

Climate & Child Malnutrition

Trends & interlinkages in Maharashtra

Outline

- Study Objectives
- Study Design
- Data Extraction & Preprocessing
- Insights
 - Reporting of Malnutrition Indicators in Maharashtra
 - Time-series & Geo-spatial trends in Malnutrition
 - Malnutrition Clusters & Hotspots
 - Time-series & Geo-spatial trends in Heat
 - Heat Clusters & Hotspots
 - Association between Climate & Malnutrition
- Next Steps:
 - Exploring associations with service delivery

Study Objectives

- To understand trend, seasonality patterns in temperature and child malnutrition across the state
- To cluster blocks based on malnutrition & heat characteristics
- To identify hotspots for malnutrition & heat
- To understand state & block-level interlinkages (if any) between heat and child malnutrition

Study Design

- Methodology:
 - Time-series & Geo-spatial analysis of climate & malnutrition indicators
 - Bi-variate analysis of climate & malnutrition indicators
 - Clustering (K-NN & Percentile-based) of blocks based on climate & malnutrition indicators
 - Identification of malnutrition hotspots & their climate characteristics using Gi* & LISA
- Datasets:
 - Maharashtra POSHAN Tracker (Line lists)
 - Climate data from open-meteo.com

Malnutrition Indicators: SAM, MAM, Underweight
Climate Variables: Temperature, Rainfall, Standard Indices

Spatial Coverage: Maharashtra
Spatial Resolution: Block

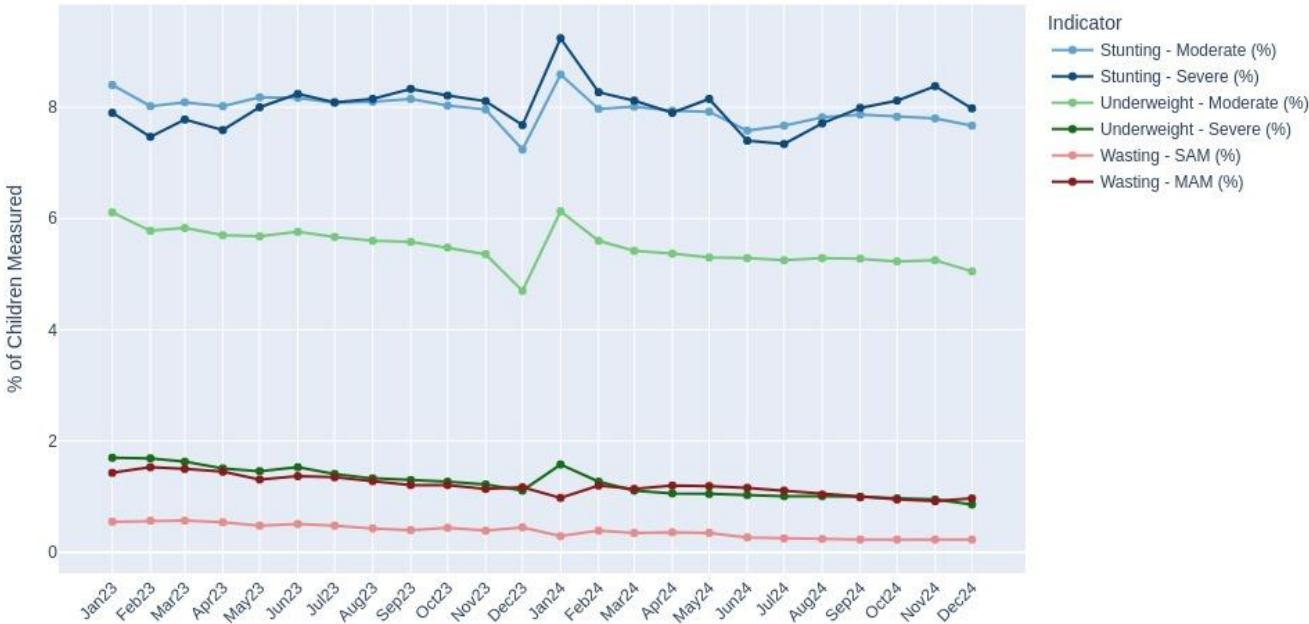
Temporal Coverage: Jan 2023-Dec 2024
Temporal Resolution: Day, Month-Year

Data Extraction & Pre-processing

- Maharashtra POSHAN data:
 - Raw data was available at the child-level
 - Mapped project IDs to blocks*
 - Aggregated indicators (sum) at the block-level
- Climate data:
 - Extracted hourly/daily resolution from open-meteo.com commercial API
 - Computed climate indices for rainfall, drought & heat waves
 - Aggregated to “month-year” resolution
- Shapefile:
 - Women & Child Development Department, Government of Maharashtra

Malnutrition trends in Maharashtra

Malnutrition Time-Series Trend, Maharashtra (Jan 2023 – Dec 2024)

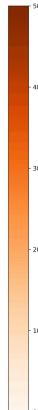
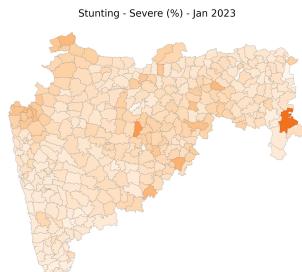
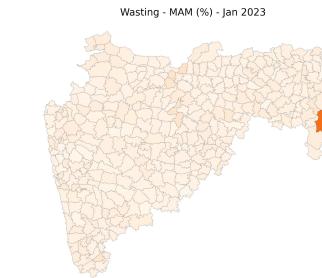
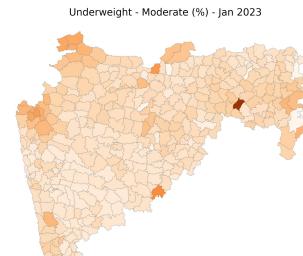
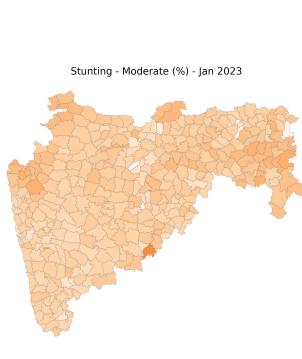


*Data Source: Growth Monitoring line lists, POSHAN API

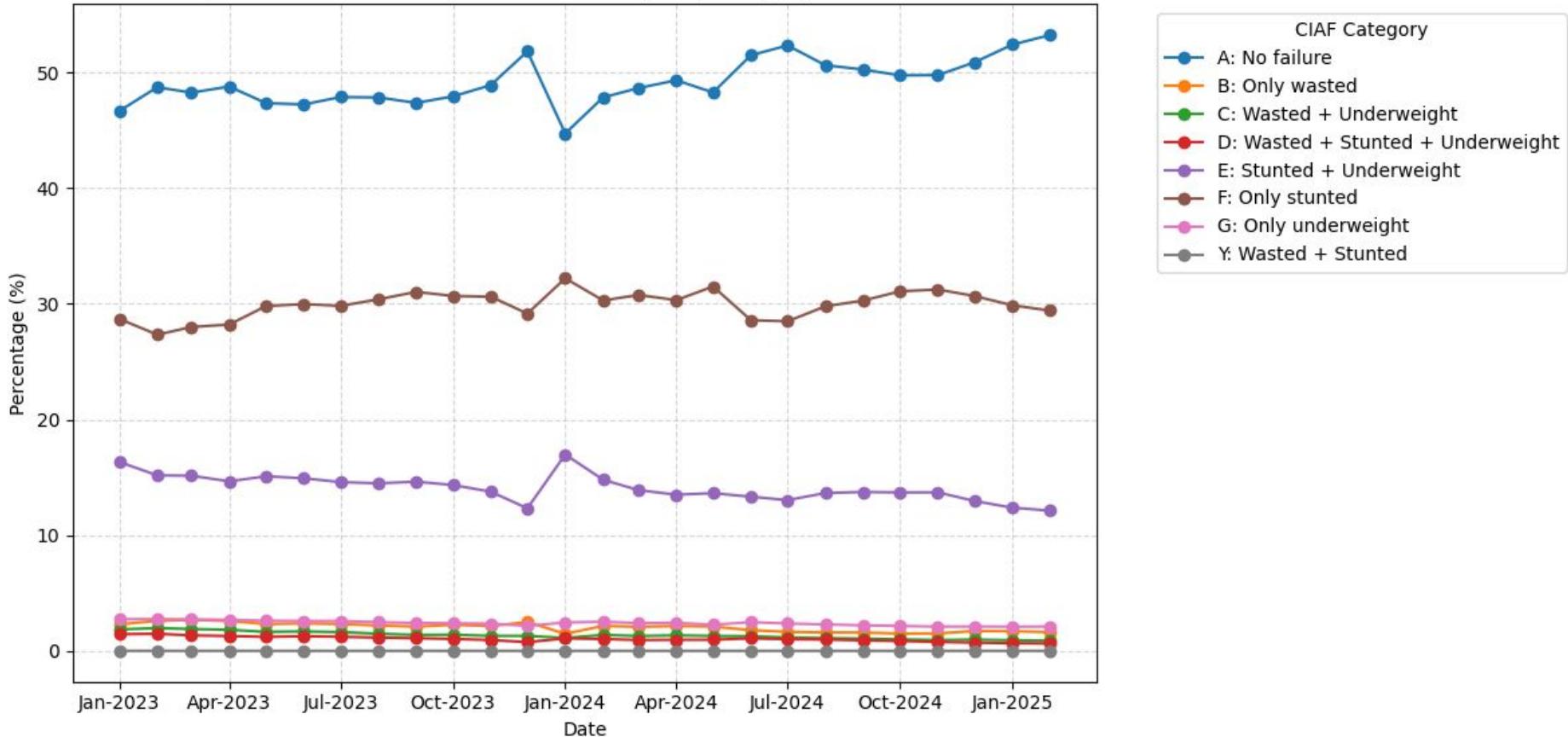
- Discrepancy in child-level data (POSHAN API) & summaries (POSHAN Dashboard)
- **Stunting** (16% vs 46% PD)
Moderate: **7.67%** (↓ 0.73%)
Severe: **7.98%** (↑ 0.08%)
- **Underweight** (6% vs 15% PD)
Moderate: **5.05%** (↓ 1.06%)
Severe: **0.86%** (↓ 0.84%)
- **Wasting** (1.2% vs 4% PD)
SAM: **0.23%** (↓ 0.32%)
MAM: **0.97%** (↓ 0.46%)

Potential under-reporting of SAM: 30% of the cases are reported by just 0.04% of blocks

Spatial and Temporal Patterns of Malnutrition (Jan 2023 - Dec 2024)

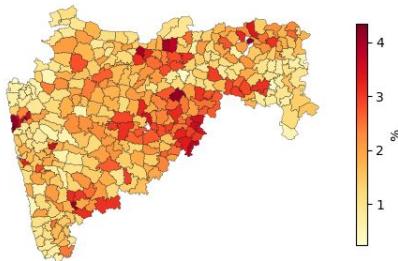


Composite Index of Anthropometric Failure (CIAF) Category Trends Over Time

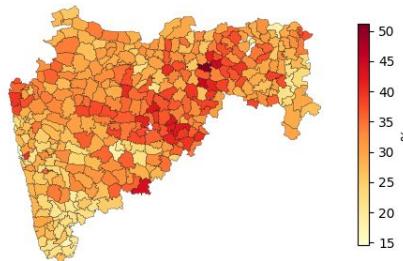


Composite Index of Anthropometric Failure (CIAF) Categories (% of Measured Children) by Block (Jan 2023 -Feb 2025)

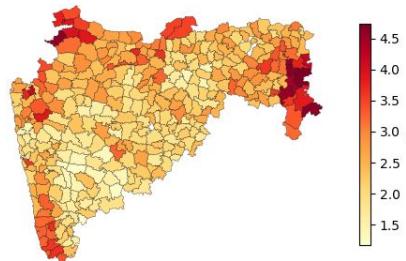
B: Only wasted
Mean: 1.8%



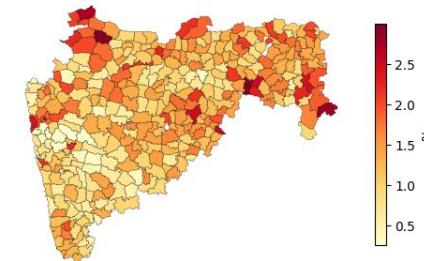
F: Only stunted
Mean: 30.7%



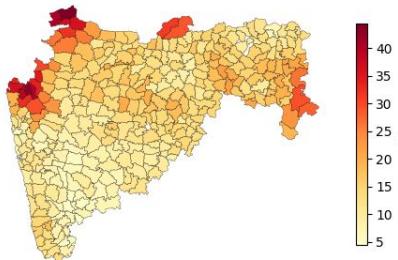
G: Only underweight
Mean: 2.4%



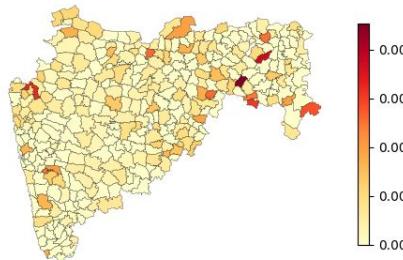
C: Wasted + Underweight
Mean: 1.3%



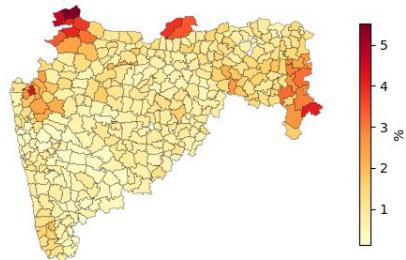
E: Stunted + Underweight
Mean: 14.0%



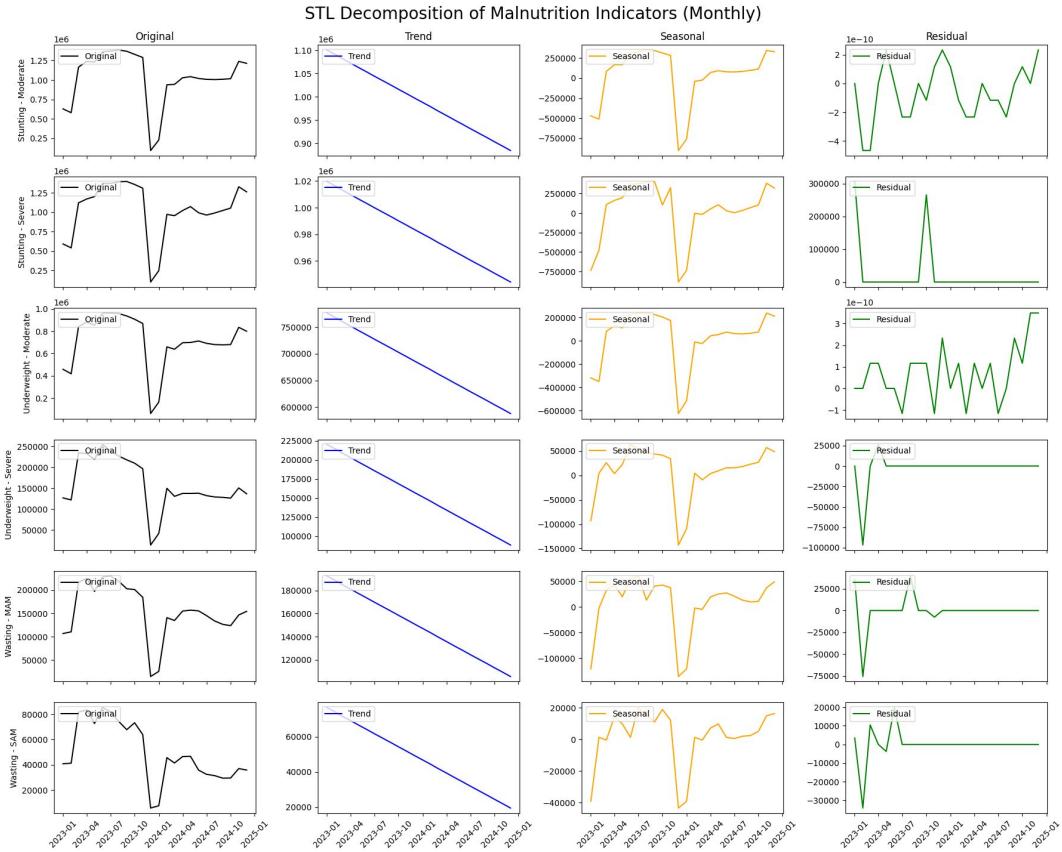
Y: Wasted + Stunted
Mean: 0.0%



D: Wasted + Stunted + Underweight
Mean: 1.0%

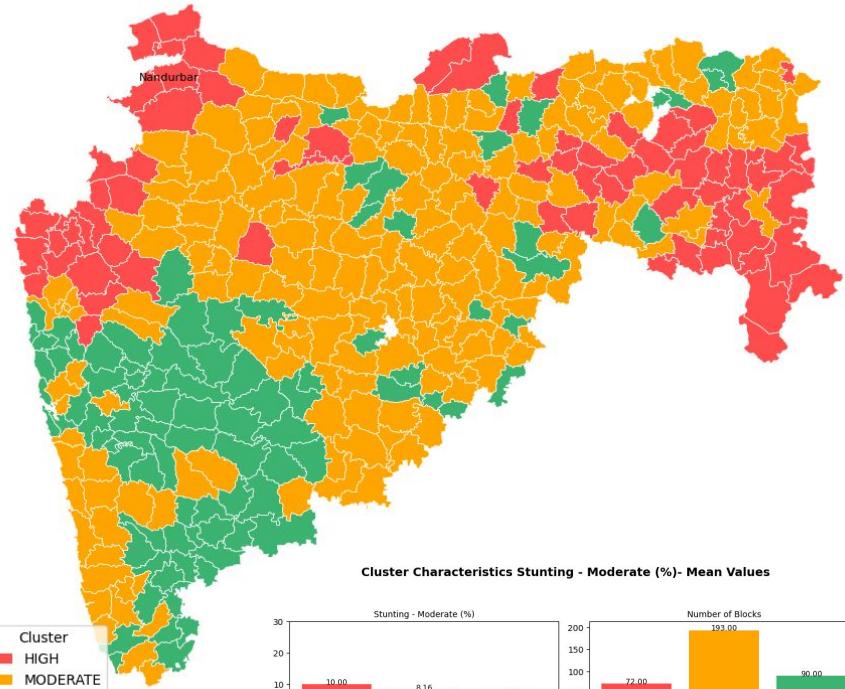
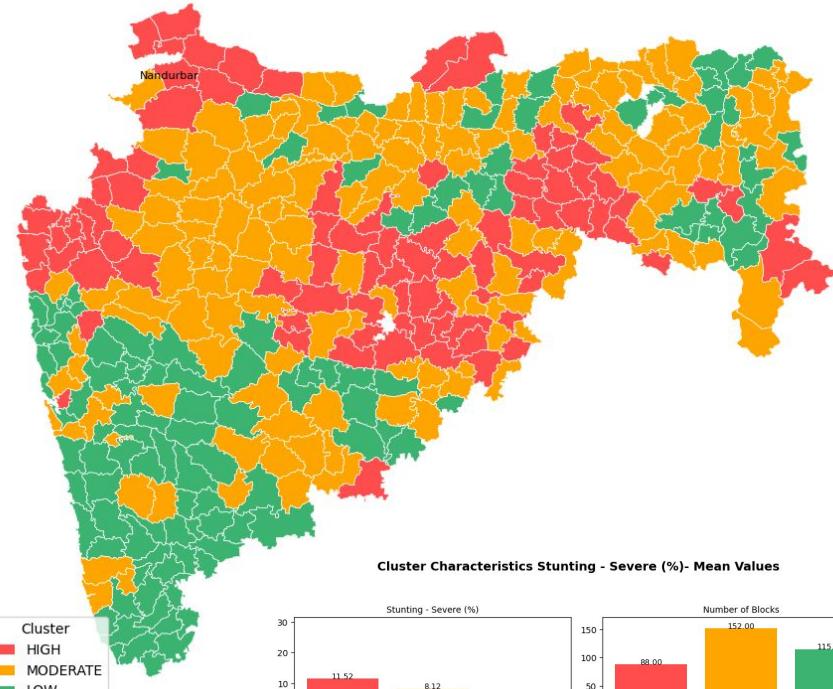


