A SCOPING STUDY
PART TWO

The Potential to Promote Climate Smart Agriculture for a Resilient Odisha

Climate Risk Profile for the Agriculture and Allied Sector in Odisha

April 2025

CSTEP

Center for Study of Science, Technology and Policy (CSTEP)

A Scoping Study:
The Potential to Promote Climate Smart Agriculture for a Climate Resilient Odisha

Part 2

Climate Risk Profile for the Agriculture and Allied Sector in Odisha

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EXECUTIVE SUMMARY

Odisha's agricultural and allied sectors, vital to the state's economy, face mounting threats from climate change. These sectors are increasingly exposed and are vulnerable to climate extremes, posing significant risks to livelihoods and food security. This scoping report series aims to identify priority districts for targeted interventions to enhance resilience and sustainability in Odisha's agriculture and allied sectors. The analysis integrates three key components: Resource Use Profiling (RUP), Greenhouse Gas (GHG) Emissions Inventory, and Climate Risk Assessment (CRA) to assess the nature, extent, and intensity of impacts on the sector. By triangulating findings from these components, the study identifies districts with inefficient resource use, high GHG emissions, and severe climate risks to guide the formulation of District-Level Climate Action Plans and the adoption of Climate Smart Agriculture (CSA) practices. The report series is divided into three parts. Part 1 explores RUP and the GHG emissions inventory, Part 2 focuses on the CRA, and the Scoping Study combines insights from Parts 1 and 2 to highlight priority districts for CSA interventions to maximise climate resilience and benefits.

This Climate Risk Assessment report, Part 2 in the scoping study report series, identifies priority districts for targeted interventions to build resilience against three major climate hazards: droughts, floods, and heatwaves. Tropical cyclone risk was incorporated at a later stage of this assessment, as cyclones have been frequently occurring event impacting Odisha. Separate risk assessments were conducted for three cyclone categories based on wind speed: 60–90 km/h, 90–120 km/h, and 120 km/h and above.

Using the IPCC AR5 Risk Assessment Framework (2014), the report evaluates the probability of **hazard** occurrence; the **exposure** of agricultural, livestock, and fisheries assets; and the inherent **vulnerability** of these sub-sectors across Odisha's districts. The findings provide a comprehensive, triangulated analysis to identify districts where climate risks are most acute due to the convergence of high hazard probability, significant asset exposure, and high vulnerability. This information will guide the development of District-Level Climate Action Plans and the promotion of CSA practices.

Key findings:

- **Drought risk:** Southern districts such as Nuapada, Balangir, Mayurbhanj, Malkangiri, Ganjam, Subarnapur, and Sundargarh face significant drought risks.
- **Flood risk:** While overall risk to flood was lower in the state, Kendrapara, Balasore and Bhadrak emerged as the most flood-prone districts, particularly affecting agriculture and livestock. Other districts, including Boudh, Cuttack, Puri, and Jajpur, are also at risk due to their low-lying topography and coastal proximity.
- **Heatwave risk:** Districts like Dhenkanal, Angul, Ganjam, Sundargarh, Mayurbhanj, Keonjhar, and Sambalpur face severe heatwave risks. Deogarh and Sundargarh showed nearly 100% exposure and are particularly vulnerable due to poor access to water and limited adaptive capacity.
- **Tropical Cyclone risk:** Balasore and Mayurbhanj face the highest risk to "severe" and "very severe" tropical cyclones due to a high probability of occurrence, with Balasore's risk amplified by significant exposure of agriculture, livestock, and fisheries assets. Nayagarh and Boudh are most at risk to cyclones with wind speeds of 60–90 km/h, driven by high probability of occurrence and inherent vulnerability.
- **Multi-hazard risk:** Districts such as Sundargarh and Mayurbhanj face compounded risks from multiple hazards, including heatwaves and droughts. Additionally, Balasore and Mayurbhanj face compounded risks from both flooding and severe tropical cyclones. These findings emphasise the need for multi-hazard resilience strategies to effectively address overlapping climate impacts.

By identifying the most at-risk districts in each sub-sector, this assessment provides a critical foundation for prioritising actions that enhance resilience, reduce vulnerabilities and risks, and ultimately support sustainable development in Odisha's agriculture and allied sectors.

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Abbreviations

AHP	Analytical Hierarchy Process
CRA	Climate Risk Assessment
CSA	Climate Smart Agriculture
DEM	Digital Elevation Model
EDI	Effective Drought Index
FAO	Food and Agriculture Organization
UNESCO	United Nations Educational, Scientific and Cultural Organization
FCF	Flood Conditioning Factor
FPO	Farmers Producer Organisation
GDVA	Gross District Value Added
GHG	Greenhouse Gas
GIS	Geographic Information System
GSDP	Gross State Domestic Product
GVA	Gross Value Added
HydroSHED	Hydrological Spatially Enabled Data
ICDP	Insemination Centre Development Project
IFS	Integrated Farming System
IMD	India Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
IPCC AR5	Intergovernmental Panel on Climate Change Assessment Report 5
IPCC AR6	Intergovernmental Panel on Climate Change Assessment Report 6
ISRO	Indian Space Research Organisation
KVK	Krishi Vigyan Kendra
LAC	Livestock Aid Centres
MODIS	Moderate Resolution Imaging Spectroradiometer
MT	Million Tonnes
OSM	Open Street Map
PDN	Percentage Departure from Normal
PDSI	Palmer Drought Severity Index
SAPCC	State Action Plan for Climate Change
SDG	Sustainable Development Goals
SHC	Soil Health Card
SHGs	Self Help Groups
SMAP	Soil Moisture Active and Passive
SPEI	Standardised Precipitation Evapotranspiration Index
SPI	Standardised Precipitation Index
Tmax	Maximum Temperature
UNFCCC	United Nations Framework Convention on Climate Change
VI	Vulnerability Index
GDACS	Global Disaster Alert and Coordination System
RUP	Resource Use Profiling
JRC	Joint Research Centre
NOAA	National Oceanic and Atmospheric Administration

JTWC	Joint Typhoon Warning Center
eTRaP	Ensemble Tropical Rainfall Potential
NASA-GPM	National Aeronautics and Space Administration Global Precipitation Measurement Mission
INFORM	Index for Risk Management
GFS	Global Forecast System
HWRF	Hurricane Weather Research and Forecast
ECMWF	European Center for Medium-Range Forecasts
ICAR	Indian Council of Agricultural Research
Tmax	Maximum Temperature
DA&FE	Department of Agriculture and Farmers' Empowerment
NSA	Net Sown Area
SECC	Socio Economic and Caste Census
SRC	State Relief Commisioner
CRC	Climate Resilience Cell
OUAT	Odisha University of Agriculture & Technology
GSVA	Gross State Value Added

1. Introduction

Odisha, spanning 155,707 sq. km with a 450 km coastline along the Bay of Bengal, is India's eighth-largest state. Its diverse geography features fertile coastal plains, central highlands, and uplands, shaped by major rivers such as the Mahanadi, Subarnarekha, and Brahmani. The state is also home to Chilika Lake, a renowned brackish water lagoon of ecological significance (Geography of Odisha, 2012). Odisha experiences a tropical climate with three distinct seasons—summer, monsoon, and winter—and receives an average annual rainfall of 1,451.2 mm, with 75-80% falling during the southwest monsoon. However, erratic and intense rainfall often leads to floods and droughts, adding to the state's vulnerability (OSDMA, 2024).

Odisha's climate-related risks vary geographically, with coastal areas being highly prone to cyclones and flooding, while inland districts frequently experience droughts and heatwaves. Additionally, parts of the state fall under seismic zones 1 and 2, further exacerbating its vulnerabilities. These climatic and geophysical extremes pose significant challenges to Odisha's economy, particularly to the agriculture and allied sectors, which form the backbone of the state's food security and livelihoods (OSDMA, 2024; IANS, 2023).

Agriculture and Allied Sectors in Odisha

Agriculture remains a cornerstone of Odisha's economy, employing nearly 80-85% of its rural population (Caritas India, 2021). The sector spans diverse agro-climatic zones, with soil types ranging from fertile alluvial soils in the coastal plains to low-fertility soils in the northern plateau. Paddy is the dominant crop, along with horticultural crops, millet, coffee, cashew, and oilseeds (APEDA, 2023).

The state has introduced several policies to address agricultural challenges, including the SAMRUDHI Agriculture Policy 2020, the Shree Anna Abhiyan, and the Odisha Organic Farming Policy.

Livestock is the second-largest contributor to the sector, accounting for 16,7% of Odisha's GSVA in 2023-24, with cattle comprising over 55% of the state's livestock (Odisha Economic Survey, 2023-24). Fisheries, the fastest-growing sub-sector, are supported by Odisha's extensive coastline and river systems. This subsector has recorded an annual growth rate of 13% in recent years and supports over 18 lakh fisherfolk and aquaculture farmers (World Bank, 2021; Annual Activities Report, 2018-19).

Despite its economic significance, Odisha's agriculture faces growing threats from climate extremes such as droughts, floods, and heatwaves. On average, 900,000 hectares of agricultural land are lost annually due to disasters, emphasising the urgency for climate-resilient strategies (Odisha State Action Plan on Climate Change, 2018).

Climate Risks and the Need for Resilience

The increasing frequency and intensity of extreme weather events have exacerbated vulnerabilities across Odisha's agriculture and allied sectors, jeopardising food security and livelihoods. The State Action Plan for Climate Change (SAPCC, 2021-30) highlights the socio-economic impacts of climate change, including water stress and reduced agricultural productivity.

Building resilience in these sectors is essential for ensuring sustainable growth and food security. Climate Smart Agriculture (CSA) offers a practical solution by enhancing resource efficiency, improving productivity, and reducing greenhouse gas emissions. Agriculture accounts for approximately 25% of Odisha's total GHG emissions, presenting significant opportunities to mitigate emissions through CSA practices (CII, 2015). These interventions not only support climate adaptation but also align with the state's carbon reduction goals, ensuring long-term sustainability for farmers and the agricultural economy. In this context, integrating CSA practices into Odisha's agricultural framework is critical to addressing climate risks, safeguarding livelihoods, and promoting a resilient, sustainable future for the state's rural communities.

The steps towards advancing agriculture resilience and sustainability in Odisha is detailed in (Figure 1).

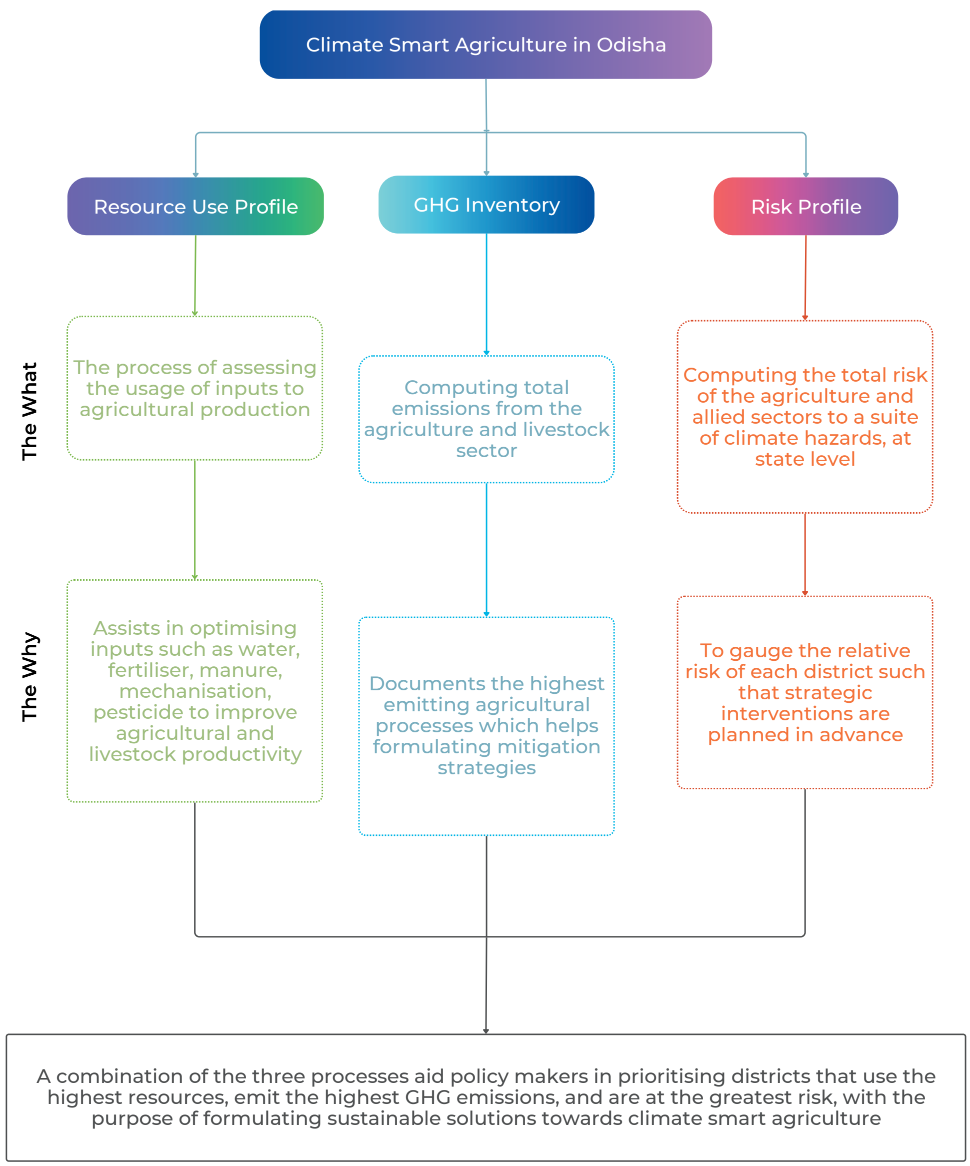


Figure 1: Steps towards advancing agriculture resilience and sustainability in Odisha

2. Objective

The overarching objective of this scoping study is to enable the prioritisation of districts in Odisha for building resilience, improving resource use efficiency and reducing emissions or sequestering emissions from the agriculture and allied sector, while factoring in current sectoral resource use patterns, greenhouse gas emissions, and climate risks to the sector. This assessment is also envisaged to be the foundation for developing District Action Plans aimed at building resilience and sustainability, and for implementation of CSA practices on a pilot basis.

The objective of Part 2 in this report series is to prioritise districts in Odisha for enhancing resilience in the agriculture and allied sectors, while accounting for existing climate risks. This assessment is intended to serve as the foundation for developing District Action Plans focused on resilience-building, sustainability, and piloting Climate-Smart Agriculture (CSA) practices.

BELOW: Woman from the Lanjia Saura region of Odisha working in a corn field. Carlos Duarte

3. Methodology

This section describes the methodologies used to conduct hazard, exposure, and vulnerability assessments in detail to evaluate the overall risk to agriculture and allied sectors in Odisha. A climate risk assessment offers a comprehensive view of Odisha's vulnerabilities and risks to specific hazards such as droughts, floods, and heatwaves (Tanti et al., 2024). It enhances the capacity to anticipate, adapt to, and mitigate these risks, particularly in the agriculture and allied sectors. This ensures that interventions are not merely reactive but strategically proactive. By integrating risk data, CSA practices can be designed with foresight, addressing potential future threats and building resilience well in advance (Dekens, 2023).

The Intergovernmental Panel on Climate Change (IPCC) AR5 Risk Assessment Framework (2014) was adopted to compute the baseline climate risk to agriculture and allied sector in Odisha. The framework describes climate risk as a function of the probability of occurrence of climate hazard(s); exposure of a system's assets to these hazards and the inherent vulnerability of the system. The three components of climate risk and the computation methods are presented in the following sections:

3.1. Hazard assessment

The IPCC defines hazards as 'the potential occurrence of a natural or human-induced physical event, trend, or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources'. The term hazard in this study refers to climate-related physical events or trends, as well as their physical consequences. Data sets and the methods used for the assessment of hazards is presented in Table 1.

Table 1: Details of data used in hazards assessment

Hazard	Data used	Data source	Time period of assessment
Droughts	Daily rainfall gridded data of spatial resolution 0.25° × 0.25° for the period 1994 to 2023	India Meteorological Department (IMD)	1994-2023
Floods	Digital elevation model (1km resolution), soil texture, land use land cover, geomorphology, rainfall data (1° x 1° from 1994 to 2023)	HydroSHEDs, FAO-UNESCO, Sentinel-2A 2021), Geological Survey of India, IMD	
Heatwaves	Daily gridded maximum temperature data of resolution 1° x 1° from 1994 to 2023	IMD	
Tropical cyclones	Tropical cyclone paths and wind speed buffer	Global Disaster Alert and Coordination Systems (GDACS)	2013-2024

Floods, droughts, heatwaves, and tropical cyclones are the most prevalent climate hazards in Odisha, with implications for agriculture and allied sectors. These hazards, the data and methods used to quantify them are provided below:

3.1.1. Drought

Drought is a meteorological anomaly characterised by a lack of moisture due to subnormal rainfall, unpredictable rainfall distribution, increased water demand, or a combination of all three elements (Gautam & Bana, 2014). Several drought indices have been developed over time, including the Standardised Precipitation Index (SPI), Standardised Precipitation Evapotranspiration Index (SPEI), Decile Index, Palmer Drought Severity Index (PDSI), Percentage Departure from Normal (PDN), and Effective Drought Index (EDI).

In this study, the SPI (McKee et al., 1995) was used to map the spatial extent of droughts. The SPI is a widely adopted index because of its ease of use, adaptability, and efficiency. It is helpful for both short-term (1-3 months) agricultural and soil moisture impacts as well as long-term (6-24 months) effects on hydrological resources, including groundwater and reservoirs. By standardising precipitation as a departure from the normal, SPI allows comparing data from various climates and geographical areas.

Gridded rainfall data from IMD with a spatial resolution of 0.25° x 0.25° from 1994 to 2023 was used for this study by extracting rainfall data for Odisha state. SPI values were calculated for twelve-month medium accumulation periods and used to estimate drought episodes. Further, the spatial autocorrelation method known as inverse distance weighting (Shepard et al., 1968; Chen et al., 2012; and Gong et al., 2014) was used for this estimation, and drought was categorised (Table 2) following McKee et al., 1995 and the spatial extent of droughts was mapped using a GIS program.

For risk calculation, the probability of occurrence was determined based on reported agricultural drought events, as documented in the Annual State Relief Commissioner reports available from 2002 to 2018. This approach was necessary because meteorological drought does not always lead to agricultural drought, as farmers experience, where crop loss or damage occurs. By using reported agricultural drought events from the Annual State Relief Commissioner reports (2002–2018) to determine the probability of occurrence, we ensured that our drought risk calculations were directly aligned with real-world impacts on agriculture and allied sectors.

Table 2: Categorisation of drought using SPI (Source: McKee et al., 1995)

Drought type	SPI
Extreme drought	−2 or less
Severe drought	−1.50 to −1.99
Moderate drought	−1.00 to 1.49-
Mild drought	−0.99 to 0
Mild wet	0 to 0.9
Moderately wet	1 to 1.49
Severely wet	1.5 to 2
Extremely wet	2 or above

Equation 1: Computation of Probability of Occurrence

$$\textbf{Probability of Occurance} = \frac{\textbf{Number of events during the given time period}}{\textbf{Total time period}}$$

3.1.2. Floods

Floods are regarded as a destructive natural disaster in terms of fatalities and property loss (Osman et al., 2023). Flooding adversely affects cropland through soil erosion, crop damage, waterlogging, soil contamination, delayed planting and harvesting, and increased pest and disease outbreaks (Kaur, et al., 2020). Many investigations specify 'flood susceptibility mapping' as an essential preventive measure in planning, management and observation of risk to property or assets (Das, 2020; Lin et al., 2019). To prepare the flood susceptibility map for Odisha, multi-sourced environmental flood conditioning factors (FCF) were used (Table 3), and Analytical Hierarchy Process (AHP) approach was followed (Chen et al., 2010; Ghorbanzadeh et al., 2018). The method used is detailed in Figure 2.

Based on the influence on floods, each FCF was categorised into classes. Further, each factor is run under a weighted overlay tool,

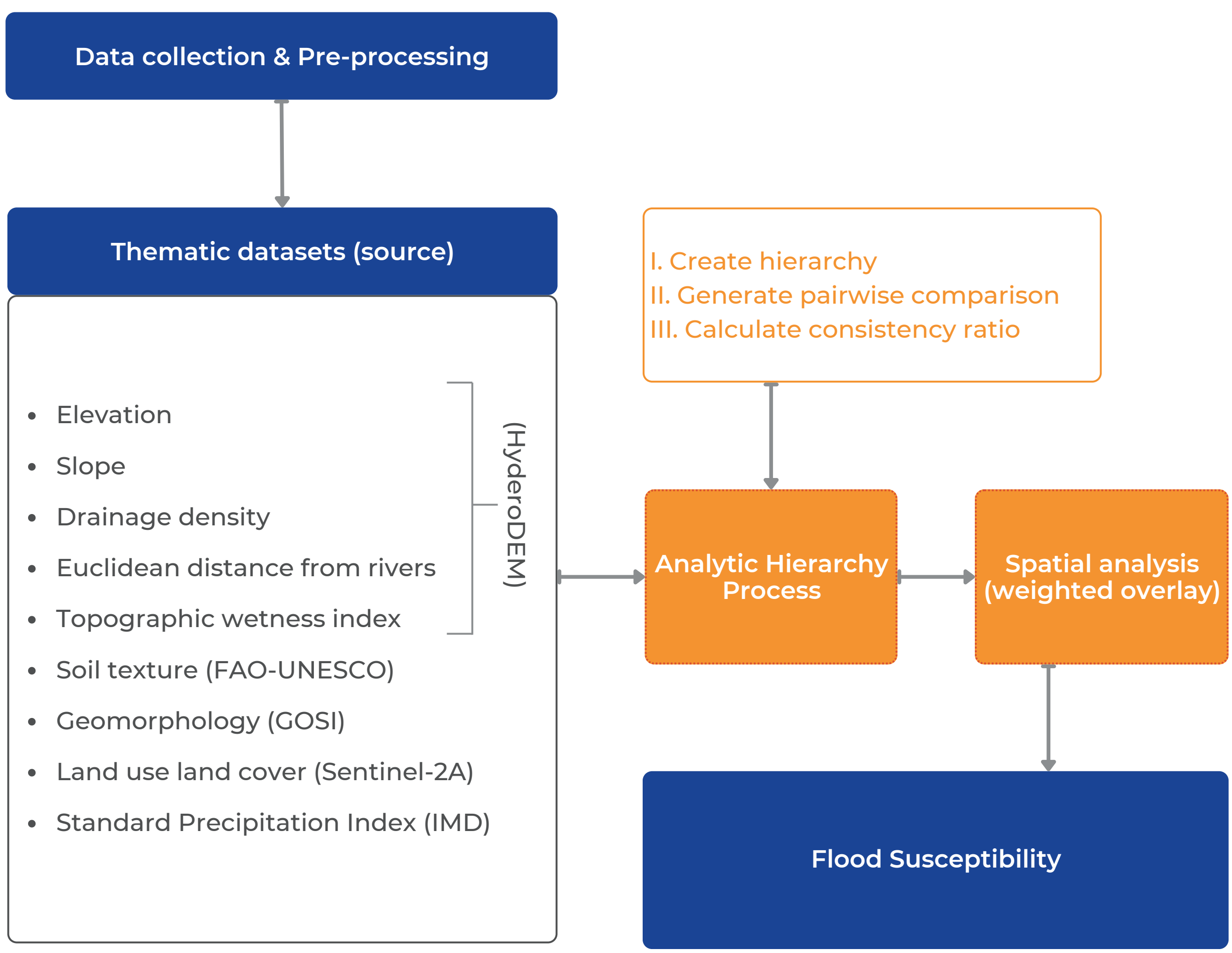


Figure 2: Methodology used to map flood susceptibility zones

which allows to pick high to low-scale flood susceptibility zones. The weighted influence factor is calculated using the AHP method. AHP is one of the most popular and widely employed multi-criteria methods in flood susceptibility mapping (Das, 2020). The AHP was employed to rank each FCF with other FCFs. The ranking or selection was done with respect to a flood susceptibility weightage, which is broken down into a set of criteria (Table 3). The final map was reclassified into moderate, high and very high flood-susceptible classes. Similar to the drought probability of occurrence computation, the probability of occurrence for risk calculation was derived from reported drought events documented in the Annual State Relief Commissioner reports from 2001 to 2023 (equation 1).

Table 3: Flood condition weights for thematic layers

SN	Flood conditioning factor	Weights
1	Elevation	6
2	Slope	6
3	Drainage density	17
4	Topographic wetness index	24
5	Elucidation distance to River	20
6	Geomorphology	19
7	Soil texture	5
8	Precipitation index	3

3.1.3. Heatwaves

An extended stretch of noticeably hotter-than-average temperatures is commonly referred to as a heatwave. IMD defines heatwaves based on maximum temperature (Tmax). IMD defines a heatwave event as "if the maximum temperature of a station reaches at least 40°C or more over the plains and at least 30°C or more in hilly regions." These conditions must be met for at least two days to declare a heatwave. Over the past few decades, the occurrence and severity of heatwave episodes in India have escalated and are expected to continue rising (Kumar et al., 2013; Rohini et al., 2019).

The number of heatwave events was calculated using the maximum temperature data from IMD. The 1°X1° resolution data was re-gridded to 25°X25° using bi-linear interpolation. 40°C was set as the uppermost threshold temperature. A heatwave was defined if two or more days exceeded 40°C. The number of heatwaves that occurred in a year were computed which facilitated the calculation of the probability of occurrence of heatwaves and this was also spatially mapped. The Special Relief Commission's (SRC) annual reports (2001-2022) have been used to validate the assessment's findings. The reports' findings corresponded with the analysis.

The heatwave probability of occurrence was derived from reported events in the Annual State Relief Commissioner reports published from 2001 to 2018. The spatial extent of each hazard was mapped using Geographic Information System (GIS).

3.1.4. Tropical cyclones

The tropical cyclone data facilitated by the Global Disaster Alert and Coordination System (GDACS) from 2013 to 2024 was considered to examine the number of tropical cyclones over the Bay of Bengal and Odisha (Table 4).

The Joint Research Centre (JRC) developed an automated system integrating tropical cyclone bulletins from National Oceanic and

Atmospheric Administration (NOAA) and Joint Typhoon Warning Centre (JTWC) into a global database. Wind impact is assessed using GDACS, while heavy rainfall impact is derived from NOAA Ensemble Tropical rainfall Potential (eTRaP) and NASA Global Precipitation Measurement Mission (NASA-GPM) data. Storm surge risk is calculated using the JRC HyFlux2 model with tropical cyclone bulletin input. Additional tools, including atmospheric data from NOAA Hurricane Weather Research and Forecast (HWRF), Global Forecast System (GFS), and European Centre for Medium-Range Forecasts' (ECMWF) high-resolution model, were used to enhance tropical cyclone impact analysis and risk evaluation.

To calculate the probability of occurrence for tropical cyclones with wind speeds of 60–90 km/hr, 90–120 km/hr, and above 120 km/hr, cyclones affecting Odisha from 2013 to 2024 were listed (Table 6) and categorized as cyclonic storms, severe cyclonic storms, or very severe cyclonic storms based on recorded wind speeds. The probability of occurrence for each category was then computed using Equation 1.

Table 4: Tropical cyclones traversing Odisha (2013–2024) with types

SN	Year	Name	Type (Source: IMD)	
1	2013	Phailin	Very severe cyclonic storm	3
2	2014	Hududa	Extremely severe cyclonic storm	1
3	2017	Ockhi	Cyclonic storm	3
4	2018	Daye	Cyclonic storm	3
5	2018	Phethai	Cyclonic storm	3
6	2018	Titili	Very severe cyclonic storm	1
7	2019	Bulbul	Very severe cyclonic storm	1
8	2019	Fani	Extremely severe cyclonic storm	1
9	2020	Amphan	Super cyclonic storm	1
10	2021	Yaas	Very severe cyclonic storm	1
11	2022	Asani	Cyclonic storm	3
12	2022	Sitrang	Cyclonic storm	3
13	2023	Mocha	Cyclonic storm	3
14	2023	Hamoon	Cyclonic storm	3
15	2023	Michaung	Severe cyclonic storm	2
16	2024	Dana	Cyclonic storm	3
17	2024	Remal	Severe cyclonic storm	2

Source: Global Disaster Alert and Coordination System and IMD

3.2. Exposure assessment

According to the IPCC AR6 (2023) exposure refers to the "presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected by extreme events."

Exposure is assessed geo-spatially in a GIS environment, as GIS is an effective tool to integrate various types of spatial data, perform complex analysis, and produce detailed maps. The approach to exposure mapping is presented in Figure 3.

Figure 3: Exposure mapping methodology

Step 1: Spatial data collection –
The exposure assessment helps identify relevant assets, infrastructure and livelihoods, across agriculture, coastal resources and fisheries, livestock, and infrastructure, which could be at risk to the impacts of climate hazards (Table 5). Majorly, open-source datasets were used for the assessment. These datasets underwent quality checks over satellite images from Google Earth Pro[1]. The quality check includes spatial accuracy and attribute verification, as well as data consistency across layers, which enhanced the reliability and utility of OpenStreetMap (OSM) data for application. The agriculture and allied sector assets considered for exposure assessment are presented below. They are either in a point, polygon or line format. However, it is essential to note that the data used in this assessment is limited to available open-source databases. Due to data scarcity, there may be gaps in identifying certain assets across districts, as not all relevant data was fully captured or accessible.

- The data was validated against data shared by the Department of Agriculture Statistics, the Directorate of Agriculture and Food Production, and the Directorate of Animal Husbandry & Veterinary Services.

1 Google Earth Pro is a free desktop application that allows users to view and analyze high-resolution satellite imagery and maps.

Table 5: Exposure indicators and data sources

Sector	Indicator	Data Source
Agriculture	Bore well	Central Ground Water Board
	Dug well	
	Tube well	
	Irrigation canals	Development Data Lab
	Net sown area	European space agency-Sentinel-2A
	Food park	OpenStreetMap
	Retail agriculture market	
	Warehouses (Godown)	The Odisha State Warehousing Corporation
Livestock	Cattle feed plant	The Odisha State Cooperative Milk Producers' Federation Limited
	Milk chilling centre	The Odisha State Cooperative Milk Producers' Federation Limited
	Milk processing units	
	Pig	Gridded livestock of the world
	Sheep	
	Cattle	
	Chicken	
	Goat	
Fisheries	Fish market	National Remote Sensing Center -Bhuvan
	Inland fish landing centres	
	Mangroves	Global Mangrove Watch (2022)
	Marine fish landing centres	Indian National Centre for Ocean Information Services
	Aquaculture	
Essential Infrastructure	Fuel point	Open Street Map
	Rural road	

Step 2: Data processing –
Once the spatial indicators were quantified, they were processed using geoprocessing tools within a GIS environment to build the geodatabase.

- **Drought** – Based on SPI values (Table 2) drought classes were defined and categorised into two (moderate drought and mild drought).
- **Flood** – Spatial analytical hierarchy model derived flood susceptibility zones (Figure 2) were considered for disaggregating flood output into three (very high and high) zones.
- **Heatwave** – Based on the number of heatwave events experienced, i.e., areas experiencing heatwaves were disaggregated into seven zones (ranging from areas experiencing one heatwave event to seven heatwave events per year).

- **Tropical cyclone** - GDACS facilitated the delineation of three wind buffer zones along tropical cyclone paths of different wind speeds: 60–90 km/h, 90–120 km/h, and above 120 km/h. The classifications are based on the Saffir-Simpson Hurricane Wind Scale using 1-min sustained winds[2]. These were used to quantify the exposure of indicators to different tropical cyclone categories. This classification aligns with IMD's categorisation (Table 6).

Step 3: Overlay analysis - The indicator layers were overlayed using GIS tools such as intersection, union, or proximity analysis, new layers that highlight areas where hazards and exposure indicators overlap were created. The results were analysed to identify assets that were highly exposed to various hazards. The percentage of assets exposed to either mild dry conditions, floods (high and very high susceptibility zones), heatwaves (cumulative exposure to 5, 6, and 7 heatwave events per year) and tropical cyclone wind buffer zones of 60–90 km/h, 90–120 km/h, and >120 km/h was calculated in a GIS platform using the Equation 2:

Table 6: Characterisation of tropical cyclone winds in km/h

Category	Sustained winds (3-min average in km/h)
Super cyclonic storm	≥221
Extremely severe cyclonic storm	166–220
Very severe cyclonic storm	118–165
Severe cyclonic storm	89–117
Cyclonic storm	63–88
Deep depression	51–62
Depression	31–50

Source: IMD

2 https://www.gdacs.org/Knowledge/models_TC.aspx

Equation 2: Equation used to assess percentage of assets exposed

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

3.3. Vulnerability assessment

The IPCC (2014) defines vulnerability as the 'propensity or predisposition to be adversely affected'. Vulnerability comprises two sub-indicators – adaptive capacity and sensitivity. The former is defined as 'the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences', and the latter is defined as 'the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change' (IPCC, 2014).

An indicator-based vulnerability assessment was conducted to evaluate the inherent vulnerability of the agriculture and allied sectors in Odisha. This involved the following key steps, as shown in Table 7.

Table 7: Steps to undertake vulnerability assessment for the agriculture and allied sectors in Odisha

SN	Step	Description
1	Scoping and objective	To rank districts of Odisha based on a vulnerability index scale ranging from very high to very low. This ranking may be used to prioritize and implement targeted resilience and adaptation strategies.
2	Type of vulnerability assessment	An indicator-based, integrated vulnerability assessment by choosing bio-physical, socio-economic, institutional and governance-based indicators that represent the sectors of interest.
3	Selection of tier	A tier-3 methodology using secondary data, GIS techniques and data from relevant line departments to quantify indicators.
4	Selection of sector, spatial scale and period	Current or inherent vulnerability was assessed for the agriculture and allied sectors, which comprise of the agriculture, livestock and fisheries sub-sectors at the state level.
5	Identification, definition and selection of indicators	Indicators were selected based on guidance from sectoral and vulnerability experts within CSTEP. The same were discussed and validated by the Climate Resilience Cell, Department of Agriculture and Farmers' Empowerment (DA&FE), Government of Odisha.
6	Quantification of indicators	Indicators were quantified using secondary data and data provided by the respective agriculture, livestock and fishery departments of the Government of Odisha, as well as using GIS techniques to quantify some bio-physical indicators.
7	Normalisation of indicators	The involvement of various bio-physical, socio-economic, institutional, and governance-related variables with differing units, required them to be normalised to dimensionless units for aggregation. This normalisation process is based on their functional relationship with vulnerability to enable their aggregation into a Vulnerability Index (VI). There are two types of functional relationships: A positive relationship, where vulnerability rises as the value of the indicator increases. In this scenario, the variables have a direct and positive functional relationship with vulnerability, and normalisation is performed using the following equation:

		Equation 3: Computation of vulnerability index when the variable exhibits a positive relationship with vulnerability $x_{ij} = \frac{X_{ij} - \text{Min } X_{ij}}{\text{Max } X_{ij} - \text{Min } X_{ij}}$ where X_{ij} is the value of the indicator j corresponding to the region i. In Equation 4, X_{ij} is the variable that is being normalised, and x_{ij} is the normalised value of X_{ij}. All x_{ij} scores will lie between 0 and 1. Value 1 will correspond to the region with maximum sensitivity, and 0 will correspond to the region with minimum sensitivity. Similarly, indicators can have a negative relationship, where vulnerability increases with a decrease in the value of the indicator. Here, indicators have a negative or inverse functional relationship with vulnerability. In this case, the normalised score is computed using the following equation: Equation 4: Computation of vulnerability index when the variable exhibits a negative relationship with vulnerability $x_{ij} = \frac{\text{Max } X_{ij} - X_{ij}}{\text{Max } X_{ij} - \text{Min } X_{ij}}$ Furthermore, outliers were computed using the interquartile method and were excluded from the normalisation process. Outlier values of sensitivity indicators that are lower than the lower limit get a score of 0 and values that are over the upper limit get a score of 1. The inverse is true for adaptive capacity indicators.
8	Assigning weights	Equal weights were assigned to all indicators
9	Aggregation	Indicators were aggregated by taking a simple mean of normalised scores for each region. This is the vulnerability index value for each region.
10	Ranking	Districts were ranked on a five-point scale: very high, high, moderate, low and very low vulnerability for visualisation.
11	Representation of results	Sectoral vulnerability assessment results have been represented as bar graphs and maps.
12	Drivers of vulnerability	The drivers of vulnerability were identified for each sector and district for the development of targeted interventions.

An indicator-based approach was used to quantify the inherent vulnerability of the agriculture and allied sector at the district level using the Common Vulnerability Assessment Framework (DST and SDC, 2020).

Indicators were classified as adaptive capacity and sensitivity indicators and were quantified using secondary sources of information. Figures 4, 5 and 6 provide the indicators quantified for the assessments.

Figure 4: Indicators used for agriculture sub-sector vulnerability assessment

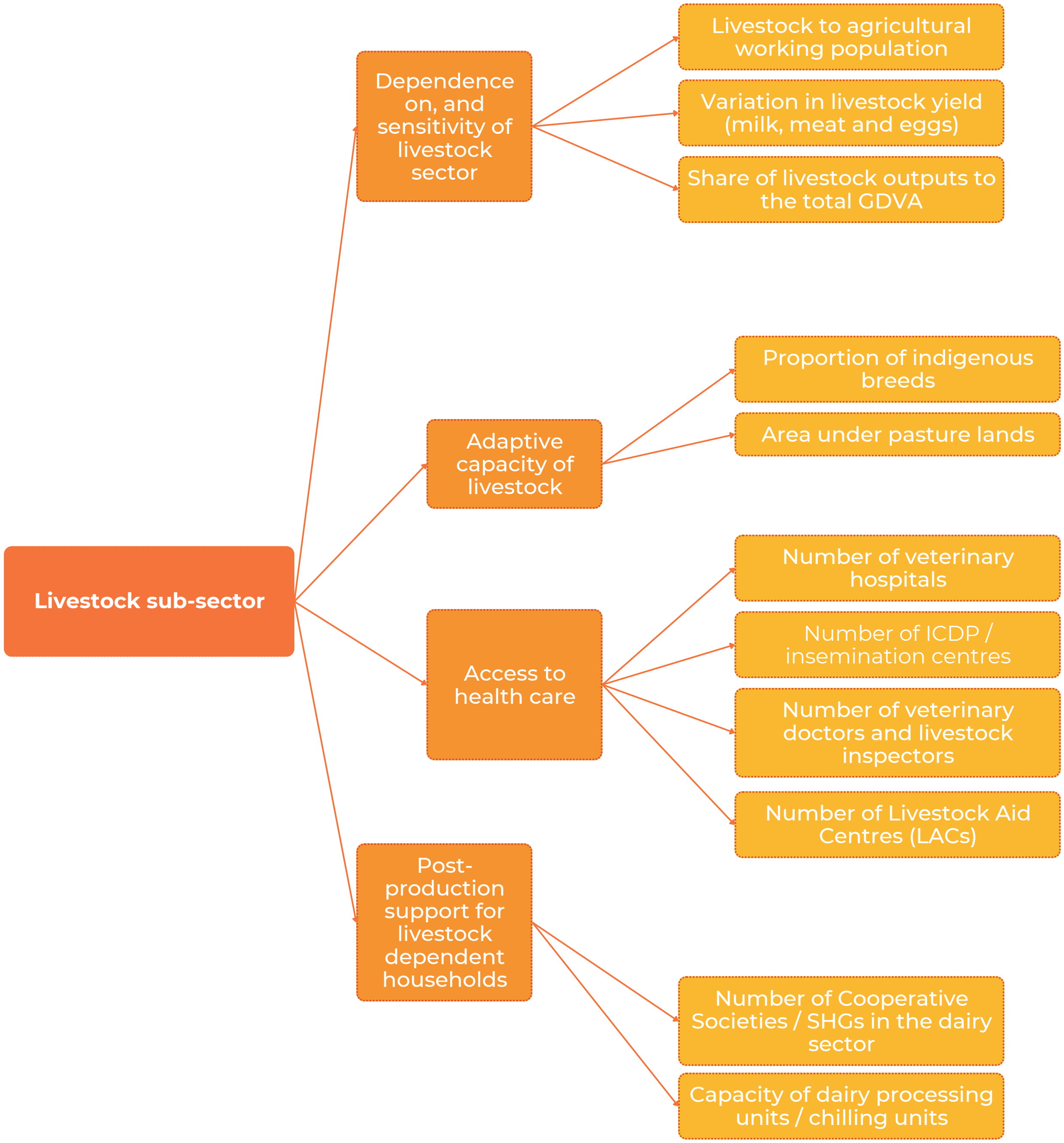


Figure 5: Indicators used for livestock sub-sector vulnerability assessment

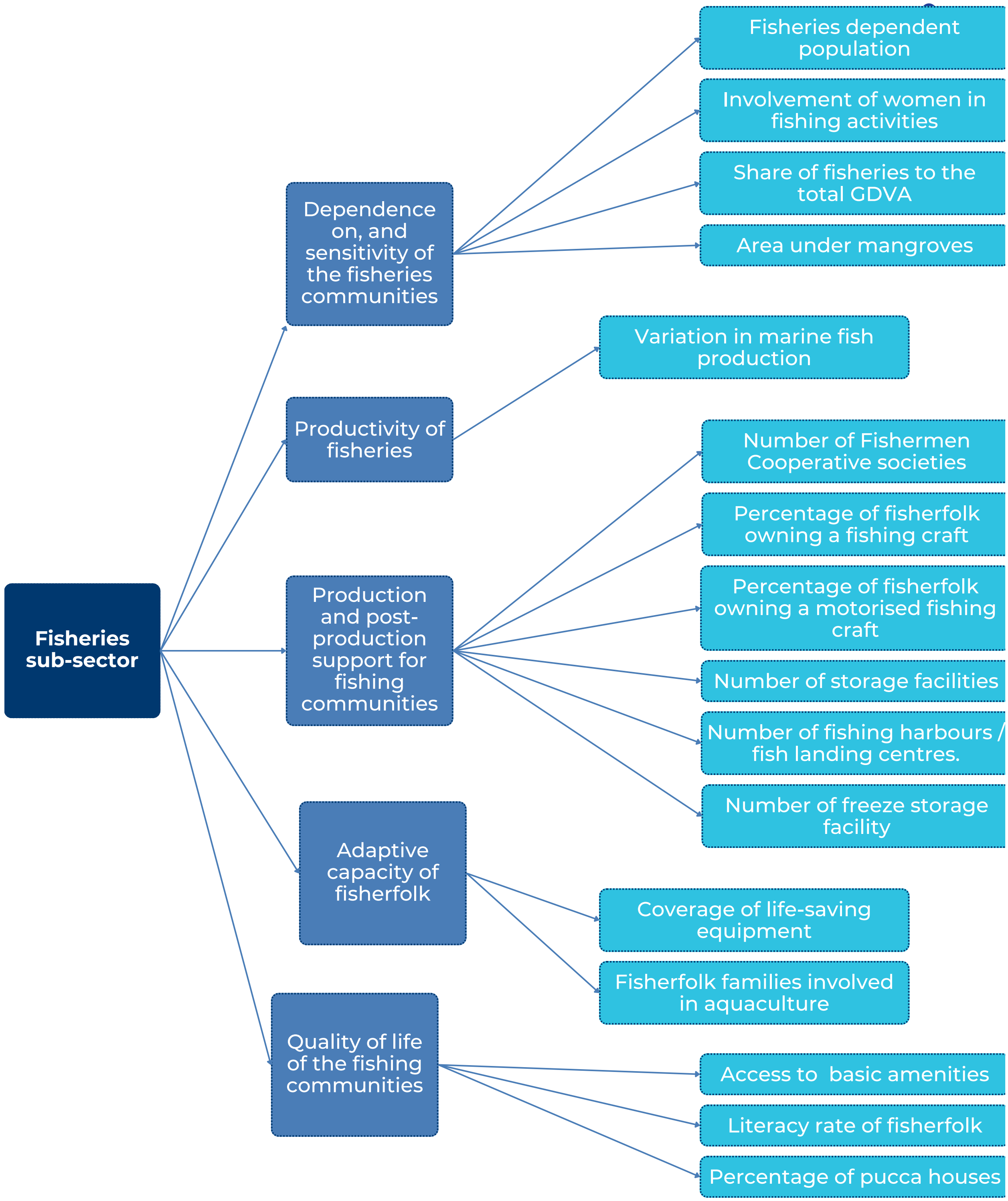


Figure 6: Indicators used for fisheries sub-sector vulnerability assessment

As indicators have different units, they were normalised using equations specified in Table 6 and then aggregated to arrive at index values for agriculture, livestock and fisheries separately, and then for the overall agriculture and allied sector. Districts are then ranked as having very high to very low vulnerability. Drivers of vulnerability are also provided. The rationale for selection of indicators, their functional relationship with vulnerability and data sources used for quantification are provided in Appendix Tables 9, 10, and 11.

3.4. Risk assessment

A comprehensive risk assessment was conducted to understand the aggregated risk to a sector from identified hazards – combining the hazard, exposure, and vulnerability components into a single risk index (Figure 7). The IPCC AR6 (2023) defines risk as the "potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change."

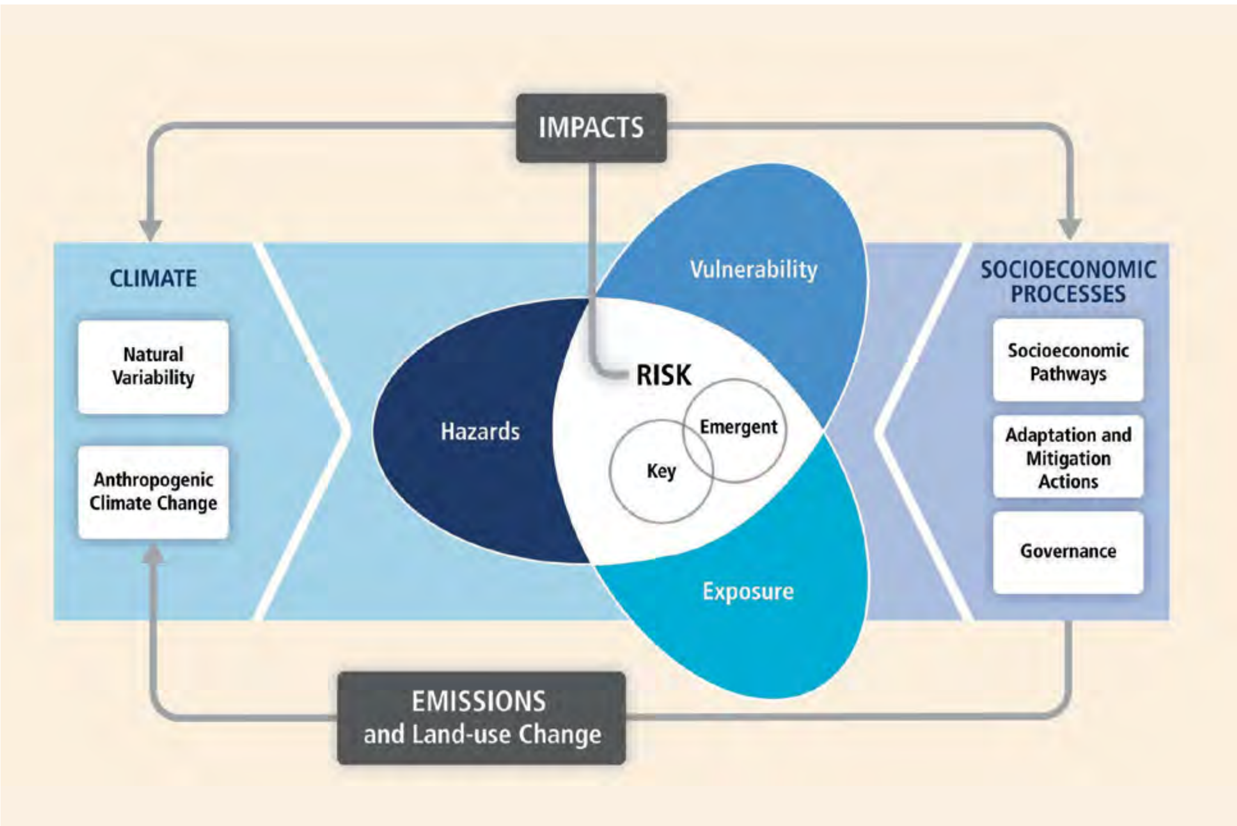


Figure 7: IPCC AR5 risk assessment framework (2014)

Risk is computed as the geometric mean (Equation 5) of the hazard probability of occurrence, percentage of exposure and vulnerability index score. For this study, a risk score is computed for each subsector and each hazard within the current/historical climate scenario (1994-2023). These scores are then used to rank the districts on a five-point scale of very high, high, moderate, low and very low risk to the hazards selected for this study.

Equation 5: Equation to compute risk

$$\text{Risk} = \sqrt[3]{(H \times E \times V)}$$

Where: H – Probability of occurrence of hazard; E – Percentage of exposure; and V – Vulnerability.

ABOVE: Pulses, vegetables and spice for sale in the weekly market in Ankadeli, Orissa, India. Wirestock

Equation 5 was used to calculate risk from floods, droughts, and tropical cyclones, with equal weights for all components. However, for heatwave risk, hazard, exposure, and vulnerability were weighted at 45%, 5%, and 50%, respectively (Equation 6). This adjustment reflects that exposure was assessed predominantly for agricultural and allied sector assets, which are not directly impacted by heatwaves. The weights were assigned based on the logic derived from the INFORM Risk Assessment methodology developed by JRC (Montserrat et al., 2017).

Equation 6: Equation used to compute heatwave risk

$$\text{Risk} = H^{0.45} \times E^{0.05} \times V^{0.50}$$

4. Results

This section presents the findings of the climate risk assessment, which involved the quantification of the probability of occurrence of hazards (droughts, floods, heatwaves, and tropical cyclones); the spatial extent of these hazards; exposure of different assets of the agriculture, livestock and fisheries sector to these hazards based on their location; and the inherent vulnerability of the sub-sectors. The sub-sectoral assessments are aggregated to present the overall exposure and vulnerability of the agriculture and allied sector. Finally, the probability of occurrence of hazard, exposure and vulnerability values are aggregated to show drought, flood or heatwave risk to each sub-sector and the agriculture and allied sector.

4.1. Climate hazard assessment

This subsection explores the likelihood of occurrence of each climate hazard – droughts, floods, heatwaves, and tropical cyclones – along with spatial mapping of these results for effective visualisation.

4.1.1. Droughts: Occurrence and the spatial extent

According to the data provided in the SRC reports, the districts of Bargarh, Sambalpur, Angul, and Deogarh experienced at least eight droughts over the period of 2002 to 2018. Whereas, Kendrapara, Koraput, and Jagatsinghapur have the lowest probability of drought occurrence (Figure 8). Koraput experienced drought in both 2009 and 2011, while Jagatsinghpur faced it once in 2002, and Kendrapara encountered drought twice, in 2002 and 2010. Notably, 2002 and 2015 were the most severe drought years, with over 80% of the state affected.

