

A National Assessment of Zambia's Malaria Surveillance System Performance for Elimination readiness by 2030

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Abstract

Background

Malaria surveillance is the “eyes and ears” of public health in Zambia, providing the critical intelligence needed to track transmission, guide interventions, and evaluate progress toward elimination. As the backbone of malaria control, its performance reflects the system’s ability to detect cases, generate reliable data, and respond effectively to emerging threats. In this study, performance was assessed using a composite score derived from multiple survey indicators, offering a clear measure of how well the surveillance system is functioning.

Methods

A cross-sectional survey of health workers involved in malaria surveillance was conducted across ten Zambian provinces from 2022 to 2024 using a structured questionnaire administered via KoBoToolbox at facility, district, and provincial levels. Performance for each surveillance attribute was measured as the mean proportion of positive responses across mapped indicators, with scores at or above 80% considered to meet the performance standard. Districts were then categorized as high ($\geq 80\%$), moderate (60–79%), or low performing ($< 60\%$). Performance was defined as a single score that combines many different survey questions about how well the malaria surveillance system was working.

Results

Of the ten attributes evaluated, five (50%) met or exceeded the 80% performance threshold. The system achieved an overall mean score of 80.4%, marginally meeting the benchmark. Simplicity was the highest-performing attribute (93.8%) and Flexibility the lowest (57.6%). Acceptability had a composite score of 89.0%, Completeness at 87.1%, Sensitivity scored 84.9%, Usefulness at 84.0%, Timeliness (79.7%), Data Quality (78.5%), Positive Predictive Value (78.2%) and Stability (70.6%). Major challenges included inadequate logistics (62.3%), insufficient trained staff (48.1%), limited community health worker motivation (55.8%), and health worker attrition (34.2%).

Conclusion

Five surveillance attributes remain below the required performance threshold. Weak flexibility reduces the system's ability to adapt to case-based and foci-level surveillance. Weak stability threatens continuous case detection, especially in areas at risk of imported malaria. Poor positive predictive value and data quality reduce the reliability of confirmed malaria case data. Weak timeliness limits rapid case investigation and response within the 1-3-7 elimination framework. Improving these five attributes is

critical for strengthening Zambia's malaria surveillance system and achieving malaria elimination by 2030.

INTRODUCTION

Malaria surveillance is no longer a passive reporting function. In countries that are moving from malaria control toward elimination, surveillance has become one of the most important public health interventions [1], [2]. A strong surveillance system allows malaria programmes to know where transmission is occurring, which populations remain at risk, whether interventions are reaching the right places, and how quickly the health system can detect and respond to changes in disease patterns. Without reliable surveillance, malaria control programmes operate with limited vision. They may miss outbreaks, misclassify transmission hotspots, delay response, or allocate resources to areas where the need is no longer greatest. Globally, the push toward malaria elimination has placed renewed emphasis on the quality, speed and usefulness of surveillance data [3], [4], [5], [6]. The World Health Organization's Global Technical Strategy for Malaria 2016 to 2030 recognizes surveillance as a core pillar of malaria elimination and calls for countries to strengthen systems that can detect cases early, monitor trends, guide targeted interventions and prevent resurgence [7]. As malaria burden declines in some areas and persists in others, national programmes require surveillance systems that are not only complete and timely, but also flexible, stable, sensitive and capable of producing data that decision-makers can trust [8], [9]. In this context, surveillance performance is not a technical detail. It is a measure of whether a country is ready to move safely and confidently toward elimination.

Zambia remains one of the countries in sub-Saharan Africa where malaria continues to pose a major public health challenge [10]. Despite sustained investments in long-lasting insecticide-treated nets, indoor residual spraying, rapid diagnostic testing, artemisinin-based combination therapy and community-based case management, malaria transmission remains heterogeneous across the country [11], [12]. Some areas experience persistent high transmission, while others have made substantial progress and are increasingly suitable for more targeted elimination-focused strategies [13], [14]. This uneven epidemiological landscape makes surveillance particularly important. Zambia's malaria programme must be able to distinguish areas of ongoing transmission from areas of reduced burden, detect outbreaks early, verify reported cases, and guide interventions at provincial, district, facility and community levels. The Zambian malaria surveillance system is implemented through a multi-level health system structure that begins at the community level and flows upward through health facilities, districts, provinces and the national level [15]. Community health workers, health facility staff, district surveillance officers, provincial surveillance teams and the National Malaria Elimination Programme all play important roles in case detection, data recording, reporting, analysis, feedback and response [16]. Routine malaria data are captured through several platforms and reporting channels, including Malaria Rapid Reporting, DHIS2, HMIS, eIDSR and community-based surveillance mechanisms. This structure provides an important foundation for national malaria intelligence. However, the existence of reporting platforms does not automatically mean that the system is performing well. A surveillance system can be

widely used but still suffer from delayed reporting, incomplete data, weak feedback, diagnostic uncertainty, staff shortages, poor interoperability and limited adaptability.

