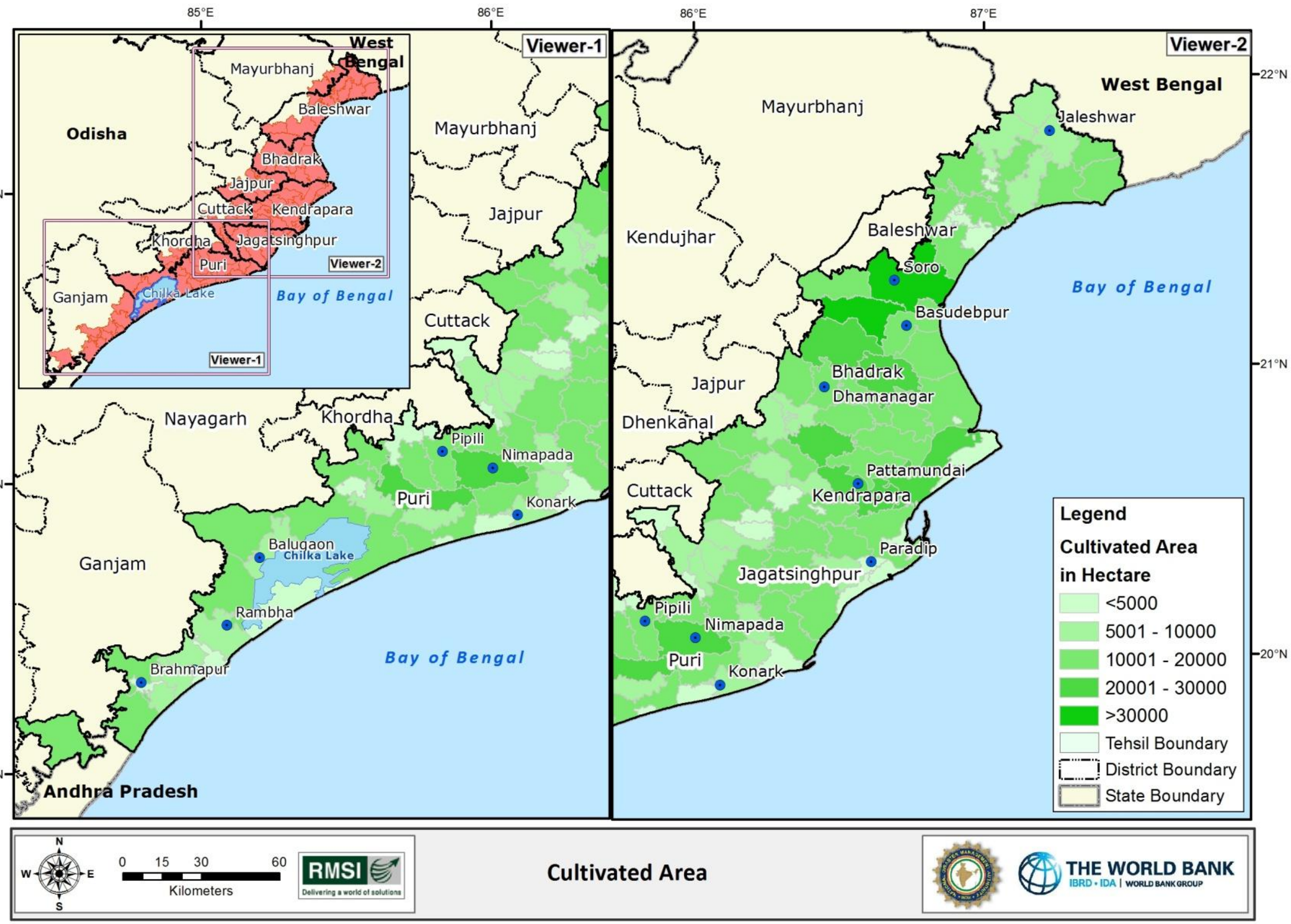


Figure 5-32: Spatial distribution pattern of crop acreage among the tehsils, Odisha

5.4.3 ECOLOGICAL ASSETS

Mangroves and coastal plantations are critical coastal ecological assets. They play a vital role in reducing the impact of storm surge and cyclonic wind further inland. The data for mangroves has been collected from the Ministry of Forests, while the data for coastal plantations has been collected from SOI. Both these datasets have been further updated using high-resolution satellite images.

Table 8-33 of Annex 8.2 presents sub-district wise areas of mangroves and coastal plantations. Figure 5-33 presents spatial distribution of mangroves and coastal plantations in the study area of Odisha. Kendrapara district has the highest percentage of mangroves (84%) followed by Bhadrak (10%), Baleshwar (3%), and Jagatsinghpur districts (3%), whereas Cuttack, Ganjam, Jajpur, Khordha, Mayurbhanj, and Puri districts have no mangrove cover within the study area. For other coastal plantations, Puri district has the highest percentage of coastal plantation (45%) whereas, Bhadrak, Cuttack, Jagatsinghpur, Kendrapara, Mayurbhanj districts do not have any coastal plantation within the study area.

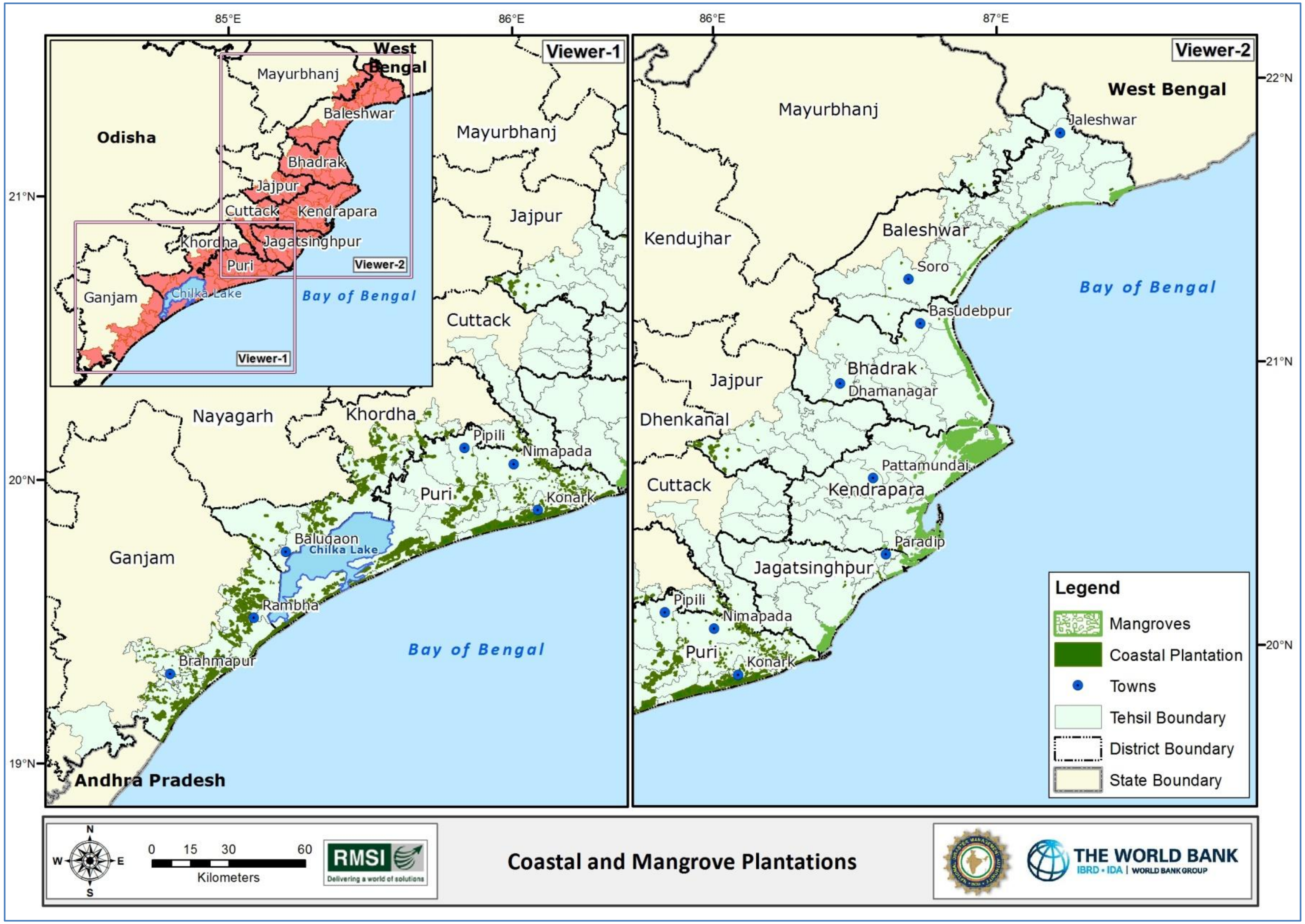


Figure 5-33: Mangroves and coastal plantations, Odisha

5.5 Exposure Values

The total exposure values have been estimated for each type of exposure element. This estimation has been carried out by multiplying the unit replacement cost with corresponding asset length/area to get the total replacement costs for each exposure type. Detailed exposure data tables for districts in Odisha are presented in Table 8-23 of Annex 8.2 of the report.

5.5.1 HOUSING, PUBLIC BUILDINGS AND ESSENTIAL FACILITIES

Figure 5-34 below presents the total exposure value for housing, public buildings and essential facilities in INR. The total estimated value of different buildings present in the study area is more than INR 1,51,763 crores, out of which residential buildings values account for about 51% of the total value, commercial buildings for about 16%, Industrial buildings for about 12%, educational institutes for about 18%, health facilities for about 2%, and religious, police stations, fire stations and administrative buildings of more than 1% of the total building exposure value.

Figure 5-34, Figure 5-35, and Figure 5-36, provide the total exposure values of for building occupancy classes, transportation assets and utility assets, respectively.

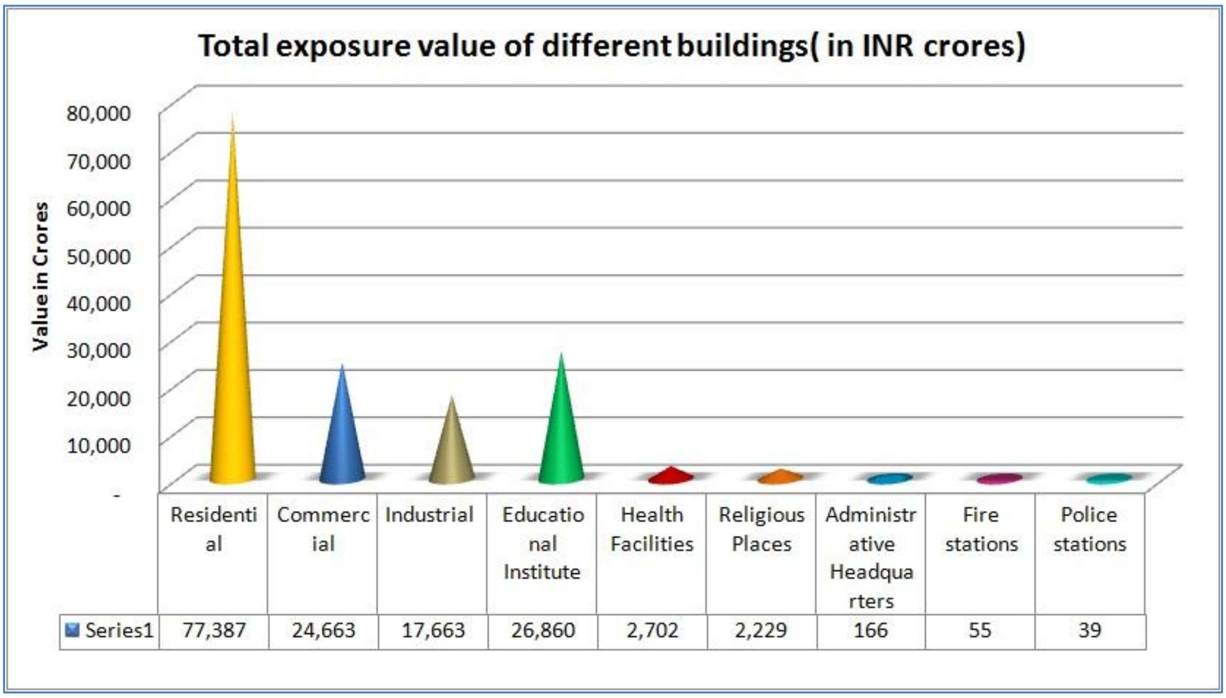


Figure 5-34: Total exposure value of different buildings in crores

5.5.2 TRANSPORTATION

Figure 5-35 below presents the total exposure value for different transport assets in INR. The total estimated value of exposure in all categories present in the study area is more than INR 64,568 crores, out of which exposure values of different types of roads account for about 41% of the total exposure value, bridges for about 36%, seaports for about 13%, railway networks for about 8%, and airstrips/airports for about 2%.

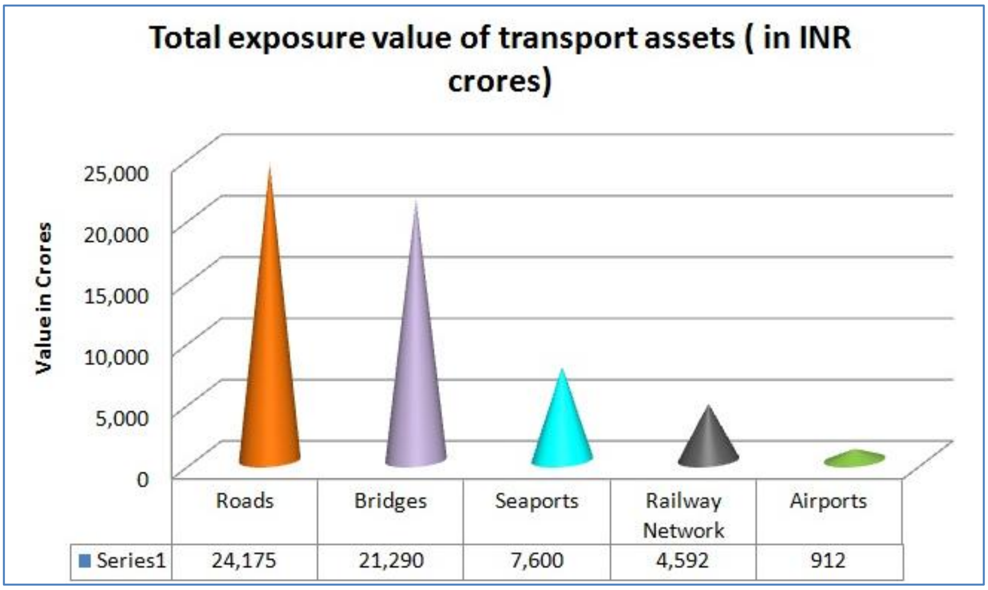


Figure 5-35: Total exposure value of transport assets in crores

5.5.3 UTILITIES

The total estimated value of exposure for all utility categories present in the study area is more than INR 6,608 crores (Figure 5-36), out of which electric lines exposure value accounts for about 52% of the total value, communication systems for about 20%, waste water for about 13% and, potable water and oil and gas for about 8% each.

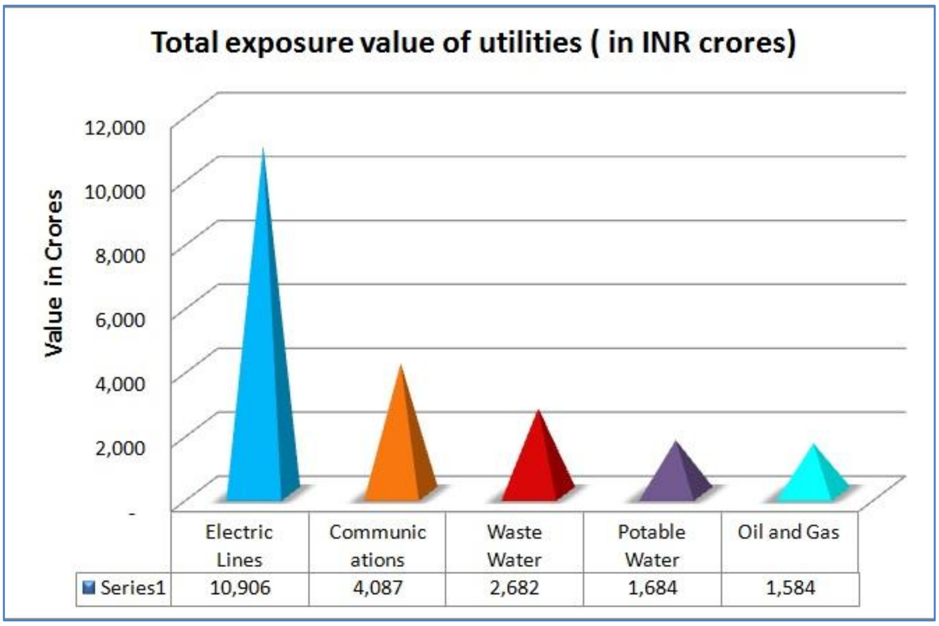


Figure 5-36: Total exposure value for utilities

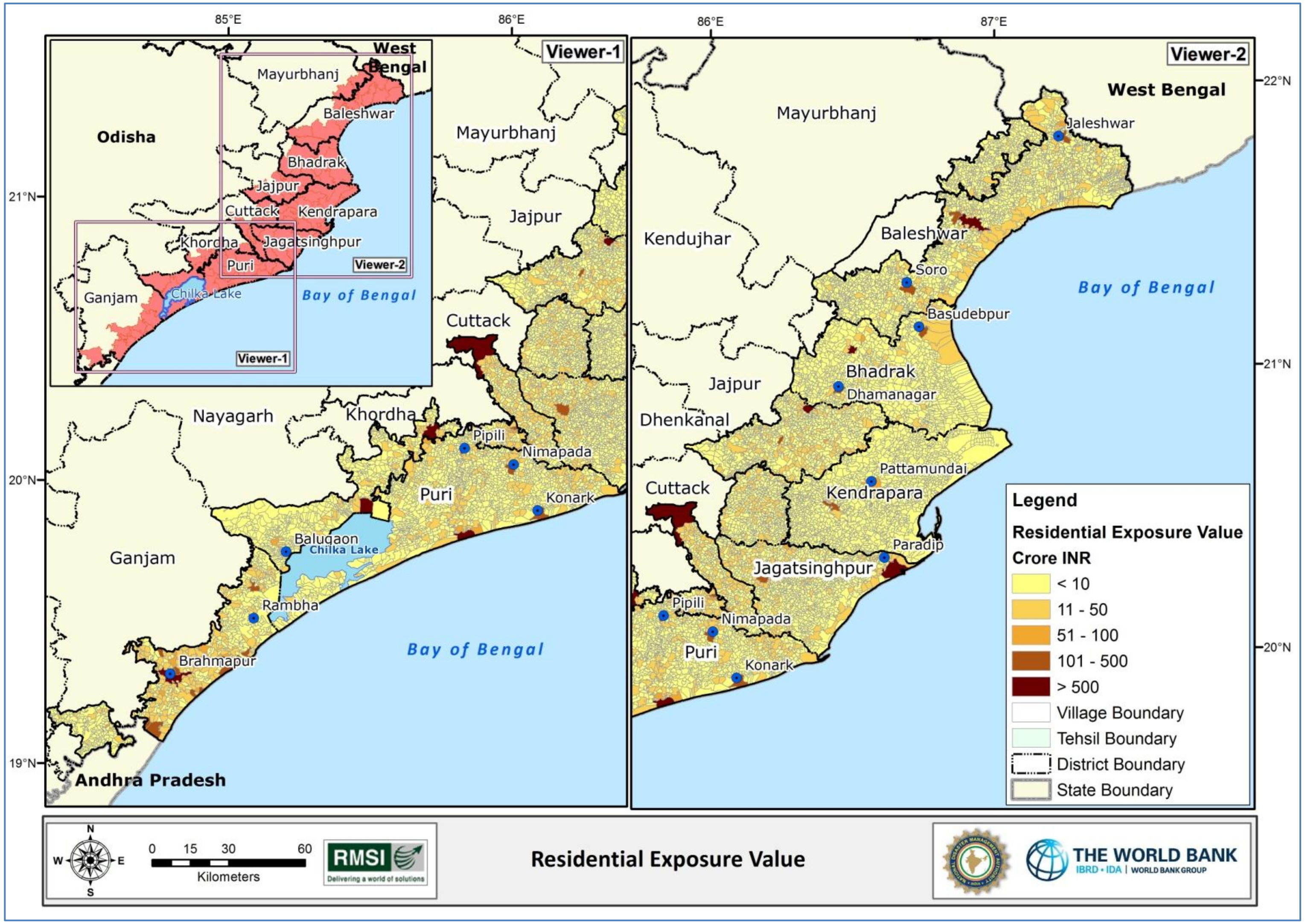


Figure 5-37: Distribution of total estimated exposure values for residential buildings at village level

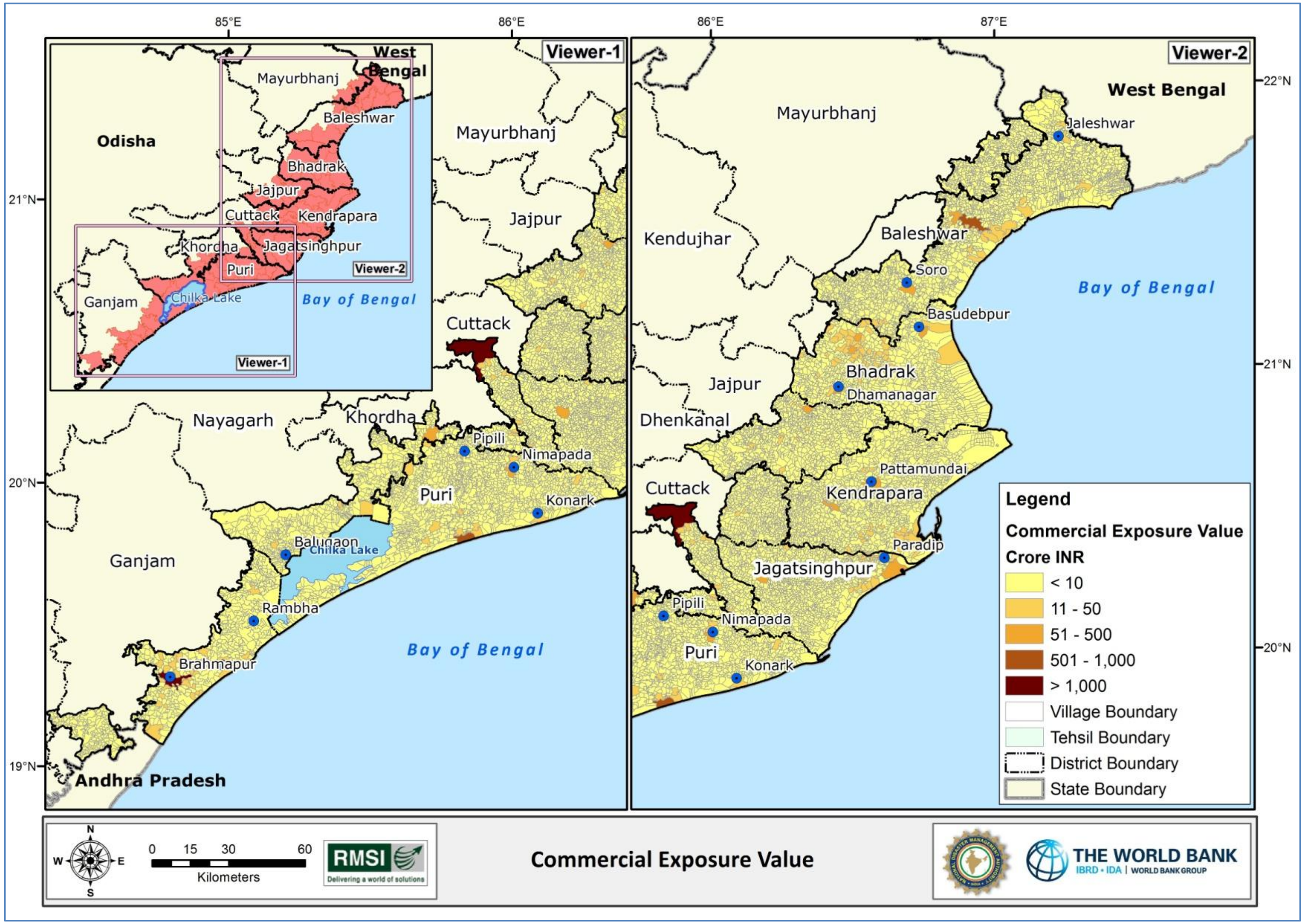


Figure 5-38: Distribution of total estimated exposure values for commercial buildings at village level