The government's SRC annual reports declare droughts using a wide range of factors in addition to rainfall. The assessment also considers other indicators: moisture stress,

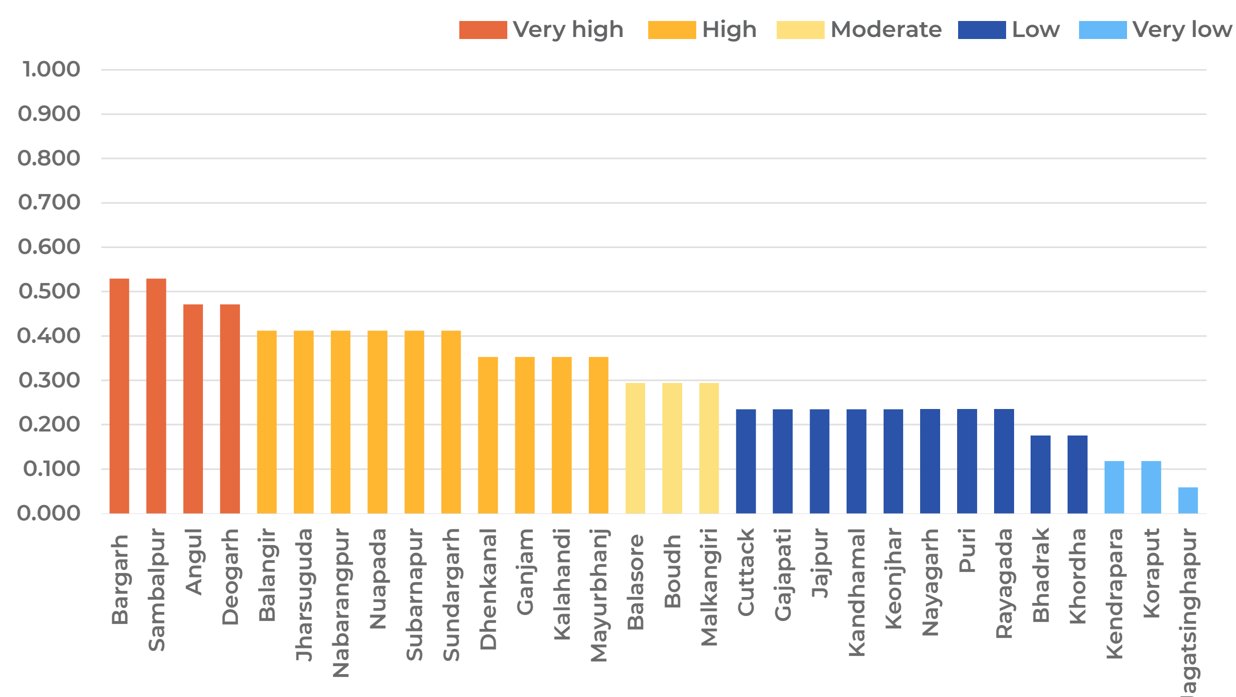


Figure 8: Probability of occurrence of extreme droughts in districts of Odisha

total area cultivated, and crop losses or damage. This comprehensive approach aids in evaluating a drought's overall impacts on agriculture and rural livelihoods; however, it does not allow for spatial mapping of agricultural drought.

Therefore, SPI was used to spatially visualise droughts across the state. The long-term average (30 years of daily, gridded data) of precipitation negates the severity of droughts observed. For this exercise, we considered mild and moderate dryness to represent drought-like conditions. The spatial map of dryness (Figure 9) is used to assess the exposure of agriculture and allied sector assets to drought-like conditions by overlaying their location onto this map.

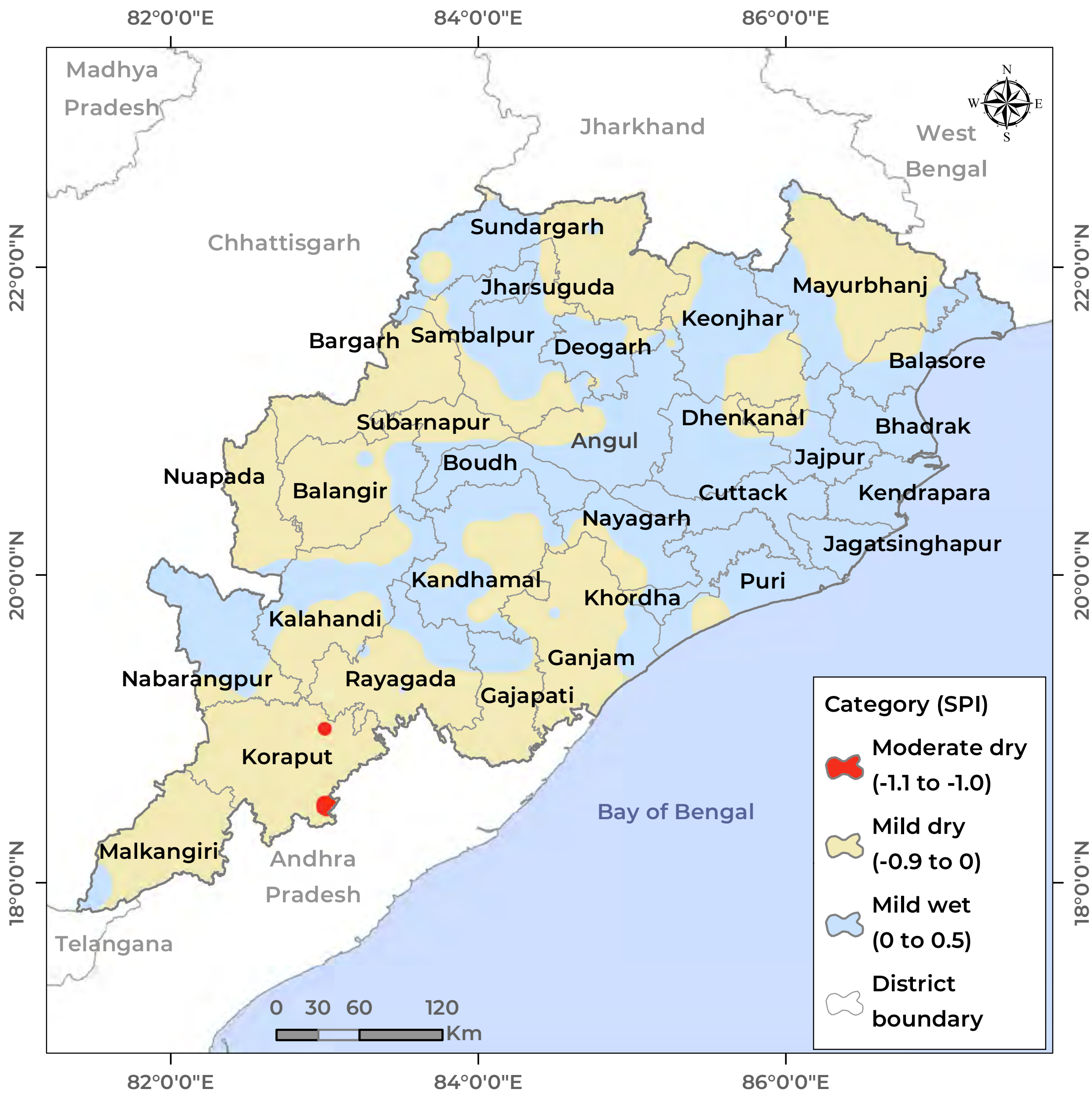


Figure 9: Spatial extent of droughts in Odisha based on SPI

4.1.2. Floods: Occurrence and the spatial extent

The probability of flood occurrence, as represented in Figure 10, was calculated based on flood events documented in the SRC reports. Jajpur, Kendrapara, Cuttack, Kalahandi, Angul, Khordha, Nayagarh, and Puri experienced the highest frequency of flooding, with at least 13 flood events recorded between 2001 and 2023. In contrast, Ganjam, Jharsuguda, Sundergarh, Dhenkanal, and Nuapada had the lowest flood occurrence, with flood events documented in no more than five years during the same period. Notably, 2001 and 2003 emerged as particularly severe years, with over 75% of the state affected by floods.

Figure 11 illustrates the spatial extent of the state's flood susceptibility, based on the SPI Index.

The regions are classified based on their susceptibility to flooding, which ranges from very high to very low susceptibility.

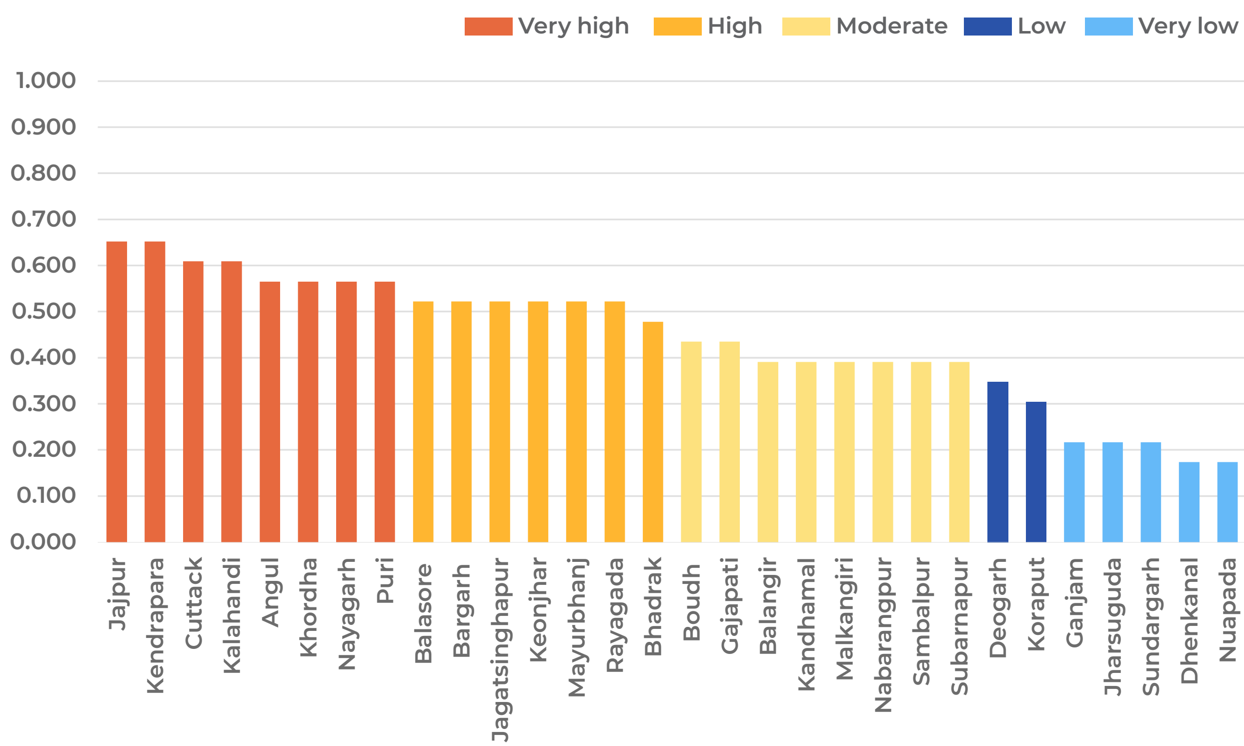


Figure 10: Probability of occurrence of floods in Odisha

Figure 11: Flood susceptibility map

4.1.3. Heatwaves: Occurrence and the spatial extent

The probability of heatwave occurrence (Figure 12), as calculated based on the events reported in the annual reports of the SRC, indicates that Angul, Dhenkanal, Ganjam, and Sambalpur are the most frequently impacted districts, with heatwave events recorded in at least 15 years during the 2001–2018 period. In contrast, Nabarangpur, Koraput, Gajapati, Rayagada, Malkangiri, Kandhamal, Boudh, Nuapada, Puri, and Deogarh experienced far fewer heatwave events, with a maximum of four occurrences over the same period, particularly in Deogarh and Puri. Notably, 2005 and 2012 were years when nearly 75% of the state faced heatwaves.

Figure 13 provides the spatial extent of heatwave events across Odisha, from at least one event to seven events per year. For the evaluation of risk, we have considered exposure of agriculture and allied sector assets to 5, 6 and 7 heatwave events. Overall, the northern and central districts have experienced the highest number of heatwave events.

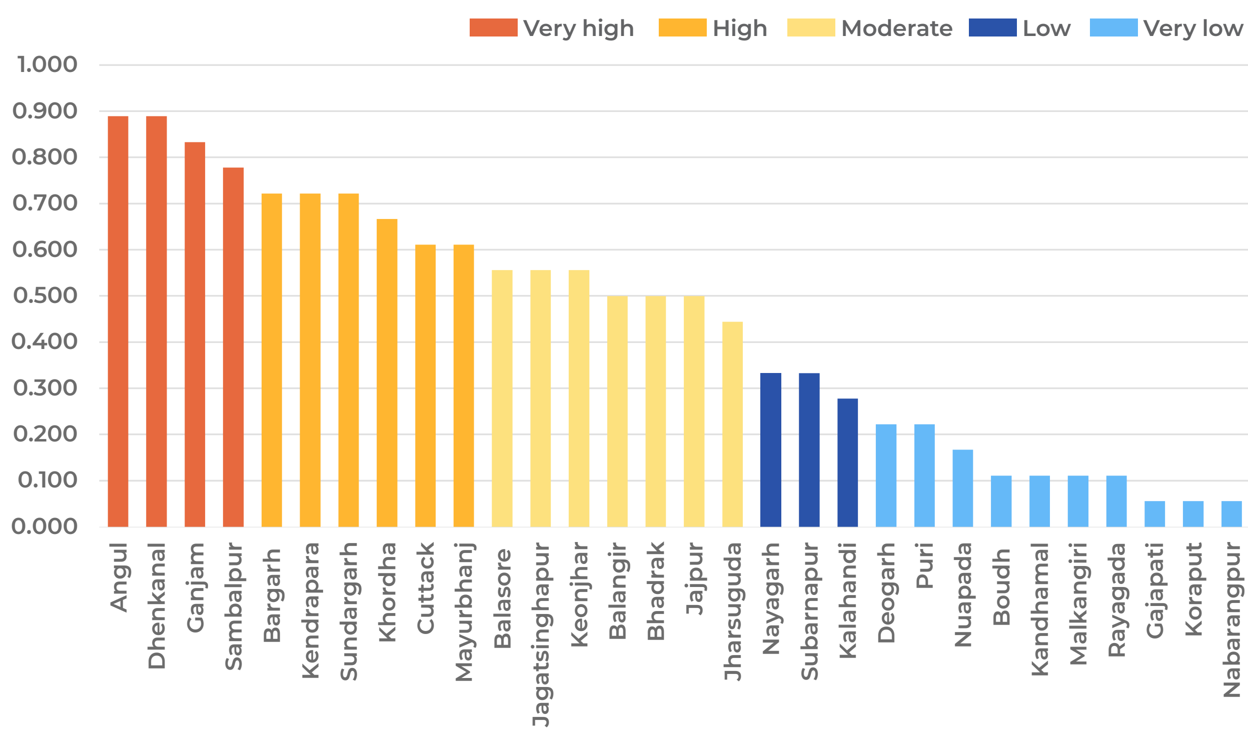


Figure 12: Probability of occurrence of at least 1 heatwave per year across districts of Odisha

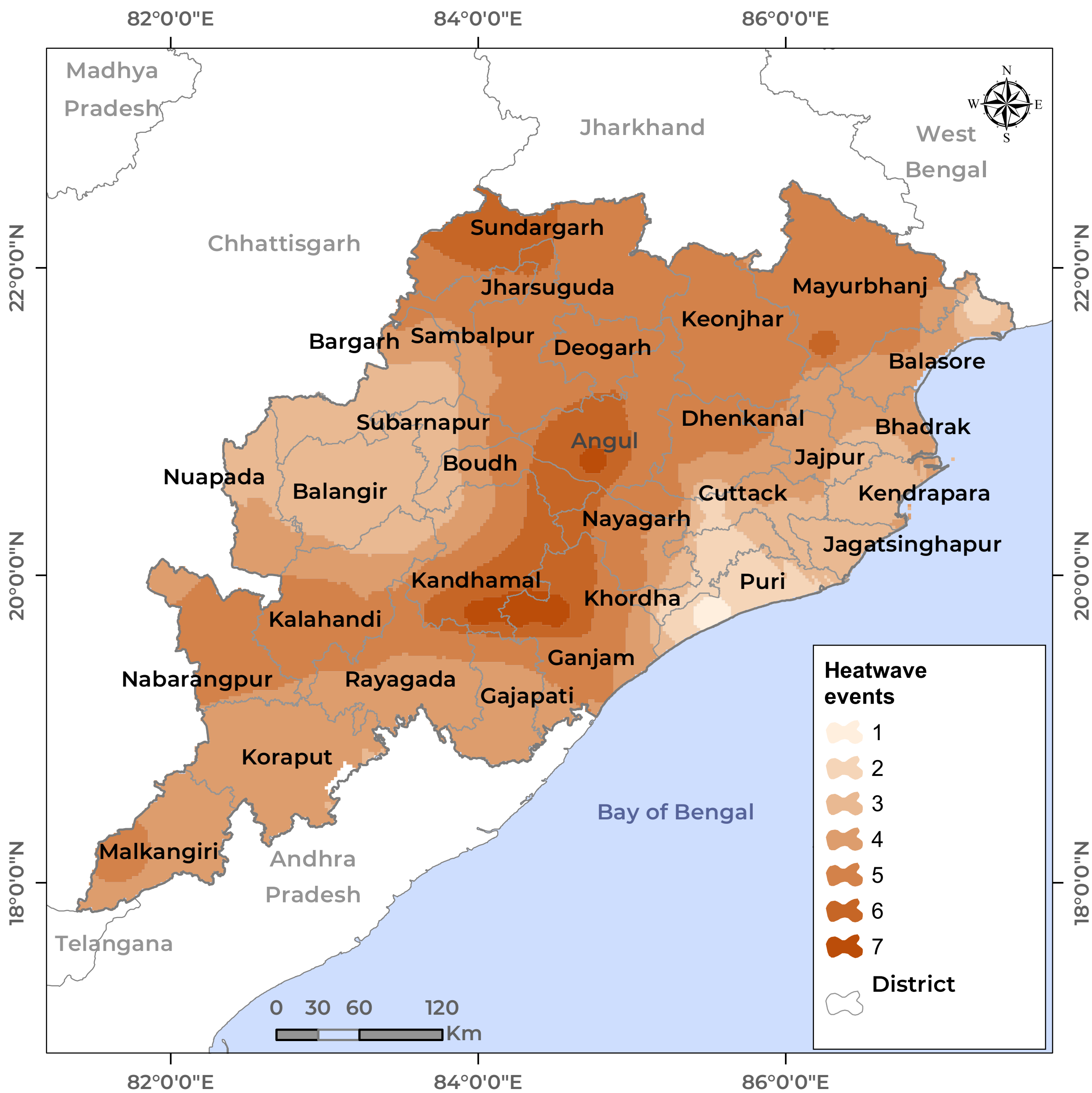


Figure 13: Spatial extent of heatwaves based on the number of events per year

4.1.4. Tropical cyclones: Occurrence and spatial extent

Based on the probability of occurrence calculated from tropical cyclone events reported in the SRC annual reports, cyclonic storms with wind speeds of 60–90 km/h are the most frequent in the state, followed by storms with wind speeds of 90–120 km/h. Very severe cyclonic storms with wind speeds exceeding 120 km/h are less frequent. While these high-intensity storms occur less often, their magnitude and potential impact are significantly greater than the more frequent, lower-intensity storms.

Balasore, located along the Bay of Bengal coast, emerges as a hotspot for severe and very severe cyclonic storms. The district recorded four events with wind speeds exceeding 120 km/h and six events in the 90–120 km/h category between 2013 and 2024 (Figure 14 and 15). Additionally, Balasore experienced nine cyclonic storms with wind speeds of 60–90 km/h between 2019 and 2024, reflecting its heightened susceptibility to frequent tropical cyclones (Figure 16).

Kendrapara, Jagatsinghpur, Khordha, and Puri also experience frequent tropical cyclones. These districts recorded at least 12 cyclonic storms with wind speeds of 60–90 km/h and at least five storms in the 90–120 km/h category during the same period (Figures 14, 15, and 16).

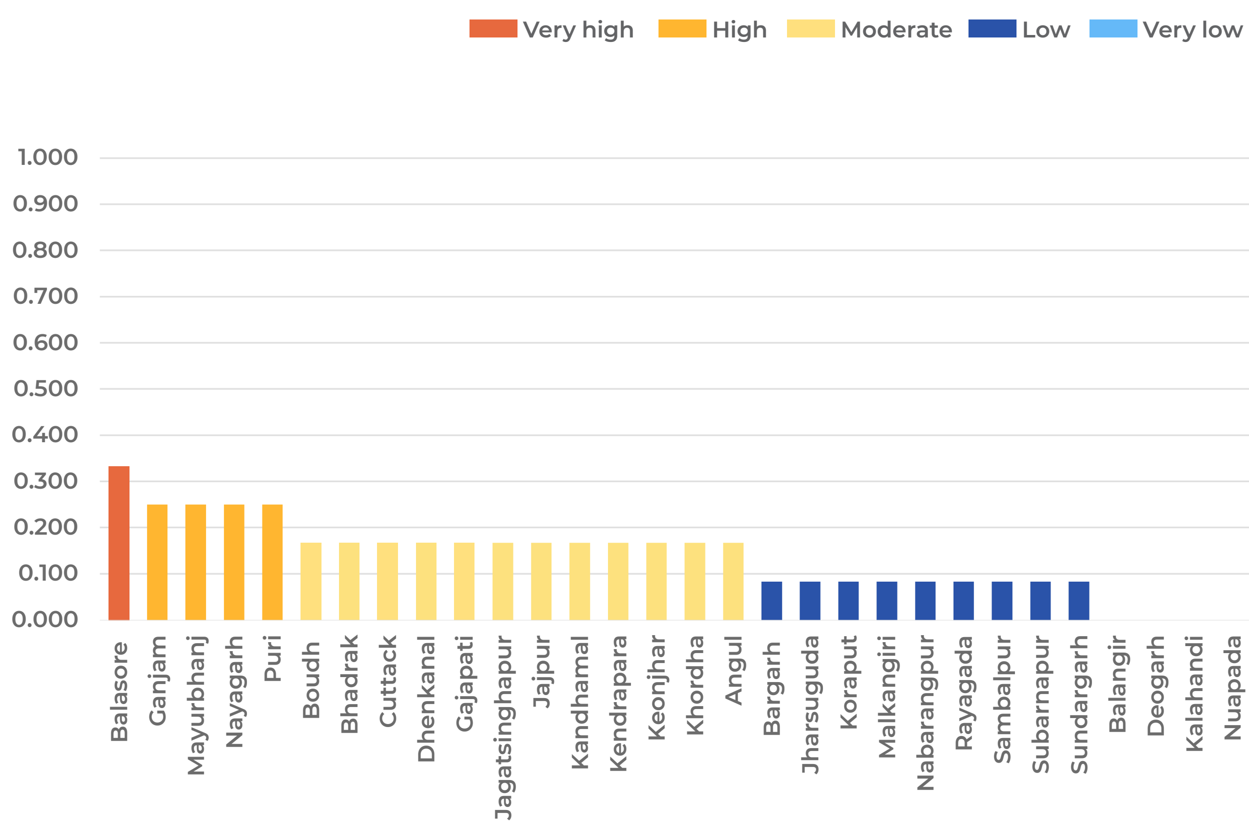


Figure 14: Probability of occurrence of tropical cyclones (wind speeds of 120 km/hr and above)

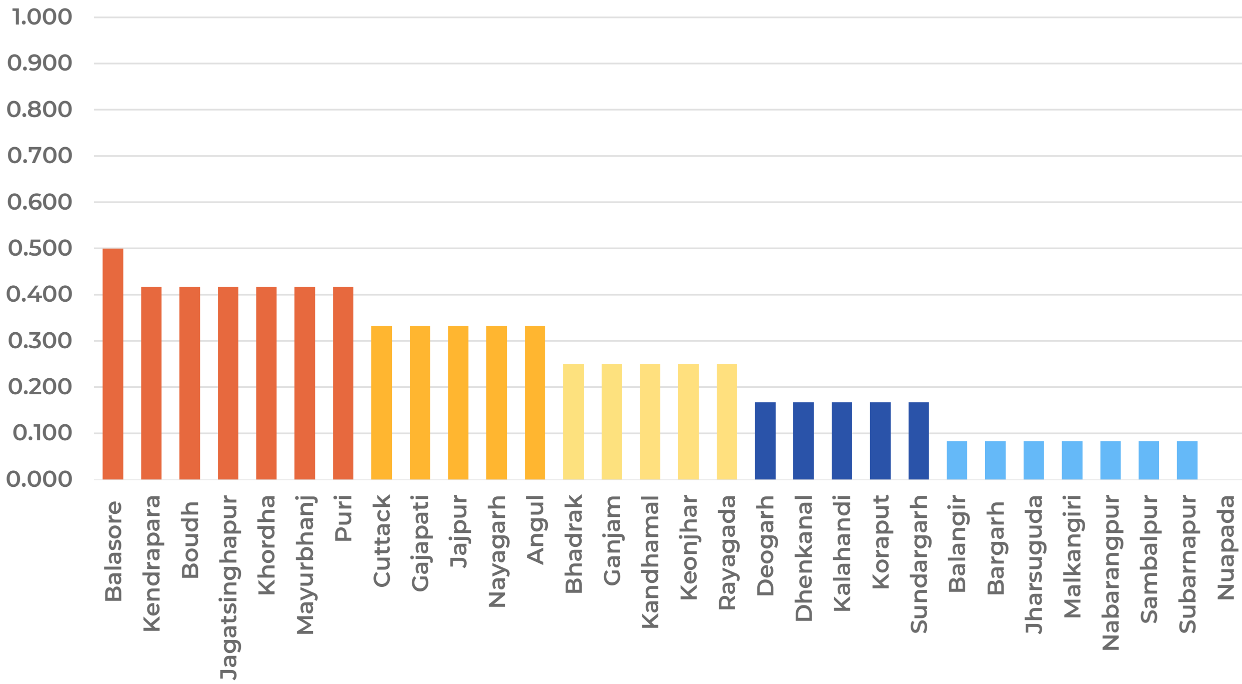


Figure 15: Probability of occurrence of tropical cyclones (wind speeds of 90-120 km/hr)

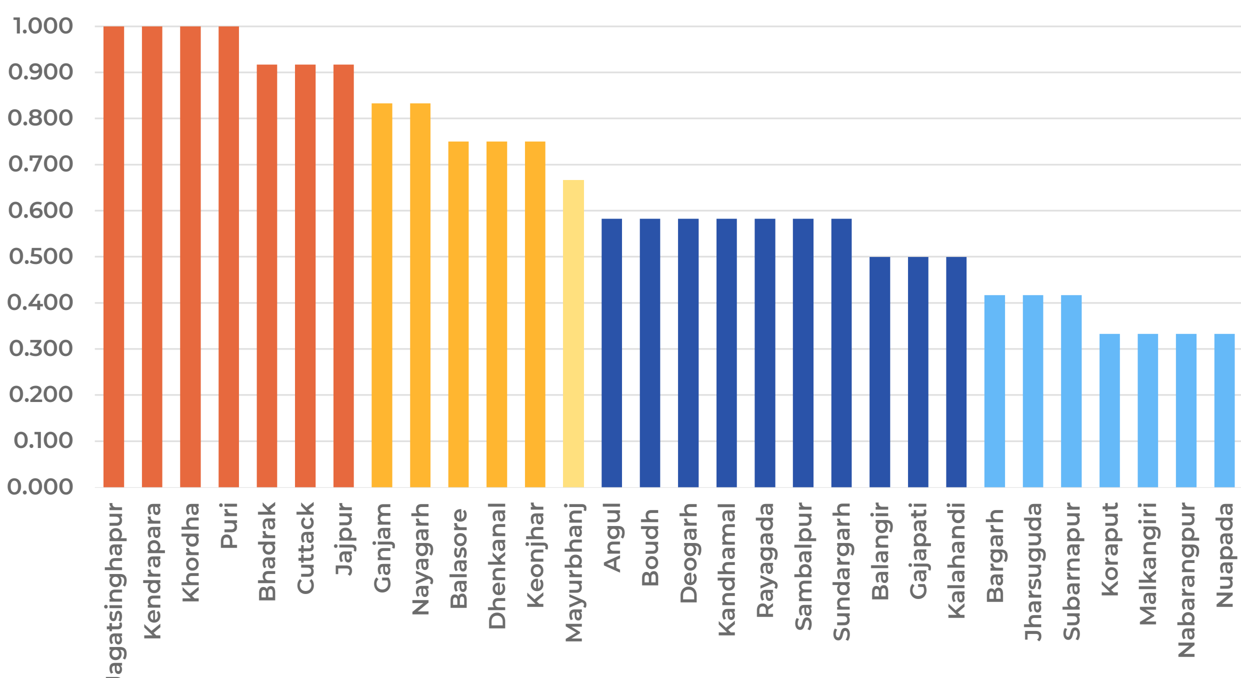
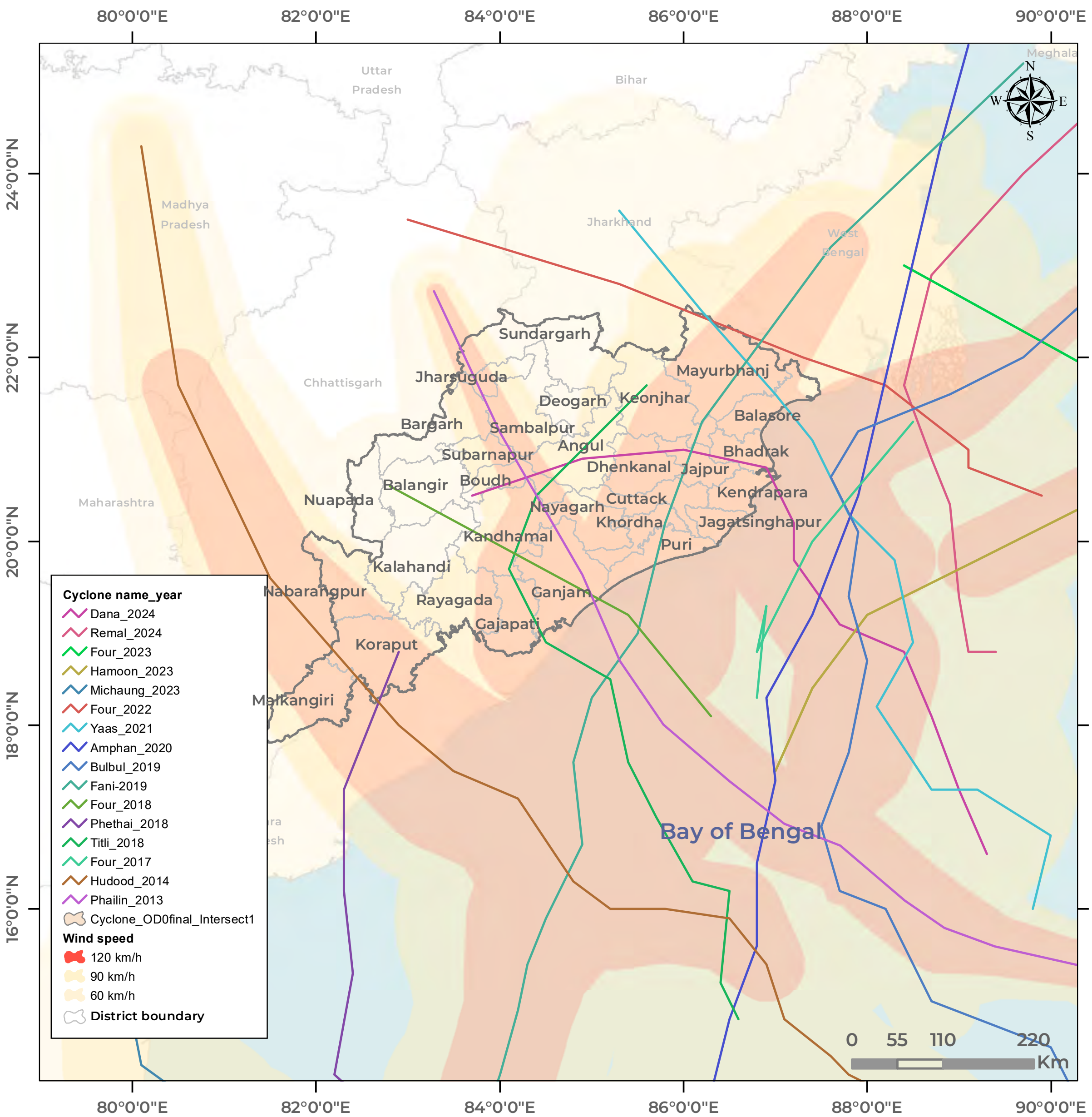


Figure 16: Probability of occurrence of tropical cyclones (wind speeds of 60-90 km/hr)

The tropical cyclone mapping analysis highlights storm patterns and intensities from 2013 to 2024, documenting 17 tropical cyclones ranging from cyclonic storms to super cyclonic storms (Table 5). The map integrates tropical cyclone tracks and wind speed zones, categorised as 60 km/h, 90 km/h, and >120 km/h, providing a spatial representation of tropical cyclone impact areas. Tropical cyclones such as Amphan (2020), Fani (2019), and Hudhud (2014) had widespread impacts (Mondal et al., 2022). The recurrence of four cyclonic storms in 2017, 2018, 2022, and 2023 suggests a pattern of repeated storm development (Figure 17).



Source: GDACS

Figure 17: Tropical cyclone tracks and wind buffer zones over Odisha

4.2. Exposure assessment

The exposure of assets that support the agriculture and the allied sectors of livestock and fisheries to drought, floods, heatwaves, and tropical cyclones were assessed individually for the different assets indicated in Section 3.2. Here, the results of overall exposure assessment of each sub-sector to drought, flood, heatwave and tropical cyclone are presented. The graphs showing the exposure of individual assets within each respective sub-sector are available in Appendix 6.1.

4.2.1. Overall exposure of agriculture and allied sector to different hazards

This section presents the results of the combined exposure analysis for the agriculture and allied sector, including the exposure of agricultural assets and livelihoods to drought, flood, heatwave and tropical cyclone. To calculate the average exposure of individual sub-sectors to each hazard, essential infrastructure was also included.

To summarise:

Exposure to drought

- Koraput district stands out, with nearly 90% of its assets exposed to mild drought, followed by Nuapada, Malkangiri and Rayagada.

- Four out of the thirty districts – Bhadrak, Cuttack, Jagatsinghapur, and Kendrapara face no exposure.

- Key contributors to the districts categorised as very highly exposed include borewells, dug wells, irrigation canals, agricultural warehouses, markets, net sown area, livestock population, and fish landing centres.

- In contrast, assets such as tube wells, food parks, cattle feed plants, milk chilling centres and processing units, mangroves, aquaculture and fish markets are least exposed (Figure 18).

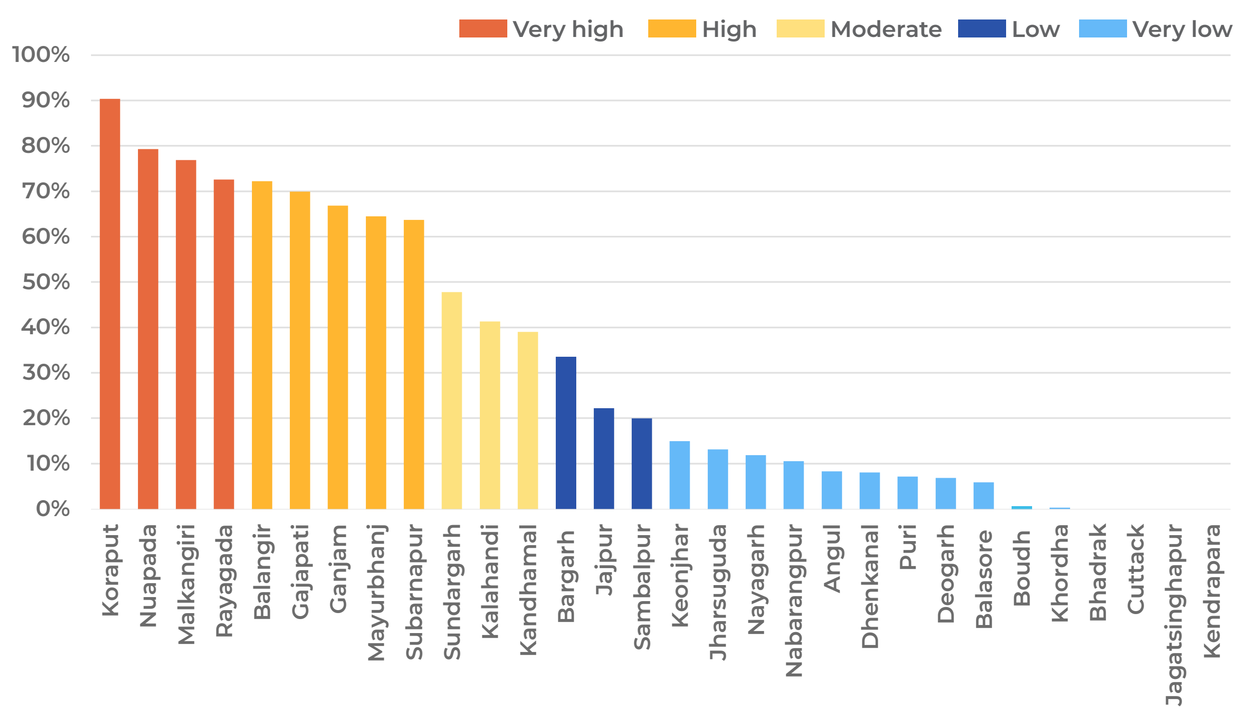


Figure 18: Average exposure of agriculture and allied sector to mild droughts

Exposure to floods

- Balasore and Kendrapara are the districts with the greatest number of assets in high flood susceptibility zones, followed closely by Boudh, Puri, and Bhadrak (Figure 19).

- More than 75% of the districts fall into the low to very low exposure category (Figure 19).

The assets that are highly exposed to floods are similar to those that are exposed to droughts. The use of open-source databases limits the analysis of exposure.

Exposure to heatwaves

- Angul, Deogarh and Jharsuguda have the highest exposure to heatwaves, with 100% of its assets in the agriculture and allied sector being exposed to this hazard. Kandhamal, Sundargarh, Mayurbhanj, and Keonjhar closely follow, with a significant proportion of their assets highly exposed to heatwaves.

- Four out of the thirty districts – Balangir, Jagatsinghapur, Nuapada, and Puri face no exposure. (Figure 20).

Exposure to tropical cyclones

The agriculture and allied sector assets in districts such as Baleshwar, Jajpur, Cuttack, Bhadrak, and Kendrapara consistently appear among the most exposed across all three wind speed categories, indicating high exposure to tropical cyclones. The percentage of agricultural assets exposed decreases as tropical cyclone wind speeds reduce, with some districts shifting between high and moderate categories. A few districts, such as Nuapada and Bargarh, exhibit low to very low exposure across all cyclone categories (Figure 21,22, 23).

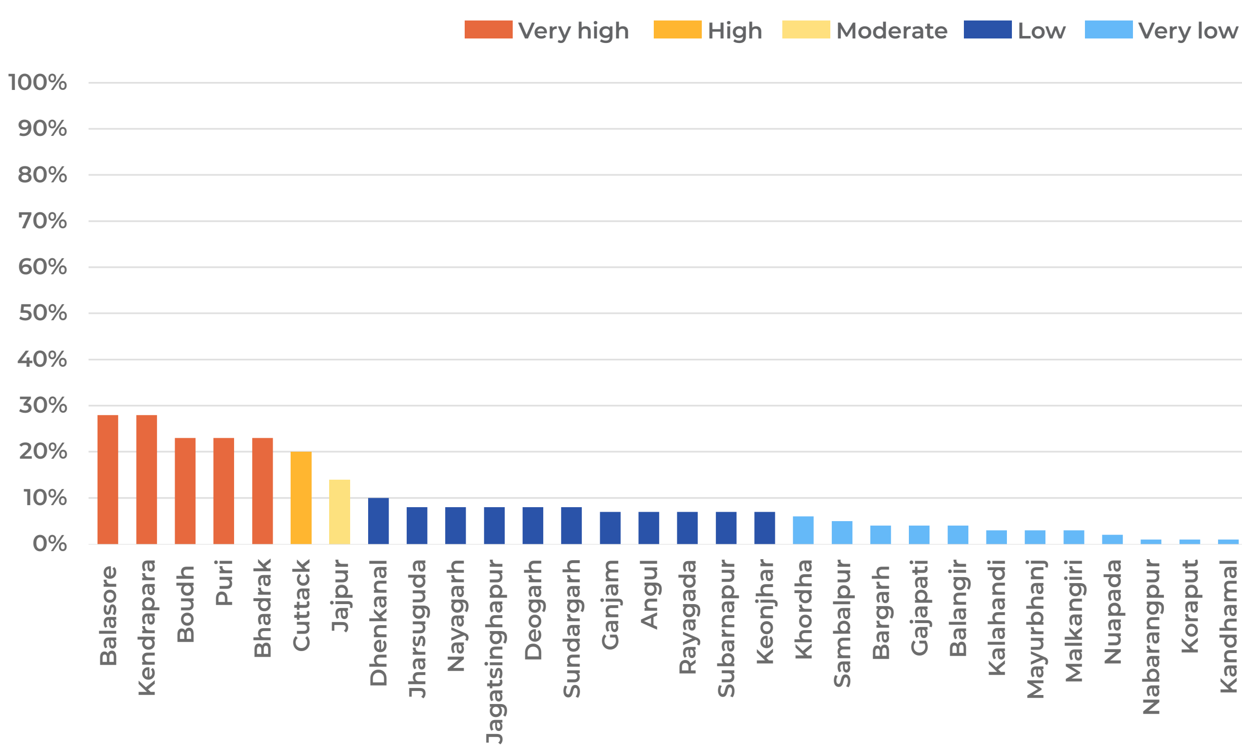


Figure 19: Average exposure of agriculture and allied sector to floods

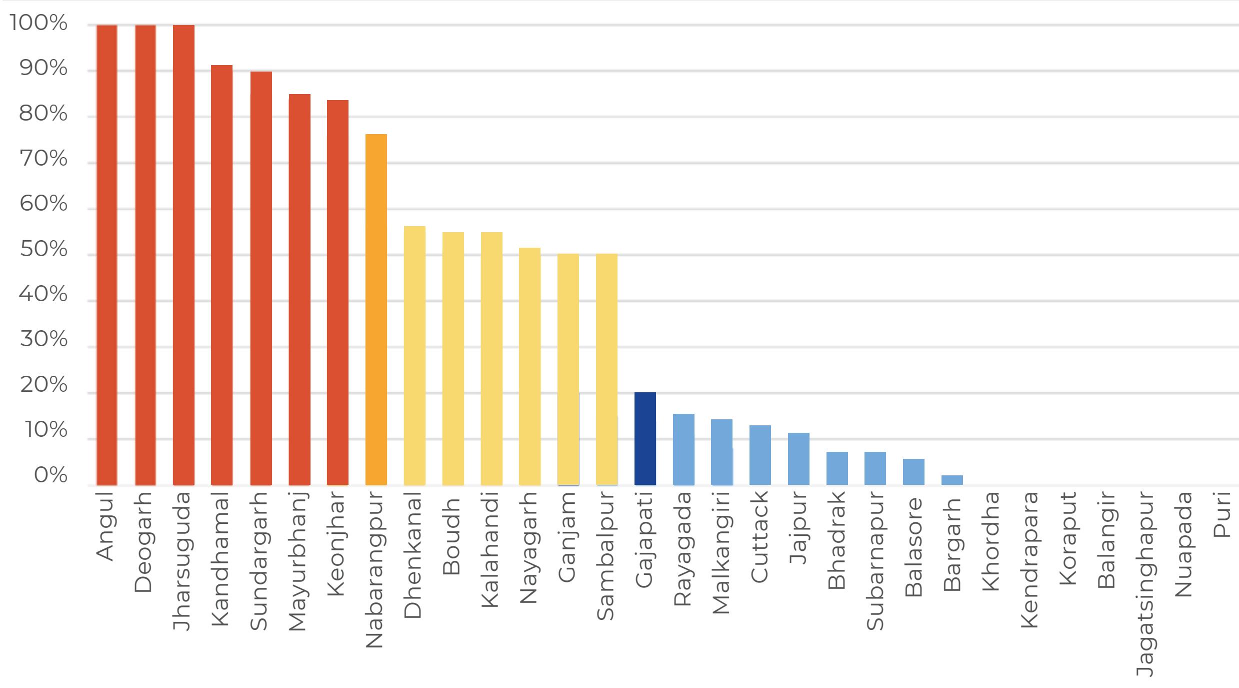


Figure 20: Average exposure of agriculture and allied sector to heatwaves

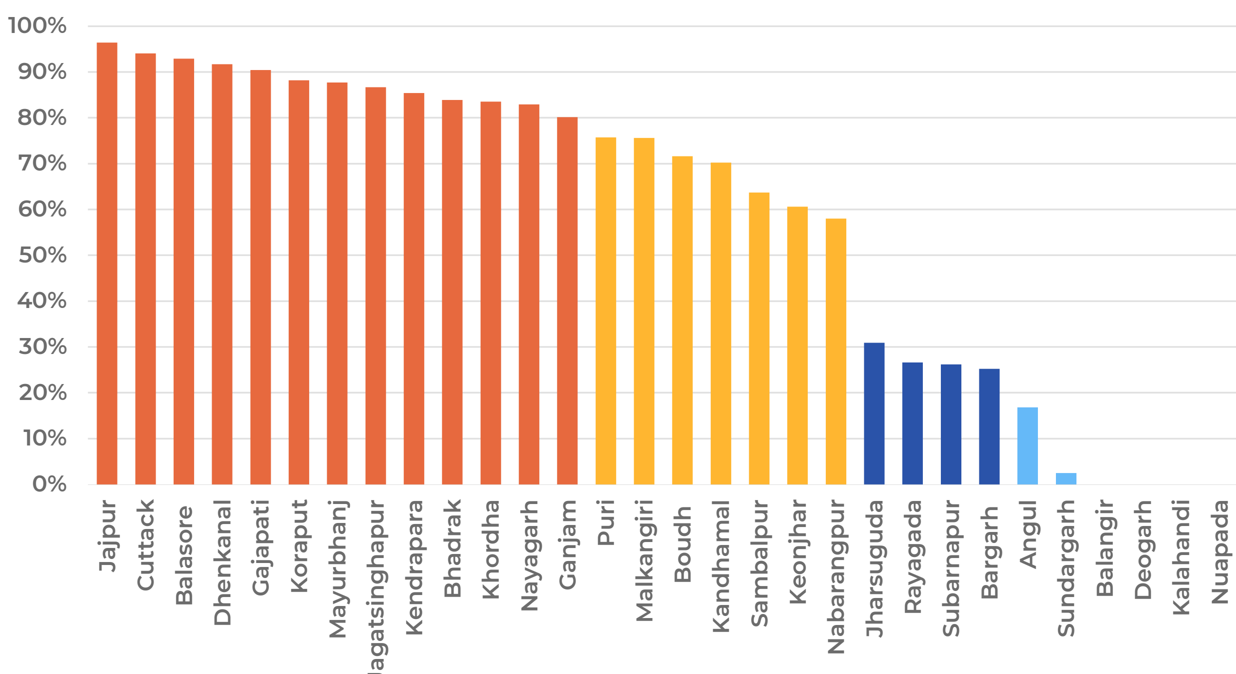


Figure 21: Overall average exposure of agriculture and allied sector to tropical cyclones 120 km/hr and above

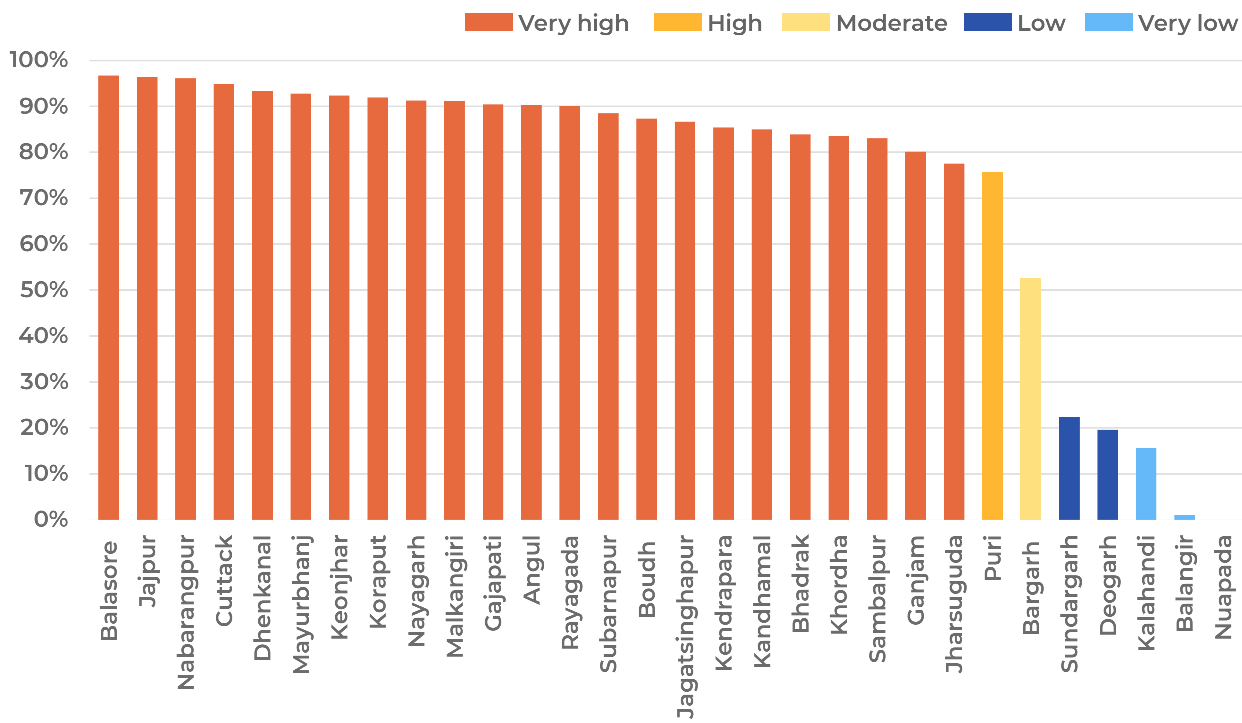


Figure 22: Overall average exposure of agriculture and allied sector to tropical cyclones 90 to 120 km/hr

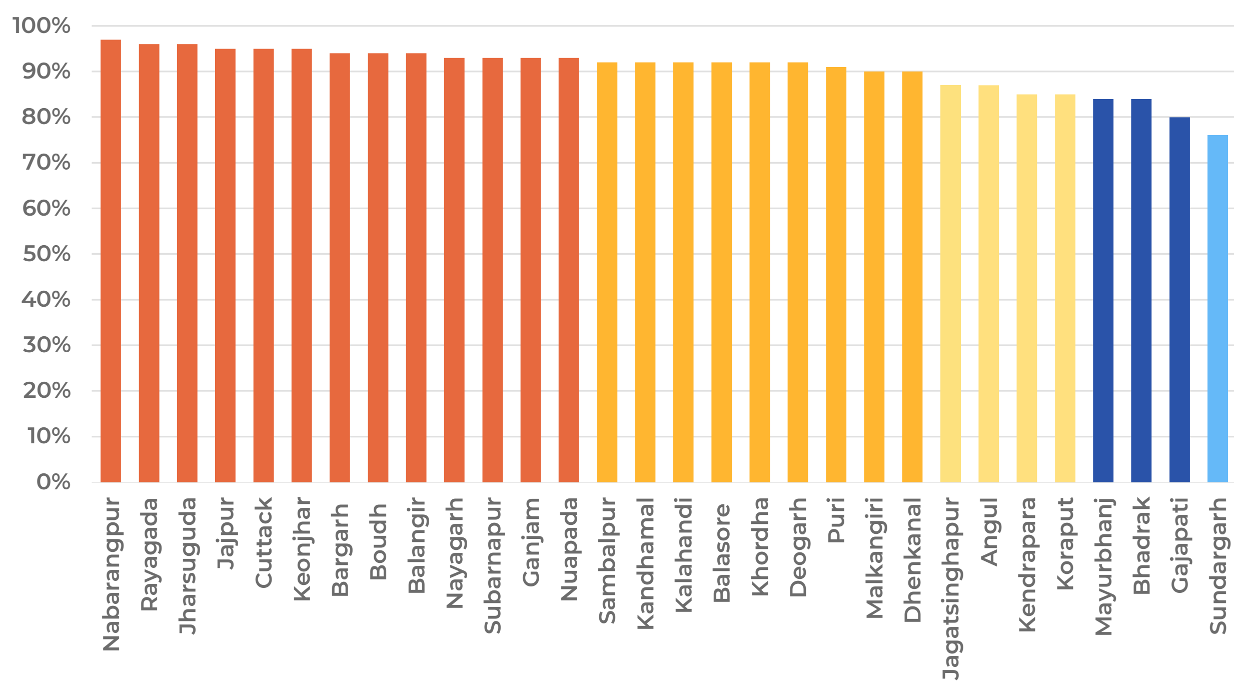


Figure 23: Overall average exposure of agriculture and allied sector to tropical cyclones 60 to 90 km/hr

4.2.2. Exposure of agriculture sub-sector to different hazards

This section presents the results of the overall average exposure analysis for the agriculture subsector, including the exposure of agricultural assets and livelihoods to droughts, floods, heatwaves, and tropical cyclones. The following indicators were considered:

1. Net sown area (NSA);
2. Irrigation infrastructure (which includes an average exposure to borewells, dug wells, tube well, and irrigation canals); and
3. Market infrastructure (storage areas, agricultural markets, and food parks)

The net sown area derived from Sentinel-2A data was cross-verified with statistical data from the Department of Agriculture and Farmer's Empowerment, and has an accuracy of 84%.