These performance gaps matter because malaria elimination depends on confidence in the data. If reporting is incomplete, malaria burden may be underestimated. If data are delayed, outbreaks may be detected too late. If laboratory confirmation is weak, routine data may overstate malaria incidence by including other febrile illnesses. If systems are unstable, data flow may be disrupted when commodities, internet connectivity, staff or reporting tools are unavailable. If the system is not flexible, it may struggle to adapt to changing epidemiology, new reporting requirements, emerging outbreaks or integration with other disease surveillance platforms. Therefore, assessing surveillance performance is essential for understanding whether Zambia's malaria surveillance system is fit for its current and future purpose. Although malaria surveillance is central to Zambia's malaria elimination agenda, there has been limited published evidence on how well the national malaria surveillance system performs across key surveillance attributes. Previous work in other African countries has shown that malaria surveillance systems often perform well in some domains, such as acceptability or simplicity, while underperforming in areas such as timeliness, stability, data quality and positive predictive value [17], [18], [19]. However, country-specific evidence is essential because surveillance systems are shaped by local health system structures, reporting tools, workforce capacity, geography, malaria transmission patterns and programme priorities. To date, no published national assessment has comprehensively evaluated the performance of Zambia's malaria surveillance system across multiple health system levels and surveillance attributes.

This evidence gap is important. Zambia's progress toward malaria elimination cannot be judged by case counts alone. It also depends on whether the system generating those counts is reliable, responsive and capable of supporting targeted public health action. A national assessment of surveillance performance provides the evidence needed to identify strengths that should be protected, weaknesses that require urgent investment, and operational bottlenecks that may threaten elimination readiness. Such an assessment is especially timely as Zambia continues to strengthen subnational malaria programming and align surveillance with elimination goals. This study therefore assessed the performance of Zambia's malaria surveillance system from 2022 to 2024 using key surveillance attributes, including simplicity, acceptability, completeness, sensitivity, usefulness, timeliness, data quality, positive predictive value, stability and flexibility. By examining performance across facility, district and provincial levels, the study provides the first national picture of how well the malaria surveillance system is functioning and where it must improve. The findings are intended to inform programme strengthening, improve the reliability of routine malaria data, and support Zambia's pathway toward malaria elimination.

METHODS

Study design

A cross-sectional study was conducted from 2022 to 2024 to assess the performance of Zambia's malaria surveillance system.

Study setting

The study was conducted in selected districts across all ten provinces of Zambia, a landlocked country in Southern Africa where malaria remains a major public health concern. Malaria transmission in Zambia is endemic, seasonal and geographically heterogeneous, with the highest burden generally observed in rural and hard-to-reach areas, particularly in Northern, Luapula, Muchinga and Western provinces. Transmission is strongly influenced by favourable ecological and climatic conditions, including seasonal rainfall, warm temperatures, floodplains, wetlands, river systems and other mosquito breeding environments [20]. The dominant malaria parasite is *Plasmodium falciparum*, transmitted mainly by *Anopheles* mosquitoes. Districts were purposively selected to reflect variation in malaria transmission intensity, geography, health system capacity and surveillance implementation experience. This included districts from high-transmission rural settings, border areas, floodplain and riverine communities, peri-urban settings and more urbanized districts. By including districts across diverse epidemiological and operational contexts, the study was able to assess how Zambia's malaria surveillance system performs under real programme conditions and how well it supports national malaria control and elimination planning.

Implementation of the malaria surveillance

Zambia's malaria surveillance system is implemented through a structured five-tier pathway that links the community, health facility, district, provincial and national levels (Figure 2). Data flow upward from the point of case detection to national programme leadership, while feedback, guidance and technical support are expected to flow downward to strengthen local action. At community level, Community Health Workers serve as the first line of surveillance by identifying suspected malaria cases, conducting passive case detection using rapid diagnostic tests, maintaining community registers, and submitting routine reports to nearby health facilities. They also support key vector surveillance activities, including tracking mosquito net distribution and indoor residual spraying records. At health facility level, clinicians, nurses and other frontline health workers diagnose and treat malaria cases confirmed by rapid diagnostic tests or microscopy, record cases in outpatient registers and tally sheets, and enter routine data into national reporting systems, including DHIS2, using standard Ministry of Health and IDSR reporting tools.