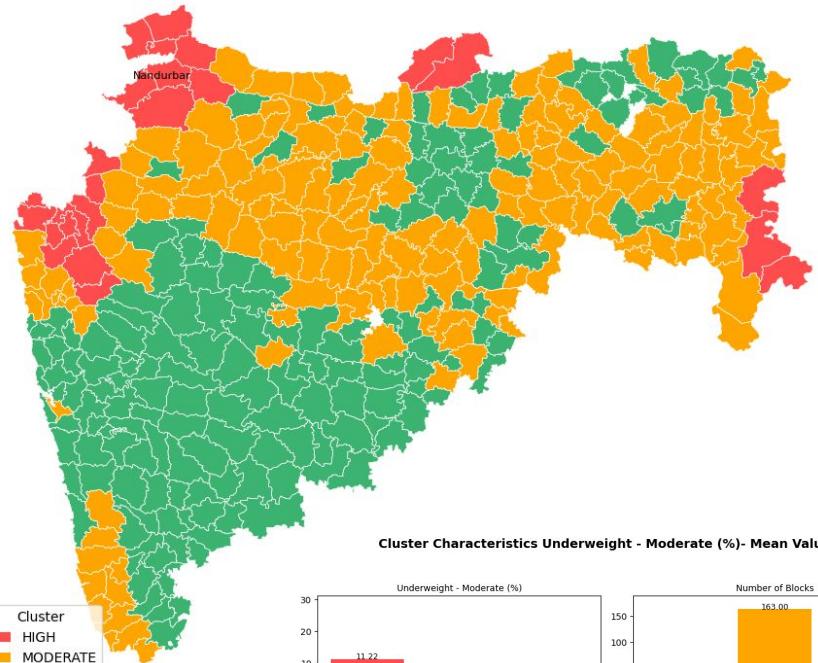
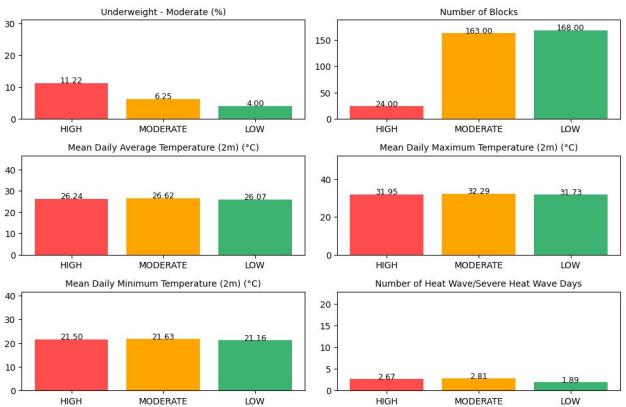
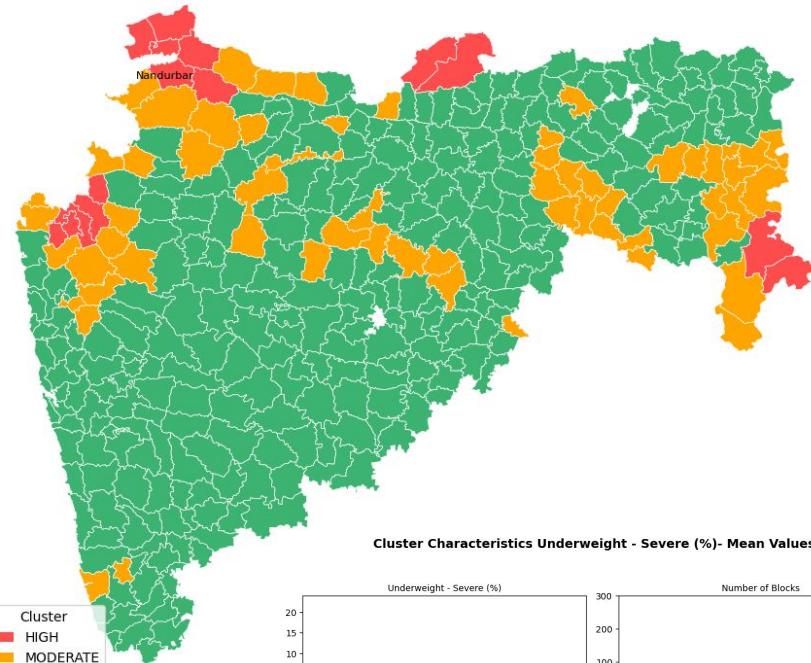
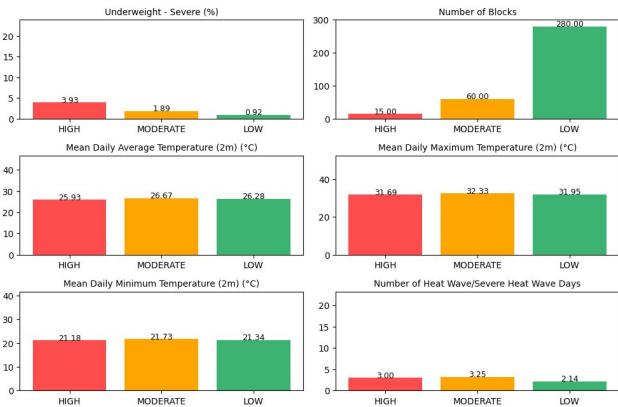
LOESS Seasonality-Trend Decomposition - Malnutrition



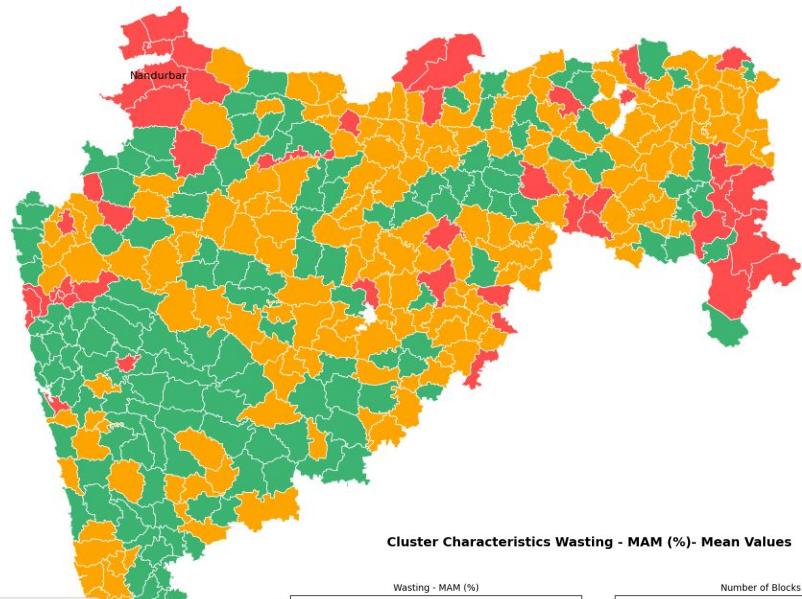
- Column 1 shows the actual number of cases by month.
- Column 2 shows the overall trend.
- Column 3 shows seasonal deviation. Drop is due to under-reporting (workers' strike).
- Column 4 shows the residuals. There is more noise (variance) in cases in 2023, and for indicators Underweight - Moderate, Stunting - Moderate.

Malnutrition Clusters (K-Means By Block, Malnutrition Indicator)

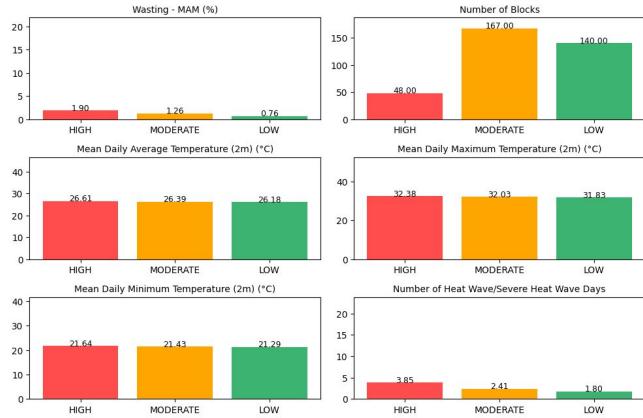
Cluster Map - Stunting - Moderate (%)**Cluster Map - Stunting - Severe (%)**

Cluster Map - Underweight - Moderate (%)**Cluster Characteristics Underweight - Moderate (%) - Mean Values****Cluster Map - Underweight - Severe (%)****Cluster Characteristics Underweight - Severe (%) - Mean Values**

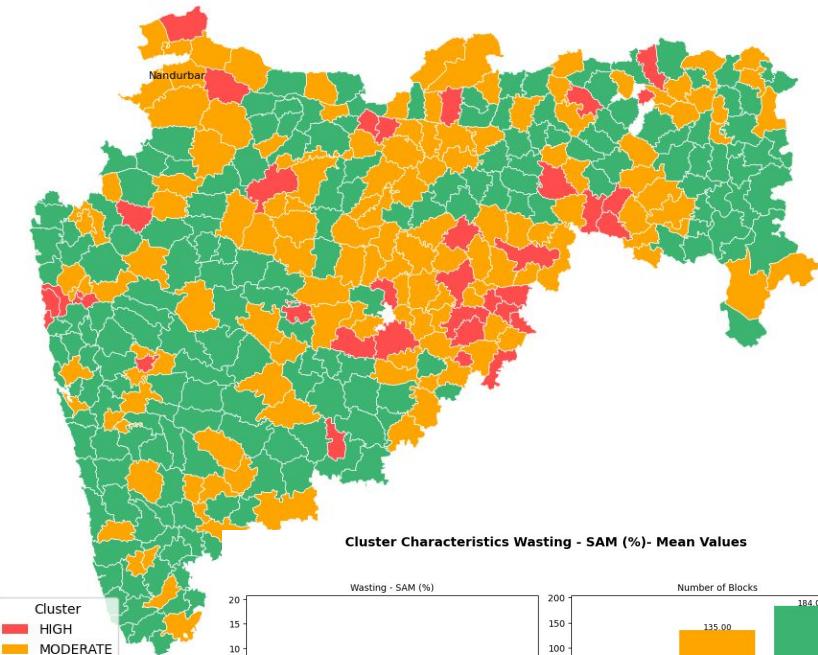
Cluster Map - Wasting - Mam (%)



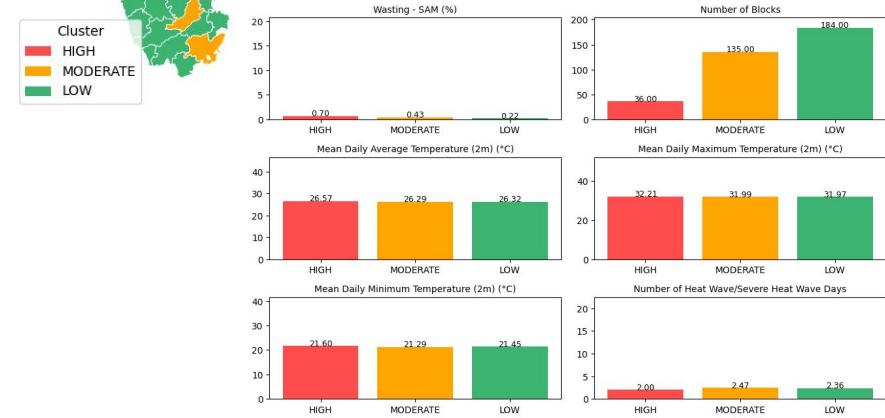
Cluster Characteristics Wasting - MAM (%) - Mean Values



Cluster Map - Wasting - Sam (%)

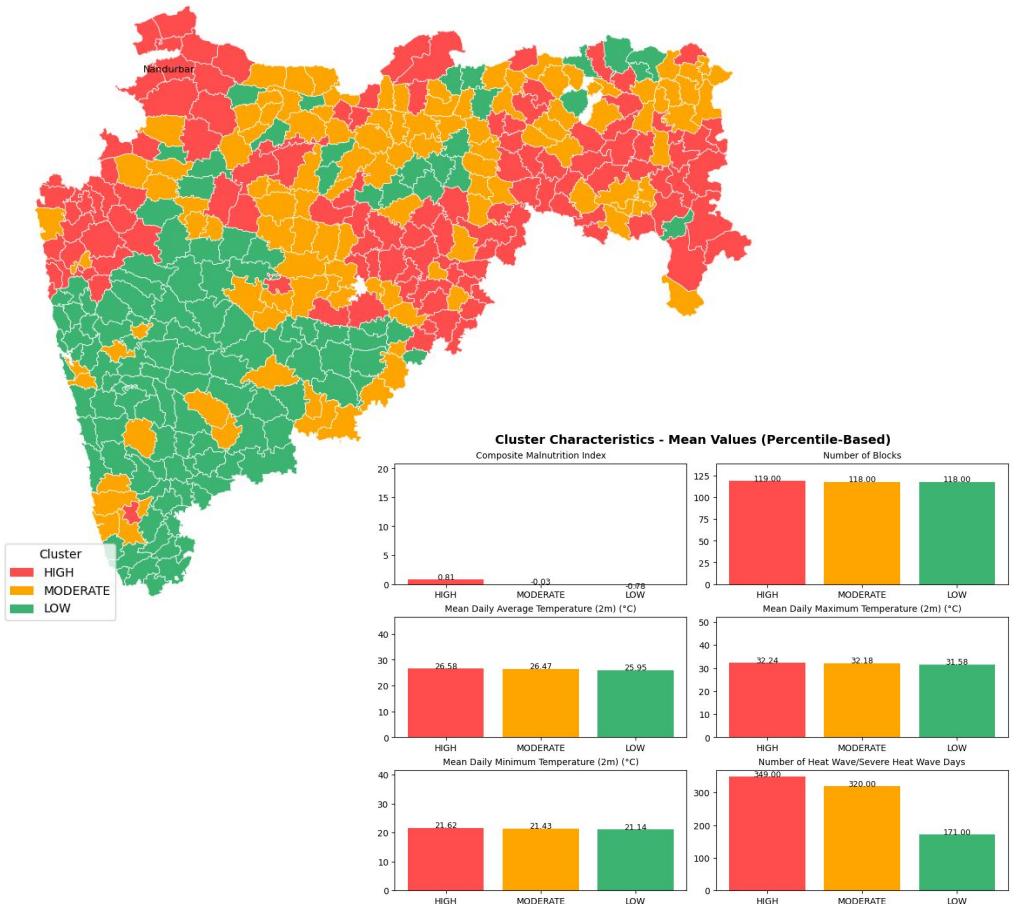


Cluster Characteristics Wasting - SAM (%) - Mean Values



Composite Malnutrition Clusters

Composite Malnutrition Index - Percentile Clustering

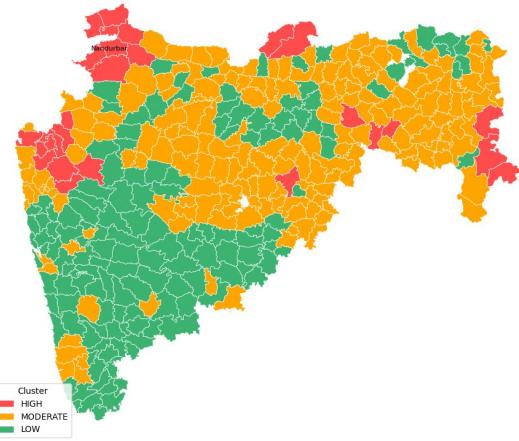


- The index is created by normalizing absolute malnutrition indicators, and calculate mean of standardized indicators.