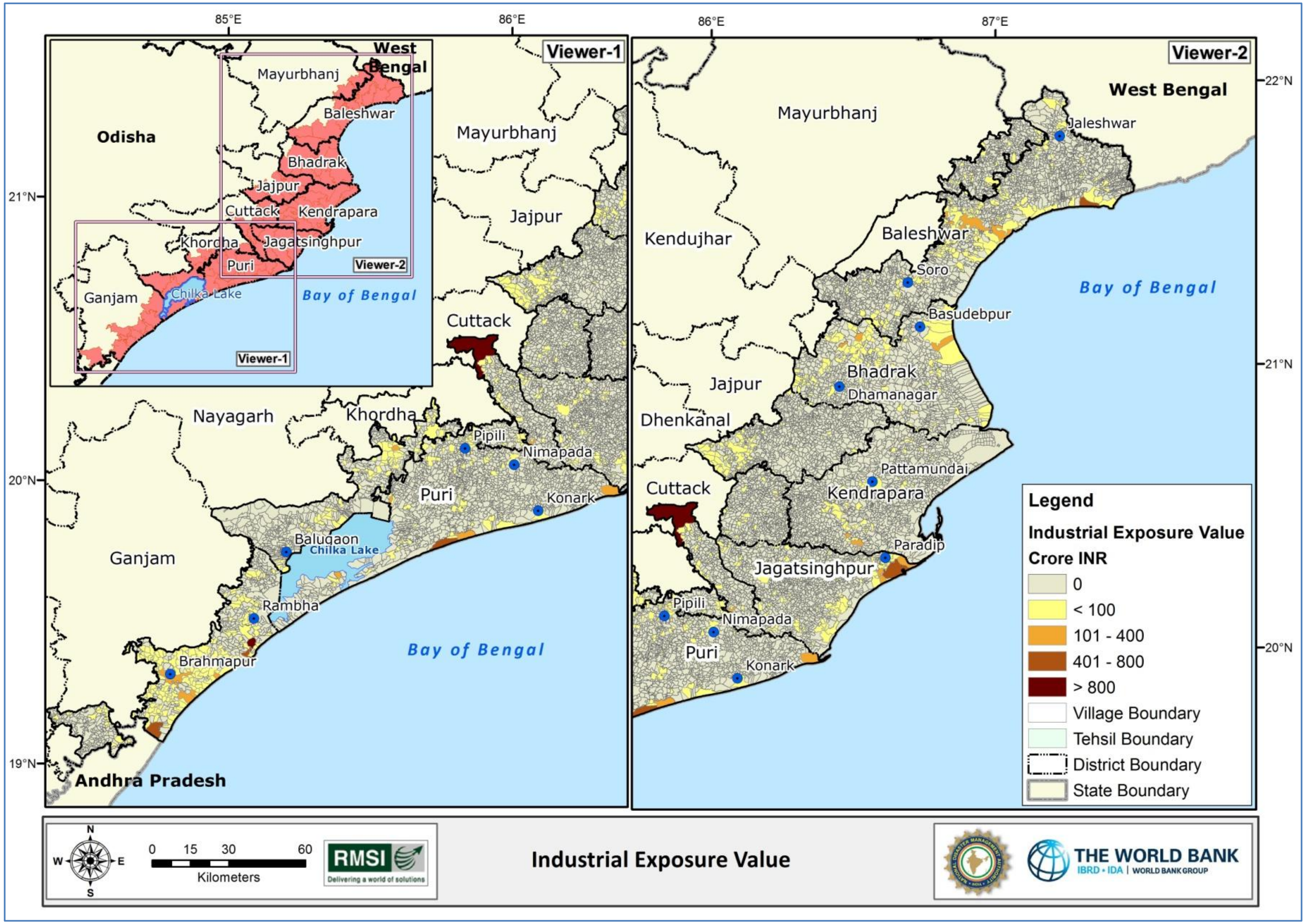


Figure 5-39: Distribution of total estimated exposure values for industrial buildings at village level

5.6 Social and Economic Vulnerability Assessment

The SoVI map (Figure 5-40) is prepared for the coastal districts of Odisha and villages were categorized into high, medium and low using the same social indicators mention in the methodology section. The pattern evolved is quite different compared to that of Andhra Pradesh, which is highly influenced by the population distribution. The northern part of the State - Mayurbhanj and southern district - Puri and Cuttack has majority of the villages with high SOVI. Bhadrak and Ganjam have relatively less number of villages with high SoVI. Some of the coastal villages of Odisha particularly Bhadrak has coastal villages (villages with seacoast) with less population density and are showing low SoVI. Many of the villages in Odisha have poor road and health facilities and is a key reason for having high SoVI. North of Chilka lake in Puri district has large number of village predominantly engaging in fisheries and has high SoVI.

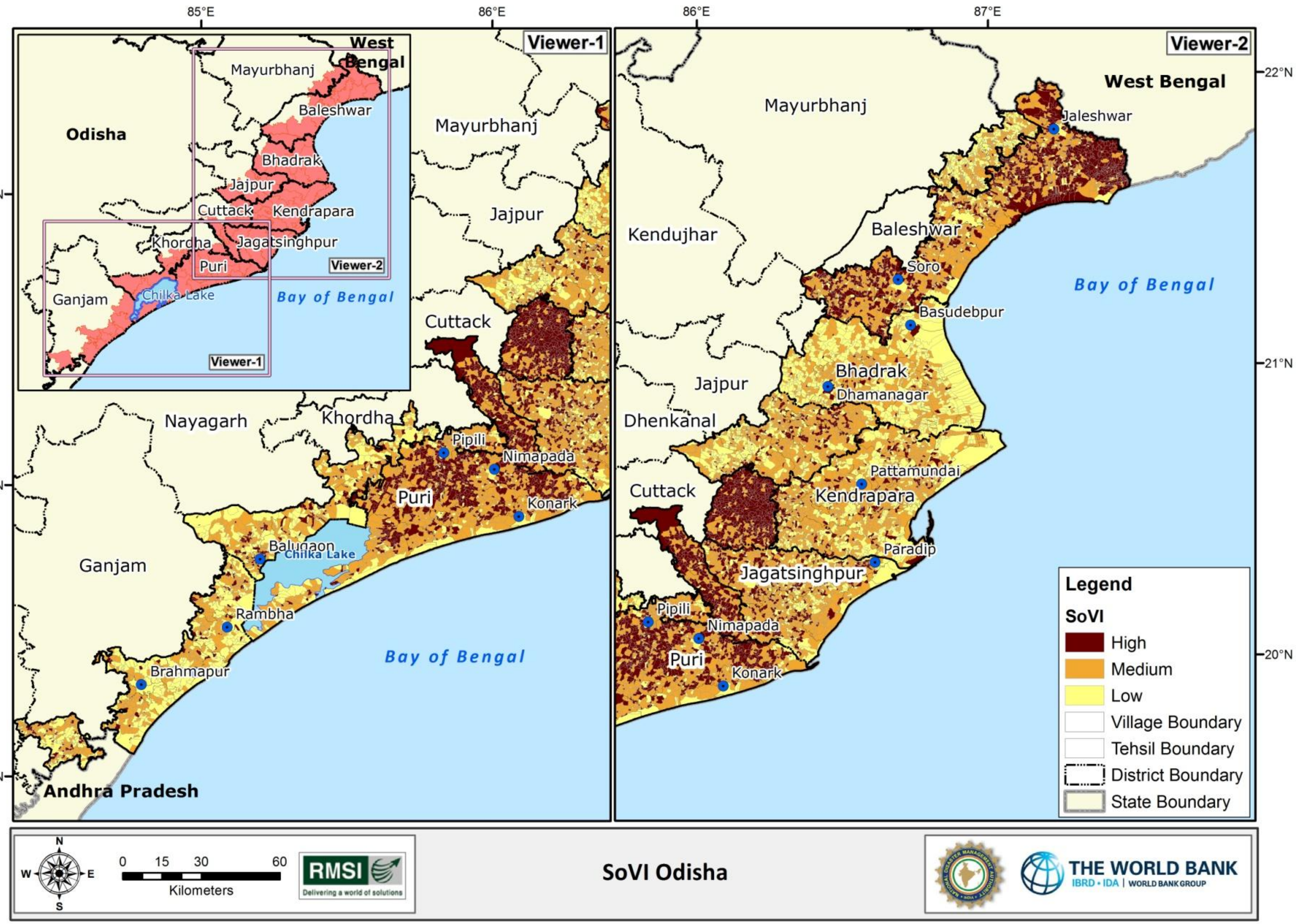


Figure 5-40: SoVI map, Odisha

5.6.1 ECONOMIC VULNERABILITY

5.6.1.1 Livelihood and occupational pattern

The livelihood and occupational pattern of coastal Odisha is provided in the Figure 5-41, Figure 5-42 and Figure 5-43. The majority of the people in the study area are engaged in fisheries and agriculture with very high density in Baleshwar. Badark, Jagatsinghpur and Puri districts also has relative large number of population depending on fisheries and agriculture for livelihood. Bhadrak and Jajpur have largest number of non-workers.

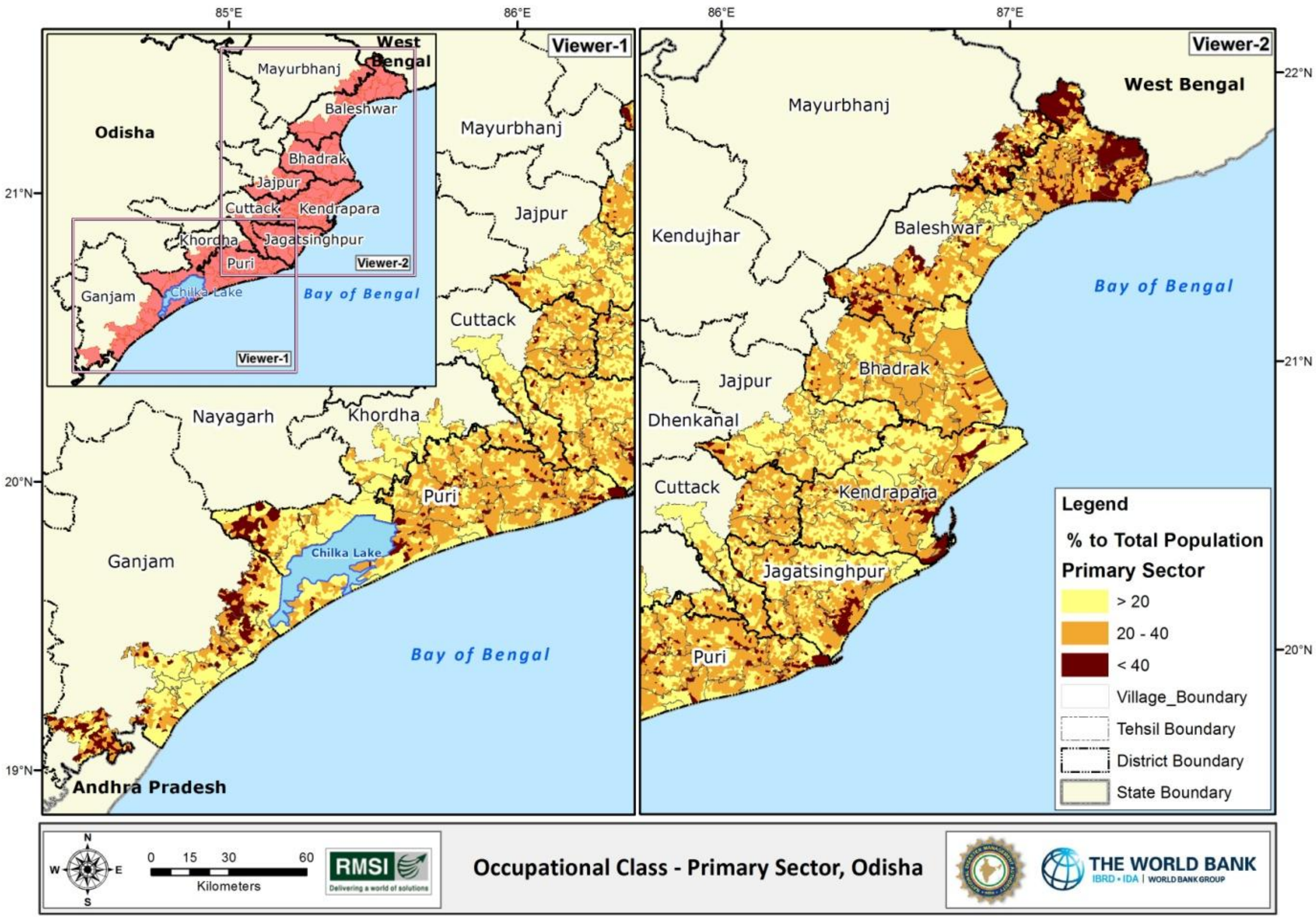


Figure 5-41: Occupational group: primary sector (agriculture and fisheries), Odisha

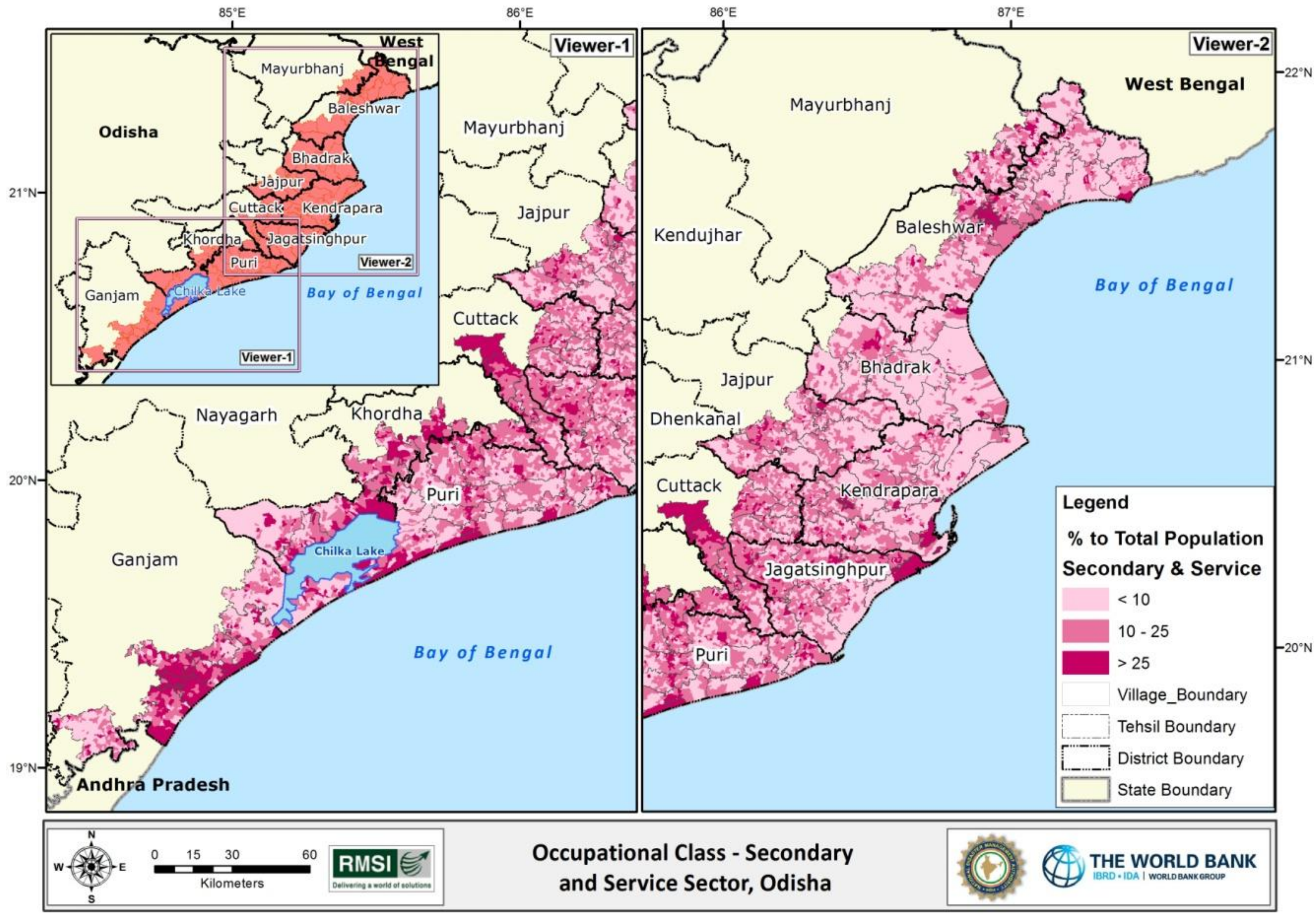


Figure 5-42: Occupational group: secondary and service sector, Odisha

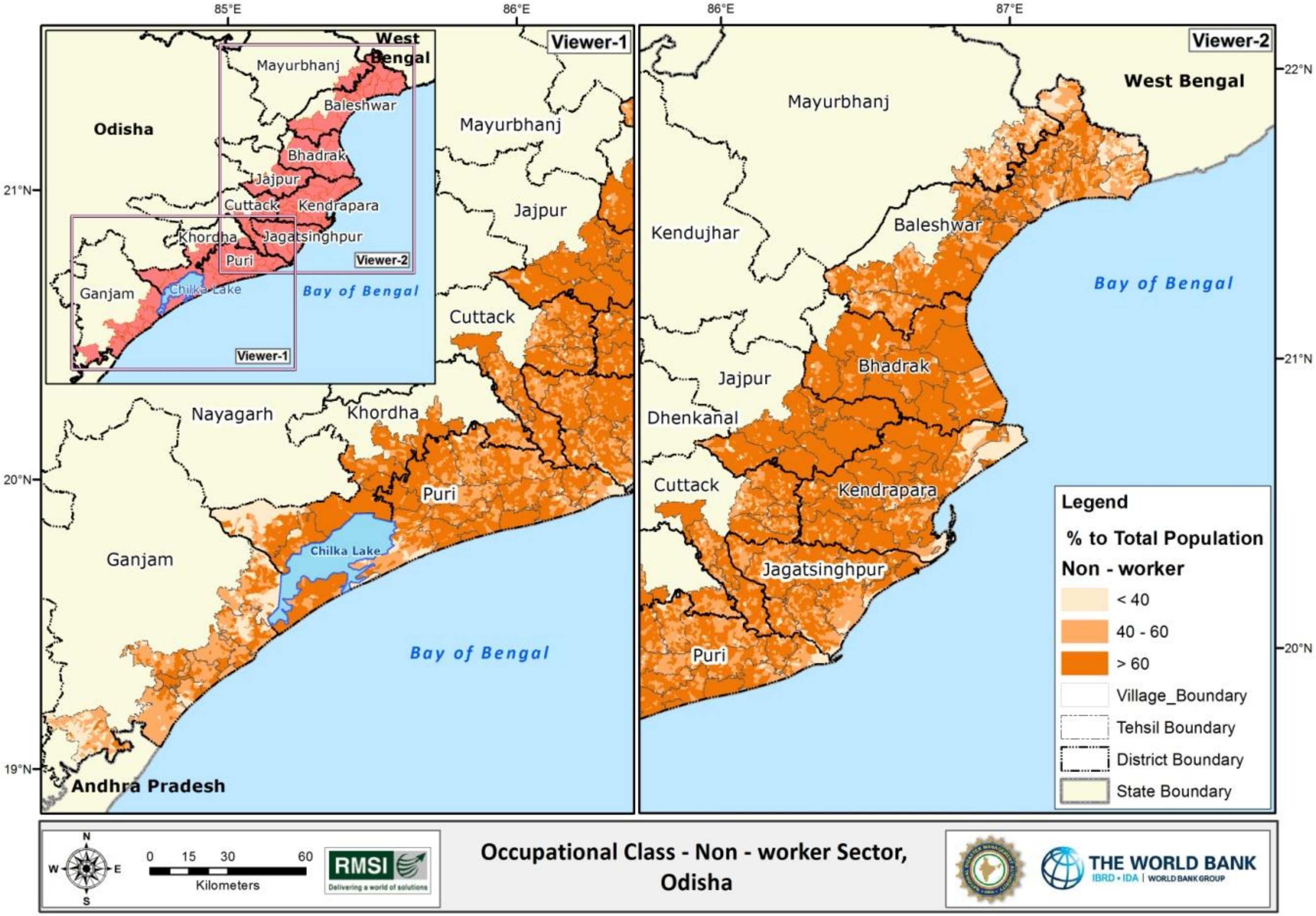


Figure 5-43: Occupational group: non-workers, Odisha

5.6.1.2 People below poverty line

The Figure 4-44 presents the distribution of poverty level among various coastal districts of Odisha. Mayurbhanj has the highest percentage of people below poverty line which is basically an agricultural district frequently affected by flood. About 60% of the population of this district is recorded as below poverty line. Other districts mostly has similar profile and about 20-25% of the population are recorded as below poverty line.

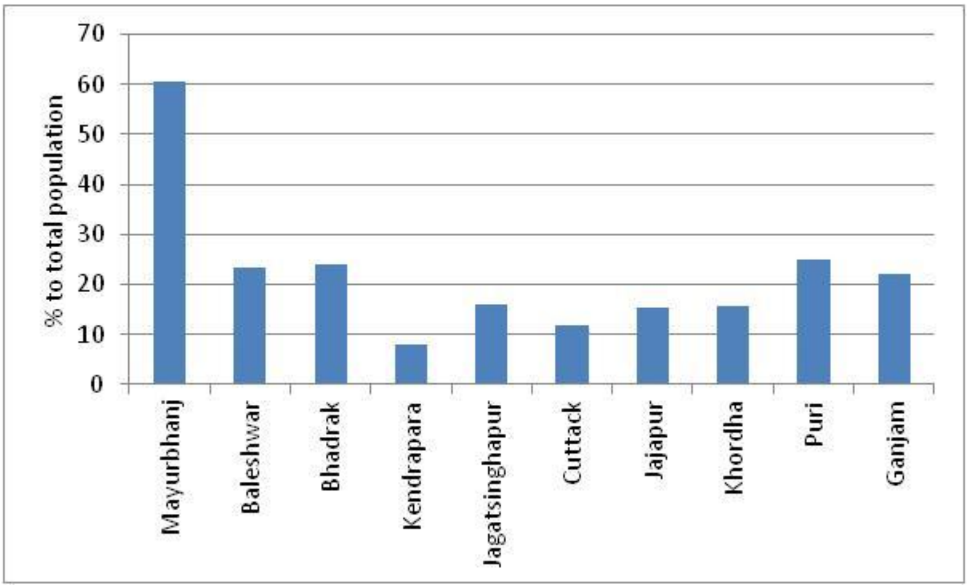


Figure 5-44: Poverty level – percentage to total population, Odisha

5.6.1.3 District level GDP

Odisha state is experiencing remarkable economic growth during the last one-decade or so and this is well reflected in the GDP of the coastal districts as well (Figure 4-45 and Figure 4-46). Three districts with highest GDP and experiencing steady growth in GDP are Cuttack, Ganjam and Khordha districts. Kendrapara is the district, which is experiencing relative slow economic growth.

