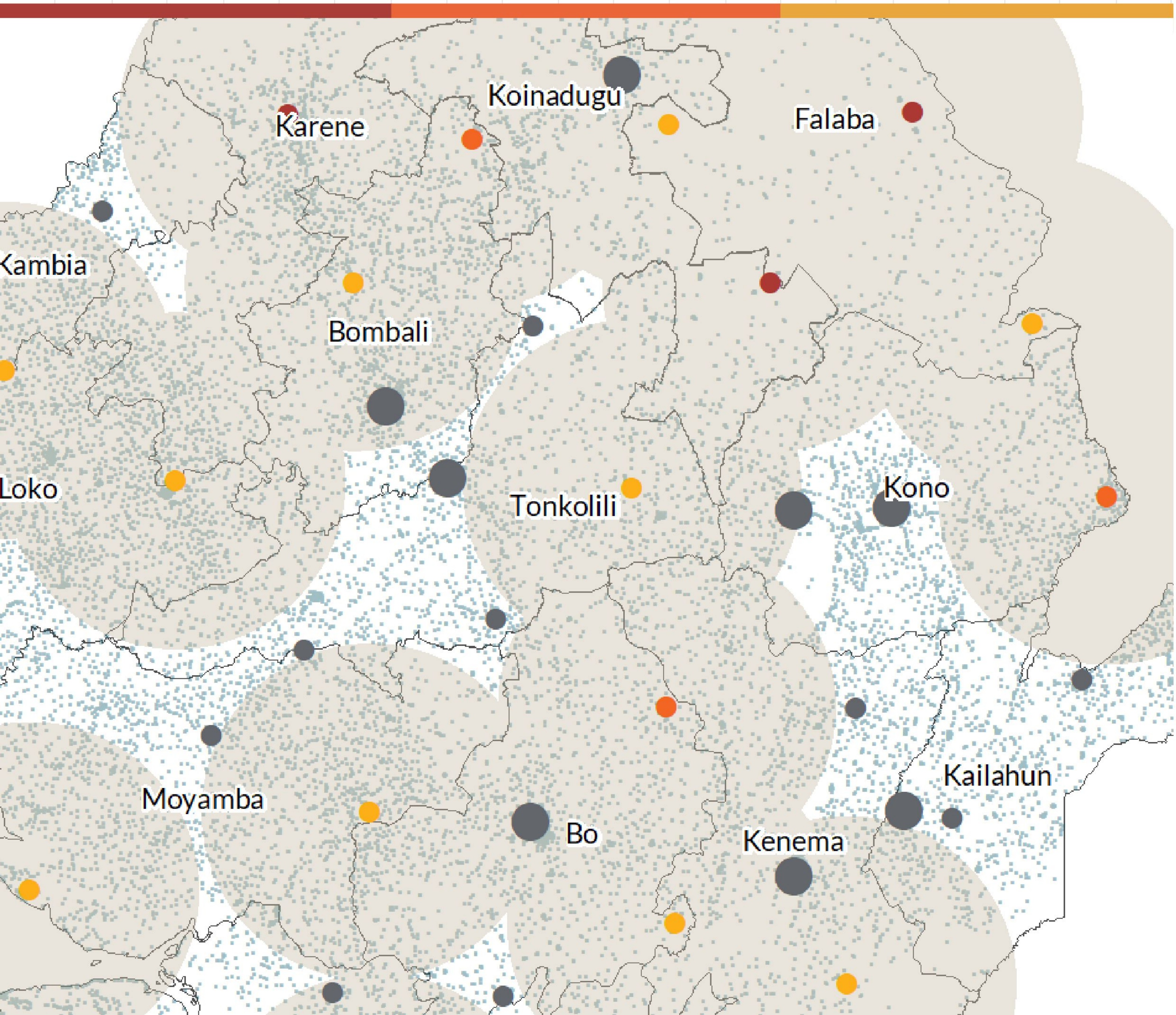
Radio Transmitter Coverage in Sierra Leone

July 2021



List of contents

Executive summary

This project is part of a continued collaboration between Sierra Leone's Ministry of Basic and Senior Secondary Education (MBSSE, referred henceforth as "the ministry") and GRID3. There were three goals at the outset. First, gauging the proportion of school-age children covered by the ministry's Education Radio "Radio Teaching Program," which is delivered via nine Education Radio transmitters distributed throughout the country. Assuming coverage was not nationwide, the second goal was to assess other known transmitters in the country for their potential to improve coverage. The final goal was to recommend locations for new transmitters to fill any remaining gaps in coverage.

An analysis was conducted by GRID3 and mirrored these requests by using a three-phase structure. Coverage areas of the Education Radio transmitters were generated using the Longley-Rice model for estimating radio wave propagation. A raster zonal statistics method was applied to these coverage areas on gridded population estimates created jointly by Statistics Sierra Leone and GRID3 (WorldPop and Statistics Sierra Leone, 2021). This analysis revealed that approximately 66 percent of school-age children (3-17 year olds) live within the signal range of a transmitter. For the second phase, the transmitters of 143 local radio stations were deduped and filtered to those outside strong signal areas of Education Radio transmitters. The remaining 14 "alternative transmitters" were ranked in descending order based on the number of unserved school-age children living within a circular area derived from a 40km radius, a figure chosen as a simplified estimate of signal range. The inclusion of these 14 transmitters increased the signal coverage of school-age children to 91 percent. Finally, a optimisation method, designed by the GRID3 team at Flowminder, was used to find locations for new transmitters in two scenarios, again based on a 40km signal radius. Radio transmitters and the 14 alternative transmitters, while Scenario 2 filled spaces among Education Radio transmitters only.

Under Scenario 1, an estimated 3 new transmitters would be required on top of the 14 alternative transmitters to increase coverage to 96 percent of school-age children, with diminishing returns thereafter due to the fragmentation of areas of poor coverage. Twenty-one (21) new transmitters in total would be needed to achieve 100 percent coverage. Scenario 2, which does not make use of alternative transmitters, would require 32 new transmitters in total to reach 100 percent of school-age children. The three top-ranked transmitters from this scenario would increase coverage to approximately 78 percent.

Recommendations include: validation of the estimated coverage areas of the Education Radio transmitters; further assessment of alternative transmitters (on criteria such as transmitter characteristics and prioritisation of high-ranked new transmitters); and taking a multifaceted approach to improving the Radio Teaching Program (specifically, one that acknowledges other compromising factors, such as access to radio receivers and electricity).

Context

School types and the Radio Teaching Program

Basic and secondary education in Sierra Leone fall into four school categories, each focusing on students from a different age cohort. Pre-primary schools cater to pupils aged between 3 and 5 years, Primary schools teach 6-11 year olds, Junior Secondary schools are for 12-14 year olds, and 15-17 year olds attend Senior Secondary schools. All students access the same Education Radio, with programs transmitted at different times for the different school categories.

Under ordinary circumstances pupils attend school in person, but during the 2014-2016 Ebola crisis all education institutions were forced to shut their doors to reduce transmission of the virus. In an effort to continue educating pupils remotely, the Radio Teaching Program was developed, with experienced teachers recording lessons for broadcasting. Over 80,000 portable radios were distributed to ensure that children could tune into these lessons. The experience of deploying this scheme meant that the ministry was well placed to roll it out again in response to the spread of COVID-19 in 2020 (Global Partnership for Education, 2020).

However, survey data collected by the Institute for Governance Reform and Oxfam Sierra Leone (2021) revealed that certain areas (namely rural districts such as Pujehun and Falaba) had low access to the Radio Teaching Program due to the lack of contiguous Frequency Modulated (FM) radio transmitter coverage and the limited availability of receivers. Identifying gaps in FM coverage is the concern of the ministry and this report, along with recommendations for how these gaps might best be filled in line with the ministry's Policy on Radical Inclusion in Schools. A first step towards understanding this issue is to determine the proportion of children from each school age group who live within coverage range of a transmitter (either specific to the Education Radio or other community radio stations) and therefore are able to access the scheme. This step will be followed by phases that assess the suitability of other existing transmitters for inclusion in the programme and suggest new sites to fill any remaining gaps.

Modelling transmitter propagation

FM radio transmitters propagate waves in all directions, with waves reaching receivers either directly (known as free space or line of sight propagation) or via reflection from the ground/an object. The spatial extent of the area of successful propagation with discernable audio for the recipient is determined by frequency of propagation, the power of the transmitter, and its elevation. Direct propagation can be disrupted by terrain features, buildings and foliage, and changes in conditions in the lower atmosphere (Sizun and de Fornel, 2005).

