# Maternal and Child Health Indicators in Sierra Leone: A Multi-Level Geospatial and Predictive Analysis

***GROUP 3 – FINAL PROJECT***
***Instructor – Dr. Saptarshi Purkayastha***


***Erica Babb***

***Haritha Reddy Karingula***

***Lalitha Pranathi Pulavarthy***

***Ross Prater***

***Ying Liu***

# Project Overview and Organization

Sierra Leone is a country in West Africa, on the Atlantic Ocean

**Capital:** Freetown

We structured the analysis around **3 health domains** that trace the **mother-to-child care continuum**: Pregnancy → Birth → Early Childhood

- Maternal Health (prenatal and delivery services)
- Immunization (preventive children's care after birth)
- Child Malnutrition (cumulative children's health outcomes)

# Maternal Health

ANC

Skilled Birth Attendance

# Maternal Health - Definitions

- **Antenatal Care (ANC):** Health services provided to pregnant women to monitor pregnancy and prevent complications.
- **Intermittent Preventive Treatment (IPT):**Malaria prevention during pregnancy using scheduled doses of antimalarial medicine (usually SP).
- **Skilled health personnel:** Professionals trained and certified to provide safe pregnancy, delivery, and newborn care.
  - **Midwives:** Primary provider specialized in pregnancy, labor, delivery, postpartum and newborn care.
  - **State Enrolled Community Health Nurse (SECHN):** Community-level nurse providing basic clinical care including maternal and child health services, immunizations, and outpatient care.
  - **Community Health Officer (CHO):**Mid-level clinician with both clinical and supervisory responsibilities at community health centers.
  - **Maternal and Child Health (MCH) Aides:** Frontline community health worker focused on maternal and child health support.

# Antenatal Care Intermittent Preventive Treatment

Question 1

**Review the trendline between ANC IPT 1 coverage and ANC IPT 2 coverage for all of Sierra Leone for all the months of 2024 and first 6 months of 2025 and mention the month in which the trendline met or will meet in the future.**

- Given to pregnant women during ANC visits to usually prevent malaria infection
- Important indicator in maternal and child health programs

| | |
|---|---|
| **Name** | ANC IPT 1 Coverage |
| **Numerator description** | IPT 1st dose total given |
| **Numerator expression** | `IPT 1st dose given at PHU Fixed+IPT 1st dose given at PHU Outreach+IPT 1st dose given by TBA Fixed+IPT 1st dose given by TBA Outreach` |
| **Denominator description** | ANC 1st visit total |
| **Denominator expression** | `ANC 1st visit Fixed+ANC 1st visit Outreach` |
| **Annualized** | No |
| **Indicator type** | Per cent, 100 |
| **Group membership** | • ANC<br>• Reproductive Health |

| | |
|---|---|
| **Name** | ANC IPT 2 Coverage |
| **Numerator description** | IPT 2 doses given total |
| **Numerator expression** | `IPT 2nd dose given at PHU Fixed+IPT 2nd dose given at PHU Outreach+IPT 2nd dose given by TBA Fixed+IPT 2nd dose given by TBA Outreach` |
| **Denominator description** | ANC 1st visit total |
| **Denominator expression** | `ANC 2nd visit Fixed+ANC 2nd visit Outreach` |
| **Annualized** | No |
| **Indicator type** | Per cent, 100 |
| **Group membership** | • ANC<br>• Reproductive Health |

**Steps:**

**Data**

**Indicators**

ANC IPT 1 Coverage
ANC IPT 2 Coverage

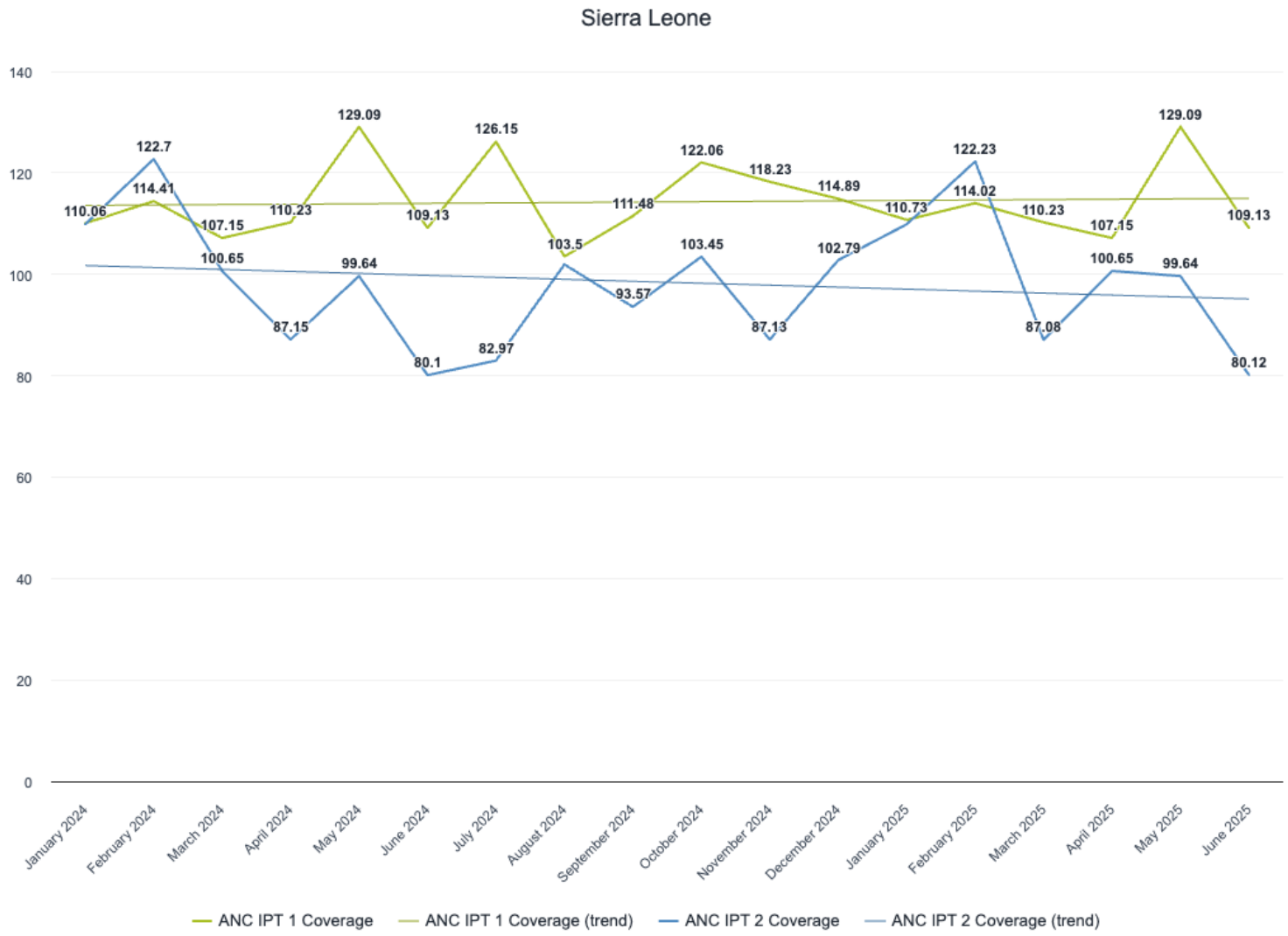
**Organisation unit**

Sierra Leone (no filters)