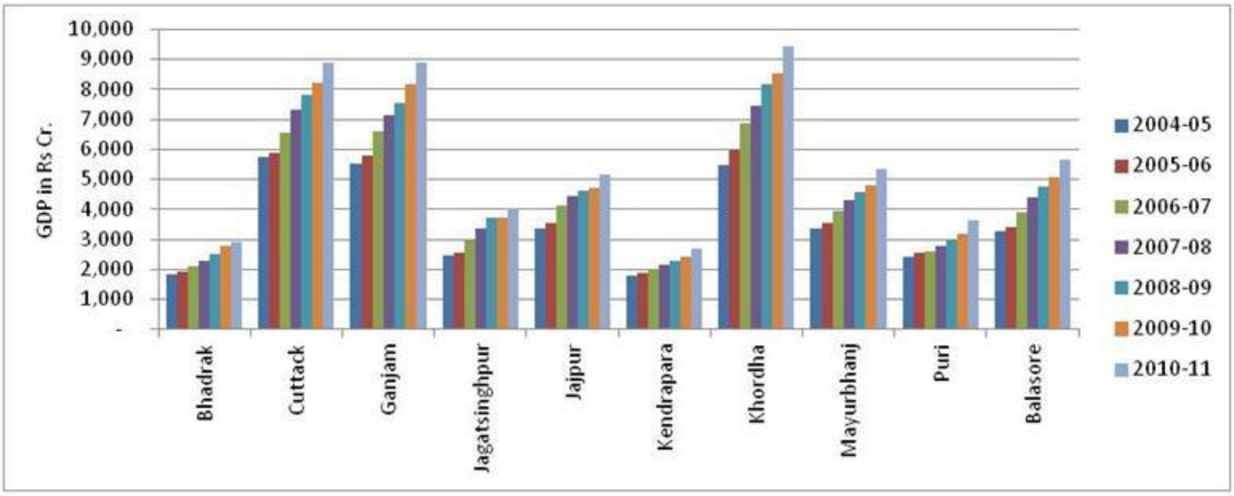


Figure 5-45: District level GDP of coastal district of Odisha (2004 to 2010)

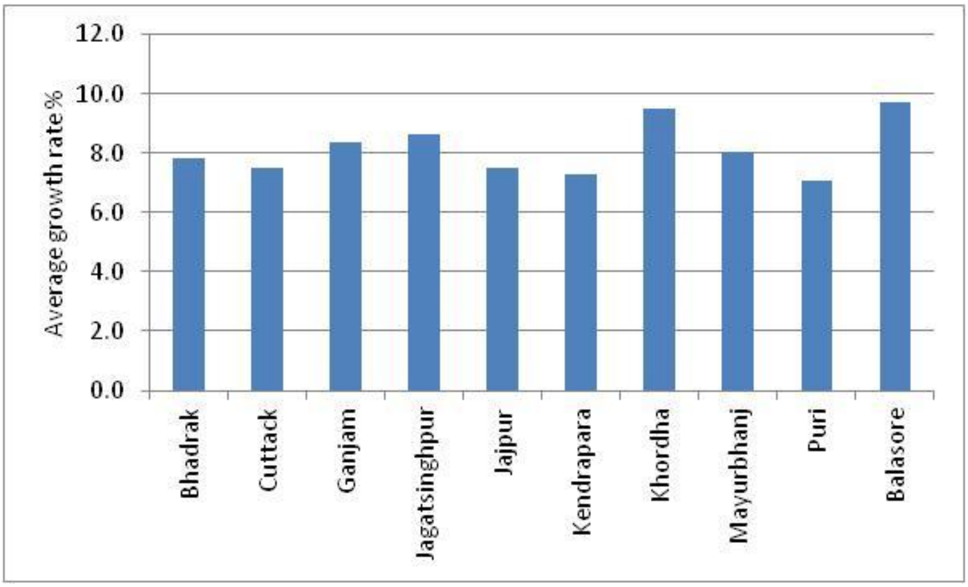


Figure 5-46: District level average GDP growth, Odisha

6 Progress on the Web Atlas Development and Testing

6.1 Introduction

Web-based Risk Atlas is under development on GeoNode platform to enable a decision support system for assessing the qualitative and quantitative risk within the coastal state and UTs. The goal of this application is to help in understanding and analyzing the impacts of disasters due to cyclone, surge, and cyclone-induced flood.

6.1.1 Requirements

The preliminary step of designing and implementing the Web Risk Atlas was to obtain a detailed understanding of the requirements. The requirements gathered for the project mainly include:

1. Centralized data storage to facilitate data sharing: this will ensure that most up-to-date exposure information on buildings, infrastructure, critical facilities, and demographics are available at a centralized place to facilitate the disaster risk reduction efforts in the cyclone prone areas of the country.
2. Sharing outcomes of the study: this will ensure that NDMA, state officials, individuals, researchers, planners, disaster management specialists, first responders, engineers, and professionals have access to the different types of exposure, vulnerability and risk data due to cyclones, surge, and cyclone induced rainfall in the study area that can be used in their respective work areas.
3. Provide a platform for deterministic risk assessment.
4. Assistance in disaster planning and preparedness: this is the dynamic aspect of the application that will allow users to see the impact of imminent or just occurred disasters on various assets in the study area
5. Bring all the agencies involved in disaster management on one common platform so that easy data and information sharing is facilitated.
6. The Risk Atlas will contain all the maps related to Hazard, Exposure, Vulnerability, hotspots, and realistic disaster scenario maps that users can use for training and decision support by creating different scenarios and choosing levels of hazards under this study.
7. Allow users of respective states to view data and maps to analyze the risks.
8. Allow users to plan for shortest evacuation routes using the Risk Atlas.

6.2 Requirement Analysis

Based on the requirements stated above, RMSI has organized the needs in such a way that optimal time utilization can be done and parallel implementation of the work can be carried out. Based on user needs, the Risk Atlas will have multiple views as follows:

i. View only: In this view, the user will only be allowed to view and query the Risk Atlas.
ii. Summary view: This will help state officials to plan risk mitigation options for their respective states.
iii. Map view: This will help users to view various maps, such as, risk maps, hot spot maps, and risk analysis maps.

Accordingly, the user interface has been designed and users have been given the flexibility to use the various views.

Keeping the user needs in mind, the requirements have been divided into two categories:

a. Functional requirements

b. Nonfunctional requirements

6.2.1 Functional Requirements

The Web risk atlas would comprise of three different kinds of users, each having access to different kinds of functionalities. The three different users are:

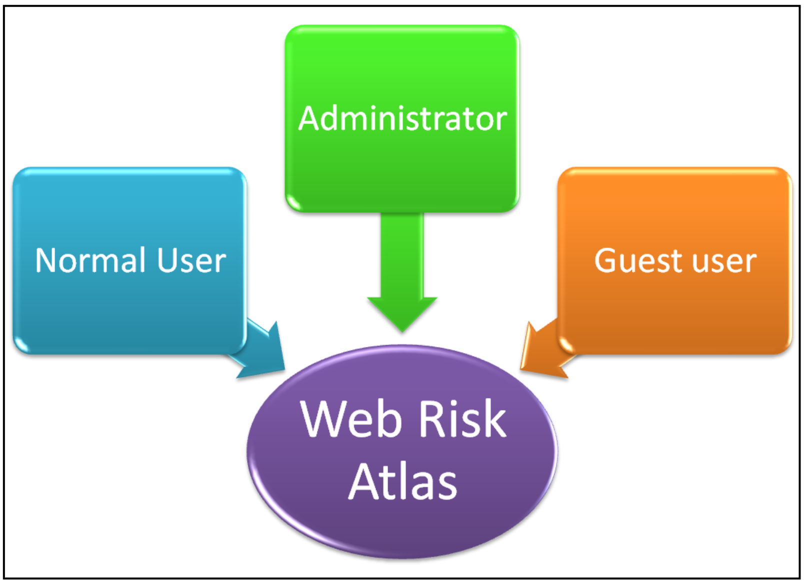


Figure 6-1: Different users of the system

a. **Administrator**: The administrator will have access to all the rights in the system.
b. **Normal user**: Each normal user will be assigned one state. User will be able to perform the various functions for their respective states only.
c. **Guest user**: The guest user will only be able to use the application once he is registered. Guest user has to follow a registration process where he/she will be asked to provide his/her name, company name, contact details, state etc. to access the system. Guest user will only be able to view and query the Risk Atlas.

Table 6-1: Various functionality and their access to each user type.

S.No.	Functionality	Administrator	Normal user	Guest user
1	Access to login	✓	✓	✓ (Registration required)
2	View Risk Atlas	✓	✓	✓
3	Query Risk Atlas	✓	✓	✓
4	Manage Exposure	✓	✓	×
5	Perform Risk Analysis	✓	✓	×
6	Manage vulnerability	✓	✓	×
7	Perform Hot- spot analysis	✓	✓	×
8	Manage User Account	✓	×	×

The various functionalities/features incorporated in the application are mentioned below. The development progress and status of these functionalities have been given in the next section.

1. **Risk Atlas Home page**

Based on the type of user and the state assigned, user will be navigated to the homepage of the application with the respective state zoomed in. In order to help disaster management specialists and other users to deal with the cyclone challenges, RMSI will provide a quick glance to various information on the homepage that would help the users in taking effective decisions. Figure below shows the homepage of the Web Risk Atlas.

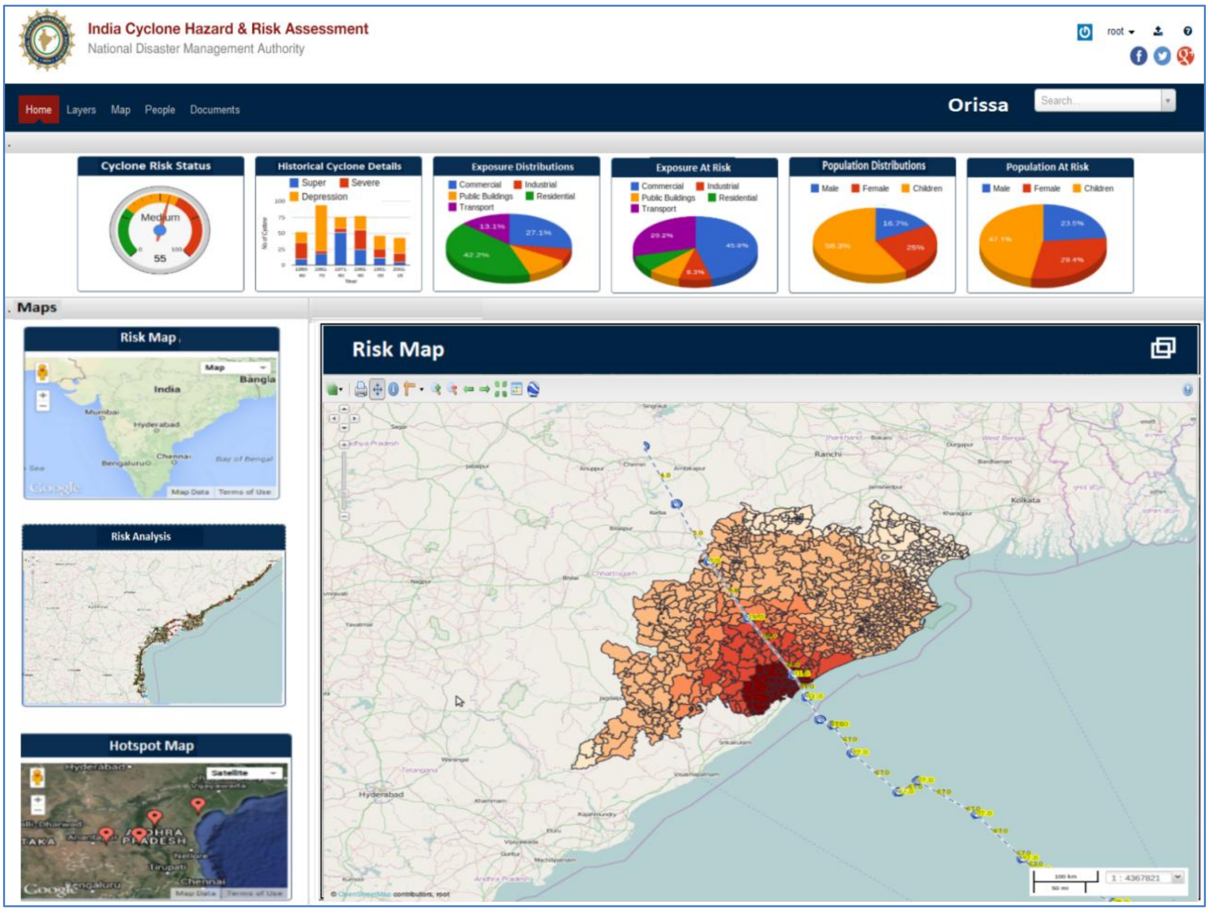


Figure 6-2: Web Risk Atlas Homepage

The homepage has been divided into three panels:

a. **<u>Left panel</u>** – It will include three maps as follows:

1. **Risk map**: It will allow the user to view various risk maps associated to hazards considered in this study. Once the user clicks the Risk map, a window will be displayed to allow the user to view and query the Risk Atlas and perform various other functions such as managing exposure, vulnerability, and performing analysis based on the access rights of the user.
2. **Risk analysis map**: It will allow the user to visualize the risk associated with a state with respect to the analysis performed by updating the exposure values.
3. **Hot- spot map**: It will allow the user to visualize hot-spot locations in a state and perform hot-spot analysis

b. **<u>Top panel</u>** – It gives a summary view to the user. It provides risk information associated to a state in the form of charts and graphs that will help decision-makers in planning and taking necessary actions to reduce the adverse affects of cyclone.

1. **Cyclone risk status**: A risk meter has been added in the application that provides the status of the cyclone risk associated to a state i.e., whether the state is under low, medium, or high-risk zone.

2. **Historical cyclone details**: It gives year wise count of cyclones that crossed a state and also provides their intensity viz., severe cyclones, super cyclones etc.
3. **Exposure distribution**: It gives the exposure distribution details for various categories such as residential, industrial, commercial, infrastructure, transport etc.
4. **Exposure at risk:** It gives the percentage of risk associated to various exposure categories (such as residential, industrial, commercial, infrastructure, transport etc.)
5. **Population distribution:** It gives the population distribution of the study area in the state.
6. **Population at risk**: It gives the percentage of risk associated to the population of the study area in the state with respect to cyclone.

c. **Right panel** – Based on the maps selected or the type of risk information user wishes to view by selecting the options from the left panel/ map view or the summary view/ top panel, the right panel displays the exposure and risk information in detail.

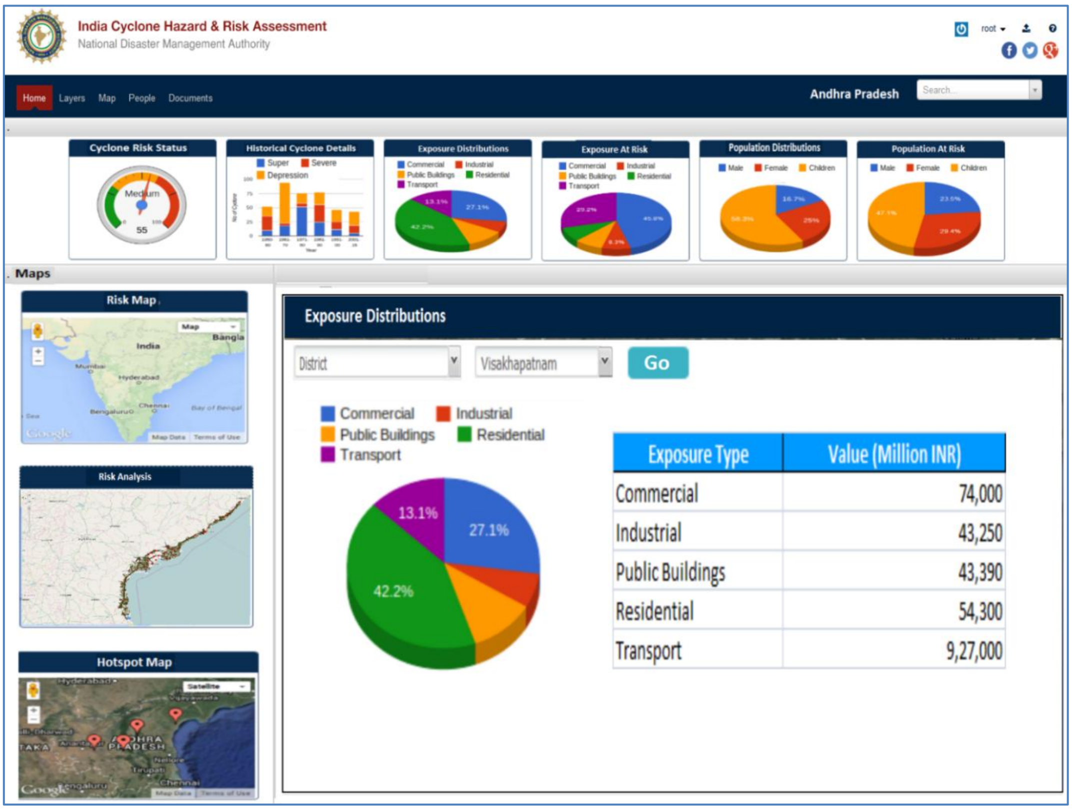


Figure 6-3: Viewing exposure distribution in detail

2. View and Query Risk Atlas

To view and query the Risk Atlas, the application will provide the user with a navigation pane and search by attribute pane respectively. Navigation pane will help the user in performing basic GIS operations such as:

- Pan
- Zoom in
- Zoom out
- Previous view
- Next view

- Attribute information tool

The Select by Attributes functionality will provide users the facility to map or highlight an active layer based on the attributes of the layer.

3. **Manage Exposure**

This functionality will allow the user to update exposure values of aggregated and site-specific details. This functionality will allow the user to modify the base values corresponding to the various occupancy types. With this functionality, the user will be able to modify the population, crop, building, and infrastructure exposures.

There will be three separate interfaces for updating aggregated exposure, site-specific exposure and building structural distribution exposure. These details will be updated at village level. Aggregated exposure interface will help in updating the occupancy details whereas with site-specific interface will help in modifying infrastructure and other details. User will be able to update structural distribution exposure of the various structural type values.

4. **Risk Analysis**

Risk analysis functionality will provide the user to work on both base and user-defined exposure values. The various hazards for which analysis can be performed are:

- Cyclone
- Flood
- Surge

These analyses will be performed at scenario level for various exposure types, viz., occupancy, essential facilities, public buildings, utilities, transportation etc.

As soon as the analysis is performed, requested analysis job is added in the queue in asynchronous mode. An option will be given to the user to view the status of the submitted analysis job from where the user can generate a report once the analysis is complete. The generated report will display tables and graphs showing the losses in monetary terms and their distribution over a region based on the choices the user has made.

5. **Manage vulnerability**

Vulnerability updates will be session specific. Changes in vulnerability will not affect the base table. The user will be provided with two interfaces. One will be to update the aggregated vulnerability functions and the other one will be to update site-specific vulnerability. Through aggregate vulnerability, the user will be able to update structural type distribution details and through the site-specific interface the user will be able to edit the vulnerability functions corresponding to various types of infrastructure, transport, and utilities.

6. **Hot-spot Analysis**

Based on the hot spot areas identified in various districts, the user will be able to perform hot spot analysis for areas falling under the state assigned. For the selected hot spot user will be able to modify the hot-spot exposure (building, infrastructure, essential facilities etc) and can then run the hot-spot analysis. The user will be able to modify the exposure for current scenario only. After the analysis is run, the changed exposure values are not reflected the next time analysis is performed.

Once the analysis is performed, a report is generated showing the risk maps that will help the user in disaster risk management functions. It will also help the user in evacuation and shelter planning.

7. **Manage user account**

This functionality is specifically for the administrator to maintain user accounts. This will include adding, modifying, or deleting user account information from the Atlas.

9. Add new user: The administrator will have the right to add a new user to the atlas. The new user will be able to login to the system with the username, password, and the role assigned to him/her by the administrator.
10. Modify the user: This will allow the administrator to edit the existing rights/ role assigned to the user.
11. Delete the user: This will allow the administrator to delete a user from the Atlas, in case the user needs to be excluded from accessing the Risk Atlas or when the user log in is no longer required to be used.

6.2.2 NON-FUNCTIONAL REQUIREMENTS

Other than the functional requirements, RMSI will also focus on the non-functional requirements of the system that would focus on the following key aspects:

1. Easy to use and well-defined user interface.
2. Accessibility: Most of the functionality of the application is operable through both mouse and keyboard interface.
3. Navigation: User will be able to easily navigate around and use the application with minimum clicks.
4. Reliability: Components of the project code will be unit tested alongside the implementation phase to ensure that they are functional.
5. Security: Risk Atlas data for a state will be accessible only to the system administrator who can also make changes to it.

6.3 Design and Implementation

This section provides the design and implementation aspects of the Risk Atlas and helps in understanding the status of the progress that has been made so far in developing the Web Risk Atlas.

6.3.1 DATABASE DESIGN

Database design defines the various tables and the relationships between the tables. RMSI has applied first, second, and third normal forms.

The following section shows the E-R diagram for both the Cyclone and Surge loss calculations.