Given these factors, modelling transmitter coverage is complex, requiring information on the environment and the transmitter itself. Geographical Information Systems (GIS) have been used in the past to create these models, relying on techniques such as viewshed analysis (i.e. techniques that use elevation models to predict the points that are visible from a fixed location and provide fairly accurate results; see Dodd, 2001). Ajewole et al. (2012) took an alternative approach, using signal strength readings on the ground to map contour lines representing different strengths. This enabled them to distinguish between different classes of coverage area. In the primary area, the strength of the signal is consistently able to override any local interference. The secondary area has a slightly weaker signal that sometimes suffers from interference, while the fringe coverage area only occasionally has useful signal strength. These classes correspond directly to quantifiable signal strengths.

Various purpose-built tools are also available for estimating propagation. Freely available software includes SPLAT! and Radio Mobile, both of which use the Longley-Rice model (also known as the Irregular Terrain Model) to return estimated coverage areas. This model incorporates elevation and transmitter characteristics to calculate transmission loss over terrain, which can then be presented as coverage areas of differing signal strength. It does not take factors such as clutter from buildings or vegetation into account, but it is suitable for high-powered transmissions over relatively long ranges, since it was developed to identify sites for TV broadcast transmitters (Phillips, C., Sicker, D., and Grunwald, 2012). Fratu et al. (2015) compared readings on the ground with simulations from Radio Mobile, Matlab, and ICS Telecom, and found that the Longley-Rice implementations in Radio Mobile and ICS Telecom both returned accurate results.

Considering that this work is looking at coverage on a national scale, the Longley-Rice model is appropriate for deriving coverage areas for the Education Radio transmitters, where some information is known about transmitter characteristics. These coverage areas can then be overlaid on spatial data representing the population of school-age children to approximate how many are in a location that is able to receive discernable audio from an FM radio.

Data

Transmitter locations

The ministry supplied GRID3 with coordinates of the nine existing Education Radio FM transmitters used to broadcast the Radio Teaching Program, as well as coordinates of known transmitters in the country that are currently not used for the initiative (hereafter referred to as "alternative transmitters"). Both Education Radio transmitters and alternative transmitters are visualised in Figure 1. Unsurprisingly, four of the nine Education Radio transmitters are located near major cities: Freetown (in the Western Area Urban District), Bo, Kenema, and Koidu (in Kono District). However, it is also evident from the map that the spatial distribution of these nine towers is not even across the country, with some in relatively close proximity to one another while elsewhere entire districts do not have a tower. Importantly, Bonthe, Kambia, Karene, Moyamba, Port Loko, and Pujehun districts do not have Education Radio transmitters. Depending on the coverage areas, the alternative transmitters may be able to fill many of these gaps.

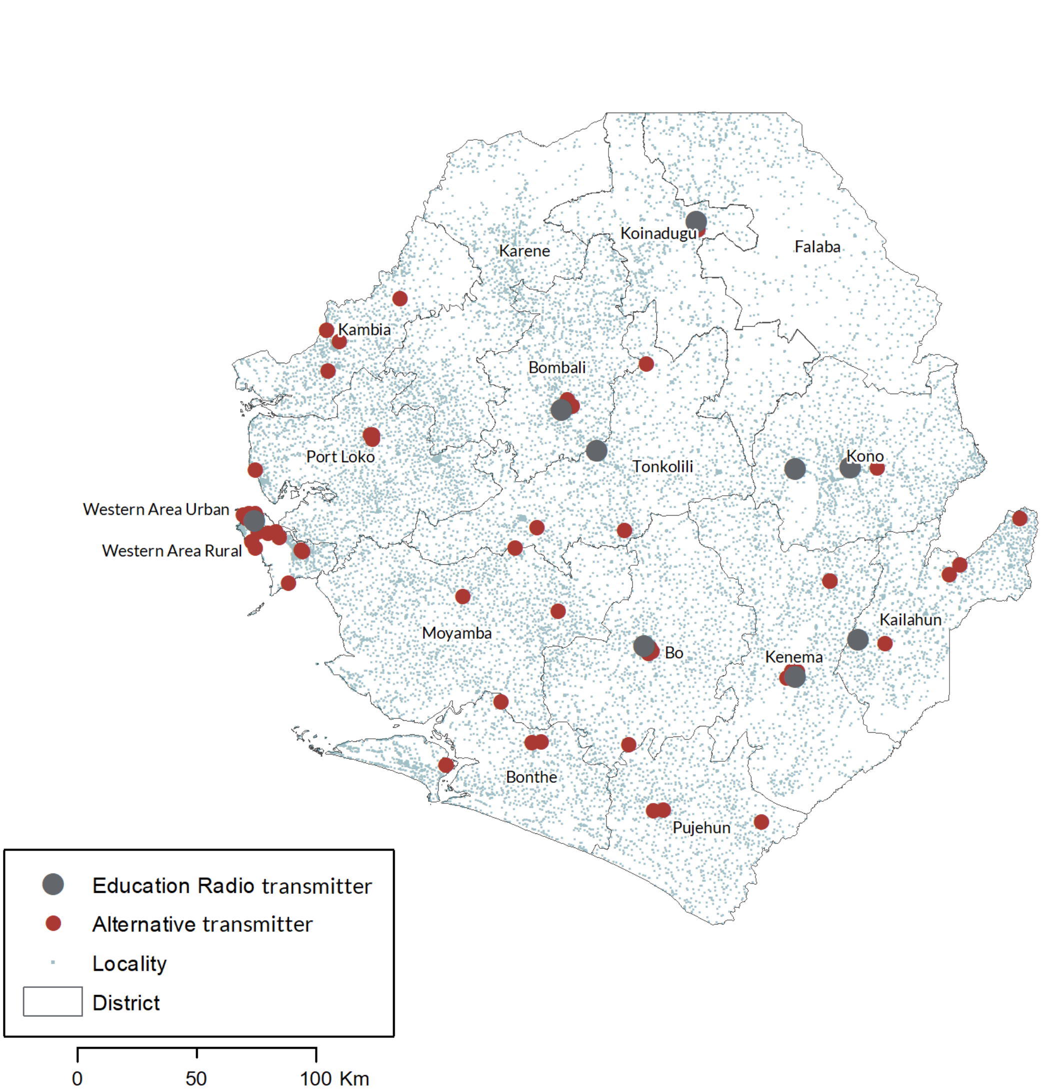


Figure 1: Location of Education Radio transmitters delivering the Radio Teaching Program within Sierra Leone and alternative transmitters not part of the initiative. Dense clusters of localities indicate a major town or city.

Population of school-age children

A layer representing school-age children was required to estimate the proportion within range of each radio transmitter. GRID3 population estimates and disaggregated age breakdowns for children at ~100m x 100m spatial resolution were sourced from Statistics Sierra Leone and WorldPop (2020). These datasets were derived from the results of the 2015 Population and Housing Census in Sierra Leone, provided by Statistics Sierra Leone and the Directorate of Science, Technology and Innovation in Sierra Leone.

As recommended by WorldPop, a penalised composite link model (PCLM) was used at the district level to ungroup these increments into individual years, regroup these years into the school cohorts, and then work out the proportion of the district's total population contained in each cohort. This proportion was used as a multiplier on a raster of total population for cells in the district. The outcome of this method was rasters representing Pre-primary, Primary, Junior Secondary, and Senior Secondary age students, respectively. Each of these rasters had the same distribution and 100m^2 cell size as the original gridded population raster.

Methodology for calculating coverage of Education Radio transmitters

Establishing transmitter coverage

Following the literature review on transmitter propagation and experimentation with freely available tools, Nautel's Radio Coverage Tool was selected to estimate the coverage areas of Education Radio transmitters. This is an online version of the Radio Mobile software, which itself is built on the Longley-Rice model. The Radio Coverage Tool was chosen in favour of Radio Mobile due to its clear user interface and relatively straightforward process for exporting coverage areas into a GIS for further analysis and visualisation. For calculating transmitter elevation and the propagation of radio waves, the tool uses elevation data collected by NASA's Shuttle Radar Topography Mission, which has a resolution of approximately 30m.

To run the tool, coordinates of the Education Radio transmitters were each added manually. Coverage areas for each site were then calculated individually, using the input parameters detailed in Table 1. Note that besides wattage, other parameters were not available for this work; defaults were used instead.