**Period**

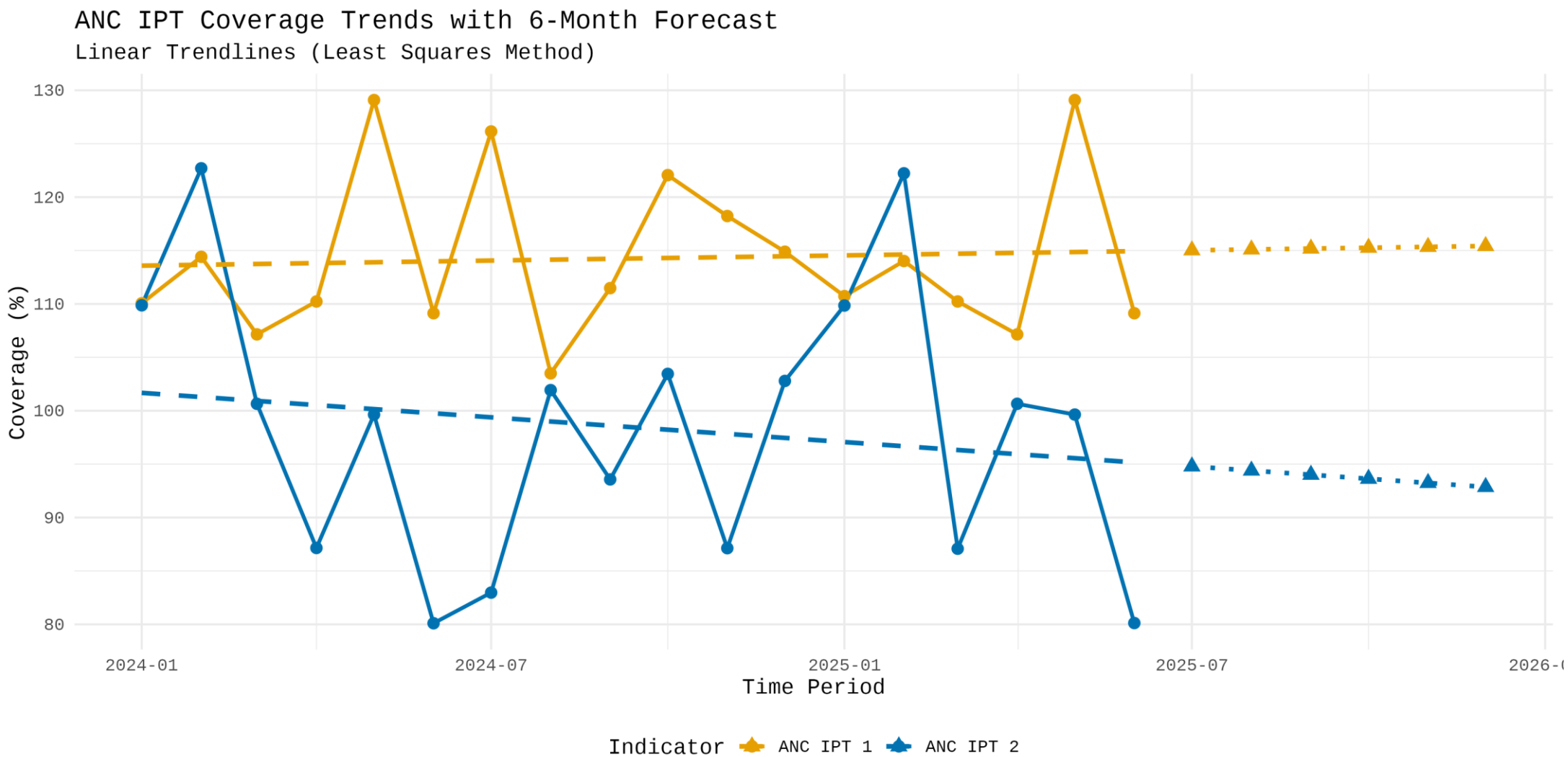
Period Type: Months

January 2024 – June 2025




**IPT 1 is consistently higher than IPT 2**
**The trendlines for ANC IPT 1 Coverage and ANC IPT 2 Coverage do NOT intersect within the January 2024 to June 2025 period**

# Forecasting



## Interpretation

**The linear trendlines for ANC IPT 1 Coverage and ANC IPT 2 Coverage do NOT meet within the observed period (January 2024 - June 2025) or the 6-month forecast period (July 2025 - January 2026). The trendlines indicate worsening retention rates between first and second IPT doses. Extrapolating backward, the trendlines would have intersected sometime before January 2024.**

## Pros of our approach

- 18-month data + 6-month forecast enables proactive planning
- Linear regression is statistically sound and reproducible
- Dual indicator comparison reveals retention dynamics
- Diverging trendlines quantify urgency of intervention

## Cons of our approach

- Linear model cannot capture policy changes or seasonality
- National aggregation masks district-level disparities
- Does not identify root causes of declining retention

# Question 2

Using SES method, forecast the ANC IPT 2 coverage for the month of Dec 2025 for the Western Area district, using data from all the previous months of 2024 and 2025. (with 2 of your own choices of alpha). Check the error for the last 6 months.

**Steps:**

**Data Indicators**

ANC IPT 2 Coverage

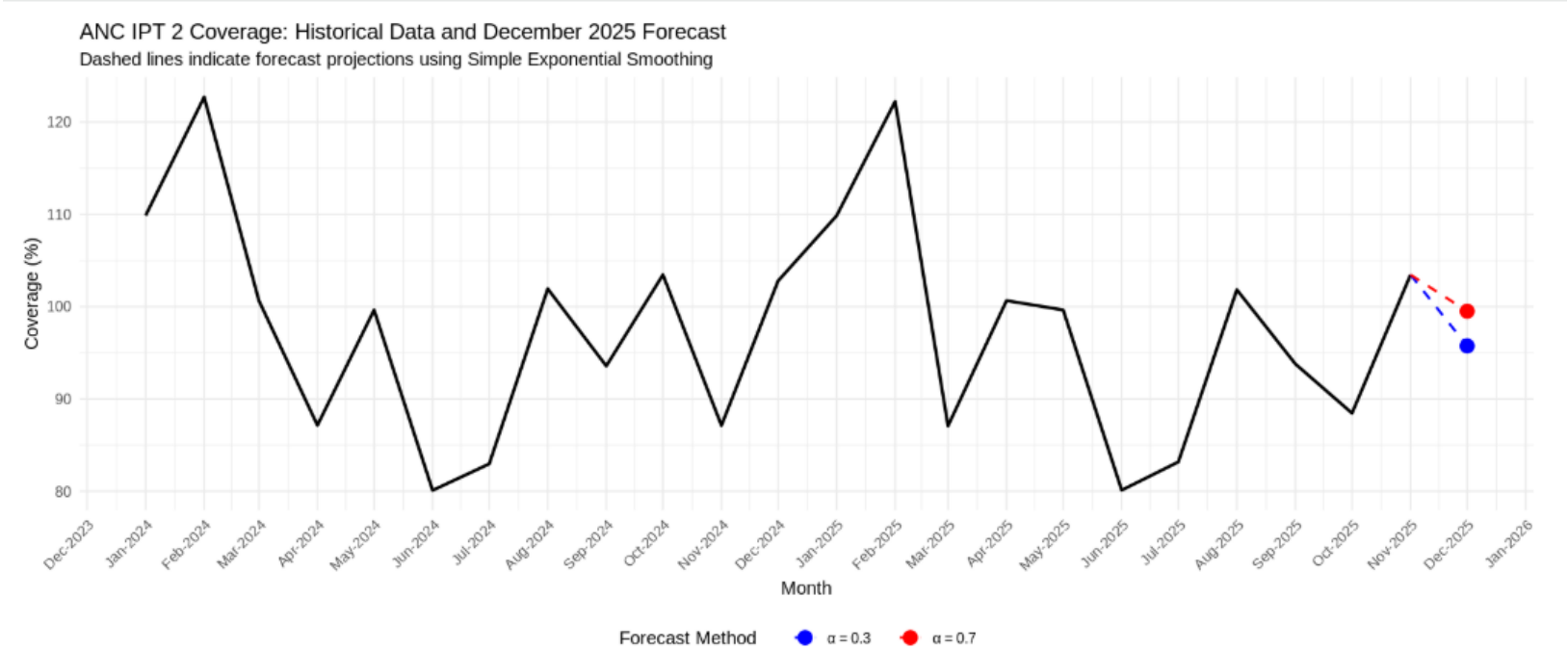
**Organisation Unit**

Western Area

**Period**

Period Type: Months

January 2024 – Nov 2025




**Interpretation:**

Both SES models showed variable forecasting performance across the last six months (June - November 2025), with the α = 0.3 model achieving better overall accuracy (MAE = 9.97) compared to α = 0.7 (MAE = 10.33). While the α = 0.7 model responded more quickly to recent changes, it produced more volatile forecasts with some large errors, particularly in August 2025. In contrast, the α = 0.3 model provided more consistent forecasts by smoothing out short-term fluctuations. The December 2025 forecast values of 95.75% (α = 0.3) and 99.51% (α = 0.7) both fall within a reasonable range of recent observations. Overall, the smoother forecasting approach with α = 0.3 offered better short-term accuracy for this dataset, suggesting that ANC IPT 2 coverage data benefits from reducing the influence of month-to-month volatility.

A data.frame: 6 × 6

| | periodname | ANC IPT 2 Coverage | Forecast_alpha_0_3 | Forecast_alpha_0_7 | Error_alpha_0_3 | Error_alpha_0_7 |
|---|---|---|---|---|---|---|
| | <chr> | <dbl> | <dbl> | <dbl> | <dbl> | <dbl> |
| 18 | June 2025 | 80.12 | 100.57530 | 99.54488 | -20.4552985 | -19.424878 |
| 19 | July 2025 | 83.18 | 94.43871 | 85.94746 | -11.2587089 | -2.767463 |
| 20 | August 2025 | 101.83 | 91.06110 | 84.01024 | 10.7689037 | 17.819761 |
| 21 | September 2025 | 93.79 | 94.29177 | 96.48407 | -0.5017674 | -2.694072 |
| 22 | October 2025 | 88.46 | 94.14124 | 94.59822 | -5.6812372 | -6.138222 |
| 23 | November 2025 | 103.45 | 92.43687 | 90.30147 | 11.0131340 | 13.148534 |

# Question 8

## Describe the location where the districts with the lowest births by skilled attendants are performed in Sierra Leone for 2024.