6.3.1.1 *E-R Diagram for cyclone loss calculation*

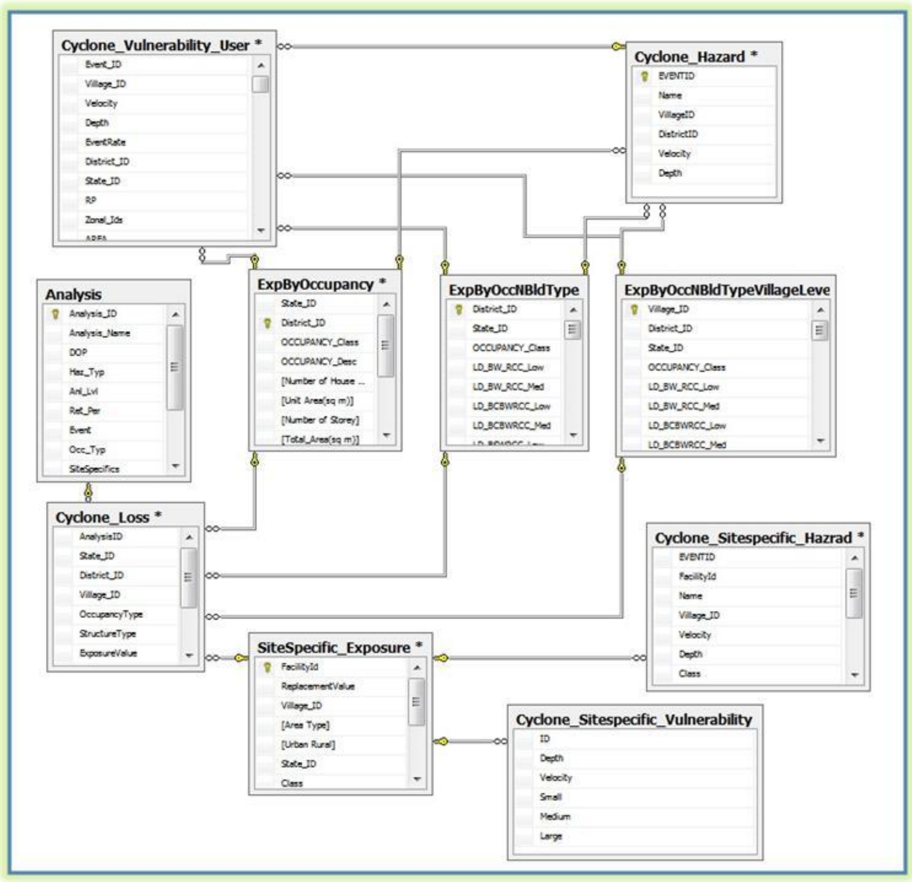


Figure 6-4: Database schema for cyclone loss calculation

6.3.1.2 E-R Diagram for storm surge loss calculation

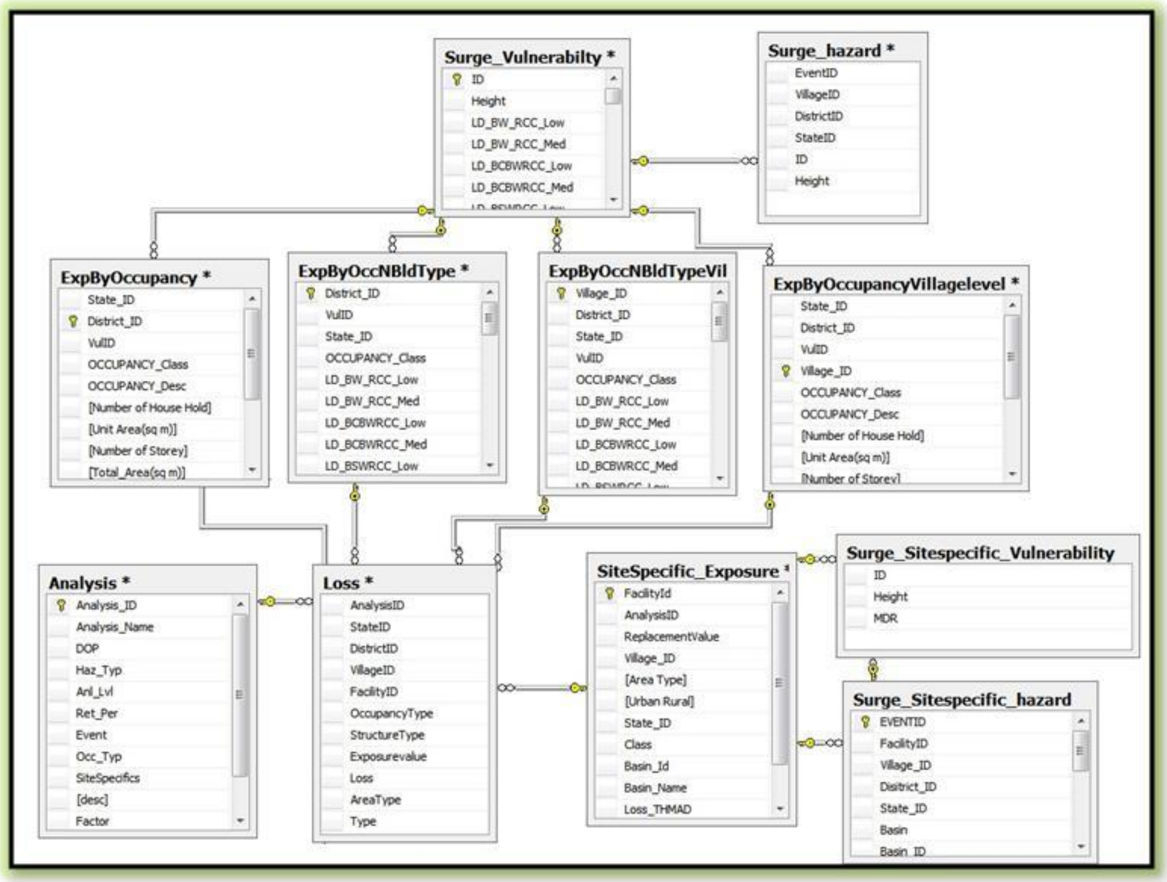


Figure 6-5: Database schema for surge loss calculation

A detailed description of the database structure and tables is provided in the Data Inventory report. Users can refer to that report for more details on database aspects.

6.3.2 USER INTERFACE DESIGN

6.3.2.1 Key aspects of user interface

1. Clarity: There will be no ambiguity in design. It would be achieved by making everything clear through language and flow of visual elements.

2. Navigation: User will be able to easily navigate around and use the application with minimum clicks.

3. Focus order: Focus order of the controls will be set in order to preserve meaning and operability.

4. Readability: Text content will be readable and understandable.

5. Label or instructions: Labels or instructions would be provided wherever content requires user input

Table 6-2: Progress in development of Risk Atlas components

Functionality	Sub Functionality	Status	Status as on Oct 23rd 2015
Login Page	Login to application	Done	
	Register to application	Done	
Homepage	Risk Summary of state	Done	
	Map Applications	In process	In process
	View Detailed Risk of state	Done	
	View Detailed Map Applications	In process	In process
Manage Risk Atlas	Manage Risk Map	Done	
	Manage Risk Analysis Map	In process	Done
	Manage Hotspot Map	In process	In process
Manage Exposure	Manage Aggregated Exposure	Done	
	Manage Site-specific Exposure	Done	
	Manage Crop exposure	In process	Done
	Manage Population	In process	Done
	Manage Hotspot Exposure	In process	In process
Manage Vulnerability	Manage Aggregated Vulnerability	Done	
	Manage Site-specific vulnerability	Done	
	Manage crop vulnerability	In process	In process
	Manage population vulnerability	In process	Done
	Manage hotspot vulnerability	In process	In process
Risk Analysis	Submit Analysis	Done	
	Create Analysis Scheduler	Done	
	Write Risk Assessment functions in database	In process	Done
	Design and implementation of Risk analysis report	In process	In process
Hotspot Analysis	Submit Hotspot Analysis	In process	In process
	Create Hotspot Analysis Scheduler	In process	In process
	Write hotspot analysis functions in database	In process	In process
	Design and implementation of Hotspot analysis report	In process	In process
Upload	Upload Layers	Done	
	Upload Document	Done	
User based Accessibility	Admin accessibility	In process	In process
	Registered user accessibility	In process	In process

6.3.2.2 User login

First page of the Risk Atlas is the login page. User needs to login to the application by entering a valid username and password.

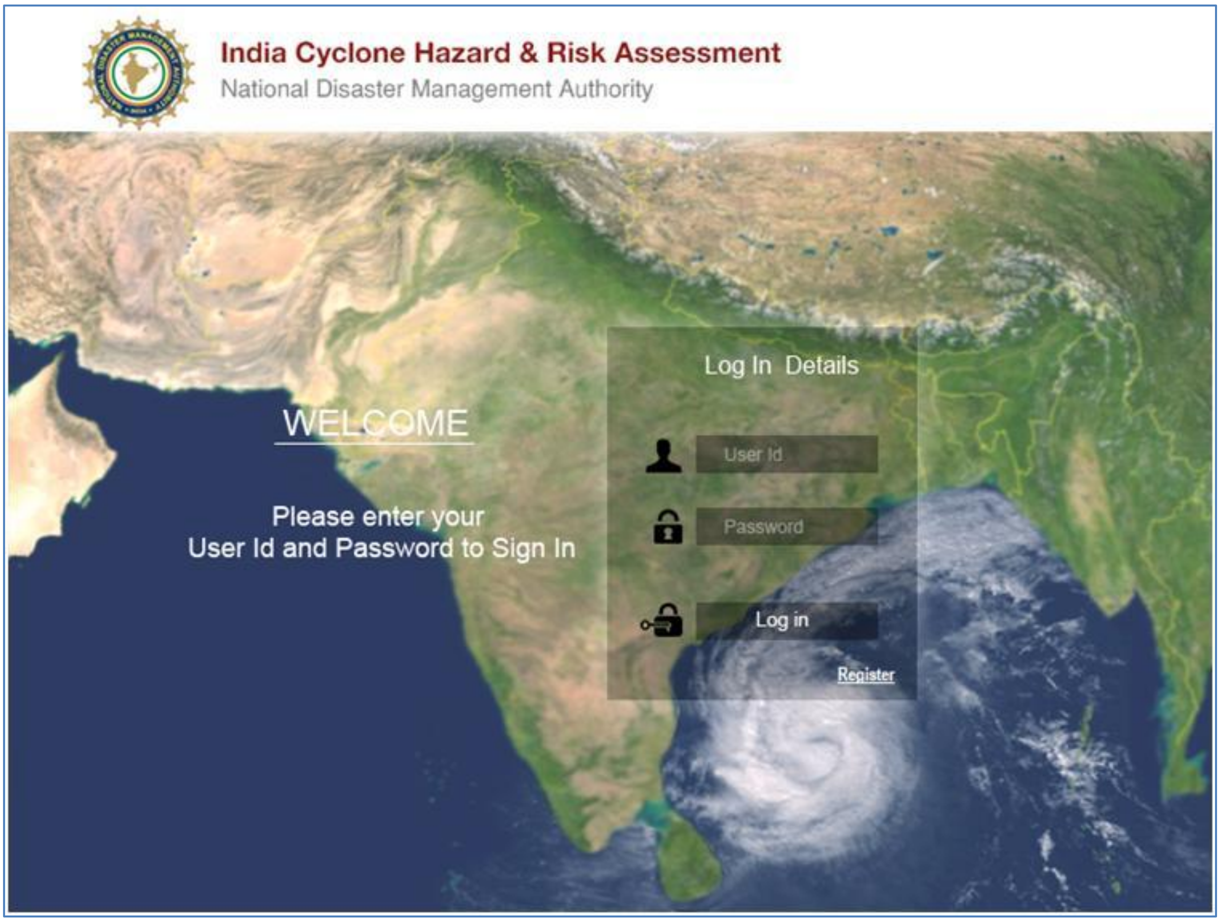


Figure 6-6: Login page

Guest user can register himself by click on the "Register" link. where user will be asked to provide his/her name, company name, contact details, state etc.

6.3.2.3 Homepage

The homepage will be displayed after the user logs in to Atlas. Homepage will show the cyclone risk summary of the user's state.

There will be three panels on the homepage, namely:

1. Top panel

The top panel will include cyclone risk summary of the state in the form of different charts. These will include:

- Cyclone risk status
- Historical cyclone details
- Exposure distribution
- Exposure at risk
- Population distribution
- Population at risk

2. Left panel

Left panel will include three application maps, namely, Risk Map, Risk Analysis Map, and Hotspot Map.

3. Right panel

Right panel here has been referred to as the Map window that will display information in the form of a map.

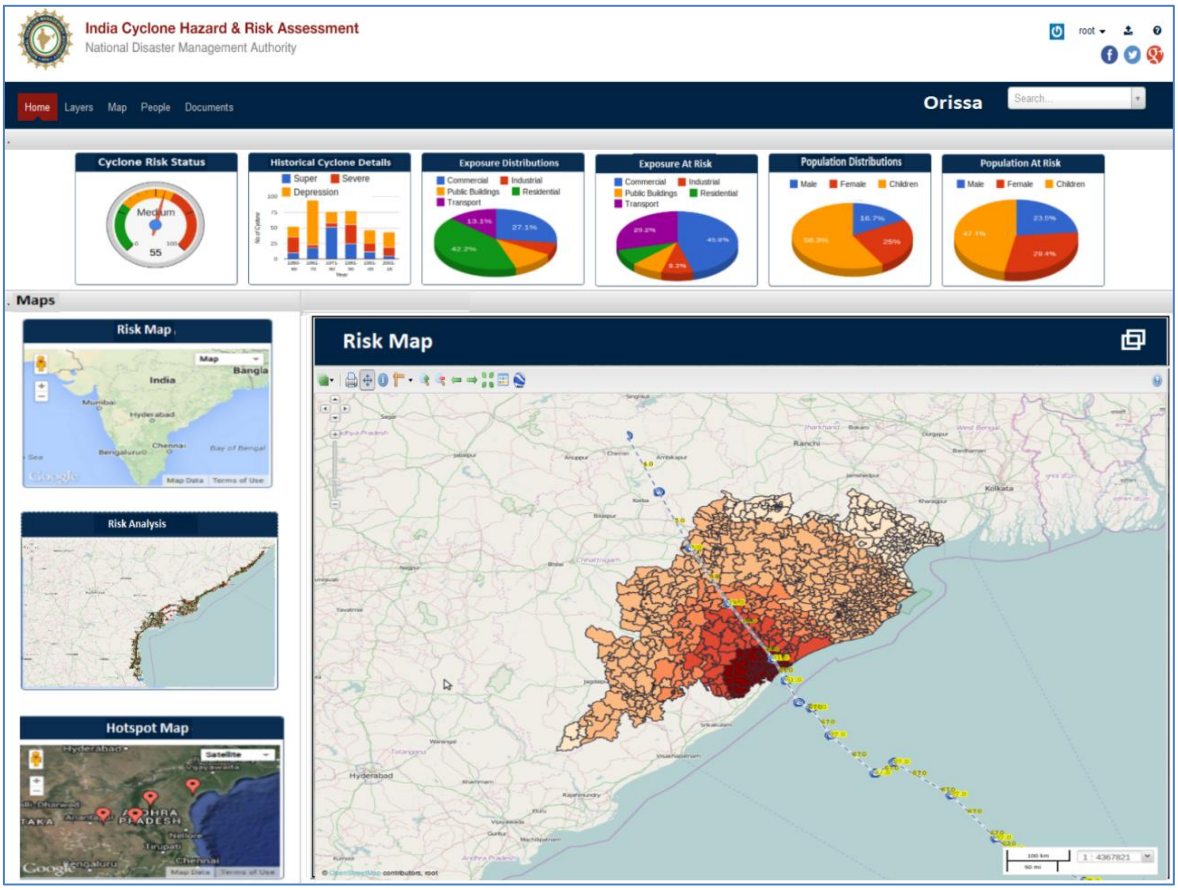


Figure 6-7: Homepage of the Risk Atlas

By clicking on an item's header, the user will be able to view more detailed information in the Right panel.

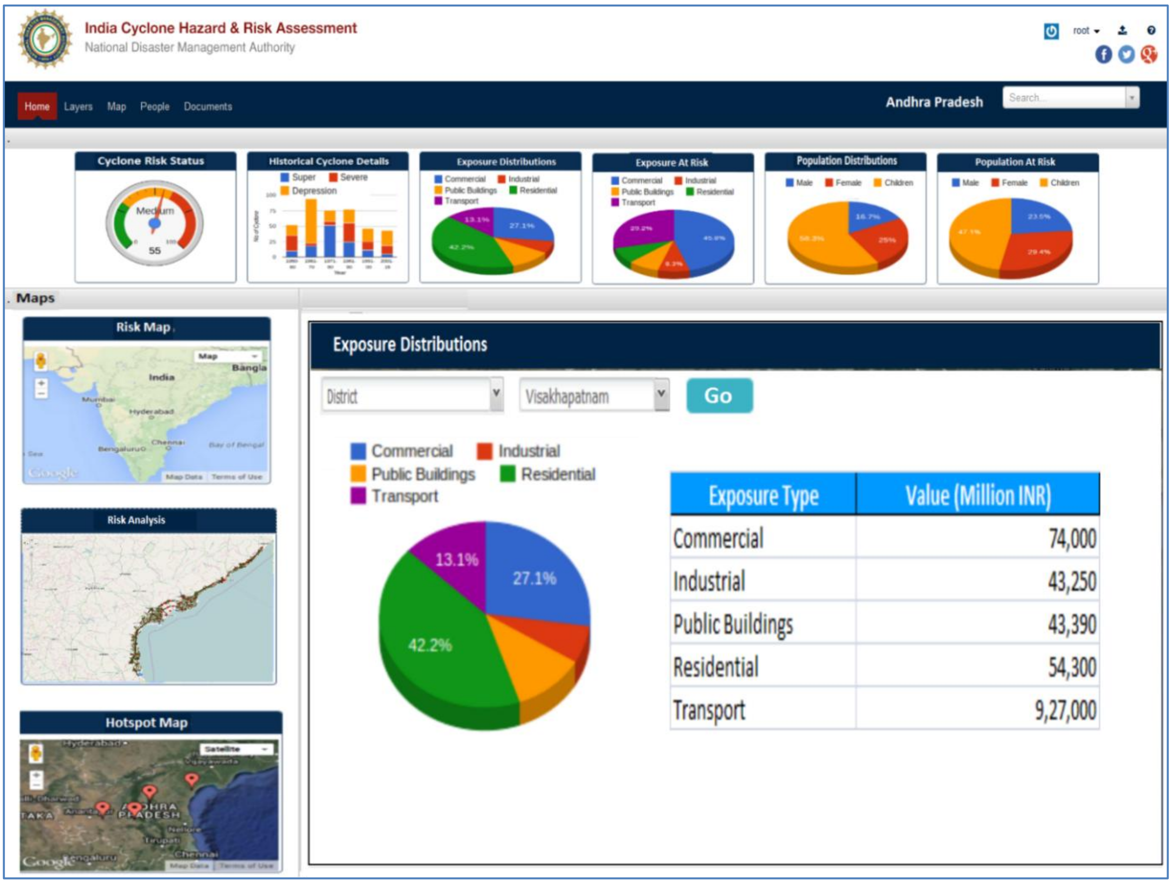


Figure 6-8: Homepage showing exposure distribution

Below section explains detailed functionality of the homepage.

6.3.2.4 Manage Risk Atlas

As given above in Homepage sub-functionality, the user can navigate to a more detailed page of Map applications.

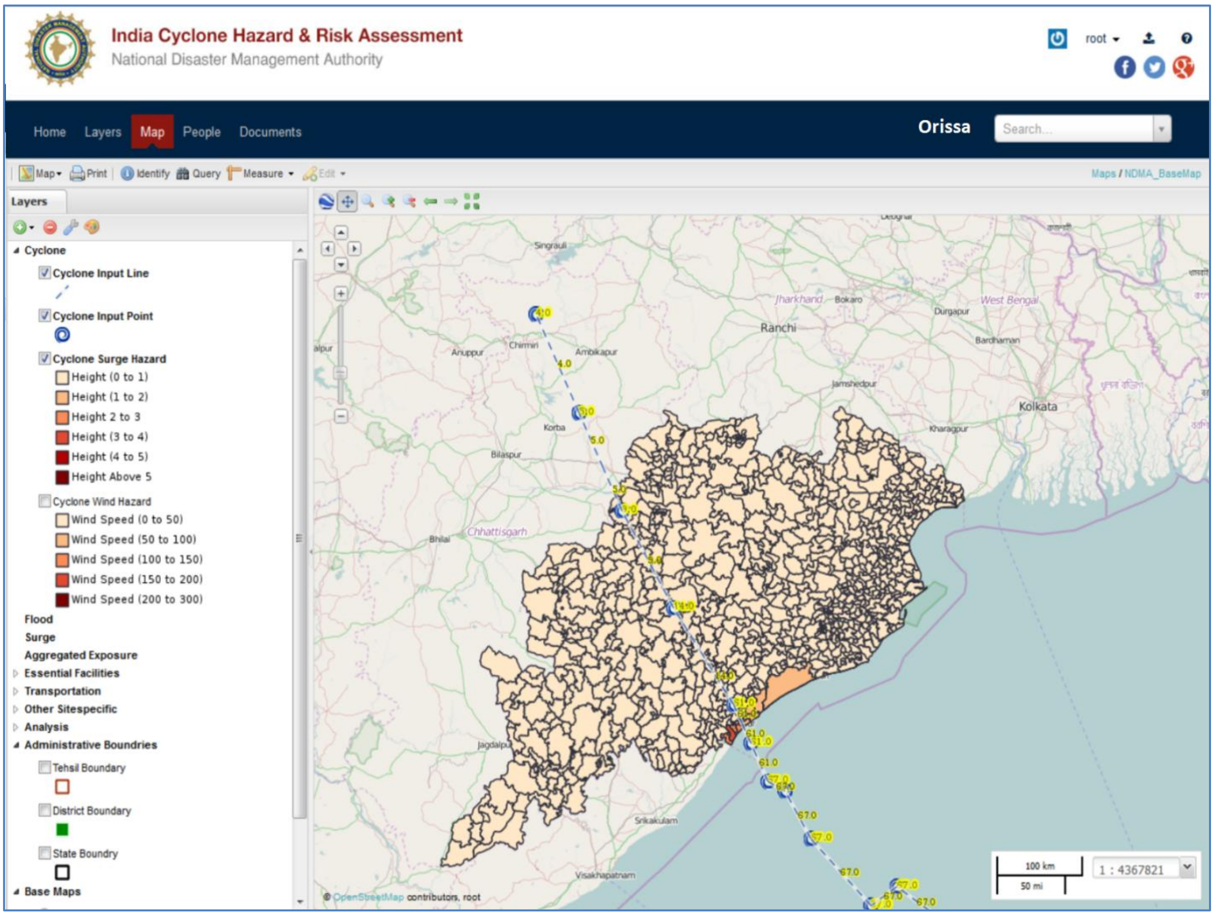


Figure 6-9: Map view of Risk Atlas

As given in the figure above, there are several options in the map panel bar of all three map applications.

1. Map Management - User will have Save/ Save As map options.
2. Layer Management - User will be able to add or remove layers and manage styles of layers for saving their own maps.
3. Print Map - User will be able to print the map.