To summarise:

- **Exposure to droughts** (Figure 24): Agricultural assets in Koraput (100%) are most exposed to droughts, closely followed by Nuapada, Balangir, Malkangiri.
- **Exposure to floods** (Figure 25): Agricultural assets in Kendrapara (34%) and Balasore (30%) are most exposed to extreme rainfall and floods.
- **Exposure to heatwaves** (Figure 26): Agricultural assets in Deogarh (98%) are most exposed, closely followed by Sundargarh, Jharsuguda, Angul, Mayurbhanj, Kandhamal, and Nabarangpur.
- **Exposure to tropical cyclones:** Bhadrak, Balasore, Kendrapara, Jajpur, Nabarangpur, Khordha, Cuttack and Jagatsinghpur have consistently high exposure of their agriculture subsector assets to tropical cyclones with wind speeds of 60-90 km/h, 90-120 km/h and >120 km/h (Figure 27, 28, and 29).

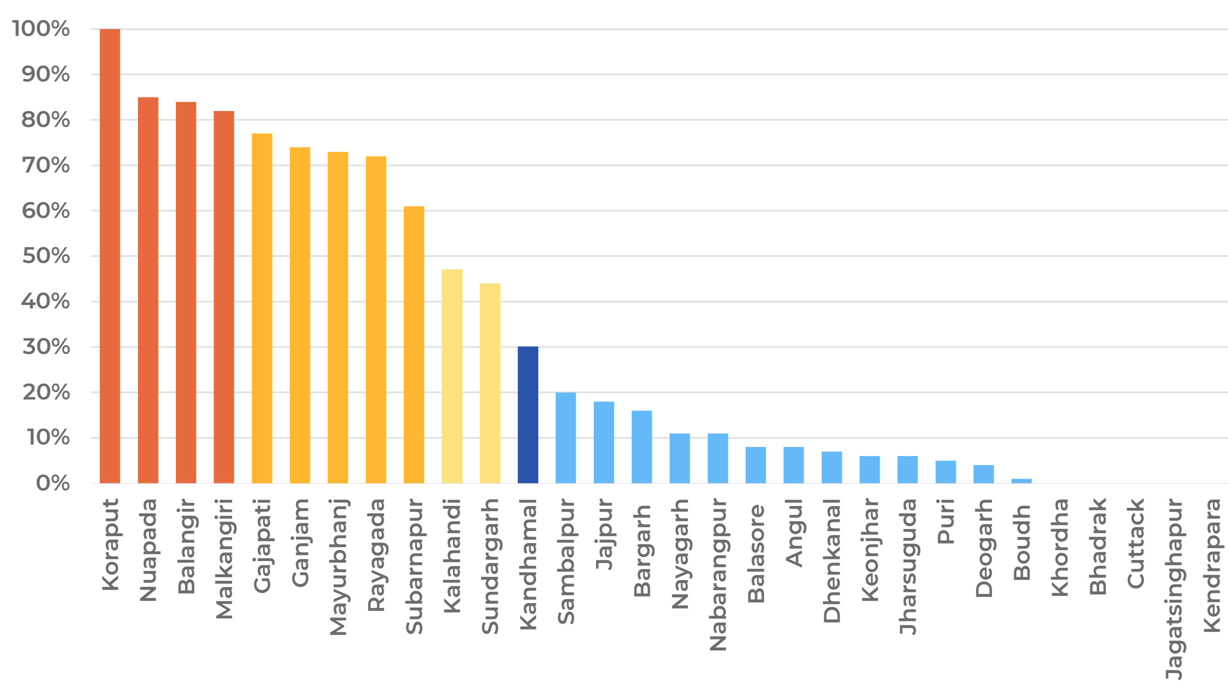


Figure 24: Average exposure of the agriculture sub-sector to droughts

Among the assets considered, tube wells and food parks are least exposed, but this could be due to the lack of data uniformly across all districts. The details of exposure for individual assets for the agricultural sub-sector can be found in the Appendix 6.

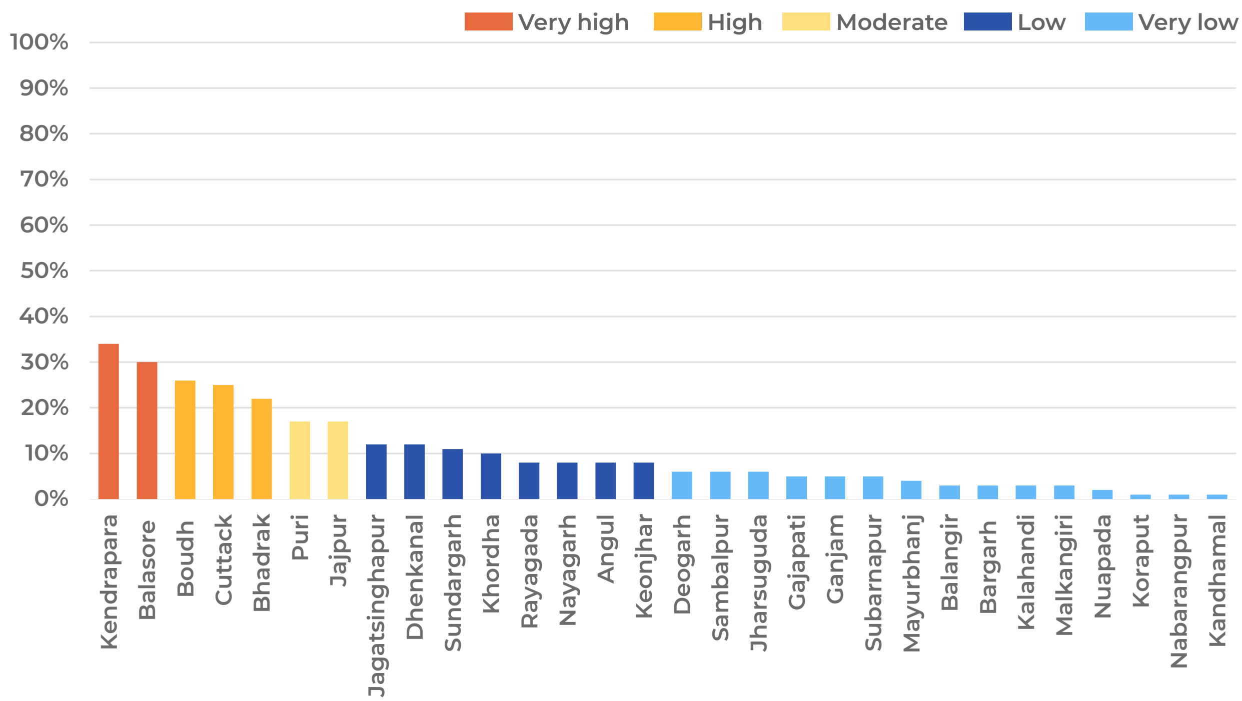


Figure 25: Average exposure of the agriculture sub-sector to floods

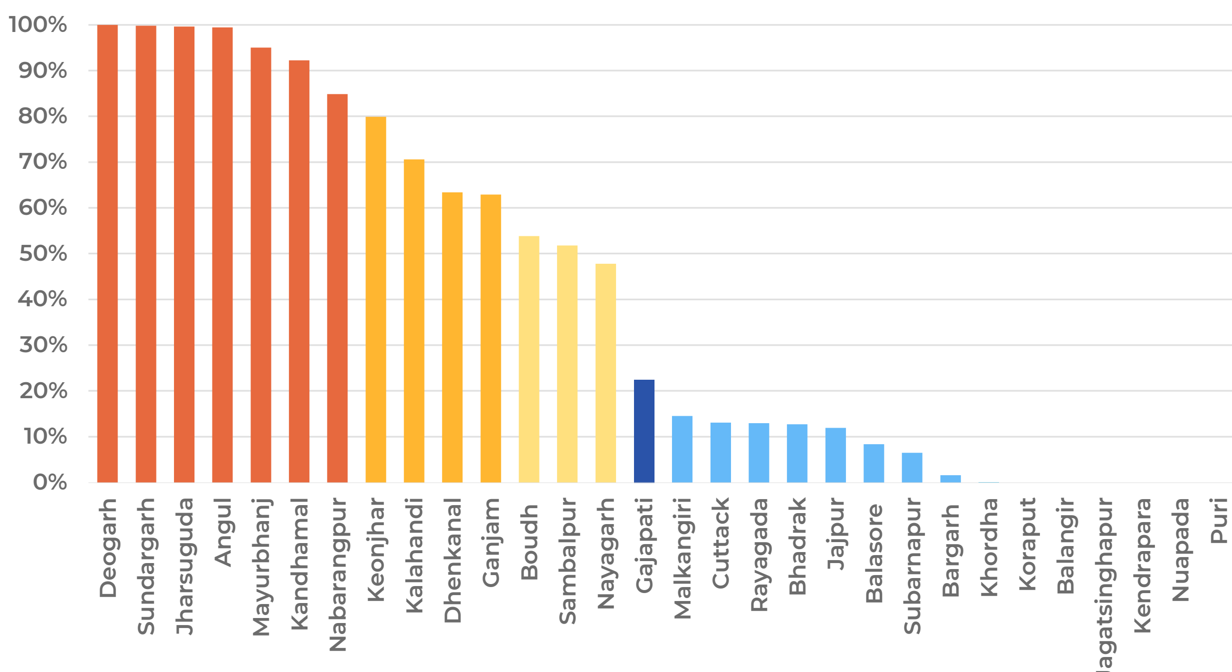


Figure 26: Average exposure of the agriculture sub-sector to heatwaves

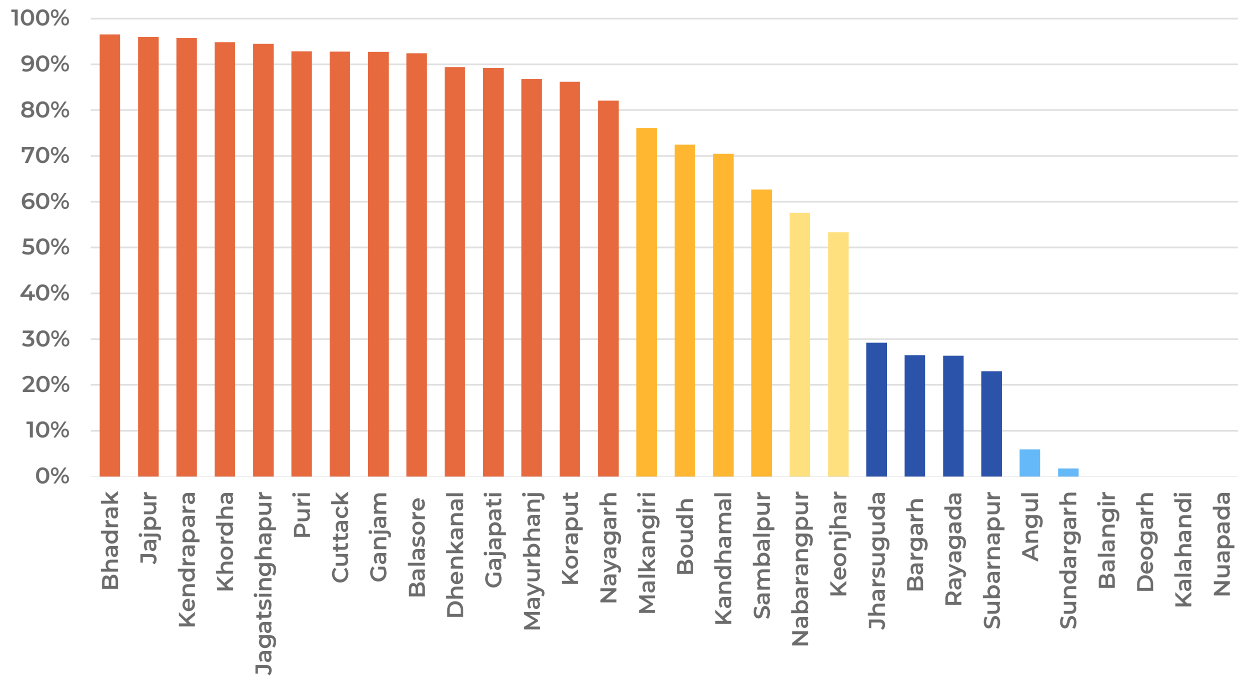


Figure 27: Average exposure of the agriculture sub-sector to tropical cyclones with wind speeds of 120 km/hr and above

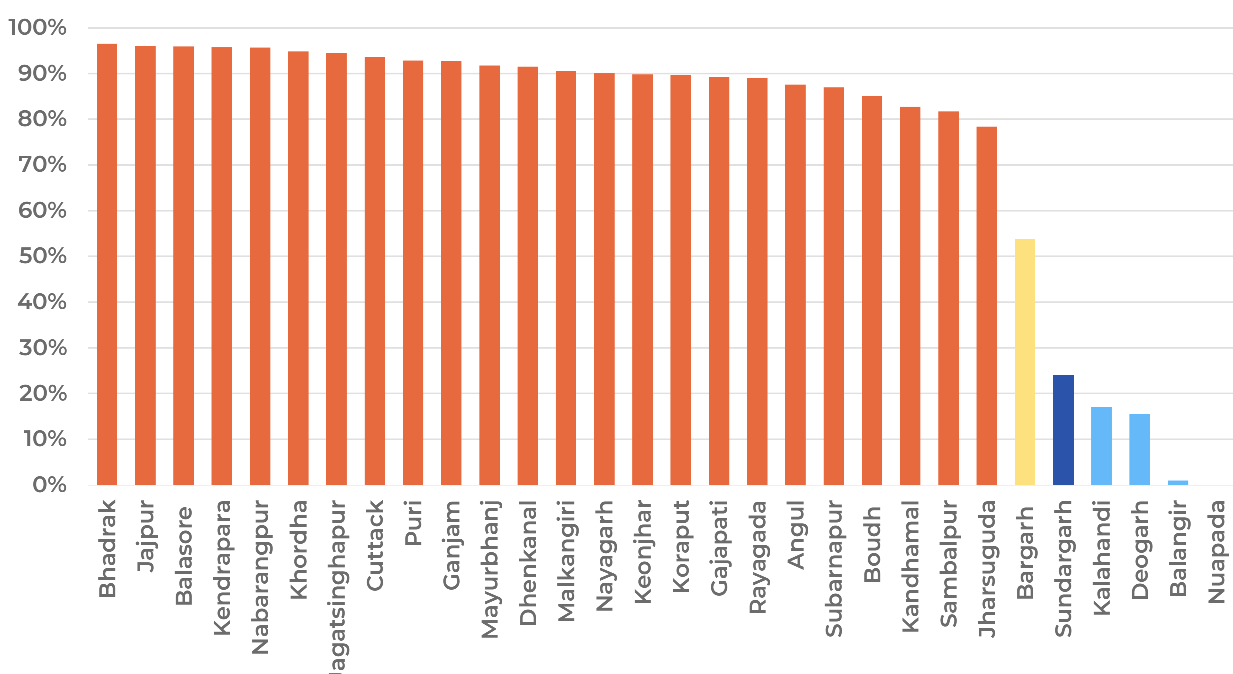


Figure 28: Average exposure of the agriculture sub-sector to tropical cyclones with wind speeds of 90 to 120 km/hr

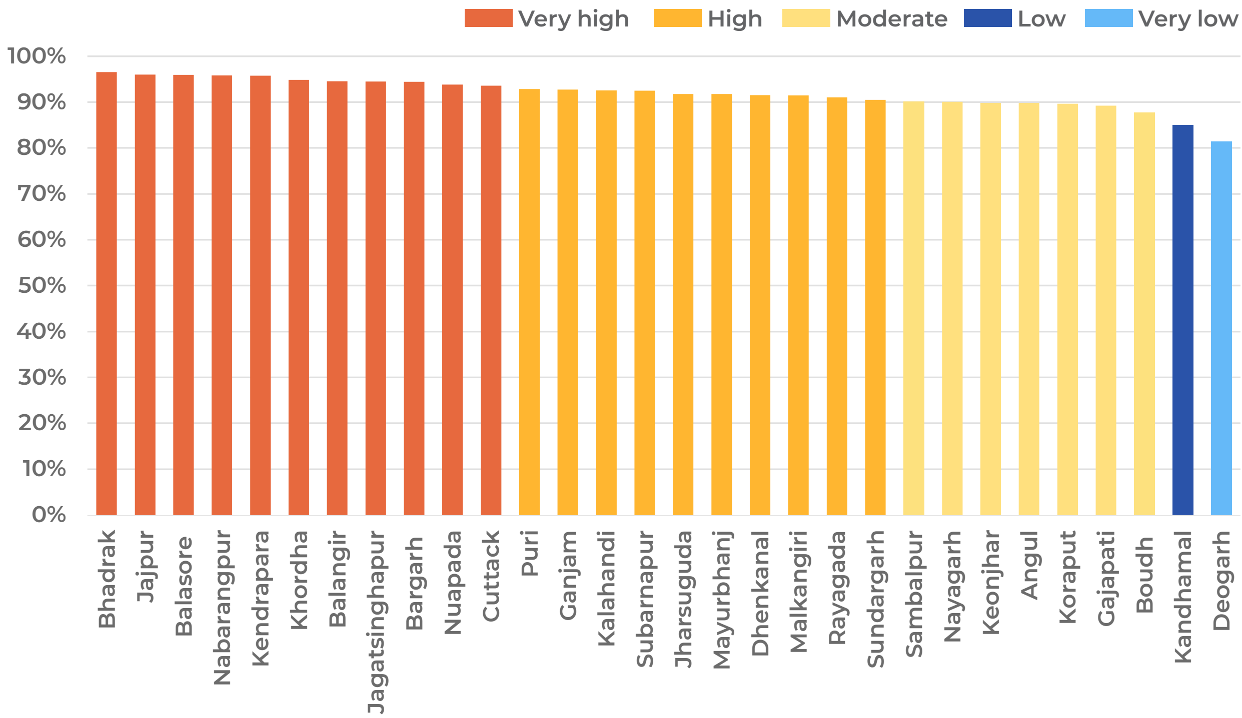


Figure 29: Average exposure of the agriculture sub-sector to tropical cyclones with wind speeds of 60 to 90 km/hr

4.2.3. Exposure of livestock sub-sector to different hazards

This section presents the results of the exposure analysis for the livestock sub-sector, including the overall average exposure of livestock assets to each hazard – droughts, floods, heatwaves, and tropical cyclones. Cattle feed plants, milk chilling centres and processing units are assets least exposed to any hazard and this may primarliy be due to lack of uniform data across all the districts of Odisha. Gridded livestock data was cross-verified and validated against the 2019 Indian Animal Husbandry Census data. The gridded data shows close alignment with the census data, with an average discrepancy of ±10%.

To summarise:

- **Exposure to droughts** (Figure 30): Livestock assets in Koraput (100%) are most exposed, closely followed by Nuapada, Malkangiri, Balangir, Rayagada, Gajapati, and Ganjam.

- **Exposure to floods** (Figure 31): Livestock assets in Balasore (57%) are most exposed, closely followed by Puri and Boudh.

- **Exposure to heatwaves** (Figure 32): Livestock assets in Deogarh, Angul, Sundargarh, and Jharsuguda are most exposed (100%), closely followed by Mayurbhanj, Keonjhar, Nabarangpur, and Kandhamal.

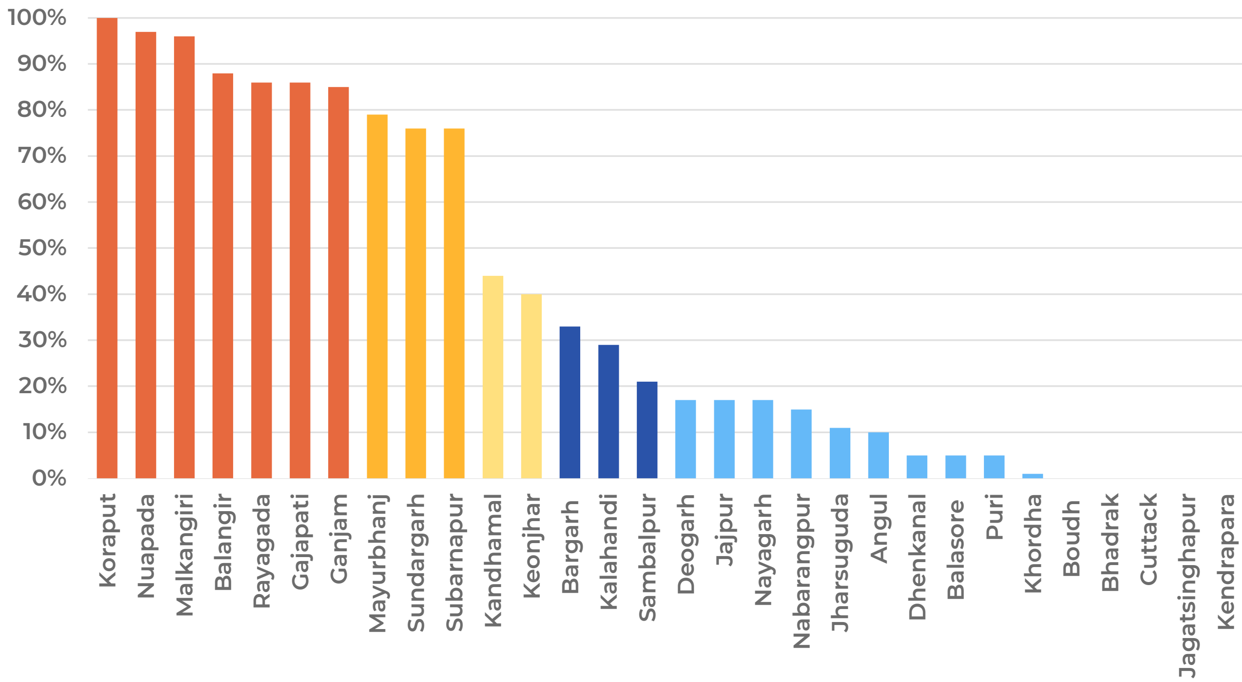


Figure 30: Average exposure of livestock sub-sector to droughts

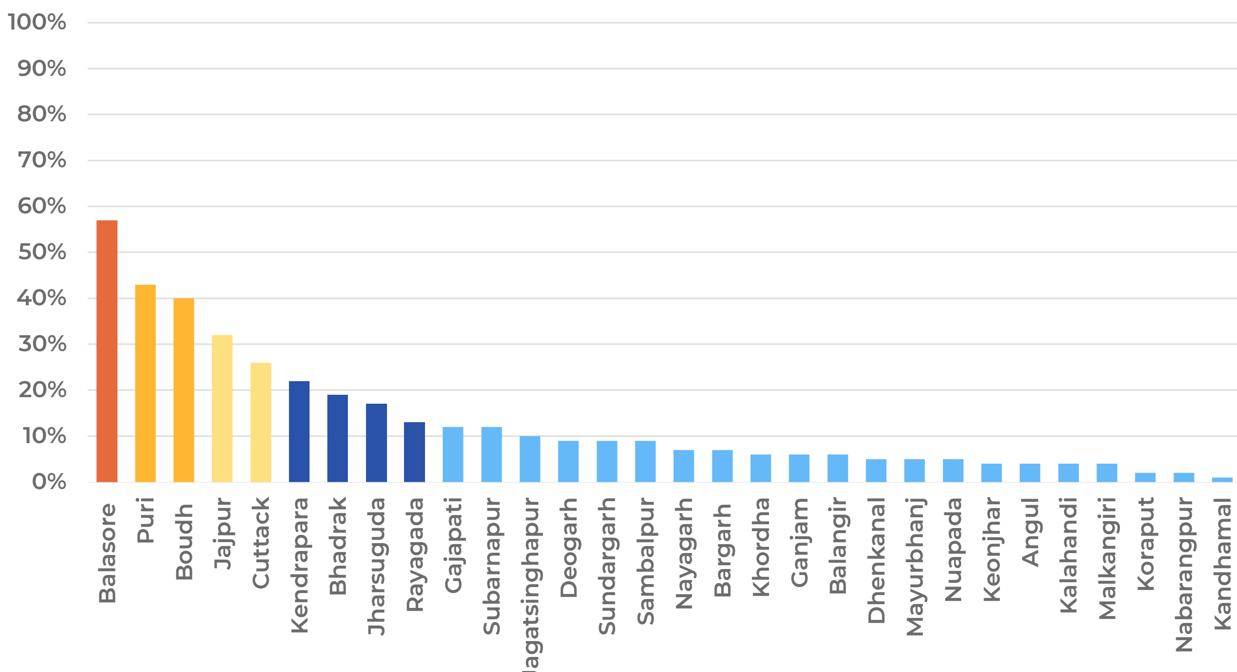


Figure 31: Average exposure of livestock sub-sector to floods

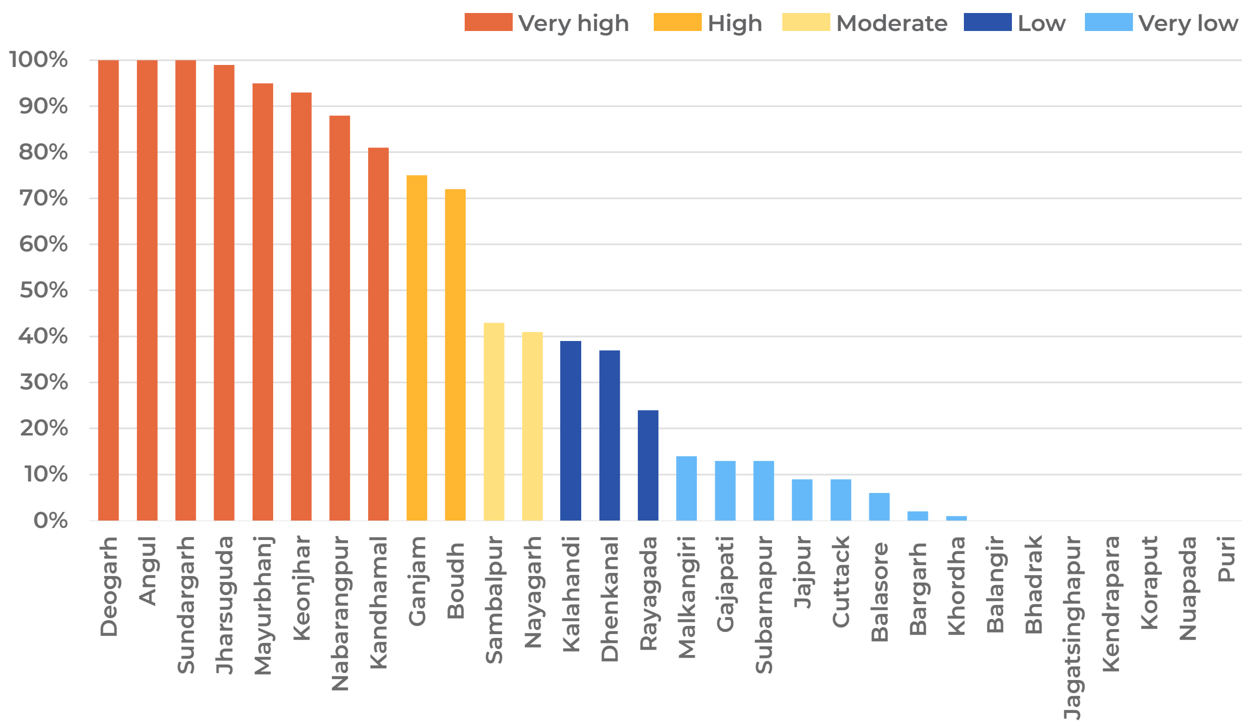


Figure 32: Average exposure of livestock sub-sector to heatwaves

- **Exposure to tropical cyclones**

  Exposure to higher wind speeds (120 km/h and above):
  - Livestock sub-sector indicators of Districts such as Gajapati, Ganjam, Jagatsinghpur, Jajpur, Kendrapara, and Khordha show 100% exposure according to the analysis (Figure 33).

  Exposure to wind speeds of 90–120 km/h:
  - Balasore, Cuttack, Dhenkanal, Gajapati, Ganjam, and Jagatsinghpur livestock assets are very highly exposed to wind speeds of 90–120 km/hr. Livestock assets in districts like Nayagarh and Angul are moderately exposed, while Jharsuguda, Deogarh, and Kalahandi have low to very low exposure (Figure 34).

  Exposure to wind speeds of 60–90 km/h:
  - Almost all districts, except Bhadrak and Puri, have 100% exposure (Figure 35).

The details of exposure for individual assets for the livestock sub-sector can be found in Appendix 6.1.2.

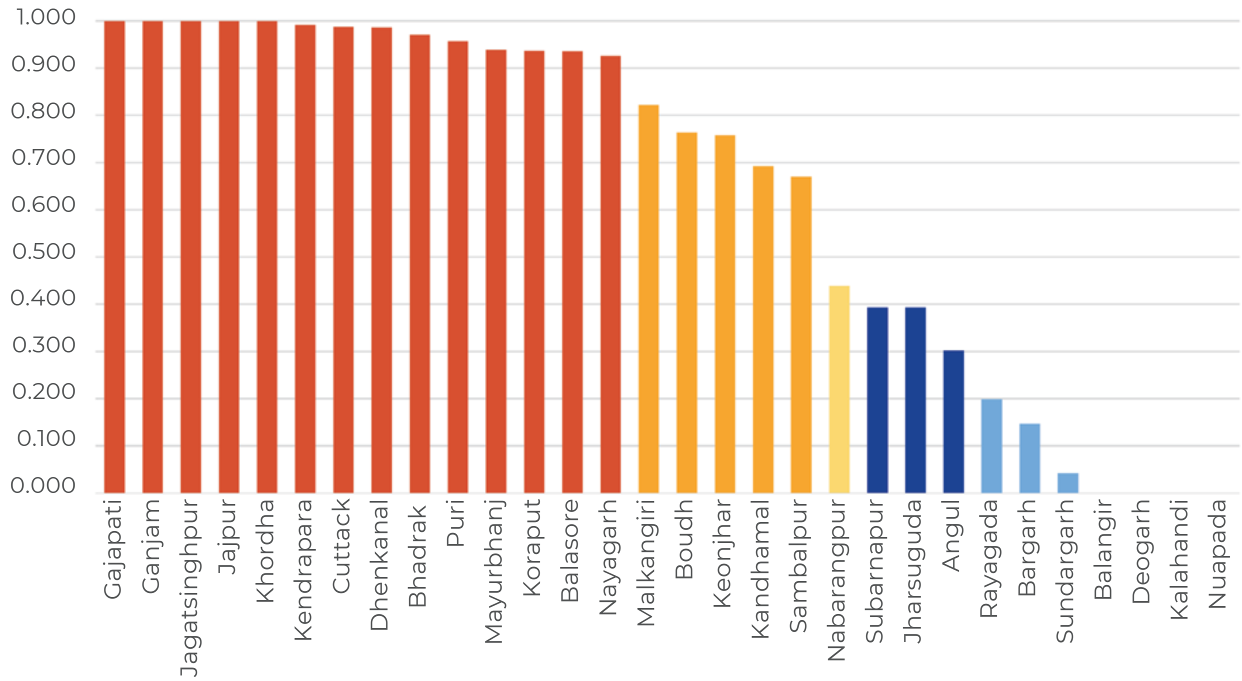


Figure 33 Exposure of livestock sub-sector to tropical cyclones with wind speeds of 120km/hr and above

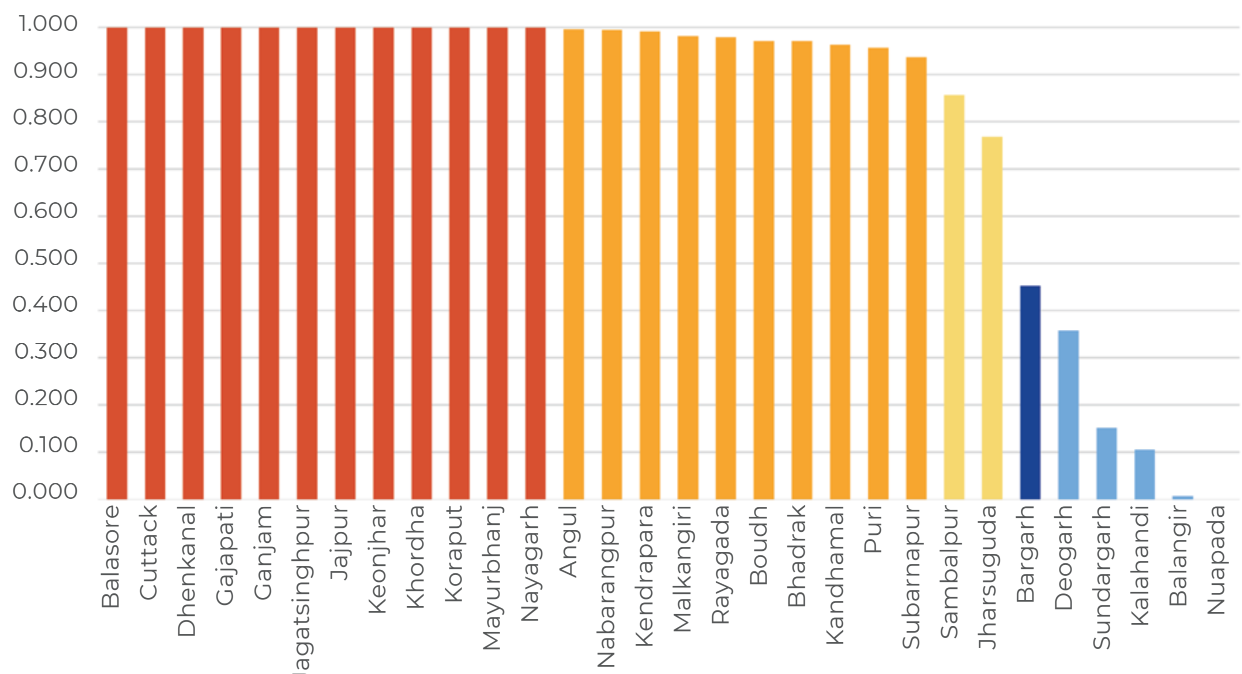


Figure 34: Exposure of livestock sub-sector to tropical cyclones with wind speeds of 90 to 120 km/hr

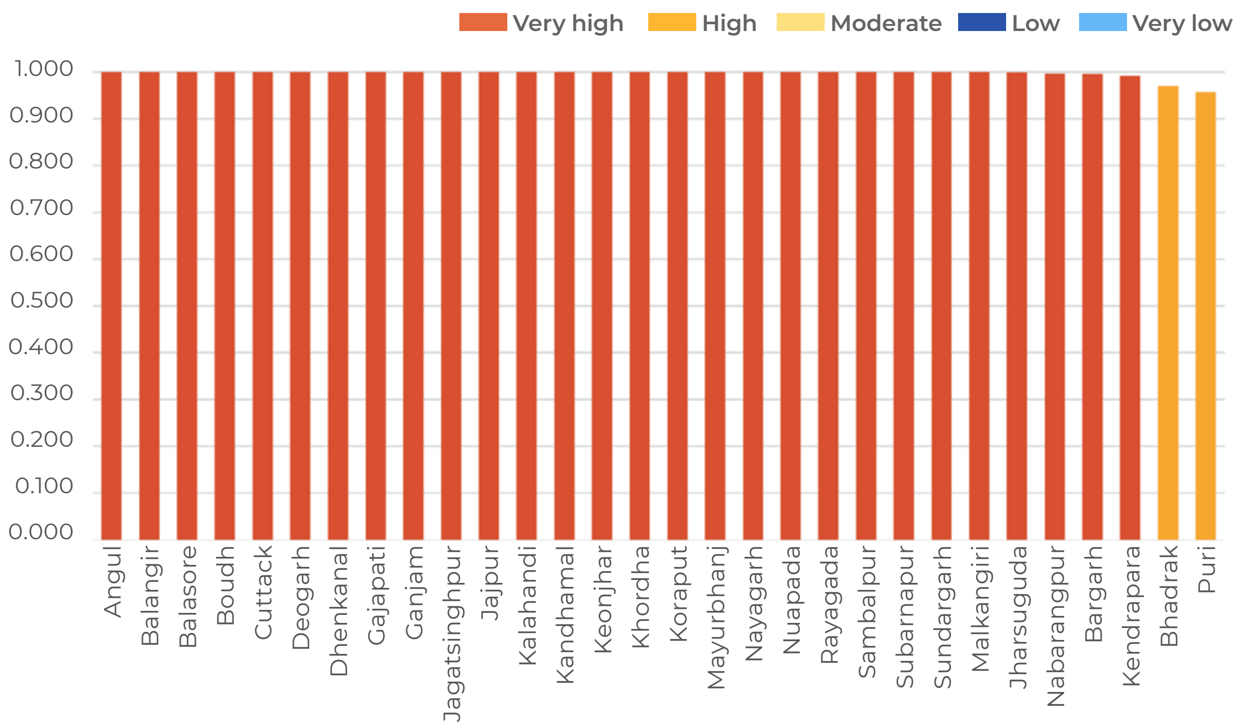


Figure 35: Exposure of livestock sub-sector to tropical cyclones with wind speeds 60 to 90 km/hr

4.2.4. Exposure of fisheries sub-sector to different hazards

This section presents the results of the exposure analysis for the fisheries sub-sector, including the overall average exposure of fisheries assets to droughts, floods, heatwaves and tropical cyclones. Exposure of individual assets have not been presented in the graphical form, due to lack of uniform data across all districts for these assets.

In summary:

- **Exposure to droughts**: Fisheries assets in Rayagada (89%) are most exposed, closely followed by Subranapur (Figure 36), due to significant exposure of essential fisheries infrastructure.
- **Exposure to floods**: Fisheries assets in Boudh (54%) are most exposed, closely followed by Cuttack, primarily due to significant exposure of fuel points (Figure 37).
- **Exposure to heatwaves**: Essential fisheries assets in Deogarh (100%) are most exposed, closely followed by Jharsuguda, Angul, and Keonjhar (Figure 38).
- **Exposure to tropical cyclones**
  - Fisheries sub-sector indicators exhibit high exposure, particularly in coastal and central districts across all wind speeds.
  - Assets in western and inland districts such as Nuapada, Kalahandi, and Sundargarh consistently have low to very low exposure.

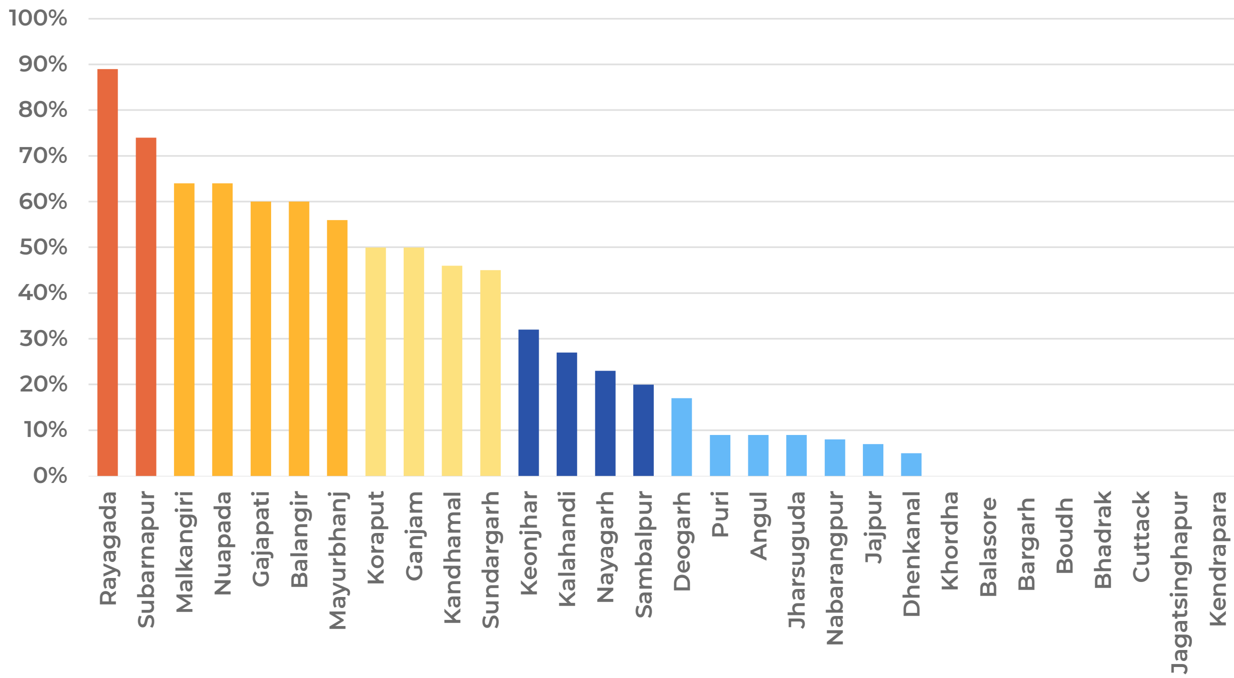


Figure 36: Average exposure of fisheries sub-sector to droughts

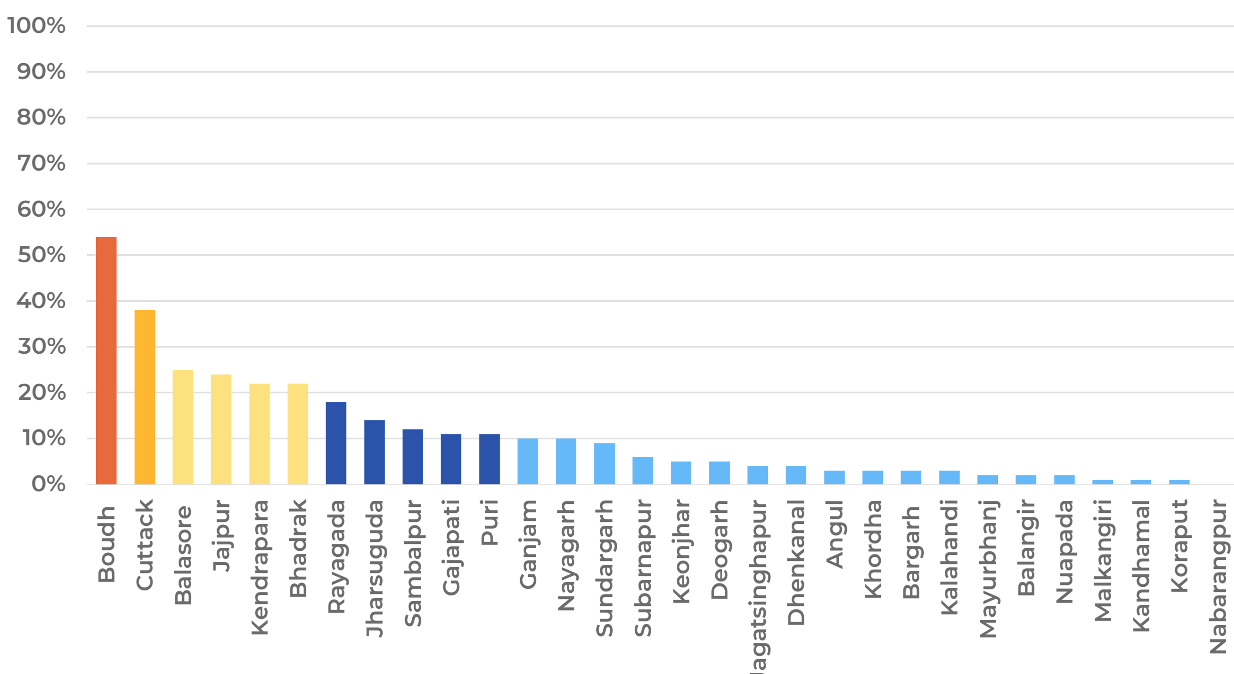


Figure 37: Average exposure of fisheries sub-sector to floods

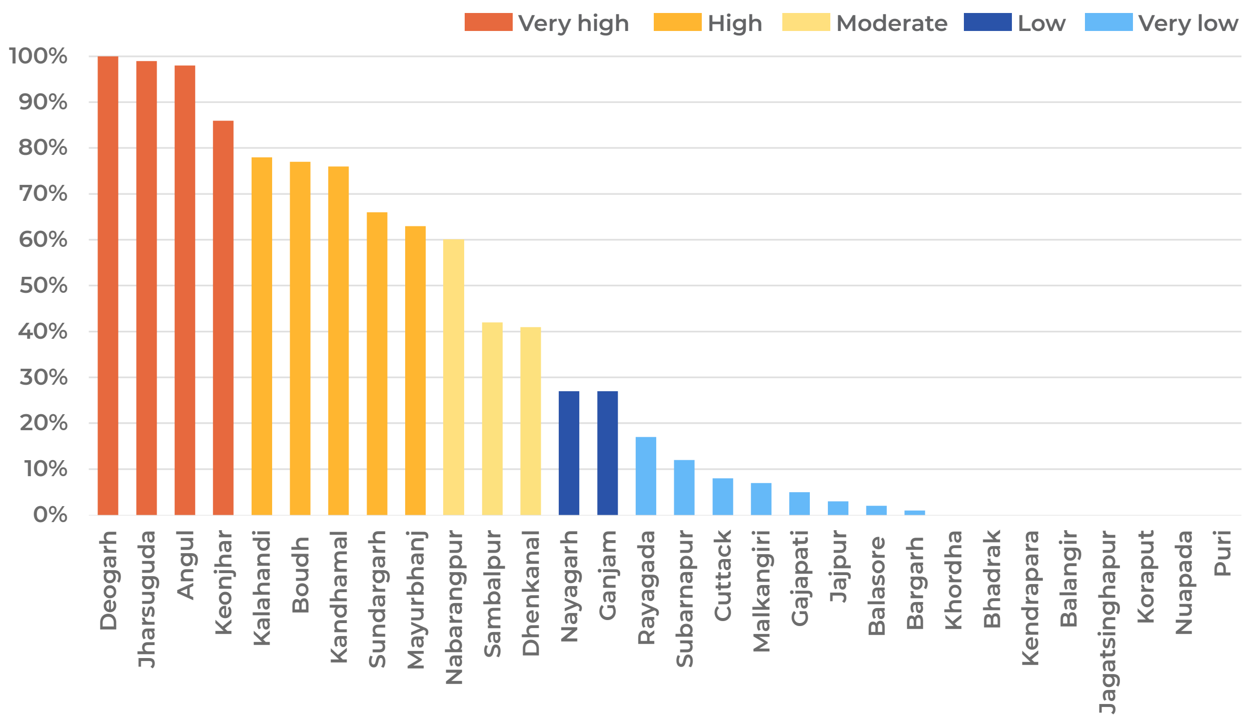


Figure 38: Average exposure of fisheries sub-sector to heatwaves

Exposure to higher wind speeds (120 km/h and above):

- Gajapati, Jajpur, Cuttack, Dhenkanal, and Nayagarh experience very high exposure.
- Districts such as Kendrapara, Bhadrak, and Khordha fall into the high exposure category (Figure 39)

Exposure to wind speeds of 90–120 km/h:

- Balasore, Cuttack, Dhenkanal, Gajapati, and Jajpur remain in the very high exposure category.
- The low exposure category includes Puri and Jagatsinghpur, while Nuapada, Kalahandi, and Sundargarh remain in the very low exposure category (Figure 40).

Exposure to wind speeds of 60–90 km/h:

- A majority of districts fall into the very high exposure category, including Angul, Balangir, Balasore, Bargarh, Cuttack, and Dhenkanal.
- Kendrapara, Bhadrak, Khordha, Ganjam, Puri, and Jagatsinghpur exhibit high exposure but not as extreme as others (Figure 41).