**Steps**

**Initial Indicators:**

- Births attended by skilled health personnel (estimated pregnancies)
- Births attended by skilled health personnel (registered live births)
- Neither indicator told the full story – missing still births
- Neither indicator told right story – calculated as percentage

**Derived Indicator:**

- All births with skilled attendants
  - Keeps 4 types of skilled attendants, adds still births
  - Replaces ‘estimated pregnancies’ or ‘registered live births’ denominators with 1 to create a factor data type

**Data:**

Indicators

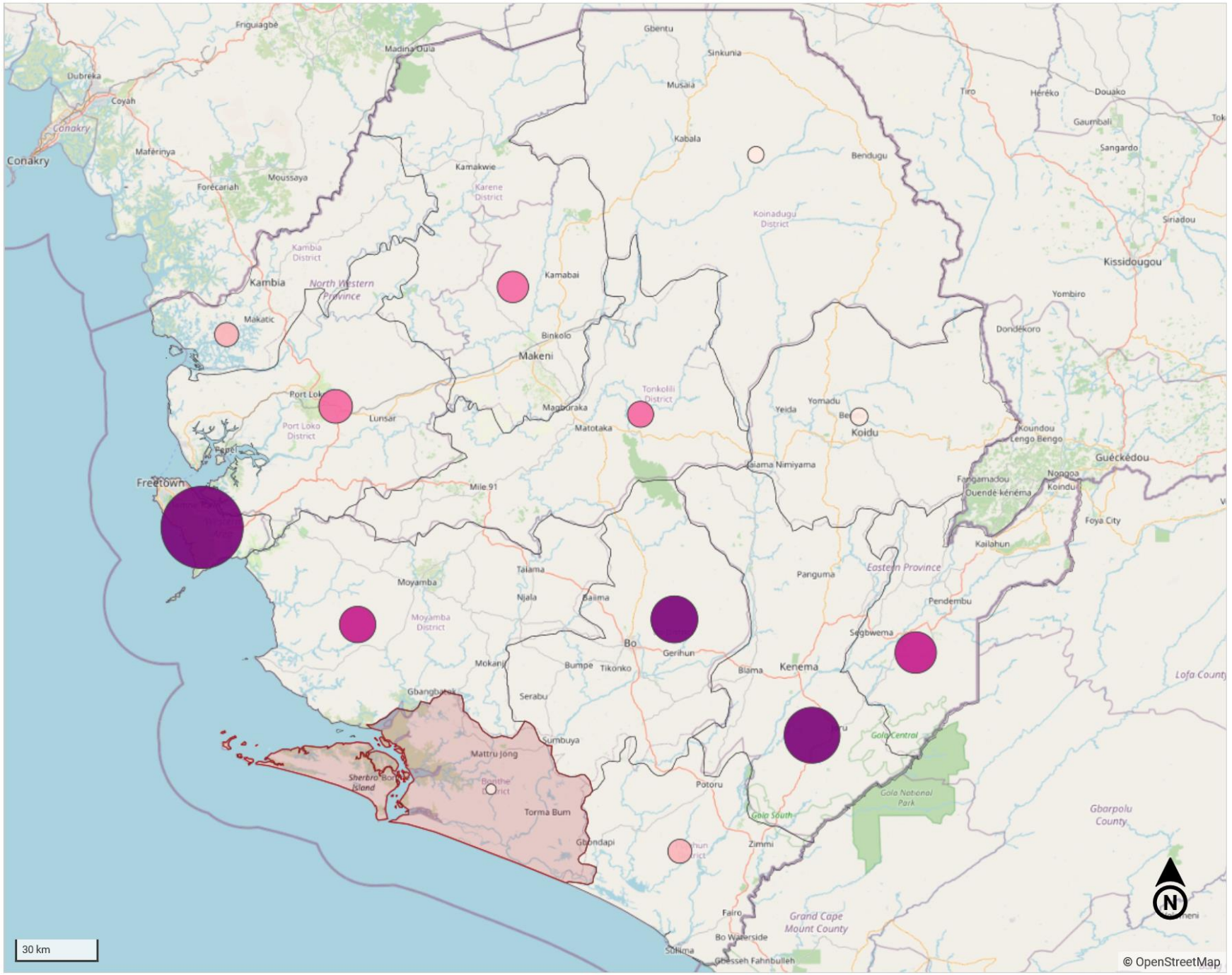
All births with skilled attendants

Organization unit

Districts

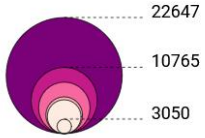
Period

2024 (Yearly)




## G3_Q8

**All births with skilled attendants**
2024




- **Bonthe** has the lowest births by skilled attendants
  - located in the far southern coastal region
  - with riverine/island terrain that limits overland access.
- Other low-performing districts (Koinadugu, Kono, Pujehun) share similar geographical challenges.
- All are far from Freetown and **lack major highways** (no primary or secondary road networks shown on the map).
- These districts are predominantly rural with low population density and **limited transport connectivity**.
- **Remoteness, difficult terrain, and weak infrastructure** likely contribute to reduced access to skilled birth services.

# Childhood Immunization

Measles coverage

Dropout rates (Penta-Measles correlation)

# Question 4

Perform a visualization-based analysis of Measles coverage for children less than 1yr in all of Sierra Leone. In this analysis, we also want to see in which months in 2024 and 2025 the coverage target of 60% were missed.

**Steps**

**Indicator:**

- Measles Coverage <1y
  - Measles doses given Fixed, <1y + Measles doses given Outreach, <1y / Total population < 1 year

**Data:**

Indicators

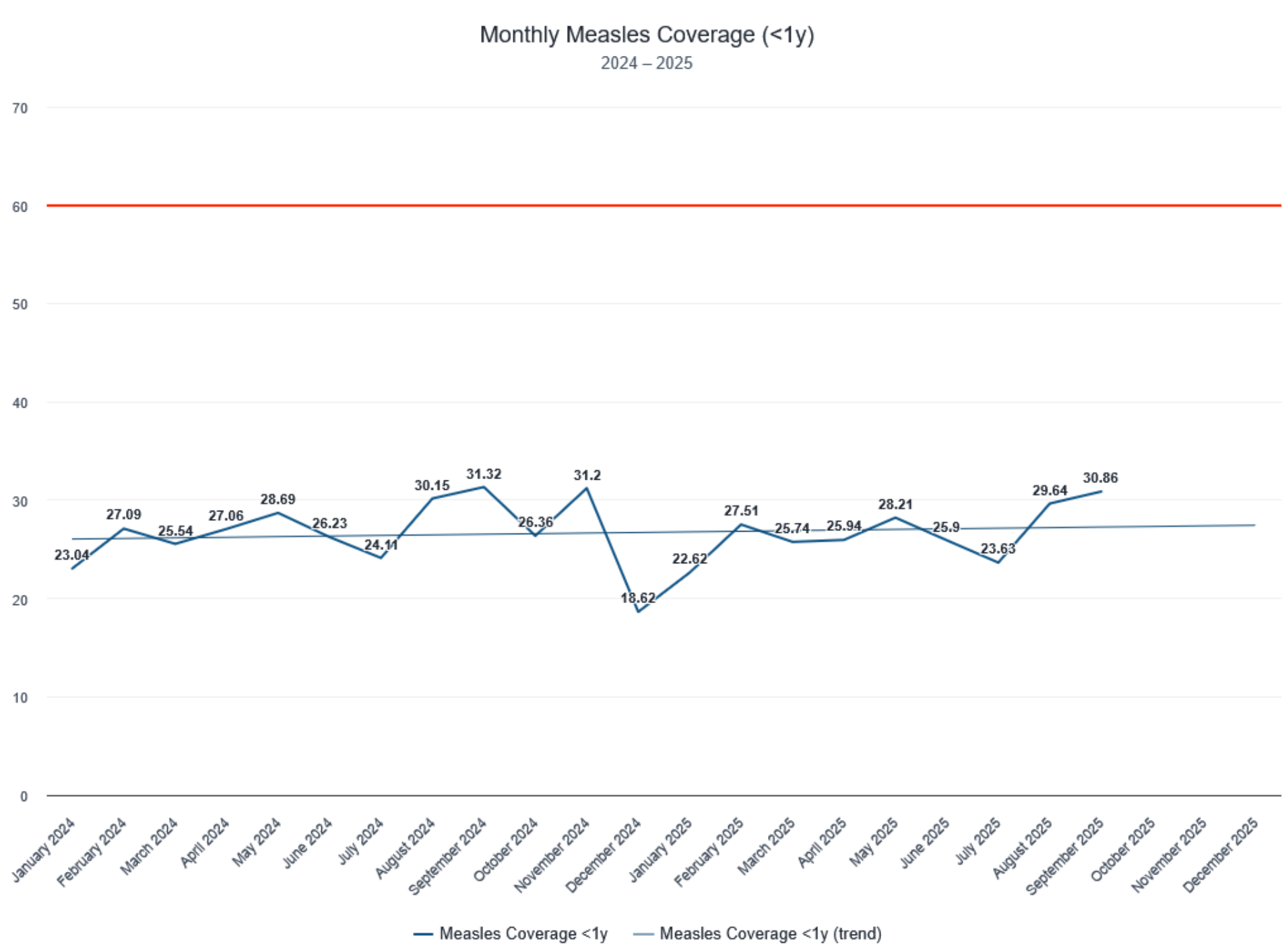
Measles Coverage <1y

Organization unit

National

Period

Jan 2024 - Dec 2025 (Monthly)




The line chart shows monthly measles coverage for children under one year across Sierra Leone for 2024 and early 2025, plotted against the 60% performance target. Coverage remains consistently below the target for all months in the period, fluctuating between approximately **18% and 32%**, with no month approaching the expected threshold. Although there are small seasonal rises around August–October of both years, the overall trend reflects **persistent national underperformance relative to the 60% benchmark**. This suggests systemic challenges in measles vaccination uptake and/or data completeness across the country rather than isolated monthly declines.

# Question 5

## Can you drill-down and identify specific districts, chiefdoms, and facilities that missed the target? What are some characteristics of these districts, chiefdoms, and facilities.