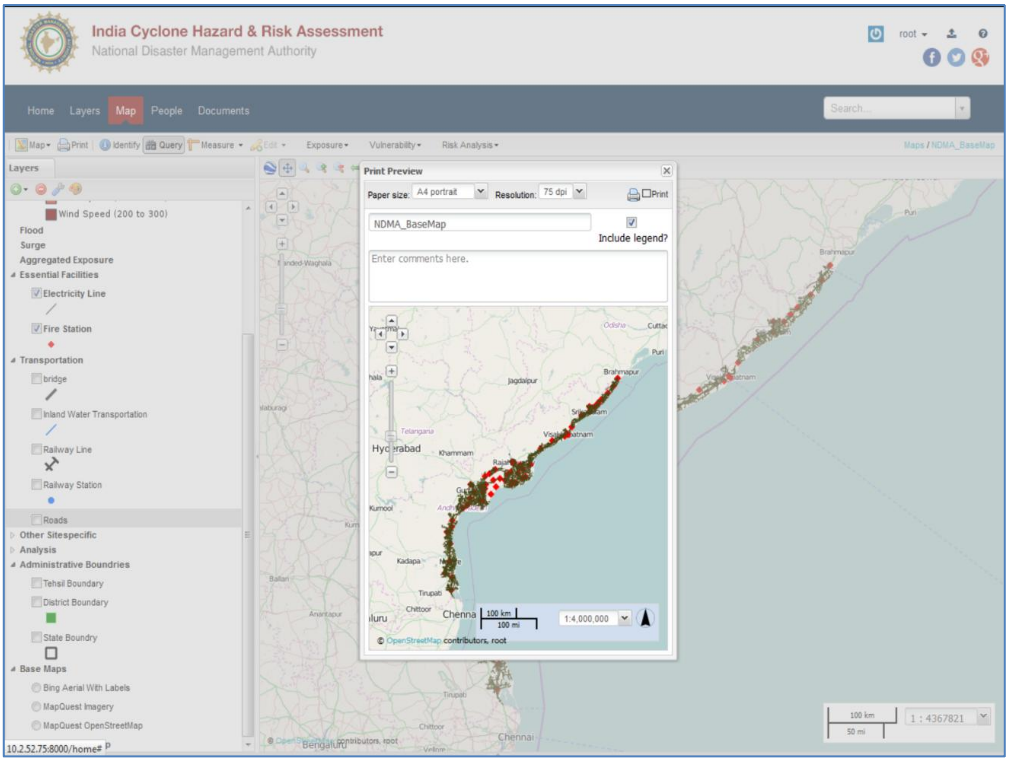


Figure 6-10: Print preview of the map

4. Query - User will be able to view and query layer's attribute details using the Query tool at top of the map panel

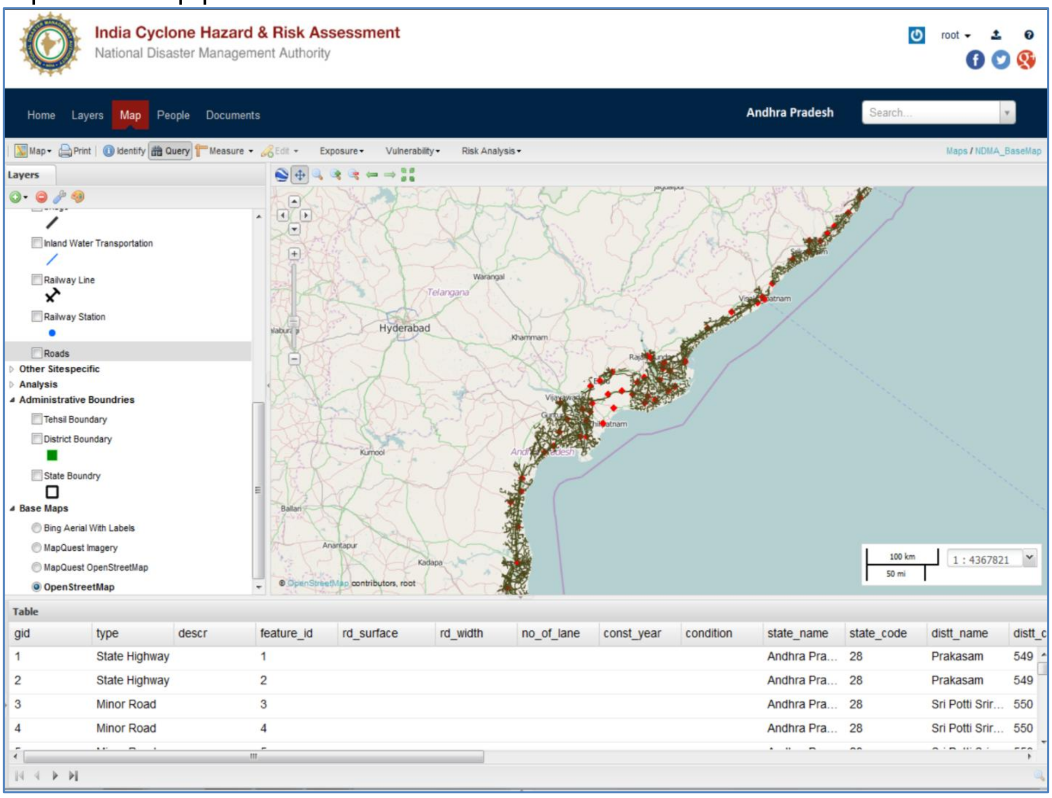


Figure 6-11: Querying on the data

5. Measure Distance/Area - User will be able to measure distance between two points/ area of map using the measure by area and measure distance tools given under the toolbar.

6.3.2.5 *Manage Exposure*

This functionality will allow the user to manage exposure details as per user's needs. Users will be able to update aggregated and site-specific exposure. User will also be able to update crop and population exposure. Updating of exposure is session specific. The changes corresponding to these exposures will not be reflected in the base table.

Below are the sub functionalities and user interfaces for updating aggregated and site-specific exposures.

Sub functionality of manage exposure

List of functionality is given below:

Sub Functionality	Descriptions	Status
Manage Aggregated Exposure	Updates the exposure value at aggregate level i.e. residential, commercial, industrial	Done
Manage Site-specific Exposure	User can manage the site-specific exposure values of their state	Done
Manage Crop exposure	User can manage the crop exposure values of their state	Done
Manage Population	User can manage the population of their state	Done
Manage Hotspot exposure	User can manage Hotspot exposure of their state	Done

6.3.2.5.1 Manage Aggregated Exposure

In manage aggregated exposure, user can perform the following functionality:

1. User can filter aggregated exposure at district or village level.
2. User can search exposure of any building structure-type.
3. User can view the replacement cost, unit replacement cost, area etc. of a particular structure-type at district-level.
4. User can update unit replacement cost and similar details of any structure type.

6.3.2.5.2 Manage Site-specific Exposure

In manage site-specific exposure, user can perform the following functionality:

1. User can filter exposure attributes of site-specific assets like transport, utilities etc. at district or village levels.
2. User can view the replacement costs, unit replacement costs, and other attributes of site-specific assets.
3. User can update replacement costs, unit replacement costs etc. of site-specific assets.
4. All the changes in exposure attributes will be user specific.

6.3.2.5.3 Manage Crop Exposure

Sub functionality of manage crop exposure is given below:

1. User can search exposure of different type of crops.
2. User can view the exposure of crops at district/ village level.
3. User can update exposure of different crops.
4. All exposure updates will be user specific.

6.3.2.5.4 Manage Population Exposure

Sub functionality of manage population exposure is given below:

- User can search male, female, and child population.
- User can view male, female, and child population at district/ village level.

- User can update population exposure.
- All updates will be user specific.

6.3.2.5.5 Manage Hotspot Exposure

Sub functionality of manage hotspot exposure is given below:

- User can search Hotspot point's exposure details at district/ village level.
- User can view the Hotspot exposure value and other attributes.
- User can update Hotspot exposure.
- All updates will be user specific.

Use case Scenario of Manage Exposure

The system requests the user to choose from the following selection criteria:

1. Based on the state of the user, system requests the user to select the district for which exposure is to be updated.
2. If the user selects any one district, the village dropdown is populated with all the villages in that district. Go to step 4.
3. If user selects all districts, the village dropdown gets disabled and the exposure value corresponding to occupancy type is shown in the search result frame.
4. System requests the user to select a site-specific category and the type for which exposure is to be updated.
5. Once the user selects the criteria, a list of selected site-specific types at village level /district level (as may be the case selected) with default exposure is displayed which can be easily modified by performing click operations.
6. Once user provides all the information, click the Save button to update exposure in the system and an appropriate message is displayed.

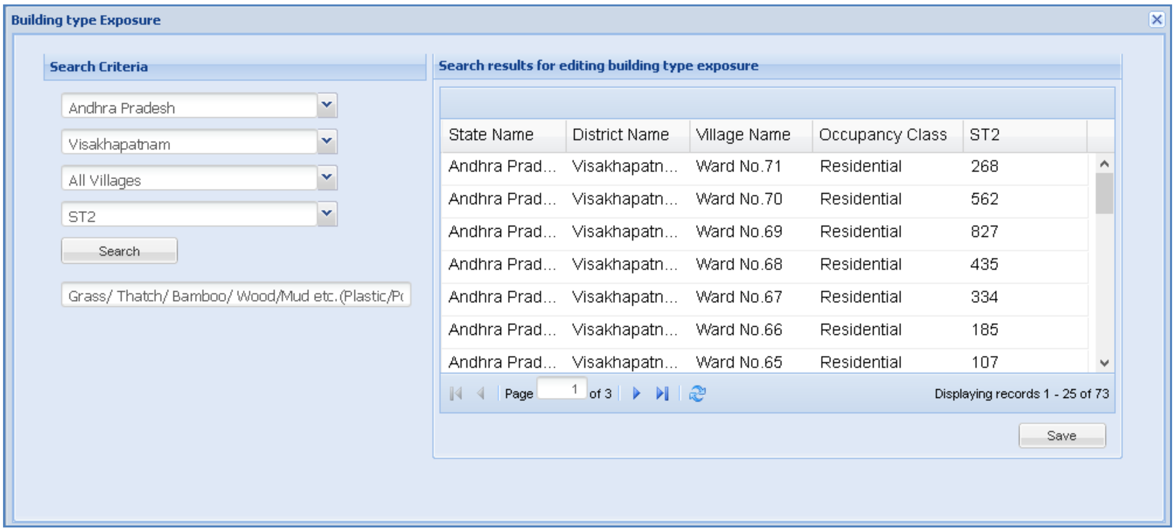


Figure 6-12: Manage aggregated exposure

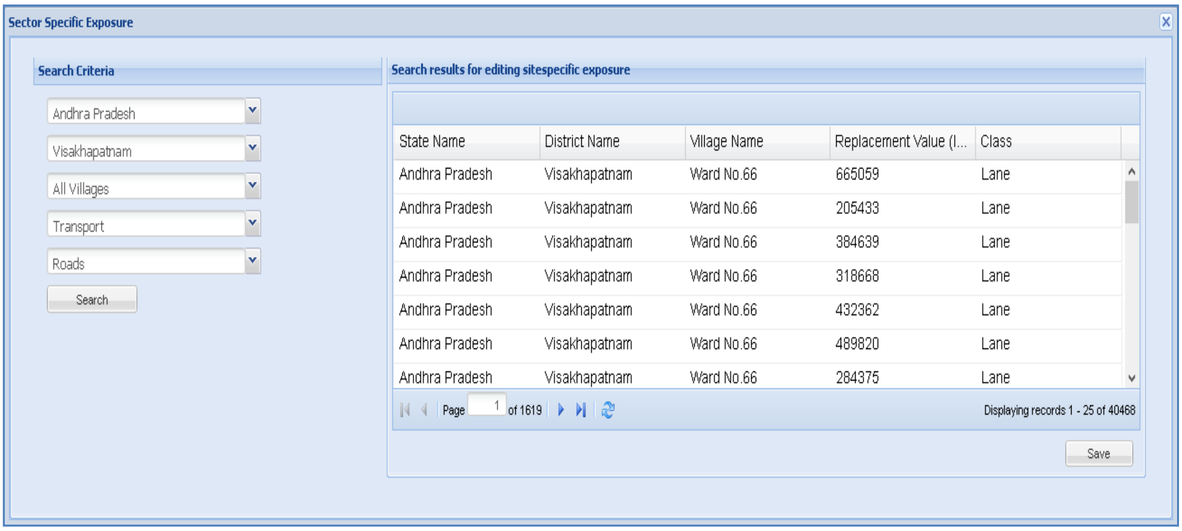


Figure 6-13: Manage site-specific exposure

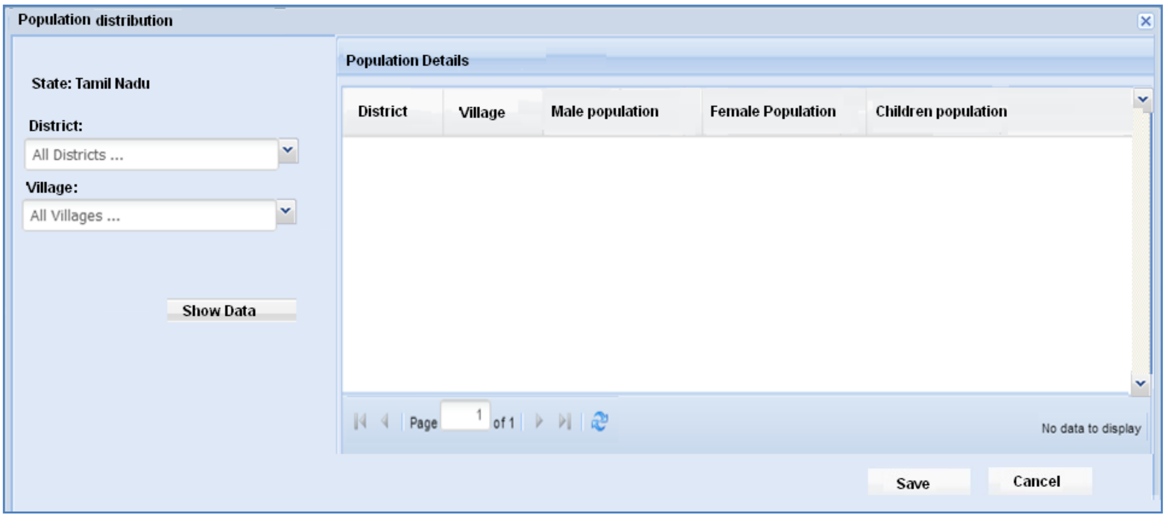


Figure 6-14: Manage population details

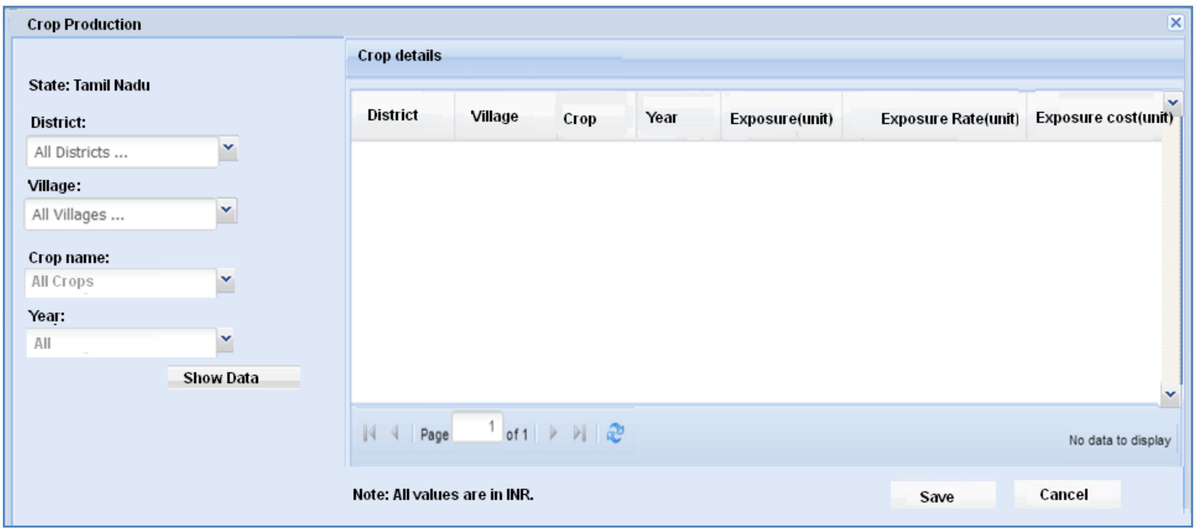


Figure 6-15: Manage crop exposure

6.3.2.6 *Manage vulnerability*

Vulnerability updates will be session specific. Change in vulnerability will not affect the base table. The system will request the user to select one of the vulnerability types from the Vulnerability menu to update the vulnerability function.

Details of vulnerability functionalities are explained in below sections.

Sub functionality of manage vulnerability

The various sub functionalities of the manage vulnerability functionality and their status are shown in the below table:

Sub Functionality	Descriptions	Status
Manage Aggregated Vulnerability	User can Manage the vulnerability of Aggregated exposure based on Cyclone /Surge/Flood Hazards.	Done
Manage Site-specific vulnerability	User can Manage the vulnerability of Site-specific exposure based on Cyclone /Surge/Flood Hazards.	Done
Manage crop vulnerability	Update the crop vulnerability	In process
Manage population vulnerability	Update population vulnerability at different hazards	In process

6.3.2.6.1 Manage Aggregated Vulnerability

In Manage Aggregated Vulnerability, user can perform the following functionality:

- User can Search vulnerability of any structure type building.
- User can view the vulnerability of any structure type.
- User can update damage functions of any structure type based on cyclone, flood, and storm surge hazards.

6.3.2.6.2 Manage Site-specific Vulnerability

In Manage Site-specific vulnerability user can perform the following functionality

- User can filter damage functions of site-specific assets like transport, utilities etc. based on cyclone, flood, and storm surge hazards.
- User can view the damage functions of site-specific assets.
- User can update damage functions of site-specific assets.
- All the changes in vulnerability will be user specific.

6.3.2.6.3 Manage Crop Vulnerability

Sub functionality of Manage Crop Vulnerability is given below:

- User can search vulnerability of different types of crops.
- User can view the vulnerability of crops based on cyclone, flood, and storm surge hazards.
- User can update vulnerability of different crops.
- All vulnerability changes will be user specific.

6.3.2.6.4 Manage Population Vulnerability

Sub functionality of Manage Population Vulnerability is given below:

- User can search vulnerability of male, female, and children population.
- User can view the vulnerability of male, female and children population based on cyclone, flood, and storm surge hazards.
- User can update Population vulnerability.

- All vulnerability changes will be user specific.

6.3.2.6.5 Manage Hotspot Vulnerability

- User can filter hotspot vulnerability based on cyclone, flood, and storm surge hazards.
- User can view Hotspot vulnerability.
- User can update the hotspot vulnerability functions at hazard level.
- All updates will be user specific.

Use case Scenario of Manage Vulnerability

As given in the below figures, user can update the aggregated vulnerability based on type of hazard. Change in vulnerability will be user specific.

As an example, user selects the menu item "Update Aggregated Vulnerability". In the dialog box, user has to perform the below operations:

1. User will be given the option to choose the type of hazard. The various hazards will be Cyclone, Flood, and Storm surge.
2. After selecting the hazard, user has to select the structure against which vulnerability/ damage functions have to be updated.
3. Depending on the type of hazard selected, vulnerability details will be displayed under "Search results for edit vulnerability" heading, which can be easily modified by performing click operations.
4. Once the user updates the values, user will be given with the option to click the Save button to save the changes made. After the values are successfully updated, an appropriate message will be displayed.

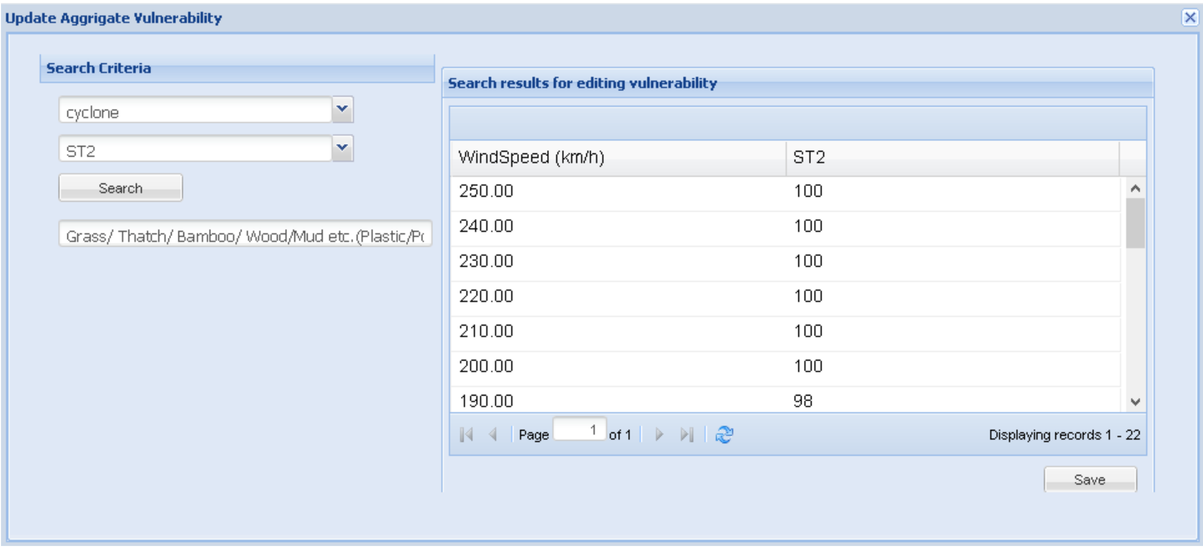


Figure 6-16: Manage Aggregated Vulnerability

User can update the vulnerability of site-specific exposure based on cyclone /surge/flood hazards. As an example, user selects the menu item "Update Site-specific Vulnerability". In the dialog box, user has to perform the below operations:

1. User will be given the option to choose the type of hazard. The various hazards will be cyclone, flood, and storm surge.
2. After selecting the hazard, user has to select the category of exposure like infrastructure, transport, or utility.
3. Then user has to select type of exposure based on category.

4. Depending on the type of hazard selected, vulnerability details will appear under "Search results for edit vulnerability" heading, which can be easily modified by performing click operations.
5. Once user updates the values, user will be given the option to click the Save button to save the changes made. After the values are successfully updated, an appropriate message will be displayed.

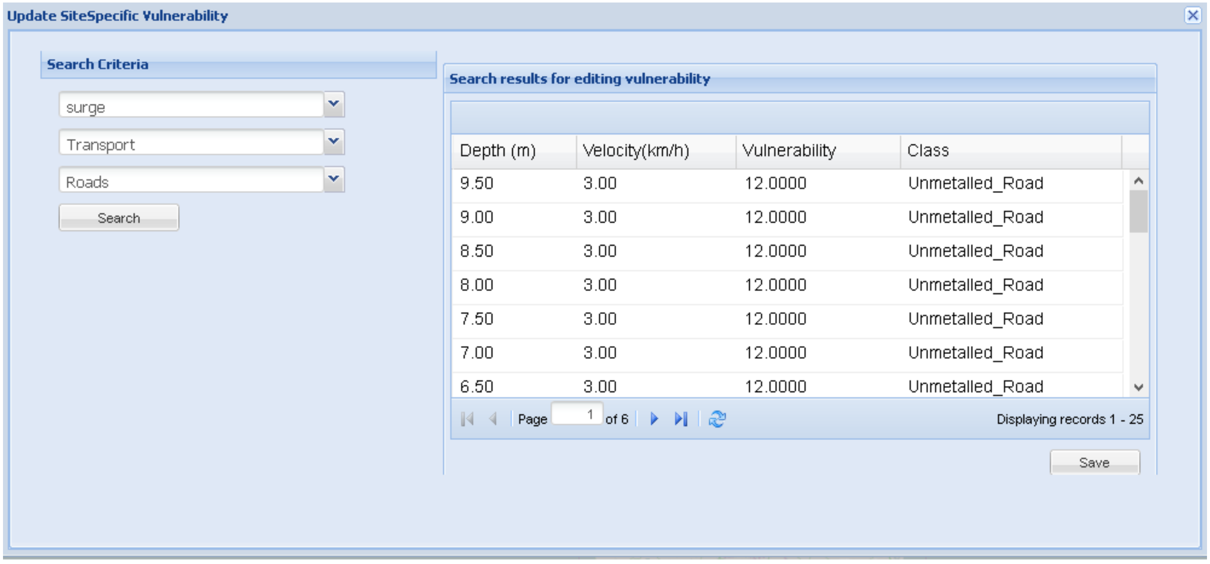


Figure 6-17: Manage Site-specific Vulnerability

Remarks:

The progress of the web atlas corresponding to the tasks that are in process and the functionalities corresponding to risk assessment will be shared as a part of the next deliverable.

6.3.3 Test Case Design

RMSI is a CMMI certified organization and follows a very robust and detailed process to ensure quality of the development. Throughout the project development phase, testing will act as an integral part of the development.