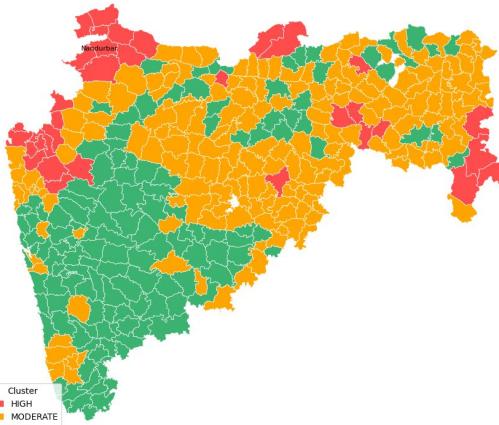
Seasonal Clusters

Cluster patterns remain consistent across seasons

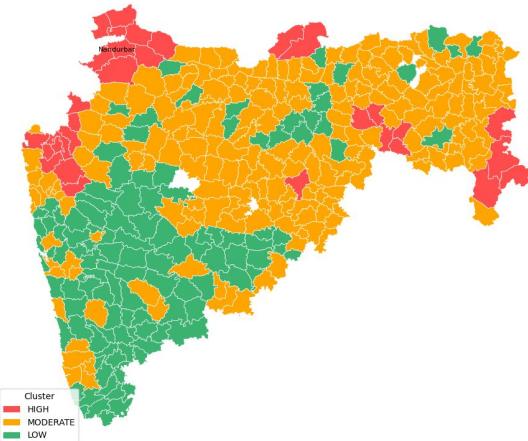
Composite Malnutrition Index - Winter (Nov-Feb)



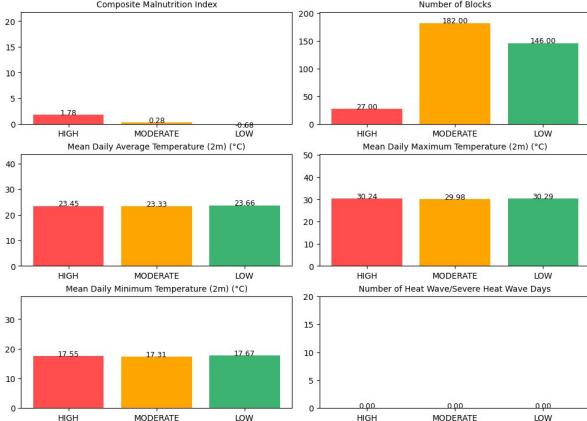
Composite Malnutrition Index - Summer (Mar-Jun)



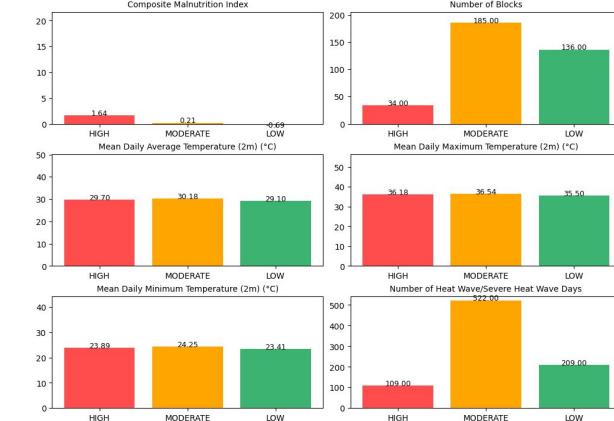
Composite Malnutrition Index - Monsoon (Jul-Oct)



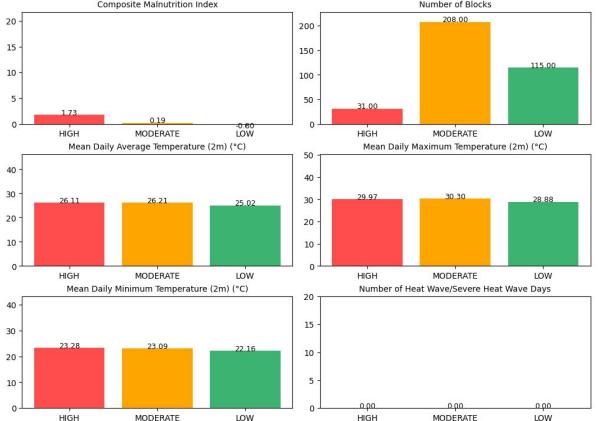
Cluster Characteristics - Winter (Nov-Feb) - Mean Values



Cluster Characteristics - Summer (Mar-Jun) - Mean Values



Cluster Characteristics - Monsoon (Jul-Oct) - Mean Values

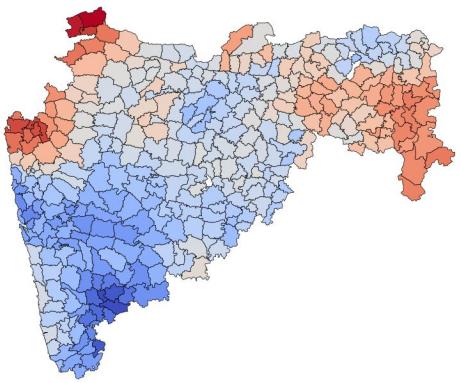


Malnutrition Hotspots

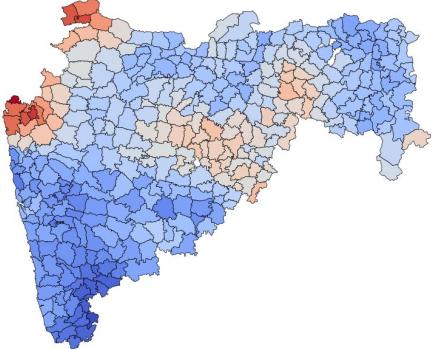
Getis-Ord Gi* & LISA Uni-variate Spatial Autoregression

- Gi* identifies statistically significant hotspots and coldspots relative to surrounding blocks.
- LISA (Local Moran's I) not only identifies clusters but also whether they are High-High (HH), Low-Low (LL), High-Low (HL), or Low-High (LH) – indicating spatial outliers
- LISA identifies spatial **clusters** & spatial **outliers**
 - High-High (HH): High, surrounded by High
 - Low-Low (LL): Low, surrounded by Low
 - High-Low (HL): High, surrounded by Low
 - Low-High (LH): Low, surrounded by High

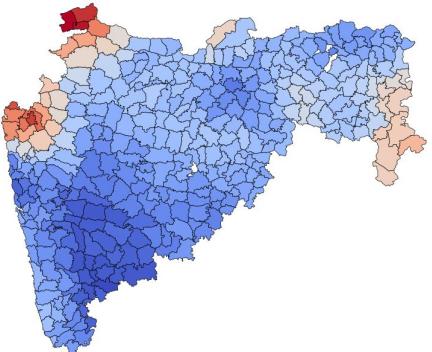
Gi* Hotspot Analysis - Stunting - Moderate (%)



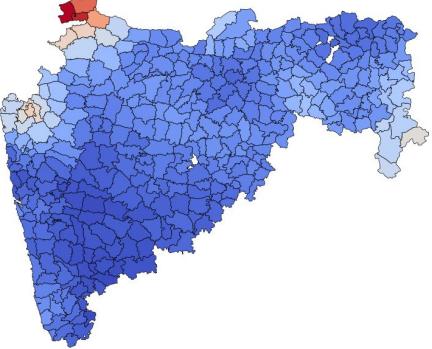
Gi* Hotspot Analysis - Stunting - Severe (%)



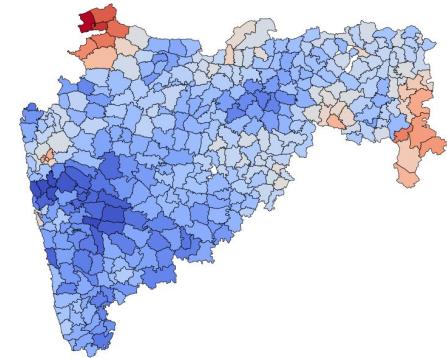
Gi* Hotspot Analysis - Underweight - Moderate (%)



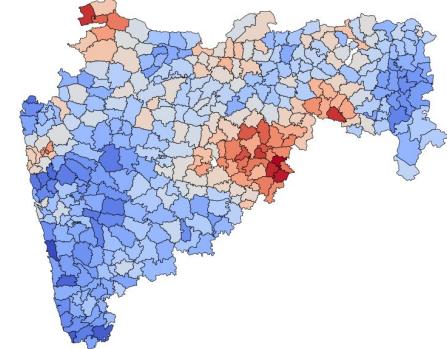
Gi* Hotspot Analysis - Underweight - Severe (%)



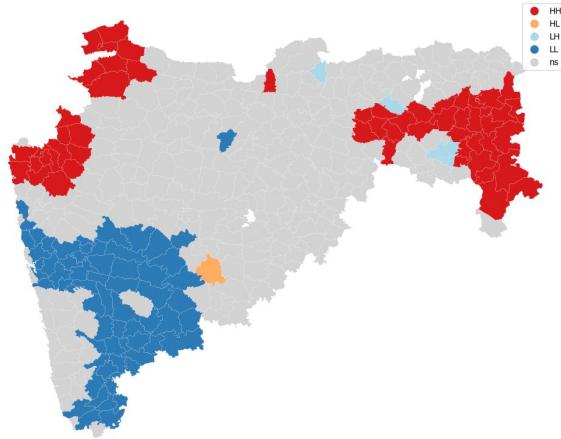
Gi* Hotspot Analysis - Wasting - MAM (%)



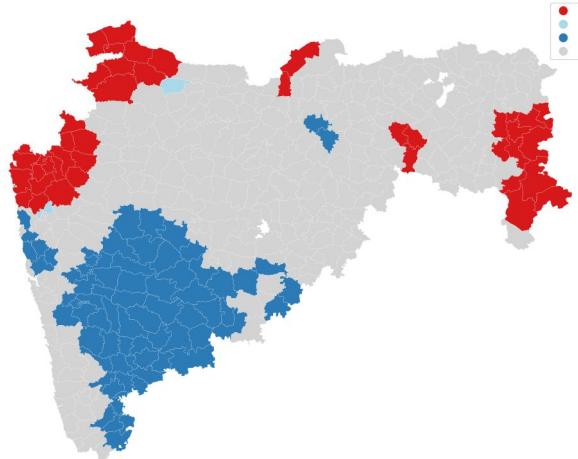
Gi* Hotspot Analysis - Wasting - SAM (%)



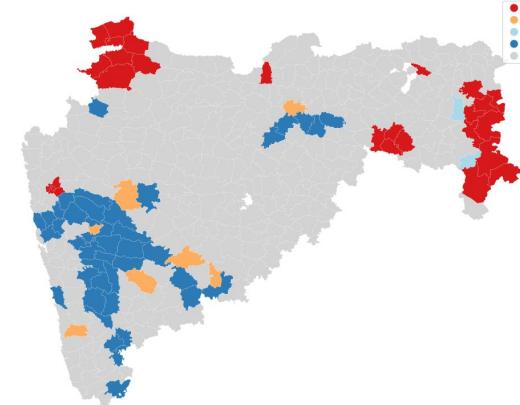
LISA Cluster Map - Stunting - Moderate (%)



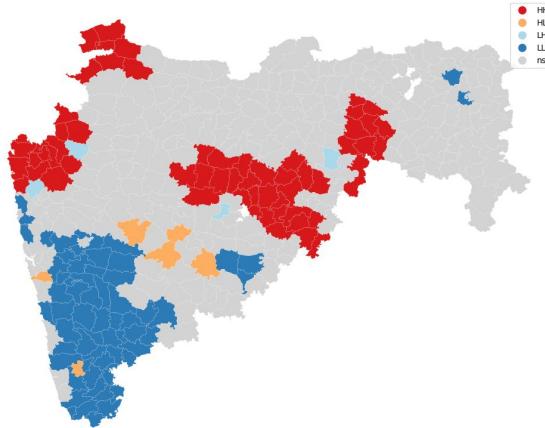
LISA Cluster Map - Underweight - Moderate (%)



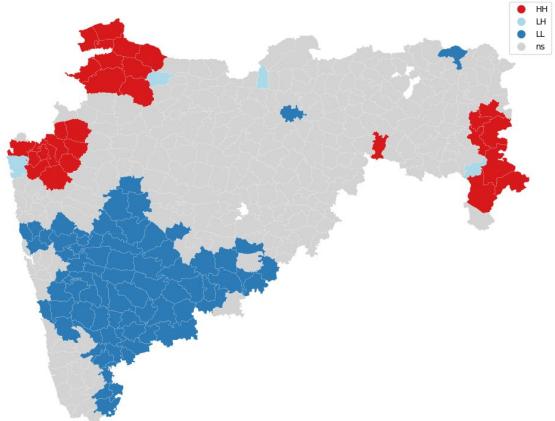
LISA Cluster Map - Wasting - MAM (%)



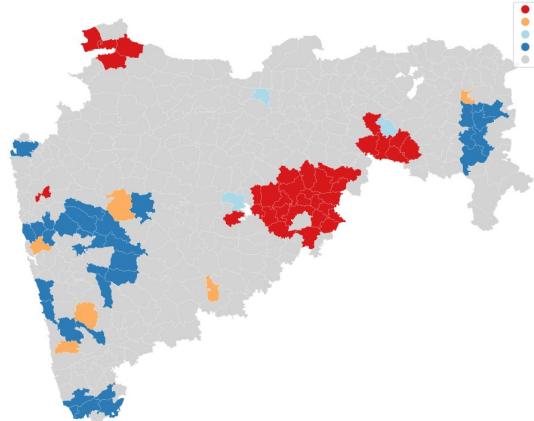
LISA Cluster Map - Stunting - Severe (%)



LISA Cluster Map - Underweight - Severe (%)

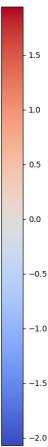
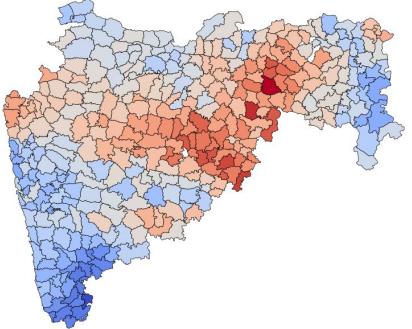


LISA Cluster Map - Wasting - SAM (%)

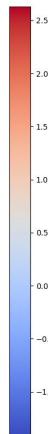
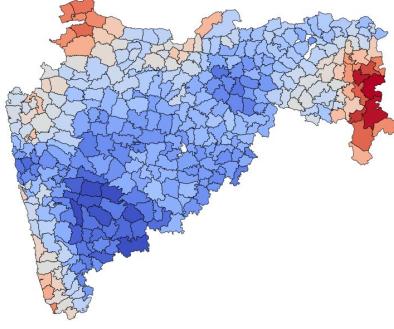


CIAF - Single Malnutrition - Hotspots

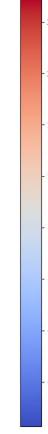
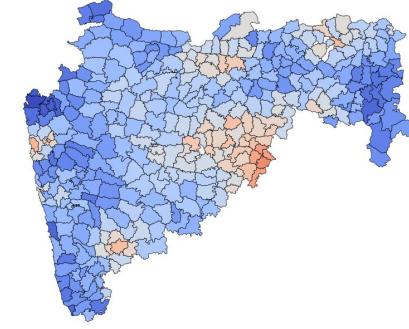
Gi* Hotspot Analysis - F: Only stunted



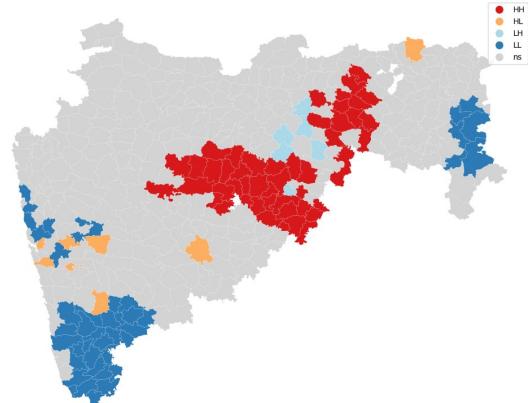
Gi* Hotspot Analysis - G: Only underweight



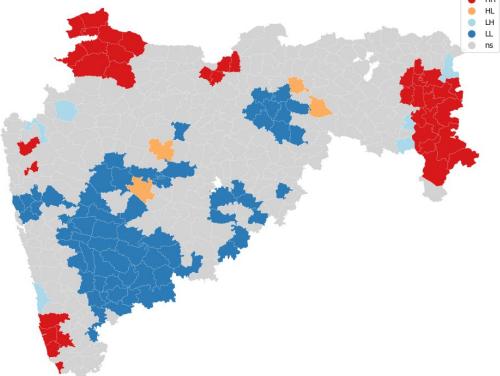
Gi* Hotspot Analysis - B: Only wasted



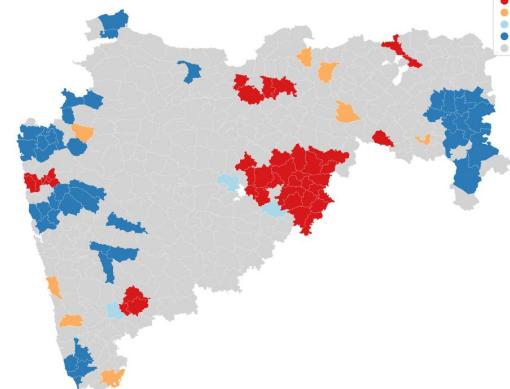
LISA Cluster Map - F: Only stunted



LISA Cluster Map - G: Only underweight

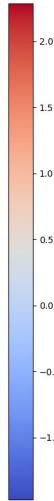
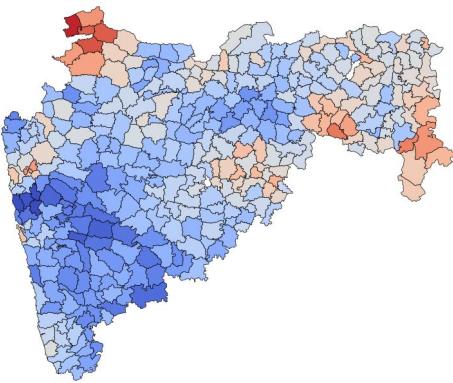


LISA Cluster Map - B: Only wasted

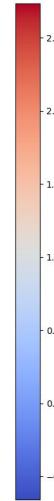
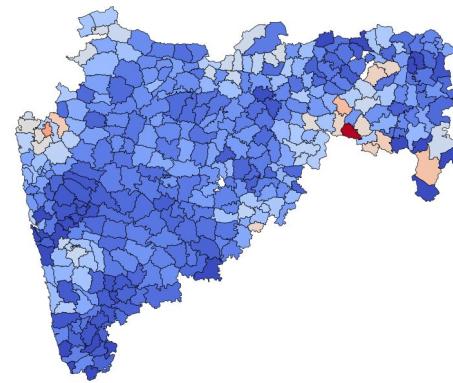