**Steps**

**Initial Indicators:**

- Measles Coverage <1y

**Derived Indicator:**

- Measles Doses <1y
  - Keeps 2 types of locations where <1y received doses
  - Replaces 'Total population < 1 year' denominator with 1 to create a factor data type

**Data:**

Indicators

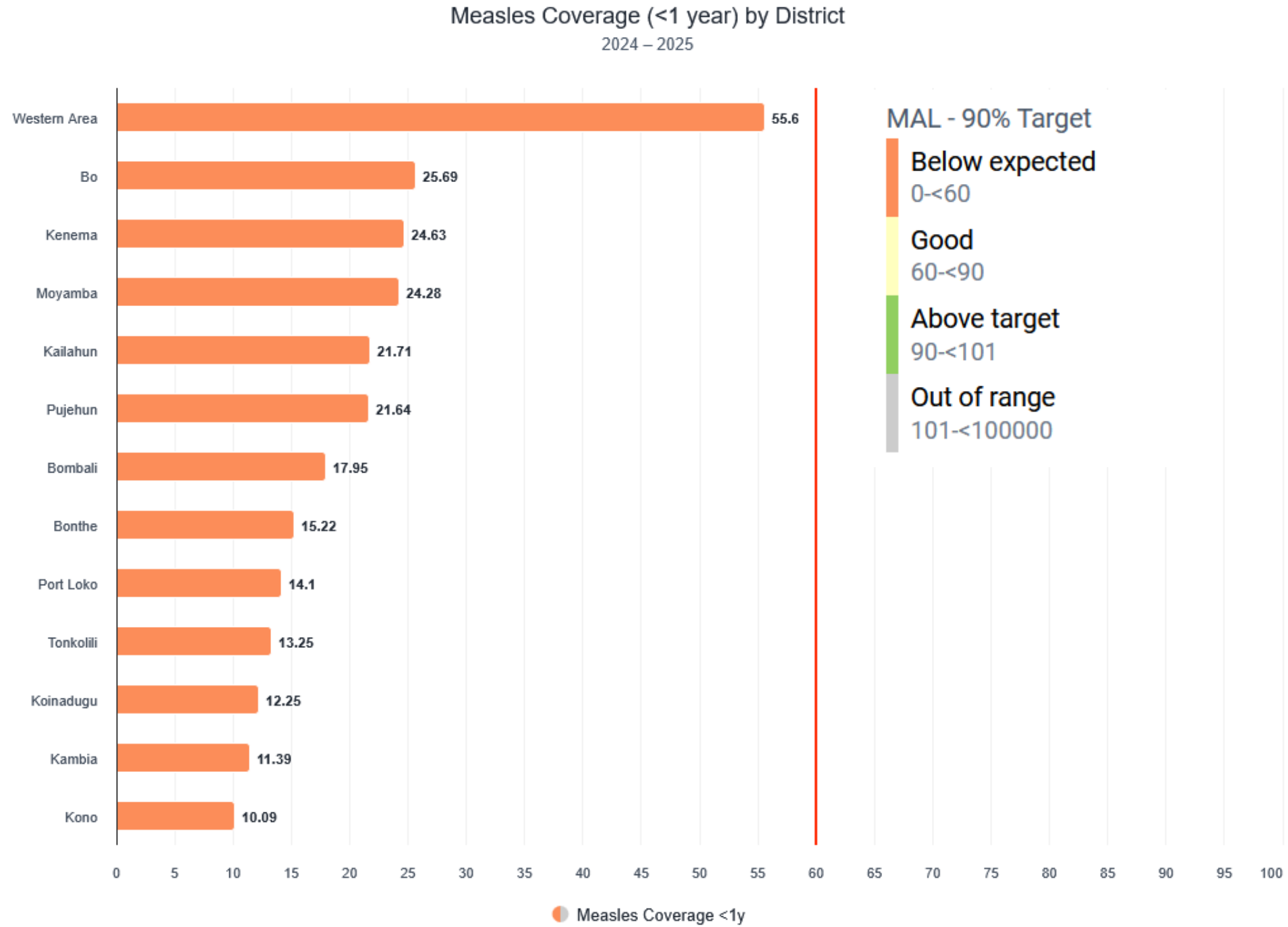
Measles Coverage <1y

Organization unit

District, Chiefdom, Facility (allows for in-map drill-down)

Period

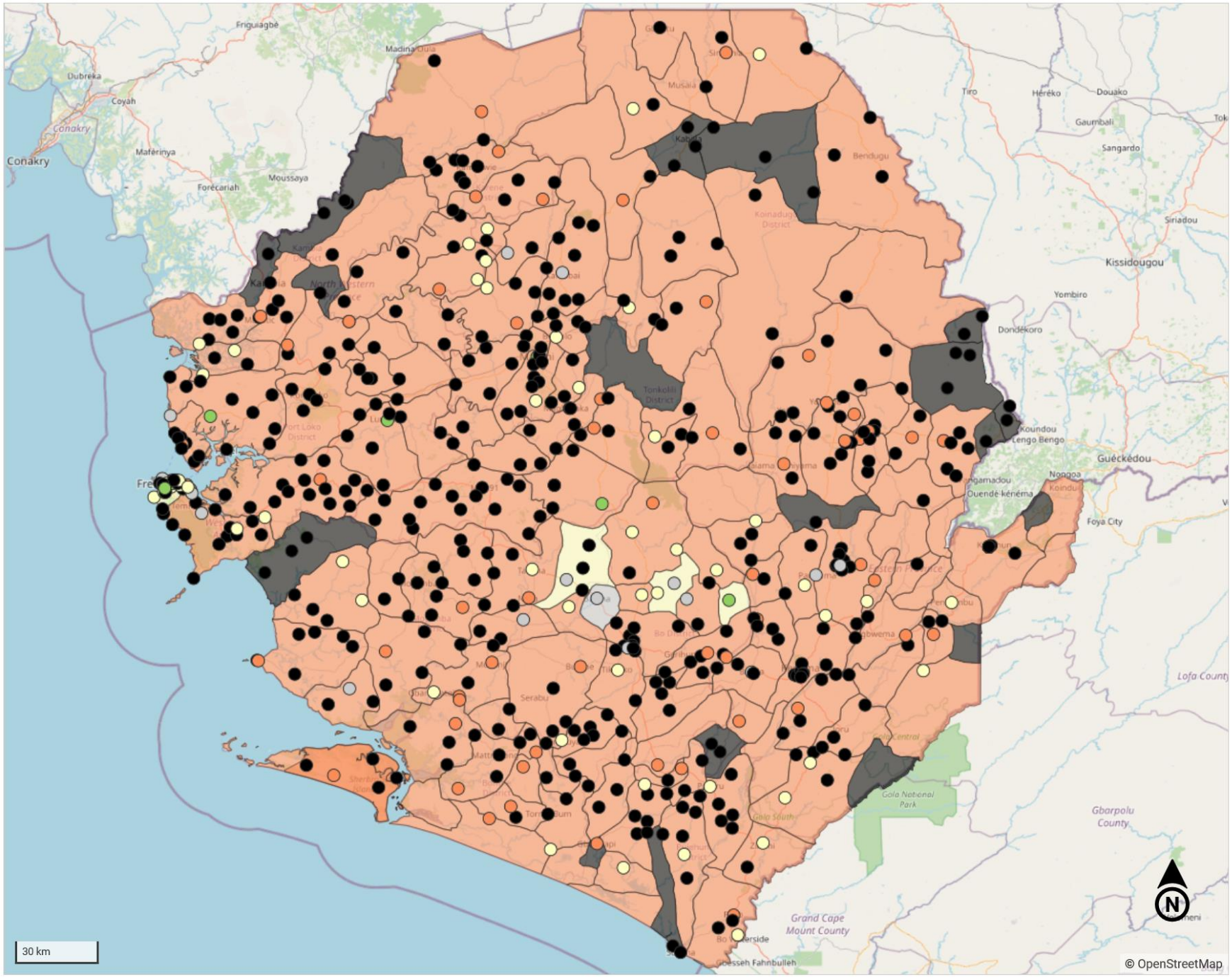
2024, 2025 (Yearly)




District-level measles coverage remains far below the 60% benchmark across Sierra Leone, with even the highest-performing district (Western Area) reaching only 55.6%. Most districts fall between 10–26%, again highlighting a widespread national gap rather than isolated low-performing areas.

# G3_Q5 - Drill-down Cheifdom and Facility Measles coverage

Analyzes measles coverage target (60%) for children less than 1yr, broken down by chiefdoms and facilities.