RMSI will carry out the following activities in this step:

Test plan creation:
A test plan will be documented stating the scope and the activities, features to be tested, the allocation of testing tasks, test designing, and entry and exit criteria. The primary purpose of the test plan would be to verify and ensure that the developed atlas meets its design specifications and other requirements. The testing would be performed keeping in mind the various aspects of user and the views created based on the identified users, the performance of the application etc.

***Test Case Preparation*:**
The purpose of preparing test cases is to have a documented way of validating specified functionality in a structured and exhaustive manner. Test case preparation will involve the following activities:

- Study of Software Requirement Specifications document
- Documenting test cases detailing the steps to carry out to validate specified functionalities
- Review of test cases to ensure adequate coverage

Test cases would be created for each module – Summary view, map view and viewing atlas.

Test Environment Preparation:

The output of this step will be a well-isolated environment suitable for system testing.

Test Case Execution and Defect Tracking:

This step involves performing the actual testing of the system and includes performing the following activities: Test site links, Execute test cases to test Business logic and functional requirements, Test overall site, Test template with target browsers, and Logging of defects found in a defect tracking tool and assignment of defects to appropriate developer for rectification. The output of this step will be a test report giving details on defects validated and new defects found with their severity and priority.

Some of the test cases are shown below:

Functionality/ Module	Sub Module/ Functionality	Test Case ID	Test Case	Test Environment--OS/Browser	Expected Results	Actual Result
Required fields	All the modules wherever applicable	1	Leave the compulsory field blank.	Google chrome ,IE & Mozilla Firefox	Screen requiring data entry should be marked with asterisk or proper message should be generated if any required box is left blank.	
Toolbar items	All the modules wherever applicable	2	Click all the toolbar items individually.	Google chrome ,IE & Mozilla Firefox	Every tool item should perform its work or if not a message should be there.	
Font type and font size	All the modules wherever applicable	3	Check for the font size, type and color of the text and images in the application as well as in the report.	Google chrome ,IE & Mozilla Firefox	Font size should not be very large or small. Also image color should be bright and clearly visible.	
	All the modules wherever applicable	4	Check for the heading , title and layer names in the application.	Google chrome ,IE & Mozilla Firefox	Heading, title and layer names should be consistent.	
Onscreen instructions	All the modules wherever applicable	5	Hover mouse over the toolbar items.	Google chrome ,IE & Mozilla Firefox	A brief description of that toolbar item should be there.	
Icons	All the modules wherever applicable	6	Check for the consistency of icons in the app.	Google chrome ,IE & Mozilla Firefox	Icons used in the application (reports & homepage) should be consistent, of same size and clearly visible.	
Controls	All the modules wherever applicable	7	Check for size of various	Google chrome ,IE & Mozilla Firefox	Controls if enabled should work and should be of same	

Functionality/ Module	Sub Module/ Functionality	Test Case ID	Test Case	Test Environment--OS/Browser	Expected Results	Actual Result
			buttons, checkbox, dropdown if any and their names.		size and their names should be meaningful and they should be properly aligned.	
Dialog box consistency	All the modules wherever applicable	8	Open dialog boxes and check for various controls on it.	Google chrome ,IE & Mozilla Firefox	Various controls (if any) should not have save/ok on one screen and cancel on other.	
Home page						
	Layer	9	Check for the layer's list.	Google chrome ,IE & Mozilla Firefox	The layers should be as per study area.	
Layers		10	Click on checkbox corresponding to each layer one at a time or more than one.	Google chrome ,IE & Mozilla Firefox	The layer checked should be visible on the map window.	
		10	Compare the legend of layer with the map displayed.	Google chrome ,IE & Mozilla Firefox	The color formation should match with the legend of the selected layer as per defined range.	
Report						
		11	Check for the contents displayed in the report.	Google chrome ,IE & Mozilla Firefox	The contents displayed in the report should be correct and consistent.	
		12	Check for page numbers in the report.	Google chrome ,IE & Mozilla Firefox	Page number should be there at every page.	
		13	Check for the alignment of text in report.	Google chrome ,IE & Mozilla Firefox	Text should be clearly aligned.	
		14	Check for the export option in report.	Google chrome ,IE & Mozilla Firefox	Report should be capable of exporting into pdf and excel format.	
		15	Export the report in pdf and excel.	Google chrome ,IE & Mozilla Firefox	Report should get saved in excel and pdf format.	
	Data	16	Check for the data displayed in results	Google chrome ,IE & Mozilla Firefox	Data displayed in results dialog should match with the database.	

Functionality/ Module	Sub Module/ Functionality	Test Case ID	Test Case	Test Environment--OS/Browser	Expected Results	Actual Result
			window.			
Performance Testing						
	Response time	17	Generate each of the report one at a time and note the response time.	G. Chrome, IE and Mozilla Firefox	Report should get generated within 10-15 sec.	
	Stress					
		18	Provide continuous load on the data, application.	Google chrome ,IE & Mozilla Firefox	There should not be any breakdown while loading any data and generation of reports.	

6.4 Testing

6.4.1 Quality Assurance

As a part of software development life cycle, system has to undergo a testing phase in order to ensure the quality as well as the efficiency of the overall software. Software has to pass through various levels of testing. Some of which are:

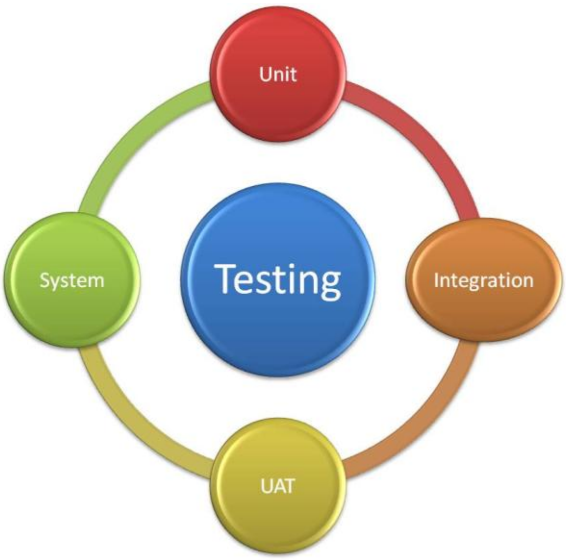


Figure 6-18: Types of testing

a) **Unit testing**

Unit testing refers to testing of the individual units of source code together with associated data and procedures to determine whether they can be used. As a part of development, unit testing of the various modules developed so far as explained in the above (section) has been done. The various activities that have been done as a part of the unit testing includes code analysis, analysis of the flow of data and the peer-review of the code. The limitation with the unit testing is that it does not catch the integration or system level errors. Thus, the integration testing of the application is required.

b) Integration testing

It refers to the testing of modules that are unit tested and have been grouped together to be further used for system testing. Integration testing of the modules that are inter- related has been done.

c) System testing

The objective of system testing exercise is to validate that the software built conforms to functional and non-functional requirements specified in Software Requirement Specifications so that it works as expected. Thus, software testing ensures the quality of product built.

To ensure that adequate effort is made towards producing quality software, a separate team for system testing comprising of full-time test engineers will be formed. Iterative builds will be released to testing team.

d) **Non-functional testing:** The purpose of this step is to test whether the portal meets the non-functional requirements including response time, ***throughput and load***. It may involve one or more of the following activities: Recording of test scripts, simulating load on system using the test scripts, and taking measurements of response time. The output of this step will be test report detailing the measurements recorded and identification of potential areas of bottlenecks.

User Acceptance Testing: The purpose of User Acceptance Testing is to establish whether the system developed meets the expectations of the system users or not. This will involve carrying out of following activities: Deployment of system at the operation environment for testing by its users, Execution of user acceptance test cases by the users, and Reporting of defects/issues by users and fixing of the same by RMSI. The output of this step will be issuance of acceptance certificate by the client.

7 References

Ahmed, F., Rafii, M.Y., Ismail, M.R., Juraimi, A.S., Rahim, H.A., Asfaliza, R. and Latif, M. A. (2013). Waterlogging Tolerance of Crops: Breeding, Mechanism of Tolerance, Molecular Approaches, and Future Prospects, BioMed Research International, vol. 2013, Article ID 963525, 10 pages, doi:10.1155/2013/963525

Airport Technology.com, (*http://www.airport-technology.com/projects/indira-gandhi-international-airport-terminal-3/*)

All India Report on 19th Livestock Census, 2012

Andhra Pradesh Pollution Control Board, (http://www.appcb.ap.nic.in/main/index_flat1.php, http://www.appcb.ap.nic.in/aboutus/list_industries.html)

Andhra Pradesh Power Generation Corporation, http://www.apgenco.gov.in/files/307.pdf),2015

Andhra Pradesh Tourism Development Corporation, (http://www.aptdc.gov.in/heritagespots.html), 2015

Andhra Pradesh Road Development Corporation (http://www.aprdc.in/projects.htm) 2015

Andhra Pradesh Municipal Asset Valuation Methodology Manual, May2010

Applied Technology Council; California, 1985

Assessment of vulnerability to cyclones and floods in Odisha, India: a district-level

Barry E. Flanagan et al 2011, Cutter, S.L and C. Finch. 2008, Cutter et al, 2000

Bharat Sanchar Nigam Limited,(*http://www.stp.bsnl.co.in/tender/LIMITEDTENDER_DEOFP1GTR_160813_190813.pdf*)

Boyer, J. S. (1982). Plant productivity and environment (crop genetic improvement). Science, vol. 218, no. 4571, pp. 443–448

Business standard, Mihir Mishra & Devika Benarjee, 10 August 2010 (http://www.business-standard.com/article/economy-policy/nhai-plancom-differ-on-cost-of-4-lane-highways-110081000072_1.html),

Capital Costs Benchmarks for Distribution Business, March, 2010

Cement Concrete roads vs Bituminous roads - A cost Analysis, (*http://pmgsy.nic.in/downloads/10janjun06_eng.pdf*),

Census of India, (*http://www.censusindia.gov.in/*), (http://www.censusindia.gov.in/DigitalLibrary/Tables.aspx), 2011

Central Public Works Department, (http://cpwd.gov.in/newsitem/latestnewspdf/PAR2012.pdf) , 2012

Centre International de Recherche sur l'Environnement et le Développement (CIRED), Stéphane Hallegatte

Crawford, R.M.M. and Braendle, R. (1996). Oxygen deprivation stress in a changing environment. Journal of Experimental Botany, Vol. 47, No. 295, pp. 145-159.

Cutter et al. 2003, Satu Kumpulainen, 2006

Damage Assessment from Storm Surge to Coastal Cities: Lessons from the Miami Area, Elisabetta Genovese

Directorate General, Factory Advice Service and Labor Institutes (http://www.dgfasli.nic.in/publication/reports/orissa/..\orissa\chapter4.html), Manufacturing Activities Covered under the Factories Act & Boilers Act

Economic survey 2012-13 Planning & Coordination Department, Govt. Of Odisha http://www.odisha.gov.in/pc/Download/Economic_Survey_2012_13.pdf

Essar ports, (http://www.essar.com/article.aspx?cont_id=3DQlvpfK228=), Des 13, 2013

Herath, S. (2003). Flood Damage Estimation of an Urban Catchment Using Remote Sensing and GIS. International Training Program on Total Risk Management. Pp. 55. http://www.adrc.asia/publications/TDRM2003June/10.pdf

Housing Damage in Windstorms and Mitigation for Australia; John Ginger, David Henderson, mark Edwards and John Holms; Cyclone testing Station, James Cook University

Housing Damage in Windstorms and Mitigation for Australia - Craig Arthur, Anthony Schofield and Bob Cechet from Geoscience Australia. The Australian Journal of Emergency Management, Vol. 23 No. 4, November 2008. https://www.em.gov.au/Documents/AJEM_Nov08_Arthur.PDF

Huke, R. E. and Huke, E. H. (1997). Rice Area by Type of Culture South Southeast, and East Asia a Revised and Updated Database, International Rice Research Institute, Los Banos, Philippines.

India Infrastructure Report, (http://www.iitk.ac.in/3inetwork/html/reports/IIR2007/10-Rural%20Housing.pdf), 2007

Indian Meteorological Department (http://www.imd.gov.in/services/cyclone/impact.htm).

International Railway Equipment Exhibition and Conference, (*http://www.ireeindia.org/RE%20Booklet.pdf*)

Krejcie, et al 1970, Xu, Gang 1999

Meenakshi Group of Companies, (http://www.meenakshigroup.com)

Maa Durga Thermal Power Company Limited, (*http://www.mtpcl.in/*)

Ministry of Education (Civil Engineering Department)

Mohanty, H. K. and Khush, G. S. (1985). Diallel analysis of submergence tolerance in rice, Oryza sativa L. Theoretical and Applied Genetics, vol. 70, no. 5, pp. 467–473.

National Highways Authority of India, (http://www.nhai.org/completednh2.asp), 2015

Northern Railway, (*http://www.nr.indianrailways.gov.in/view_detail.jsp?lang=0&dcd=3265&id=0,4,268*), 02/12/2013

National Cyclone Risk Mitigation Project,(http://ncrmp.gov.in), 2015

Odisha State Pollution Control Board, (http://www.orissapcb.nic.in/industrystat.asp), 2015

Odisha State Disaster Management Authority, (http://www.osdma.org)

Open Street Map, (www.openstreetmap.org), 2015

Odisha Culture Website, (http://www.orissaculture.gov.in/Heritage.asp) culture, heritage, fairs & festivals

Planning commission of India, (http://planningcommission.gov.in/aboutus/committee/wrkgrp12/transport/report/wg_cen_roads.pdf), 2015

Pradhan Mantri Gramin Sadak Yojna, (*http://omms.nic.in/Home/HomePage/*), (http://pmgsy.nic.in/downloads/10janjun06_eng.pdf) 2015

Power Plant in Odisha, (https://en.wikipedia.org/wiki/List_of_power_stations_in_India), power plants.

Public Works Department, (https://pwddelhi.com/UI/Home/SectorWiseReport.aspx?enc=9J3T0Ky+opEjCrT08q8UfA==), 2015

Rathore, T. R. and Warsi, M. Z. K. (1998). Production of maize under excess soil moisture (waterlogging) conditions in Proceedings of the 2nd Asian Regional Maize Workshop PACARD, Laos Banos, Philippines..

R. Mallikarjuna Reddy, R. Nageshwar Rao, M. Gopinath Reddy;August 2012 Livestock Development in Andhra Pradesh: Status and Potential

Revenue Disaster Management, Government of Andhra Pradesh, http://disastermanagement.ap.gov.in/website/shelters.htm

Socio Economic Survey 2014-2015 (http://www.ap.gov.in/socio/Annexure.pdf)

Spectrum Power Generation Limited, (http://www.spgl.co.in/),2015

US Energy Information System,(http://www.eia.gov/todayinenergy/detail.cfm?id=10611)-

World Geo Database, (*www.geodeg.com*),*2015*

Yourarticlelibrary.com, (http://www.yourarticlelibrary.com/india-2/pipeline-6-major-pipelines-of-india/19721/), 6 Major Pipelines of India

Collaku, A. and Harrison, S. A. (2002). Losses in wheat due to waterlogging. Crop Science, vol. 42, no. 2, pp. 444–450.

Musgrave, M. E. and Ding, N. (1998). Evaluating wheat cultivars for waterlogging tolerance," Crop Science, vol. 38, no. 1, pp. 90–97.

http://emergencypreparedness.cce.cornell.edu/disasters/Documents/PDFs/Dealing%20with%20Flooded%20Vegetable%20Fields.pdf

http://www.ap.gov.in/socio/chapter_5_Agriculture%20and%20Allied%20Activities.pdf

8 Annex 1: Detailed Exposure Data

8.1 Detailed Exposure data of Andhra Pradesh

Table 8-1: District-wise distribution of population

District	Male Population	Female Population	SC Population	ST Population	Total Population
East Godavari	19,59,399	19,68,690	7,58,972	27,729	39,28,089
Guntur	9,33,279	9,47,228	4,32,340	78,675	18,80,507
Krishna	8,92,822	8,89,283	3,47,333	34,762	17,82,105
Prakasam	6,33,552	6,35,284	2,81,377	70,229	12,68,836
Sri Potti Sriramulu Nellore	9,77,048	9,63,504	4,26,755	1,94,923	19,40,552
Srikakulam	8,10,059	8,23,536	1,20,672	44,280	16,33,595
Vishakhapatnam	12,61,172	12,46,344	2,21,597	24,865	25,07,516
Vizianagaram	92,287	91,256	15,463	993	1,83,543
West Godavari	12,49,370	12,56,986	4,38,589	22,315	25,06,356
Grand Total	**88,08,988**	**88,22,111**	**30,43,098**	**4,98,771**	**1,76,31,099**

Table 8-2: District-wise distribution of population based on literacy and age

District	Total Number of Literate Persons	Total Number of Illiterate Persons	Total Population Under 15 age group	Total Population over 60 age group
East Godavari	26,30,597	12,97,467	9,47,935	3,96,724
Guntur	12,13,918	6,66,601	4,56,439	2,02,931
Krishna	11,96,320	5,85,758	4,13,300	2,54,614
Prakasam	7,90,542	4,78,301	3,29,424	1,33,625
Sri Potti Sriramulu Nellore	12,41,656	6,98,896	4,68,772	1,91,368
Srikakulam	9,43,235	6,90,354	4,12,148	1,83,003
Vishakhapatnam	17,21,729	7,85,804	5,97,196	2,47,560
Vizianagaram	84,013	99,533	46,541	21,160
West Godavari	17,49,554	7,56,821	5,89,886	2,73,742
Grand Total	**1,15,71,564**	**60,59,535**	**42,61,641**	**19,04,727**

Table 8-3: District-wise distribution of Census houses based on uses

District	Residential	Commercial	Industrial	Educational Institutes	Health Facilities	Religious Places
East Godavari	10,87,348	1,03,527	7,715	6,224	2,173	11,032
Guntur	5,08,742	72,673	5,695	2,747	1,167	5,744
Krishna	4,95,158	73,989	5,466	3,069	1,583	6,191
Prakasam	2,78,654	48,559	5,397	1,851	965	3,980
Sri Potti Sriramulu Nellore	5,09,404	70,845	5,487	3,421	1,578	6,055
Srikakulam	4,28,968	63,940	2,909	3,323	1,539	4,580
Vishakhapatnam	7,16,989	78,031	5,357	1,686	908	3,146
Vizianagaram	46,668	5,372	958	365	94	473
West Godavari	6,91,802	75,095	5,602	3,840	1,701	8,065
Grand Total	**47,63,733**	**5,92,031**	**44,586**	**26,526**	**11,708**	**49,266**

Table 8-4: Estimated area for different housing types (in sq. km.)

District	Residential Area	Commercial Area	Industrial Area	Educational Institute	Health Facilities	Religious Places
East Godavari	174.50	27.80	17.90	5.3	0.4	0.5
Guntur	131.20	18.10	4.70	2.1	0.2	0.2
Krishna	172.20	19.50	6.90	2.0	0.3	0.3
Prakasam	89.60	14.10	3.60	1.5	0.2	0.2
Sri Potti Sriramulu Nellore	139.20	15.50	5.50	3.2	0.3	0.3
Srikakulam	69.90	12.10	2.20	2.1	0.2	0.2
Vishakhapatnam	89.10	11.50	21.20	1.7	0.3	0.1
Vizianagaram	8.10	1.00	0.70	0.2	0.0	0.0
West Godavari	143.00	28.10	8.80	2.7	0.2	0.3
Grand Total	**1,016.80**	**147.70**	**71.50**	**20.9**	**2.1**	**2.1**

Table 8-5: Classification of structure based on wall and roof combination

Sl. No.	Building Category	Structural Types (combination of major wall and roof materials)
1	ST1	Grass/Thatch/ Bamboo/Wood/Mud etc. used as roof in combination of Grass/thatch/bamboo etc. as wall material
2	ST2	Grass/ thatch/ bamboo/ wood/ plastic/ polythene etc. used as roof material in combination of Mud/ unburnt brick and stone not packed with mortar as wall materials
3	ST3	Grass/Thatch/ Bamboo/Wood/Mud etc. with material of wall Wood
4	ST4	Grass/ thatch/ bamboo/ wood/ plastic/ polythene etc. used as roof material in combination of burnt brick/ stone packed with mortar/concrete as wall materials
5	ST5	Plastic/ Polythene roof with material of wall Grass/thatch/bamboo etc.
6	ST6	Hand made tiles/ machine made tiles/burnt bricks/stone/slate/concrete used as roof material in combination of Grass/thatch/bamboo etc. as wall material
7	ST7	Hand made tiles/ machine made tiles used as roof material in combination of Mud/unburnt brick/stone not packed with mortar as wall material
8	ST8	Hand made tiles/ machine made tiles used as roof material in combination of stone packed with mortar/burnt brick/concrete as wall material
9	ST9	Hand made tiles/ machine made tiles/burnt bricks/stone/slate/concrete used as roof material in combination of wood as wall material
10	ST10	Burnt bricks/stone/slate used as roof material in combination of Mud/unbrunt brick as wall material
11	ST11	Burnt bricks/stone/slate used as roof material in combination of Stone packed with mortar/burnt brick/concrete as wall material
12	ST12	G.I./Metal/Asbestos sheets with material of wall Grass/thatch/bamboo etc.
13	ST13	G.I./Metal/Asbestos sheets used as roof material in combination of Mud/unburnt brick/Stone not packed with mortar as wall material
14	ST14	G.I./Metal/Asbestos sheets with material of wall Wood
15	ST15	G.I./Metal/Asbestos sheets with material of wall G.I./metal/asbestos sheets with material of wall
16	ST16	G.I./Metal/Asbestos sheets used as roof material in combination of Stone packed with mortar/ burnt brick/ concrete as wall material
17	ST17	Concrete used as roof material in combination of Mud/unburnt brick/Stone not packed with mortar as wall material
18	ST18	Concrete used as roof material in combination of Burnt brick/Stone packed with mortar/Concrete as wall material
19	ST19	Plastic/ Polythene used as roof material in combination of Wood wall material
20	ST20	Plastic/ Polythene used as roof material in combination of Stone not packed with mortar wall material
21	ST21	Burnt Brick used as roof material in combination of Stone not packed with mortar as wall material
22	ST22	Stone/Slate used as roof material in combination of Stone not packed with mortar as wall material
23	ST23	Plastic/ Polythene used as roof material in combination of Mud/unburnt brick as wall material
24	ST24	Plastic/ Polythene used as roof material in combination of Stone packed with mortar as wall material
25	ST_Other	Any Other

Table 8-6: District-wise estimated exposure value for different houses by occupancy and uses (in crores)

District	Residential	Commercial	Industrial	Educational Institute	Health Facilities	Religious Places
East Godavari	142,330	4,998	6,266	7,636	491	434
Guntur	57,841	3,163	4,082	3,020	241	226
Krishna	45,152	2,685	4,029	2,909	393	242
Prakasam	36,090	2,813	3,549	2,107	263	159
Sri Potti Sriramulu Nellore	72,573	3,675	3,822	4,710	379	241
Srikakulam	55,687	2,943	1,925	2,999	268	181
Vishakhapatnam	200,463	7,013	4,641	2,529	499	132
Vizianagaram	2,621	148	636	266	13	18
West Godavari	83,554	3,253	4,495	3,906	333	316
Grand Total	696,311	30,691	33,445	30,081	2,880	1,950

Table 8-7: District-wise estimated length for different types of roads (in KM)