Table 1: Input parameters for Education Radio transmitters when running the Radio Coverage Tool

Parameter	Input used
Frequency (MHz)	103 (default)
Antenna Centre height above the ground (m)	50
System	Custom (allows manual adjustment of power)
Power (watts)	2,000 for the Freetown transmitter, 500 for others
Line loss (dB)	0.3 (default)
Antenna gain (dBi)	3.22
Receiver system	FM car receiver stereo (closest match to a radio on a table or shelf, which is the likely listening scenario)
Maximum range (km)	100 for Freetown, 50 for others

Opacity (%)	40

After the individual transmitter coverage area was calculated by the Radio Coverage Tool, the resulting files were exported and processed using QGIS (an open-source GIS software) to create one vector layer featuring polygons representing strong and weak coverage areas for each Education Radio transmitter. This vector layer was then used to calculate the coverage of school-age children, as described in the next section.

Calculating the proportion of school-age children within strong and weak coverage areas

A script was written in Python that carried out the following steps for each of the four raster files (Pre-primary, Primary, Junior Secondary, and Senior Secondary) representing different school cohorts. These steps were carried out for coverage areas of strong signal and coverage areas of both strong and weak signal:

1. Any overlapping polygons representing transmitter coverage were dissolved into a single polygon to prevent double counting of the population.
2. For each raster, the zonal stats function from the rasterstats package was used to extract the sum of all cells with centre points covered by a polygon.
3. The percentage of population living within the transmitter coverage was calculated by dividing this sum by the sum of all cells in the raster.

Current coverage of Education Radio transmitters

Figure 2 illustrates the areas of Sierra Leone that fall within the estimated maximum transmission range of at least one Education Radio transmitter based on this analysis. Much of the country and more highly populated regions are within range of one or more of the current Education Radio transmitters, but there are disparate locations outside this threshold. Of particular note are the areas between the Freetown transmitter on the west coast and the polygon in the centre of the country representing coverage from the Bombali and Bo transmitters. These potential blank spots include towns in Kambia and Moyamba districts. The biggest contiguous area that might be out of range is in the south of the country, with notable localities including Bonthe Island, Matru, and Gbangbatok. The entire Bonthe and Pujehun districts are currently not covered. It is also worth noting that transmitters in the northeast and east of the country, such as Koinadugu and Kono, provide smaller, less contiguous coverage than those in Bo and Bombali. This can be explained by the bigger variations in elevation in the northeastern and eastern regions of the country, causing disruption to radio wave propagation.

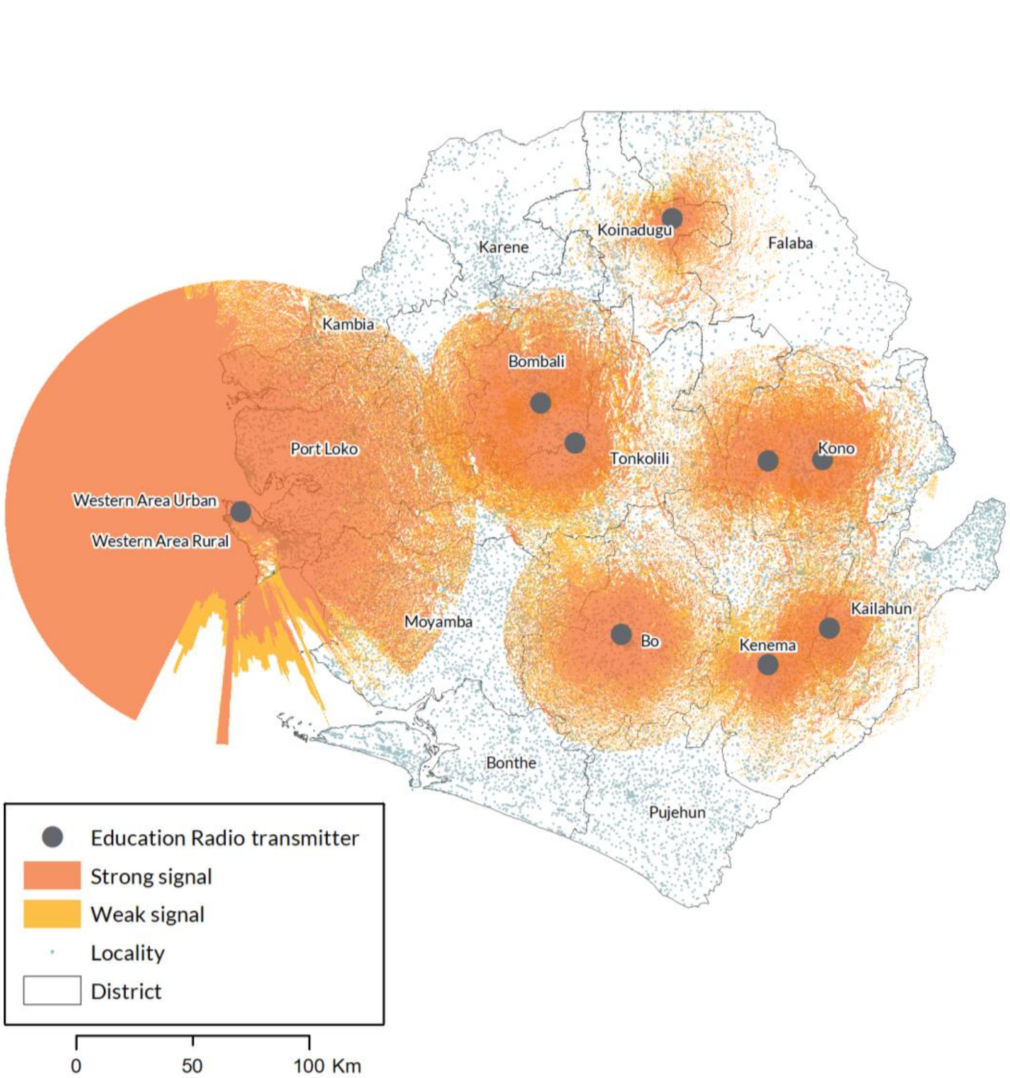


Figure 2: The estimated maximum coverage area of each Education Radio transmitter. Children in strong signal areas are predicted to consistently receive good quality audio while those in weak signal areas may experience some interference.

Having visualised the estimated maximum coverage areas, Table 2 presents the proportion of each school-age cohort covered by these areas. An average of 66.6 percent of all school-age children live within the estimated strong or weak coverage area of at least one transmitter. This figure is optimistic, since this analysis did not take into account obstructions such as buildings or trees (which disrupt transmitter propagation). For strong signal only, an average of 56.4 percent are within the estimated coverage area. Differences between coverage of age cohorts at the various distance thresholds are relatively small, with the biggest being 2.25 percentage points between Junior Secondary and Pre-primary under the "strong only" signal strength. This reflects the co-location of schools in communities.

Table 2: Percentage of each school-age cohort reachable by estimated signal range of transmitters

Signal strength	% Gridded population within estimated signal range of transmitters			
	Pre-primary	Primary	Junior Secondary	Senior Secondary
Strong and weak	66.76	65.45	67.23	66.97
Strong only	56.22	55.05	57.3	57.04

Methodology for identifying suitable additional transmitters

The estimated coverage of the Education Radio transmitters suggests that around a third of school-age children may not be able to receive the broadcasts under the current strategy. To increase the proportion covered, additional transmitters should be considered for inclusion in the initiative. In areas where there are no existing transmitters, new transmitters may need to be constructed. Deciding which additional transmitters might be suitable for inclusion and where new transmitters might be located should happen in a systematic manner, allowing the maximum increase in proportion of coverage for the minimum number of extra transmitters. The optimisation algorithm, a service placement tool, provides this solution.

Inputs

Transmitter characteristics for alternative transmitters and potential new sites were unknown, so a fixed radius was used when generating the coverage areas of these towers. A radius parameter of 40km was chosen based on information from the ministry and the signal strength estimates of the eight 500W transmitters fed into the Radio Coverage Tool. The following inputs were used for ranking of additional transmitters and identification of locations for new transmitters:

- **The locations of alternative transmitters.** These were provided by the ministry as a list of over 143 radio stations registered with the government, some of which use the same transmitters. In a preparatory phase, the list was filtered to ensure it only contained unique transmitters. The remaining transmitters were then buffered to 40km. Any transmitters with buffers that were entirely inside the coverage area of an Education Radio transmitter were removed. Fourteen (14) transmitters remained after this filtering process.
- **Coverage areas of Education Radio transmitters** generated in the previous section.
- **One raster layer for all school-age children.** This was produced by summing the raster layers for each school cohort used in the previous section.