**Measles Coverage <1y**
2024, 2025

- Below expected 0 - 60 (60)
- Good 60 - 90 (53)
- Above target 90 - 101 (10)
- Out of range 101 - 100000 (21)
- No data (457)

**Measles Coverage <1y**
2024, 2025

- Below expected 0 - 60 (129)
- Good 60 - 90 (4)
- Above target 90 - 101 (0)
- Out of range 101 - 100000 (1)
- No data (18)

## Chiefdoms

| 2024, 2025 | | | | | |
|---|---|---|---|---|---|
| | Stock PHU dispensed Measles | Measles Doses <1y | Total population < 1 year | Measles Coverage <1y - Calc | Measles Coverage <1y |
| Bramaia | 104 | | 1 284.98 | 0 | |
| Gbinleh Dixion | 208 | | 961.99 | 0 | |
| Bendu Cha | 228 | 62 | 123.5 | 8.1 | 25.07 |
| Mafindor | 244 | | 250.5 | 0 | |
| Toli | 302 | | 206 | 0 | |
| Dema | 318 | 92 | 215 | 18.6 | 21.37 |
| Gbane Kandor | 318 | | 229.5 | 0 | |
| Sittia | 330 | 206 | 375.5 | 35.15 | 27.39 |
| Mambolo | 334 | 395 | 1 760.48 | 7.1 | 11.2 |
| Kpanga Krim | 342 | | 177 | 0 | |
| Gbo | 344 | 241 | 118 | 91.53 | 101.98 |
| Selenga | 350 | 216 | 227.5 | 0 | 47.41 |
| Langrama | 382 | | 187 | 0 | |

## Facilities

| 2024, 2025 | | | | | |
|---|---|---|---|---|---|
| | Stock PHU dispensed Measles | Measles Doses <1y | Total population < 1 year | Measles Coverage <1y - Calc | Measles Coverage <1y |
| Wellington Health Centre | 4 674 | 3 990 | 1 375.48 | 38.39 | 144.84 |
| Kissy Health Centre | 3 630 | 2 483 | 1 328.98 | 35.97 | 93.29 |
| Matotoka CHC | 3 320 | 182 | 237.5 | 28.47 | 38.26 |
| PMO Clinetown | 2 880 | | 2 474.47 | 0 | |
| Kroo Bay CHC | 2 802 | 2 090 | 687.99 | 153.35 | 151.68 |
| Ginger Hall Health Centre | 2 240 | 1 447 | 578.49 | 139.16 | 124.9 |
| George Brook Health Centre | 2 076 | 1 219 | 924.99 | 8 | 65.8 |
| St Anthony clinic | 1 976 | 1 708 | 1 254.48 | 13.39 | 67.98 |
| Jenner Wright Clinic | 1 912 | 1 292 | 682.99 | 42.17 | 94.45 |
| Lunsar CHC | 1 896 | 913 | 454.49 | 147.86 | 100.3 |
| Tombo CHC | 1 728 | 814 | 677.49 | 107.46 | 59.99 |
| Masuba MCHP | 1 722 | | 1 393.98 | 0 | |
| UFC Magburaka | 1 720 | | 777.49 | 0 | |

This map shows that measles coverage remains below the 60% target across nearly all chiefdoms, with the lowest-performing areas also containing the highest concentration of “no-data” facilities. The clustering of non-reporting facilities in remote, hard-to-reach regions suggests that the appearance of low coverage is driven by both true service gaps and significant under-reporting in these areas.

Additionally, many chiefdoms and facilities show high measles vaccine stock dispensed but zero or missing doses recorded, indicating data quality and reporting gaps rather than a true absence of immunization services. These reporting lapses are concentrated in rural and hard-to-reach areas, suggesting that low coverage values often reflect limited data visibility rather than low vaccination activity.

# Question 6

Based on the above evaluation, can you describe the type of trend of low measles vaccination coverage? Add the visualization that you think is most appropriate for such analysis on the slides.

- **Time-Based Trend:** Monthly measles coverage remains chronically low throughout 2024–2025, with all months falling far below the 60% threshold and showing only modest fluctuations—indicating persistent systemic challenges rather than temporary disruptions. There is a slight positive trend.
- **Geographic Trend:** Low coverage clusters in remote and hard-to-reach districts where facilities are dispersed, road access is limited, and chiefdoms show widespread gaps in service visibility, suggesting that geographic barriers strongly shape immunization outcomes.
- **Reporting/Data Quality Trend:** Many facilities display high measles stock issuance but zero or missing doses administered, revealing substantial under-reporting and data completeness issues that artificially depress coverage values and obscure true performance.

Together, the line graph, district bar chart, and drill-down map provide complementary perspectives—showing *when* coverage is low, *where* it is most affected, and *why* gaps in reporting and access contribute to the national shortfall.

# Question 7

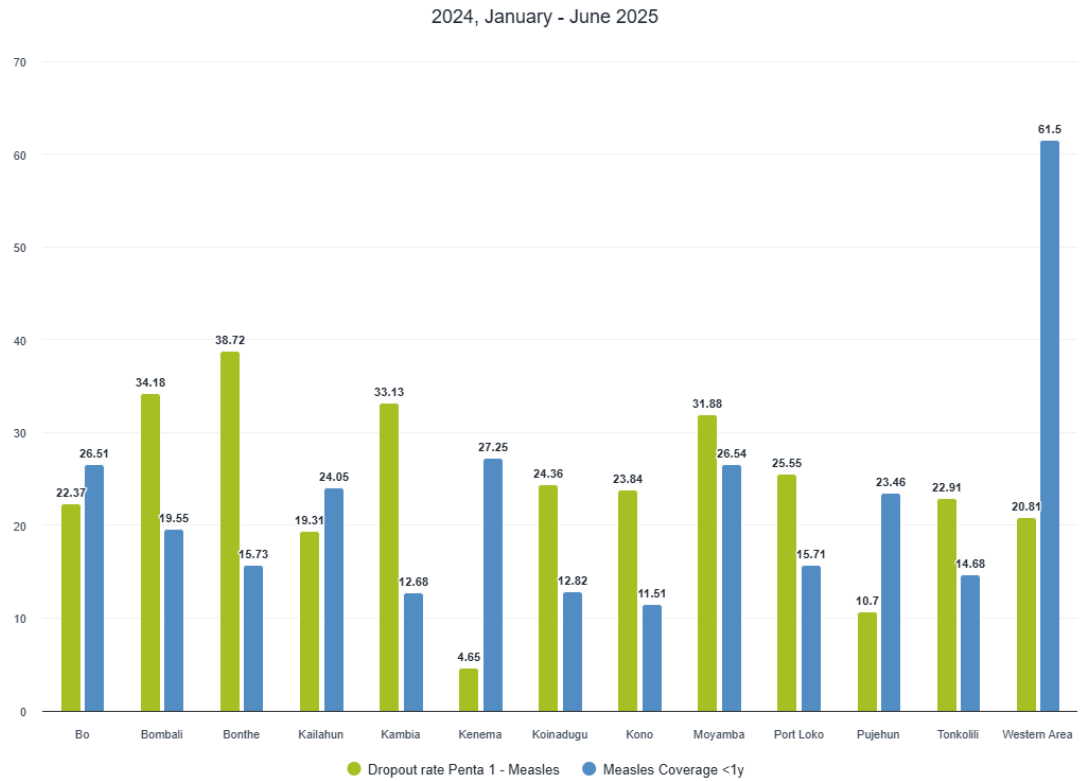
Create a bar chart comparing the Dropout Penta 1 -measles and measles coverage < 1y for all the districts in Sierra Leone for 2024 and the first 6 months of 2025. Do you see a correlation between these two indicators? Analyze the correlation and interpret the results.

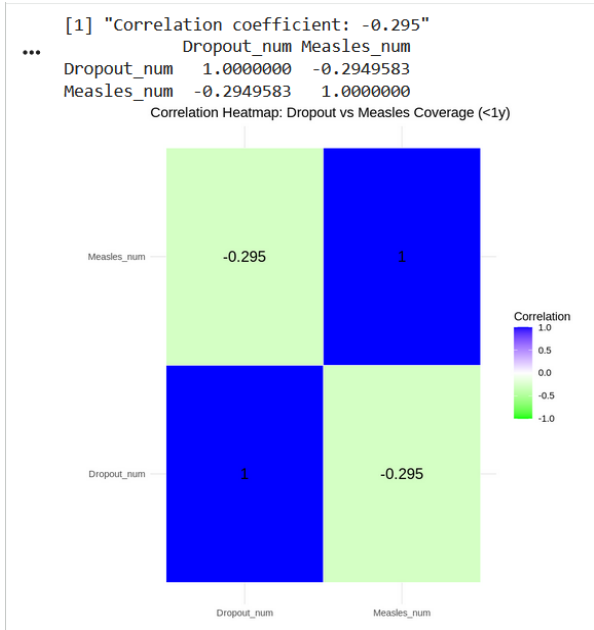
## Q7: Results and Interpretation

The bar chart compares Dropout rate (Penta1 → Measles) and Measles Coverage <1 year across all districts in Sierra Leone from January 2024 to June 2025. Overall, the chart reveals substantial variation across districts, with no strong or consistent inverse relationship between dropout rates and measles coverage.

The Pearson correlation coefficient between Dropout rate (Penta1 → Measles) and Measles Coverage <1 year is –0.295. This indicates a weak negative correlation. In practical terms, this means that districts with higher dropout rates tend to have slightly lower measles coverage, but the relationship is not strong.

While reducing dropout may contribute to small improvements in measles coverage, broader system-level and operational issues must also be addressed to achieve substantial gains in immunization performance.



Child Malnutrition

General Malnutrition

Severe Malnutrition

# Question 3a

Where is the chiefdom with the lowest malnutrition rate located in the geography of Sierra Leone? Name the Chiefdoms near the capital city of Sierra Leone which have high malnutrition rate. Hint: Use Google streets layer to find the capital city.