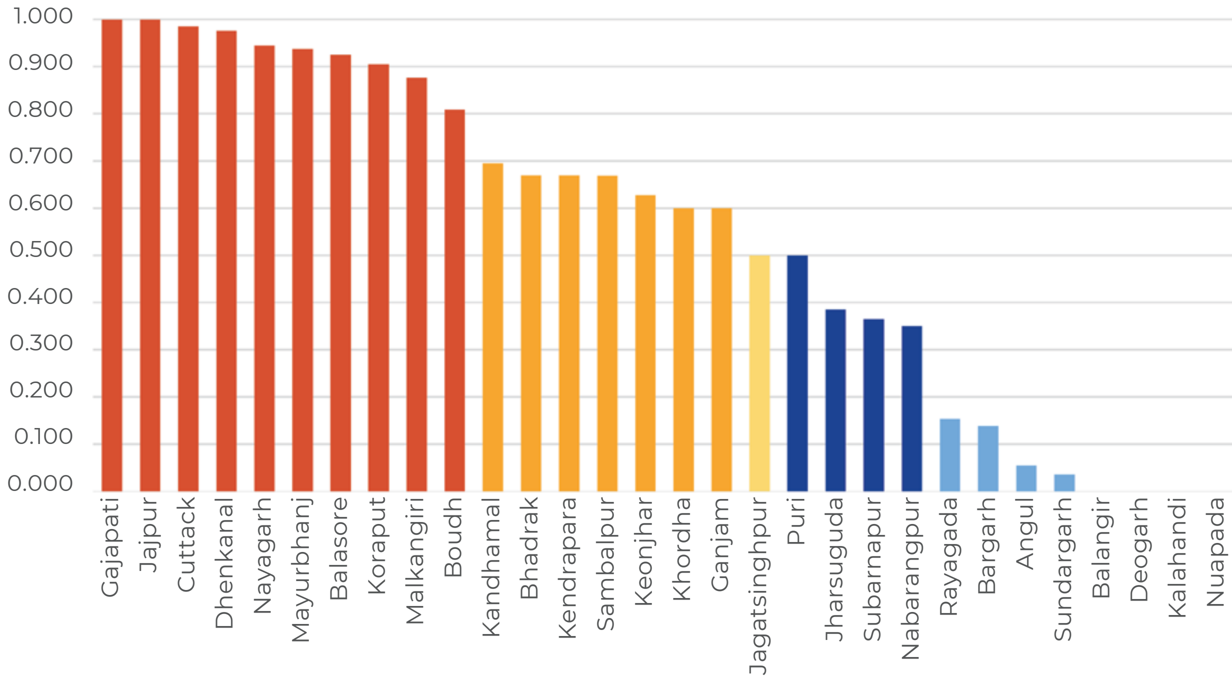


Figure 39: Exposure of fisheries sub-sector to tropical cyclones with wind speeds of 120 km/hr and above

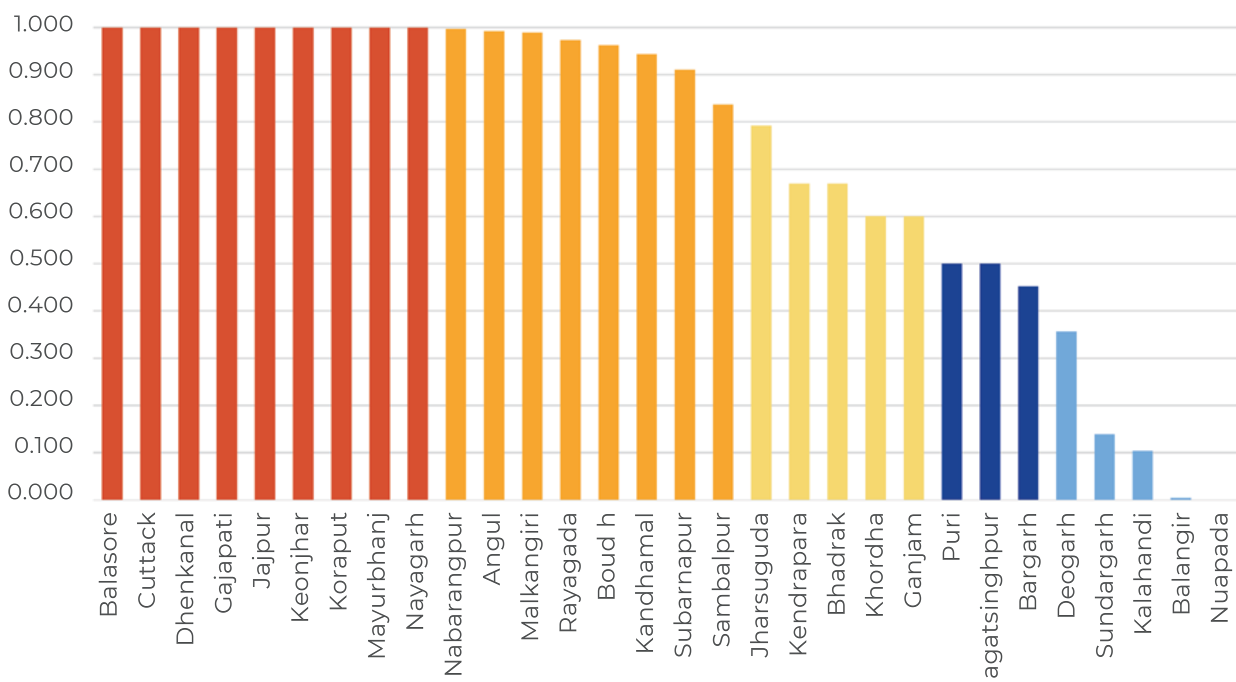


Figure 40: Exposure of fisheries sub-sector to tropical cyclones with wind speeds of 90 to 120 km/hr

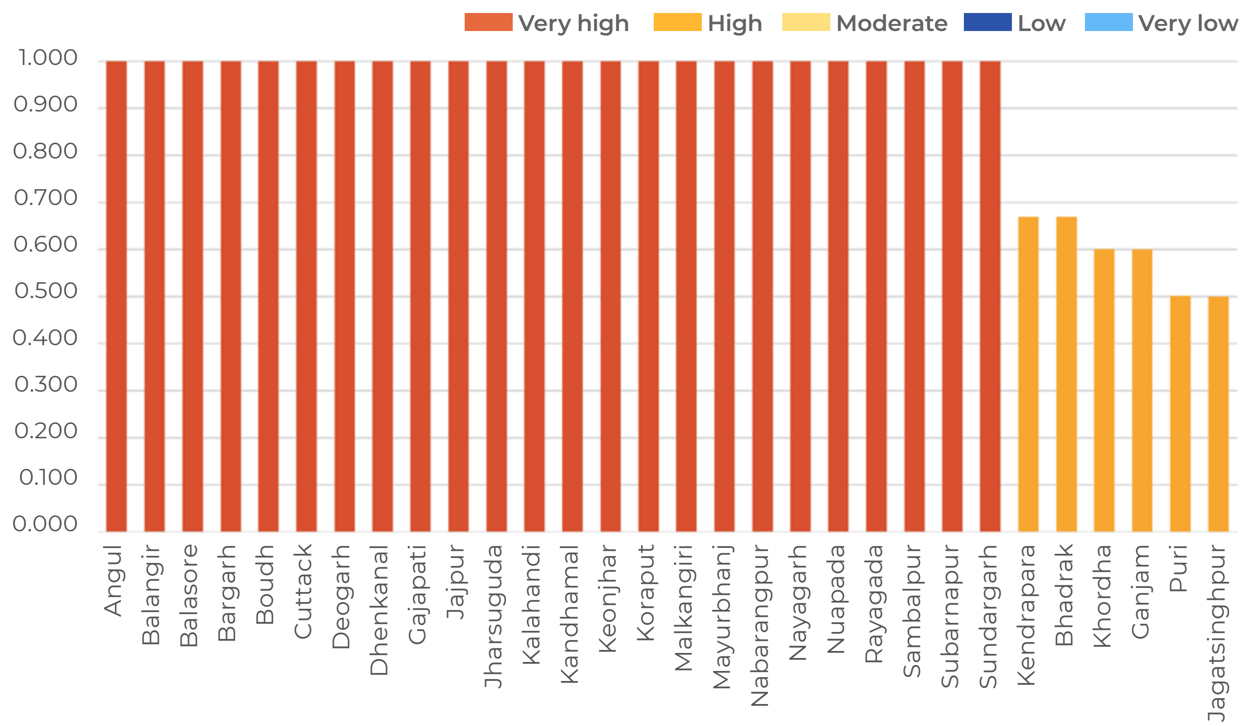


Figure 41: Exposure of fisheries sub-sector to tropical cyclones with wind speeds of 60 to 90 km/hr

4.3. Vulnerability

The list of indicators selected to represent each sub-sector of the larger agriculture and allied sector, along with the rationale for selection of certain indicators, functional relationship and data sources, are presented in Appendix 6.2. In the following sections, the overall vulnerability of agriculture, livestock and fisheries that constitute agriculture and allied sector are presented, followed by the results of the vulnerability assessments for each sub-sector.

4.3.1. Overall vulnerability of agriculture and allied sectors

All indicators from the agriculture, livestock and fisheries sub-sector – 32 sub-indicators in all – were aggregated to arrive at the agriculture and allied sector vulnerability index scores for all districts. The sub-indicators represent the dependence on agriculture and sensitivity of the workforce; productivity and adaptive capacity of crop cultivation; adaptive capacity of farming communities; dependence on and sensitivity of livestock sector; adaptive capacity of livestock production; access to health care for livestock;

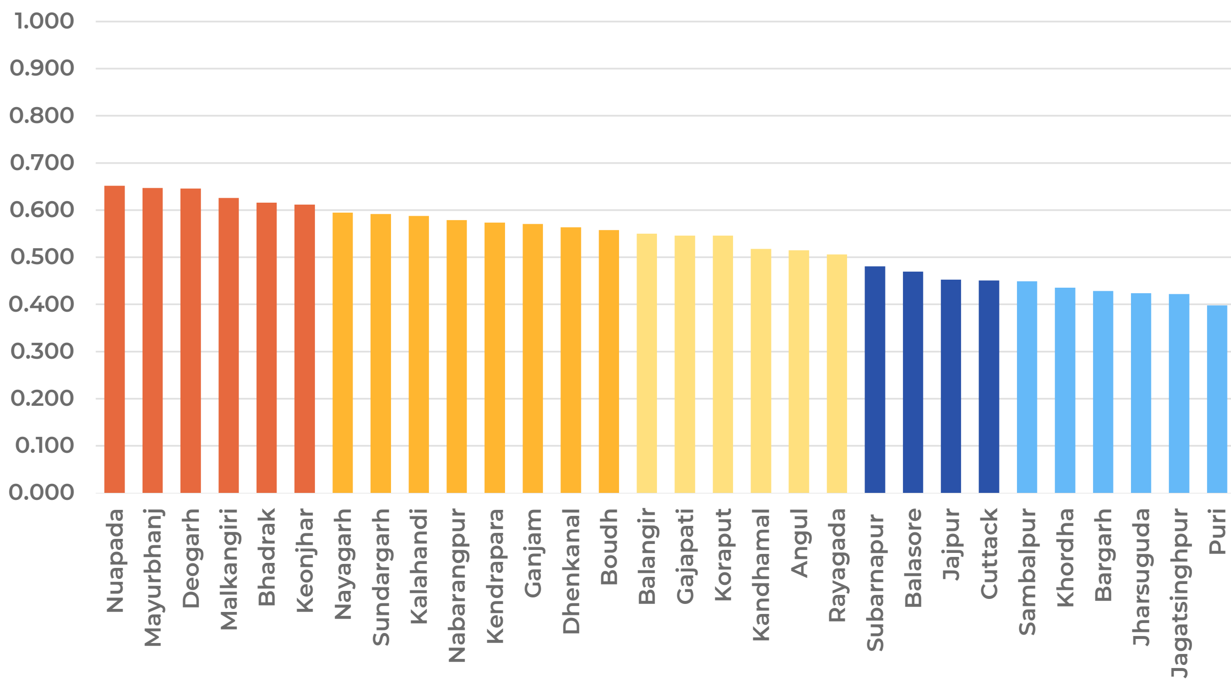


Figure 42: Vulnerability ranking of agriculture and allied sector at a district level for Odisha

post-production support for livestock-dependent households; and fish productivity.

According to this assessment:

- Nuapada, Mayurbhanj, Deogarh, Malkangiri, Bhadrak and Keonjhar districts have been ranked as having very high vulnerability.

- Eight districts – Nayagarh, Sundargarh, Kalahandi, Nabarangpur, Kendrapara, Ganjam, Dhenkanal, and Boudh were ranked as having high vulnerability (Figure 42). The spatial distribution of agriculture and allied sector vulnerability is provided in Figure 43.

According to the Odisha SAPCC (2021-30), the districts which are identified as most vulnerable are: Subranapur, Dhenkanal, Jajpur, Kalahandi, Balangir, and Kendrapara. This discrepancy in the results could be attributed to the fact that different indicators and timeframes were used in the two analyses, making direct comparison difficult.

A comparison of sub-sectoral and overall sector-level assessment reveals that three districts – Mayurbhanj, Deogarh and Kendujhar are consistently ranked as either very high or high vulnerability districts (Table 8).

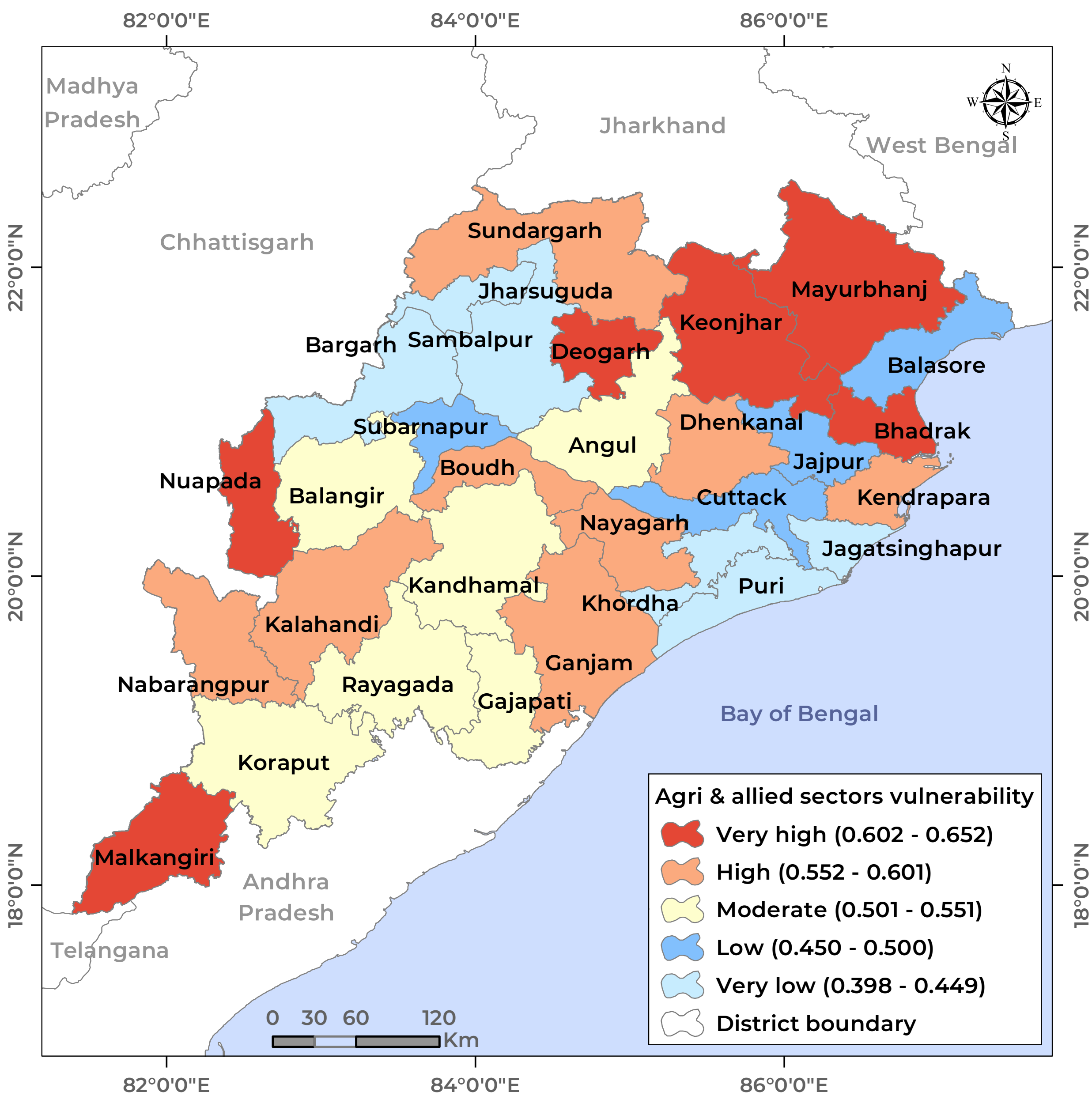


Figure 43: Vulnerability map of the agriculture and allied sector

Table 8: Comparison of district rankings of sub-sectoral and overall sector vulnerability assessment

District	Agriculture & Allied	Agriculture	Livestock	Fisheries
Nuapada	0.652	0.691	0.644	
Mayurbhanj	0.647	0.644	0.696	
Deogarh	0.646	0.595	0.758	
Malkangiri	0.626	0.649	0.63	
Bhadrak	0.616	0.604	0.571	0.63
Keonjhar	0.612	0.613	0.629	
Nayagarh	0.595	0.603	0.622	
Sundargarh	0.592	0.562	0.666	
Kalahandi	0.588	0.619	0.553	
Nabarangpur	0.579	0.628	0.551	
Kendrapara	0.574	0.585	0.474	0.663
Ganjam	0.571	0.536	0.63	0.542
Dhenkanal	0.564	0.536	0.611	
Boudh	0.558	0.542	0.597	
Balangir	0.550	0.588	0.518	
Gajapati	0.546	0.55	0.632	
Koraput	0.546	0.522	0.57	
Kandhamal	0.518	0.558	0.564	
Angul	0.515	0.568	0.452	
Rayagada	0.506	0.558	0.46	
Subarnapur	0.481	0.479	0.505	
Balasore	0.470	0.545	0.391	0.596
Jajpur	0.453	0.516	0.366	
Cuttack	0.451	0.419	0.553	
Sambalpur	0.449	0.421	0.467	
Khordha	0.436	0.313	0.63	
Baragarh	0.429	0.577	0.337	
Jharsuguda	0.424	0.466	0.361	
Jagatsinghpur	0.422	0.466	0.44	0.485
Puri	0.398	0.364	0.523	0.452

*Red: Very high; Orange: High; Yellow: Moderate; Dark blue: Low; Light blue: Very low

- The key drivers of vulnerability (Figure 44) in the districts that are ranked as being **very highly vulnerable** are:
  - Fewer ICDP/Insemination centres for livestock
  - Poor mechanisation
  - Fewer livestock aid centres
  - Poor irrigation coverage
  - Low cropping intensity
  - Fewer veterinary hospitals
  - High farm burden on Krishi Vigyan Kendras
  - High percentage of working population dependent on agriculture
  - Low road density
  - Low coverage of Integrated Farming systems
  - Fewer Farmers organised into FPOs
  - Less pasture area
  - Fewer Co-operative Societies and SHGs in the Dairy Sector
  - Low percentage contribution of livestock to the GDVA

- In districts ranked as **high in vulnerability**, key drivers identified are:
  - Fewer storage facilities to total number of farms
  - Fewer Co-operative Societies and SHGs in the Dairy Sector
  - Poor insurance coverage
  - Fewer agricultural markets to total number of farms
  - Fewer veterinary doctors and livestock inspectors
  - Less pasture area
  - Low coverage of horticulture tree plantations
  - Low road density
  - High percentage of marginal and small landholders
  - Poor mechanisation
  - Low capacity of dairy processing/chilling units

- **Common drivers** for all the districts that have been ranked as very high or high in vulnerability are:
  - Fewer Co-operative Societies and SHGs in the Dairy Sector
  - Fewer storage facilities to total number of farms
  - Fewer veterinary doctors and livestock inspectors
  - High percentage of marginal and small landholders
  - Less pasture area
  - Low road density
  - Poor insurance coverage
  - Poor mechanisation

These drivers may be considered as entry points for interventions to build resilience. Alternatively, districts with very high or high vulnerability may be prioritized to undertake a granular assessment of vulnerability to identify more nuanced drivers of vulnerability for targeted and contextualised resilience building.

FACING PAGE: Adivasi woman from the Kondh tribe selling vegetables in the Koraput market in Odisha, India.

Oscar Espinosa

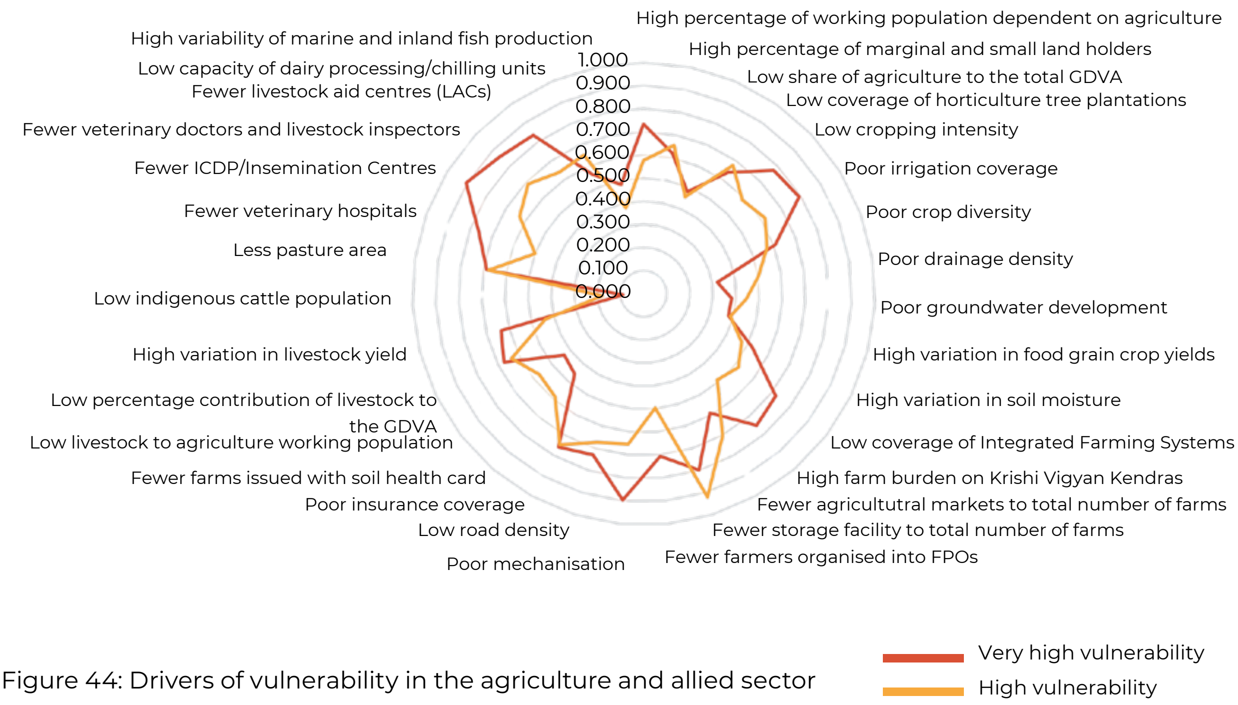


Figure 44: Drivers of vulnerability in the agriculture and allied sector

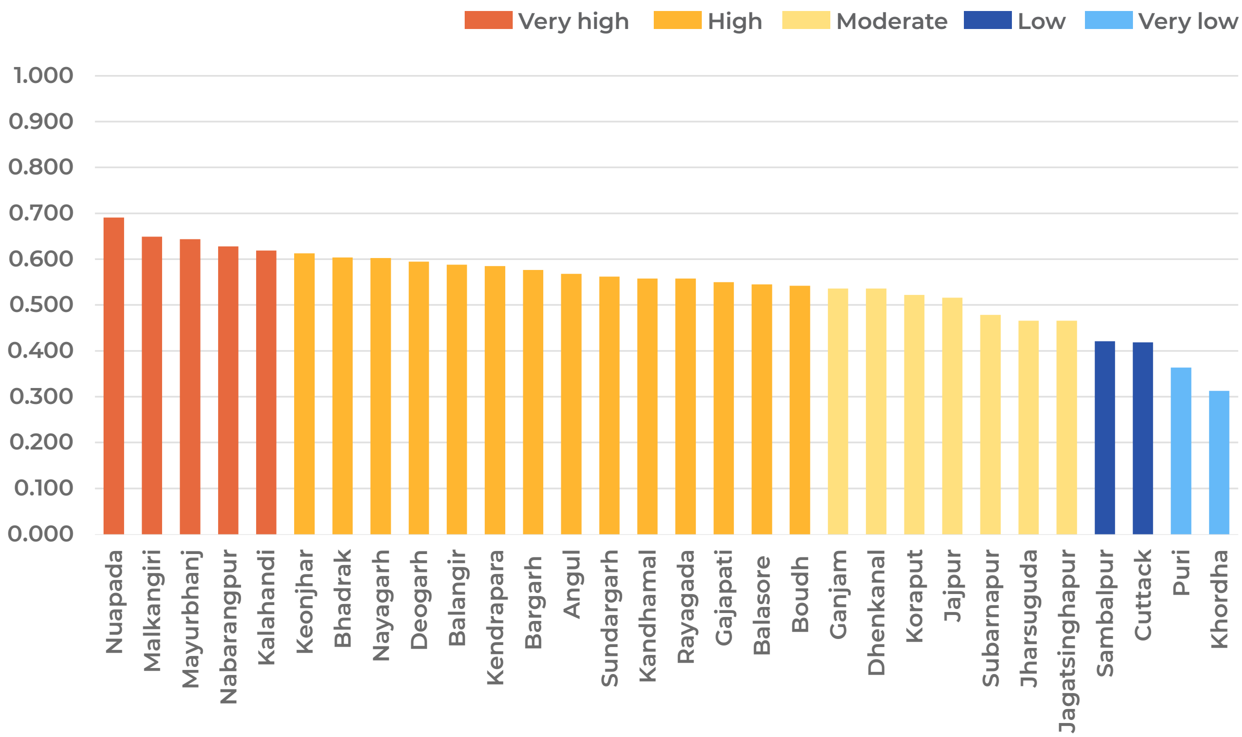


Figure 45: Vulnerability ranking of agriculture sub-sector at a district level for Odisha

4.3.2. Vulnerability assessment of agriculture sub-sector

Aggregation of the 19 sub-indicators (refer to Figure 4) representing the agriculture sub-sector in Odisha indicates that the most vulnerable districts are **Nuapada, Malkangiri, Mayurbhanj**, **Nabarangpur**, and **Kalahandi**, and the same is presented in Figure 45. The spatial distribution of agriculture vulnerability is provided in Figure 46.

Vulnerability of districts that are ranked as having very high vulnerability are driven by relatively lesser mechanisation; higher percentage of working population dependent on agriculture; poorer insurance coverage; fewer storage facilities to total number of farms; lower irrigation coverage; and lower coverage of horticulture tree plantations (Figure 47)

Similarly, the vulnerability of districts ranked as having high vulnerability are driven by fewer storage facilities to total number of farms; lower road density; high percentage of marginal and small landowners; lesser mechanisation; lower cropping intensity; and poorer irrigation coverage as compared to the districts ranked as having moderate, low and very low vulnerability.

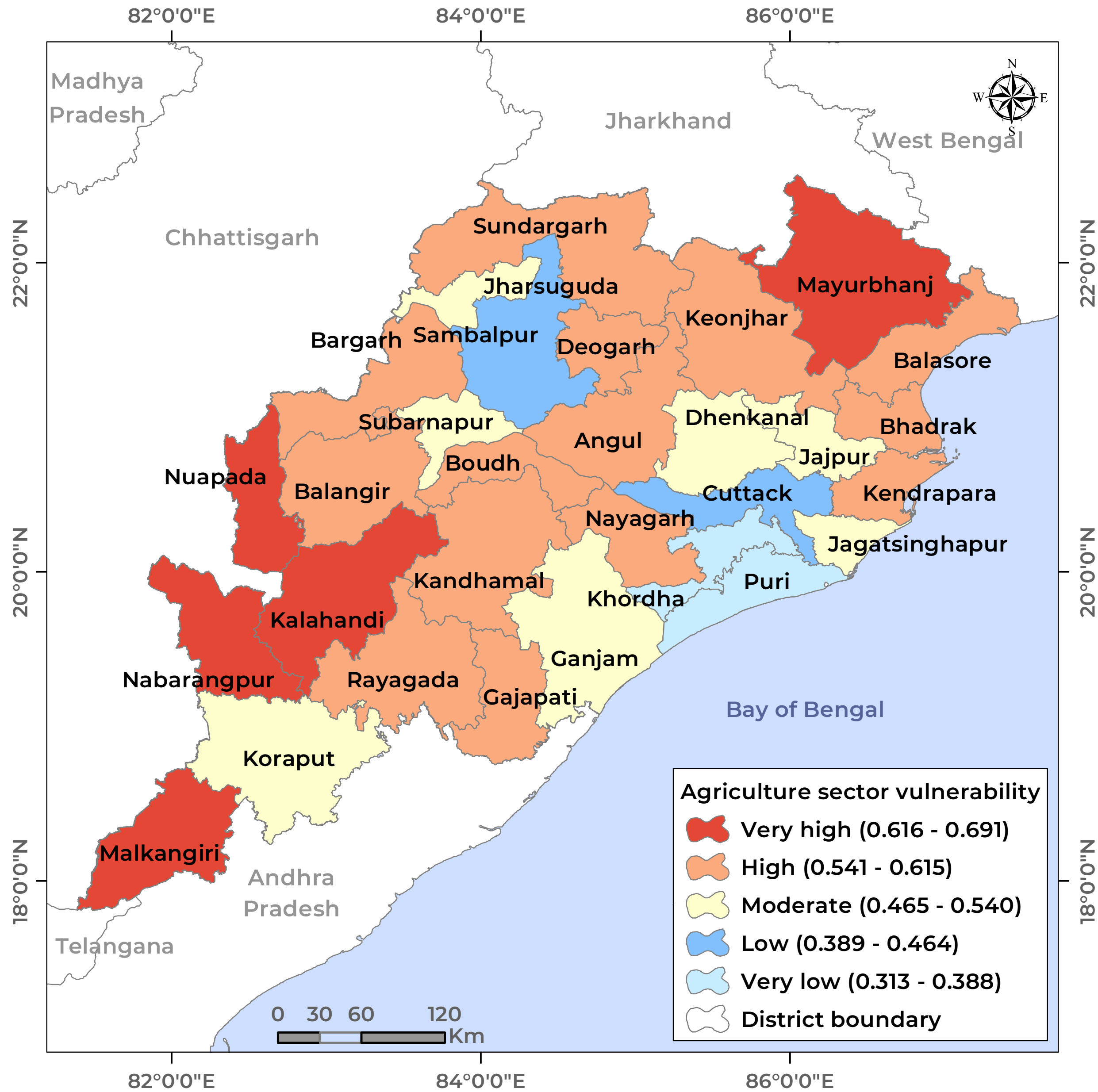


Figure 46: Vulnerability map of the agriculture sub-sector

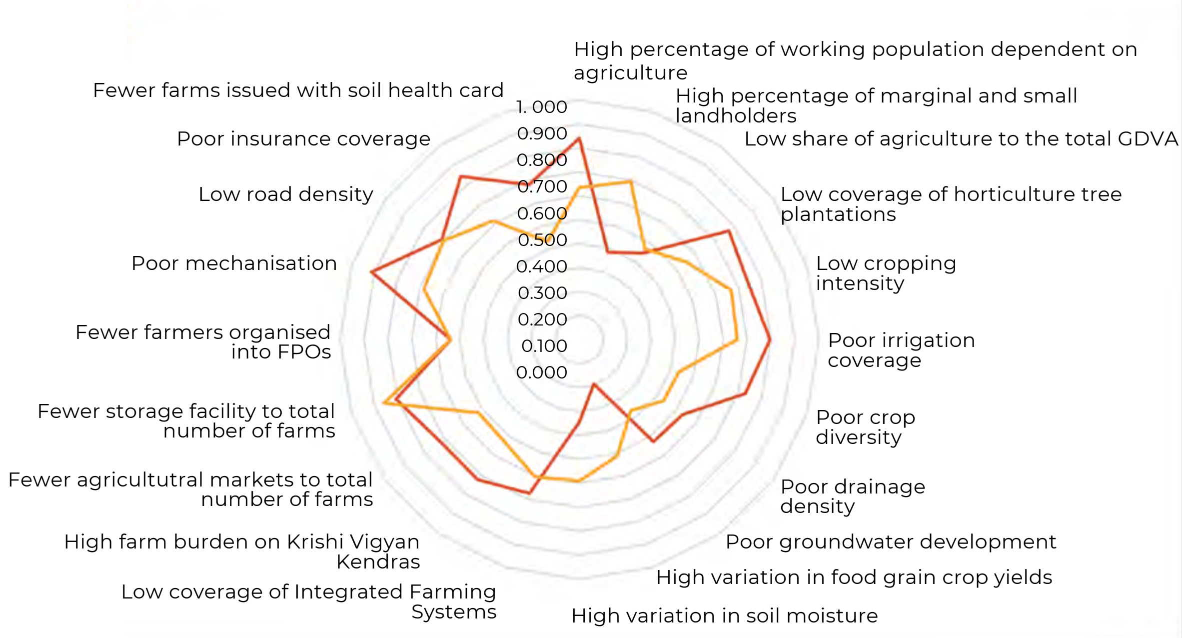


Figure 47: Drivers of vulnerability in the agriculture sub-sector

BELOW: Agricultural workers using tractor mounted paddy threshing machine or harvester to extract ripe rice grains in Odisha, India.

Manoranjan Mishra

4.3.3. Vulnerability assessment of livestock sub-sector

The 11 livestock-related sub-indicators (refer to Figure 5) were aggregated, and vulnerability index scores were compared across all districts of Odisha. According to the assessment, two districts, Deogarh and Mayurbhanj, are ranked as having very high vulnerability and ten districts are ranked as having high vulnerability – Sundargarh, Nuapada, Gajapati, Khordha, Malkangiri, Ganjam, Keonjhar, Nayagarh, Dhenkanal and Boudh (Figure 48). The spatial distribution of livestock vulnerability is provided in Figure 49.

The major drivers of vulnerability (Figure 50) in districts ranked as very highly vulnerable (Deogarh and Mayurbhanj) are fewer veterinary doctors and livestock inspectors; fewer ICDP/Insemination Centres; lower capacity of dairy processing/chilling units; fewer livestock aid centres (LACs); lesser pasture area; higher variation in livestock yield; fewer veterinary hospitals; and fewer co-operative societies and SHGs in the dairy sector.

Likewise, in districts ranked as having high vulnerability fewer co-operative societies and SHGs in the dairy sector; fewer ICDP/ Insemination Centres and fewer livestock aid centres (LACs) significantly drive vulnerability.

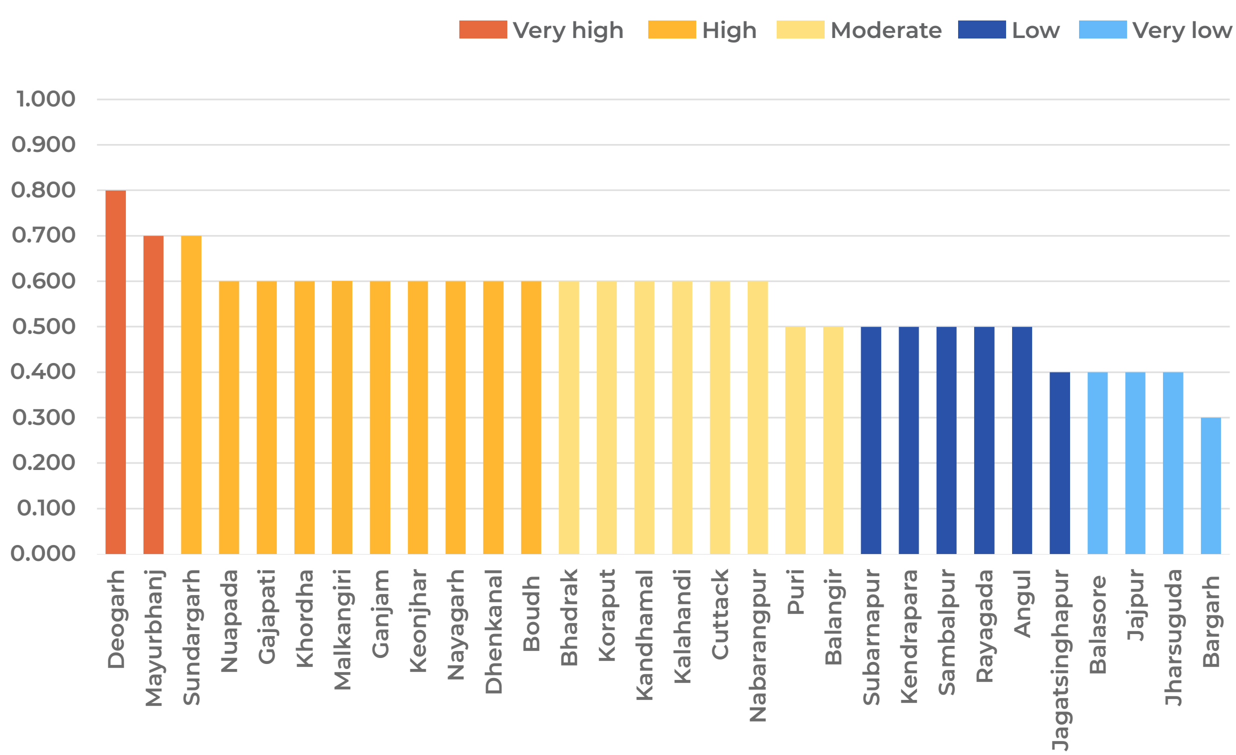


Figure 48: Vulnerability ranking of livestock sub-sector at a district level for Odisha

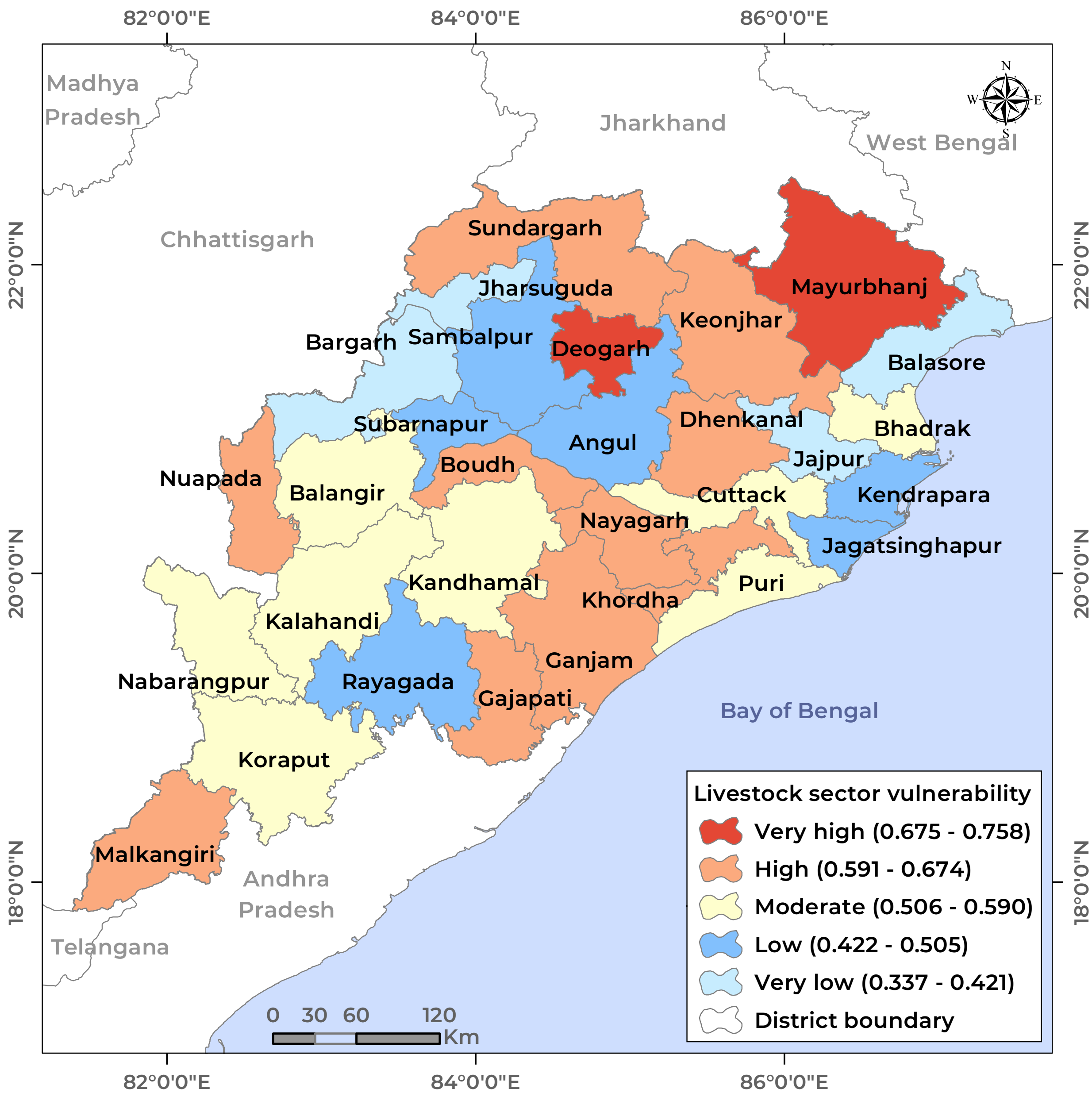


Figure 49: Vulnerability map of the livestock sub-sector

FACING PAGE: Indigenous shepherds lead a group of sheep and cattle along the roads around a Khond village, in Odisha. Stefano Barzellotti

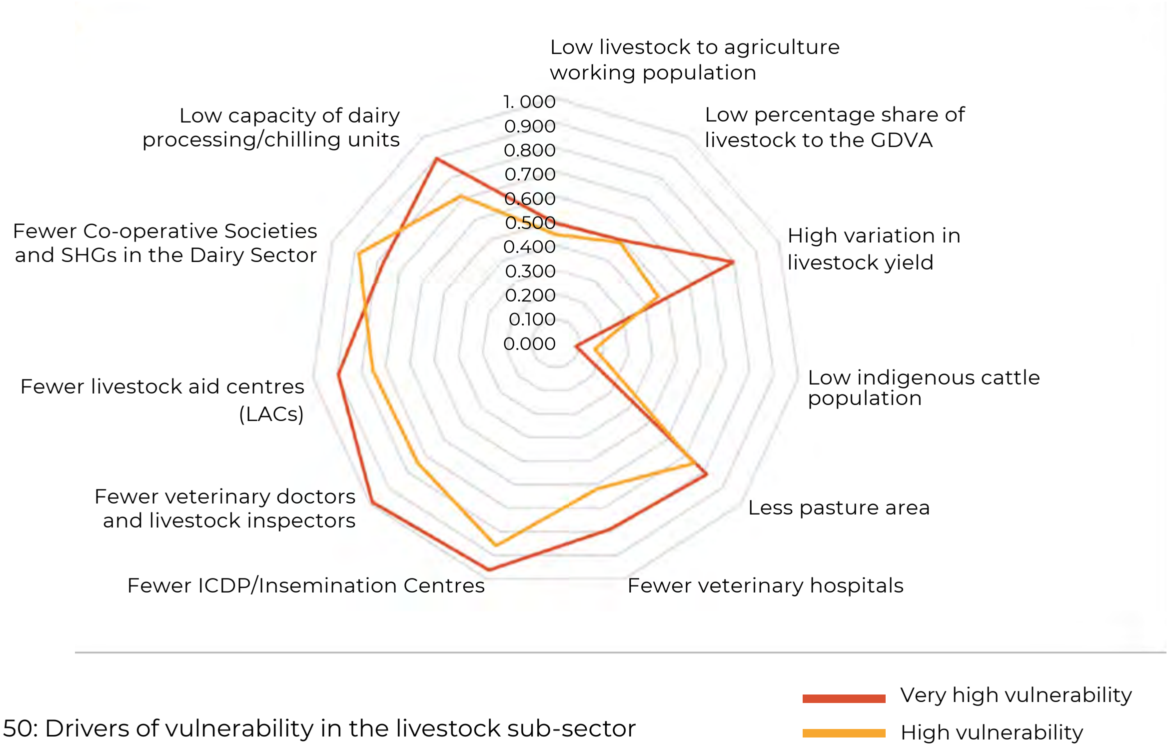


Figure 50: Drivers of vulnerability in the livestock sub-sector

4.3.4. Vulnerability assessment of fisheries sub-sector

The assessment of vulnerability for fisheries sub-sector considered only the six coastal districts of Odisha and utilised 15 sub-indicators to represent the sector. According to the assessment, the fisheries sub-sectors in Kendrapara and Bhadrak districts are relatively more vulnerable, followed by Balasore, which is classified as having high vulnerability (Figure 51). The spatial distribution of vulnerability is provided in Figure 52.

In Kendrapara and Bhadrak, fewer fisherfolk have pucca houses as compared to the other coastal districts. Also, fewer fisherfolk own a fishing craft, and fewer still have access to motorised fishing crafts. There is relatively low participation of fisherfolk in fishermen co-operative societies, and the fishing sector doesn't contribute as much to the GDVA in these districts. There is also lower involvement of women in fishing activities; with a high variation in marine fish production; and fewer cold storage facilities (Figure 53).

Balasore, which is ranked as being highly vulnerable, also experiences similar issues related to the involvement of women in fishing activities; ownership of motorised and non-motorised fishing crafts; and membership in fishermen co-operative societies. Additionally, this district records a high proportion of fisherfolk to the total population, highlighting a dependence on the sector; poor uptake of aquaculture practices; poor coverage of life-saving equipment; and a low coverage of mangroves driving vulnerability in this district.

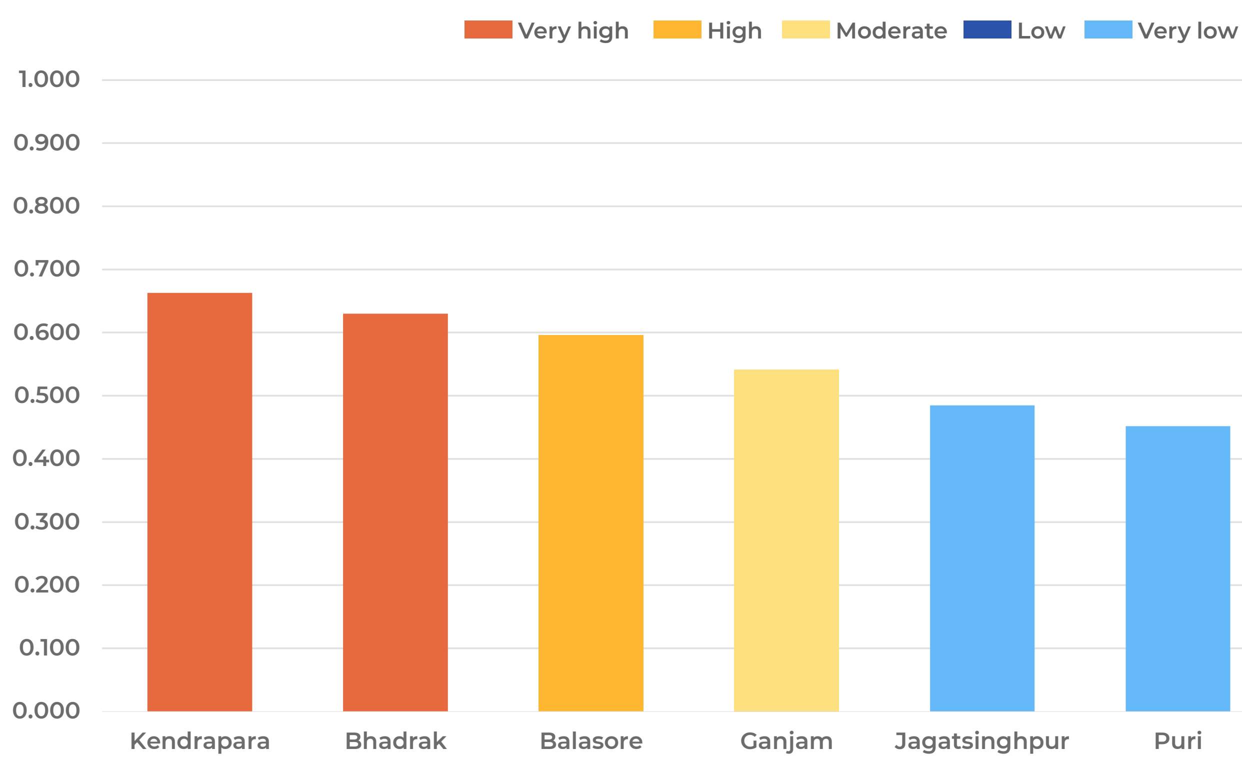


Figure 51: Vulnerability ranking of fisheries sub-sector at a district level for Odisha

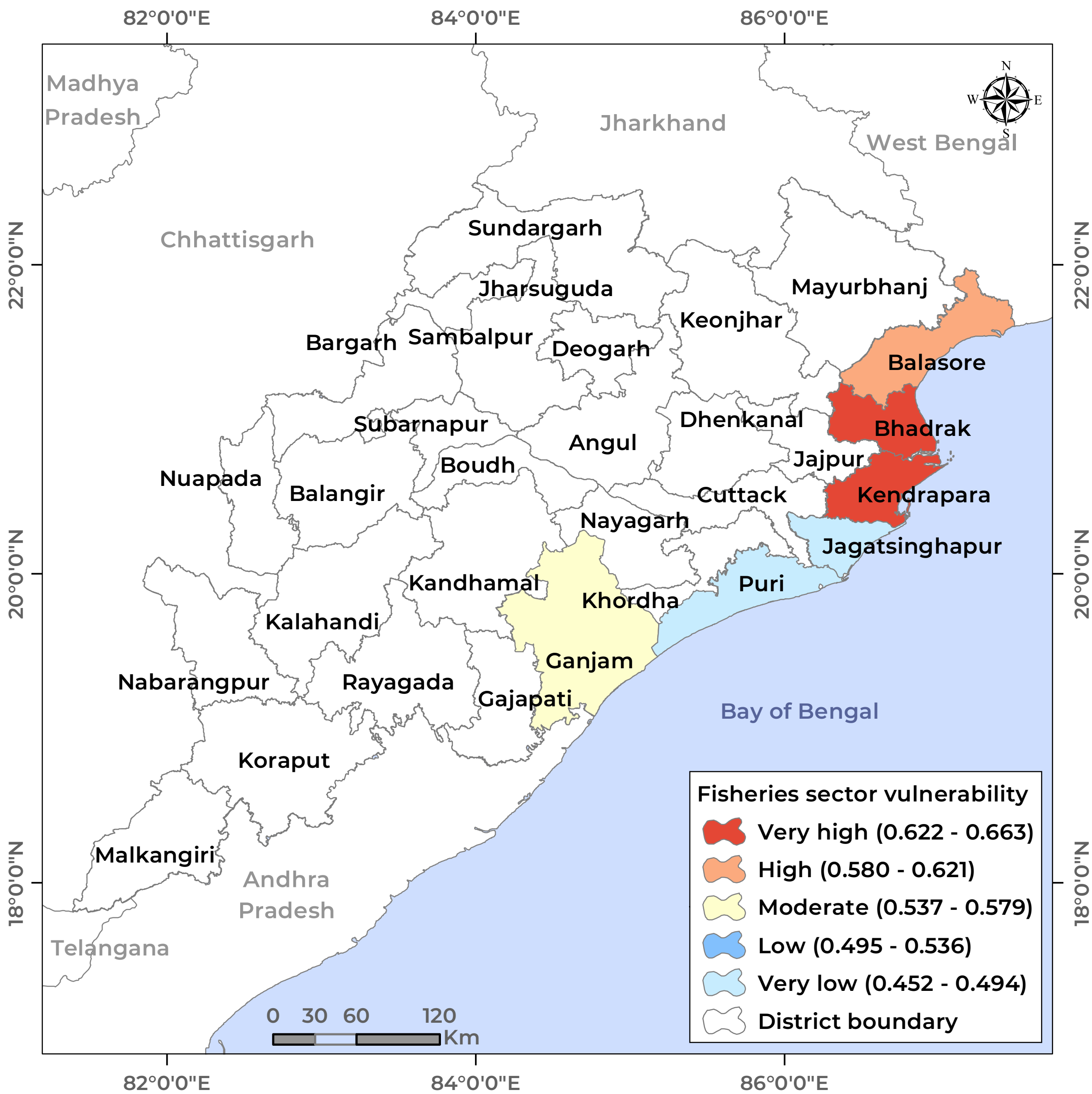


Figure 52: Vulnerability map of the fisheries sub-sector

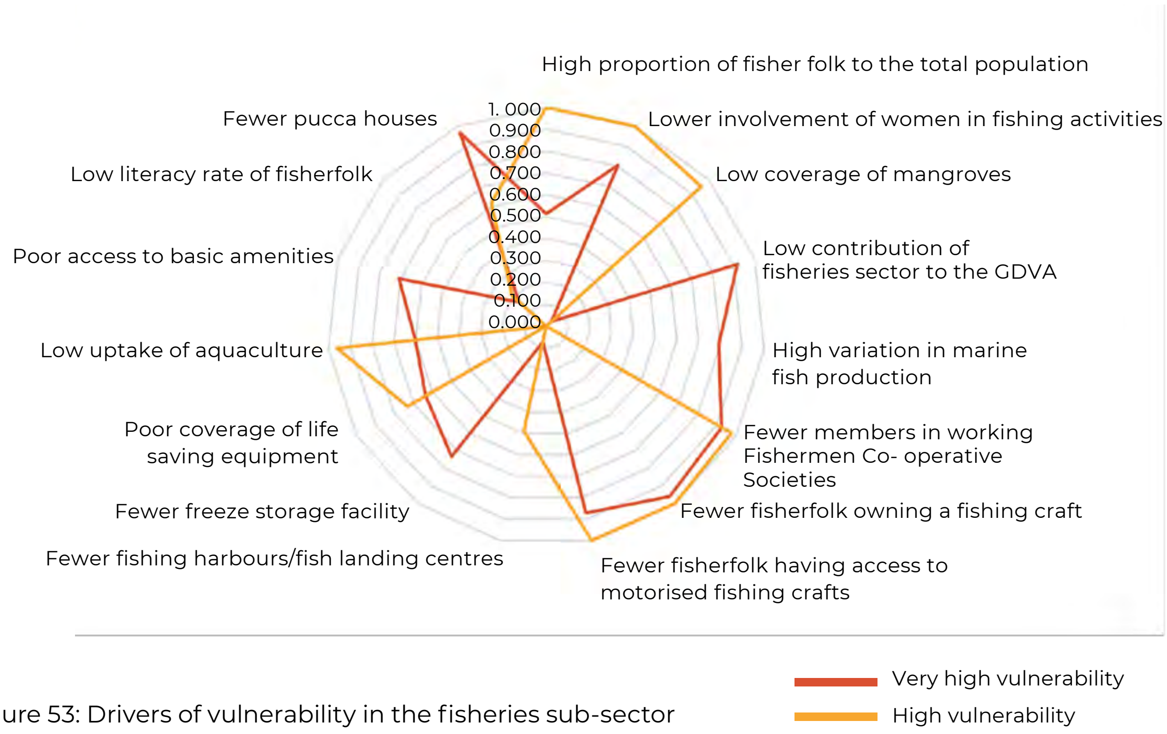


Figure 53: Drivers of vulnerability in the fisheries sub-sector

4.4. Climate risk

Climate risk arises when climate hazard, exposure and vulnerability interact and intersect. The overlay of the three components of risk is presented in this section as drought risk, flood risk, heatwave risk, and tropical cyclone risk (segregated into risks from three different magnitudes of cyclones). This section presents the aggregated risk to agriculture and allied sectors, followed by risk to individual sub-sectors – agriculture, livestock, and fisheries.