Coverage and ranking of alternative transmitters

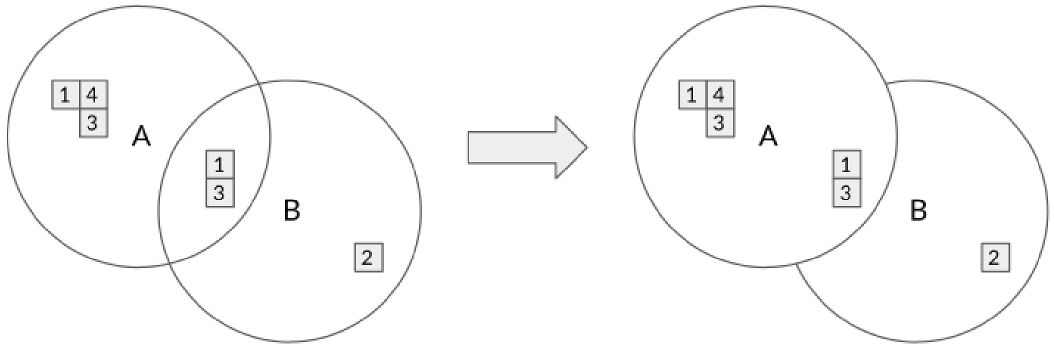
To identify the number of additional children covered by each transmitter and sort them into a hierarchy of biggest to smallest gain, a Python script was written to do the following for the “all school-age children” raster:

1. Generate a new version of the raster layer that excludes any cells underneath the coverage areas of the Education Radio transmitters.
2. Buffer each alternative transmitter to 40km.
3. Use zonal statistics to sum the population in the raster under each buffer, as in the “Unranked” example shown in Figure 3.
4. Rank the buffers from lowest to highest sum.
5. Starting with the buffer that has the lowest sum, remove any sections of the buffer that overlap with other buffers. Extract this “cut” buffer and carry out the same process for subsequent buffers.

6. Using the new cut buffers list, recalculate the sum of the population of school-age children (the "Ranked" example in Figure 3).
7. Re-rank the original buffers according to these sums and repeat steps 5 and 6 until the rank order stops changing.

Unranked: total population within original buffers.

Ranked: B now has a crescent buffer after the overlap with A was removed.



A covers 5 population cells with a sum of 12.
B covers 3 population cells (2 which are also covered by A) with a sum of 6.

A covers 5 population cells, maintaining its sum of 12.
B covers 1 population cell with a sum of 2.
No double counting of population.

Figure 3: Simple example of ranking two buffers of site A and site B to avoid double counting of population cells and to identify the site that should be prioritised because it covers the largest number of people (in this case, site A)

Using the optimisation algorithm to situate new transmitters

The optimisation method was used to place new transmitters in locations that would most efficiently cover any remaining school-age children under two scenarios: children outside the range of any Education Radio or alternative transmitters (Scenario 1) and those outside the range of any Education Radio transmitters only (Scenario 2). This method uses an iterative algorithm to find all non-contiguous areas derived from a 40km radii around local peaks of the uncovered population. New transmitters are placed in these areas and the population within a 40km radius of these new transmitters is removed. The process is repeated until the entire remaining population is within the coverage area of at least one new transmitter (meaning 100 percent coverage has been achieved).

Because multiple transmitters are placed on each iteration, the resulting list of new transmitters is not returned in order of population covered. To establish this order and gain an understanding of which new transmitters should be prioritised, the list was fed into the same ranking method that was used to assess the coverage of the alternative transmitters.

Results

Assessment of alternative transmitters

Figure 4 displays the 14 alternative transmitters that were kept following the filtering process. The map shows that in general the alternative transmitters fill some of the gaps between the estimated coverage areas of the Education Radio transmitters, as well as boosting coverage in areas of potentially low signal strength. Under the scenario of each alternative transmitter having a broadcasting range of 40km, the proportion of all school-age children covered by a strong or weak signal would increase from 66.3 percent to 90.9 percent. For reference, a combination of the Education Radio transmitters and 110 spatially unique alternative transmitters, most of which fall within Education Radio broadcast areas, are estimated to cover 94 percent of the total population (not just school age children).

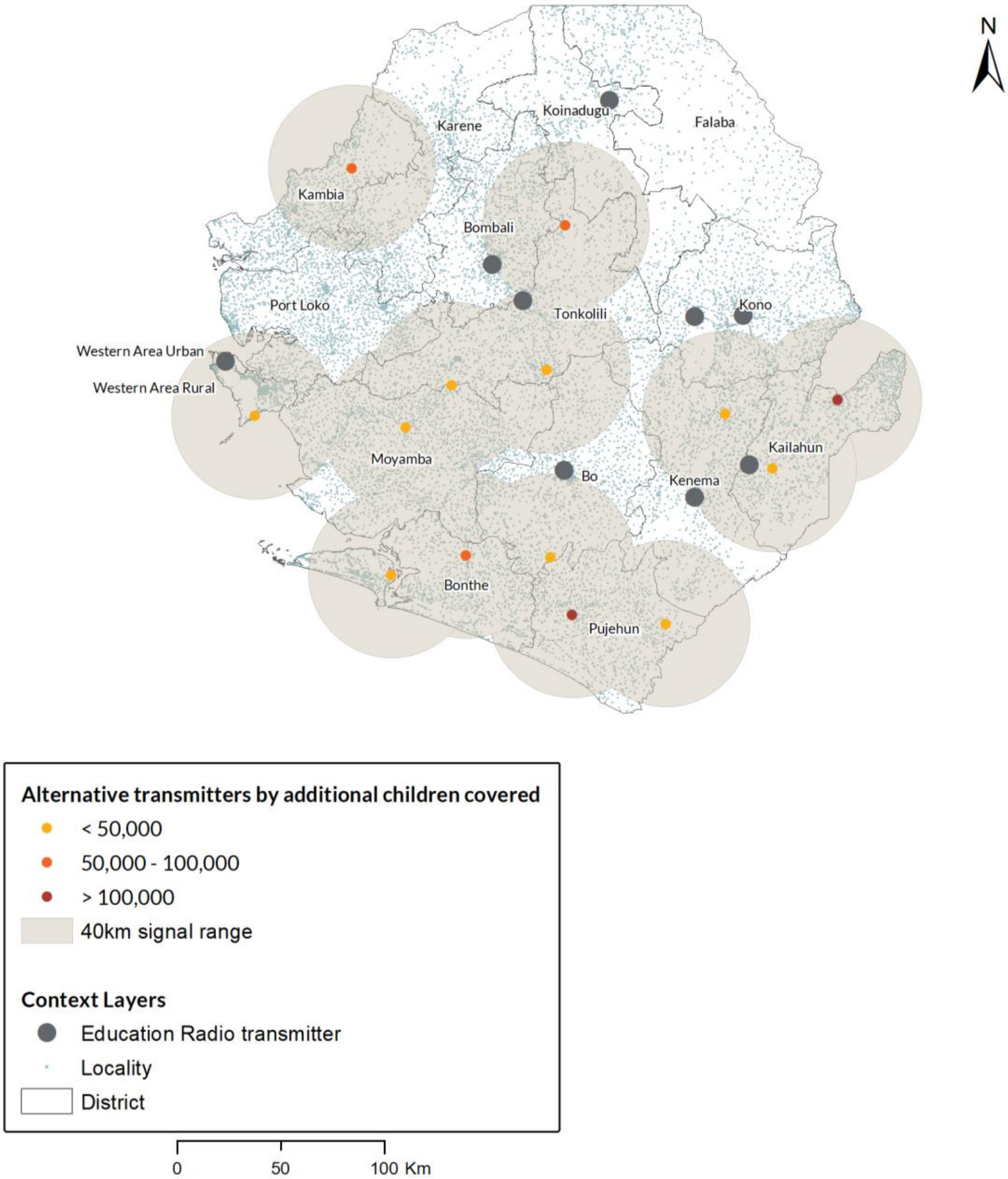


Figure 4: Alternative transmitters and their buffers for 40km signal range along with locations of the Education Radio transmitters

As might be expected from the map, there is considerable variation in the number of additional children each alternative transmitter reaches. Figure 5 presents these data and provides the named location and radio station of the transmitters. The five highest ranked stations are located in the districts of Kailahun, Pujehun, Bonthe, Kambia, and Tonkolili. The top-ranked transmitter is situated inside the town of Kailahun and is used to broadcast the Sierra Leone Broadcasting Corporation (SLBC) station, reaching the eastern tip of Sierra Leone. An estimated 155,225 school-age children who are currently not covered by an Education Radio Transmitter live within 40km of this location, equivalent to approximately 5.4 percent of all school-age children.