**Steps**

**Initial Indicators:**

- Weight for height <70% rate
- Weight for height 70-79% rate

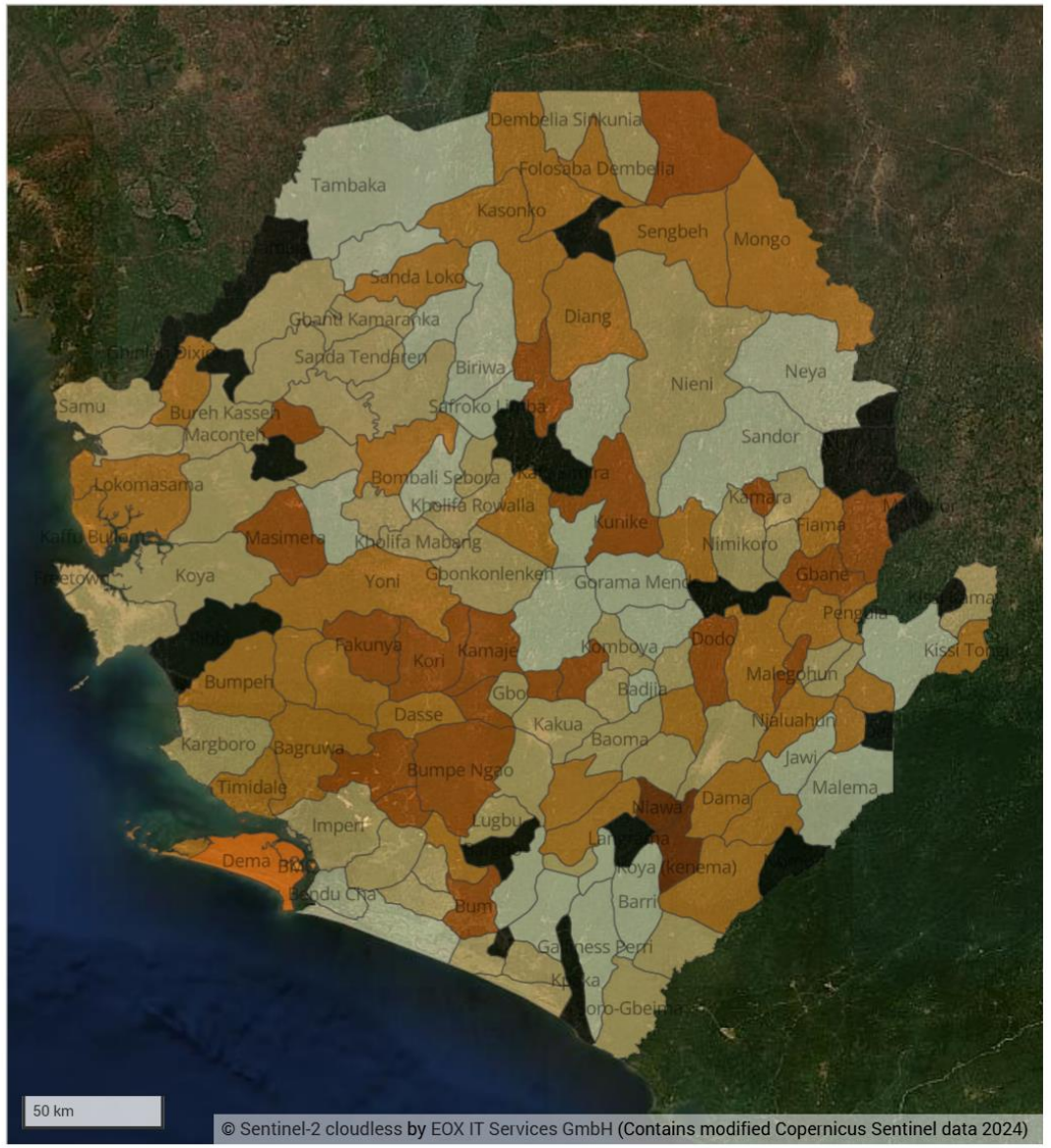
**Derived Indicator:**

- Weight for height <79% rate
  - Encompasses both severe and moderate malnutrition

**Data:**

Indicators
Weight for height <79% rate

Organization unit
Chiefdom
Period
2024, 2025




**G3_Q3a - Total Malnutrition Rates**

**Weight for height <79% rate**

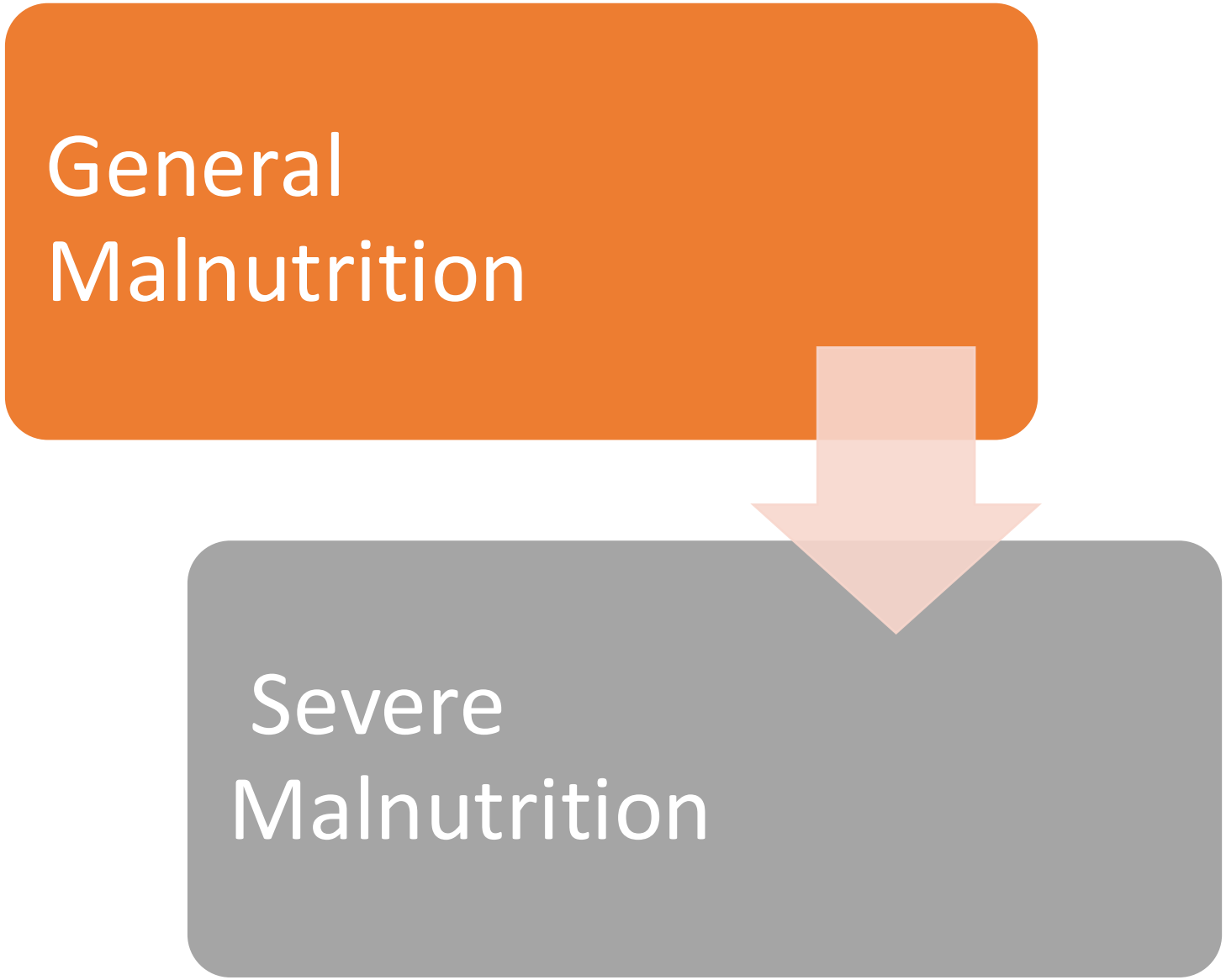
2024, January 2025, February 2025, March 2025, April 2025, May 2025, June 2025, July 2025, August 2025, September 2025

- 2.6 - 17 (25)
- 17 - 31.3 (48)
- 31.3 - 45.6 (37)
- 45.6 - 59.9 (21)
- 59.9 - 74.3 (2)
- No data (19)

**Lowest:** Malema (2.4)

**Highest near Freetown:**
Kaffu Bullom (33.21)
Lokomasama (34.77)

# Malnutrition



# Question 3b

By analyzing the monthly choropleth maps of 2024 and 2025 for severe malnutrition rate by district using a computer vision algorithm, how well can you predict (given the same legend) the severe malnutrition rate of Bo district for November 2025, if all the other districts malnutrition rate is shown on the map.