CIAF - Compound Malnutrition - Hotspots

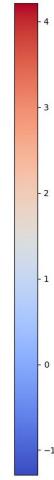
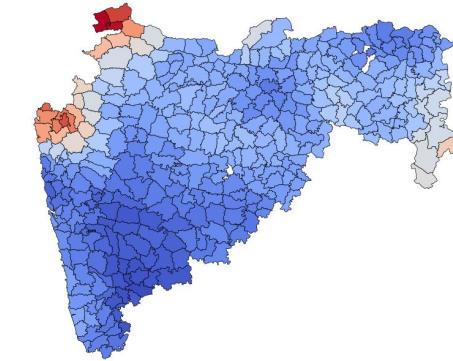
Gi* Hotspot Analysis - C: Wasted + Underweight



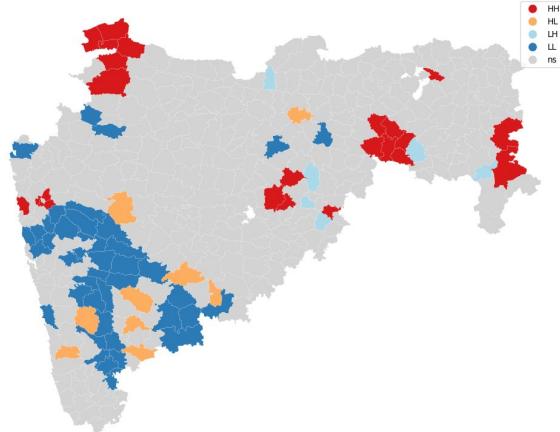
Gi* Hotspot Analysis - Y: Wasted + Stunted



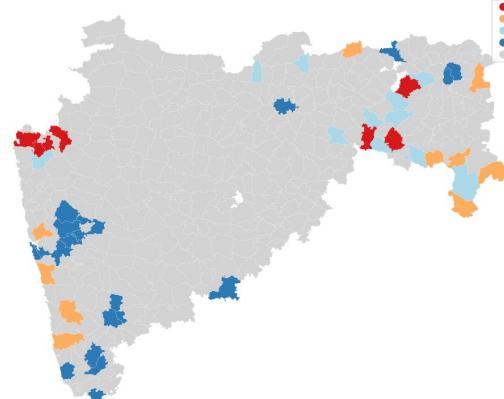
Gi* Hotspot Analysis - E: Stunted + Underweight



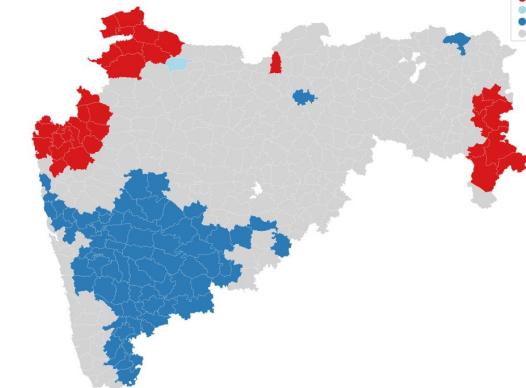
LISA Cluster Map - C: Wasted + Underweight



LISA Cluster Map - Y: Wasted + Stunted

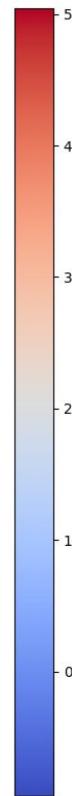
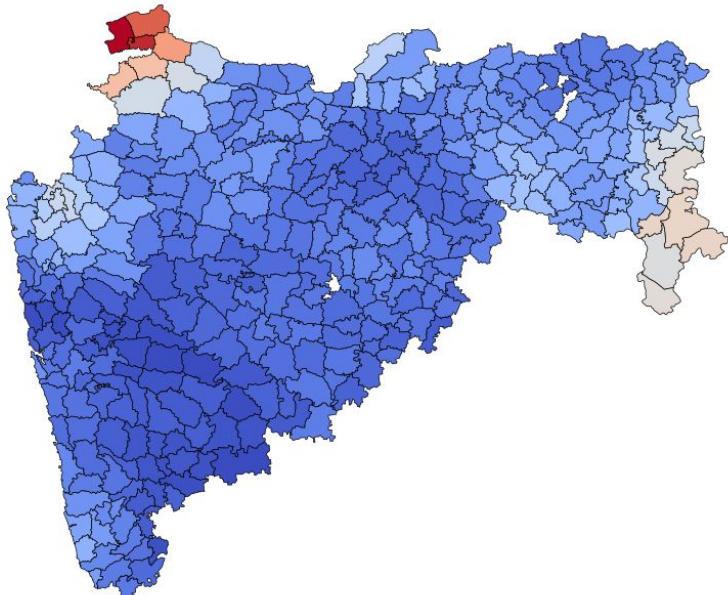


LISA Cluster Map - E: Stunted + Underweight

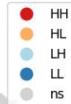
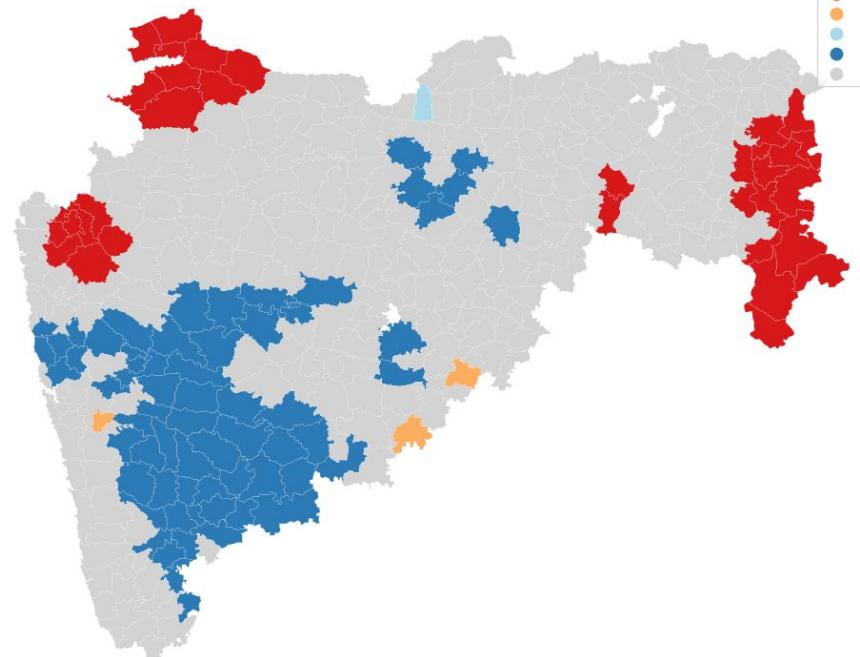


CIAF - Triple Malnutrition - Hotspots

Gi* Hotspot Analysis - D: Wasted + Stunted + Underweight

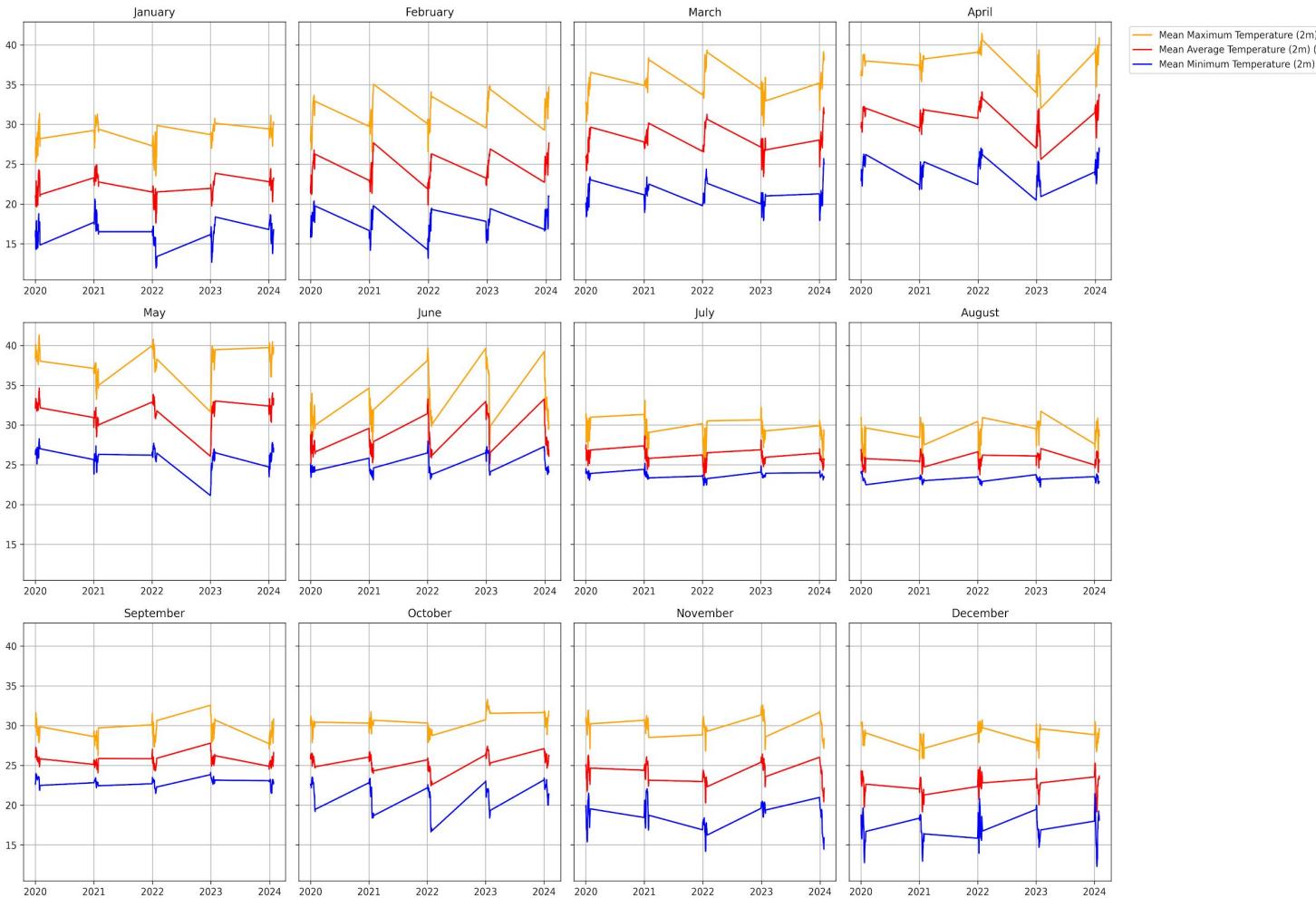


LISA Cluster Map - D: Wasted + Stunted + Underweight



Temperature (Heat) patterns in Maharashtra

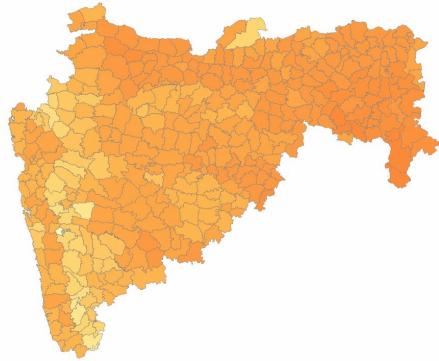
Daily Temperatures by Month (Across Different Years)



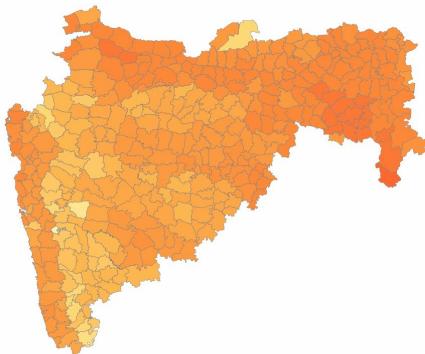
- 2022 & 2023 reported extreme winters and summers compared to other years.
- April 2022 recorded extreme heat days, with max temp of 45 degrees celsius.

Block & Month-wise Temperatures

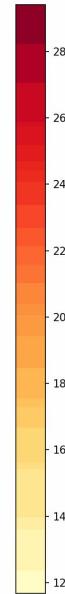
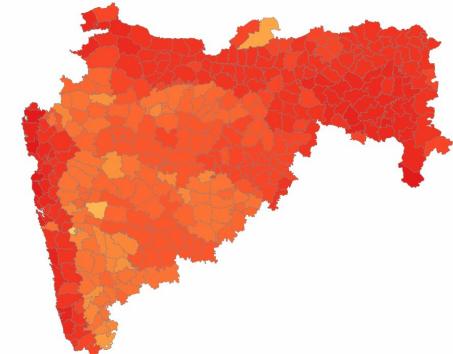
Mean Maximum Temperature (2m) - Aug 2022



Mean Average Temperature (2m) - Aug 2022

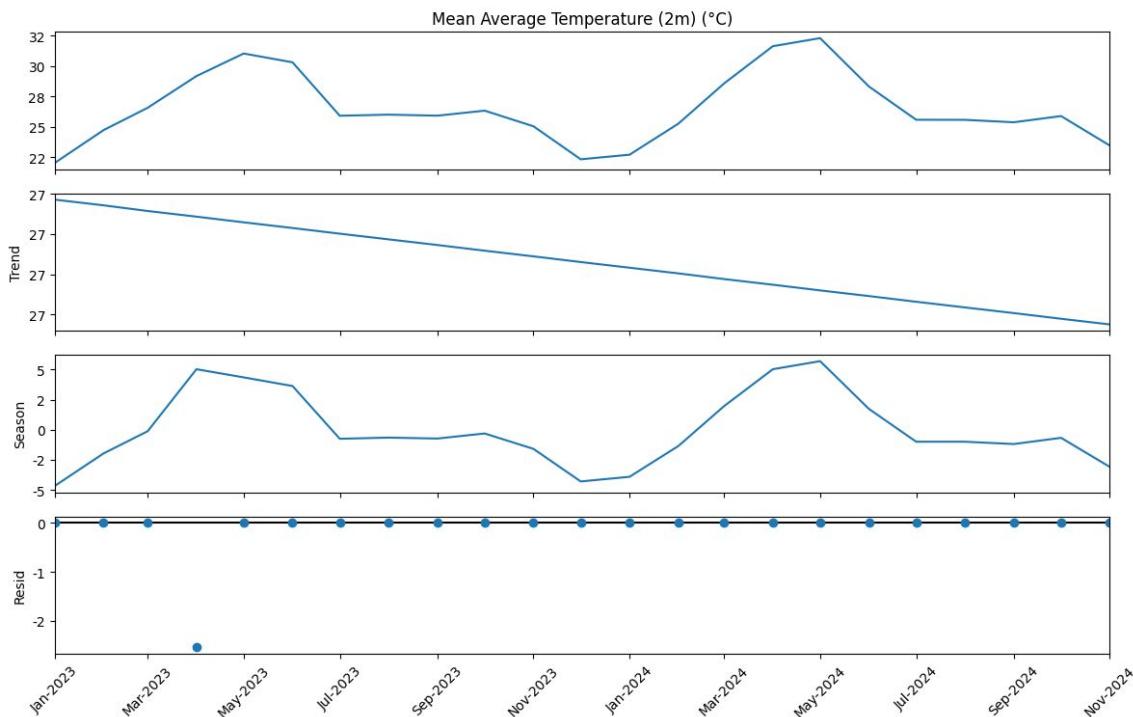


Mean Minimum Temperature (2m) - Aug 2022



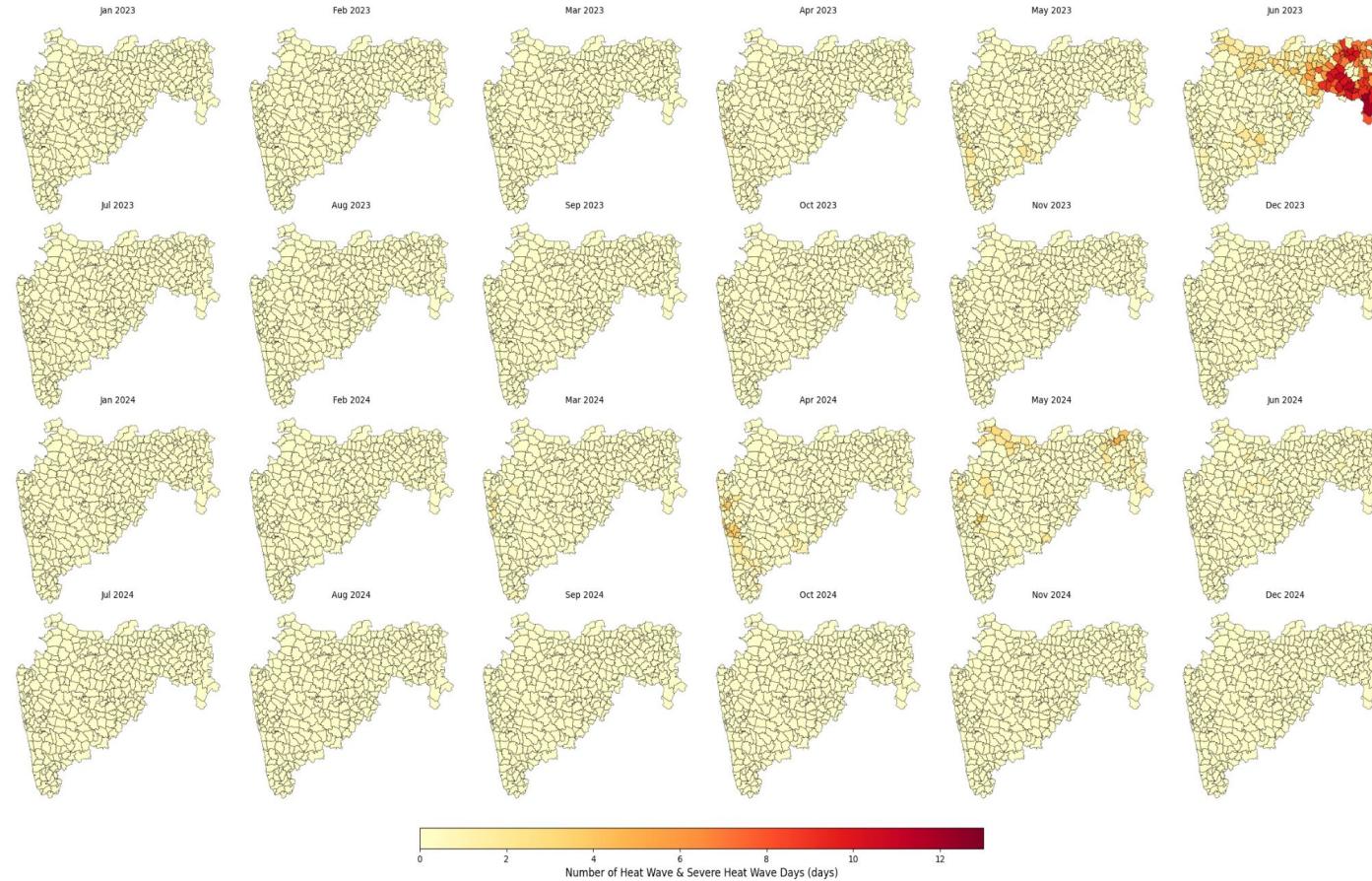
Seasonality-Trend Decomposition - Avg Mean Temperature

STL Decomposition: Mean Average Temperature (2m) ($^{\circ}\text{C}$) (Maharashtra)



- Panel 1 shows the mean average temperature by month.
- Panel 2 shows a marginal decrease in avg. temperature over 23 months.
- Panel 3 shows seasonal deviation. Temperature peaks between March - July, and troughs between November & February, but variation in specific months when temperature peaked.
- Column 4 shows the residuals. There is little noise in the data.