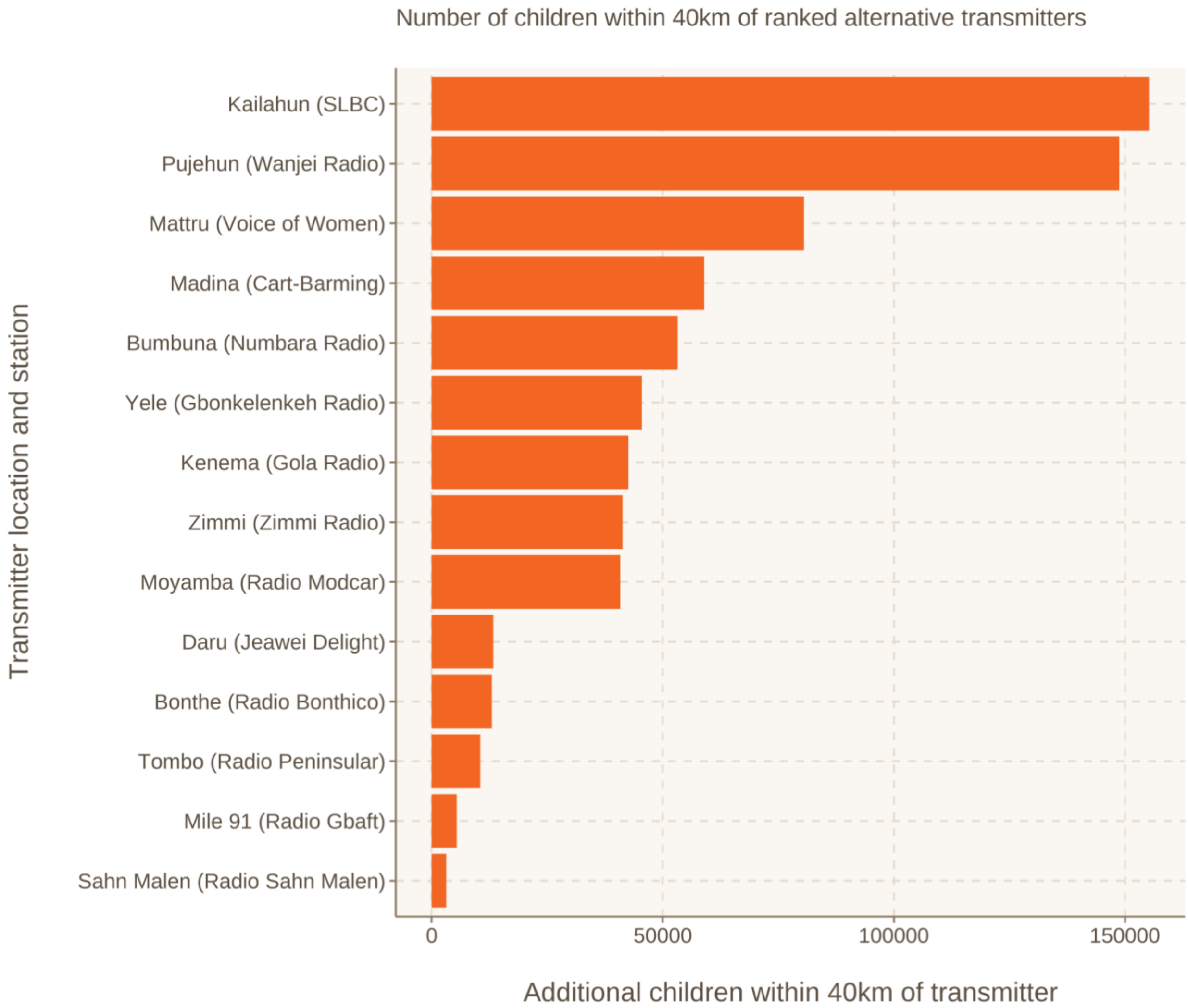


Figure 5: The estimated additional number of children covered by each alternative transmitter after filtering and ranking

It is important to remember that many of these alternative transmitters are next to or near other alternative transmitters that were discarded during the filtering process. It would be helpful to carry out further comparison with immediate neighbours to find the best option; difference in transmitter characteristics and willingness to participate in the Radio Teaching Program would be important factors when making a final decision about the site to use. Listenership is also an important criteria for this prioritisation process.

Scenario 1: new sites to fill gaps between Education Radio and alternative transmitters

Figure 6 illustrates the sites for new transmitters returned by the optimisation algorithm for Scenario 1. The addition of these sites in combination with the 14 alternative transmitters would mean that all school-age children would be covered by the Radio Education initiative, under the assumption that alternative and new transmitters have effective signal ranges of 40km. By comparing Figure 6 with Figure 4, it can be seen that the four new sites potentially serving over 20,000 children are in locations in the north of the country (which is poorly covered by the Education Radio transmitters or alternative transmitters). Lower ranked new sites tend to be found in places where their 40km coverage area overlaps with either weak signal from an Education Radio transmitter or the coverage area of analternative transmitter.

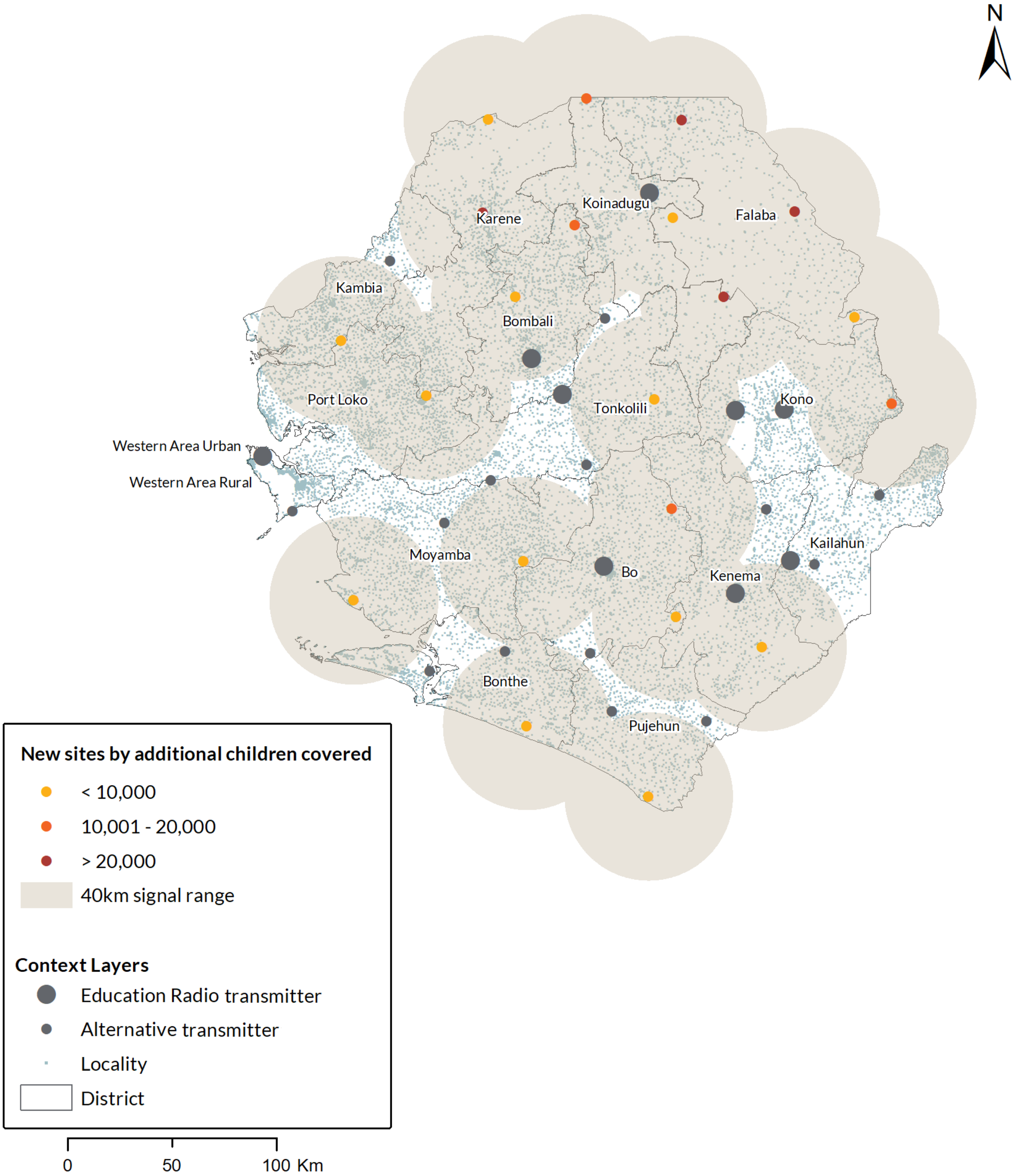


Figure 6: New transmitters and their buffers for 40km signal range, along with alternative and Education Radio transmitters (Scenario 1)

Figure 7 shows how the coverage of school-age children increases with the placement of each new transmitter, starting from the 90.9 percent coverage provided by the Education Radio and alternative transmitters. The addition of three new sites lifts this to 96 percent of children covered, while 21 in total are required to reach 100 percent coverage. The lower graph demonstrates this more explicitly: the number of additional children served by each new transmitter decreases quickly because the remaining areas of poor coverage are sparsely populated or are fragments between covered areas. In total, 107 children are served by the final new transmitter in this run of the algorithm. The key point here is that achieving total coverage would require a prohibitively expensive number of transmitters (assuming the radius parameter remains at 40km); affordable gains can be madeby prioritising those that have a higher ranking.