District	Major Road	Minor Road	National Highway	Other Road	State Highway	Grand Total
East Godavari	335.8	2,284.7	196.3	4,705.5	164.3	7,686.7
Guntur	153.2	1,442.4	85.5	2,725.1	114.9	4,521.1
Krishna	192.1	1,965.9	230.9	2,281.0	-	4,669.7
Prakasam	84.2	1,029.4	141.1	2,585.7	50.8	3,891.2
Sri Potti Sriramulu Nellore	280.2	1,398.4	165.8	5,131.3	43.0	7,018.5
Srikakulam	88.1	1,193.4	211.2	2,938.6	92.9	4,524.2
Vishakhapatnam	305.0	585.4	105.0	2,723.9	42.3	3,761.7
Vizianagaram	-	178.2	34.6	360.3	10.3	583.4
West Godavari	182.5	1,603.4	191.4	3,252.1	111.7	5,341.1
Grand Total	1,621.0	11,681.1	1,361.7	26,703.5	630.3	41,997.5

Table 8-8: District-wise estimated exposure value for different types of roads (in crores)

District	Major Road	Minor Road	National Highway	Other Road	State Highway	Grand Total
East Godavari	1,679.2	571.2	1,903.8	1,741.1	905.4	6,800.7
Guntur	765.9	360.6	829.7	1,008.3	633.1	3,597.5
Krishna	960.3	491.5	2,239.3	844.0	-	4,535.0
Prakasam	420.9	257.3	1,368.7	956.7	280.1	3,283.7
Sri Potti Sriramulu Nellore	1,400.8	349.6	1,608.0	1,898.6	236.7	5,493.7
Srikakulam	440.5	298.3	2,048.5	1,087.3	512.0	4,386.6
Vishakhapatnam	1,525.0	146.3	1,018.5	1,007.9	233.3	3,931.0
Vizianagaram	-	44.6	335.3	133.3	56.7	569.9

District	Major Road	Minor Road	National Highway	Other Road	State Highway	Grand Total
West Godavari	912.3	400.8	1,857.0	1,203.3	615.4	4,988.8
Grand Total	8,104.9	2,920.3	13,208.8	9,880.3	3,472.7	37,586.9

Table 8-9: District-wise estimated length and exposure values for different types of rail networks

District	Length in KM			Total Replacement Cost (in crores)		
	Double Line	Single Line	Grand Total	Double Line	Single Line	Grand Total
East Godavari	219.0	101.5	320.5	2,070	639	2,709
Guntur	153.4	110.3	263.6	1,449	695	2,144
Krishna	41.7	112.1	153.8	394	706	1,100
Prakasam	225.1	5.5	230.6	2,127	35	2,162
Sri Potti Sriramulu Nellore	314.0	81.8	395.9	2,968	516	3,483
Srikakulam	259.2	24.3	283.4	2,449	153	2,602
Vishakhapatnam	175.9	233.8	409.8	1,663	1,473	3,136
West Godavari	136.3	86.4	222.7	1,288	544	1,833
Grand Total	1524.6	755.7	2280.4	14,408	4,761	19,169

Table 8-10: District-wise estimated length and exposure values for bridges, airports and seaports

Districts	Bridge		Airport		Seaport	
	Total Length (in KM)	Total Replacement Cost (in crores)	Total Area (in sq km)r	Total Replacement Cost (in crores)	Total Area (in sq km)	Total Replacement Cost (in crores)
East Godavari	46.5	8,838.4			0.9	3,200
Guntur	18.2	3,461.4				
Krishna	16.7	3,168.4				
Prakasam	13.0	2,466.9				
Sri Potti Sriramulu Nellore	17.1	3,244.8			2.9	5.200
Srikakulam	11.4	2,171.4				
Vishakhapatnam	13.3	2,536.2	0.56	2,775	13.8	11,600
Vizianagaram	1.7	328.8				
West Godavari	18.7	3,549.4				
Grand Total	156.7	29,765.8	0.56	2,775	17.6	20,000

Table 8-11: District-wise estimated length and exposure values for different type of electric line

Districts	Total Length (in km)			Total Replacement Cost (in crores)		
	Main Power Line	Other Power Line	Grand Total	Main Power Line	Other Power Line	Grand Total
East Godavari	636.2	2,342.1	2,978.3	39.4	103.8	143.2
Guntur	229.9	1,951.3	2,181.2	14.3	86.4	100.7
Krishna	252.5	1,082.8	1,335.3	15.7	48.0	63.6
Prakasam	375.2	1,326.3	1,701.5	23.3	58.8	82.0
Sri Potti Sriramulu Nellore	973.2	2,235.7	3,208.9	60.3	99.0	159.4
Srikakulam	315.0	1,734.7	2,049.6	19.5	76.8	96.4
Vishakhapatnam	577.4	575.3	1,152.7	35.8	25.5	61.3
Vizianagaram	8.7	225.0	233.7	0.5	10.0	10.5
West Godavari	344.6	1,014.0	1,358.6	21.4	44.9	66.3
Grand Total	3,712.7	12,487.0	16,199.7	230.2	553.2	783.4

Table 8-12: District-wise estimated length and exposure values for oil and gases

District Name	Length (In KM)	Replacement cost (in crores)
East Godavari	240.0	1920.4
Krishna	107.9	862.8
Vishakhapatnam	62.7	501.3
West Godavari	145.9	1167.5
Grand Total	556.5	4452.0

Table 8-13: District-wise estimated length and exposure values for waste water and potable water lines

Districts	Total Waste Water Length (in km)	Total Potable Water Length (in km)	Total Replacement Cost of Waste Water(in crore)	Total Replacement Cost of Potable Water(in crore)
East Godavari	2,535.8	3,853.4	1,267.9	1,926.7
Guntur	2,052.3	2,408.5	1,026.1	1,204.3
Krishna	1,699.9	2,647.9	850.0	1,323.9
Prakasam	1,522.3	2,055.8	761.1	1,027.9
Sri Potti Sriramulu Nellore	1,944.1	4,409.8	972.0	2,204.9
Srikakulam	1,197.0	1,005.1	598.5	502.5
Vishakhapatnam	2,588.6	2,504.8	1,294.3	1,252.4
Vizianagaram	219.1	173.6	109.5	86.8
West Godavari	2,340.5	4,542.7	1,170.2	2,271.3

Districts	Total Waste Water Length (in km)	Total Potable Water Length (in km)	Total Replacement Cost of Waste Water(in crore)	Total Replacement Cost of Potable Water(in crore)
Grand Total	16,099.6	23,601.6	8,049.8	11,800.8

Table 8-14: District-wise estimated count and exposure values for communication

Districts	Total Count of Landline Connections	Total Count of Mobile Connections	Total Count of Telecommunication Towers	Total Replacement Cost of Landline Connections (in crores)	Total Replacement Cost of Mobile Connections (in crores)	Total Replacement Cost of Telecommunication Towers (in crores)
East Godavari	33,868	334,394	5,390	16.8	24.4	901.8
Guntur	32,004	230,283	3,742	15.9	16.8	653.9
Krishna	36,078	207,999	4,439	17.9	15.2	848.1
Prakasam	11,935	180,606	3,427	5.9	13.2	577.4
Sri Potti Sriramulu Nellore	18,942	250,085	6,235	9.4	18.3	1,096.3
Srikakulam	12,709	181,918	3,486	6.3	13.3	585.5
Vishakhapatnam	29,710	378,728	3,953	14.7	27.6	380.4
Vizianagaram	721	18,895	406	0.4	1.4	78.2
West Godavari	37,065	317,836	3,726	18.4	23.2	667.2
Grand Total	213,032	2,100,744	34,804	105.7	153.4	5,788.6

Table 8-15: District level crop acreage distribution (in hectare)

Type of Crops	Srikakulam	Vizianagarm	Visakhapatnam	East Godavari	West Godavari	Krishna	Guntur	Prakasam	Nellore	Grand Total
Arhar (Tur)	-	-	-	-	-	-	9,890.2	20,288.1	-	30,178.2
Bajra	2,054.8	-	3,316.1	1,393.3	-	-	-	-	-	6,764.2
Coriander	-	-	-	-	2,247.4	-	-	-	-	2,247.4
Cotton(lint)	-	1,553.2	-	6,522.8	2,709.2	21,402.3	46,526.5	10,641.8	1,757.9	91,113.8
Dry chillies	-	-	-	-	-	5,765.5	-	-	-	5,765.5
Groundnut	17,071.0	5,095.4	-	-	-	-	-	-	1,438.0	23,604.4
Maize	-	-	-	1,166.4	1,312.8	-	-	-	-	2,479.1
Masoor	-	-	-	1,334.8	-	5,912.7	11,767.8	16,705.7	-	35,721.0
Mesta	8,556.7	5,371.4	-	-	-	-	-	-	-	13,928.2
Moong	-	-	-	-	-	9,066.9	3,291.9	5,254.4	-	17,613.2
Niger seed	-	-	4,009.3	-	-	-	-	-	-	4,009.3
Others	9,171.9	3,785.9	13,376.0	5,816.8	3,694.7	11,656.1	8,423.7	27,820.3	2,726.6	86,471.9
Ragi	-	-	7,822.7	-	-	-	-	-	-	7,822.7
Rice	1,13,548.0	14,146.1	24,818.2	1,81,483.1	1,58,848.2	1,46,800.7	82,863.1	12,936.2	13,128.7	7,48,572.4
Sesamum	-	1,897.6	-	-	-	-	-	-	1,685.9	3,583.4
Small millets	-	-	4,816.0	-	-	-	-	-	-	4,816.0
Sunflower	-	-	-	-	-	-	-	-	1,515.1	1,515.1
Turmeric	1,792.0	-	-	-	2,138.5	-	-	-	-	3,930.5
Grand Total	1,52,194.5	31,849.6	58,158.2	1,97,717.1	1,70,950.7	2,00,604.2	1,62,763.2	93,646.4	22,252.1	10,90,136.1

Table 8-16: Sub-district level area of mangroves (in sq km)

Sub-districts	Districts	Area in Sq.km
Allavaram	East Godavari	0.10
I Polavaram	East Godavari	10.04
Kakinada	East Godavari	0.71
Kakinada (Urban)	East Godavari	0.03
Karapa	East Godavari	0.03
Katrenikona	East Godavari	5.94
Sakhinetipalle	East Godavari	0.02
Tallarevu	East Godavari	29.19
Uppalaguptam	East Godavari	0.04
Bapatla	Guntur	0.37
Karlapalem	Guntur	0.29
Nizampatnam	Guntur	2.36
Pittalavaripalem	Guntur	0.01
Repalle	Guntur	3.40
Bantummilli	Krishna	0.21
Koduru	Krishna	0.26
Kruttivennu	Krishna	2.08
Machilipatnam	Krishna	3.76
Nagayalanka	Krishna	6.54
Chinna Ganjam	Prakasam	0.01
Kottapatnam	Prakasam	0.00
Ongole	Prakasam	0.04
Allur	Sri Potti Sriramulu Nellore	0.05
Chillakur	Sri Potti Sriramulu Nellore	0.14
Muttukuru	Sri Potti Sriramulu Nellore	0.27
Venkatachalam	Sri Potti Sriramulu Nellore	0.11
Bhimavaram	West Godavari	0.03
Mogalturru	West Godavari	0.06
Narasapur	West Godavari	0.00
Grand Total		66.09

Table 8-17: District level coastal and mangroves area distribution (in sq. km)

District	Coastal Plantation	Mangroves
	Area in (Sq. Km.)	Area in (Sq. Km.)
East Godavari	360.2	496.1
Guntur	76.0	69.2
Krishna	40.5	138.3
Prakasam	249.1	0.5
Sri Potti Sriramulu Nellore	250.0	6.2
Srikakulam	324.3	

District	Coastal Plantation	Mangroves
	Area in (Sq. Km.)	Area in (Sq. Km.)
Vishakhapatnam	268.1	
Vizianagaram	49.0	
West Godavari	49.1	0.9
Grand Total	1666.3	711.3

8.2 Detailed Exposure data of Odisha

Table 8-18: District-wise distribution of population

District	Male Population	Female Population	SC Population	ST Population	Total Population
Baleshwar	11,17,810	10,66,229	4,69,428	1,88,124	21,84,039
Bhadrak	7,26,270	7,12,826	3,14,385	25,887	14,39,096
Cuttack	8,02,298	7,59,779	3,02,443	16,903	15,62,077
Ganjam	6,68,694	6,45,867	2,50,725	22,569	13,14,561
Jagatsinghpur	5,90,934	5,71,731	2,53,755	8,025	11,62,665
Jajpur	5,94,839	5,84,216	3,08,280	33,138	11,79,055
Kendrapara	7,40,939	7,45,831	3,19,734	9,770	14,86,770
Khordha	4,52,870	4,34,447	1,56,181	29,316	8,87,317
Mayurbhanj	1,14,600	1,12,804	26,677	1,09,104	2,27,404
Puri	8,99,679	8,66,393	3,38,013	6,354	17,66,072
Grand Total	67,08,933	65,00,123	27,39,621	4,49,190	1,32,09,056

Table 8-19: District-wise distribution of population based on literacy an age

District	Total Number of Literate Persons	Total Number of Illiterate Persons	Total Population Under 15 age group	Total Population over 60 age group
Baleshwar	15,49,725	6,34,349	6,22,556	2,01,696
Bhadrak	10,42,706	3,96,362	4,05,254	1,37,902
Cuttack	12,30,688	3,31,394	3,70,654	1,65,387
Ganjam	8,59,575	4,54,953	3,60,204	1,26,993
Jagatsinghpur	9,09,108	2,53,560	2,68,130	1,40,827
Jajpur	8,57,575	3,21,490	3,16,115	1,22,249
Kendrapara	11,24,362	3,62,407	3,91,975	1,77,355
Khordha	6,51,692	2,35,623	2,24,701	90,549
Mayurbhanj	1,28,933	98,484	73,475	19,647
Puri	13,43,172	4,22,898	4,33,162	1,96,567
Grand Total	96,97,536	35,11,520	34,66,226	13,79,172

Table 8-20: District-wise distribution of Census houses based on uses

District	Residential	Commercial	Industrial	Educational Institutes	Health Facilities	Religious Places
Baleshwar	4,89,716	1,49,141	3,657	5,026	385	8,287
Bhadrak	2,81,648	1,19,002	2,506	2,857	734	7,075
Cuttack	3,36,514	1,03,757	3,208	2,416	911	5,742
Ganjam	2,80,369	62,170	5,776	2,174	503	3,226
Jagatsinghpur	2,65,818	77,655	2,058	3,086	373	5,880
Jajpur	2,68,504	70,430	20	2,507	295	5,598
Kendrapara	3,40,663	95,188	2,010	3,325	359	6,596
Khordha	1,85,046	48,993	595	1,843	1,203	4,635
Mayurbhanj	52,869	13,121	240	644	63	278
Puri	3,87,149	87,586	3,481	3,469	527	9,363
Grand Total	28,88,296	8,27,043	23,551	27,347	5,353	56,680

Table 8-21: Estimated area for different housing types (in sq. km.)

District	Residential Area	Commercial Area	Industrial Area	Educational Institute	Health Facilities	Religious Places
Baleshwar	276.6	40.9	6.3	3.2	0.1	0.3
Bhadrak	69.4	13.8	1.0	1.8	0.1	0.3
Cuttack	119.7	33.4	3.3	1.9	0.5	0.2
Ganjam	45.1	20.0	6.7	2.2	0.2	0.1
Jagatsinghpur	129.6	31.5	9.2	2.3	0.1	0.2
Jajpur	71.8	19.1	0.4	1.5	0.1	0.2
Kendrapara	103.2	29.5	0.5	1.9	0.0	0.3
Khordha	65.9	14.7	4.8	1.6	0.5	0.2
Mayurbhanj	37.1	6.8	0.2	0.3	0.0	0.0
Puri	85.1	25.4	1.1	2.3	0.2	0.4
Grand Total	1,003.5	235.1	33.5	18.9	1.8	2.4

Table 8-22: Classification of structure based on wall and roof combination

Sl. No.	Building Category	Structural Types (combination of major wall and roof materials)
1	ST1	Grass/Thatch/ Bamboo/Wood/Mud etc. used as roof in combination of Grass/thatch/bamboo etc. as wall material
2	ST2	Grass/ thatch/ bamboo/ wood/ plastic/ polythene etc. used as roof material in combination of Mud/ unburnt brick and stone not packed with mortar as wall materials
3	ST3	Grass/Thatch/ Bamboo/Wood/Mud etc. with material of wall Wood
4	ST4	Grass/ thatch/ bamboo/ wood/ plastic/ polythene etc. used as roof material in combination of burnt brick/ stone packed with mortar/concrete as wall materials
5	ST5	Plastic/ Polythene roof with material of wall Grass/thatch/bamboo etc.
6	ST6	Hand made tiles/ machine made tiles/burnt bricks/stone/slate/concrete used as roof material in combination of Grass/thatch/bamboo etc. as wall material
7	ST7	Hand made tiles/ machine made tiles used as roof material in combination of Mud/unburnt brick/stone not packed with mortar as wall material
8	ST8	Hand made tiles/ machine made tiles used as roof material in combination of stone packed with mortar/burnt brick/concrete as wall material
9	ST9	Hand made tiles/ machine made tiles/burnt bricks/stone/slate/concrete used as roof material in combination of wood as wall material
10	ST10	Burnt bricks/stone/slate used as roof material in combination of Mud/unbrunt brick as wall material
11	ST11	Burnt bricks/stone/slate used as roof material in combination of Stone packed with mortar/burnt brick/concrete as wall material
12	ST12	G.I./Metal/Asbestos sheets with material of wall Grass/thatch/bamboo etc.
13	ST13	G.I./Metal/Asbestos sheets used as roof material in combination of Mud/unburnt brick/Stone not packed with mortar as wall material
14	ST14	G.I./Metal/Asbestos sheets with material of wall Wood
15	ST15	G.I./Metal/Asbestos sheets with material of wall G.I./metal/asbestos sheets with material of wall
16	ST16	G.I./Metal/Asbestos sheets used as roof material in combination of Stone packed with mortar/ burnt brick/ concrete as wall material
17	ST17	Concrete used as roof material in combination of Mud/unburnt brick/Stone not packed with mortar as wall material
18	ST18	Concrete used as roof material in combination of Burnt brick/Stone packed with mortar/Concrete as wall material
19	ST19	Plastic/ Polythene used as roof material in combination of Wood wall material
20	ST20	Plastic/ Polythene used as roof material in combination of Stone not packed with mortar wall material
21	ST21	Burnt Brick used as roof material in combination of Stone not packed with mortar as wall material
22	ST22	Stone/Slate used as roof material in combination of Stone not packed with mortar as wall material
23	ST23	Plastic/ Polythene used as roof material in combination of Mud/unburnt brick as wall material
24	ST24	Plastic/ Polythene used as roof material in combination of Stone packed with mortar as wall material
25	ST_Other	Any Other

Table 8-23: District-wise estimated exposure value for different houses by occupancy and uses (INR in crores)

District	Residential	Commercial	Industrial	Educational Institute	Health Facilities	Religious Places
Baleshwar	11,371.2	2,943.5	2,982.0	4,532.4	142.9	169.3
Bhadrak	5,642.9	3,164.7	1,963.5	2,495.7	179.9	144.5
Cuttack	14,024.5	4,140.4	2,551.5	2,651.6	805.6	117.3
Ganjam	16,501.3	2,751.6	3,879.0	3,134.8	325.9	65.9
Jagatsinghpur	7,261.1	3,010.0	1,633.5	3,315.4	166.8	120.1
Jajpur	5,550.6	2,197.9	115.5	2,081.9	87.0	114.4
Kendrapara	1,272.0	2,439.6	1,371.8	2,684.9	64.6	134.8
Khordha	4,768.9	1,300.8	547.5	2,269.4	658.2	94.7
Mayurbhanj	801.7	192.7	162.0	430.9	11.9	5.7
Puri	10,192.9	2,522.6	2,457.0	3,263.4	259.0	191.3
Grand Total	77,387.1	24,663.8	17,663.3	26,860.5	2,702.0	1,158.0

Table 8-24: District-wise estimated length for different types of roads (in KM)

District	Major Road	Minor Road	National Highway	Other Road	State Highway	Grand Total
Baleshwar	120.8	2,151.7	122.4	1,433.1	66.7	3,894.8
Bhadrak	82.2	1,440.7	39.7	1,387.4	107.4	3,057.3
Cuttack	28.4	1,515.2	21.4	837.7	79.3	2,482.1
Ganjam	60.0	1,619.2	120.9	1,159.6	144.1	3,103.8
Jagatsinghpur	89.4	2,245.7	10.2	1,195.6	102.2	3,643.1
Jajpur	21.3	1,273.2	60.5	887.8	144.2	2,387.1
Kendrapara	197.0	2,218.9	45.2	1,620.3	112.5	4,193.9
Khordha	52.3	1,049.3	86.6	1,020.3	13.3	2,221.8
Mayurbhanj	-	402.7	17.0	260.0	28.0	707.7
Puri	242.4	2,398.5	129.5	2,135.9	86.4	4,992.6
Grand Total	893.7	16,315.1	653.4	11,937.7	884.2	30,684.2

Table 8-25: District-wise estimated exposure value for different types of roads (in crores)

District	Major Road	Minor Road	National Highway	Other Road	State Highway	Grand Total
Baleshwar	603.9	537.9	1,187.6	530.3	367.5	3,227.2
Bhadrak	410.8	360.2	384.9	513.3	591.9	2,261.1
Cuttack	142.0	378.8	208.0	310.0	437.2	1,475.9
Ganjam	300.2	404.8	1,172.7	429.0	794.0	3,100.7
Jagatsinghpur	446.8	561.4	99.2	442.4	563.3	2,113.1
Jajpur	106.7	318.3	586.9	328.5	794.6	2,135.0
Kendrapara	985.1	554.7	438.2	599.5	619.9	3,197.5
Khordha	261.3	262.3	839.5	377.5	73.6	1,814.3
Mayurbhanj	-	100.7	164.5	96.2	154.4	515.8
Puri	1,211.8	599.6	1,256.6	790.3	475.8	4,334.1

District	Major Road	Minor Road	National Highway	Other Road	State Highway	Grand Total
Grand Total	4,468.6	4,078.8	6,338.2	4,417.0	4,872.1	24,174.7

Table 8-26: District-wise estimated length and exposure values for different types of rail networks

Districts	Length in KM			Total Replacement Cost (in crores)		
	Double Line	Single Line	Grand Total	Double Line	Single Line	Grand Total
Baleshwar	85.4	12.7	98.1	807.3	80.1	887.4
Bhadrak	34.1	-	34.1	322.1	-	322.1
Cuttack	18.3	-	18.3	173.1	-	173.1
Ganjam	89.4	6.6	96.1	845.0	41.8	886.8
Jagatsinghpur	74.9	-	74.9	707.6	-	707.6
Jajpur	23.9	-	23.9	225.9	-	225.9
Kendrapara	83.3	-	83.3	787.2	-	787.2
Khordha	4.8	19.7	24.5	45.3	124.1	169.4
Mayurbhanj	40.2	8.3	48.5	379.9	52.2	432.1
Puri	454.3	47.3	501.7	4,293.4	298.3	4,591.7
Grand Total	85.4	12.7	98.1	807.3	80.1	887.4

Table 8-27: District-wise estimated length and exposure values for bridges, airports and seaports