Number of Heat Wave & Severe Heat Wave Days (1 Jan 2023 – 31 Dec 2024) based on Mean Max Temperature from 2020-2024



- There are no recurring seasonal trends in heat waves between 2023 & 2024
- June 2023 recorded exceptionally high temperatures (but was an exception)

* Calculated roughly based on [IMD's SOP](#)

Identification of Heat Wave Days

A Heat wave ‘day’ has been identified based on the following rules:

- Maximum Temperature $\geq 40^{\circ}\text{C}$ in plains, 30°C in hilly regions
 - IMD classifies hilly regions as having an altitude above 1000m. As the exact elevation of every block is unknown at the time of the analysis, the plains cut-off has been used
- AND deviation from normal is:
 - $\geq 4.5^{\circ}\text{C}$ (for Heat Wave)
 - $\geq 6.5^{\circ}\text{C}$ (for Severe Heat Wave)

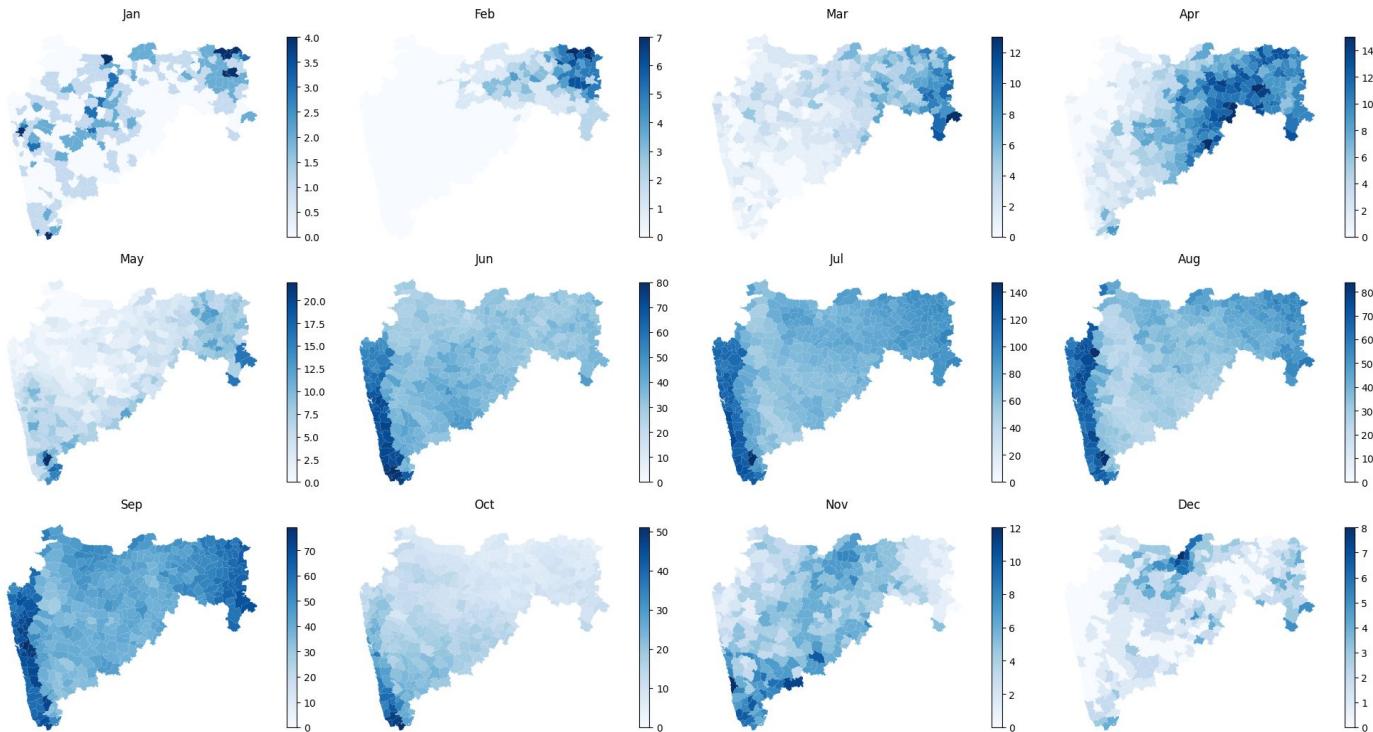
For this analysis, “Normal” is defined as the average daily max temperature over a 4 year period.

- OR If actual max temperature $\geq 45^{\circ}\text{C}$, heat wave is declared irrespective of normal.

Rainfall patterns in Maharashtra

Monthly Rainfall Patterns in Maharashtra (1 Jan 2023 - 31 Dec 2024)

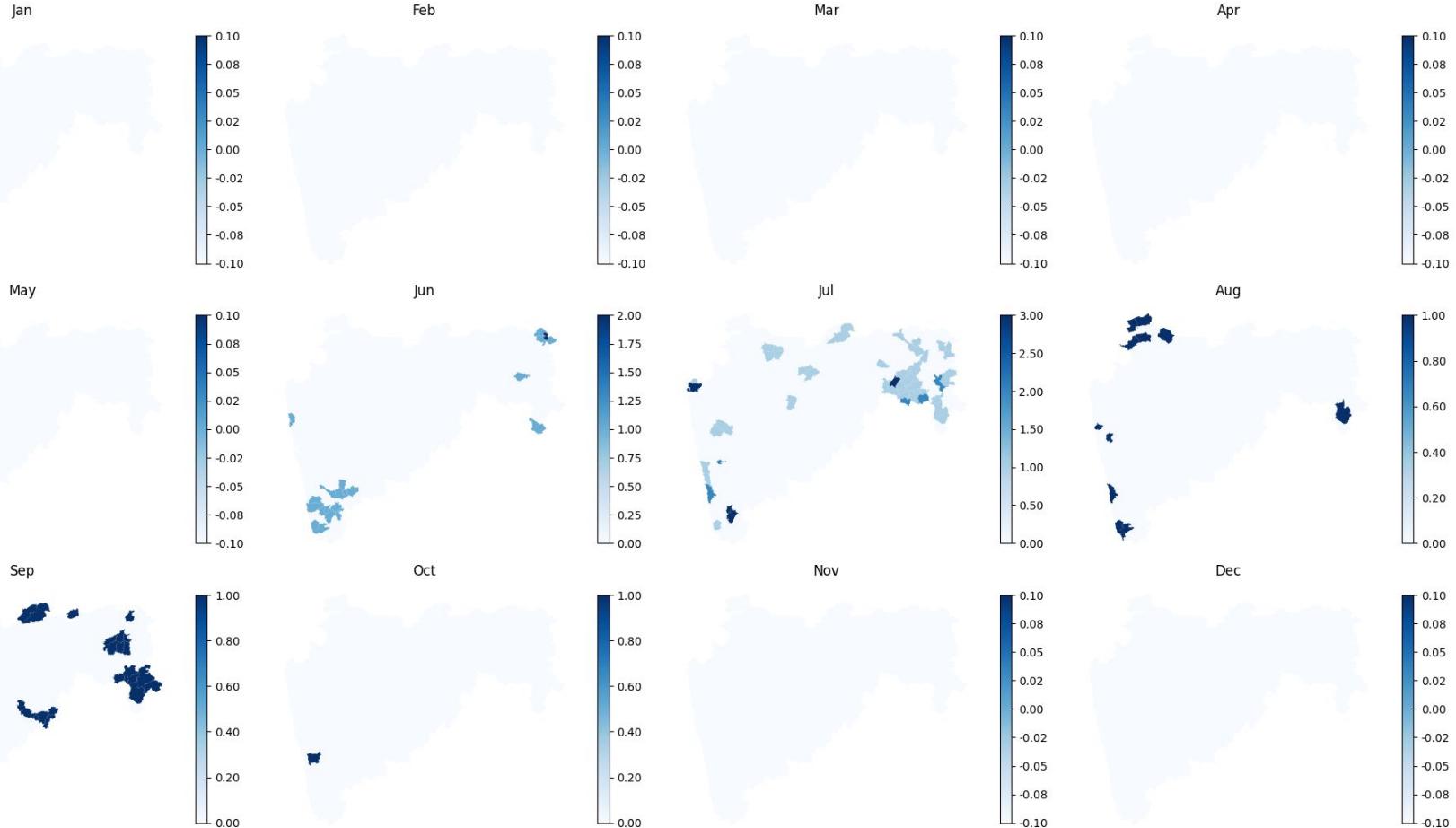
Sum of Daily Rainfall Scores (0-5)



* Daily Rainfall Scores are based on [IMD's](#) intensity terminology

- June marks the onset of monsoon in the state, and July reports the highest rainfall
- There is scanty rainfall in scattered regions during summer & winter

Number of Very Heavy & Extremely Heavy Rainfall Days by Month (1 Jan 2023 - 31 Dec 2024)



* Categorisation based on [IMD's](#) intensity terminology

IMD daily rainfall intensity classification

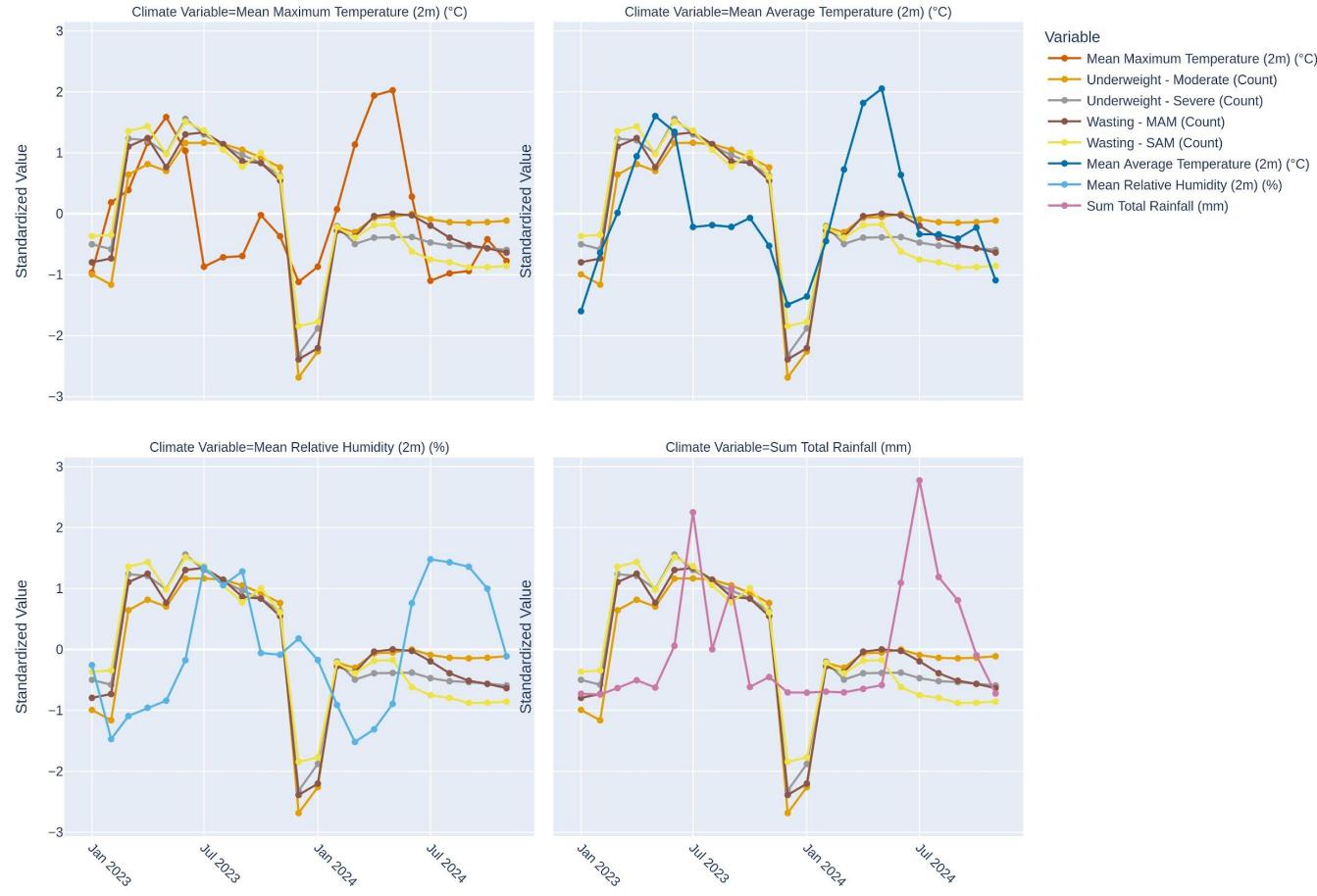
Table 1.5.

Terminology for intensity of 24 hour accumulated rainfall

S. No.	Terminology	Rainfall (mm)	Rainfall (cm)	Percentile
1.	Very light rainfall	Trace -2.4		
2.	Light rainfall	2.5-15.5	Upto 1	Upto 65
3.	Moderate rainfall	15.6-64.4	2-6	65-95
4.	Heavy Rainfall	64.5- 115.5	7-11	95-99
5.	Very Heavy Rainfall	115.6-204.4	12-20	99.0-99.9
6.	Extremely heavy rainfall	Greater than or equal to 204.5 mm	21 cm or more	>99.9
7.	Exceptionally Heavy Rainfall	When the rainfall observed is a value near about the highest recorded rainfall at or near the station for the month or the season. However, this term will be used only when the actual rainfall amount exceeds 12 cm		

Drought patterns in Maharashtra

Standardized Climate and Malnutrition Trends (2023–2024)

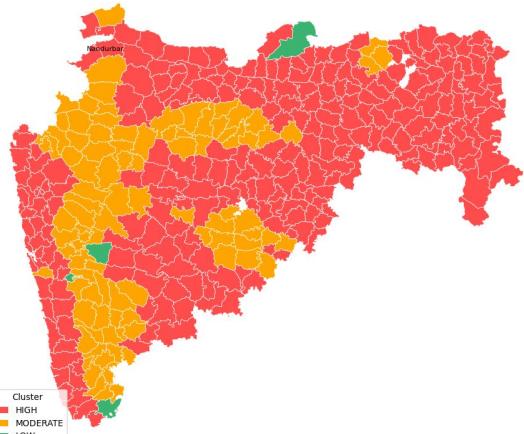


[link](#)

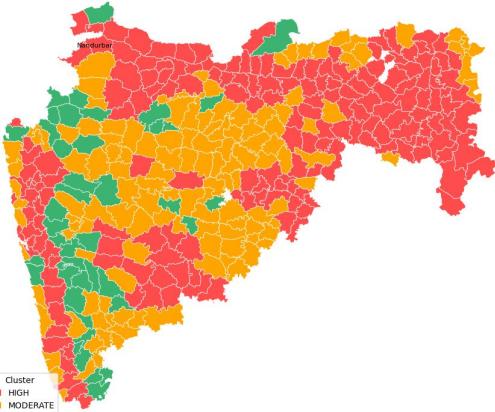
Temperature Clusters (K-Means By Block, Temperature variable)

Heat clusters in Maharashtra

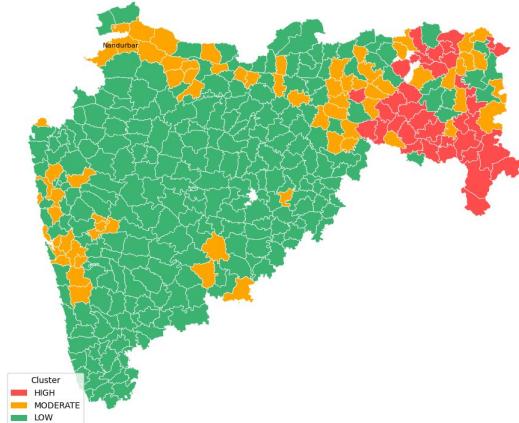
Cluster Map - Mean Daily Average Temperature (2M) (°C)



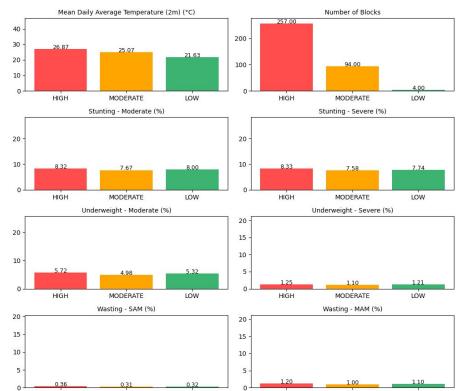
Cluster Map - Mean Daily Maximum Temperature (2M) (°C)



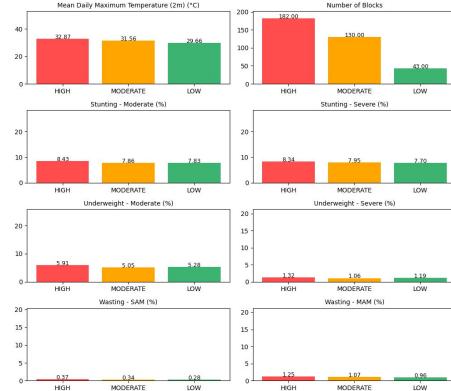
Cluster Map - Number Of Heat Wave/Severe Heat Wave Days