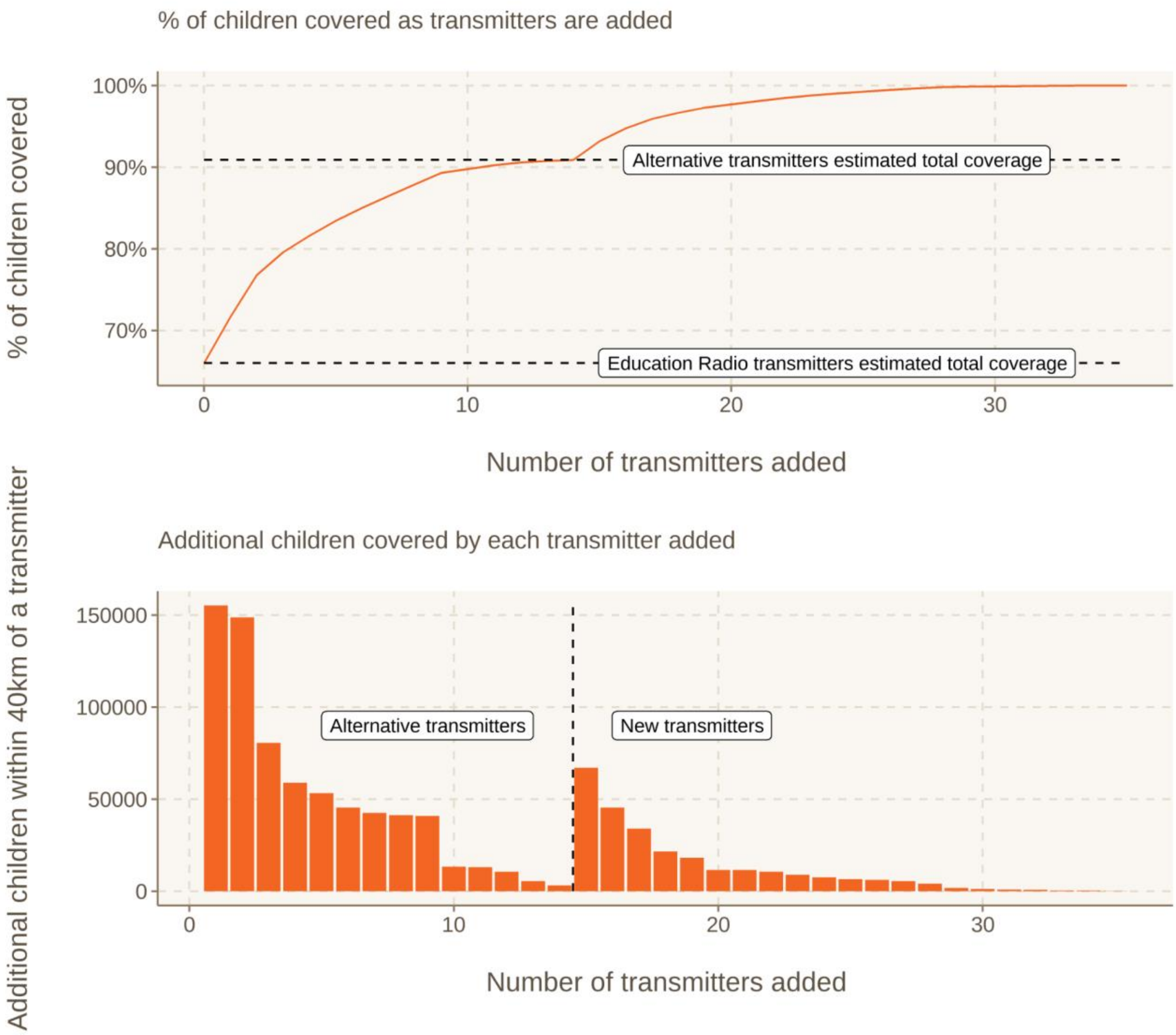


Figure 7: The increase in coverage of school-age children as alternative and new transmitters are added in order of their ranking (Scenario 1)

Figure 8 presents all the new transmitters that cover at least 1,000 additional children, labelled by their closest locality. The top ranked new transmitter is near Kamakwie in Karene District, filling a coverage gap north of the Bombali Education Radio transmitter and able to broadcast to an estimated 67,015 children who live within 40km of the site. Kondembaia in the south of Koinadugu District, where the second highest transmitter is situated, is located between Education Radio transmitters further north in Koinadugu and in Kono, and from the estimation made by the Radio Coverage Tool includes some fragmented coverage from these existing transmitters. If new transmitters are to be constructed, Figure 8 provides strong evidence about which locations should be prioritised. The third-highest ranked site at Bindi is in Falaba, where the ministry already has plans to construct a new transmitter. The algorithm's result supports the ministry's choice of location because it is evidently an underserved part of the country.

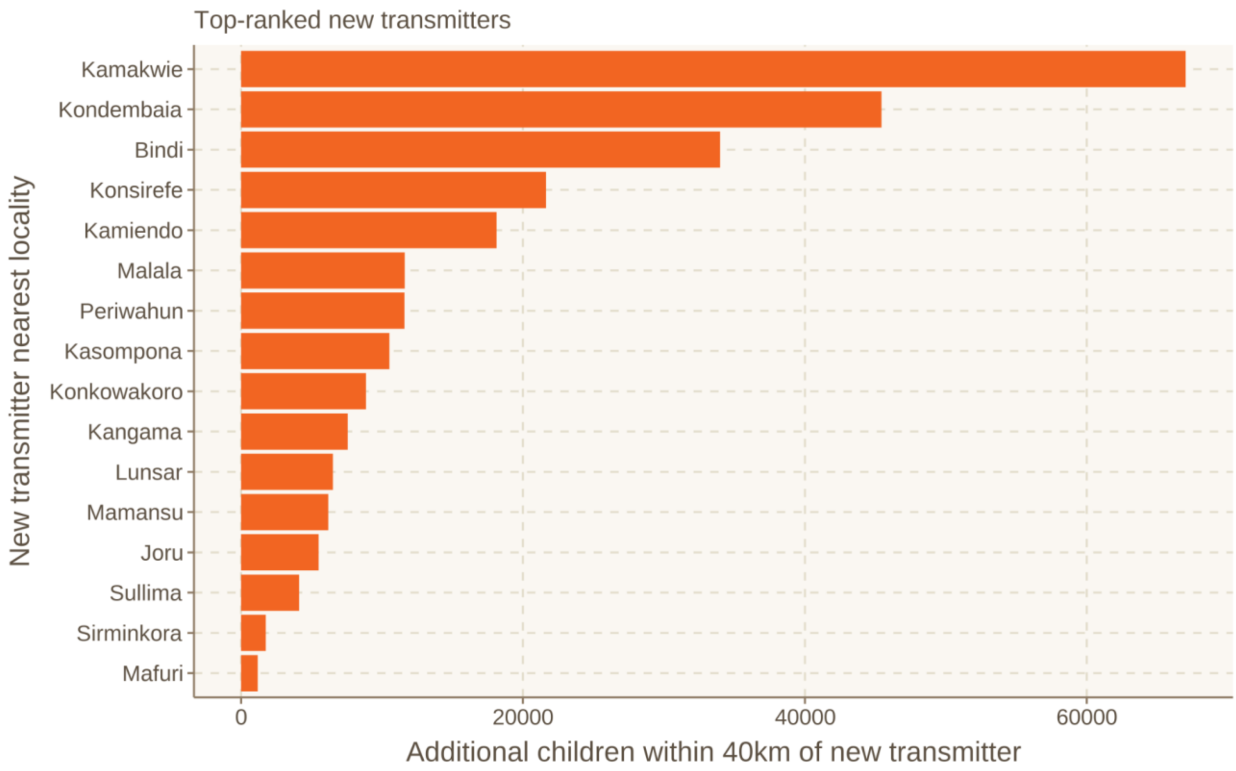


Figure 8: New sites covering a minimum of 1,000 additional children (Scenario 1)

Scenario 2: new sites to fill gaps between Education Radio transmitters

Scenario 2 did not include alternative transmitters, meaning the optimisation algorithm was run to find new site locations in the coverage gaps of the Education Radio transmitters only. The results are shown in Figure 9. The two transmitters that would each potentially serve over 100,000 children are in locations similar to those of the highest-ranked alternative transmitters (see Figure 4) in Pujehun and Kailahun districts. Those with the lowest rankings are typically in positions that are relatively close to Education Radio transmitters where signal is disrupted by irregular terrain. Filling all these small areas of poor signal is necessary to achieve 100 percent coverage of all school-age children.