4.4.1. Overall climate risk assessments for the agriculture and allied sectors

Drought risk: Most districts fall in the very high to moderate drought risk category, while Boudh, Cuttack, Jagatsinghapur and Kendrapara exhibit no risk to drought (Figure 54). The results of the risk assessment have been spatially mapped in Figure 55. Seven districts are categorised as having very high risk to drought – Nuapada, Balangir, Mayurbhanj, Malkangiri, Ganjam, Subaranapur, and Sundargarh, as they have a higher probability of occurrence of agricultural drought and are highly exposed to drought like conditions, putting a significant percentage of their agricultural and allied sector assets at risk, underscoring the need for comprehensive drought resilience strategies.

Flood risk: Most districts are ranked as having low to very low flood risk, with Kendrapara, Balasore and Bhadrak receiving a relative rank of very high risk (Figure 56). These coastal districts, off the Bay of Bengal, are characterised by their low-lying topography and proximity to major river systems – Baitarani, Budhabalanga, and Subarnarekha that often lead to flooding, affecting vast areas of agricultural land and causing substantial economic losses. These factors expose critical infrastructure and agricultural assets to substantial flood-related risks.

Heatwave risk: Overall, close to half of the districts in Odisha are at very high and high risk to heatwaves, with four districts – Balangir, Jagatsinghapur, Nuapada and Puri being at no risk at all (Figure 58). Among the four districts, Balangir and Jagatsinghapur face a moderate probability of occurrence, while Puri and Nuapada face a very low probability of heatwave occurrence, and none of the selected agriculture & allied assets in these districts are exposed to heatwaves. The results have been spatially represented in Figure 59. The assessment identifies Angul, Sundargarh, Mayurbhanj, Keonjhar, Dhenkanal, and Ganjam, as districts with significant risk to heatwaves.

Dhenkanal and Angul are particularly noteworthy, as they show the highest probability of occurrence of heatwaves. This high probability of occurrence, combined with existing vulnerabilities such as poor access to water and limited adaptive capacity, makes Angul and Dhenkanal critical districts for climate-resilient intervention.

FACING PAGE: Local village woman, in Odisha, are waiting with buckets in their hand for the return of fishing boat. They carry buckets full of fish to the wholesale buyer from the fishing boat. Supratim Bhattacharjee

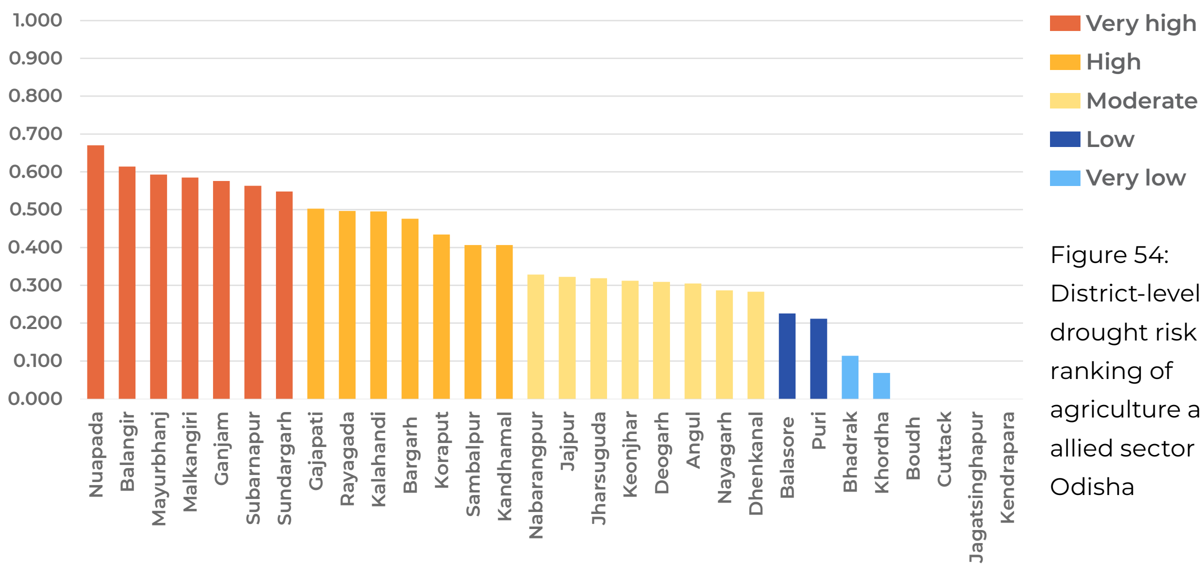


Figure 54: District-level drought risk ranking of agriculture and allied sector in Odisha

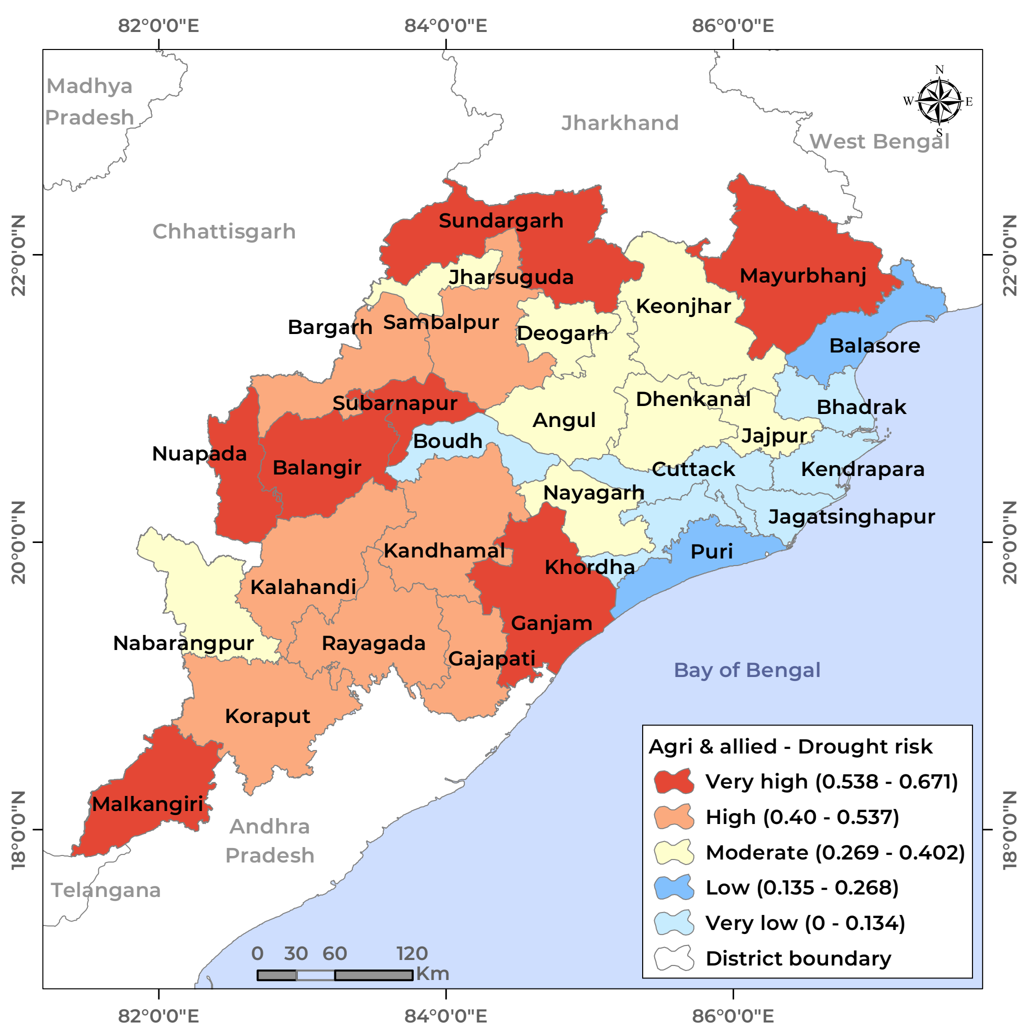


Figure 55: Drought risk map of the overall agriculture and allied sector in Odisha

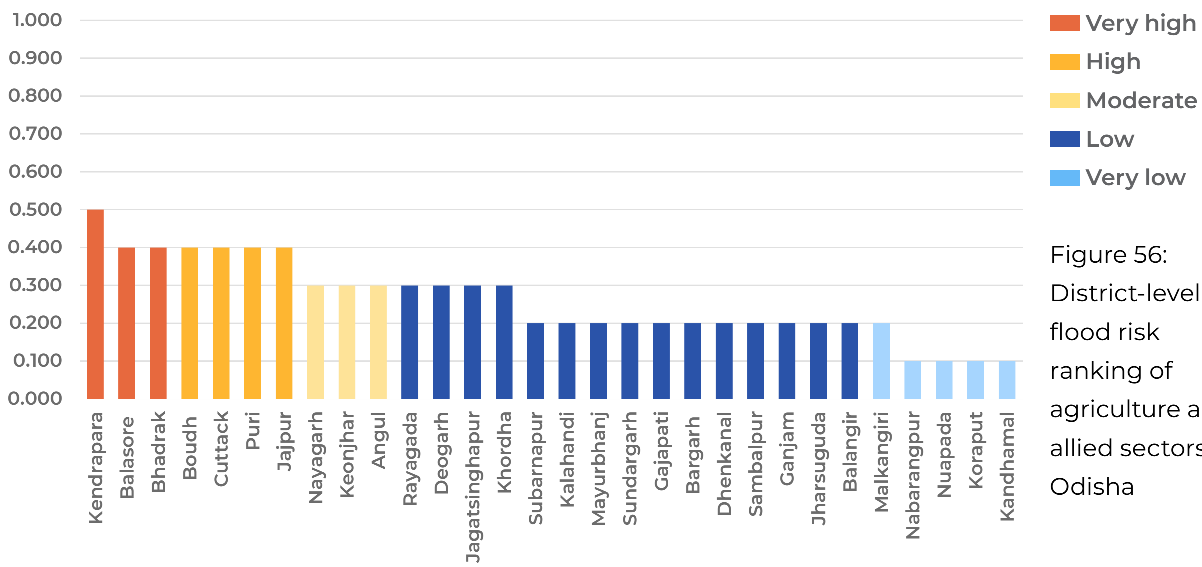


Figure 56: District-level flood risk ranking of agriculture and allied sectors in Odisha

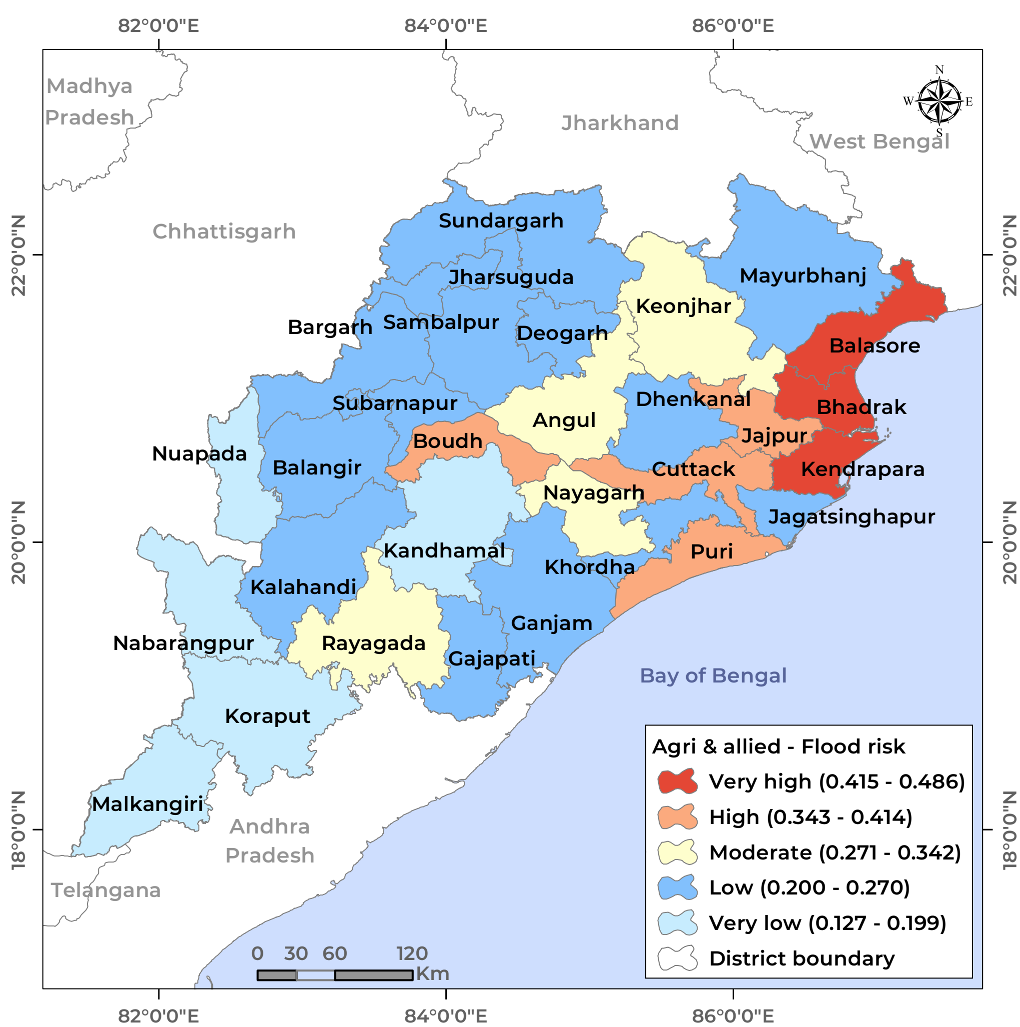


Figure 57: Flood risk map of the agriculture and allied sector in Odisha

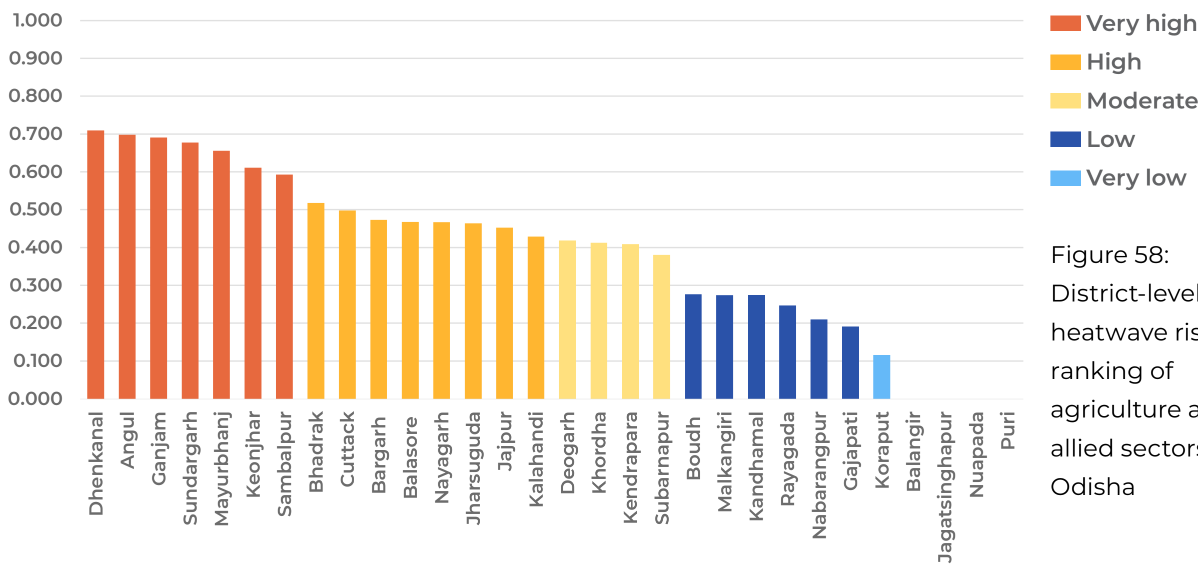


Figure 58: District-level heatwave risk ranking of agriculture and allied sectors in Odisha

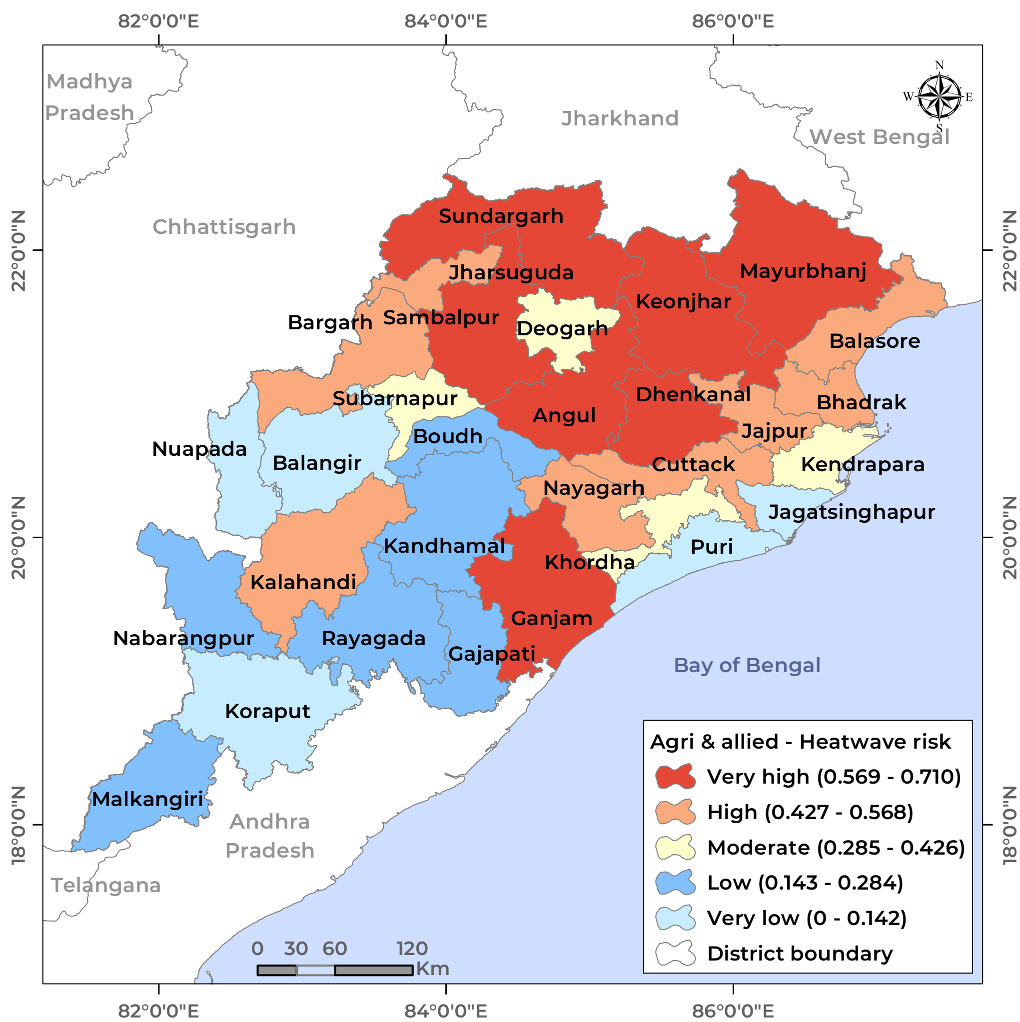


Figure 59: Heatwave risk map of the agriculture and allied sectors in Odisha

Tropical cyclone risk
Balasore and Mayurbhanj face the highest risk to severe (90–120 km/h) and very severe (120 km/h and above) tropical cyclones. Balasore's risk is driven by its very high probability of occurrence, attributed to its proximity to the Bay of Bengal, and high exposure of agriculture, livestock, and fisheries assets. Mayurbhanj's high risk stems from a slightly lower probability than Balasore but very high inherent vulnerability (Figures 60 and 62).

Similarly, Nayagarh and Boudh face the highest risk to tropical cyclones with wind speeds of 60–90 km/h due to their very high probability of occurrence and high inherent vulnerability (Figure 64).

4.4.2. Climate risk assessments for the agriculture sub-sector

To summarise the findings from this sub-section:

- Nearly 35%, 20%, and 50% of districts in Odisha are highly at risk to droughts, floods, and heatwaves, respectively, in terms of their agriculture sub-sector.

- Additionally, almost 60% of the districts are highly at risk to 'very severe' and 'severe' tropical cyclones with wind speeds of 90 to >120 km/hr. Nearly 35% of districts face a high risk to cyclonic storms with wind speeds reaching 60-90 km/hr.

Drought risk: Nuapada and Balangir, have similar risk indexes (~0.7), closely followed by Mayurbhanj, Malkangiri, and Ganjam (~0.6). Four districts –Bhadrak, Cuttack, Jagatsinghapur and Kendrapara have zero risk to drought (Figure 66). The spatial distribution of drought risk to agriculture sub-sector is presented Figure 67.

Flood risk: A significant majority of the districts in Odisha are ranked either low to very low in terms of risk to flood for the agriculture sub-sector, with only two districts – Kendrapara and Balasore ranked as very high (~0.5), closely followed by Bhadrak, Cuttack, Boudh and Jajpur. It is important to note that this is a relative scale, and thus Kendrapara, relative to the other districts in the state is at very high risk to floods (Figures 68 and 69).

Heatwave risk: Angul has the highest heatwave risk index (~0.7) attributed to the high probability of occurrence of heatwaves in the region, closely followed by Dhenkanal, Ganjam, Sundargarh, Mayurbhanj, and Keonjhar, all of which have similar risk index values (~0.6-0.7). The heat risk scores exhibit a significant range, from ~ 0.7 to 0. Five districts – Balangir, Jagatsinghapur, Kendrapara, Nuapada and Puri are not at risk to heatwaves for this sector (Figure 70 and 71).

Tropical cyclones: Bhadrak and Kendrapara, both face the highest risk from cyclonic storms (60–90 km/hr) due to their coastal proximity (Figure 76). Balasore and Mayurbhanj have the highest risk from severe (90–120 km/hr) and very severe (120 km/hr and above) cyclones, primarily due to the high probability of the occurrence of such storms in these districts (Figure 74 and 72). In all four districts, high cyclone risk is driven by a high probability of occurrence and significant exposure of agricultural assets.

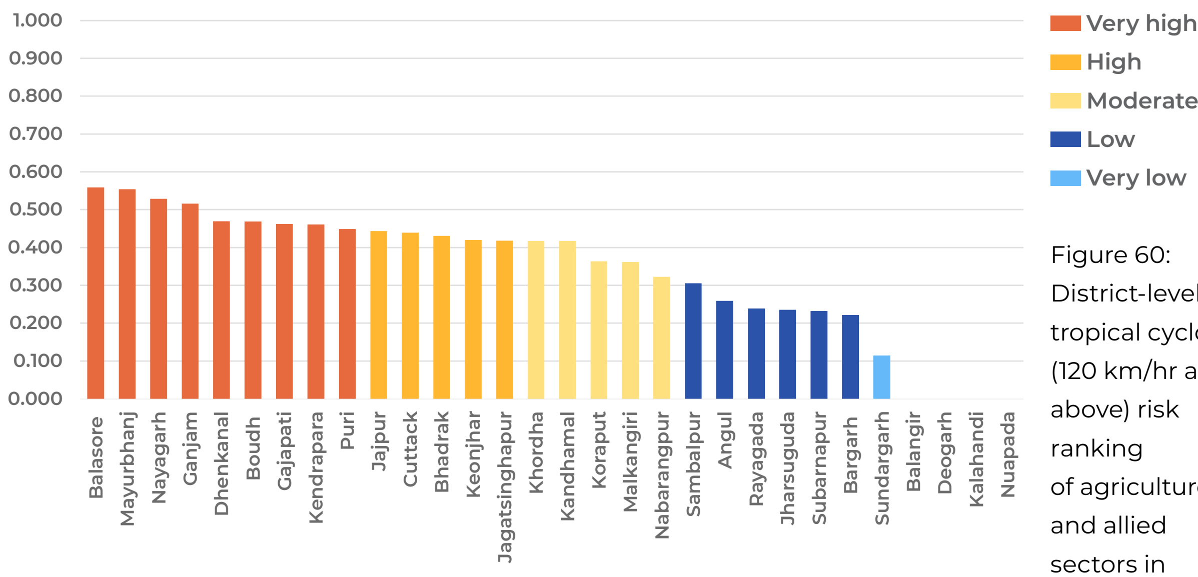


Figure 60: District-level tropical cyclone (120 km/hr and above) risk ranking of agriculture and allied sectors in Odisha

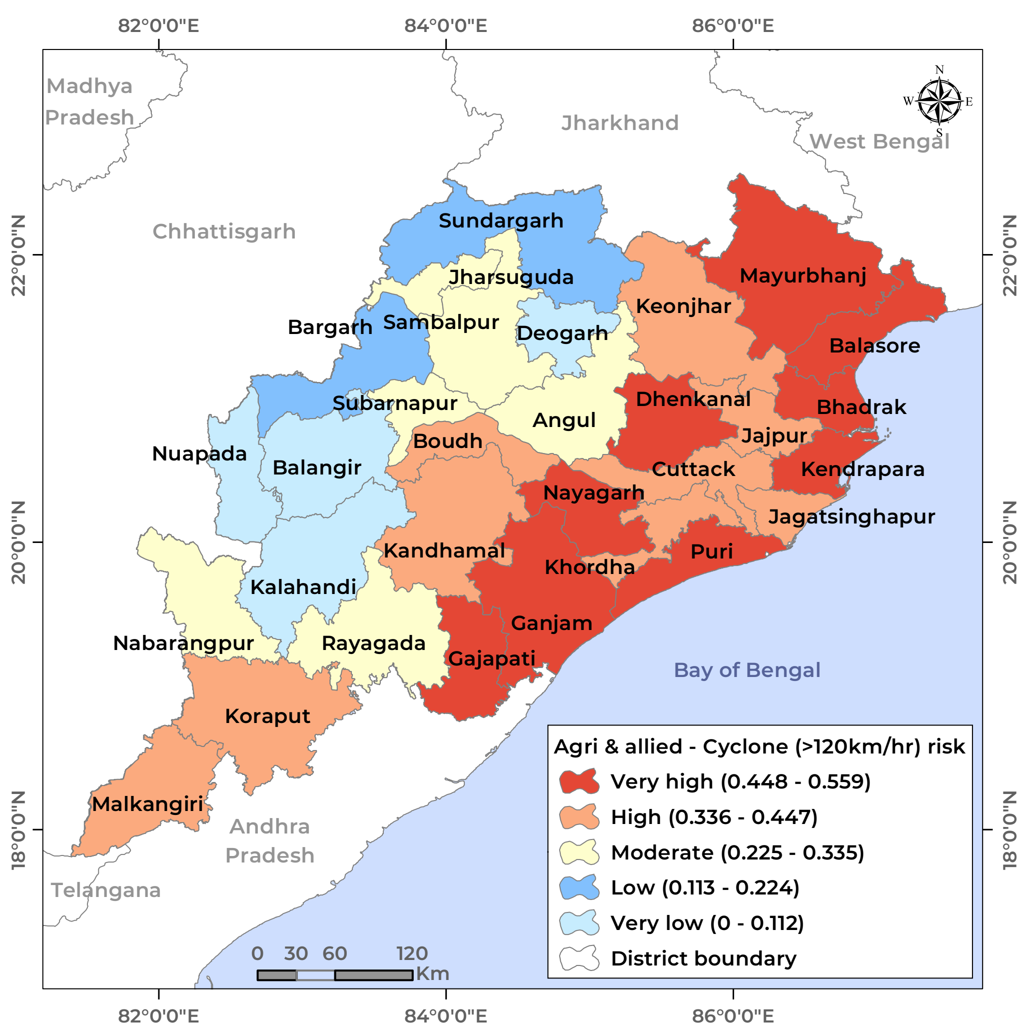


Figure 61: Tropical cyclone (120 km/hr and above) risk map of the agriculture and allied sectors in Odisha

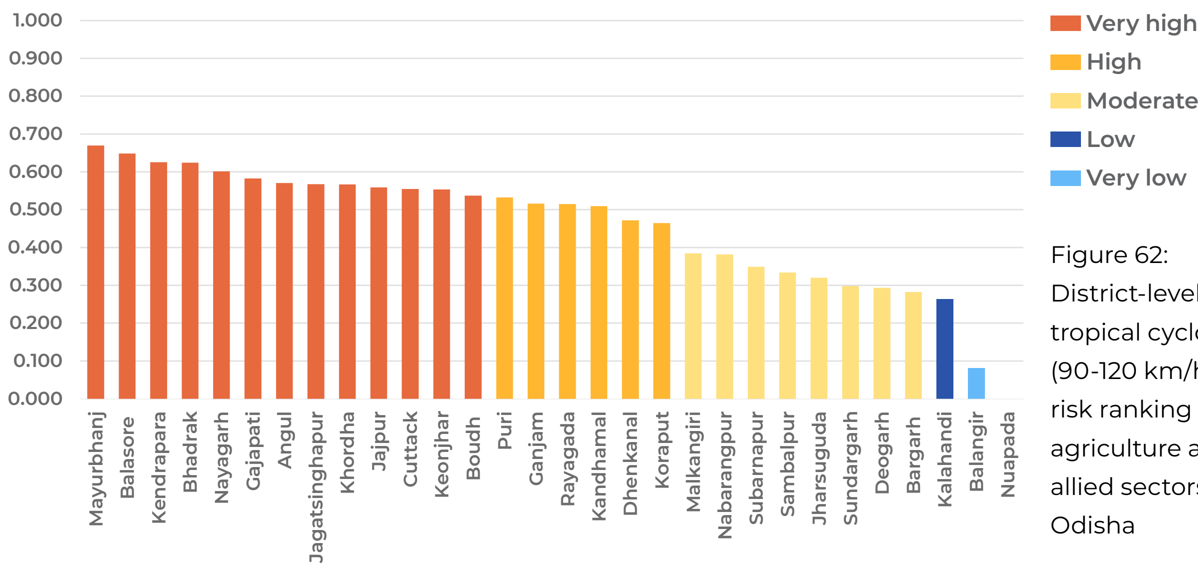


Figure 62: District-level tropical cyclone (90-120 km/hr) risk ranking of agriculture and allied sectors in Odisha

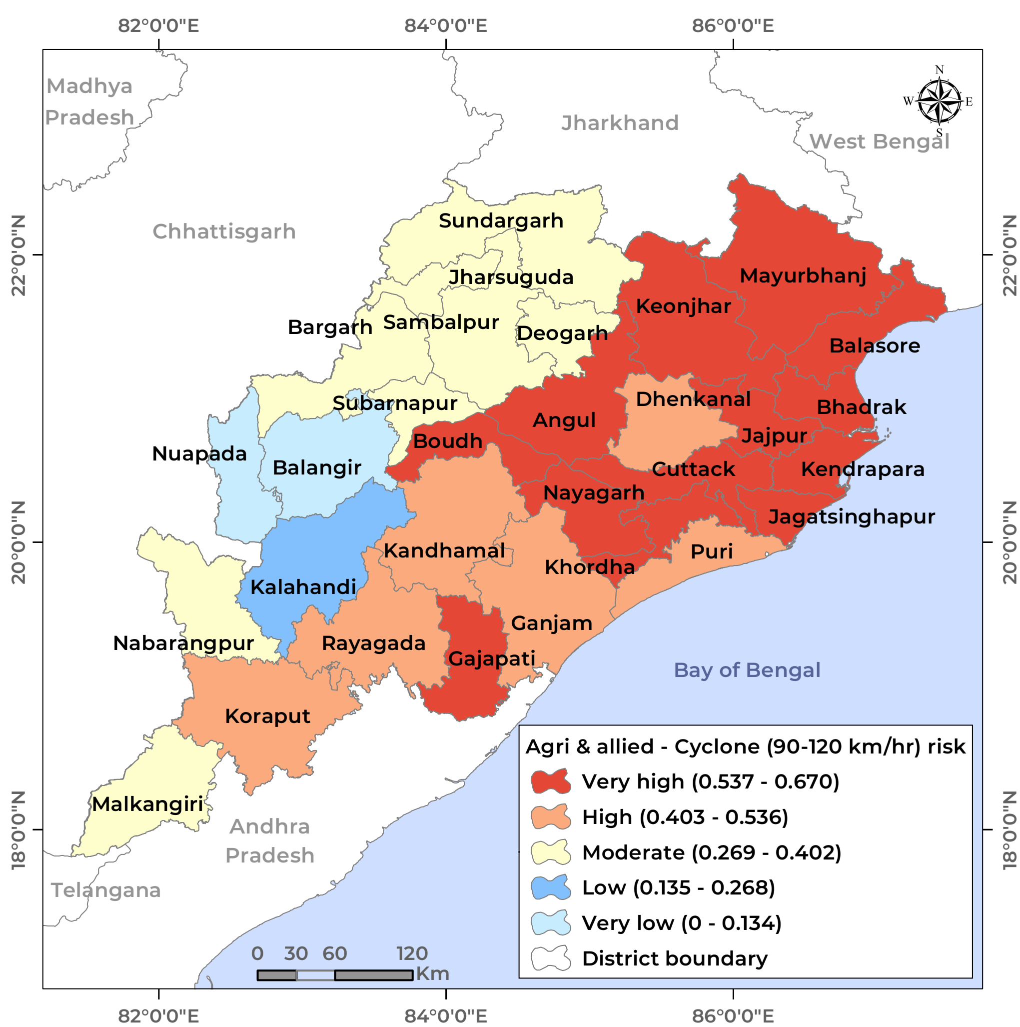


Figure 63: Tropical cyclone (90-120 km/hr) risk map of the agriculture and allied sectors in Odisha

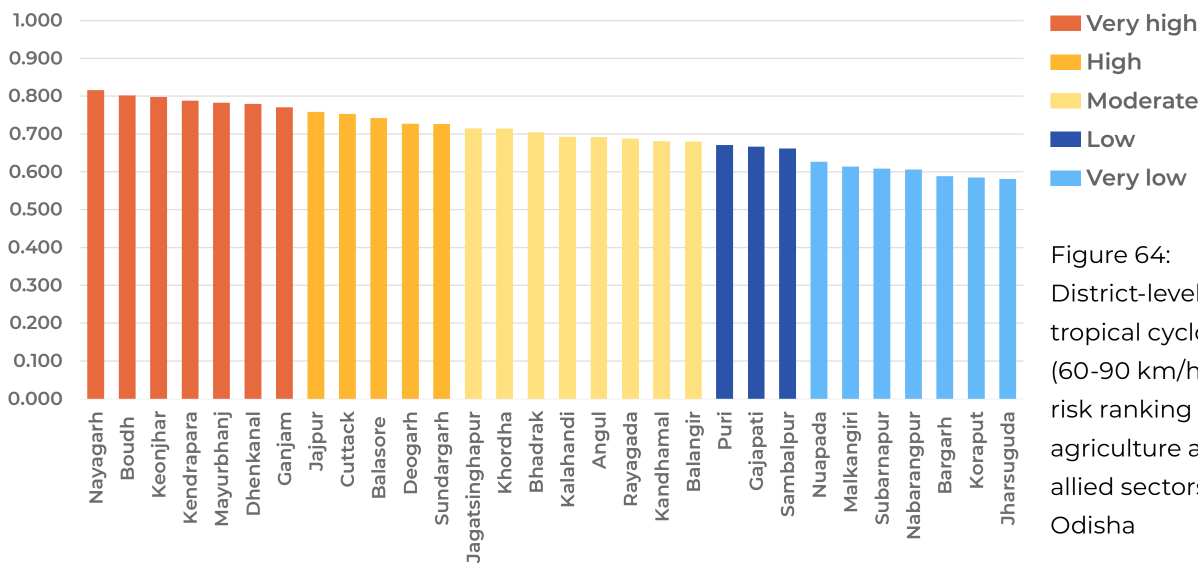


Figure 64: District-level tropical cyclone (60-90 km/hr) risk ranking of agriculture and allied sectors in Odisha

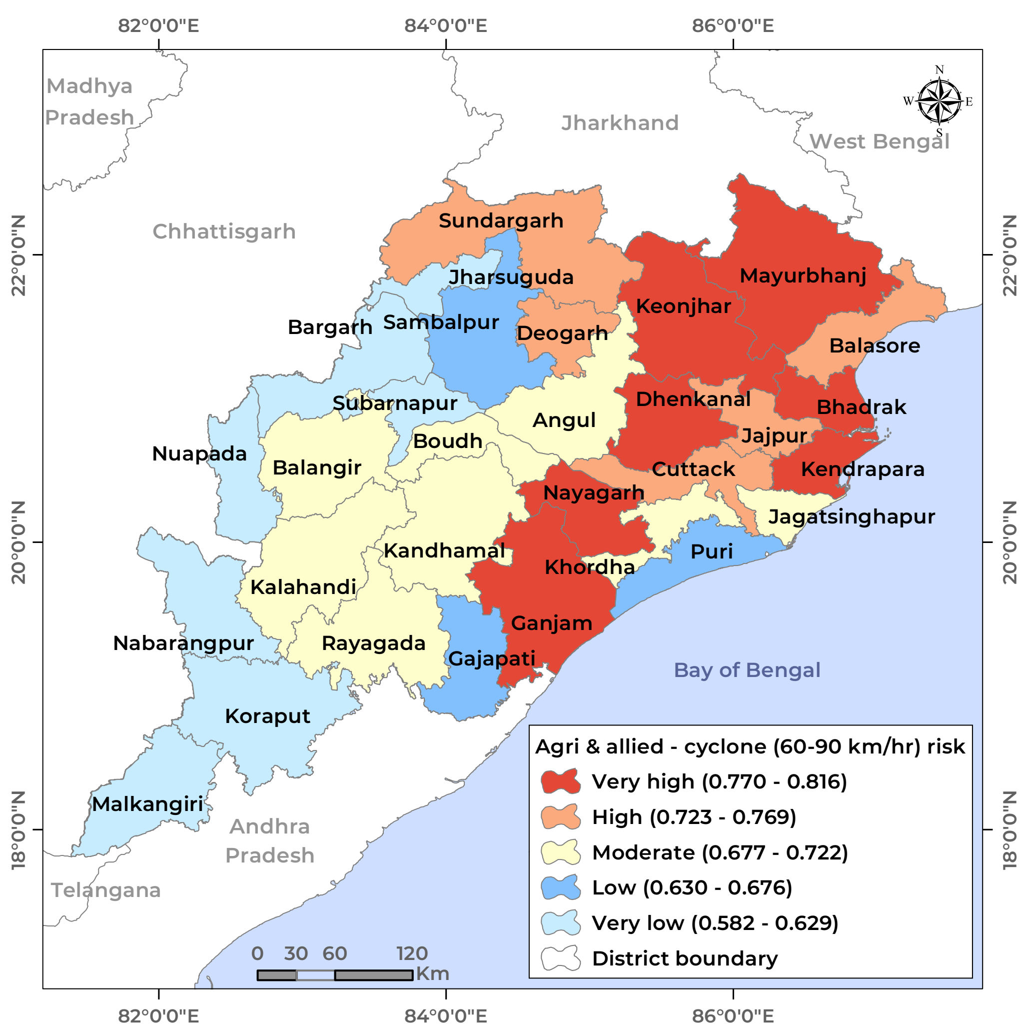


Figure 65: Tropical cyclone (60-90 km/hr) risk map of the agriculture and allied sectors in Odisha

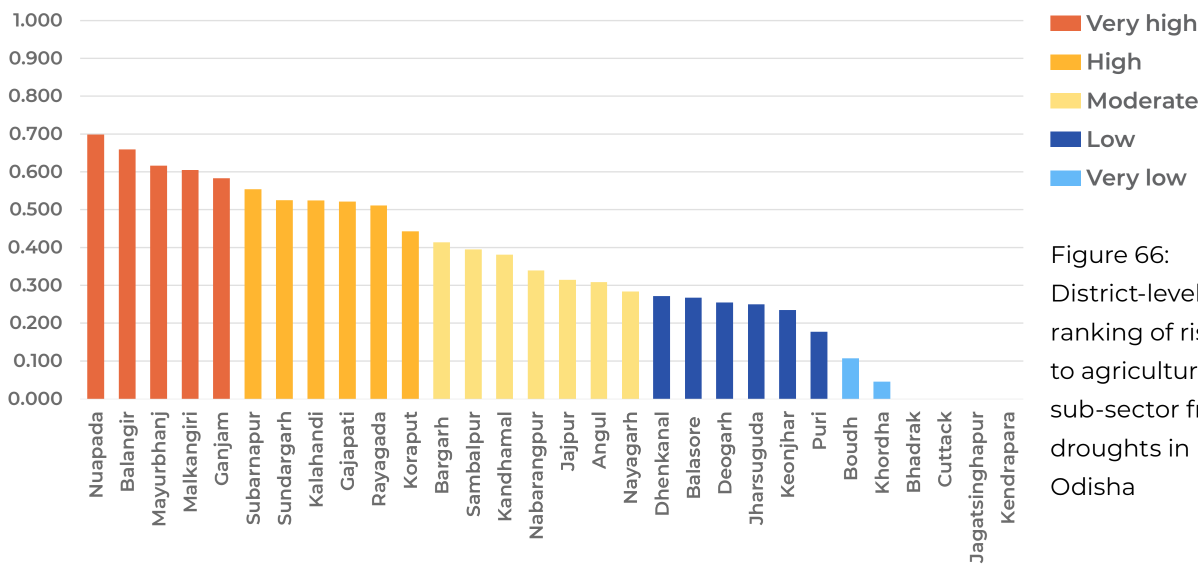


Figure 66: District-level ranking of risk to agricultural sub-sector from droughts in Odisha

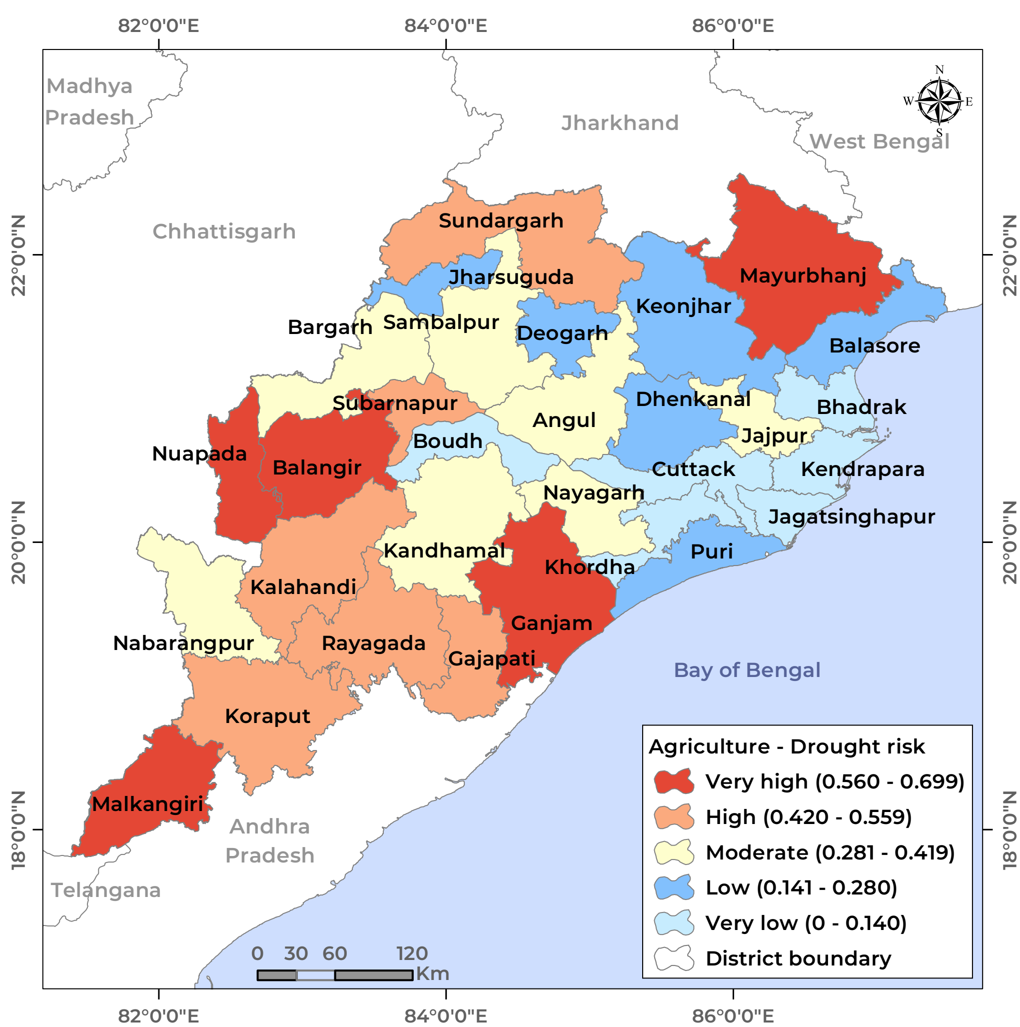


Figure 67: Drought risk map of the agriculture sub-sector

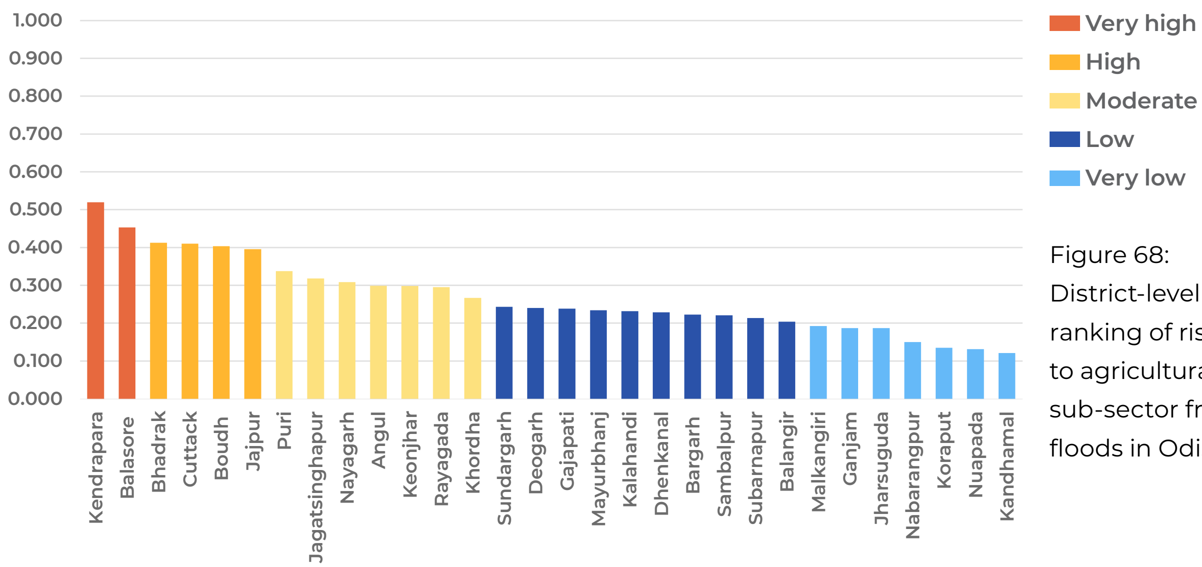


Figure 68: District-level ranking of risk to agricultural sub-sector from floods in Odisha