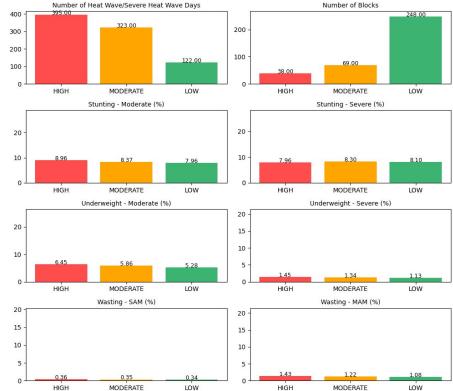
Cluster Characteristics Mean Daily Average Temperature (2m) (°C)- Mean Values



Cluster Characteristics Mean Daily Maximum Temperature (2m) (°C)- Mean Values

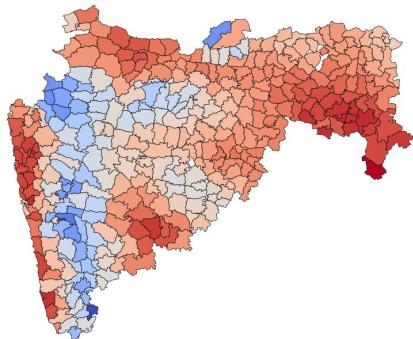


Cluster Characteristics Number of Heat Wave/Severe Heat Wave Days- Mean Values

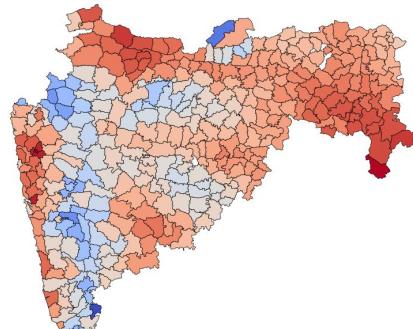


Heat Hotspots in Maharashtra

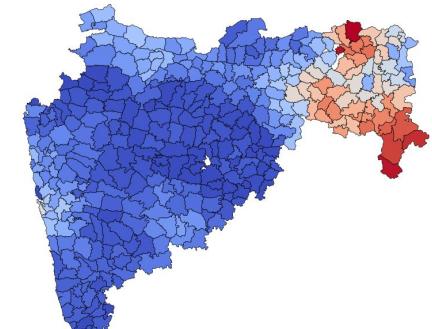
Gi* Hotspot Analysis - Mean Daily Average Temperature (2m) (°C)



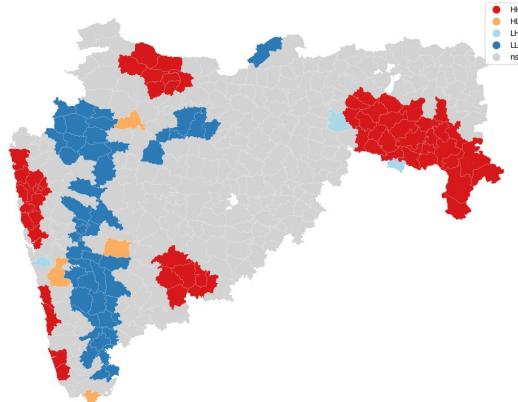
Gi* Hotspot Analysis - Mean Daily Maximum Temperature (2m) (°C)



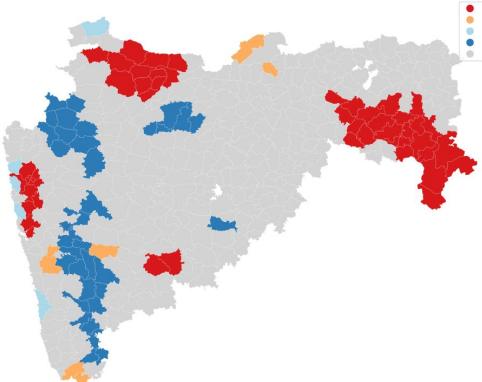
Gi* Hotspot Analysis - Number of Heat Wave/Severe Heat Wave Days



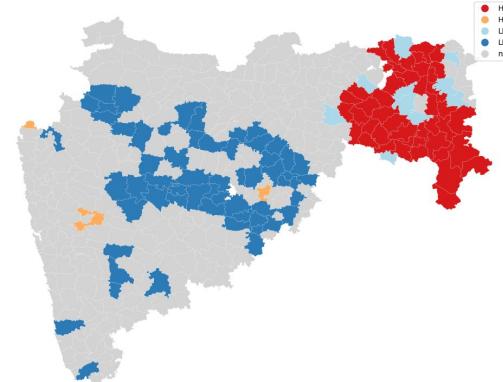
LISA Cluster Map - Mean Daily Average Temperature (2m) (°C)



LISA Cluster Map - Mean Daily Maximum Temperature (2m) (°C)

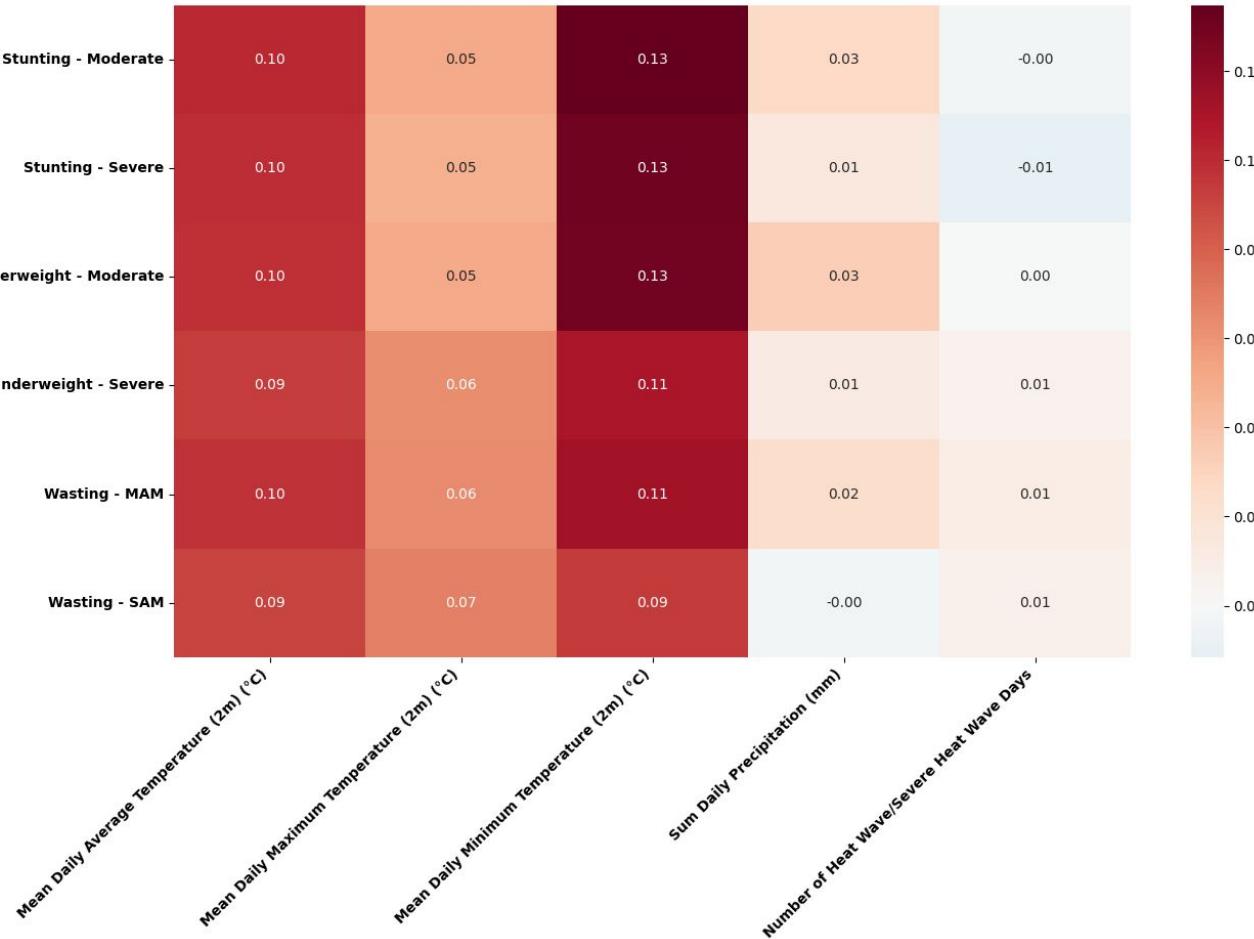


LISA Cluster Map - Number of Heat Wave/Severe Heat Wave Days



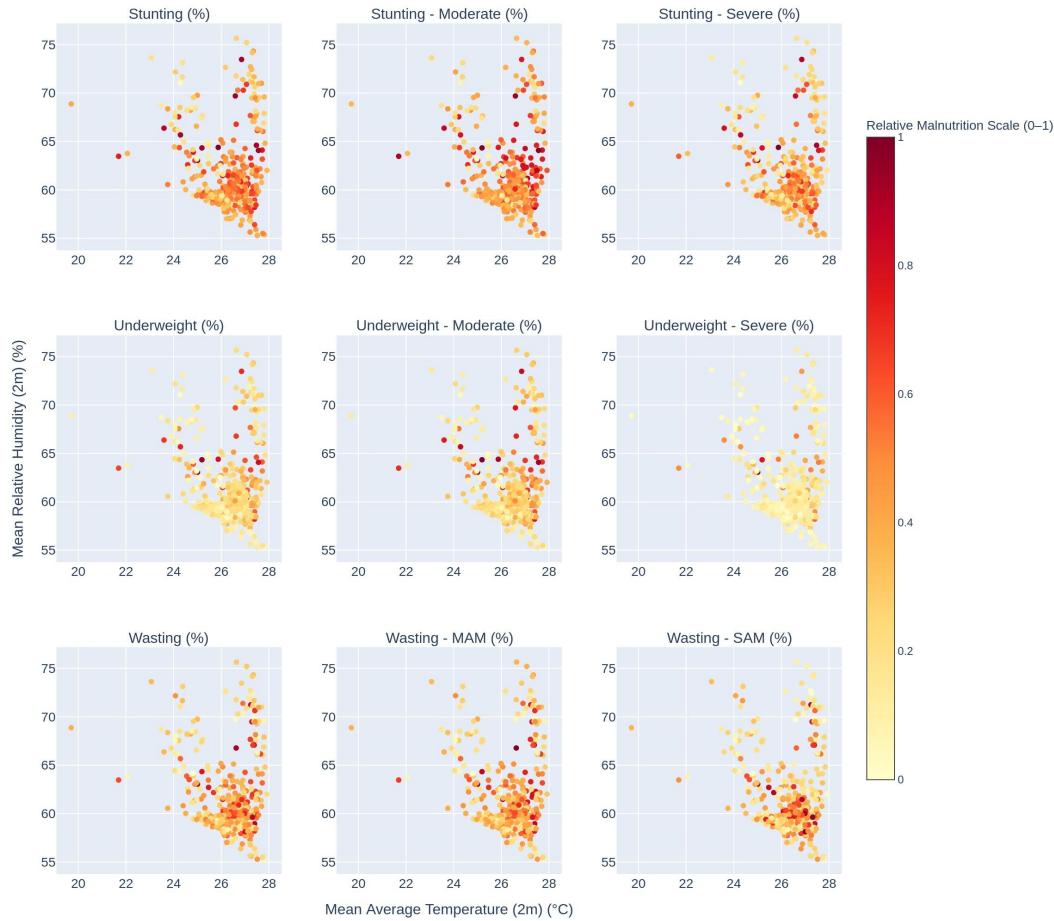
Association b/w climate & malnutrition
variables

Pearson Correlation - Climate vs Malnutrition
(By Block, Maharashtra, Jan 2023 - Dec 2024)

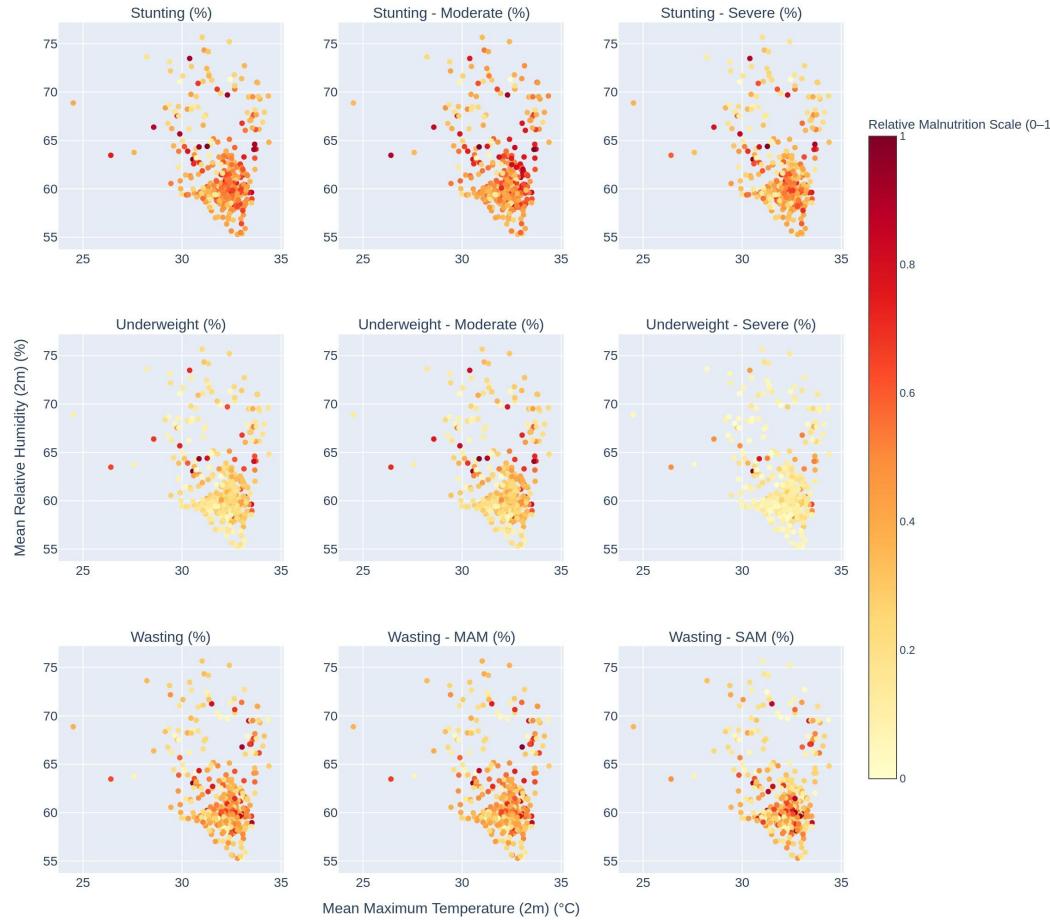


- State-level analysis shows no significant correlations, but patterns emerge at the block level (particularly for avg min temperature)
- Minimum & Average temperatures show a marginally higher association with malnutrition (indicating warmer temperatures as opposed to extreme heat events may have a stronger association with malnutrition)

Effect of Mean Average Temperature & Relative Humidity on Malnutrition Outcomes (By Block, Maharashtra, Jan 2023- Jan 2025)

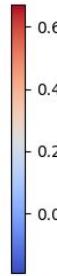
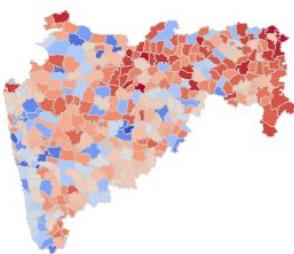


Effect of Mean Maximum Temperature & Relative Humidity on Malnutrition Outcomes (By Block, Maharashtra, Jan 2023- Jan 2025)

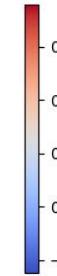
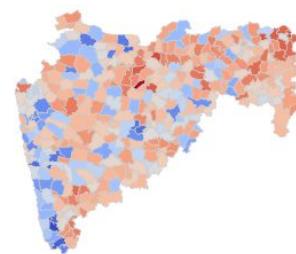


Block-level Correlation: Malnutrition vs Mean Temp (Jan 2023 - Nov 2024)

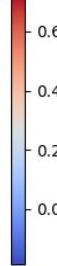
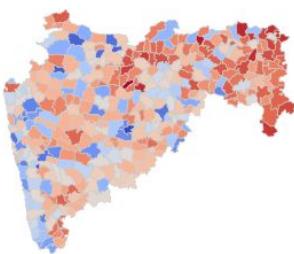
Avg Temp vs Moderate Stunting



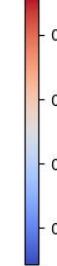
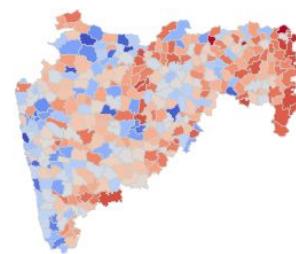
Avg Temp vs Severe Stunting



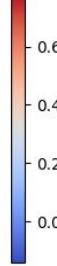
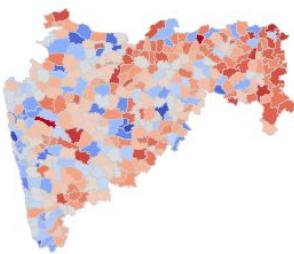
Avg Temp vs Moderate Underweight



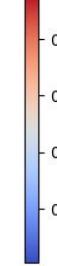
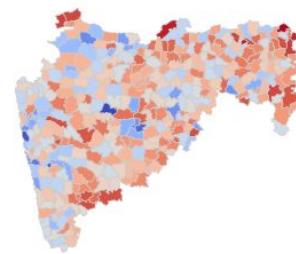
Avg Temp vs Severe Underweight



Avg Temp vs MAM



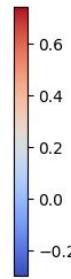
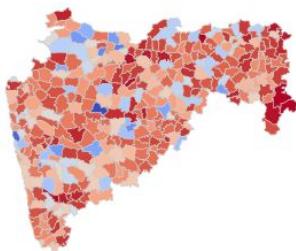
Avg Temp vs SAM