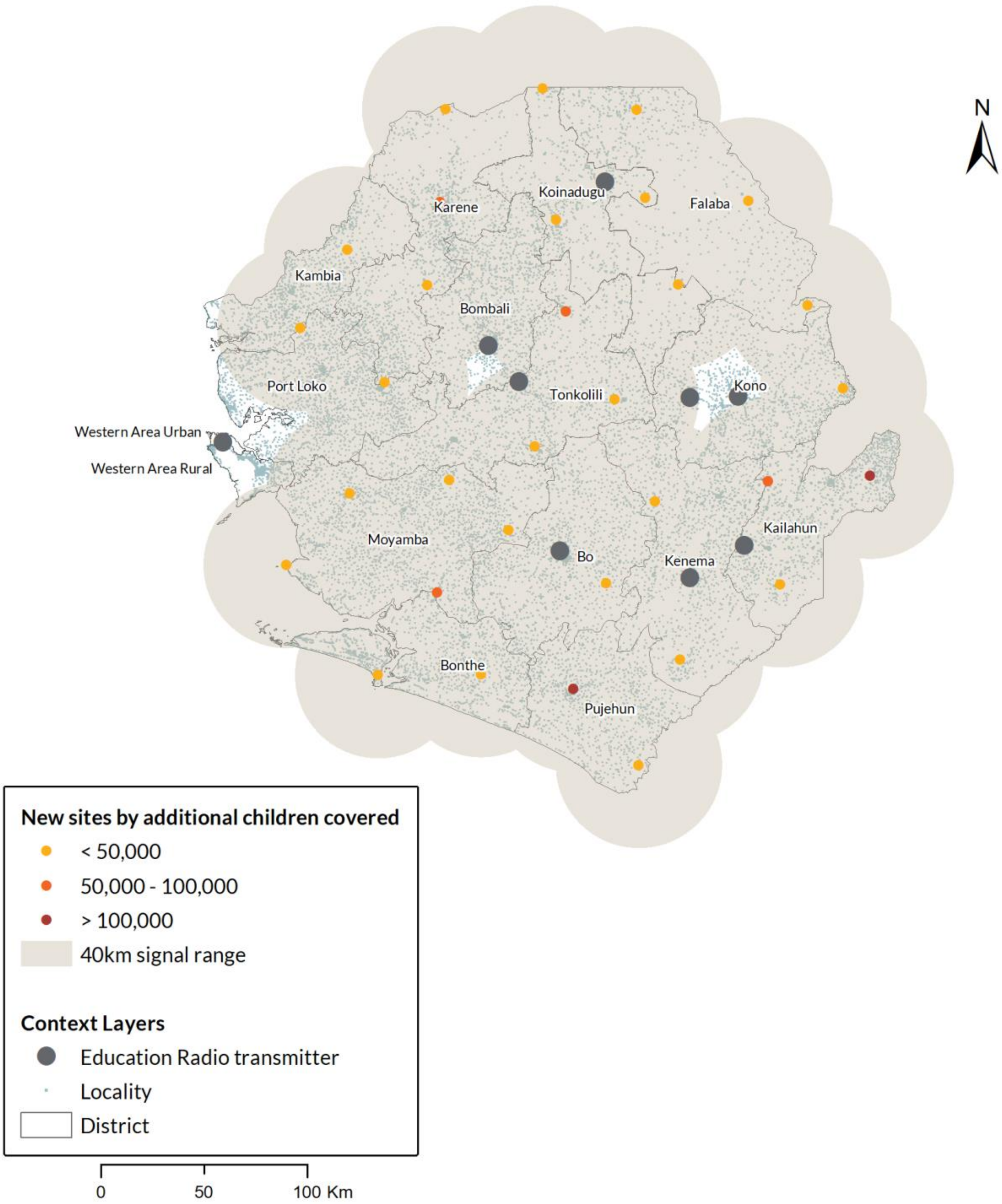


Figure 9: New transmitters and their buffers for 40km signal range, along with Education Radio transmitters (Scenario 2)

The coverage curve from adding new transmitters can be seen in Figure 10. Coverage can be increased to 78 percent by the addition of 3 new transmitters, while reaching 100 percent would require 32 in total. As in Scenario 1 (Figure 7), there is a fast decline in the number of additional children served by each new transmitter. In this scenario, the final new transmitter would cater to approximately 148 additional children.

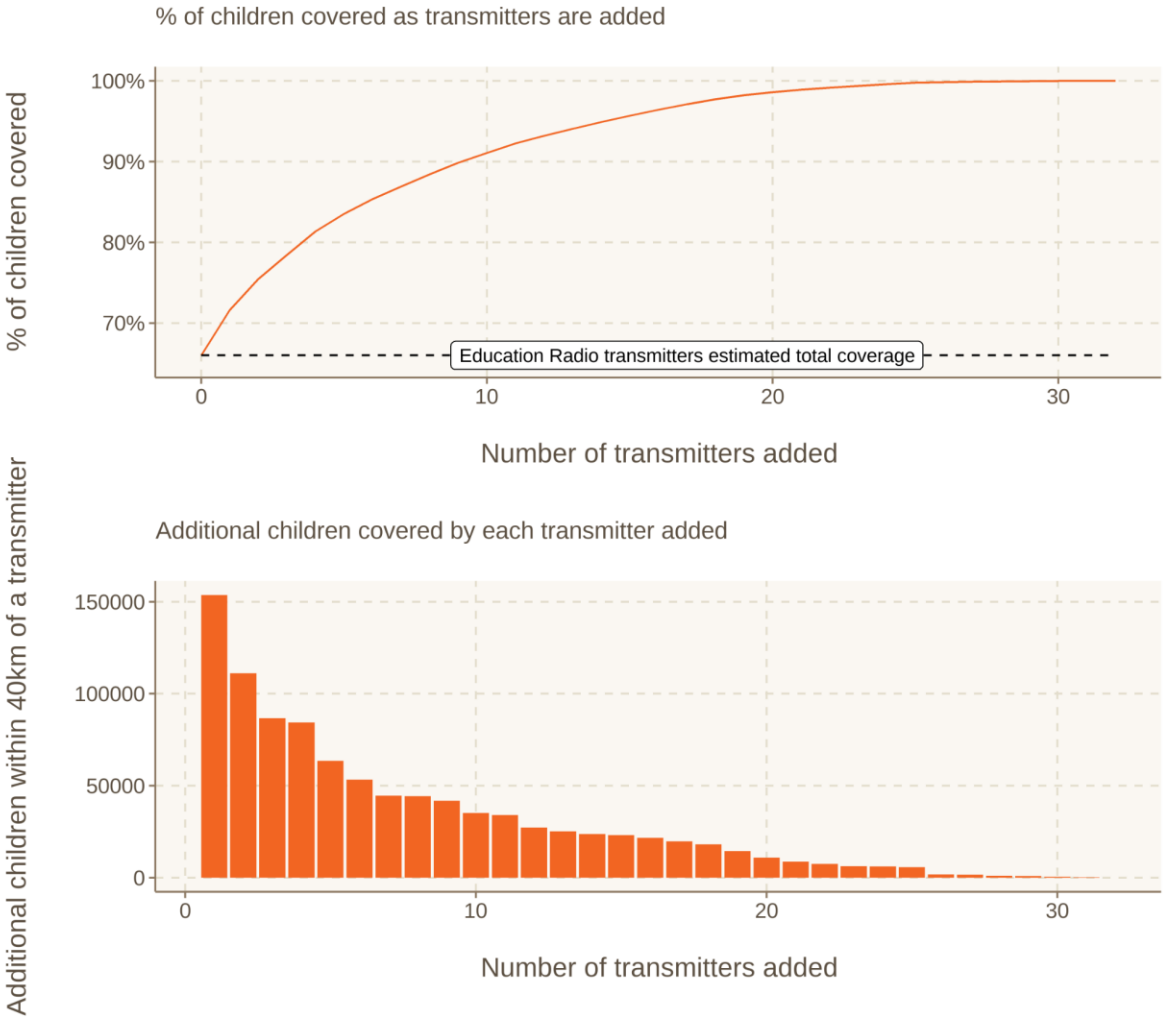


Figure 10: The increase in coverage of school-age children as new transmitters are added in order of their ranking (Scenario 2)

The 16 new transmitters from Scenario 2 that cover at least 20,000 additional children each are shown in Figure 11. The top-ranked new transmitter is to the east of Pujehun town in Pujehun District, with a 40km coverage area that encompasses Potoru to the east and Torma Bum to the west. A transmitter at this site with a 40km range would broadcast to an estimated 153,629 children. Buedu (in eastern Kailahun District) is the closest locality to the second-best ranked new transmitter, which has approximately 111,098 school-age children living within its 40km coverage area. As in Scenario 1, Kamakwie in Karene District is also highly ranked as a possible location, adding weight to the argument that the north of the country is underserved by the Education Radio initiative.