Districts	Bridges		Airports		Seaports	
	Total Length in KM	Total Replacement Cost (in crores)	Total Area (in Sq Km)	Total Replacement Cost in crores	Total Area (in Sq Km)	Total Replacement Cost (in crores)
Baleshwar	16.8	3,193.3				
Bhadrak	6.7	1,274.8				
Cuttack	34.7	6,586.7				
Ganjam	7.4	1,401.1	0.0	86.1	0.3	2,000.0
Jagatsinghpur	11.3	2,140.5			6.2	5,600.0
Jajpur	9.1	1,736.0				
Kendrapara	11.7	2,216.6				
Khordha	0.9	176.2				
Mayurbhanj	1.2	231.6	0.2	826.0		
Puri	12.3	2,333.1				
Grand Total	112.1	21,290.0	0.2	912.1	6.5	7,600.0

Table 8-28: District-wise estimated length and exposure values for different type of electric lines

Districts	Total Length (in Km)			Total Replacement Cost in (crores)		
	Main Power Line	Other Power Line	Grand Total	Main Power Line	Other Power Line	Grand Total
Baleshwar	239.6	1,199.9	1,439.6	14.9	53.2	68.0
Bhadrak	249.2	1,105.9	1,355.1	15.5	49.0	64.4
Cuttack	68.1	638.8	706.9	4.2	28.3	32.5
Ganjam	333.7	1,257.4	1,591.2	20.7	55.7	76.4
Jagatsinghpur	118.5	783.1	901.7	7.3	34.7	42.0
Jajpur	137.8	855.6	993.4	8.5	37.9	46.4
Kendrapara	186.3	1,177.1	1,363.3	11.5	52.1	63.7
Khordha	273.9	757.3	1,031.3	17.0	33.6	50.5
Mayurbhanj	24.1	224.5	248.6	1.5	9.9	11.4
Puri	131.2	1,473.3	1,604.5	8.1	65.3	73.4
Grand Total	1,762.4	9,473.1	11,235.6	109.3	419.7	528.9

Table 8-29: District-wise estimated length and exposure values for oil and gases

District Name	Length (In KM)	Replacement cost (in crores)
Baleshwar	89.5	716.0
Bhadrak	53.5	427.7
Jagatsinghpur	7.2	57.7
Kendrapara	47.8	382.6
Grand Total	198.0	1584.1

Table 8-30: District-wise estimated length and exposure values for waste water and potable water lines

Districts	Total Waste Water Length (in Km)	Total Potable Water Length (in Km)	Total Replacement Cost of Waste Water (in crores)	Total Replacement Cost of Potable Water (in crores)
Baleshwar	765.7	452.5	382.9	226.3
Bhadrak	582.9	100.5	291.5	50.3
Cuttack	683.0	530.1	341.5	265.0
Ganjam	855.4	872.5	427.7	436.3
Jagatsinghpur	574.7	439.2	287.3	219.6
Jajpur	214.8	91.6	107.4	45.8
Kendrapara	435.7	265.9	217.8	133.0
Khordha	322.3	173.6	161.2	86.8
Mayurbhanj	45.1	40.8	22.6	20.4
Puri	885.2	400.7	442.6	200.3

Districts	Total Waste Water Length (in Km)	Total Potable Water Length (in Km)	Total Replacement Cost of Waste Water (in crores)	Total Replacement Cost of Potable Water (in crores)
Grand Total	5,364.7	3,367.5	2,682.4	1,683.7

Table 8-31: District-wise estimated length and exposure values for communications

Districts	Total Count of Landline Connection	Total Count of Mobile Connection	Total Count of Telecommunication Towers	Total Replacement Cost of Landline Connection (in Crores)	Total Replacement Cost of Mobile Connection (in Crores)	Total Replacement Cost of Telecommunication Towers (in Crores)
Baleshwar	14,220	2,10,740	3,367	7.1	15.4	606.7
Bhadrak	6,193	1,39,045	2,460	3.1	10.2	469.5
Cuttack	10,588	1,69,071	1,708	5.3	12.3	250.9
Ganjam	6,864	1,42,772	2,457	3.4	10.4	366.9
Jagatsinghpur	6,522	1,35,002	1,992	3.2	9.9	348.2
Jajpur	5,384	1,01,229	1,435	2.7	7.4	275.8
Kendrapara	4,692	1,59,735	2,729	2.3	11.7	516.6
Khordha	3,527	88,695	1,930	1.7	6.5	318.5
Mayurbhanj	603	12,825	505	0.3	0.9	101.0
Puri	7,432	1,60,640	3,776	3.7	11.7	704.2
Grand Total	66,025	13,19,754	22,359	32.7	96.3	3,958.1

Table 8-32: District level crop acreage distribution (in hectare)

Type of Crops	Mayurbhanj	Baleshwar	Bhadrak	Kendrapara	Jagatsinghpur	Cuttack	Jajpur	Khordha	Puri	Ganjam	Grand Total
Pigeonpea	406.1	-	-	-	-	-	1,428.5	432.5	-	2,442.0	**4,709.2**
Dry ginger	-	538.6	99.1	-	-	-	-	-	-	-	**637.6**
Groundnut	-	1,618.0	-	2,531.1	840.9	1,021.1	6,870.5	-	2,392.2	-	**15,273.8**
HorseGram	-	-	-	-	936.3	1,642.0	-	593.3	1,714.7	-	**4,886.3**
Jute	-	-	142.0	1,017.0	-	-	-	-	-	-	**1,159.0**
Mesta	253.4	-	-	-	-	-	-	-	-	-	**253.4**
Green gram	-	1,957.0	1,908.5	11,889.2	16,148.7	9,229.1	4,314.3	9,243.2	3,184.5	11,228.7	**69,103.3**
Niger seed	308.4	-	-	-	-	-	-	-	-	-	**308.4**
Others	817.6	1,375.5	218.2	825.4	511.1	1,902.0	2,254.8	1,193.3	889.8	4,814.1	**14,802.0**
Ragi	-	-	-	-	-	-	-	-	-	1,301.4	**1,301.4**
Rice	19,973.6	1,91,011.1	1,40,741.6	1,21,272.8	82,128.2	59,523.6	78,790.0	69,772.8	1,45,231.6	63,160.0	**9,71,605.3**
Sesame	-	557.4	-	-	-	-	-	-	-	-	**557.4**
Black gram	148.1	-	1,872.9	6,771.6	2,543.4	6,123.1	5,069.2	1,895.9	6,821.5	1,812.1	**33,057.9**
Grand Total	**21,907.3**	**1,97,057.7**	**1,44,982.4**	**1,44,307.1**	**1,03,108.6**	**79,440.9**	**98,727.4**	**83,131.1**	**1,60,234.3**	**84,758.3**	**11,17,655.0**

Table 8-33: Sub-district level area of mangroves (in sq km)

Sub-Districts	Districts	Area (in Sq.Km.)
Balaramgadi Marine	Baleshwar	2.8
Baleshwar	Baleshwar	2.2
Baliapal	Baleshwar	1.9
Basta	Baleshwar	2.8
Bhograi	Baleshwar	13.0
Singla (p)	Baleshwar	0.9
Soro	Baleshwar	1.1
Bansada	Bhadrak	51.9
Basudebpur	Bhadrak	4.1
Dhamara Marine	Bhadrak	0.1
Naikanidihi	Bhadrak	28.8
Abhyachandpur	Jagatsinghpur	0.7
Balikuda	Jagatsinghpur	17.5
Ersama	Jagatsinghpur	5.0
Paradip	Jagatsinghpur	3.7
Aali	Kendrapara	0.2
Jamboo Marine	Kendrapara	199.3
Mahakalapada	Kendrapara	79.6
Marsaghai	Kendrapara	0.2
Rajkanika	Kendrapara	0.7
Rajnagar	Kendrapara	424.4
Grand Total		840.91

Table 8-34: District level area of coastal plantations and mangroves (Sq.Km.)

	Coastal Plantations	Mangroves
Districts	Area in (Sq. Km.)	Area in (Sq. Km.)
Baleshwar	6.1	24.7
Bhadrak	0.5	84.9
Cuttack	2.4	
Ganjam	147.0	
Jagatsinghpur	1.1	26.9
Jajpur	11.8	
Kendrapara	2.0	704.4
Khordha	105.9	
Mayurbhanj	0.8	
Puri	227.4	
Grand Total	505.0	840.9

8.3 List of talukas in Andhra Pradesh and Odisha in the study area

Table 8-35: Details of talukas, in Andhra Pradesh and Odisha in the study area

State	District	Subdivision	Talukas/Tehsil	Area (Sq Km)	Remarks
	East Godavari		Ainavalli	97.63	
	East Godavari		Alamurui	78.78	
	East Godavari		Allavaram	108.63	
	East Godavari		Amalapuram	79.67	
	East Godavari		Ambajipeta	53.76	
	East Godavari		Anaparthi	58.71	
	East Godavari		Atreyapuram	265.13	
	East Godavari		Bikkavolu	101.38	
	East Godavari		Gollaprolu	128.20	
	East Godavari		I Polavaram	215.52	
	East Godavari		Kadiam	65.85	
	East Godavari		Kajuluru	114.36	
	East Godavari		Kakinada	104.38	
	East Godavari		Kakinada (urban)	7.55	
	East Godavari		Kapileswarapuram	118.74	
	East Godavari		Karapa	104.19	
	East Godavari		Katrenikona	169.76	
	East Godavari		Kottapalle	107.75	
	East Godavari		Kottapeta	85.42	
	East Godavari		Malikipuram	94.17	
	East Godavari		Mamidikuduru	100.10	
	East Godavari		Mandapeta	109.43	
	East Godavari		Mummidivaram	99.18	
	East Godavari		Pamarru	126.54	
	East Godavari		Pedda Gannavaram	114.62	
	East Godavari		Peddapudi	106.00	
	East Godavari		Pithapuram	125.56	
	East Godavari		Rajahmundry Rural	58.65	
	East Godavari		Rajahmundry Urban	32.19	
	East Godavari		Ramachandrapuram	107.72	
	East Godavari		Ravulapalem	95.35	
	East Godavari		Rayavaram	76.60	
	East Godavari		Razole	86.45	
	East Godavari		Sakhinetipalle	120.93	
	East Godavari		Samalkot	146.84	
	East Godavari		Tallarevu	261.25	
	East Godavari		Tondangi	173.74	
	East Godavari		Tuni	216.84	
Andhra Pradesh	East Godavari		Uppalaguptam	119.43	

State	District	Subdivision	Talukas/Tehsil	Area (Sq Km)	Remarks
	Guntur		Amrutaluru	124.48	
	Guntur		Bapatla	265.66	
	Guntur		Bhattiprolu	95.56	
	Guntur		Chebrolu	130.63	
	Guntur		Cherukupalli	97.42	
	Guntur		Duggirala	146.73	
	Guntur		Edlapadu	121.24	
	Guntur		Kakumanu	179.35	
	Guntur		Karlapalem	104.97	
	Guntur		Kollipara	110.93	
	Guntur		Kolluru	117.91	
	Guntur		Mangalagiri	141.37	
	Guntur		Nagaram	142.89	
	Guntur		Nizampatnam	186.42	
	Guntur		Peda Kakani	119.66	
	Guntur		Pedda Nandipadu	141.17	
	Guntur		Pittalavaripalem	71.37	
	Guntur		Ponnuru	172.18	
	Guntur		Repalle	266.80	
	Guntur		Tadepalle	59.70	
	Guntur		Tenali	115.29	
	Guntur		Tsundur	105.50	
	Guntur		Vatticherukuru	116.80	
	Guntur		Vemuru	101.74	
	Krishna		Avanigadda	74.79	
	Krishna		Bantummilli	126.84	
	Krishna		Bapulapadu	222.55	
	Krishna		Challapalle	93.31	
	Krishna		Ghantasala	117.66	
	Krishna		Gudivada	111.64	
	Krishna		Gudlavalleru	125.24	
	Krishna		Guduru	127.60	
	Krishna		Kaikalur	162.51	
	Krishna		Kalidindi	177.48	
	Krishna		Kankipadu	113.07	
	Krishna		Koduru	216.63	
	Krishna		Kruttivennu	184.95	
	Krishna		Machilipatnam	405.72	
	Krishna		Mandavalli	163.47	
	Krishna		Mopidevi	85.03	
	Krishna		Movva	142.38	
	Krishna		Mudinepalle	175.88	

State	District	Subdivision	Talukas/Tehsil	Area (Sq Km)	Remarks
	Krishna		Nagayalanka	417.43	
	Krishna		Nandivada	166.16	
	Krishna		Pamarru	121.14	
	Krishna		Pamidimukkala	119.19	
	Krishna		Pedana	141.30	
	Krishna		Peddaparupudi	96.16	
	Krishna		Totlavalluru	107.45	
	Krishna		Unguturu	145.87	
	Krishna		Vuyyuru	85.44	
	Prakasam		Chinna Ganjam	180.30	
	Prakasam		Chirala	105.12	
	Prakasam		Gudulur	247.37	
	Prakasam		Inkollu	144.81	
	Prakasam		Kandukur	229.81	
	Prakasam		Karamchedu	162.20	
	Prakasam		Kottapatnam	165.96	
	Prakasam		Maddipadu	167.11	
	Prakasam		Nagulaupalapadu	247.21	
	Prakasam		Ongole	203.68	
	Prakasam		Paruchuru	222.85	
	Prakasam		Singarayakonda	111.03	
	Prakasam		Tangutur	201.80	
	Prakasam		Ulavapadu	187.04	
	Prakasam		Vetapalem	92.11	
	Prakasam		Zarugumalli	183.72	
	Sri Potti Sriramulu Nellore		Allur	188.85	
	Sri Potti Sriramulu Nellore		Bogole	182.17	
	Sri Potti Sriramulu Nellore		Chillakur	333.67	
	Sri Potti Sriramulu Nellore		Chittamur	274.46	
	Sri Potti Sriramulu Nellore		Dagadarti	247.80	
	Sri Potti Sriramulu Nellore		Doravarisatram	274.39	
	Sri Potti Sriramulu Nellore		Gudur	248.97	
	Sri Potti Sriramulu Nellore		Indukurupeta	141.52	
	Sri Potti Sriramulu Nellore		Jaladanki	293.75	
	Sri Potti Sriramulu Nellore		Kavali	328.15	
	Sri Potti Sriramulu Nellore		Kodavalur	110.88	

State	District	Subdivision	Talukas/Tehsil	Area (Sq Km)	Remarks
	Sri Potti Sriramulu Nellore		Kota	185.43	
	Sri Potti Sriramulu Nellore		Kovur	87.21	
	Sri Potti Sriramulu Nellore		Manubolu	222.77	
	Sri Potti Sriramulu Nellore		Muttukuru	179.57	
	Sri Potti Sriramulu Nellore		Nayudupeta	6.86	
	Sri Potti Sriramulu Nellore		Nellore	354.36	
	Sri Potti Sriramulu Nellore		Sullurpeta	422.39	
	Sri Potti Sriramulu Nellore		Tada	481.49	
	Sri Potti Sriramulu Nellore		Totapalligudur	155.50	
	Sri Potti Sriramulu Nellore		Vakadu	241.50	
	Sri Potti Sriramulu Nellore		Venkatachalam	302.28	
	Sri Potti Sriramulu Nellore		Vidavalur	165.75	
	Srikakulam		Amudalavalasa	109.79	
	Srikakulam		Echcherla	158.77	
	Srikakulam		Gara	163.53	
	Srikakulam		Ichchapuram	103.19	
	Srikakulam		Kanchili	127.32	
	Srikakulam		Kaviti	114.90	
	Srikakulam		Kotabommali	151.03	
	Srikakulam		Laveru	173.23	
	Srikakulam		Mandasa	223.30	
	Srikakulam		Nandigam	181.94	
	Srikakulam		Narasannapeta	119.54	
	Srikakulam		Palasa	150.27	
	Srikakulam		Polaki	139.36	
	Srikakulam		Ranasthal	187.85	
	Srikakulam		Santbommali	193.27	
	Srikakulam		Sompeta	168.25	
	Srikakulam		Srikakulam	157.65	
	Srikakulam		Tekkal	132.18	
	Srikakulam		Vajrapukotturu	136.23	
	Vishakhapatnam		Achchutapuram	139.36	
	Vishakhapatnam		Bhimunipatnam	130.78	
	Vishakhapatnam		Elamanchili	80.76	
	Vishakhapatnam		Gajuwaka	111.57	
	Vishakhapatnam		Munagapaka	79.04	

State	District	Subdivision	Talukas/Tehsil	Area (Sq Km)	Remarks
	Vishakhapatnam		Nakkapalli	227.29	
	Vishakhapatnam		Paravada	145.86	
	Vishakhapatnam		Payakaraopeta	110.82	
	Vishakhapatnam		Pedagantyada	79.09	
	Vishakhapatnam		Pendurti	111.41	
	Vishakhapatnam		Rambilli	152.23	
	Vishakhapatnam		Sarvasiddhi Rayavaram	166.77	
	Vishakhapatnam		Visakhapatnam (Rural)	131.30	
	Vishakhapatnam		Visakhapatnam (Urban)	97.84	
	Vizianagaram		Bhogapuram	113.95	
	Vizianagaram		Denkada	126.44	
	Vizianagaram		Pusapatirega	150.36	
	West Godavari		Achanta	67.62	
	West Godavari		Akividu	119.51	
	West Godavari		Attili	85.10	
	West Godavari		Bhimadolu	215.27	
	West Godavari		Bhimavaram	193.77	
	West Godavari		Denduluru	184.92	
	West Godavari		Elamanchili	81.52	
	West Godavari		Eluru	233.97	
	West Godavari		Ganapavaram	100.56	
	West Godavari		Iragavaram	79.41	
	West Godavari		Kalla	157.54	
	West Godavari		Kovvuru	99.59	
	West Godavari		Mogalturru	139.08	
	West Godavari		Narasapur	163.86	
	West Godavari		Nidamarru	116.10	
	West Godavari		Palakoderu	92.06	
	West Godavari		Palakollu	86.11	
	West Godavari		Peddapadu	170.67	
	West Godavari		Pentapadu	117.26	
	West Godavari		Penugonda	67.64	
	West Godavari		Penumantra	81.77	
	West Godavari		Peravalli	78.96	
	West Godavari		Poduru	91.39	
	West Godavari		Tanuku	70.28	
	West Godavari		Undi	129.60	
	West Godavari		Unguturu	194.79	
	West Godavari		Viravasaram	90.38	
Odisha	Mayurbhanj		Rasagobindapur	245	Either Discrepancy In

State	District	Subdivision	Talukas/Tehsil	Area (Sq Km)	Remarks
					Tehsil Boundary Or Shape
	Mayurbhanj		Baisinga	263	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Raibania	185	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Jaleswar	192	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Bhograi	212	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Kamarda	141	
	Baleshwar		Baliapal	216	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Singla (p)	207	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Basta	237	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Rupsa	34	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Baleshwar	353	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Sahadevkhunta	8	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Chandipur	91	
	Baleshwar		Balaramgadi Marine	4	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Bampada	22	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Remuna	117	Either Discrepancy In Tehsil Boundary Or Shape

State	District	Subdivision	Talukas/Tehsil	Area (Sq Km)	Remarks
	Baleshwar		Khaira	258	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Soro	521	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Similia	284	Either Discrepancy In Tehsil Boundary Or Shape
	Baleshwar		Bampada	34	Either Discrepancy In Tehsil Boundary Or Shape
	Bhadrak		Bhandari Pokhari	215	
	Bhadrak		Dhamanagar	153	
	Bhadrak		Bhadrak Rural	410	
	Bhadrak		Basudebpur	250	
	Bhadrak		Naikanidihi	262	
	Bhadrak		Tihidi	305	
	Bhadrak		Dhusuri	172	
	Bhadrak		Chandabali	195	
	Bhadrak		Bansada	367	
	Bhadrak		Dhamara Marine	7	
	Kendrapara		Rajkanika	263	
	Kendrapara		Rajnagar	401	
	Kendrapara		Jamboo Marine	239	
	Kendrapara		Aali	223	
	Kendrapara		Pattamundai	307	
	Kendrapara		Kendrapara	12	
	Kendrapara		Kendrapara	221	
	Kendrapara		Nikirai	105	
	Kendrapara		Derabish	83	
	Kendrapara		Patkura	220	
	Kendrapara		Marsaghai	161	
	Kendrapara		Mahakalapada	329	
	Jagatsinghpur		Paradip	61	
	Jagatsinghpur		Paradeep Luck	45	
	Jagatsinghpur		Kujang	148	
	Jagatsinghpur		Abhyachandpur	71	
	Jagatsinghpur		Ersama	269	
	Jagatsinghpur		Tirtol	310	
	Jagatsinghpur		Jagatsinghapur	281	
	Jagatsinghpur		Biridi	115	

State	District	Subdivision	Talukas/Tehsil	Area (Sq Km)	Remarks
	Jagatsinghpur		Naugaon	123	
	Jagatsinghpur		Balikuda	303	
	Cuttack		Mahanga	203	
	Cuttack		Salepur	144	
	Cuttack		Nischintakoili	51	
	Cuttack		Nemalo	92	
	Cuttack		Kishannagar	149	
	Cuttack		Cuttack Sadar	145	
	Cuttack		Gobindpur	82	
	Cuttack		Olatapur	37	
	Cuttack		Niali	206	
	Cuttack		Cuttack Town	121	
	Jajpur		Jajapur	113	
	Jajpur		Jajpur Sadar	158	
	Jajpur		Dharmasala	179	
	Jajpur		Badachana	255	
	Jajpur		Balichandrapur	133	
	Jajpur		Binjharpur	236	
	Jajpur		Bari Ramachandrapur	136	
	Jajpur		Mangalpur	188	
	Khordha		Khordha Sadar	145	
	Khordha		Balipatna	163	
	Khordha		Airfield (kapila Prasad)	30	
	Khordha		Jatani	137	
	Khordha		Jankia (p)	174	
	Khordha		Nirakarpur	61	
	Khordha		Tangi (p)	290	
	Khordha		Balugaon	178	
	Khordha		Banapur	426	
	Puri		Delanga	180	
	Puri		Pipili	206	
	Puri		Nimapara (p)	319	
	Puri		Kakatpur	112	
	Puri		Astaranga	145	
	Puri		Konark	119	
	Puri		Gop	209	
	Puri		Ramachandi	89	
	Puri		Satyabadi	316	
	Puri		Chandanpur	132	
	Puri		Sadar	237	
	Puri		Brahmagiri	357	

State	District	Subdivision	Talukas/Tehsil	Area (Sq Km)	Remarks
	Puri		Gadisagada	114	
	Puri		Krushnaprasad	950	
	Puri		Puri (m)	18	
	Ganjam		Khallikote	355	
	Ganjam		Rambha	238	
	Ganjam		Chatrapur	119	
	Ganjam		Ganjam	71	
	Ganjam		Chamakhandi	103	
	Ganjam		Arjyapalli Marine	18	
	Ganjam		Brahmapur Sadar	189	
	Ganjam		Gopalpur	93	
	Ganjam		Golanthara	256	
	Ganjam		Jarada	329	
	Ganjam		Berhampur	35	

8.4 Field survey photographs

Figure 8-1: Residential buildings in rural areas

Figure 8-2: Residential buildings in urban areas

Figure 8-3: Commercial buildings in rural and urban areas

Figure 8-4: Educational institutes in rural and urban areas

Figure 8-5: Health facilities in rural and urban areas

Figure 8-6: Sample photographs of religious places

Table: Sample photographs of Cyclone shelters places

Figure 8-7: Sample photographs of other type of buildings

Figure 8-8: Sample photographs of bridges

Figure 8-9: Sample photographs of roads and ports

Figure 8-10: Sample photographs of petrol pumps

END OF REPORT