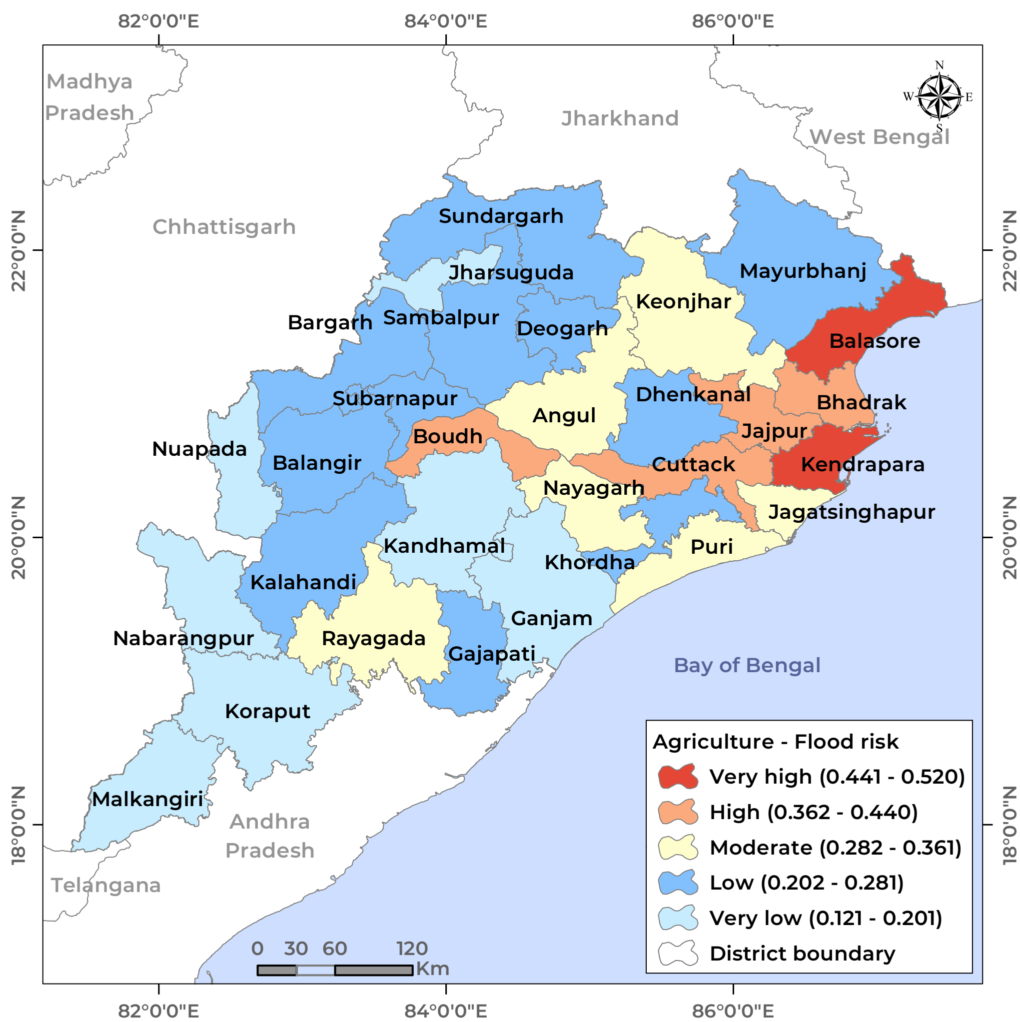


Figure 69: Flood risk map of the agriculture sub-sector

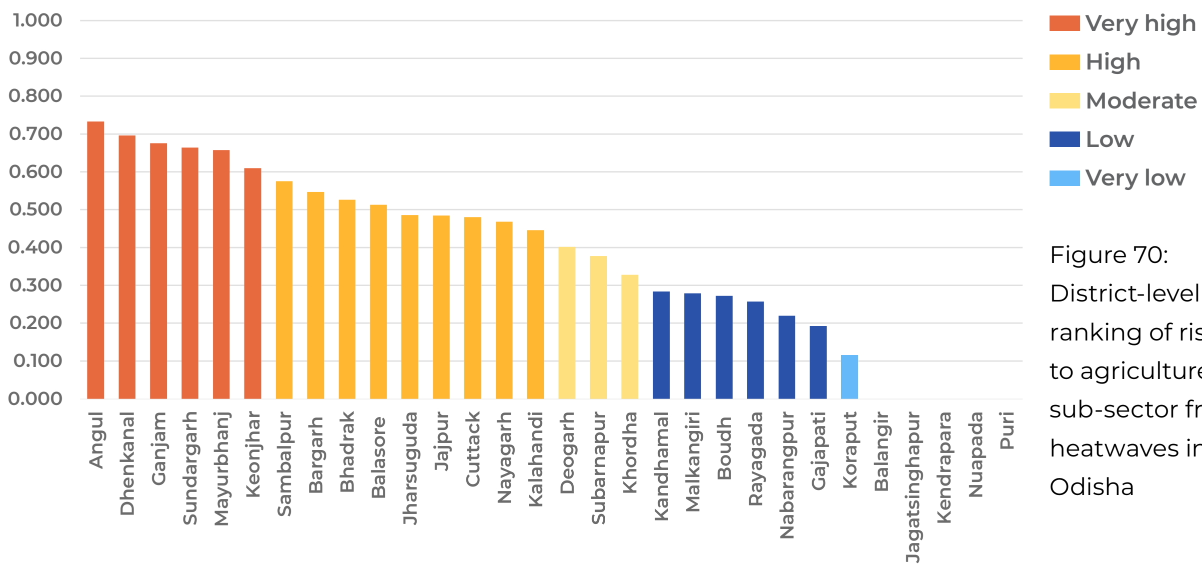


Figure 70: District-level ranking of risk to agriculture sub-sector from heatwaves in Odisha

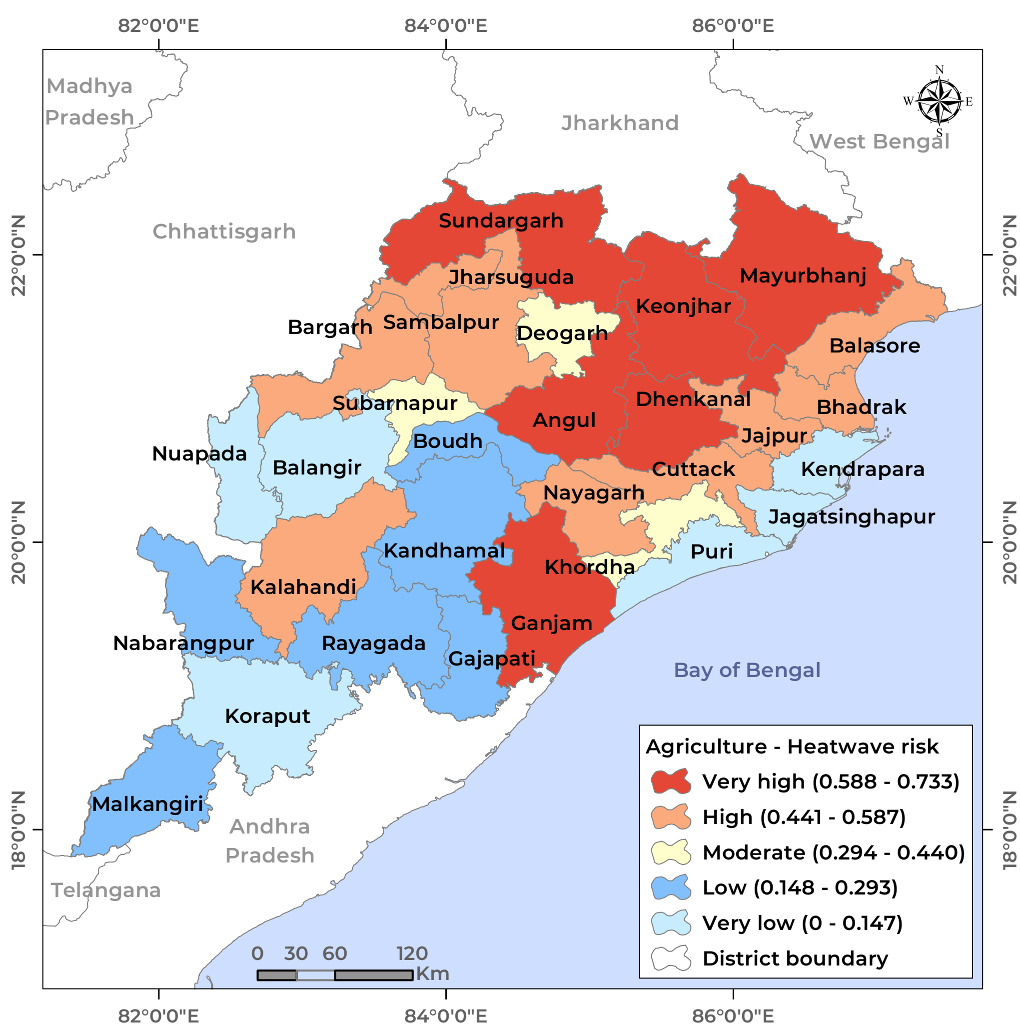


Figure 71: Heatwave risk map of the agriculture sub-sector

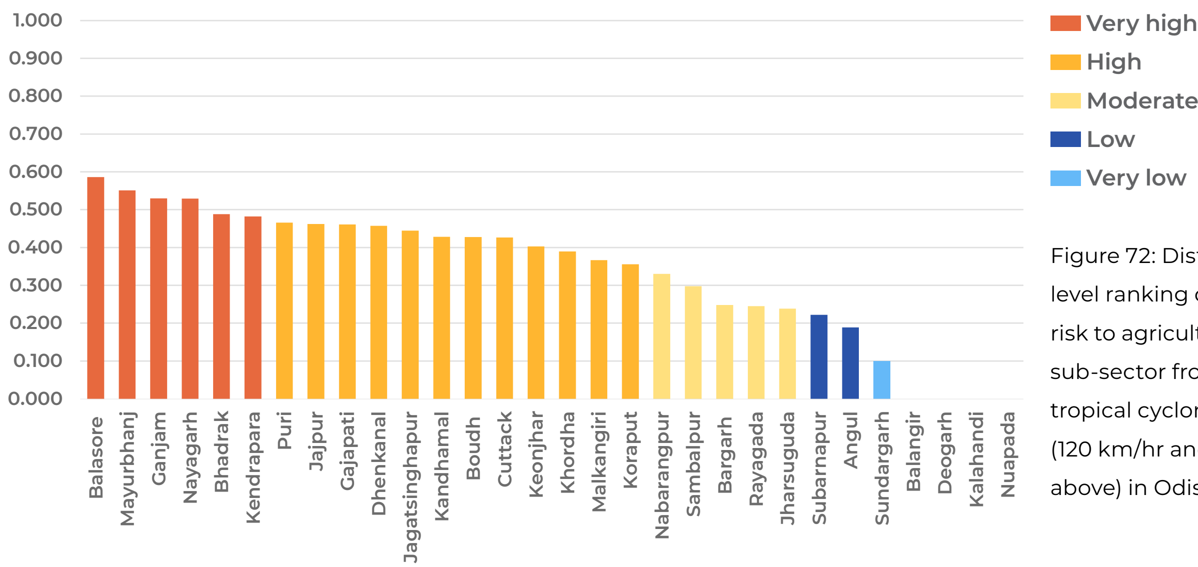


Figure 72: District-level ranking of risk to agricultural sub-sector from tropical cyclones (120 km/hr and above) in Odisha

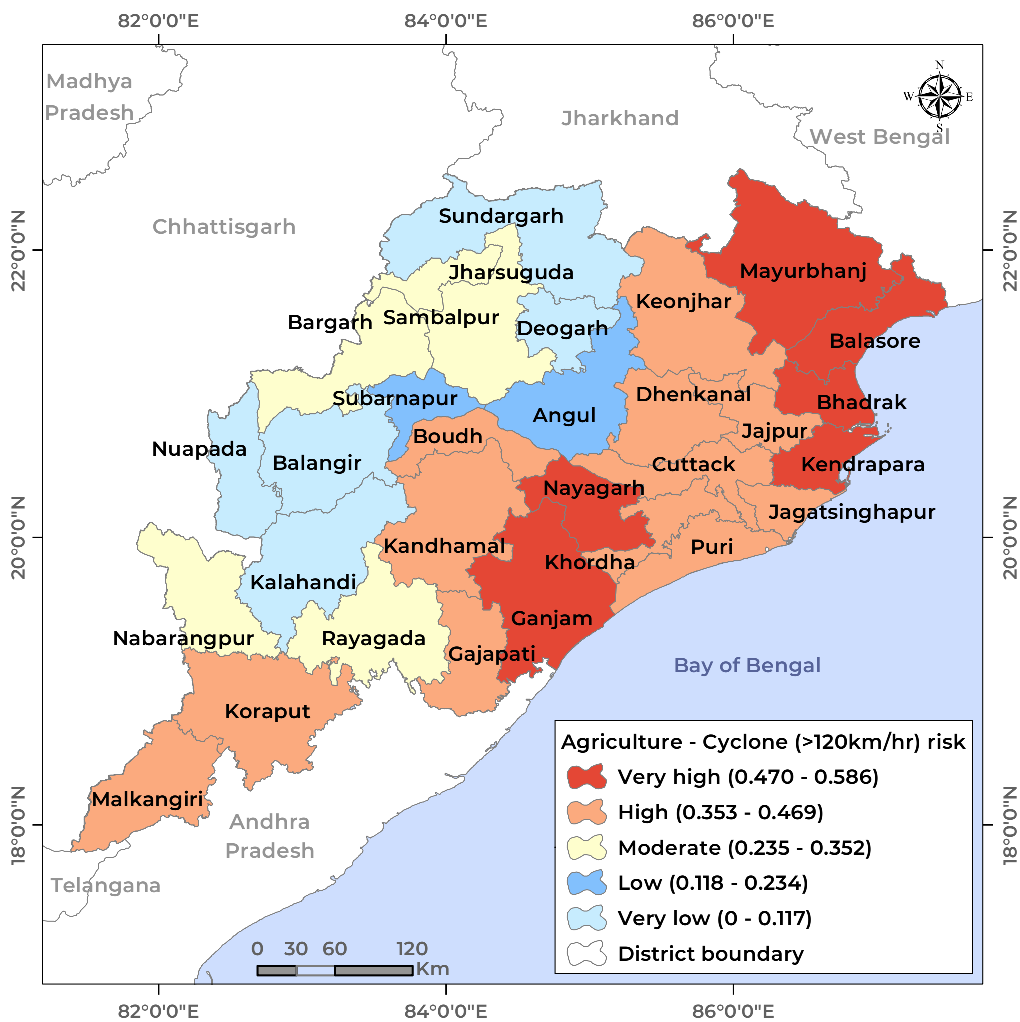


Figure 73: Tropical cyclone (120 km/hr and above) risk map of the agriculture sub-sector

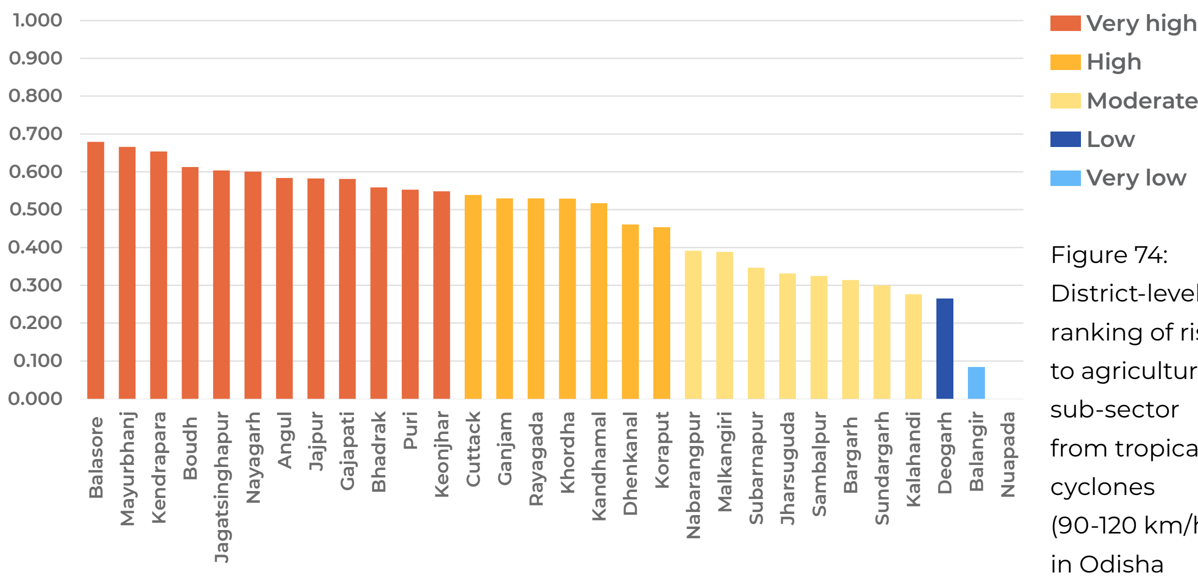


Figure 74: District-level ranking of risk to agricultural sub-sector from tropical cyclones (90-120 km/hr) in Odisha

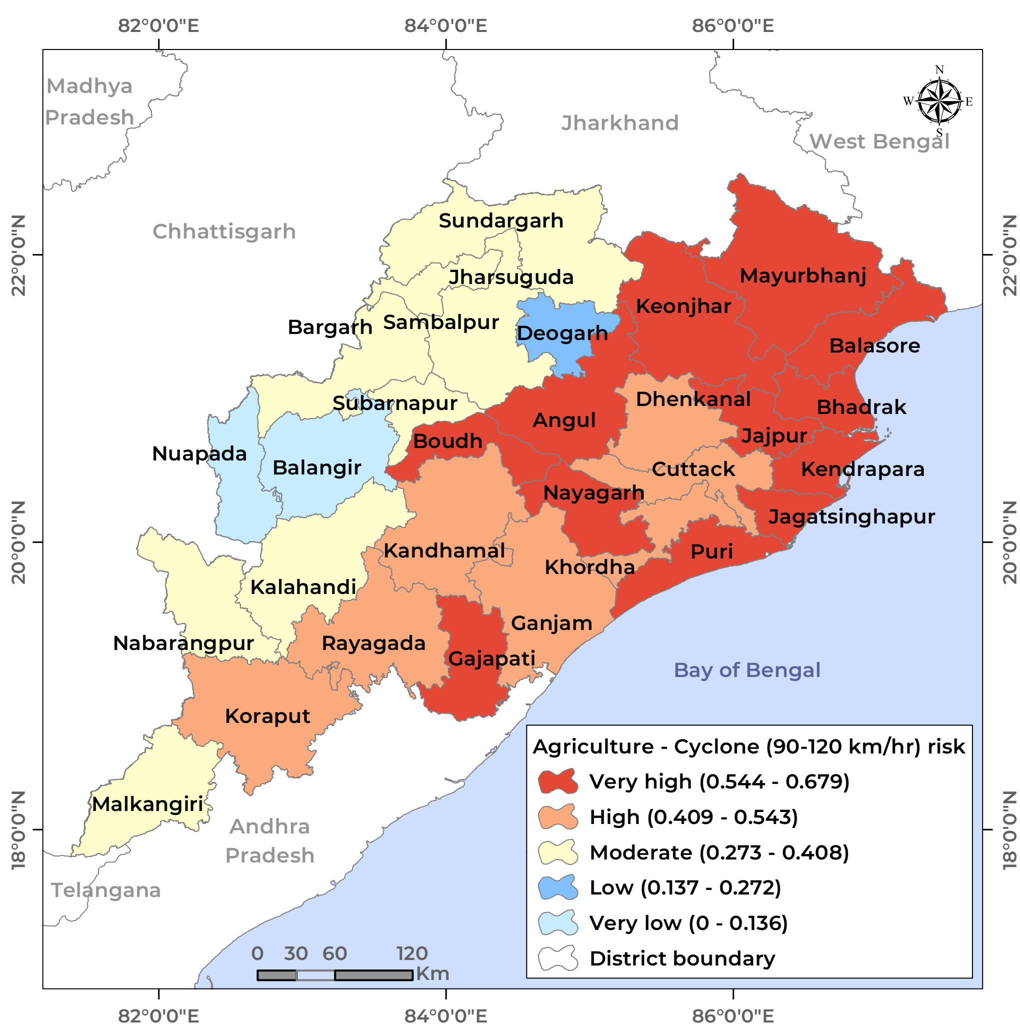


Figure 75: Tropical cyclone (90-120 km/hr) risk map of the agriculture sub-sector

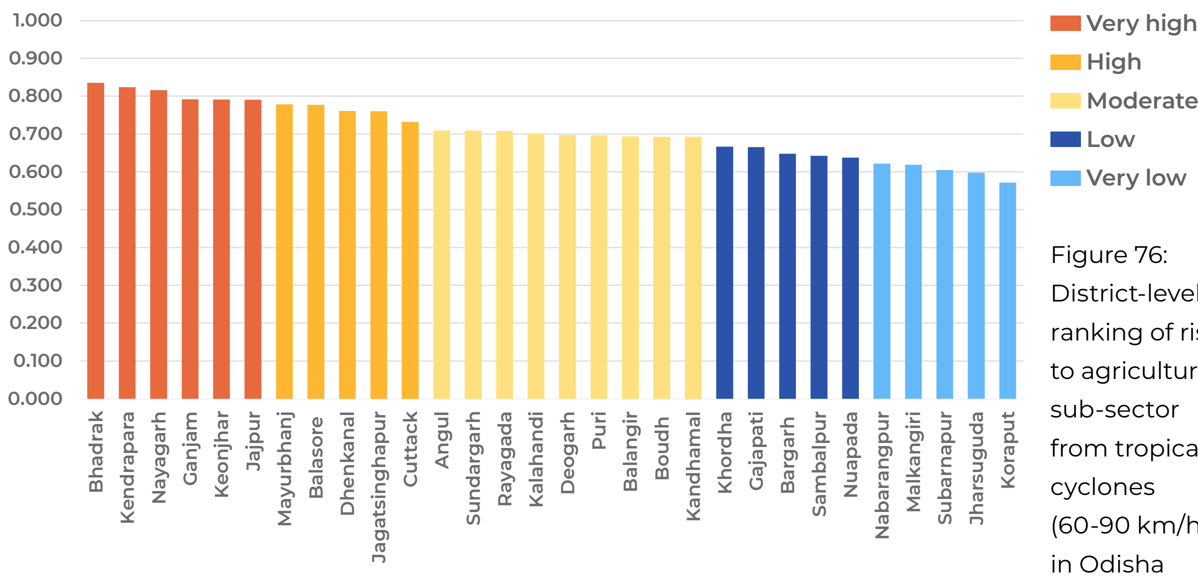


Figure 76: District-level ranking of risk to agricultural sub-sector from tropical cyclones (60-90 km/hr) in Odisha

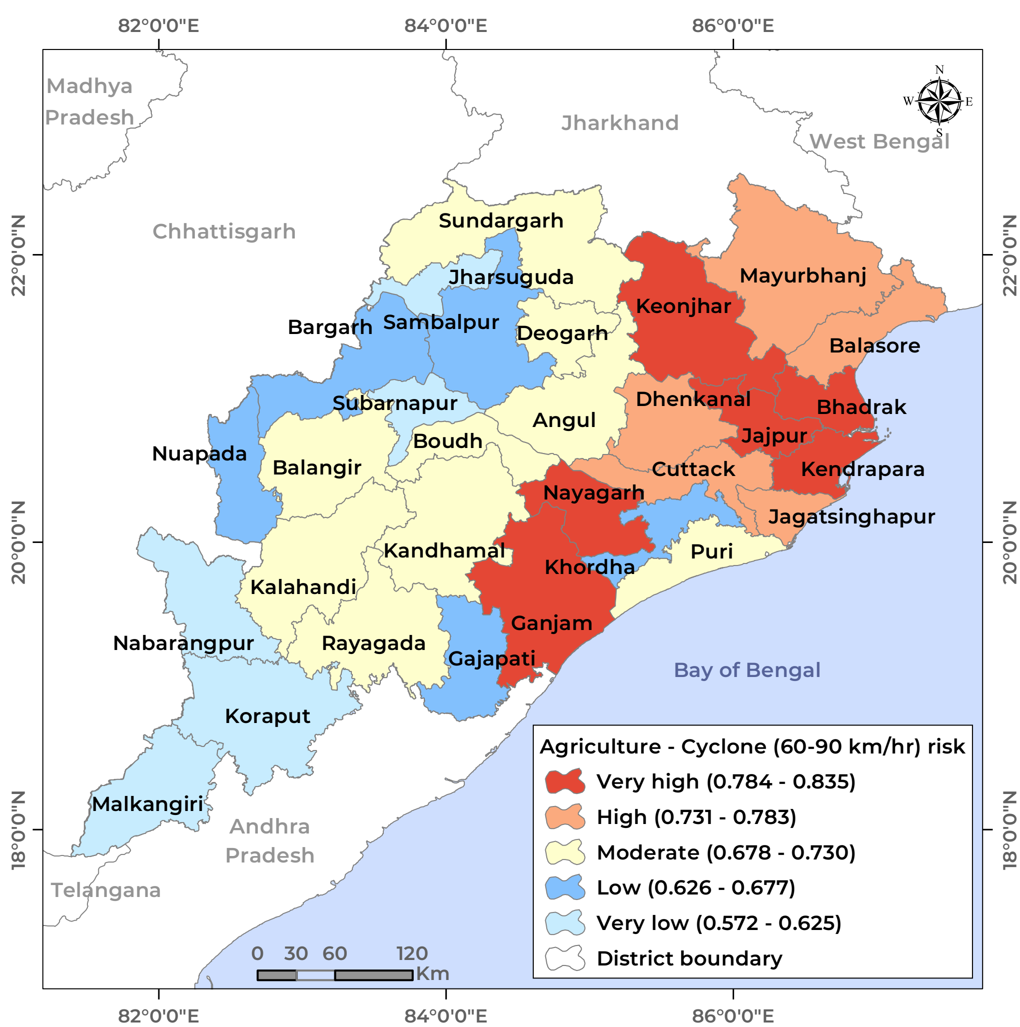


Figure 77: Tropical cyclone (60-90 km/hr) risk map of the agriculture sub-sector

4.4.3. Climate risk assessments for livestock sub-sector

In summary:

- Nearly 43%, 13%, and 46% of districts in Odisha are highly at risk to droughts, floods, and heatwaves, respectively.
- Moreover, 60%, 63%, and 46% of the state's livestock assets are highly at risk to tropical cyclones with wind speeds of 120 km/hr and above, 90-120 km/hr, and 60-90 km/hr, respectively.

Drought risk: Nuapada, Sundargarh and Mayurbhanj have similar risk index values (~0.7) and are ranked as having a very high risk to droughts as compared to the other districts in the state. The livestock sub-sector in four districts - Bhadrak, Cuttack, Jagatsinghapur and Kendrapara have zero risk to drought for the livestock sub-sector as well (Figure 78 and 79).

Flood risk: Similar to the agriculture sub-sector, Puri, Balasore, Boudh, and Cuttack have the highest flood risk index (~0.5), closely followed by Jajpur, Kendrapara, and Bhadrak. Also, a significant majority of the districts are at low to very low risk to flood when the livestock sub-sector is considered (Figures 80 and 81).

Heatwave risk: Ganjam, Dhenkanal, Sundergarh, Mayurbhanj, and Angul, all have similar risk index values of approximately ~0.7 closely followed by Keonjhar and Sambalpur (~0.6), indicating very high risk to heatwaves for the livestock sub-sector. The heat risk scores also exhibit a significant range, from ~ 0.7 to 0, with seven districts having no heatwave risk to their livestock sub-sector (Figures 82 and 83).

Tropical cyclone risk: Risk values for cyclonic storms with wind speeds of 60-90 km/hr are the highest, as compared to the more severe cyclonic storms (with wind speeds of 90-120 km/hr or more than 120 km/hr). Mayurbhanj, Khordha, Ganjam, Nayagarh, and Cuttack districts have the highest risk to all three categories of cyclones. This can be attributed to the fact that these districts are in close proximity to the Bay of Bengal, with high exposure of their livestock assets.

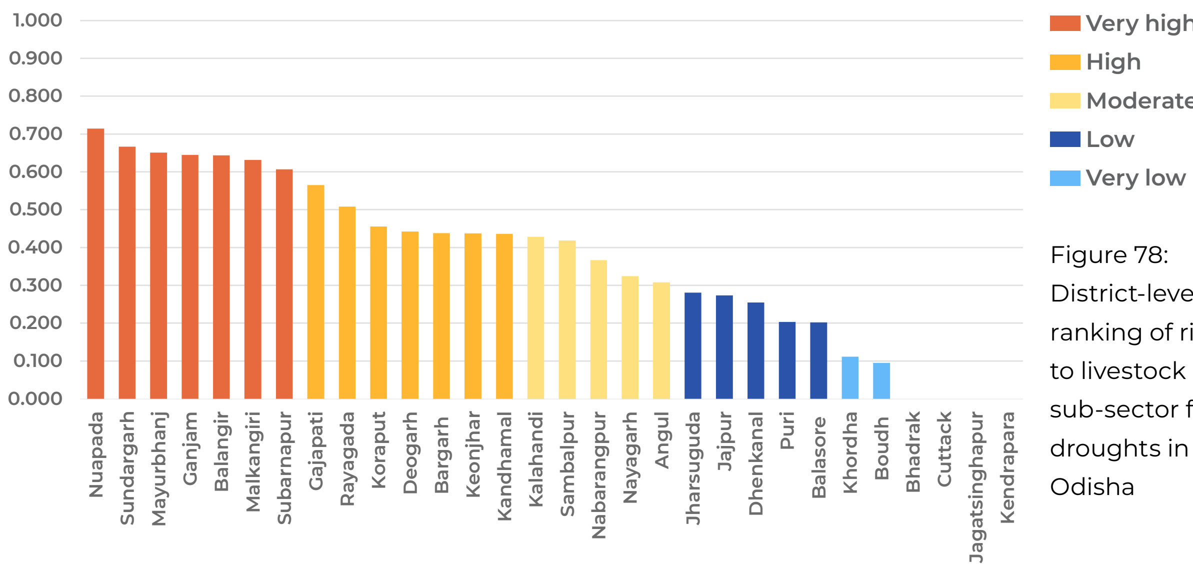


Figure 78: District-level ranking of risk to livestock sub-sector from droughts in Odisha

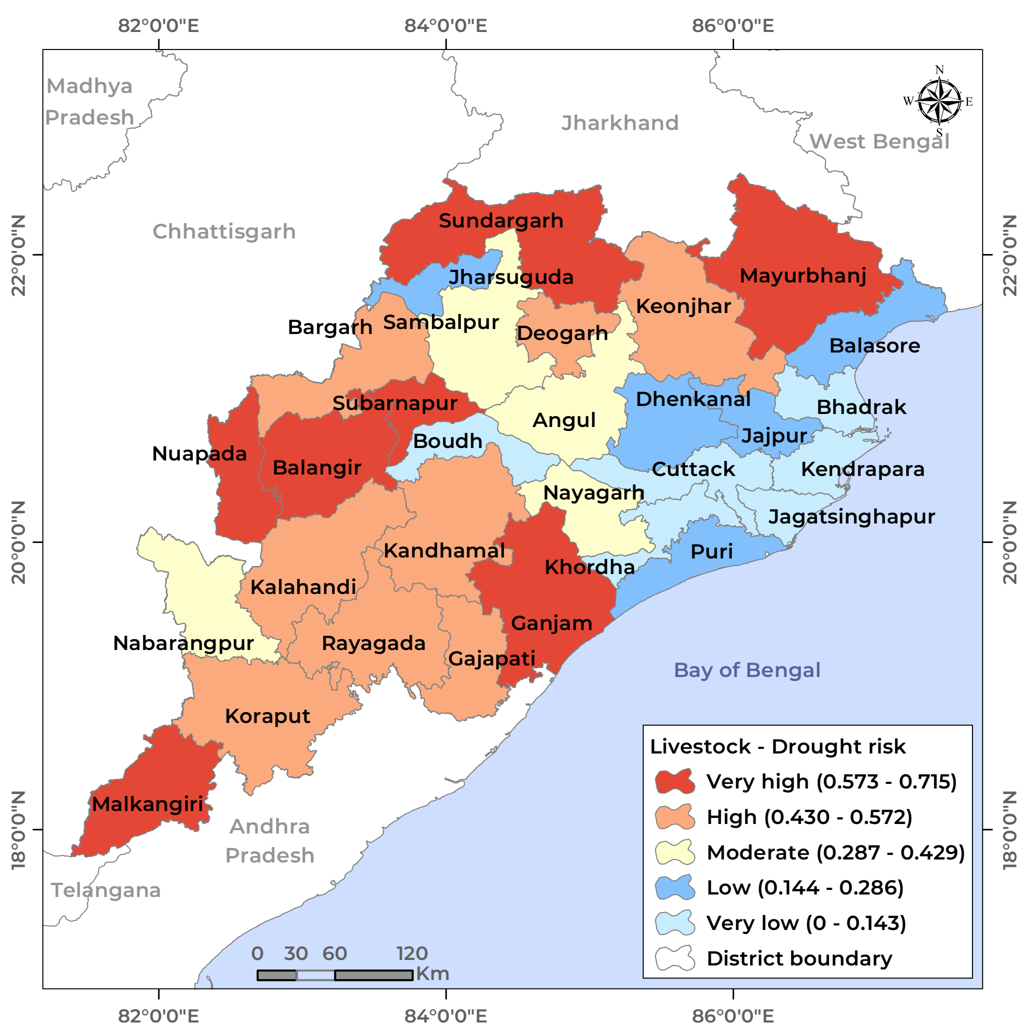


Figure 79: Drought risk map of the livestock sub-sector

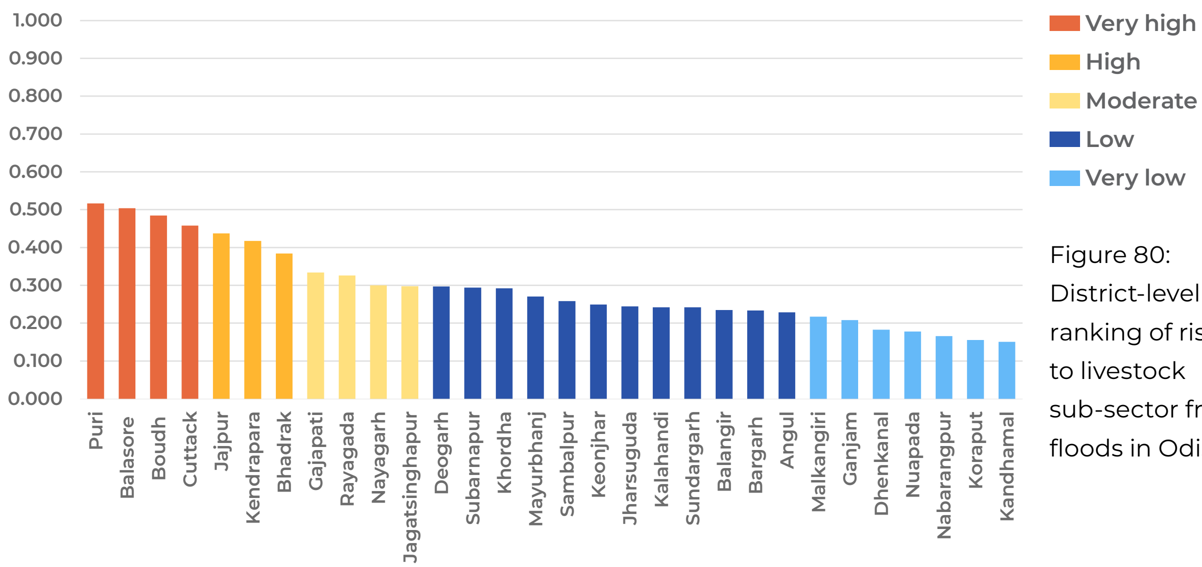


Figure 80: District-level ranking of risk to livestock sub-sector from floods in Odisha

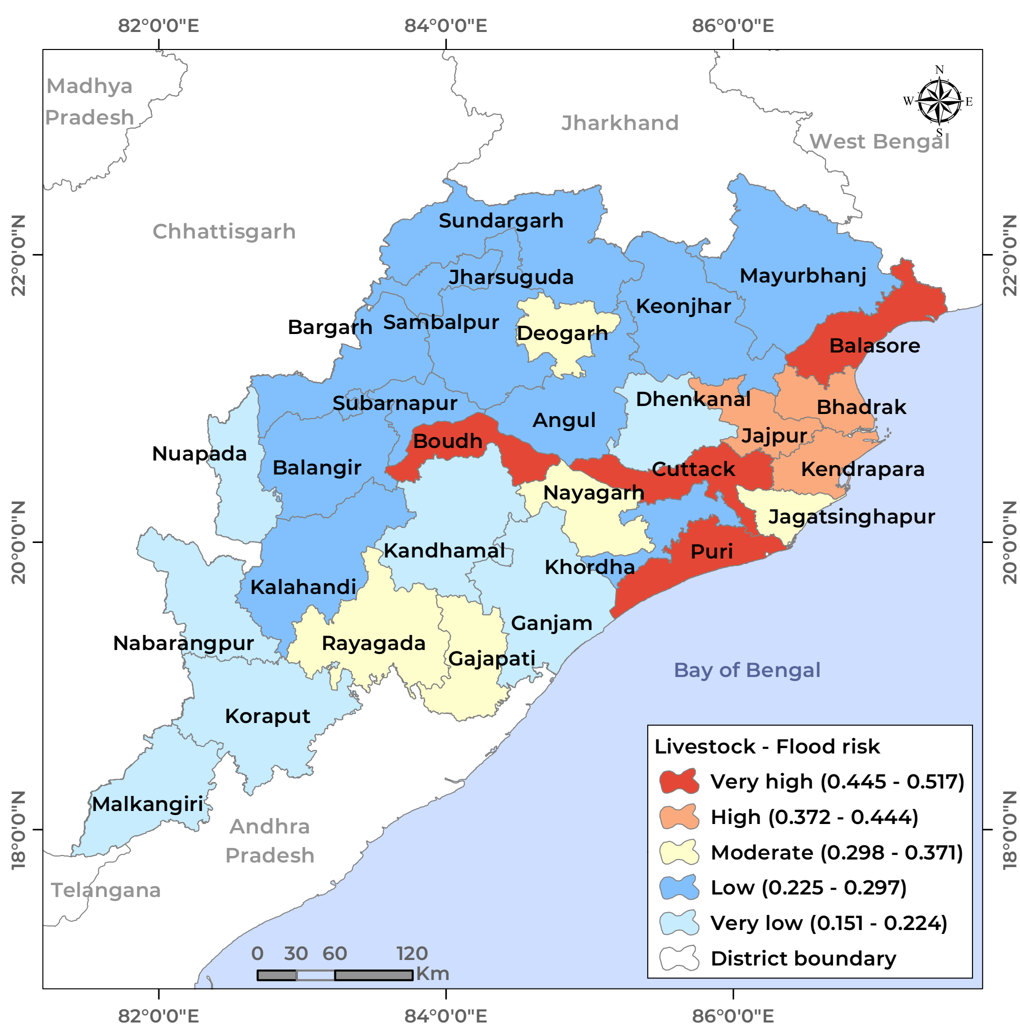


Figure 81: Flood risk map of the livestock sub-sector

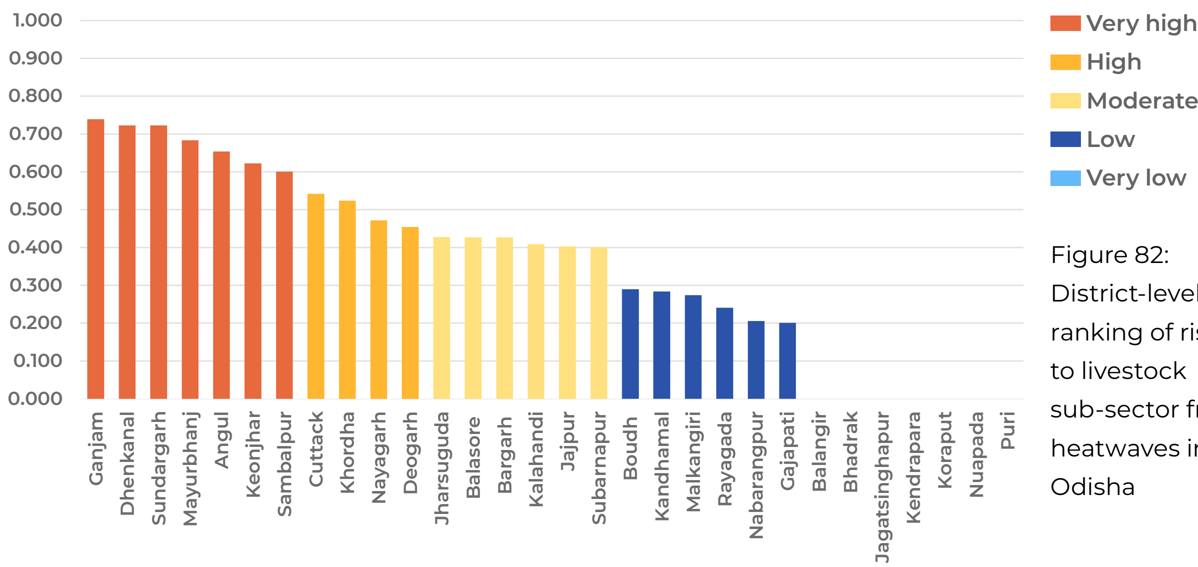


Figure 82: District-level ranking of risk to livestock sub-sector from heatwaves in Odisha

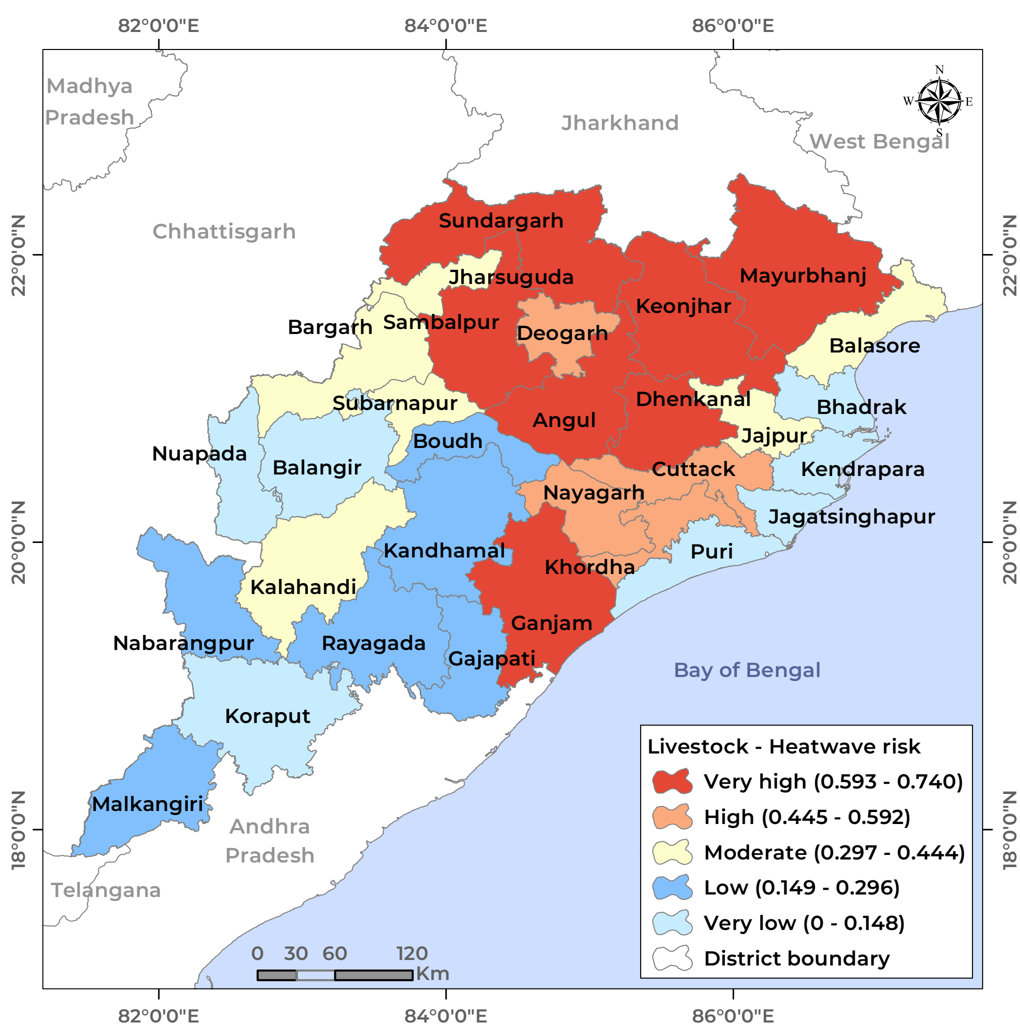


Figure 83: Heatwave risk map of the livestock sub-sector

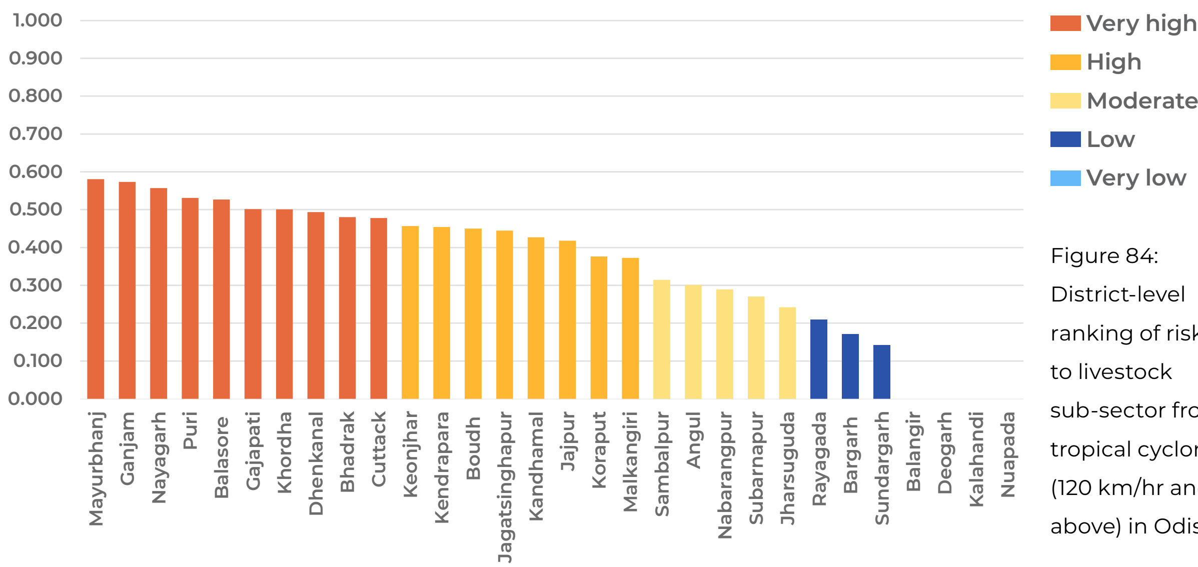


Figure 84: District-level ranking of risk to livestock sub-sector from tropical cyclones (120 km/hr and above) in Odisha

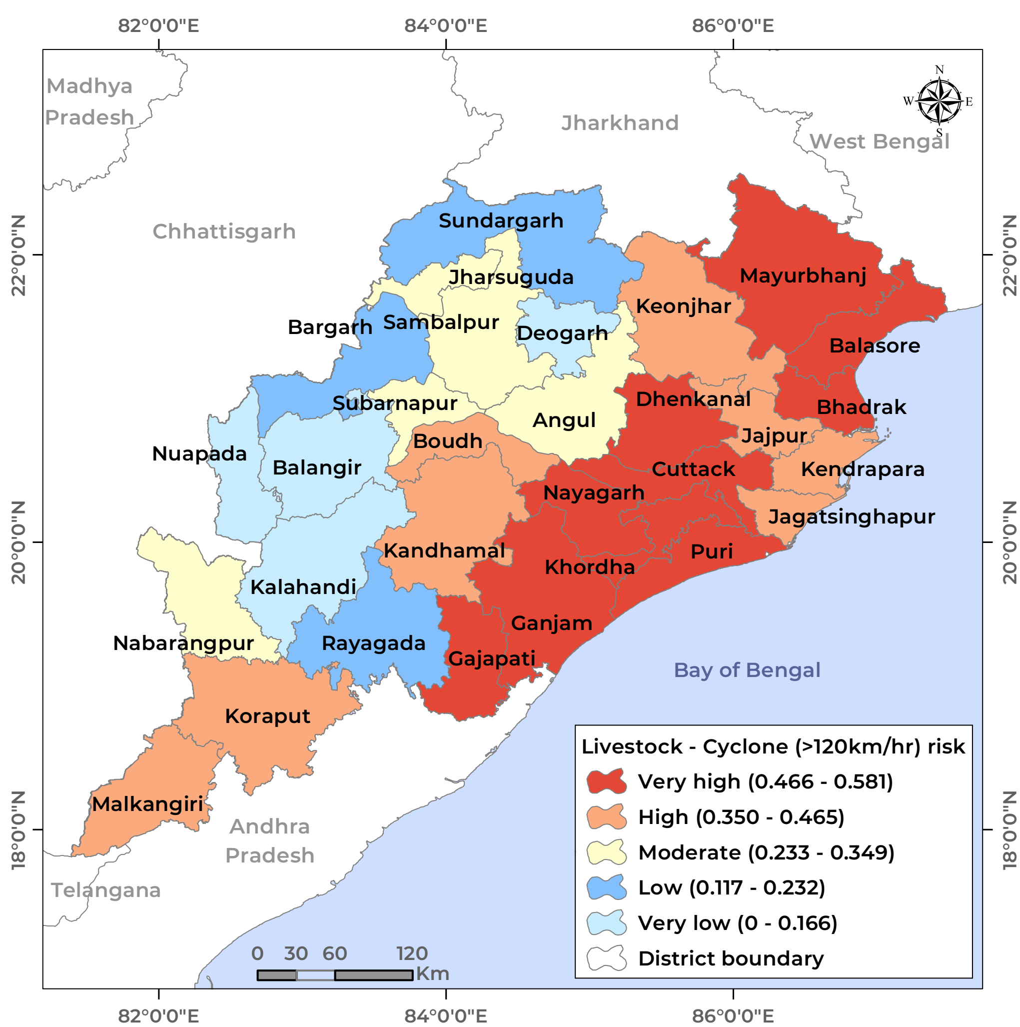


Figure 85: Tropical cyclone (120 km/hr and above) risk map of the livestock sub-sector

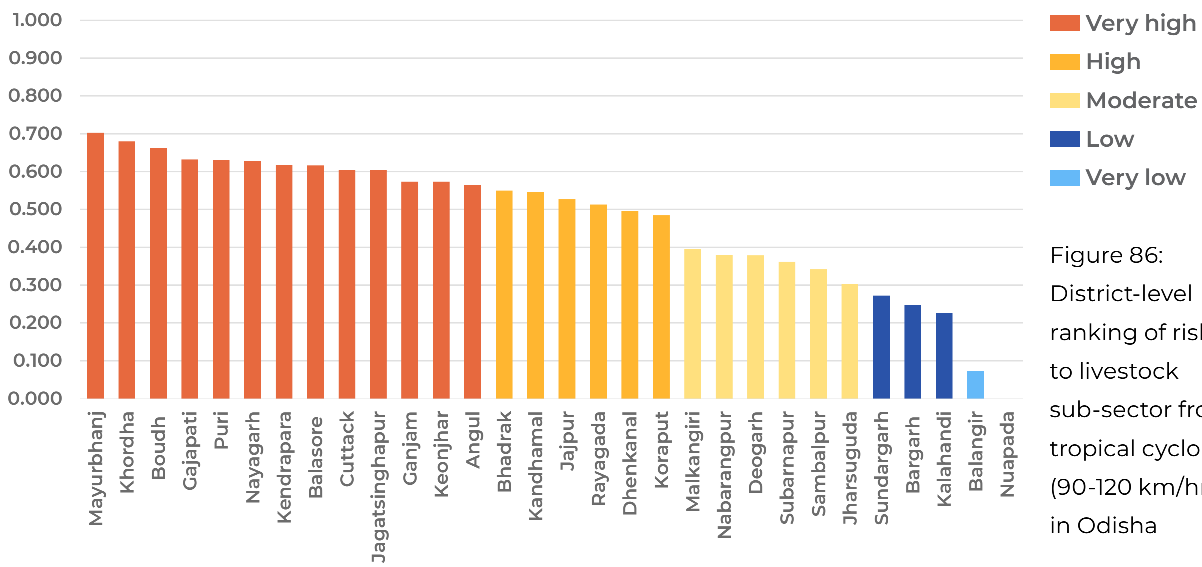


Figure 86: District-level ranking of risk to livestock sub-sector from tropical cyclones (90-120 km/hr) in Odisha