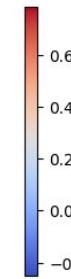
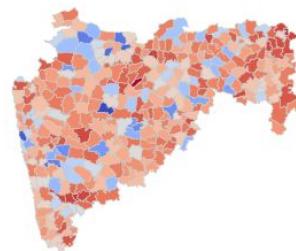
- 13 Blocks have a positive correlation b/w avg. temp & malnutrition indicators ($r \geq 0.7$), including:
 - Buldana District: Deolgaon Raja Block
 - Gondiya District: Gondiya, Salekasa Blocks
 - Wardha District: Ashti Block
 - Pune District: Ambegaon Block
- Blue regions are potentially no-data zones

Block-level Correlation: Malnutrition vs Min Temp (Jan 2023 - Nov 2024)

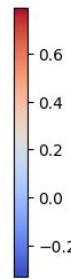
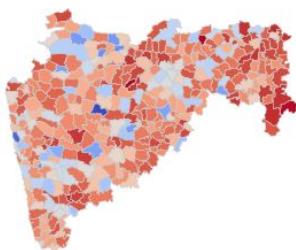
Min Temp vs Moderate Stunting



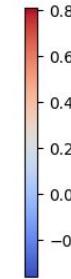
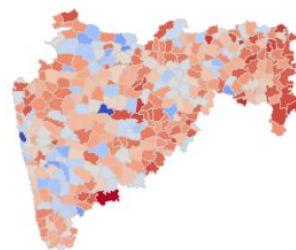
Min Temp vs Severe Stunting



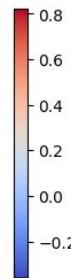
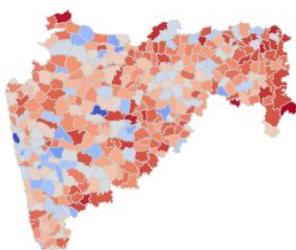
Min Temp vs Moderate Underweight



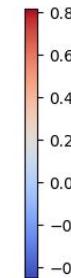
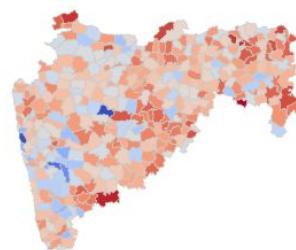
Min Temp vs Severe Underweight



Min Temp vs MAM



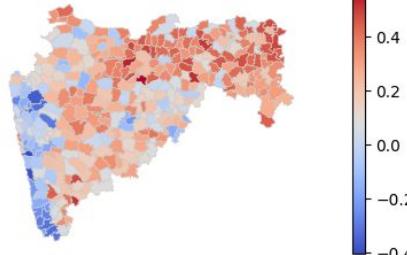
Min Temp vs SAM



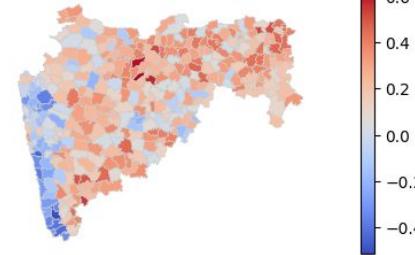
- There is stronger block-level correlation b/w minimum temperature & malnutrition (but weak block-level correlation with maximum temperature)
- 54 blocks have a correlation coefficient > 0.7 , of which 5 blocks have a correlation coefficient > 0.8

Block-level Correlation: Malnutrition vs Mean Max Temp (Jan 2023 – Nov 2024)

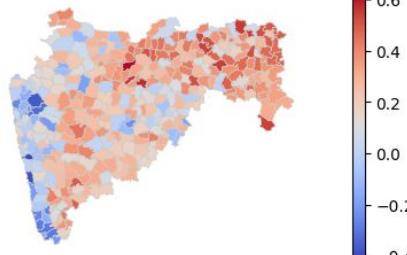
Max Temp vs Moderate Stunting



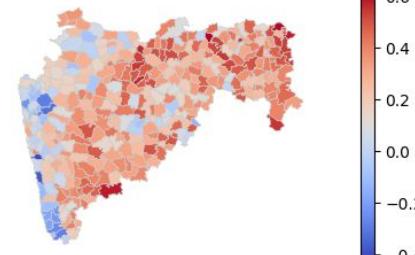
Max Temp vs Severe Stunting



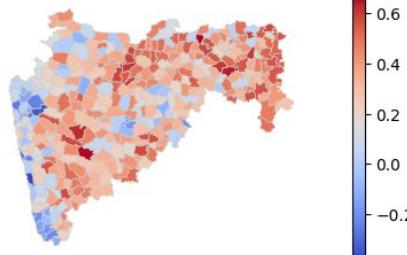
Max Temp vs Moderate Underweight



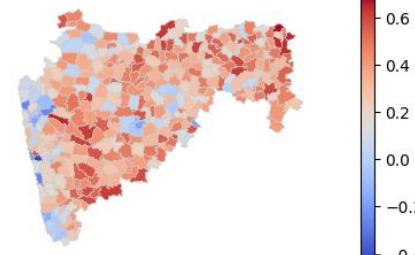
Max Temp vs Severe Underweight



Max Temp vs MAM

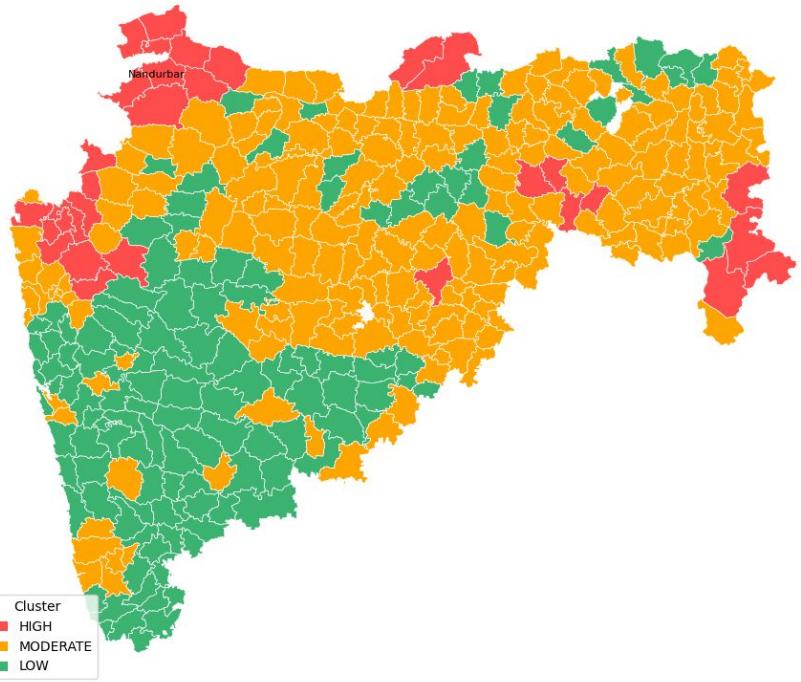


Max Temp vs SAM

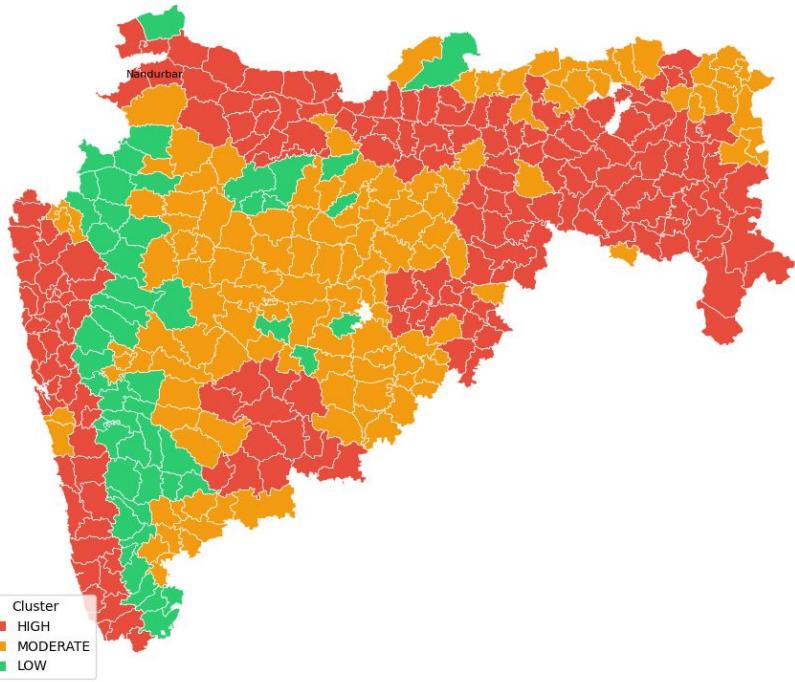


Comparison of Malnutrition & Temperature Clusters & Hotspots

Composite Malnutrition Index (K-Means Clustering)

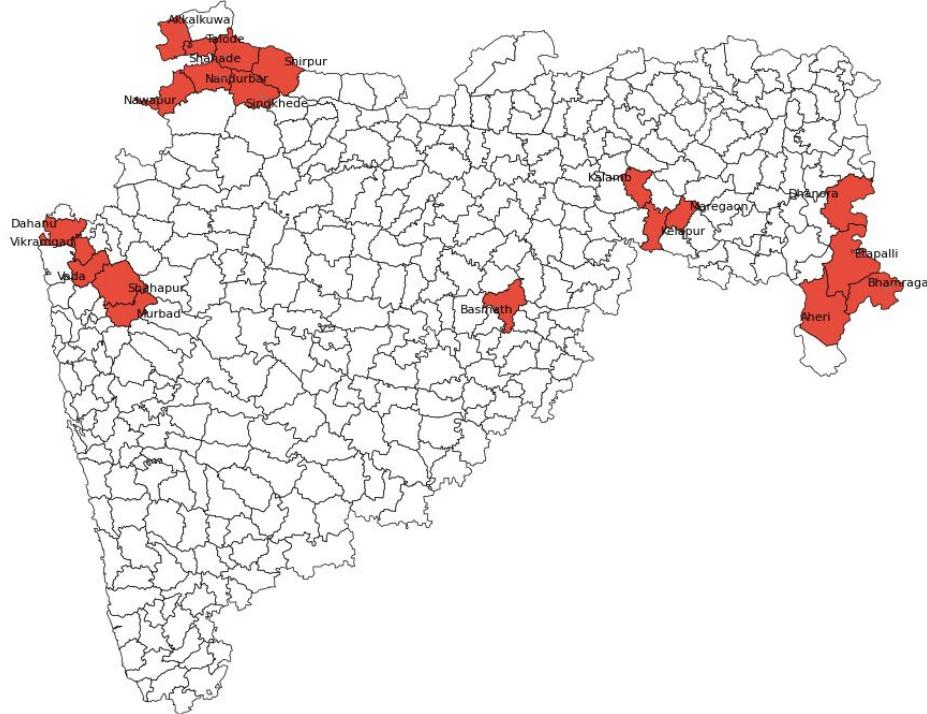


Composite Temperature Index (K-Means Clustering)



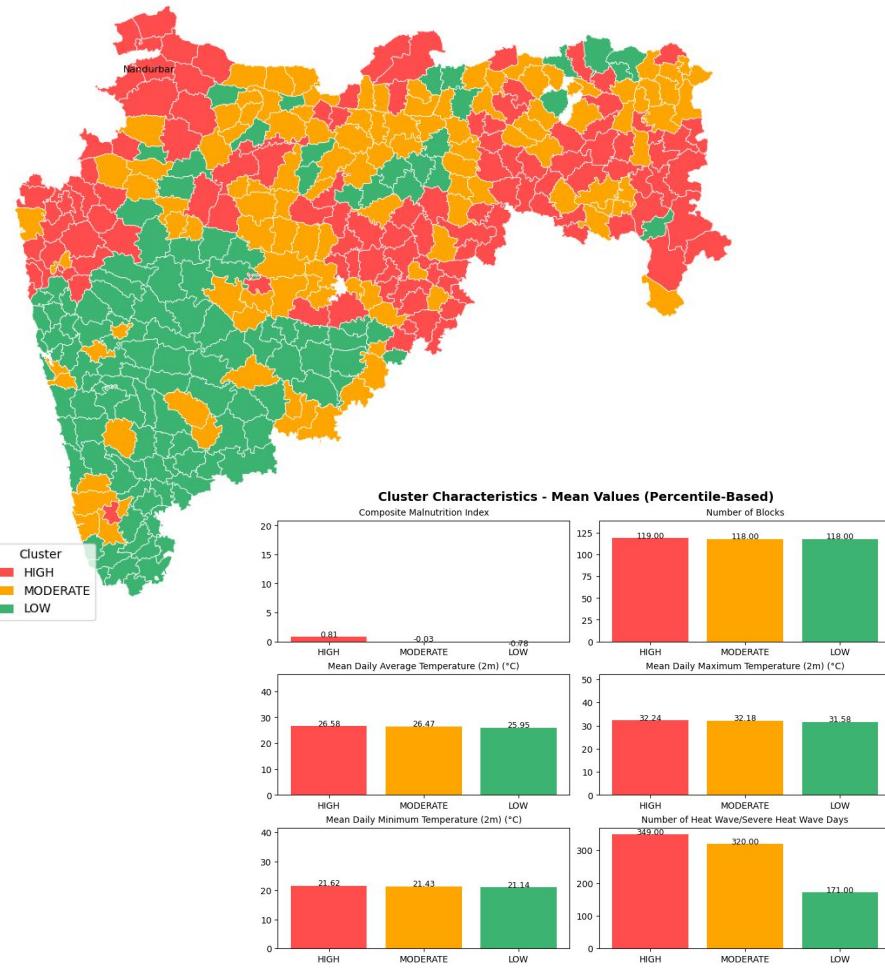
20 Blocks in 'High' Cluster for Malnutrition & Heat (K-Means)

Blocks in 'High' Cluster for Composite Malnutrition & Composite Temperature Indices (K-Means Clustering)

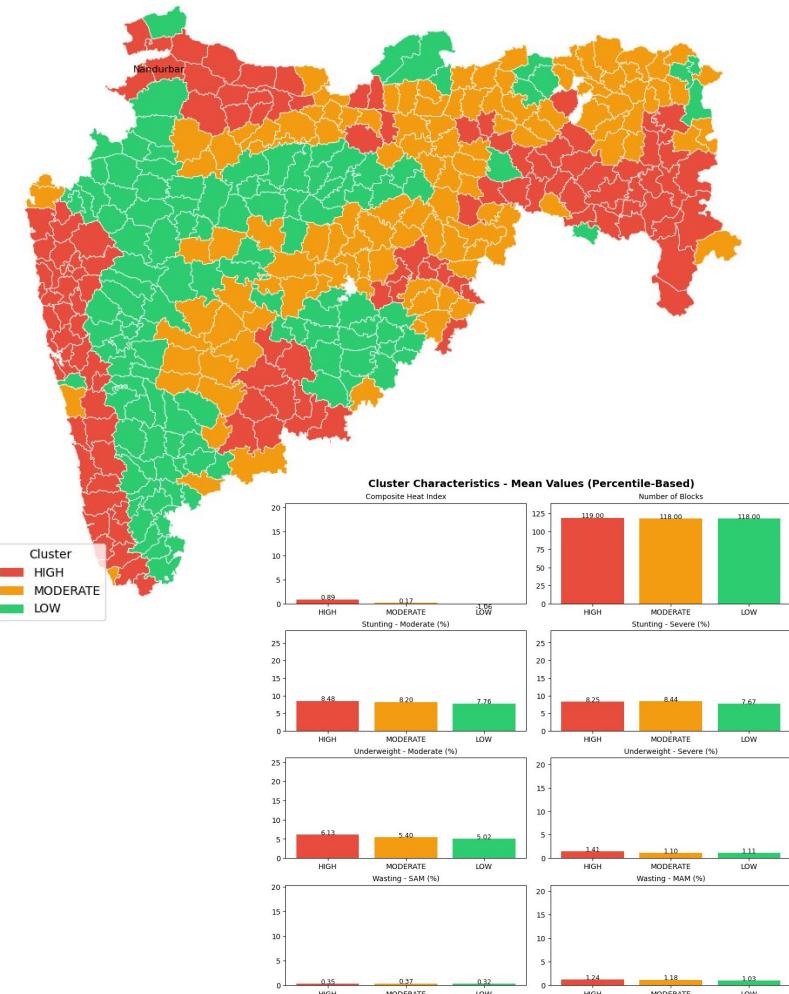


- Akkalkuwa, Talode, Shahade, Nandurbar, Nawapur, Shirpur, Sinikhede, Dhanora, Etapalli, Bhamragad, Aheri, Kalamb, Kelapur, Maregaon, Basmath, Shahapur, Murbad, Dahanu, Vikramgad & Vada blocks are in the 'high' cluster for temperature & malnutrition.