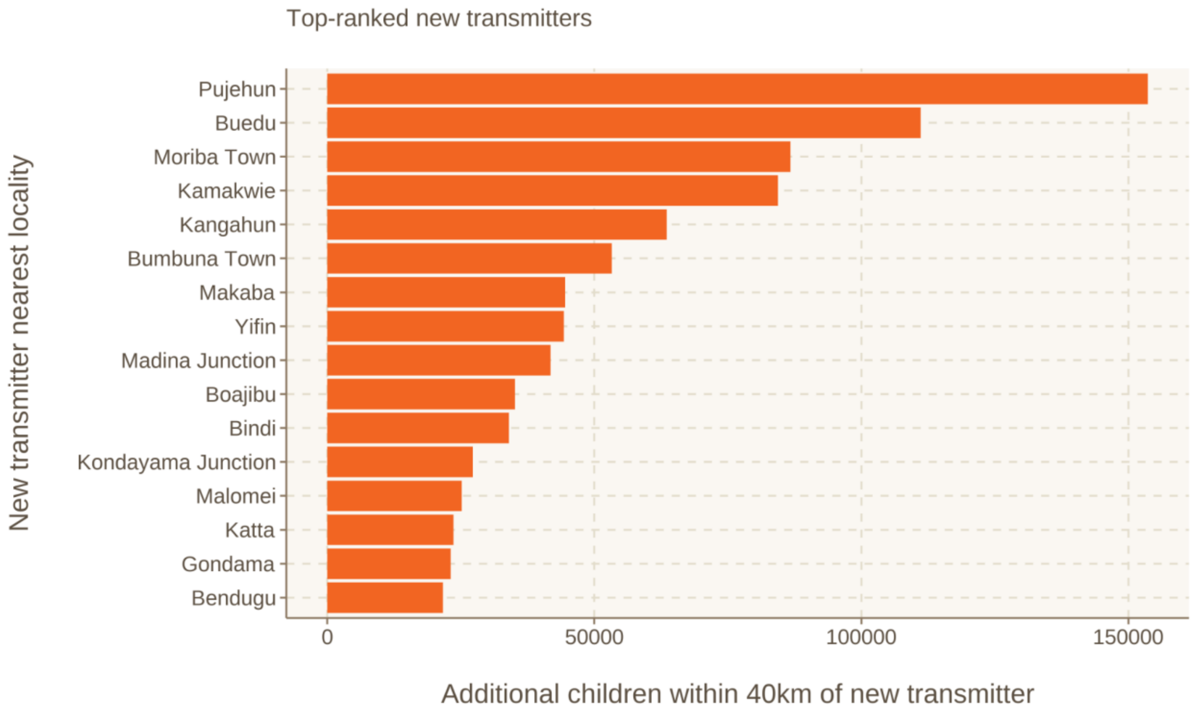


Figure 11: New sites covering a minimum of 20,000 additional children (Scenario 2)

Key findings, limitations, and recommendations

This work used the Longley-Rice model inside Nautel's Radio Coverage tool to estimate the coverage areas of nine Education Radio transmitters and subsequently the proportion of school-age children within these areas. A total of 143 alternative transmitters were then assessed for their potential to fill any gaps in coverage, using a 40km radius to generate their coverage areas. Finally, the optimisation algorithm was run to select sites that would best cover remaining school-age children, again using a 40km radius for each coverage area. The key findings of these three phases are as follows:

1. An **estimated two-thirds of school age children are within broadcasting range** of the nine Education Radio transmitters, an encouraging figure when the initiative is one of the main ways of disseminating lessons during health crises. There is little variation among the age cohorts for different school types.

2. Fourteen (14) alternative transmitters from the original list of 143 radio stations have good potential to **expand the initiative's coverage to 90.9 percent** because they serve areas outside the strong signal zones of Education Radio transmitters. After ranking, 9 of these 14 transmitters have over 40,000 school-age children living within a 40km radius. Transmitters at Kailahun, Pujehun, Mattru, Madina, and Bumbana were the highest ranked, making them the best options for increasing the proportion of children covered.

3. Under Scenario 1, which includes alternative transmitters, a further **three new transmitters would be required to ensure 96 percent of children are covered** by the initiative. These sites are at Kamakwie (Karene District), Kondembaiaa (Koinadugu District), and Bindi (Falaba District) and would each serve over 30,000 school-age children.

4. Without alternative transmitters, **three new transmitters would increase coverage to approximately 78 percent**, as modelled in Scenario 2. These sites are at Pujehun (Pujehun District), Buedu (Kailahun District), and Moriba Town (Moyamba District).

Limitations

While the results of this project should provide some useful guidance on the current state and possible future of the Education Radio initiative, it is necessary to detail and reflect on its limitations. It is also important to understand that the results of each phase depended on the choices made in the previous phase.

1. When running the Radio Coverage tool, default values were used for frequency, line loss, antenna gain, and opacity; the antenna height was always inputted as 50m. This was because of the limited information available on the characteristics of the nine Education Radio transmitters. Substantial differences in these parameters would result in differently sized coverage areas for the Education Radio transmitters.

2. A 40km radius was used when assessing alternative transmitters and placing new transmitters. Alternative transmitters may have characteristics that do not correspond with this radius; and if new transmitters are constructed, they may also have differing

characteristics. In addition, the circular coverage areas generated from these radii do not take into account elevation and other features that would disrupt radio wave propagation.

3. The filtering of alternative transmitters to minimise overlapping coverage areas may not match the specific transmitter in a locality best suited to the initiative.

4. Input rasters for school-age children were drawn from estimates and do not contain information about ownership of FM receivers. Low ownership or access to radio was highlighted as a particular issue for women and girls in rural parts of Sierra Leone by the Institute for Governance Reform and Oxfam Sierra Leone (2021) and could compromise the intended positive impact of increasing radio coverage in these locations.

Recommendations

With the findings and lmitations of the analysis in mind, four recommendations can be made:

1. **Validation of existing (no) coverage areas.** Both the assessment of alternative transmitters and suggestions for new sites are predicated upon the Education Radio transmitter coverage areas that were generated by the Radio Coverage tool. Validating these coverage areas is strongly recommended before making decisions about how to expand the initiative. Fieldwork could be conducted at a sample of locations to determine coverage strength, perhaps on a district-by-district basis, beginning with those that have been identified as having little-to-no coverage, such as Bonthe.

2. **Formalise a process for further assessment of alternative transmitters and compare the cost / benefits of inclusion with building new transmitters.** The 14 filtered alternative transmitters should not be considered as final, since many of them share sites or are very close to alternative transmitters that were discarded to avoid duplication of coverage areas. A more detailed assessment that incorporates transmitter characteristics and willingness to participate in the initiative is required to help make the ultimate decision about which ones to include. The 14 ranked alternative transmitters should be compared on these criteria with other alternative transmitters in the locality. There may also be a case for omitting the alternative transmitters in favour of new transmitters, as in Scenario 2.

3. **Achieving 100 percent coverage is challenging; careful selection of new transmitter sites is key to making the biggest gains for the lowest expenditure.** Each of the top three best-ranked new transmitters in Scenario 1 would improve coverage by at least 1 percent based on the 40km coverage areas. Transmitters with the equivalent rankings in Scenario 2 improve coverage by at least 3 percent. Gains could be even greater with effective positioning and powerful antennas. The list and ranking of new transmitter sites highlights underserved areas and is a strong starting point when considering where to direct investment for construction.

4. **A multifaceted approach to improving the Radio Teaching Program.** This work focused exclusively on the problem of increasing the number of children covered. Adding transmitters to the initiative should happen in tandem with schemes to enable vulnerable households to access radio receivers, as recommended by the Institute for Governance Reform and Oxfam Sierra Leone (2021). Its report also flags concerns about student

satisfaction with the Radio Teaching Program and the preference towards dissemination via television among some children in urban areas.

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@GRID3Global

info@grid3.org

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