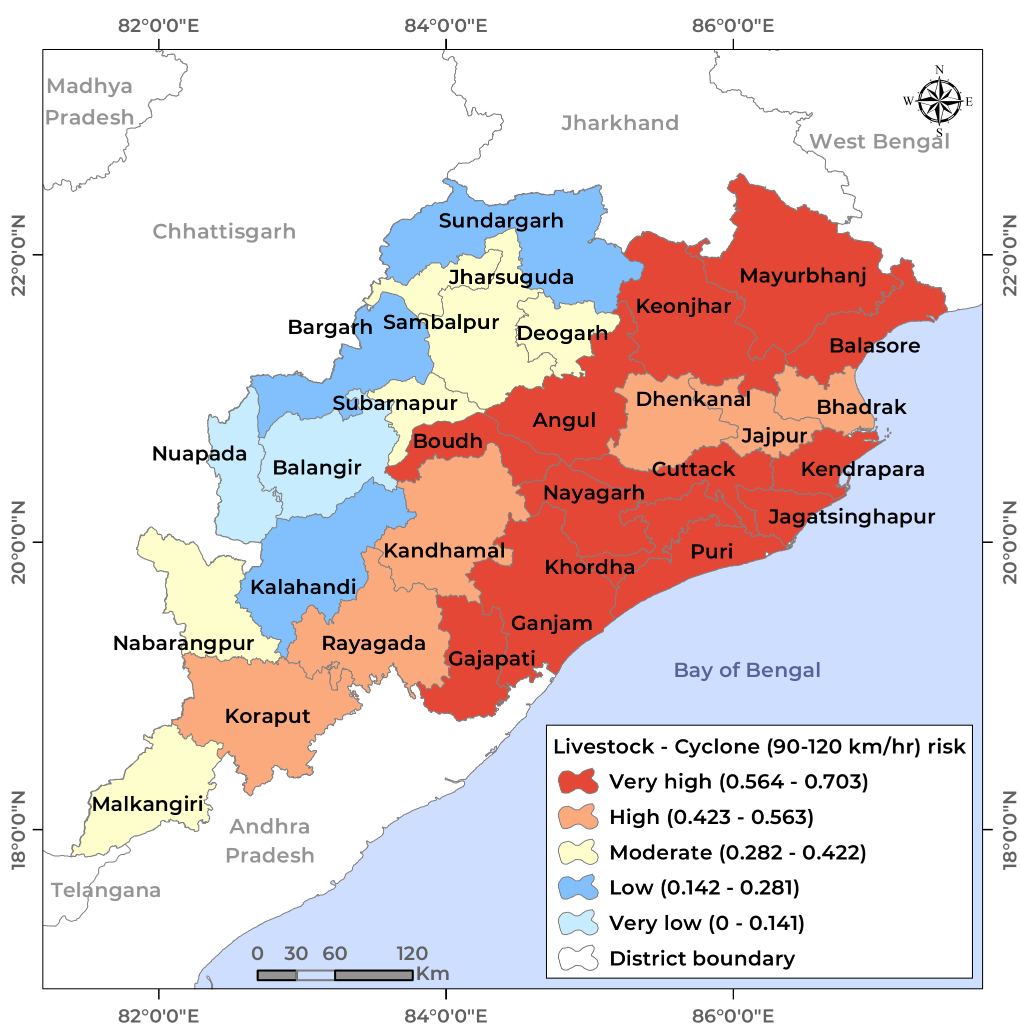


Figure 87: Tropical cyclone (90-120 km/hr) risk map of the livestock sub-sector

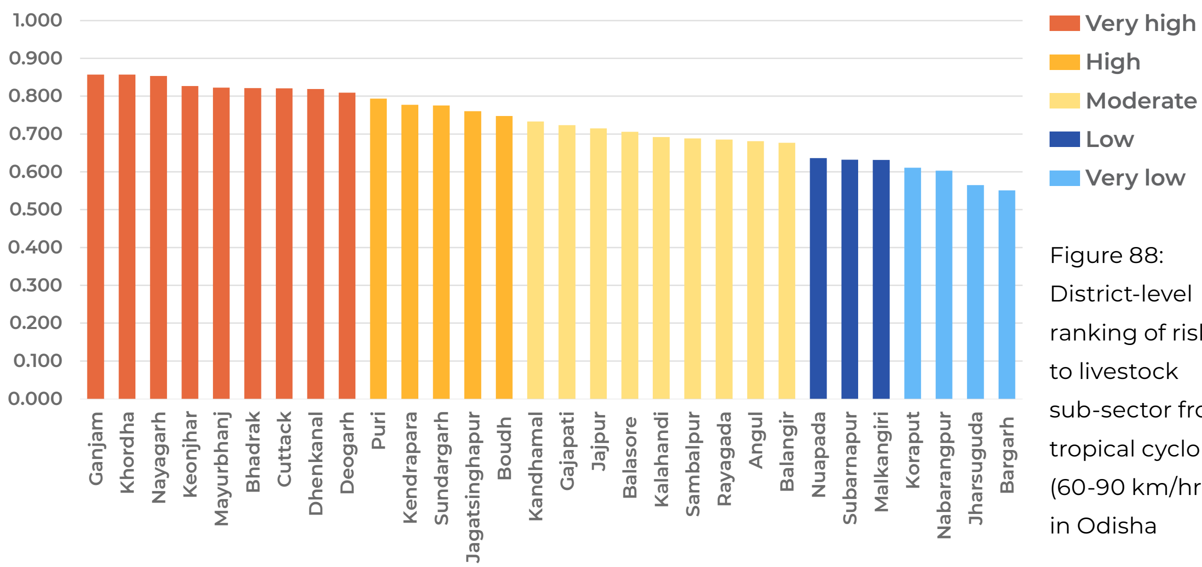


Figure 88: District-level ranking of risk to livestock sub-sector from tropical cyclones (60-90 km/hr) in Odisha

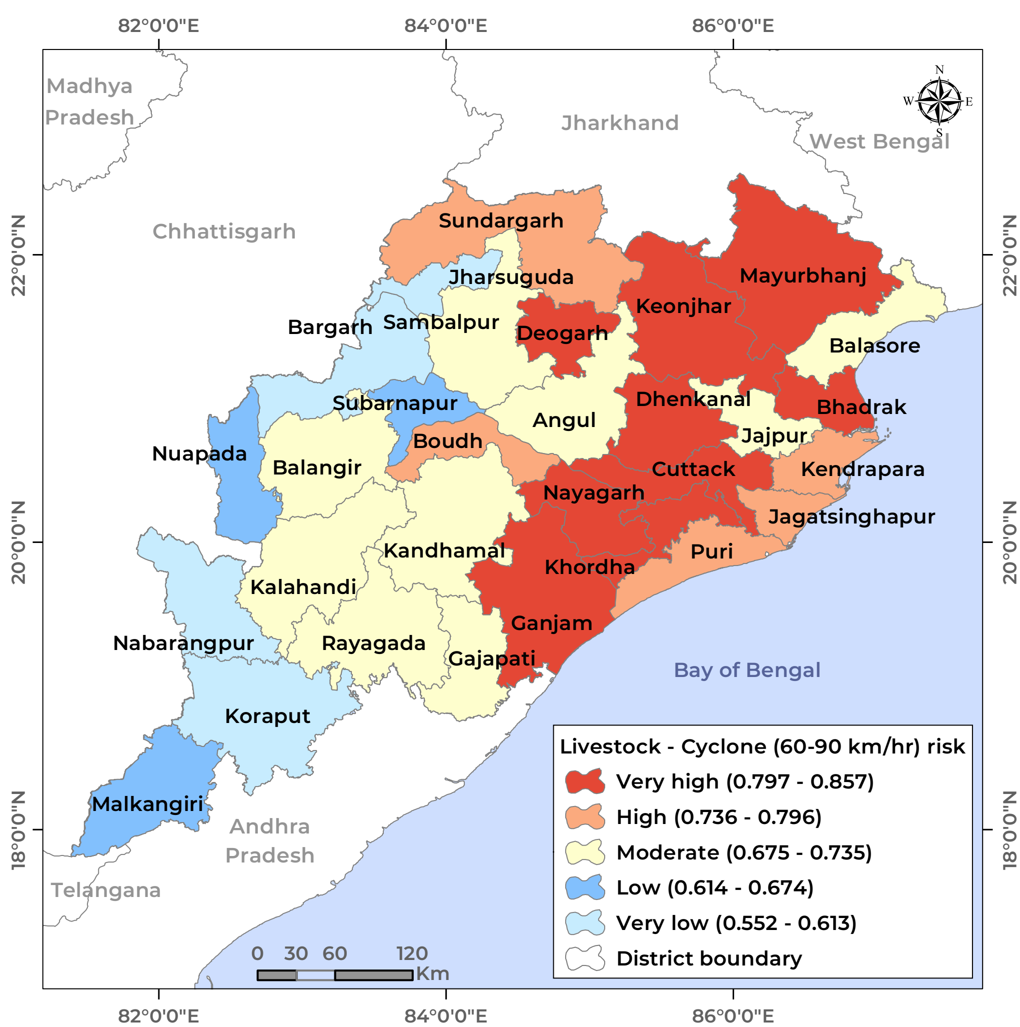


Figure 89: Tropical cyclone (60-90 km/hr) risk map of the livestock sub-sector

4.4.4. Climate risk assessments for fisheries sub-sector

In summary:

- Nearly 33%, 50%, and 66% of coastal districts in Odisha are highly at risk to droughts, floods, and heatwaves, respectively.

- Moreover, 16%, 33%, and 50% of the state's fisheries assets are highly at risk to tropical cyclones with wind speeds of 120 km/hr and above, 90-120 km/hr, and 60-90 km/hr, respectively.

Drought risk: The fishery sub-sector in only two districts, Ganjam and Puri among the coastal districts considered, is at risk to drought, with Ganjam being at very high risk and Puri being at moderate drought risk. The ranking is based on incremental classification of the risk index values. The remaining four districts – Balasore, Bhadrak, Jagatsinghapur and Kendrapara are not at risk to drought when the fisheries sub-sector is considered (Figure 90 and 91).

Flood risk: Districts with high flood risk (i.e., Kendrapara, Balasore, and Bhadrak) exhibit a combination of high probability of occurrence and vulnerability. Despite moderate exposure values to their fisheries assets, their overall risk remains elevated due to significant vulnerability (Figure 92). These results are spatially represented in Figure 93.

Heatwave risk: Four of the six coastal districts—Ganjam, Balasore, Kendrapara, and Bhadrak—exhibit very high to high flood risk. Ganjam's high risk is primarily driven by a high probability of occurrence and moderately high vulnerability. In contrast, Balasore's high risk is largely due to the sector's high inherent vulnerability, despite the moderate probability of occurrence and exposure. (Figures 94 and 95).

Tropical cyclone risk: Balasore consistently exhibits a high risk across all three categories of cyclonic storms. For storms with wind speeds of 90-120 km/hr and above 120 km/hr, this risk is primarily driven by a high probability of occurrence and significant exposure of fisheries assets (Figures 96 and 98). However, for storms with wind speeds of 60-90 km/hr, the high risk is mainly due to exposure and the sector's high inherent vulnerability (Figure 100).

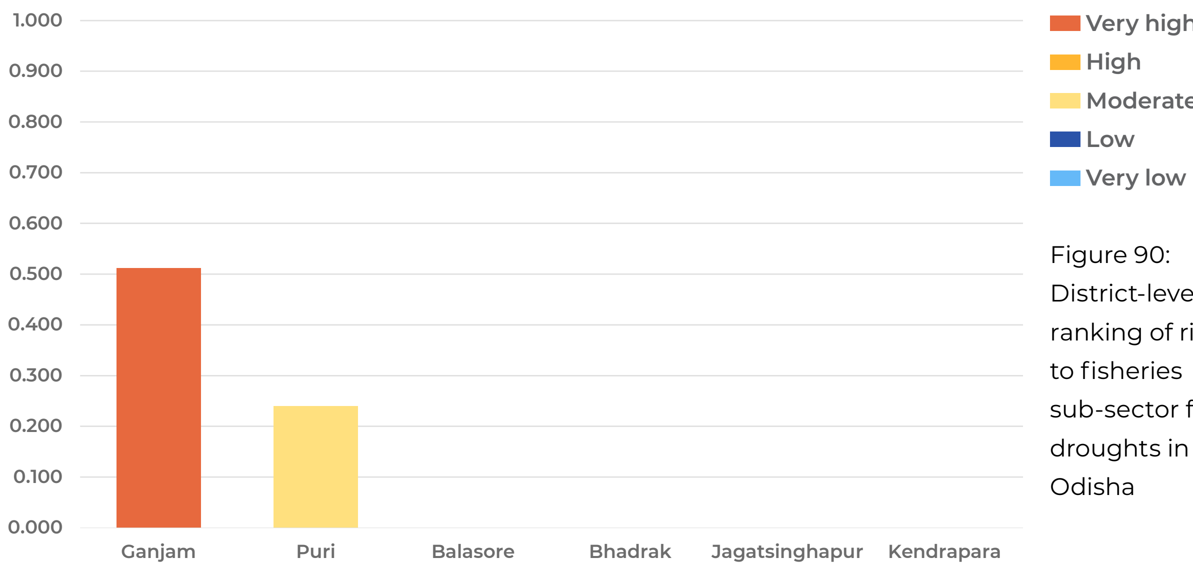


Figure 90: District-level ranking of risk to fisheries sub-sector from droughts in Odisha

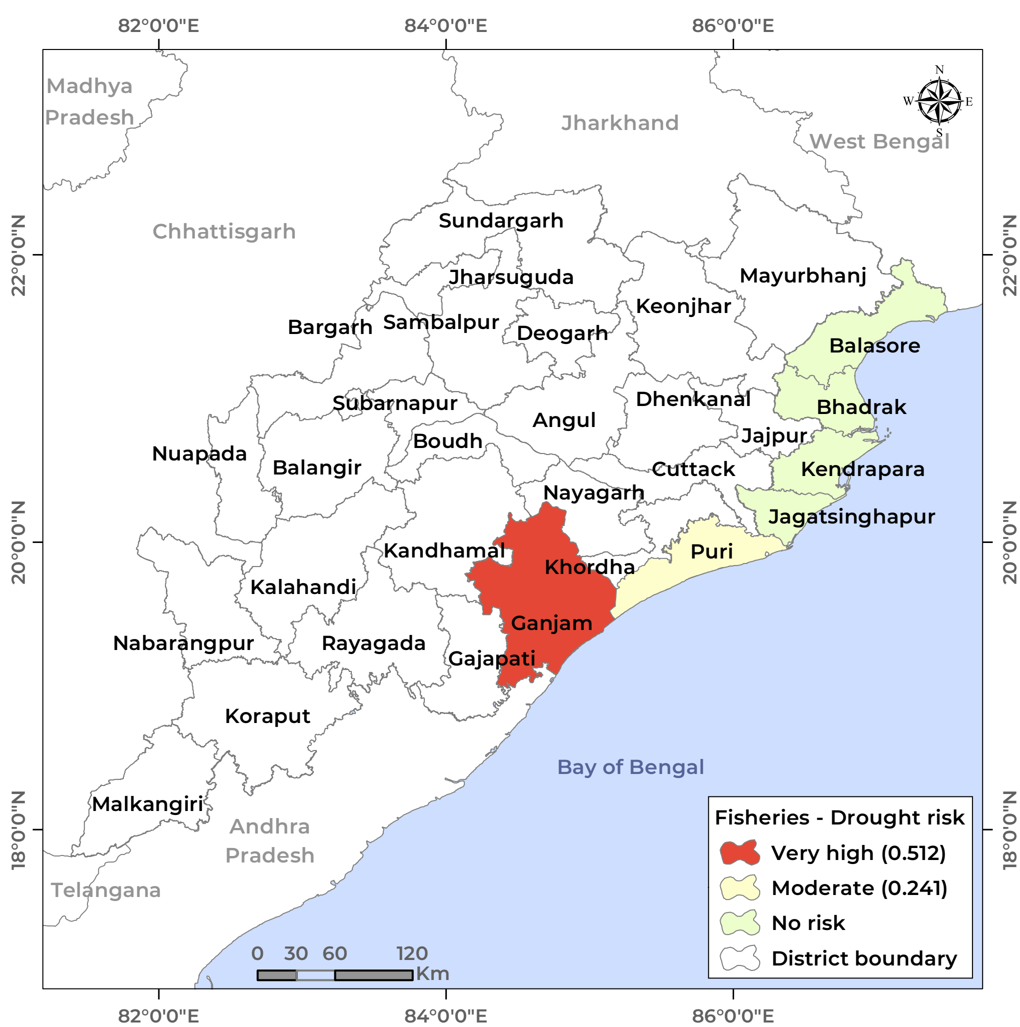


Figure 91: Drought risk map of the fisheries sub-sector

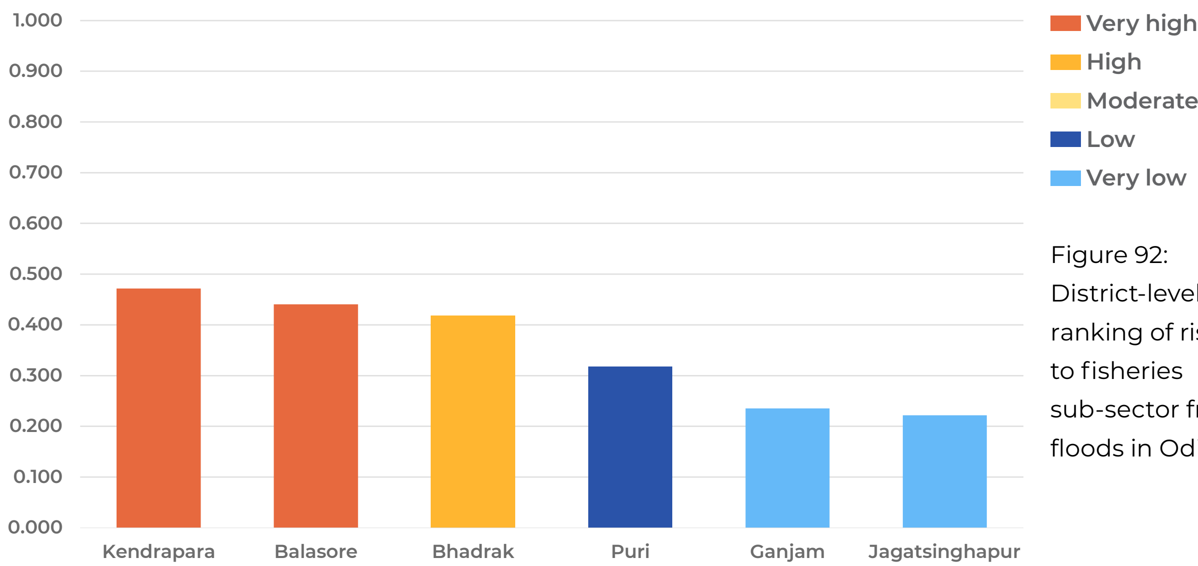


Figure 92: District-level ranking of risk to fisheries sub-sector from floods in Odisha

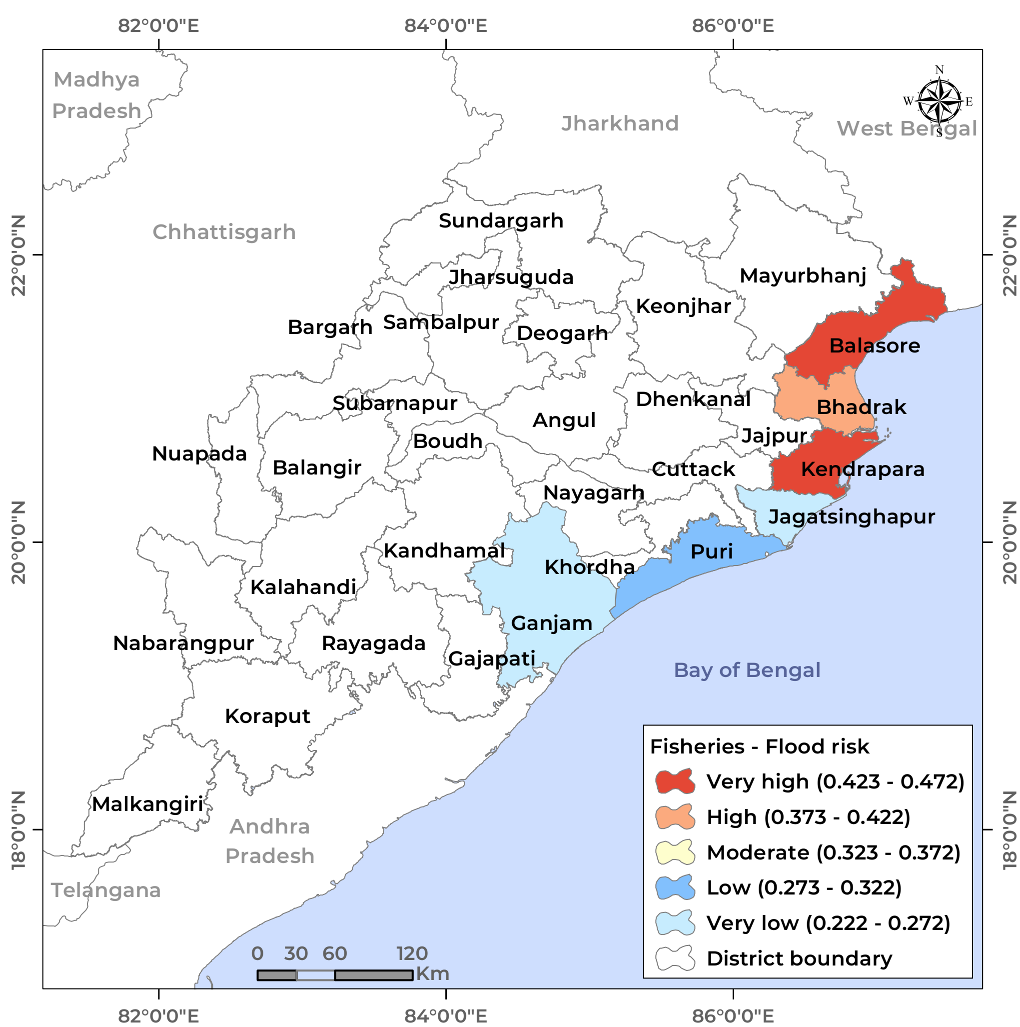


Figure 93: Flood risk map of the fisheries sub-sector

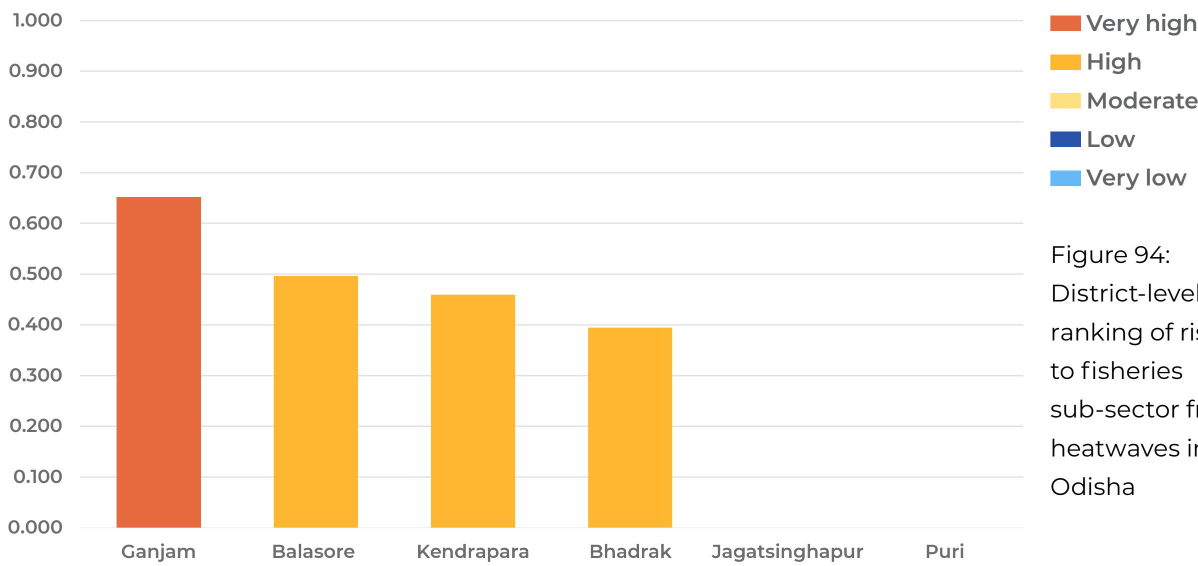


Figure 94: District-level ranking of risk to fisheries sub-sector from heatwaves in Odisha

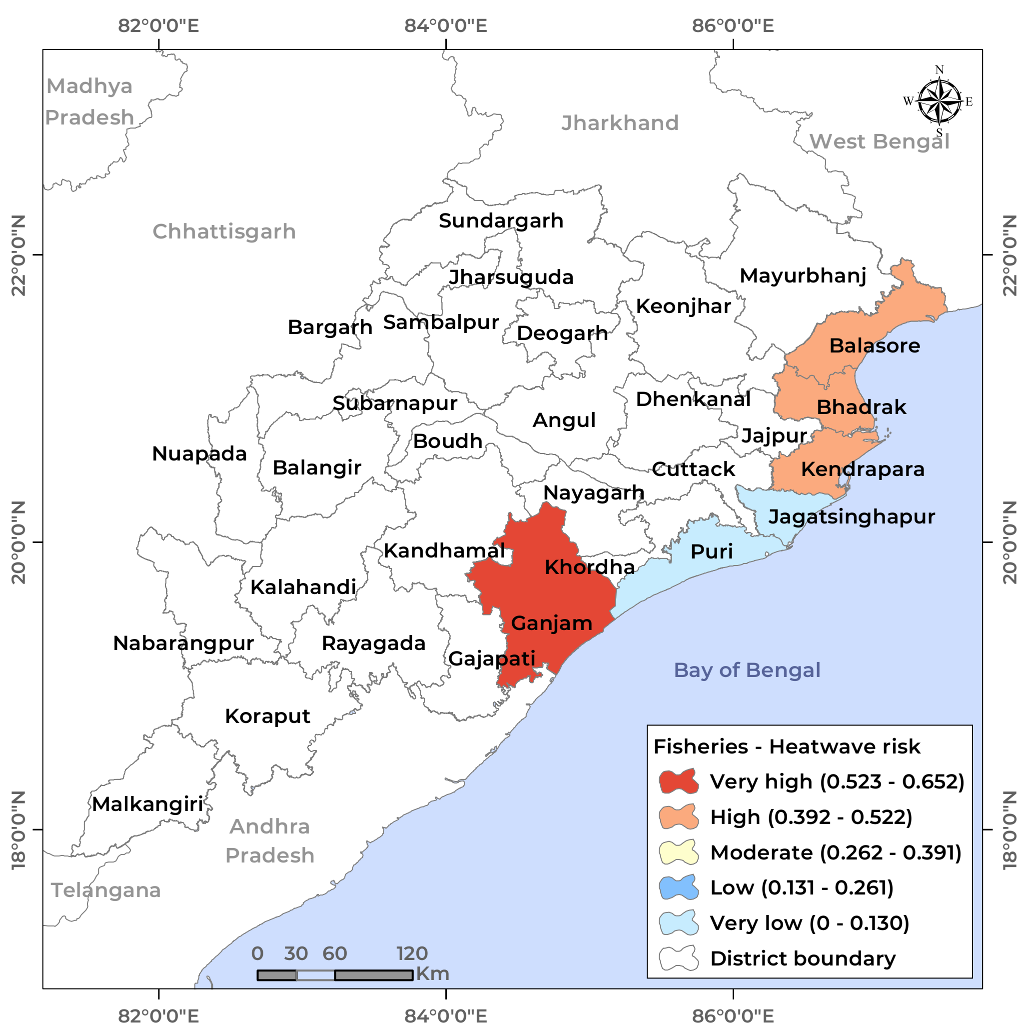


Figure 95: Heatwave risk map of the fisheries sub-sector

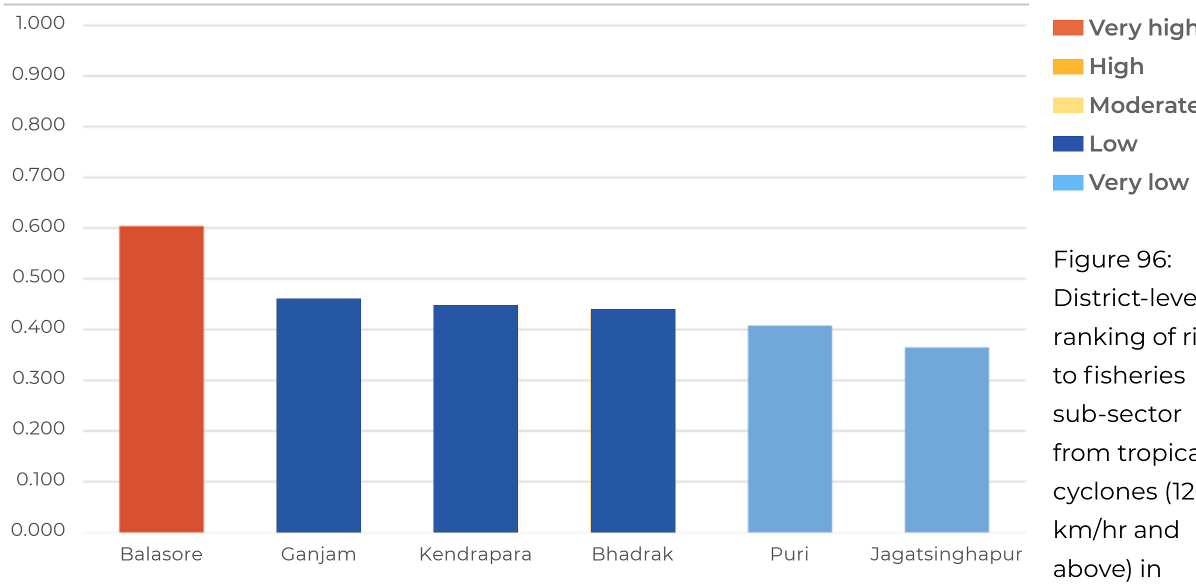


Figure 96: District-level ranking of risk to fisheries sub-sector from tropical cyclones (120 km/hr and above) in Odisha

Figure 97: Tropical cyclone (120 km/hr and above) risk map of the fisheries sub-sector

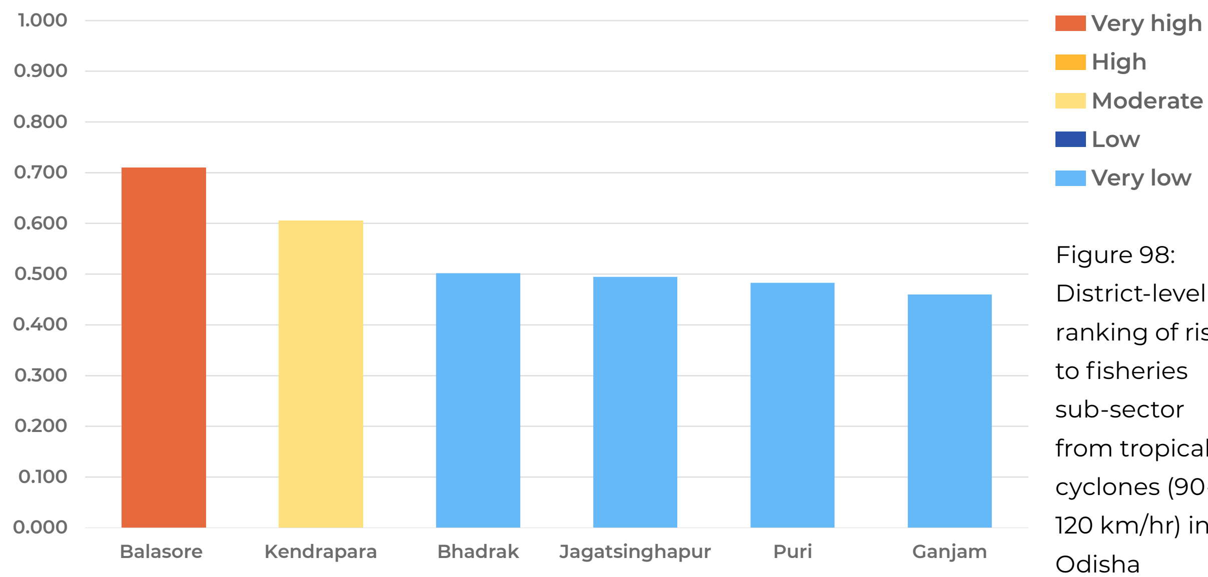


Figure 98: District-level ranking of risk to fisheries sub-sector from tropical cyclones (90-120 km/hr) in Odisha

Figure 99: Tropical cyclone (90-120 km/hr) risk map of the fisheries sub-sector

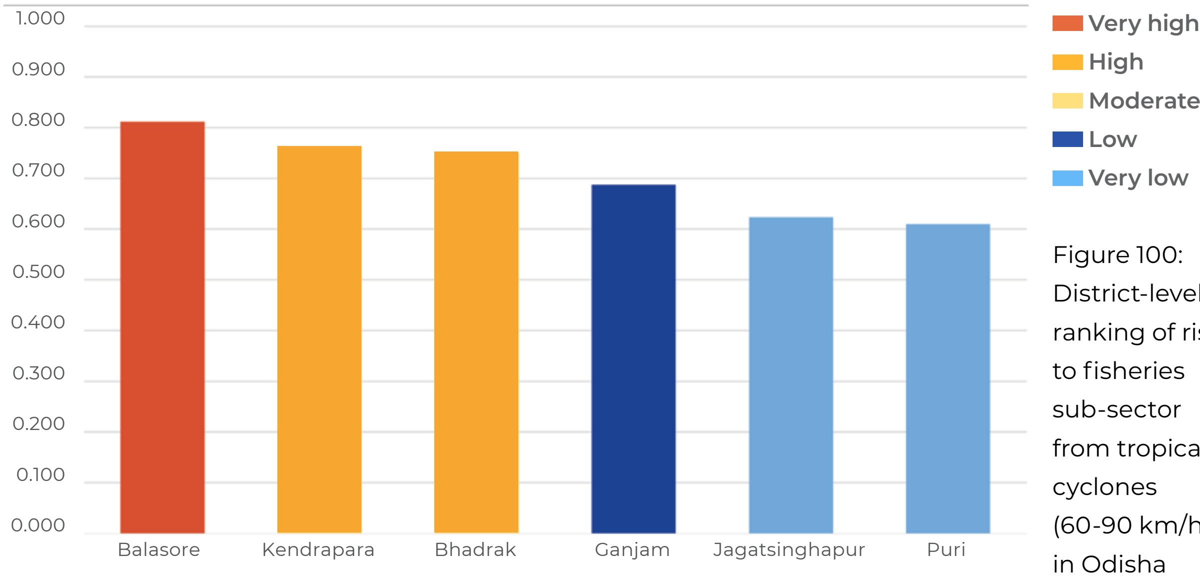


Figure 100: District-level ranking of risk to fisheries sub-sector from tropical cyclones (60-90 km/hr) in Odisha

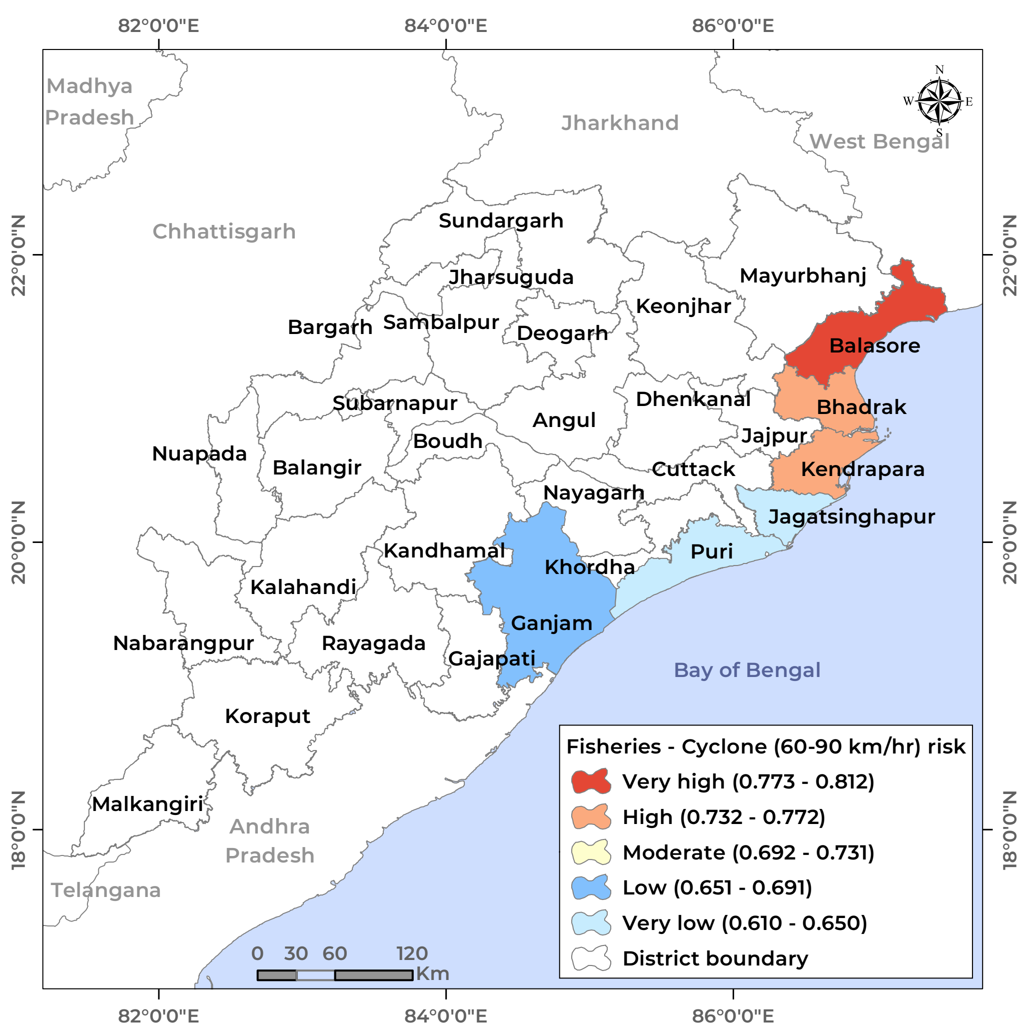


Figure 101: Tropical cyclone (60-90 km/hr) risk map of the fisheries sub-sector

5. Conclusions

The findings from this climate risk assessment highlight significant inter-district variations in climate risks across Odisha, emphasising the need for targeted interventions tailored to specific hazards and district-level vulnerabilities.

Southern districts, including Nuapada, Balangir, Mayurbhanj, Malkangiri, Ganjam, Subarnapur, and Sundargarh, face heightened risks from droughts, necessitating investments in extensive irrigation solutions, crop diversification, and soil and water conservation practices. Similarly, Kendrapara, Balasore and Boudh, with very high flood risk, and Bhadrak, Cuttack, Puri, and Jajpur, with high flood risk, should be prioritised for flood resilience measures, such as improving drainage infrastructure and mitigating coastal inundation impacts.

Heatwaves pose very high risks in districts like Angul, Dhenkanal, Ganjam, Sundargarh, Mayurbhanj, Keonjhar, and Sambalpur, primarily in northern Odisha. Targeted heat-resilience measures, including improved water management, low-cost cooling solutions for livestock, and the promotion of heat-tolerant crop varieties, are essential in these areas. Sundargarh and Mayurbhanj, identified as highly vulnerable to heatwaves and droughts, exemplify the need for multi-hazard resilience strategies to address compounded climate risks.

Additionally, coastal districts face added risks to tropical cyclones, with Balasore and Mayurbhanj facing the highest risk to severe and very severe tropical cyclones due to a high probability of occurrence.
The results of this study align with findings from the Odisha SAPCC (2021-30) for most at-risk districts, such as Mayurbhanj, Keonjhar, Bhadrak, and Ganjam. However, differences in indicator selection, hazard-specific focus areas, and temporal scales between the two analyses highlight the importance of context-specific assessments.

This analysis underscores the critical need to implement climate-resilient practices and policies that optimise resource use and build resilience against specific climate risks. A multi-pronged approach combining irrigation solutions, conservation practices, infrastructure investments, and climate-smart agriculture will be pivotal in enhancing adaptive capacity and reducing vulnerabilities in Odisha's most at-risk districts.

6. Appendix

6.1. Results of sub-sectoral exposure analysis

This section presents the results of the exposure analysis for individual sub-sectors – agriculture and livestock – only covering the exposure of each asset and livelihood source, along with essential infrastructure (roads and fuel points), to the three identified hazards.

6.1.1. Exposure of agriculture sub-sector to different hazards

Exposure to droughts

The keys insights from Figures 102, 103, and 104 are:

- **Koraput**'s agricultural assets are most exposed to drought, as the district consistently ranks in the very high exposure category across all assets, including irrigation infrastructure, net sown area (NSA), and storage facilities.
- Nuapada, Malkangiri, and Balangir show significant drought exposure across multiple asset categories, highlighting them as key areas of concern.
- **Bargharh, Ganjam, Gajapati,** and **Rayagada** also have high levels of exposure, particularly in terms of NSA and market infrastructure.

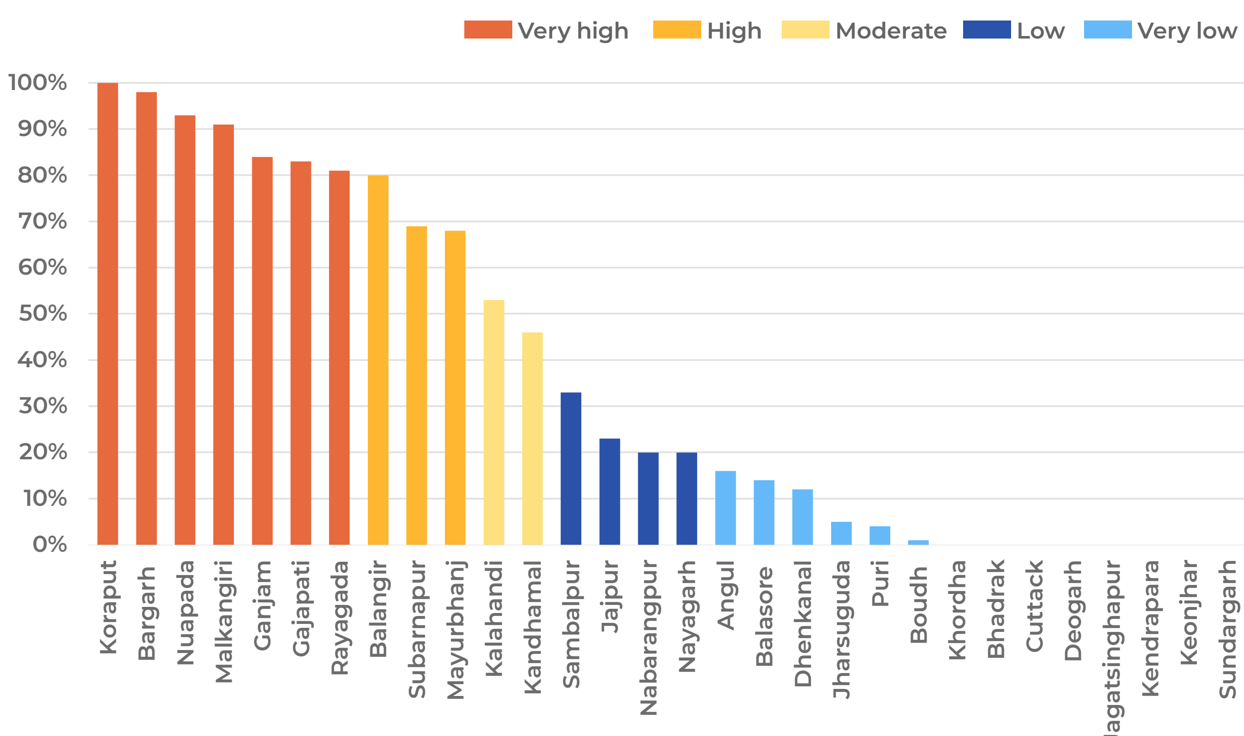


Figure 102: Exposure of net sown area to drought

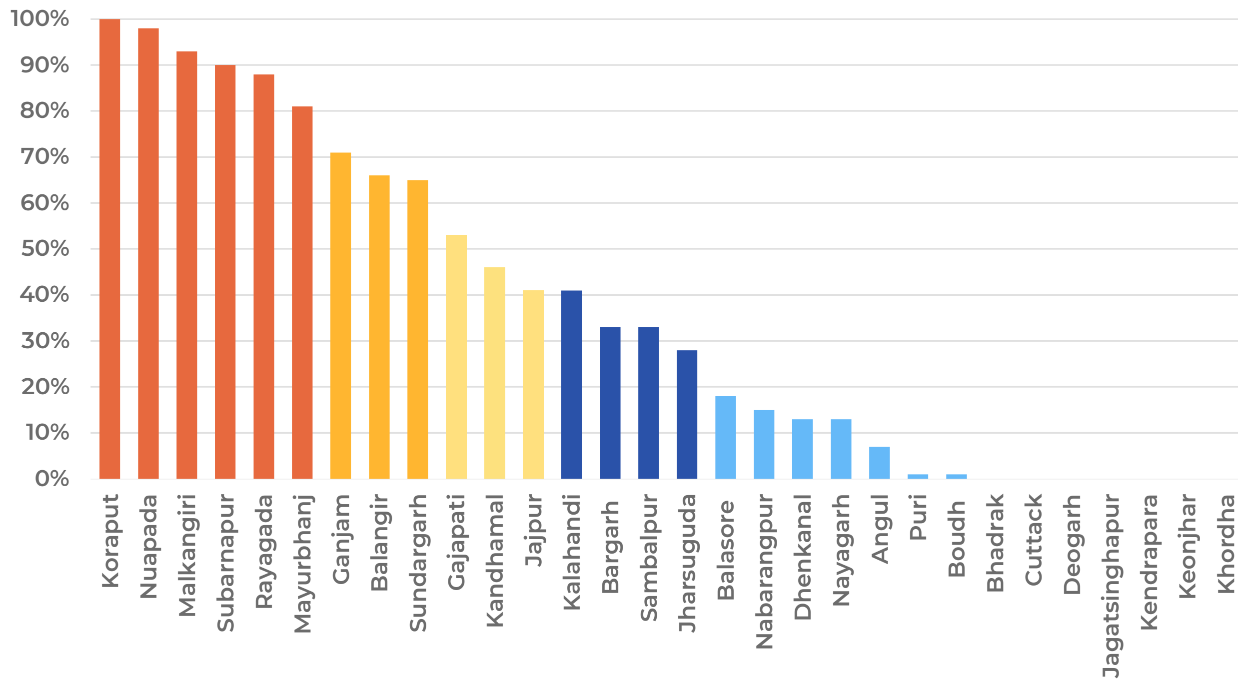


Figure 103: Average exposure of irrigation infrastructure to drought

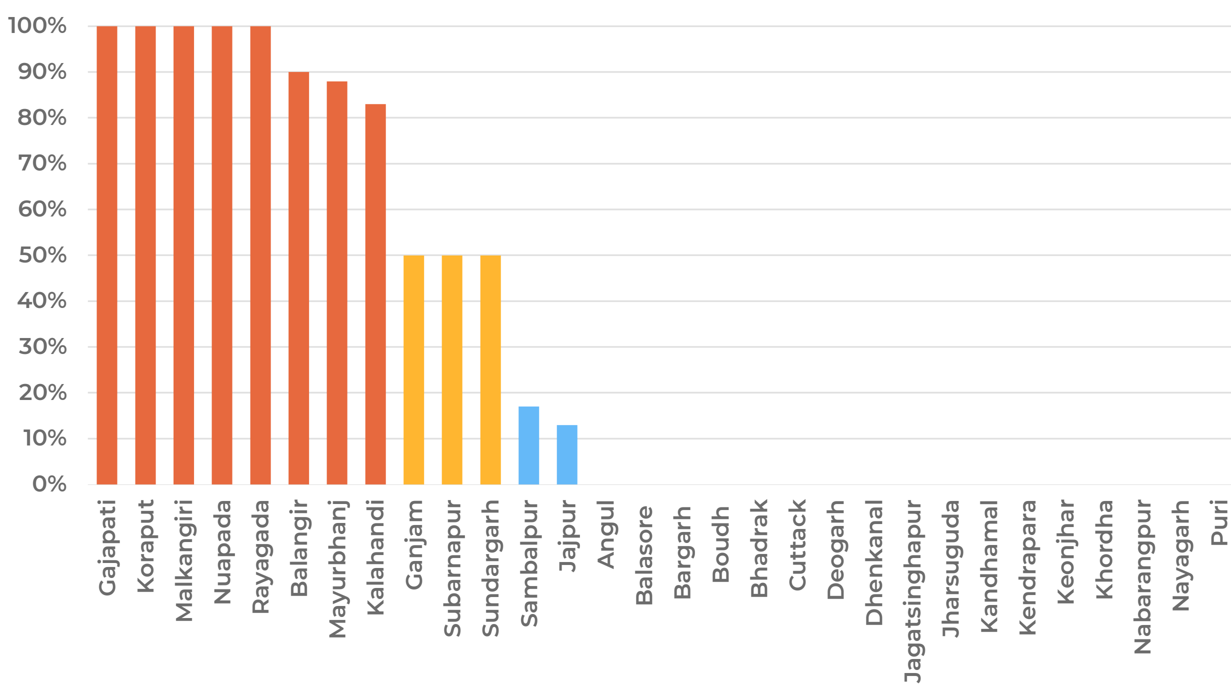


Figure 104: Average exposure of storage areas, agriculture markets, and food parks to drought

Exposure to floods

The key insights from Figures 105, 106 and 107 are:

- Agricultural assets in **Kendrapara** are most exposed to floods, facing very high exposure across all asset categories (irrigation infrastructure, market infrastructure, and NSA). **Puri**'s NSA is almost as highly exposed.

- **Balasore and Bhadrak** are also significantly exposed to floods, particularly in terms of market infrastructure and NSA.

- The market infrastructure in almost 75% of the districts face no exposure to floods.

- **Cuttack** faces relatively high exposure in all categories, emphasising the district's exposure to floods.

Exposure to heatwaves

The key insights from Figures 108, 109 and 110 are:

- Agricultural assets in **Deogarh** district are the most exposed to heatwaves.