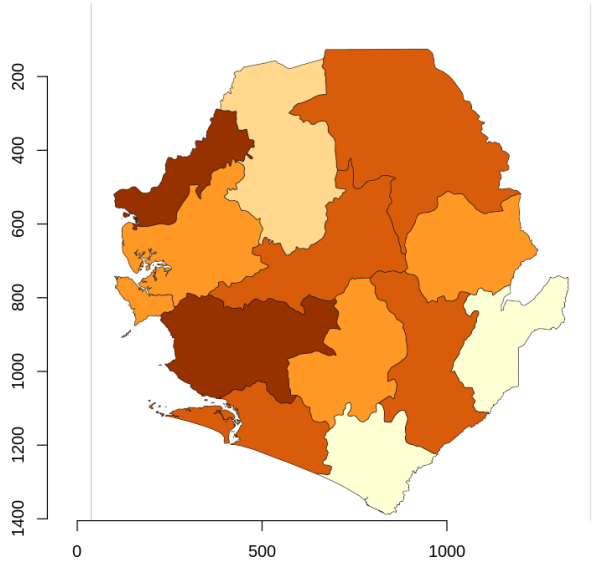
# Methodology: Data Preparation

1. **Data Collection:** 21 monthly choropleth maps (Jan 2024–Sep 2025)
2. **District Segmentation:** Generated district masks by selecting a representative pixel in each district and expanding it using a region-growing algorithm
3. **Numeric Dataset:** Date, district name, malnutrition rate
4. **Binning:** Created six bins based on data distribution
5. **Legend and Map Recoloring:** Fixed palette (yellow → orange → red) based on bins; district masks recolored to match

**Result:** 21 standardized maps (.png)

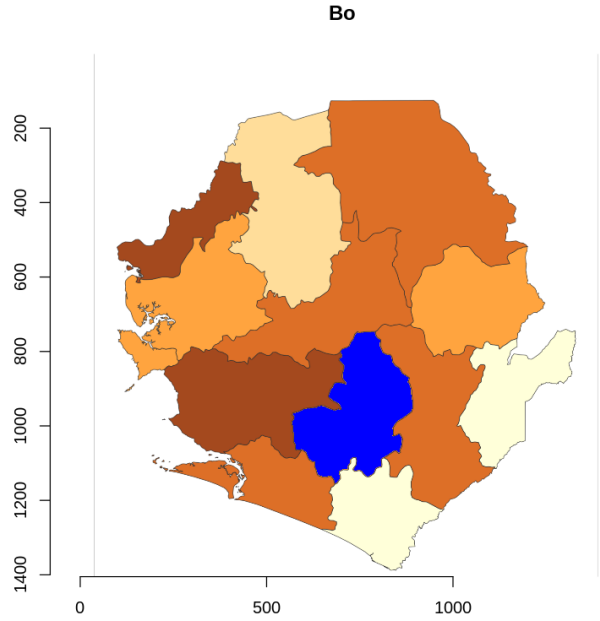
# Methodology: Data Preparation

**1. Data Collection**



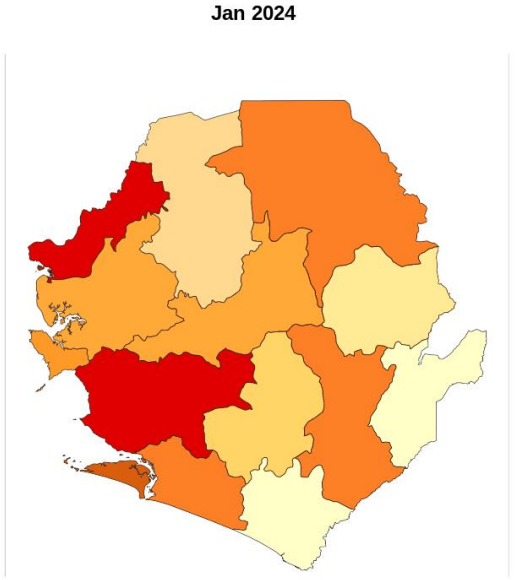

Original Map (Jan 2024)

**2. District Segmentation**




Growing Region for Bo

**5. Legend and Map Recoloring**




Recolored Map (Jan 2024)

# Methodology: Modeling

1. **Train/Test Split:** Months 1–14 for training and months 15–20 for testing. Month 21 (Sep 2025) was withheld to avoid information leakage.
2. **Image Preprocessing:** Each map was converted into a standardized numerical tensor, then stacked into 4D tensors suitable for CNNs.
3. **Label Preparation:** Extracted Bo district's malnutrition bin for each month converted it into integer and one-hot formats for model training.
4. **Model Build:** Used ResNet50 pretrained on ImageNet as a frozen feature extractor and added a small classification head (GAP → Dense → Dropout → Softmax) to predict 1 of 6 bins.
5. **Training:** Custom head was trained (ResNet50 frozen) using the training set for 30 epochs with a batch size of 2, and performance was validated on the test set.

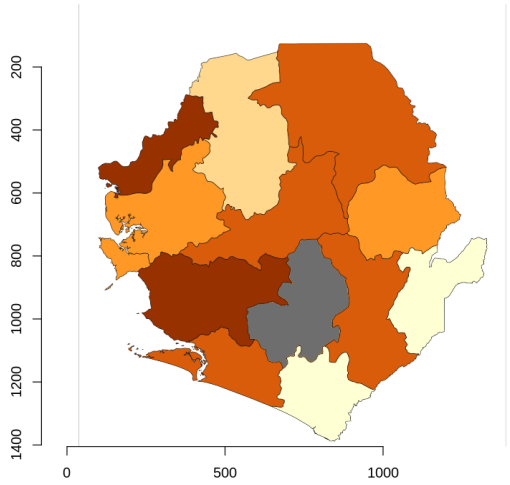
# Methodology: Modeling

**Unmasked Model:**

- The model is trained and validated on full map images, **including Bo district**.

**Masked model:**

- Bo district in each map is removed and replaced with a neutral color. The model must infer Bo's malnutrition bin using information from **other districts only**



# Results: Bo Malnutrition for Sep 2025

**True Bo Bin:** 4–<5

**True Malnutrition Rate:** 4.79

**Predicted Bin (Unmasked):** 5–<6

**Predicted Bin (Masked):** 5–<6

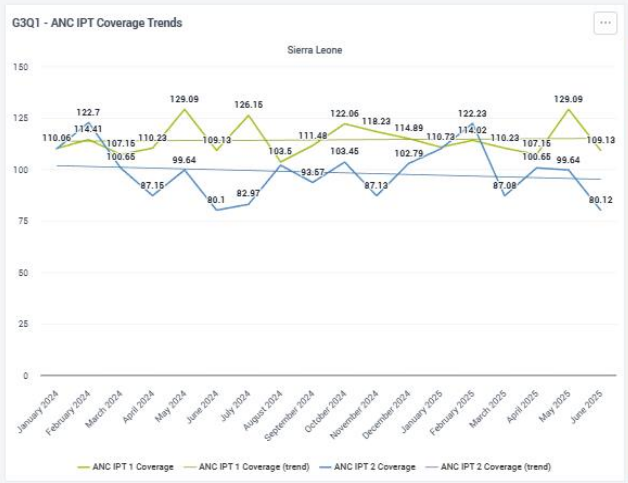
**F1 Score** for both: 0.667

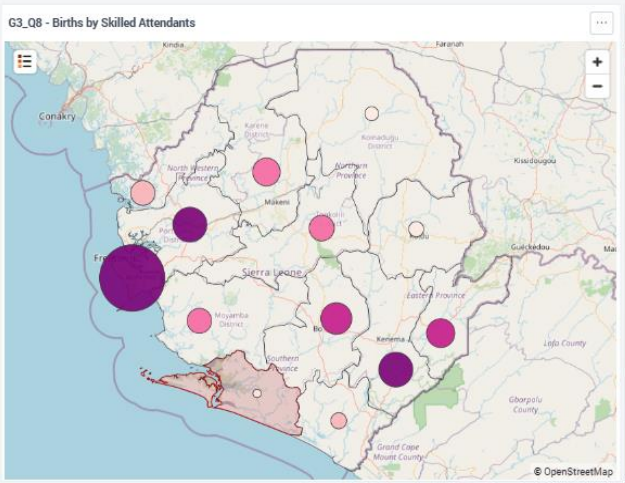
| bin | Unmasked prob | Masked prob |
|---|---|---|
| 0–<4 | 0.008617246 | 0.011142994 |
| 4–<5 | 0.219855204 | 0.208571613 |
| 5–<6 | 0.421176523 | 0.444702476 |
| 6–<7 | 0.288796067 | 0.265611470 |
| 7–<9 | 0.053368282 | 0.062812224 |
| 9+ | 0.008186695 | 0.007159117 |

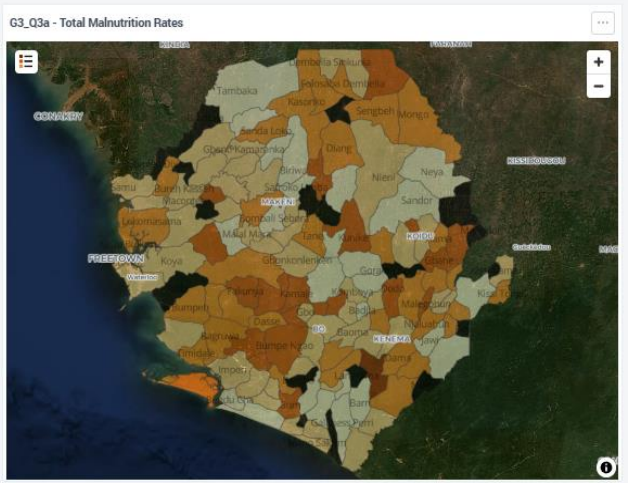
# Question 9

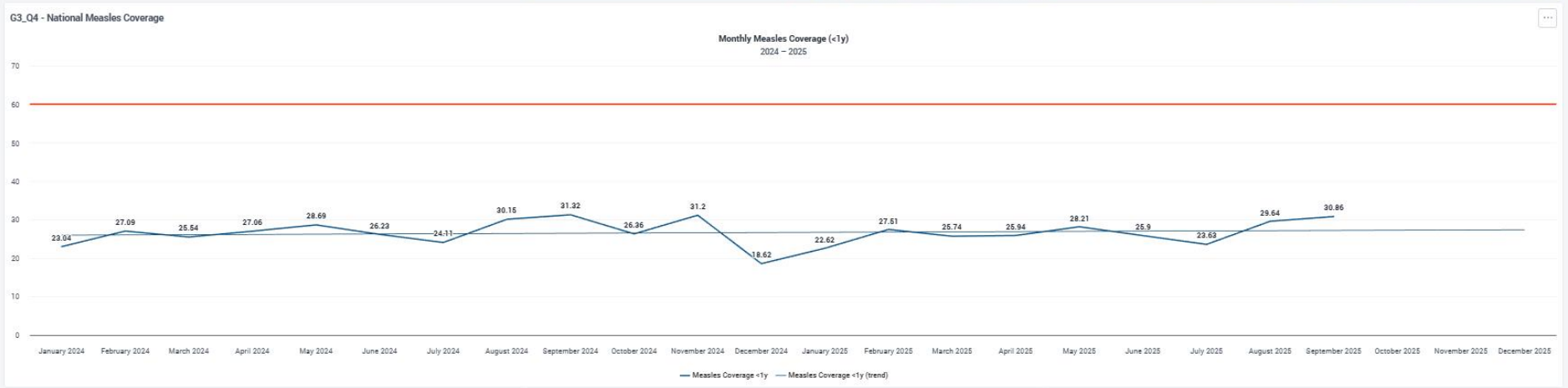
Create a new dashboard of the charts/maps/tables used to answer the above questions.