Composite Malnutrition Index - Percentile Clustering

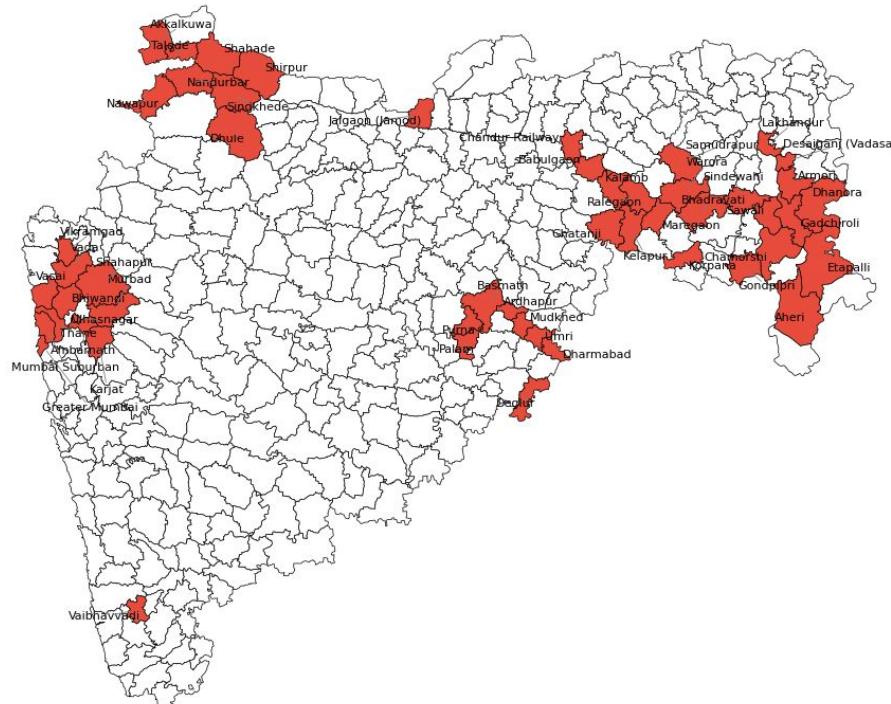


Composite Heat Index - Percentile Clustering

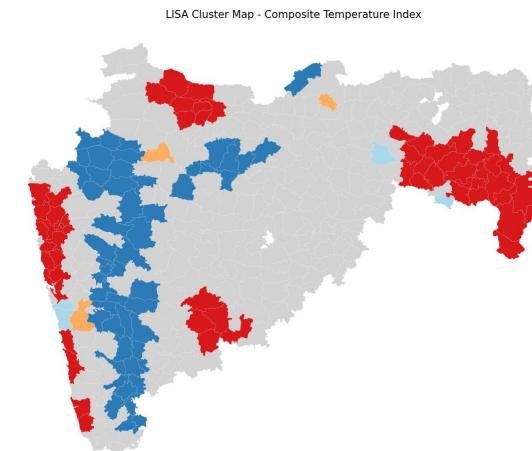
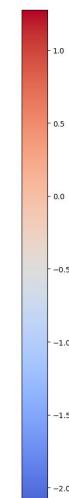
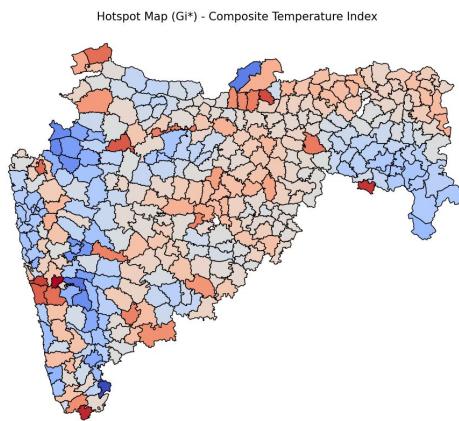
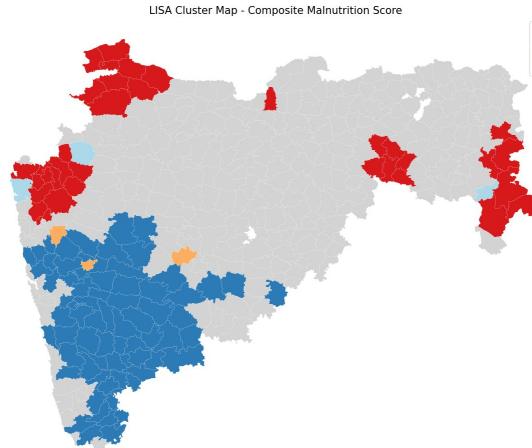
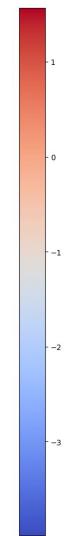
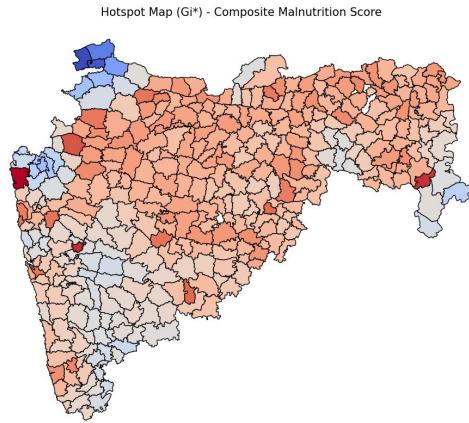


52 Blocks in ‘High’ Cluster for Malnutrition & Heat (Percentile-based)

Blocks in 'High' Cluster for Composite Malnutrition & Composite Heat Indices (Percentile-Based)

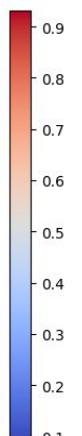
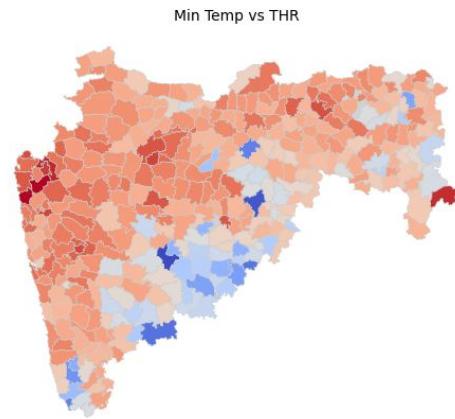
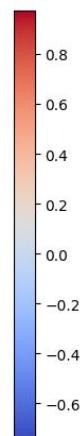
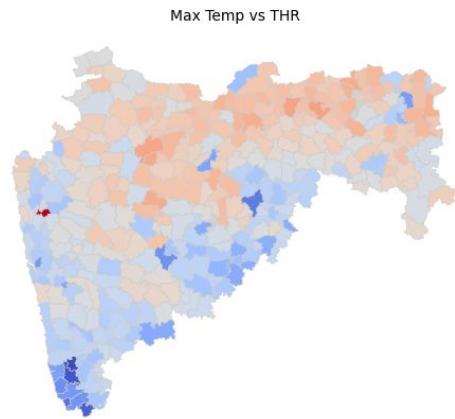
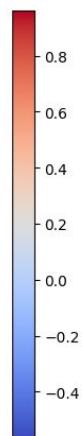
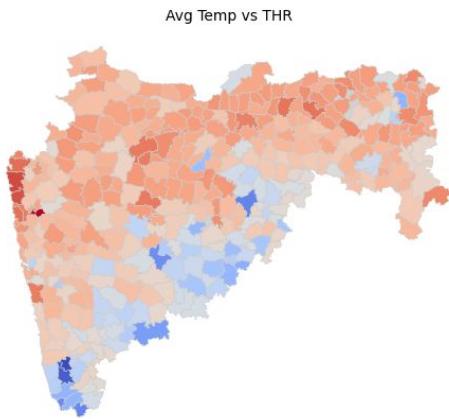


- Rank-based clustering yields more clusters than distance-based clustering.



Next steps: Expand scope to service delivery - e.g., THR

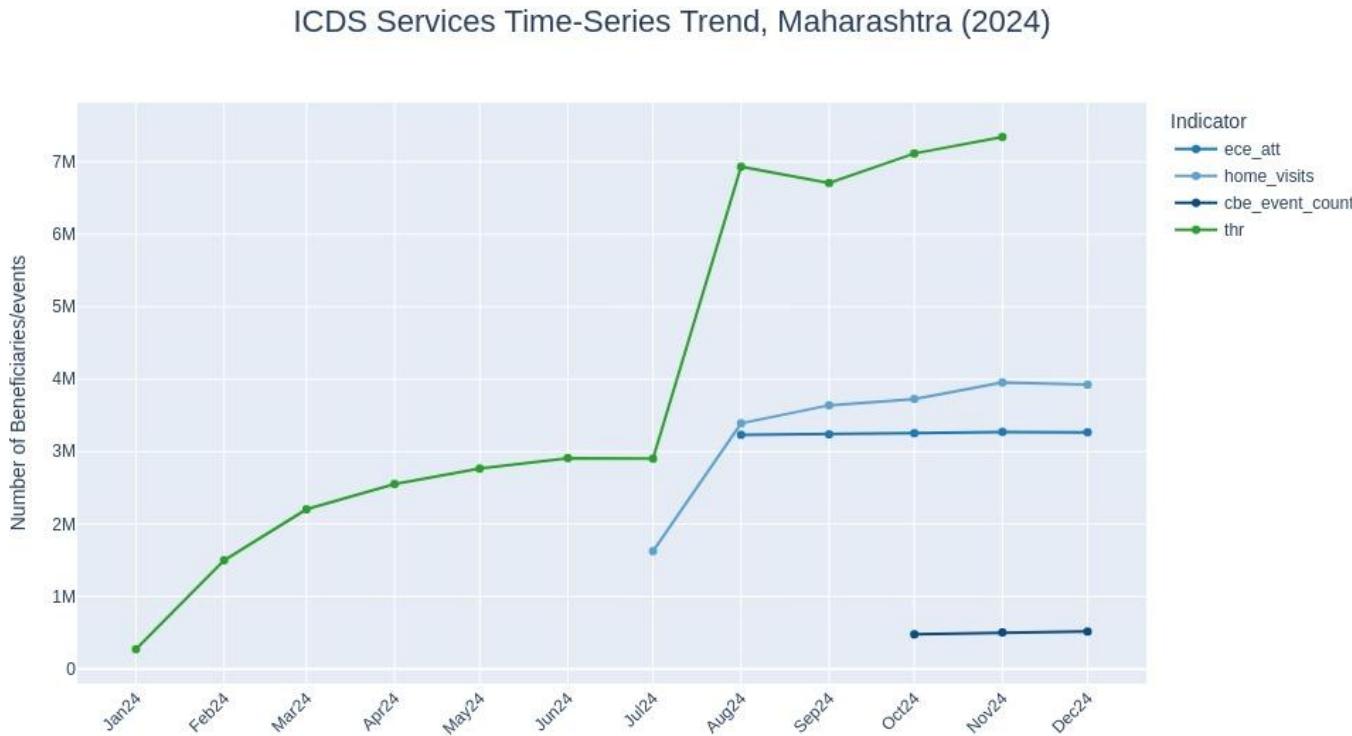
Block-level Correlation: THR vs Climate (Jan 2024 – Dec 2024)



Pearson correlation coefficients (r):

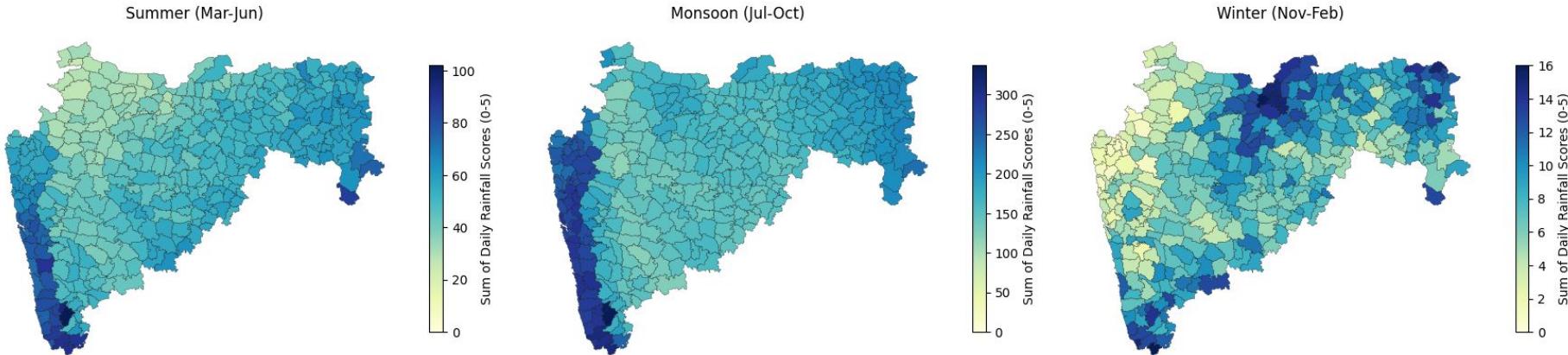
- THR vs. Mean Daily Maximum Temperature: -0.06
- THR vs Mean Daily Average Temperature: 0.03
- THR vs Mean Daily Minimum Temperature: 0.12

Next steps: Expand scope to service delivery - data quality assessment



Next steps: Expand scope to include rainfall, drought

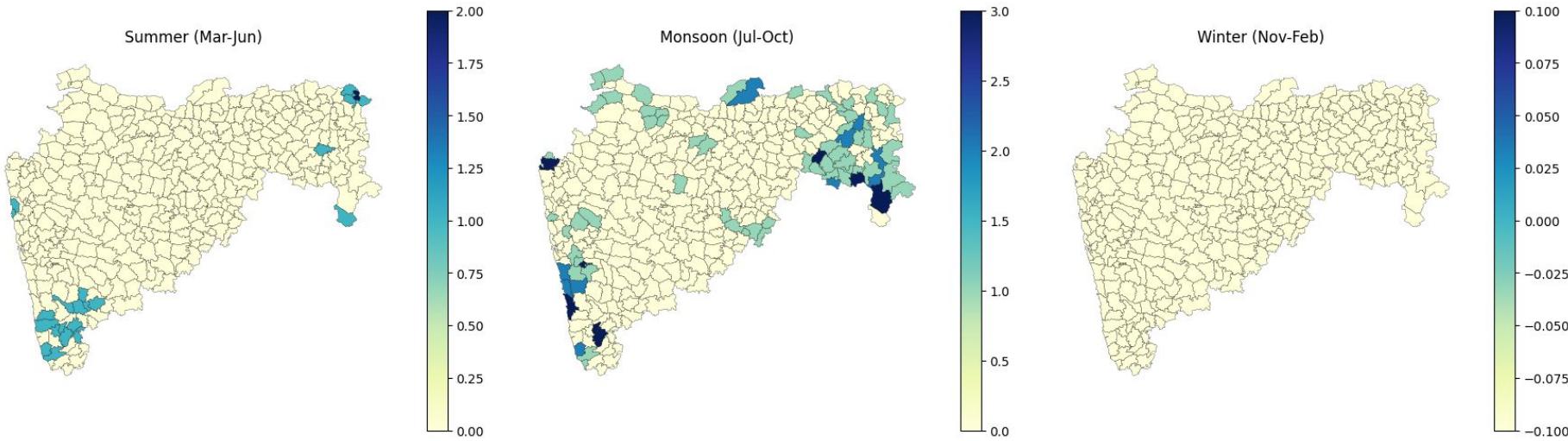
Seasonal Rainfall Patterns in Maharashtra (1 Jan 2023 - 31 Dec 2024)



* Daily Rainfall Scores are based on [IMD's](#) intensity terminology

- The west coast of Maharashtra records the highest level of rainfall during monsoon, and summer.
- Scarce rainfall during the winter is experienced in northern, north-eastern and southern pockets.

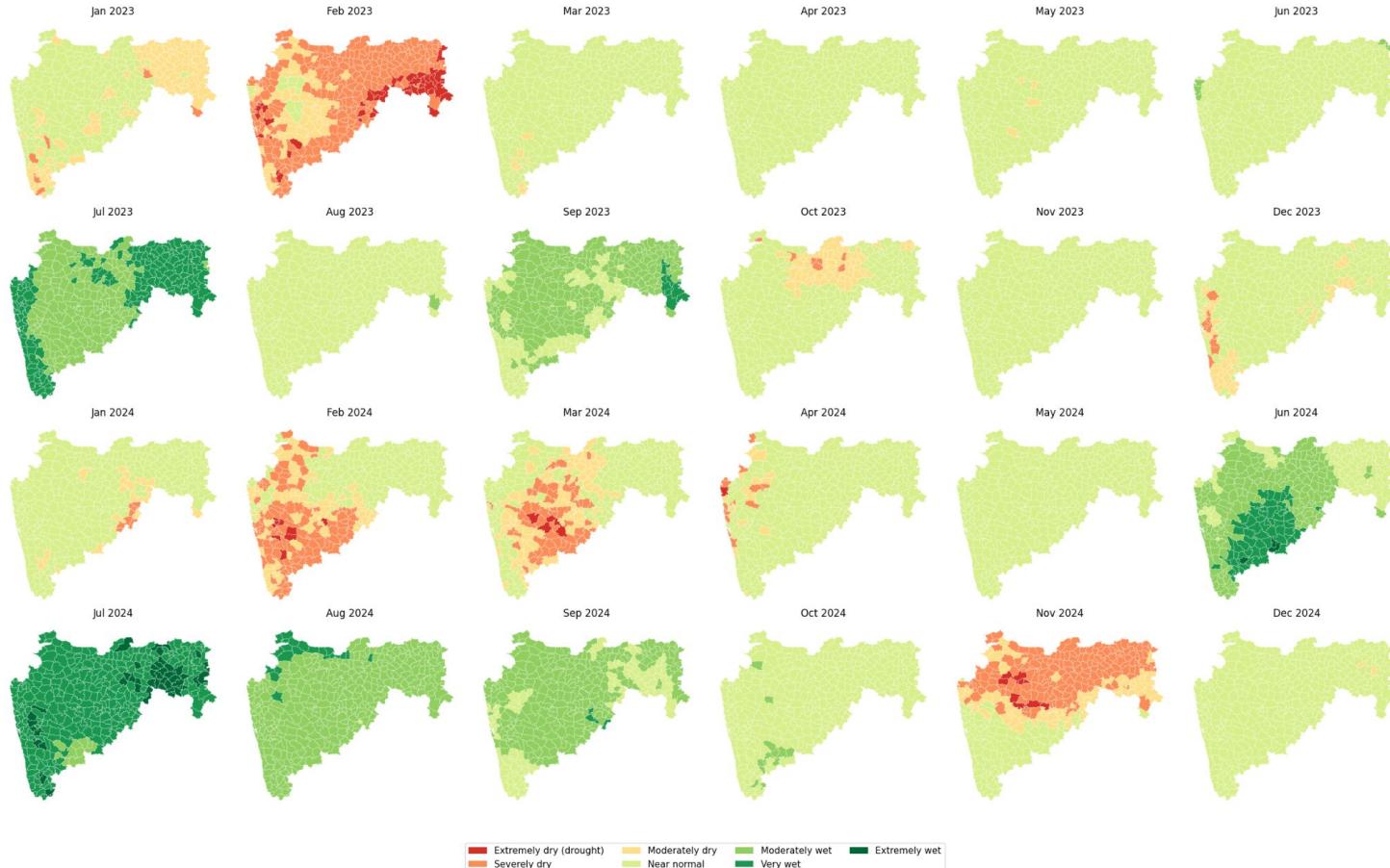
Number of Very Heavy & Extremely Heavy Rainfall Days by Season (1 Jan 2023- 31 Dec 2024)



* Categorisation based on [IMD's](#) intensity terminology

- Over the past 2 years, Maharashtra has not experienced many very heavy or extremely heavy rainfall days
- 8 blocks experienced 3 days of very heavy/extremely heavy rainfall in the monsoon season between 2023 & 2024

Standard Precipitation Index Category by Month-Year (Jan 2023 – Dec 2024)



* Calculated based on [IMD's](#) Standard Precipitation Index calculated based on daily rainfall (precipitation)

Thank You