- **Angul, Sundergarh,** Jahrsuguda, Mayurbhanj, and **Kandhamal** also experience significant heatwave exposure.

Exposure to tropical cyclones

- Boudh has the highest exposure (80%) of net sown area to tropical cyclones across all three wind speed categories, followed closely by Kendrapara.

- Exposure to irrigation infrastructure and market areas is 100% in all districts due to cyclones with wind speeds of 60–90 km/h.

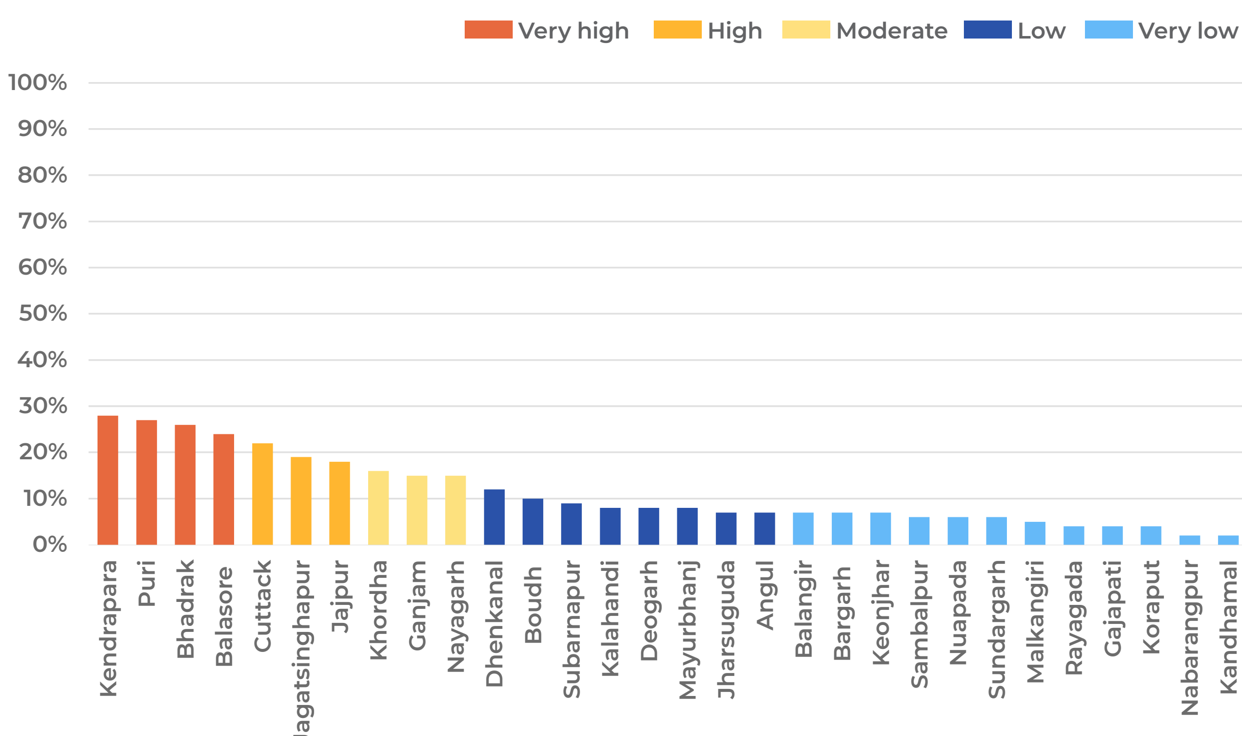


Figure 105: Exposure of net sown area to floods

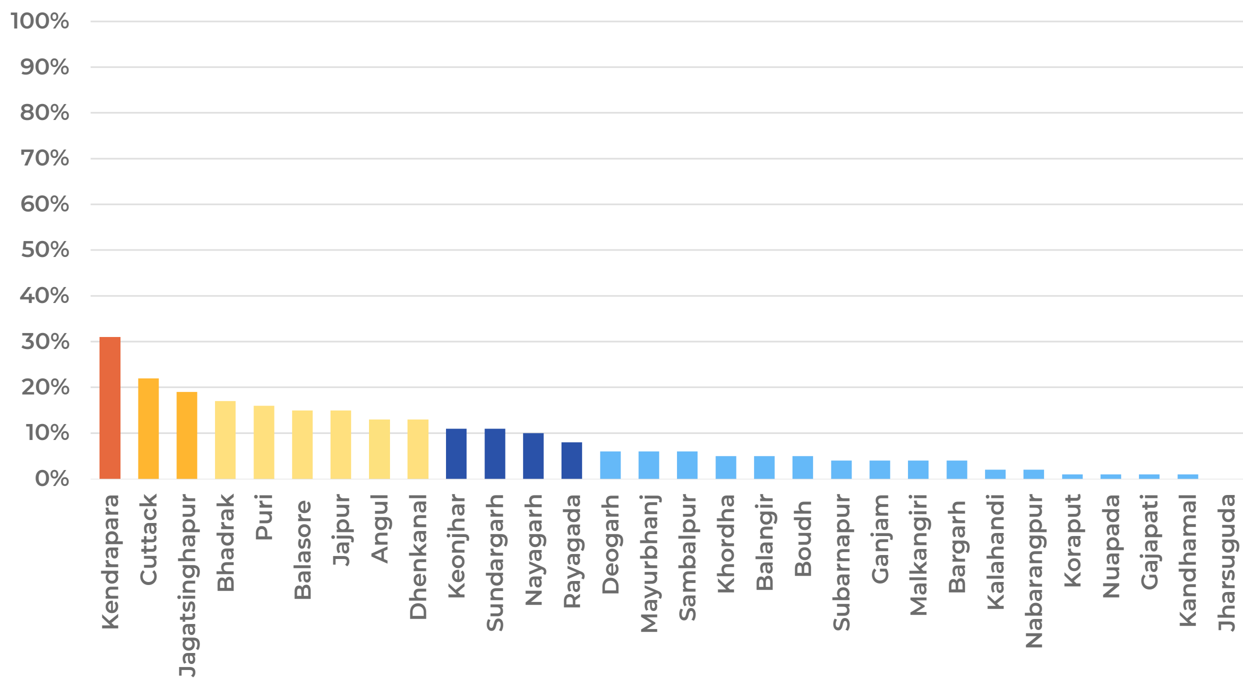


Figure 106: Exposure of irrigation infrastructure to floods

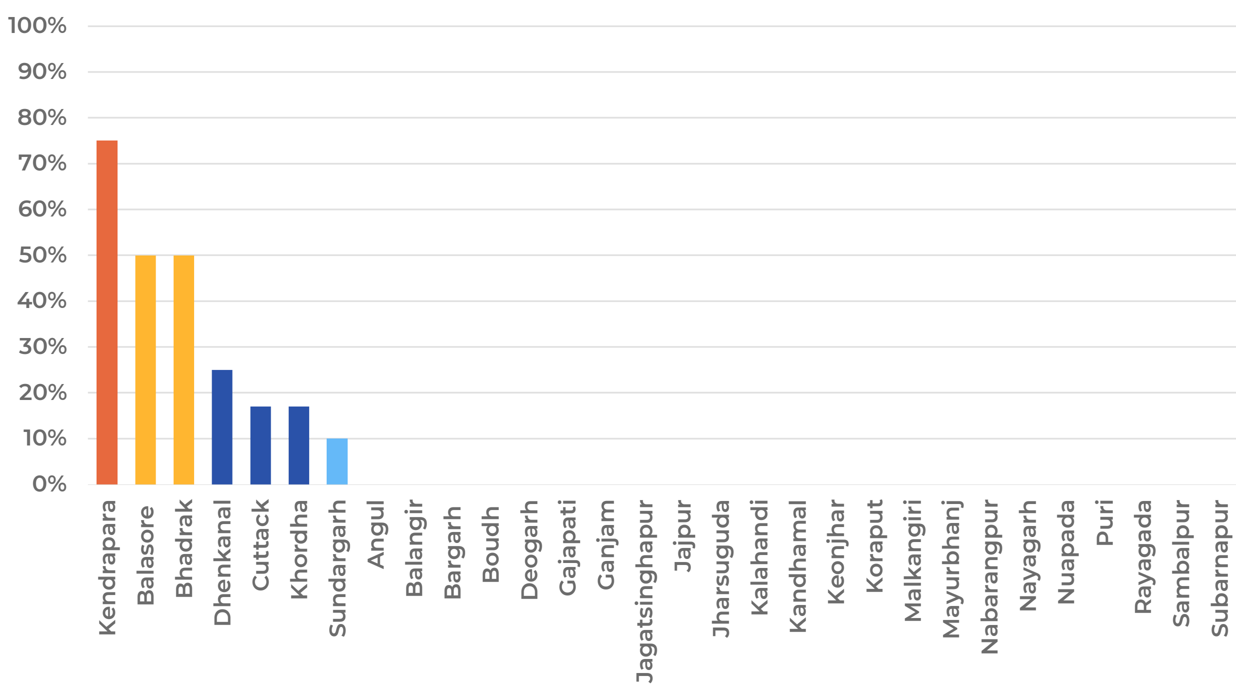


Figure 107: Average exposure of storage areas, agriculture markets, and food parks to floods

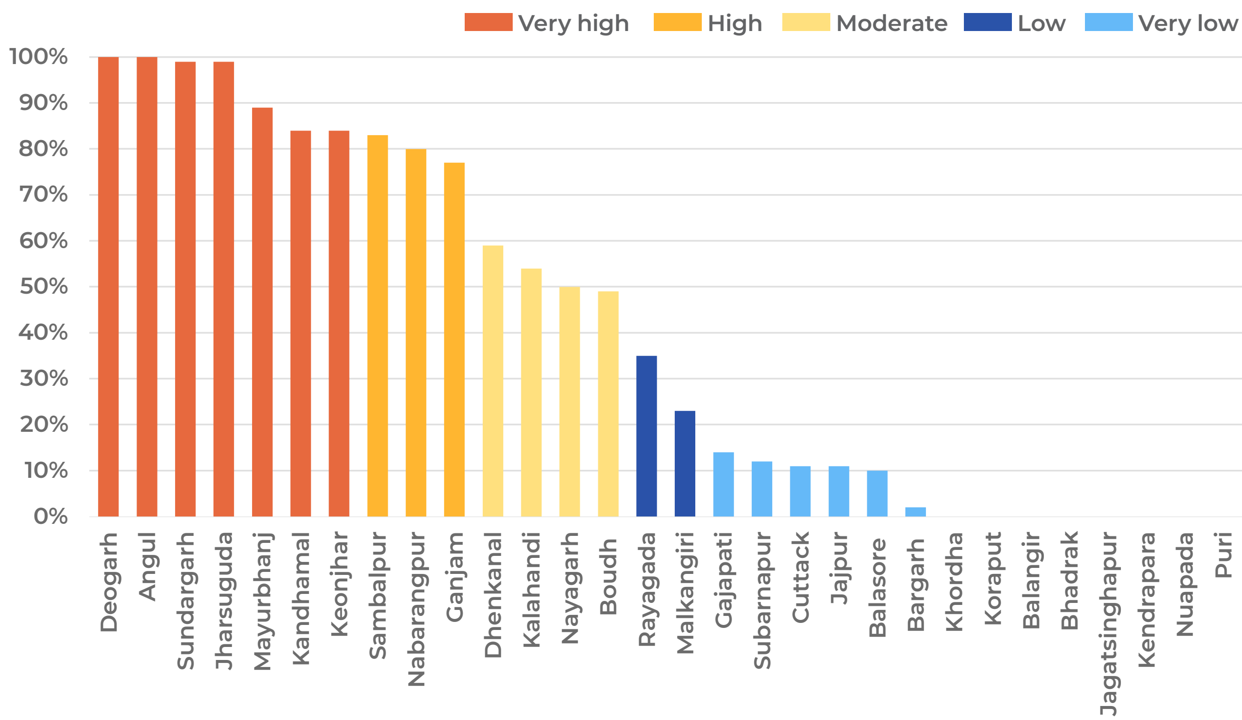


Figure 108: Exposure of net sown area to heatwaves

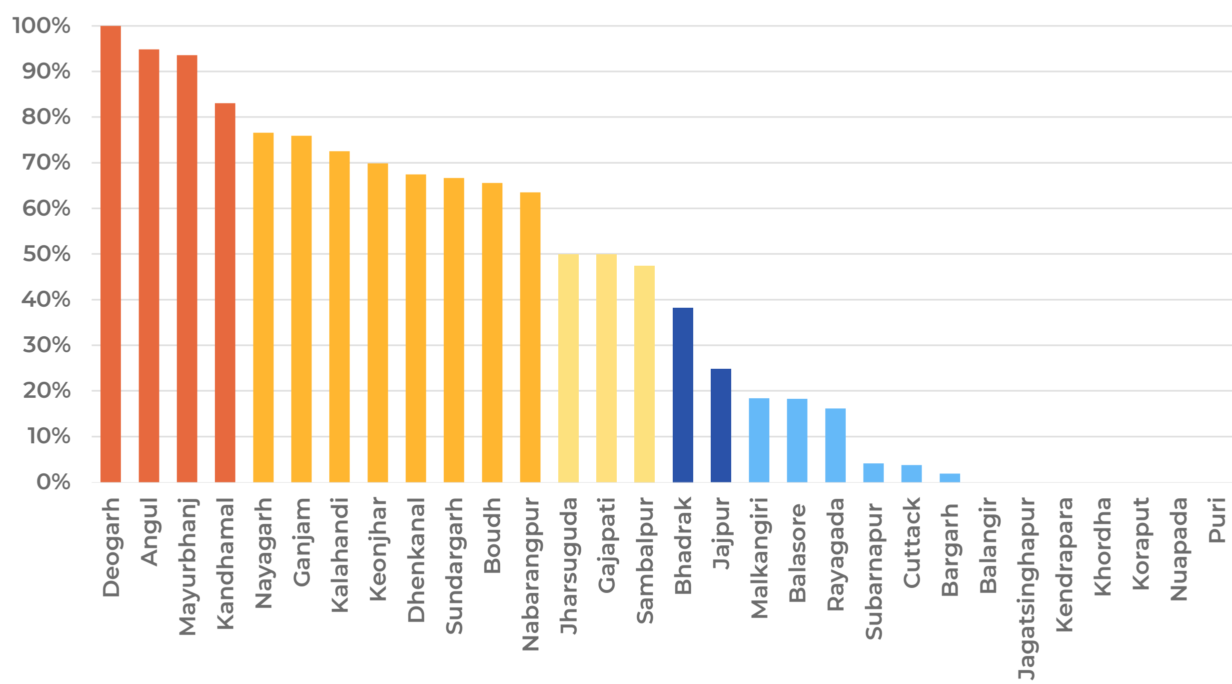


Figure 109: Exposure of irrigation infrastructure to heatwaves

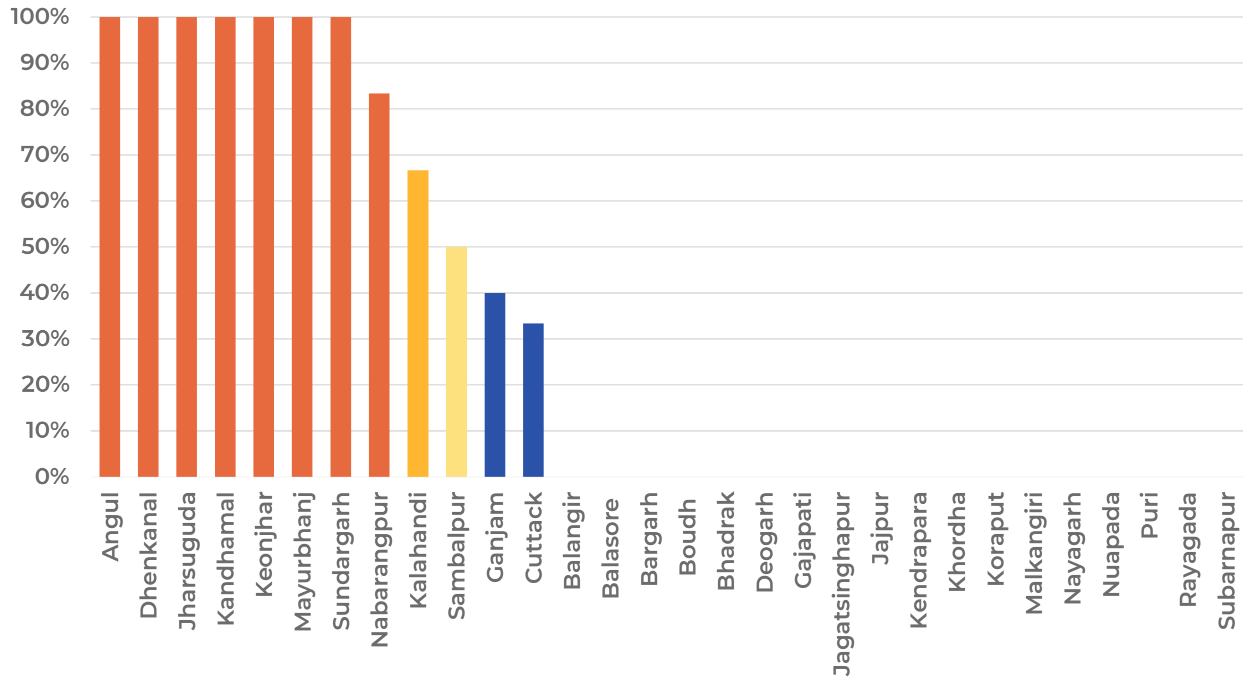


Figure 110: Exposure of storage areas and agriculture markets to heatwaves

6.1.2. Exposure of livestock sub-sector to different hazards

Exposure to droughts

The key insights from Figure 111 are:

- **Koraput** consistently shows 100% exposure, both in terms of livestock population and average livestock assets, making it the most exposed district.

- **Bargharh, Nuapada and Malkangiri** follow closely, with livestock populations and assets facing near-total exposure.

Exposure to floods

The key insights from Figure 112 are:

- **Balasore** has the highest average exposure of livestock and livestock-related assets to floods, according to this assessment.

- **Puri and Kendrapara** have the highest exposure of livestock to floods

Exposure to heatwaves

The key insights from Figure 113 are:

- Overall, livestock sub-sector in **Deogarh, Angul, Sundergarh,** Jharsuguda, Mayurbhanj, Keonjhar, Nabarangpur, Angul, and Kandhamal are the most exposed to heatwaves.

- In terms of livestock population most exposed to heatwaves, **Deogarh** and **Malkangiri** observe the highest**.**

Exposure to tropical cyclones

- Angul has the highest exposure of livestock population to both high-magnitude cyclones (>120 km/h) and tropical cyclones with wind speeds of 60–90 km/h.

- Nearly all districts have 100% livestock exposure to cyclones with wind speeds of 60–90 km/h, except Boudh (85%) and Puri (80%).

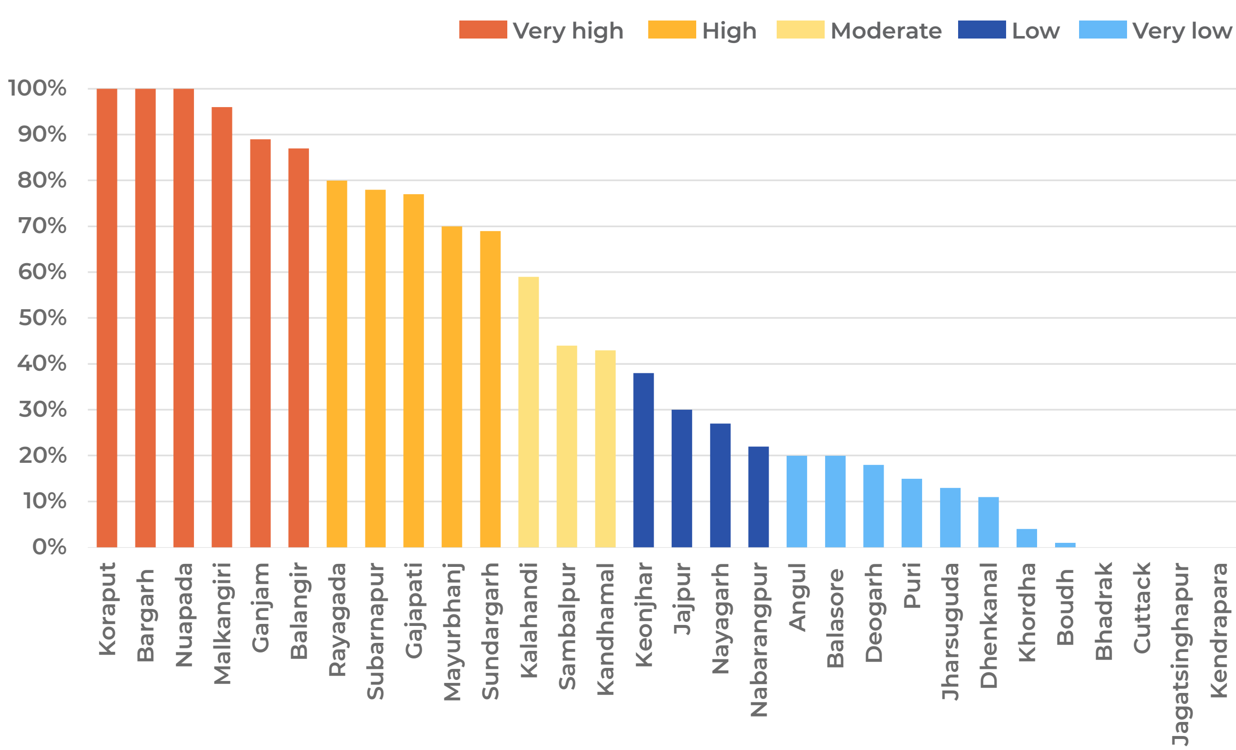


Figure 111: Exposure of livestock population (cattle, sheep, goats, pigs and poultry) to drought

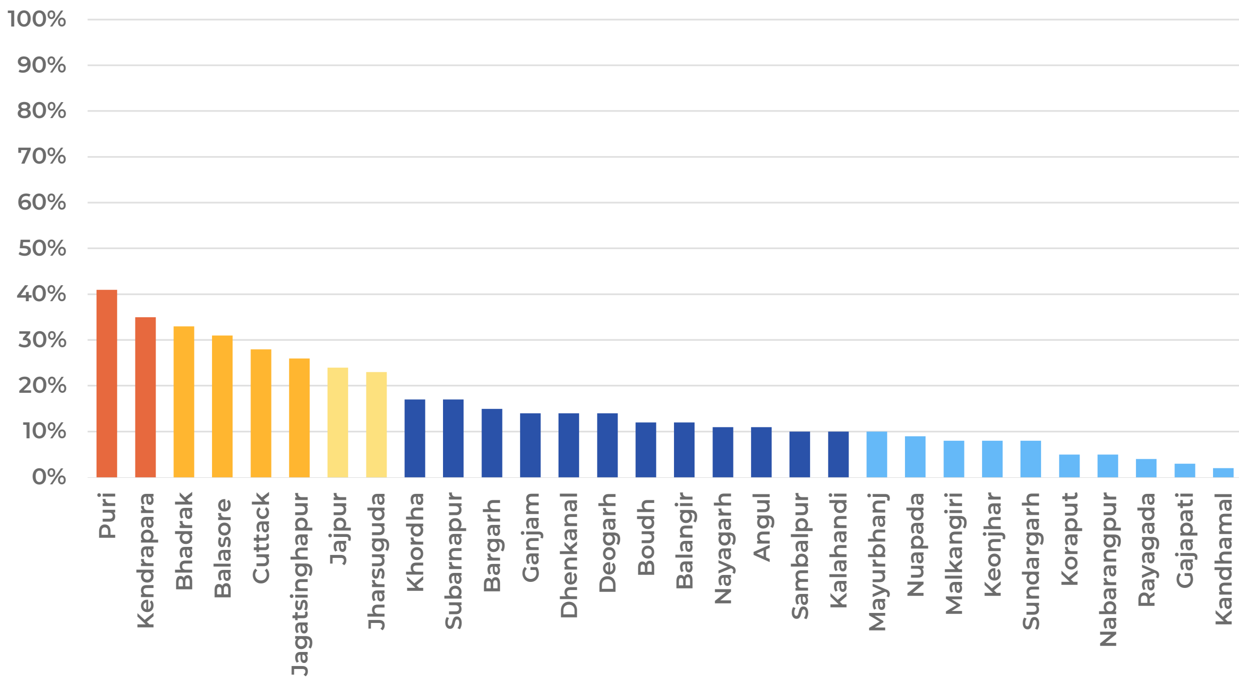


Figure 112: Exposure of livestock population (cattle, sheep, goats, pigs and poultry) to floods

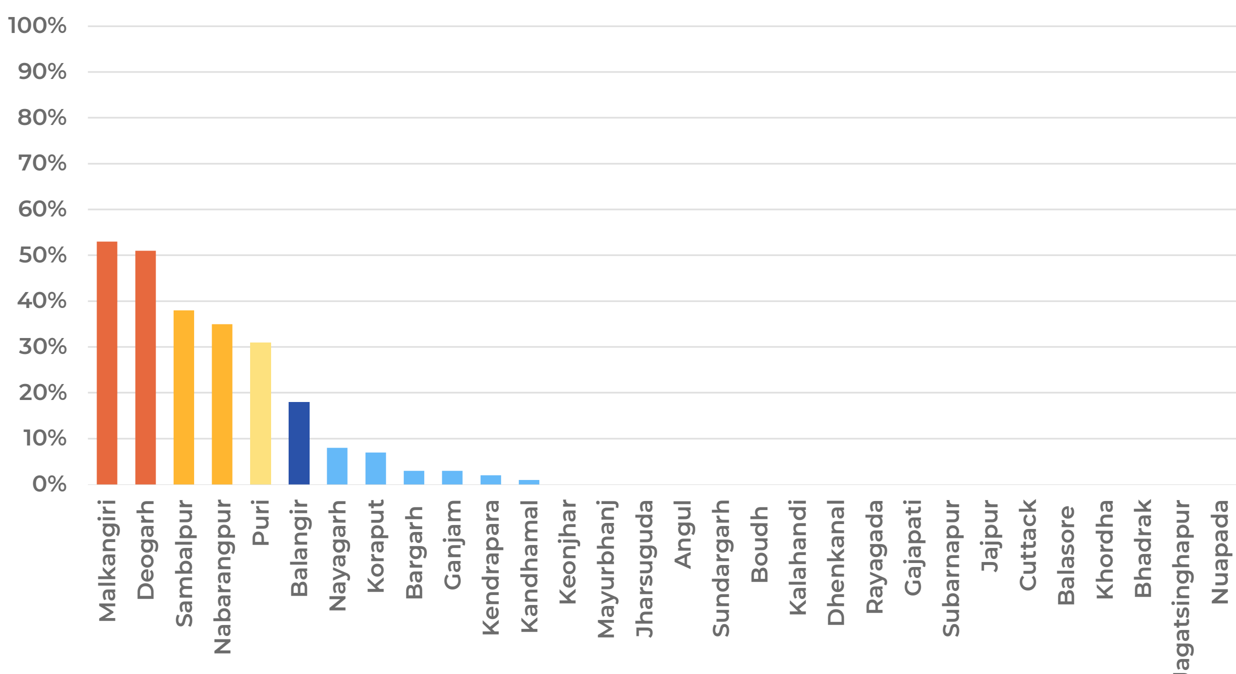


Figure 113: Exposure of livestock population (cattle, sheep, goats, pigs and poultry) to heatwaves

6.1.3. Exposure of essential infrastructure assets
6.1.4. to different hazards

This section presents the results of the exposure analysis of essential infrastructure assets (the average exposure to fuel points and rural roads) to each hazard – droughts, floods, heatwaves and tropical cyclones.

To summarise the findings from this sub-section:

- **Exposure to droughts**: Essential infrastructure assets in Koraput (99%) are the most exposed, closely followed by Gajapati and Balangir (Figure 114).

- **Exposure to floods**: Essential infrastructure assets in Boudh (54%) are most exposed, closely followed by Balasore (Figure 115).

- **Exposure to heatwaves**: essential infrastructure assets in Deogarh, Angul, and Sundergarh (100%) are most exposed, closely followed by Jharsuguda, Mayurbhanj, Keonjhar, Nabarangpur, Angul, and Kandhamal (Figure 116).

Exposure to tropical cyclones

- Essential infrastructure in Boudh, Gajapati, Ganjam, Jagatsinghpur, Jajpur, Kendrapara, Khordha, and Puri has the highest exposure (100%) to tropical cyclones with wind speeds exceeding 120 km/h.

- Additionally, nearly 50% of the state's essential infrastructure is exposed to cyclones with wind speeds of 90–120 km/h, while 100% is exposed to cyclones with wind speeds of 60–90 km/h.

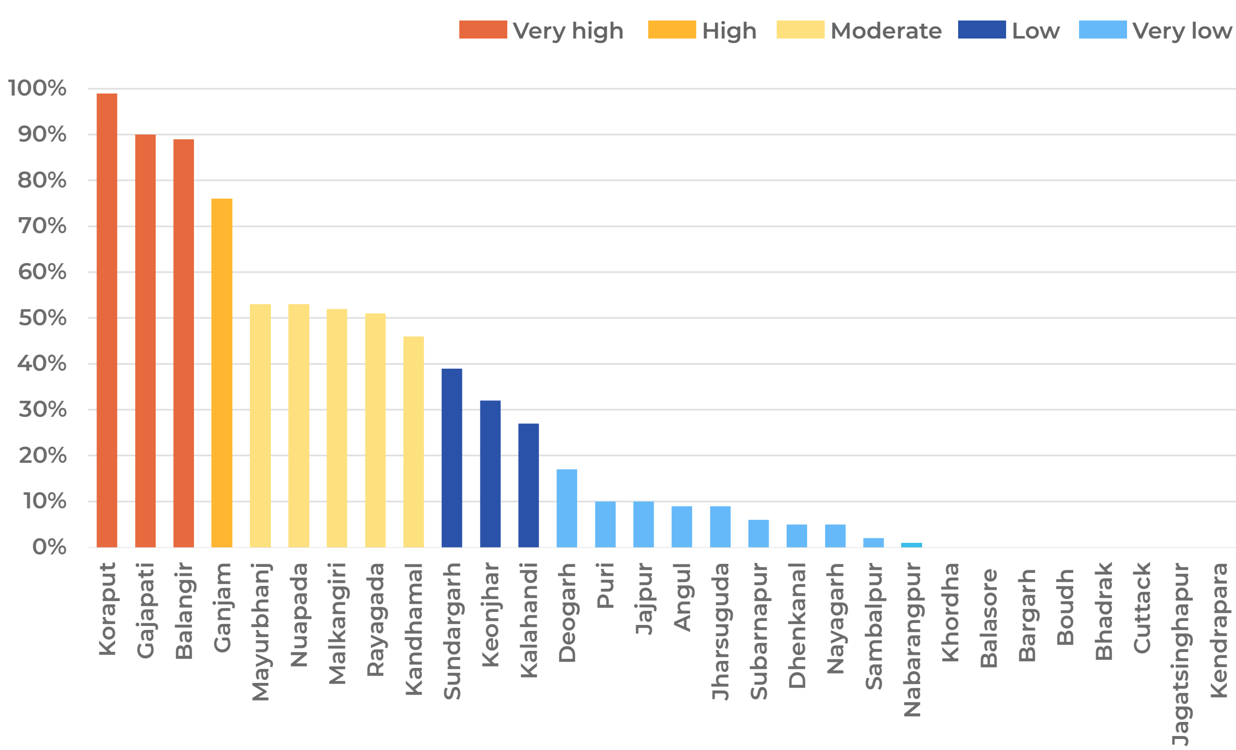


Figure 114: Exposure of rural roads and fuel points to drought

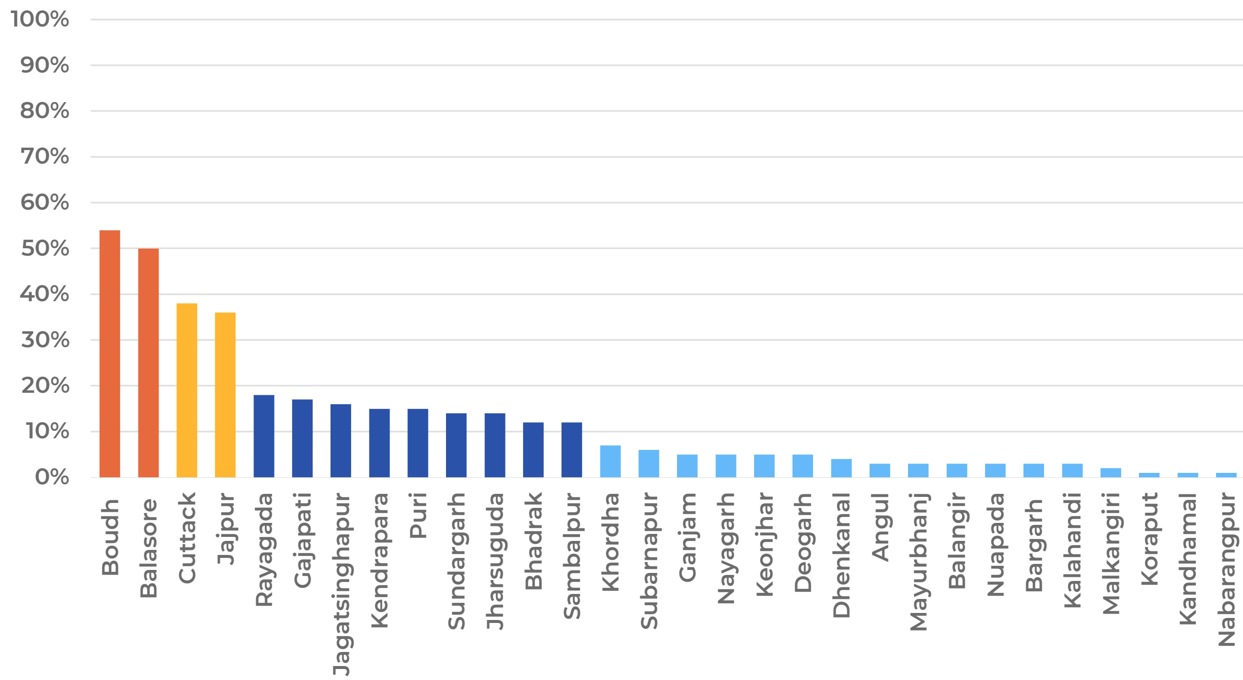


Figure 115: Exposure of rural roads and fuel points to floods

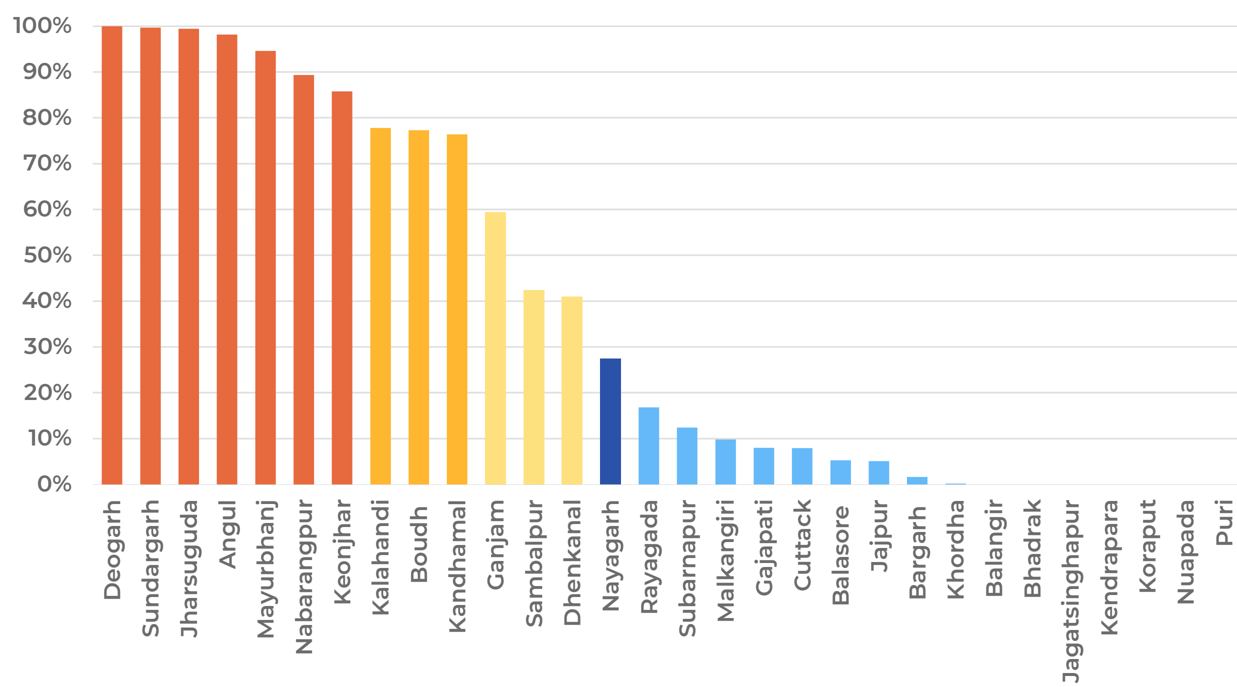


Figure 116: Exposure of rural roads and fuel points to heatwaves

6.2. Indicators for vulnerability assessment

This section presents the rationale, data sources, and functional relationships for each indicator used in the vulnerability assessment of agriculture, livestock and fisheries sub-sectors.

6.2.1. Vulnerability assessment indicators for agriculture sub-sector

Three primary indicators were selected to assess the vulnerability of the agricultural sector at the district level in Odisha. These indicators include:

1. **Dependence and sensitivity of the workforce on agriculture:** Measures the extent to which each district's workforce relies on agriculture and its susceptibility to climate impacts.
2. **Productivity and adaptive capacity of crop cultivation:** Focuses on the efficiency of crop production and the ability of agricultural systems to adapt to changing climate conditions.
3. **Adaptive capacity of farming communities:** Assesses the resilience of farming communities, including their access to resources and capacity to implement adaptive strategies.

To account for these broad indicators, a total of 19 standardised sub-indicators were selected, as listed in Table 9. These sub-indicators were normalised using either Equation 3 or Equation 4 to ensure comparability across different metrics. The normalised scores were then aggregated by calculating a simple arithmetic mean to derive an overall vulnerability score for each district.

Table 9: Rationale, functional relationship and data sources of indicators and sub-indicators selected for the agriculture sub-sector

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Dependence and sensitivity of the district's workforce on Agriculture	Agricultural workforce share	This metric captures the extent of the working population de-pendent on agriculture for their livelihoods, thereby reflecting socio-economic sensitivity.	Positive	Census 2011
	Percentage area under marginal and small land holdings	This indicator is crucial for understanding the distribution of land ownership, as small and marginal landowners often face additional challenges due to limited resources, which increases their socio-economic sensitivity.	Positive	Agriculture Census (2016)

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Dependence and sensitivity of the district's workforce on Agriculture	Percentage contribution of the agricultural sector to the total GDVA	The share of the agricultural sector in the total Gross District Value Added (GDVA) reflects the economic contribution of agriculture relative to other sectors. This share also influences the adaptive capacity of the agricultural population, as a higher dependence on agriculture may limit their ability to diversify income sources and adapt to external shocks.	Negative	Value of output report (2015-16), Advance estimates of GSDP (2022-23)
	Percentage area under horticulture trees (2023-24)	This indicator reflects the extent of agricultural diversification and economic reliance on high-value crops, which directly impacts income stability and the workforce's vulnerability to climate and market fluctuations. Furthermore, horticulture tree crops are hardier than field crops against extreme weather events and thus enhances the resilience of farmers.	Negative	Department of Agriculture Statistics, DA&FE, Odisha
Productivity and adaptive capacity of crop cultivation	Cropping intensity (ratio of gross cropped area to net sown area) (2023-24)	Cropping intensity measures the frequency of crop cycles per year, indicating how effectively land is utilised and the potential for overall productivity.	Negative	Department of Agriculture Statistics, DA&FE, Odisha
	Gross area irrigated	This ratio signifies the extent of irrigation area to the gross area of crops sown, highlighting the effectiveness of water management in supporting crop cultivation.	Negative	Computed using Odisha Agriculture Statistics, 2018
	Crop diversity index	A greater crop diversity enhances resilience against pests, diseases, and climate variability.	Negative	Computed using data provided for the year 2023-24 by the Department of Agriculture Statistics, DA&FE, Odisha

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Productivity and adaptive capacity of crop cultivation	Drainage density	Measures the extent of natural water management systems in agricultural areas. Efficient drainage helps prevent waterlogging and improves soil conditions.	Negative	Hydro river v.10.
	Stage of groundwater extraction	Directly reflects the sustainability of water resources essential for irrigation. High levels of groundwater extraction, especially in areas with poor water quality or lacking command infrastructure, can lead to resource depletion, reduced water availability, and lower productivity over time.	Negative	Dynamic groundwater resources of Odisha (2023)
	Variation in paddy crop yields (2019-24)	Consistent yields of the major crop (paddy) reflect effective farming practices and adaptive capacity, while significant variations may indicate sensitivity to climate variability, pest infestations, or resource constraints.	Positive	Department of Agriculture Statistics, DA&FE, Odisha
	Variation in soil moisture	Consistent soil moisture supports stable crop growth, while high variability may signal sensitivity to drought-like conditions or inefficient water use, impacting crop productivity.	Positive	MODIS (SMAP)
Adaptive capacity of farming communities	Area under Integrated Farming System (IFS) (2021-24)	Reflects the adoption of diversified and sustainable agricultural practices, reducing dependency on a single income source while enhancing resource efficiency.	Negative	Department of Agriculture Statistics, DA&FE, Odisha
	Krishi Vigyan Kendra (KVK) density	The number of KVKs per 1,000 hectares of net cropped area signifies the availability of agricultural extension services. KVKs provide critical support in knowledge dissemination, innovative practices, and farmer training.	Negative	ICAR, Department of Agriculture Statistics, DA&FE, Odisha

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Adaptive capacity of farming communities	Agri-market density	Calculated as the number of agriculture markets available per 1,000 hectares of net cropped area. This metric helps assess how market accessibility impacts farming communities. A higher density of Agri markets reduces transportation costs and possibly minimises post-harvest losses.	Negative	Department of Agriculture Statistics, DA&FE, Odisha
	Access to storage facilities	A higher number of storage facilities per 1,000 hectares of net cropped area reduces the risk of spoilage and loss, allowing farmers to better manage supply and market timing.	Negative	Department of Agriculture Statistics, DA&FE, Odisha
	Mechanisation	Farmers with access to mech-anised equipment and advanced irrigation systems experience increased efficiency and pro-ductivity, enable timely sowing and harvesting, and benefit from reduced labour intensity and minimised operational delays.	Negative	Census 2011, Department of Agriculture Statistics, DA&FE, Odisha
	Road density	Higher road density facilitates easier access to markets, inputs, and services, reducing transportation costs and enhancing the efficiency of agricultural operations.	Negative	Open Street Map
	Insured farmers	Indicates the financial protection and ability to manage risks, which enhances the adaptive capacity of farmers. Higher insurance coverage supports quicker recovery and investment in adaptation measures.	Negative	SDG data (2016-24)
	Percentage of operational holdings with soil health card	A higher percentage of farmers issued with soil health cards enhances their ability to manage soil fertility and optimise crop yields, reducing risks associated with soil degradation and poor agricultural practices.	Negative	SDG data (2015-22)

6.2.2. Vulnerability assessment indicators for livestock sub-sector

Four primary indicators were selected to assess the vulnerability of the livestock sector at the state level in Odisha. These indicators include:

1. **Dependence on and sensitivity of livestock:** Evaluates the degree to which livestock contributes to livelihoods in each district and the sector's sensitivity to climate impacts.

2. **Adaptive capacity of livestock production:** Assesses the efficiency and flexibility of livestock production systems in responding to climate risks and changing conditions.

3. **Access to health care:** Focuses on the availability and quality of veterinary services, which are essential for maintaining livestock health and resilience under climate stress.

4. **Post-production support for livestock-dependent households:** Measures the support available for households reliant on livestock, including access to processing and marketing resources, which are crucial for ensuring economic resilience.

To account for these broad indicators, a total of 11 standardised sub-indicators were selected, as listed in Table 10.

Table 10: Rationale, functional relationship and data sources of indicators and sub-indicators selected for the livestock sub-sector

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Dependence on and sensitivity of livestock	Livestock to agriculture working population	A higher ratio indicates a greater reliance on livestock as a diversified source of income, which enhances the adaptive capacity of farmers.	Negative	Livestock Census (2019), SECC (2011)
	Percentage share of livestock sector to the GDVA	A higher share signifies the sector's significant contribution to the district's economy, reflecting a greater reliance on livestock for economic output.	Negative	Value of output report (2015-16), Advance estimates of GSDP (2022-23)
	Livestock yield variation (2019-22)	This variation reflects sensitivity to factors such as disease, climate conditions, and feed availability, emphasising the need for effective management and adaptation strategies to stabilise yields and support the resilience of livestock-dependent livelihoods.	Positive	Statistical abstract of Odisha- 2023

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Adaptive capacity of livestock production	Proportion of Indigenous cattle population	A higher indigenous cattle population enhances the adaptive capacity of livestock production by leveraging breeds that are often better suited to local environmental conditions and resilient to regional diseases.	Negative	Livestock census (2019)
	Percentage of pasture area (2021-22)	A higher percentage of pasture area supports the adaptive capacity of livestock production by providing adequate grazing resources, which improves livestock health and productivity.	Negative	Statistical abstract 2023
Access to healthcare	Veterinary hospitals per 1,000 livestock population	A higher number of veterinary hospitals improve livestock healthcare by offering essential services and treatment, enhancing health management and strengthening community resilience.	Negative	Statistical abstract 2023
	ICDP/ Insemination centres per 1,000 livestock population	ICDP/Insemination Centres improve livestock productivity by providing essential breeding services and support, that can enhance genetic quality and reproductive success.	Negative	Statistical abstract 2023
	Veterinary doctors and livestock inspectors per 1,000 livestock population	A higher number of veterinary doctors and livestock inspectors enhances livestock health management by providing timely medical care and routine inspections. This improves disease control, supports better animal welfare.	Negative	Statistical abstract 2023
	Livestock aid centres (LACs) per 1,000 livestock population	livestock aid centres (LACs) provide additional access to essential support services, including emergency care, feed distribution, and disease management.	Negative	Statistical abstract 2023

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Post-production support for livestock dependent households	Co-operative Societies and SHGs in the Dairy Sector per 1,000 female bovine population	A higher number enhances post-production support by facilitating collective marketing, processing, and resource sharing.	Negative	Directorate of Animal Husbandry & Veterinary Services and Statistical abstract 2023
	Capacity of dairy processing/ chilling units	Improves post-production support by enhancing the ability to process and store dairy products efficiently. This reduces spoilage, extends shelf life, and ensures better market access, thus stabilising incomes and supporting the resilience of dairy-dependent households.	Negative	Directorate of Animal Husbandry & Veterinary Services

6.2.3. Vulnerability assessment indicators for fisheries sub-sector

Five primary indicators were selected to assess the vulnerability of the fisheries sector at the district level in Odisha. These indicators include:

1. **Dependence on and sensitivity of fishing communities:** Evaluates how heavily fishing communities rely on fisheries for their livelihoods and their vulnerability to climate impacts.

2. **Fish productivity:** Assesses the efficiency of fish production, which can directly affect the availability of fish stocks.

3. **Production and post-production support for fishing communities:** Focuses on the resources and infrastructure available for fish processing, storage, and marketing, which are crucial for maintaining livelihoods in the sector.

4. **Adaptive capacity of fisherfolk:** Measures the ability of fisherfolk to adjust to climate risks, highlighting their access to resources and capacity for resilience.

5. **Quality of life:** Evaluates the overall living standards of fishing communities, including access to basic services and infrastructure, which are important for long-term resilience and well-being.

To account for these broad indicators, a total of 15 standardised sub-indicators were selected, as listed in Table 11.

Table 11: Rationale, functional relationship and data sources of indicators and sub-indicators selected for the fisheries sub-sector

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Dependence on and sensitivity of fishing communities	Fisher folk to the total population	A higher ratio indicates a greater reliance on fishing for livelihoods, highlighting the significant dependence of the community on this sector.	Positive	Directorate of Fisheries, Indiastat Districts, 2011
	Percentage of women involved in fishing activities	Fishing communities often exhibit a distinct gendered division of labour, where women typically play key roles in post-harvest activities such as fish processing, marketing, and net mending. The degree of participation of women reflects the community's reliance on women's labour for economic sustenance.	Negative	Odisha Marine Fisheries Census (2016)
	Percentage share of GDVA from fisheries sector	A higher share reflects the economic contribution of fisheries sector relative to other sectors.	Negative	Value of output report (2015-16), Advance estimates of GSDP (2022-23)
	Mangrove coverage	Higher mangrove coverage enhances the resilience of coastal and fishing communities by providing critical ecosystem services such as coastal protection, habitat for marine life, and support for fisheries.	Negative	Global Mangrove Watch, 2022
Fish productivity	Variation in marine fish production	A high variation indicates fluctuations in fish availability and catch volumes, impacting the stability of livelihoods dependent on fishing.	Positive	Directorate of Fisheries, Statistical abstract 2023
Production and post-production support for fishing communities	Number of members in working fishermen co-operative societies	This strengthens the capacity of fishing communities to access resources, improve efficiency, and stabilise incomes, thereby supporting overall resilience.	Negative	Odisha Marine Fisheries Census (2016)

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Production and post-production support for fishing communities	Percentage of fisherfolk owning a fishing craft	This ownership supports better production capabilities and stability in the sector, enhancing the overall resilience and economic security of fishing communities.	Negative	Odisha Marine Fisheries Census (2016)
	Percentage of fisherfolk having access to motorised fishing vessels	Enhances fisherfolk's ability to reach fishing grounds more efficiently and transport their catch to markets in a timely manner. This improves operational efficiency, reduces time and costs, and supports greater economic stability.	Negative	
	Fishing harbours / fish landing centres per 1,000 MT of fish catch	A higher number enhances operational efficiency, reduces post-harvest losses, and supports the economic stability and resilience of fishing communities.	Negative	Directorate of Fisheries
	Freeze storage facility per 1,000 MT of fish catch	Higher freeze storage capacity facilities improve the ability to store fish products for longer periods, reducing spoilage and maintaining quality.	Negative	Odisha Marine Fisheries census (2016)
Adaptive capacity of fisherfolk	Coverage of life-saving equipment	This increased access to safety gear supports better preparedness and resilience in adverse conditions.	Negative	
	Involvement in aquaculture	Higher involvement in aquaculture enhances the adaptive capacity of fisherfolk by diversifying income sources and reducing reliance on wild fish stocks.	Negative	

Indicator	Sub-Indicator	Rationale	Functional Relationship	Data Sources
Quality of life of fisherfolk	Access to basic amenities	Improves the quality of life by ensuring essential services such as clean water, sanitation, and healthcare are available.	Negative	Odisha Marine Fisheries census (2016)
	Literacy rate of fisherfolk	Enhances the access to information, education, and opportunities for skill development.	Negative	
	Percentage of fisherfolk households with pucca houses	Higher number of pucca houses improves the quality of life by providing durable and safe housing, which enhances living conditions and protection from environmental hazards.	Negative	

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Women with pots, full of fish and crab, on their heads, on a beach in Puri, Odisha.

. RCH Photo

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