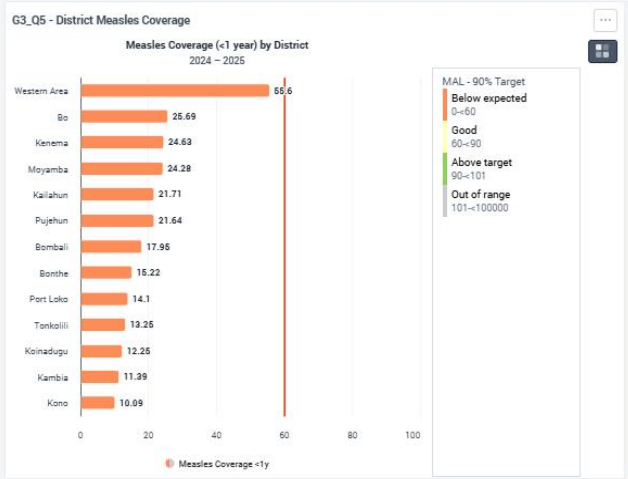
# Dashboard

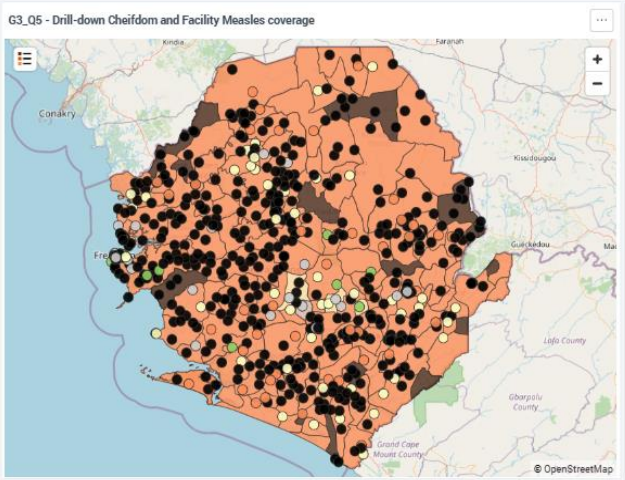

G3Q1 - ANC IPT Coverage Trends
Sierra Leone
ANC IPT 1 Coverage
ANC IPT 1 Coverage (trend)
ANC IPT 2 Coverage
ANC IPT 2 Coverage (trend)

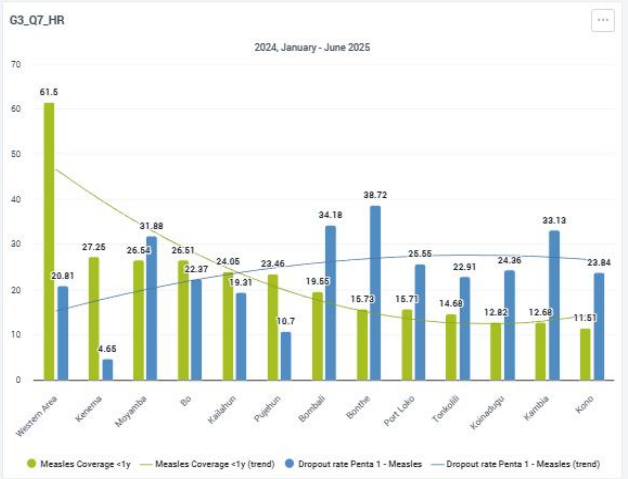

G3_Q8 - Births by Skilled Attendants
© OpenStreetMap


G3_Q3a - Total Malnutrition Rates


G3_Q4 - National Measles Coverage
Monthly Measles Coverage (<1y)
2024 – 2025
Measles Coverage <1y
Measles Coverage <1y (trend)


G3_Q5 - District Measles Coverage
Measles Coverage (<1 year) by District
2024 – 2025
MAL - 90% Target
Below expected
0-<60
Good
60-<90
Above target
90-<101
Out of range
101-<100000
Western Area
Bo
Kenema
Moyamba
Kailahun
Pujehun
Bombali
Bonthe
Port Loko
Tonkolili
Koinadugu
Kambia
Kono
Measles Coverage <1y


G3_Q5 - Drill-down Cheifdom and Facility Measles coverage
© OpenStreetMap


G3_Q7_HR
2024, January - June 2025
Measles Coverage <1y
Measles Coverage <1y (trend)
Dropout rate Penta 1 - Measles
Dropout rate Penta 1 - Measles (trend)

# Question 10

Describe any three validation rules that are appropriate to validate data that you have used in your analysis (from any of the above questions). What are some of the quality issues with the data that you used for your analysis?

# Data Quality Issues Identified in the Analysis

**1. Widespread missing values for doses administered (<1 year)**

Many facilities reported **stock but no doses**, leading to artificially low or zero coverage. This distorted district and chiefdom averages.

**2. Inconsistent or outdated population denominators**

Some facilities showed extremely small or unusual “population <1” values, producing coverage estimates >100% or creating volatility across months.

**3. Facilities not reporting at all despite receiving vaccines**

Black dots on the map (no-data facilities) often corresponded to remote locations; these non-reporting sites cause large geographic blind spots in the dataset.

**4. Over-reporting or duplicate entries in high-volume urban facilities**

A few facilities showed implausibly high doses relative to expected catchment size, suggesting reporting duplication or incorrect data element selection.

**5. Spatial reporting biases**

Urban facilities consistently reported complete data, while rural, riverine, and hard-to-reach chiefdoms showed data gaps—indicating systematic geographic bias in reporting.

# Validation Rules

**1. Live births + Still births = Total births (consistency rule)**

**Rule:**
Live_Births + Still_Births = Total_Births
**Rationale:**
This ensures internal consistency in birth reporting. If the sum does not equal the reported total, it indicates data entry errors or incomplete reporting by the facility. This rule is important because total births are foundational denominators for maternal and child health indicators used in earlier questions.

**2. Measles stock dispensed < Measles stock existing (inventory rule)**

**Rule:**
Measles_Stock_Dispensed ≤ Measles_Stock_On_Hand
**Rationale:**
A facility should never dispense more measles vaccine doses than the stock it has available. Violations indicate supply chain reporting errors, incorrect stock recordings, or misaligned reporting periods. In your dataset, some facilities reported high stock but zero doses, while others showed mismatches between stock flow and service delivery—making this an essential validation rule.

**3. Population under 1 year < Population under 5 years (demographic rule)**

**Rule:**
Population_<1yr < Population_<5yr
**Rationale:**
Demographically, the number of children aged <1 should always be smaller than the number of children <5. If the <1 population exceeds the <5 population, it signals errors in population estimates, catchment definitions, or denominator assignments. This rule is critical because incorrect denominators lead to impossible coverage values such as >100% or erratic monthly fluctuations observed in the dataset.

# Appendix

# Question 2

**Step 1: Prepare the data**
Import the ANC IPT 2 coverage data for Western Area (Jan 2024–Nov 2025) and convert it into a monthly time series object.

**Step 2: Fit SES models**
Apply **Simple Exponential Smoothing (SES)** using two smoothing parameters:

- **α = 0.3** (gives smoother forecasts, less responsive to recent changes)
- **α = 0.7** (places stronger weight on recent observations)

Applied Simple Exponential Smoothing (SES), which models only the level component (no trend or seasonality).

**Step 3: Generate the December 2025 forecast**
Use each SES model to produce a **one-step-ahead forecast** for December 2025.

**Step 4: Evaluate forecasting performance**
Extract the model's **one-step-ahead fitted values** for the last sixhistorical months (Jun–Nov 2025) and compare them with theactual data.
Compute:

- Forecast values
- Forecast errors for each month
- MAPE for the 6-month evaluation period

**Step 5: Visualize the results**
Plot:

- Jan 2024–Nov 2025 actual coverage (black line)
- Forecast projections from November to December (dashedlines)
- Forecast points for December (blue for α = 0.3, red for α =0.7)

## Question 3b Model Fit

```
====================================
        Confusion Matrix
====================================
      Pred
Truth  0-<4 4-<5 5-<6 6-<7 7-<9 9+
  0-<4    0    0    0    0    0  0
  4-<5    0    0    0    0    0  0
  5-<6    0    0    4    0    0  0
  6-<7    0    0    2    0    0  0
  7-<9    0    0    0    0    0  0
  9+      0    0    0    0    0  0
```