At district level, surveillance teams aggregate facility-level data, verify completeness and quality, monitor epidemic thresholds, and trigger investigation or response when malaria cases exceed expected levels (Figure 2). Provincial teams then compile and analyze district data, identify performance gaps, provide technical feedback, and conduct supportive supervision to improve reporting quality and surveillance performance. At national level, the National Malaria Elimination Programme and the Ministry of Health consolidate provincial data, generate national malaria reports, guide policy and resource allocation, and report progress to regional and global partners, including WHO, Roll Back Malaria and SADC. This layered

structure gives Zambia an important platform for malaria intelligence, with DHIS2 serving as the central digital backbone for data capture, transmission and use [21], [22]. However, the effectiveness of this system depends not only on the presence of reporting channels, but also on the reliability, timeliness, completeness and quality of data generated at each level as the country works toward its 2030 malaria elimination targets.

Study Population

The study included 452 health workers involved in malaria surveillance activities at health facility, district and provincial levels across all ten provinces of Zambia. The study population comprised health workers and surveillance officers involved in malaria surveillance activities at different levels of the health system. At health facility level, eligible participants included Environmental Health Technologists, Community Health Assistants, Public Health Nurses, Clinical Officers and Facility In-charges. At district level, participants included District Surveillance Officers, Malaria Elimination Officers and District Epidemiologists. At provincial level, participants included Provincial Surveillance Officers involved in malaria surveillance coordination, reporting, supervision and data use.

Sample Size and Sampling

A total of 452 respondents were purposively selected to participate in the study (table 1). This sample size was considered sufficient for a national descriptive assessment because it included health workers directly involved in malaria surveillance activities across facility, district and provincial levels, while ensuring representation from all ten provinces of Zambia. Purposive sampling was appropriate because the study targeted personnel with practical knowledge of malaria case detection, reporting, data verification, supervision and use of surveillance information. Respondents were selected from districts with varying malaria transmission intensities, surveillance capacities and implementation contexts, including districts with well-established surveillance systems and those known to experience operational challenges. This approach allowed the assessment to capture a broad range of frontline and managerial experiences relevant to the performance of Zambia's malaria surveillance system.

Data collection

Data were collected using a standardized structured questionnaire adapted from the CDC framework for evaluating public health surveillance systems [23]. The questionnaire was programmed in KoBoToolbox and administered to health personnel involved in malaria surveillance at health facility, district and provincial levels across Zambia. It was organized into thematic sections aligned with key surveillance system attributes, including simplicity, acceptability, completeness, sensitivity, usefulness, timeliness, data quality, positive predictive value, stability and flexibility. Likert-scale questions were used to assess perception-based items, while binary and multiple-choice questions captured factual and frequency-based information. Data were collected on knowledge of malaria surveillance procedures, ease of reporting, availability and use of reporting tools, timeliness of reporting, data quality practices, system

challenges, feedback mechanisms, training received and perceived performance of the surveillance system across the assessed attributes.

Data management

Data were managed using a reproducible R-based workflow to ensure that the dataset was cleaned, organized and analyzed consistently. The raw survey file was first imported and checked to ensure that variable names, questionnaire sections and response categories were correctly aligned. Because the questionnaire contained several thematic sections, each survey item was linked to its relevant surveillance performance domain, such as simplicity, flexibility, timeliness, stability, data quality, usefulness and governance. Key background variables, including province, district, health-system level, job title and years of experience in malaria surveillance, were also cleaned and standardized. Inconsistent spellings, abbreviations and differences in capitalization were corrected, particularly for province and district names, to support accurate tabulation, mapping and comparison across geographic areas.

Survey responses were then converted into numerical scores so that performance could be assessed in a consistent way across all surveillance attributes. Responses indicating better system performance were assigned higher scores, while responses indicating poorer performance were assigned lower scores. The scores for individual questions were combined within each surveillance domain and then scaled from 0 to 100, with higher scores representing stronger malaria surveillance performance. An overall performance score was calculated for each respondent by averaging the domain scores. Respondents with an overall score of 80% or higher were classified as having high malaria surveillance performance, while those below 80% were classified as lower-performing for regression analysis. Predictor variables included respondent characteristics, level of the health system, province, experience, awareness of the surveillance system, plan review practices, availability of guidelines, data validation, reporting timeliness and external oversight. This approach allowed the analysis to capture both the human and operational dimensions of malaria surveillance performance in Zambia.

Data analysis

Data were analyzed using R through a reproducible Quarto workflow. Descriptive analysis was first conducted to summarize the characteristics of respondents and the performance of the malaria surveillance system. Categorical variables, including province, district, health-system level, job title, training status, awareness of the surveillance system and years of experience, were summarised using frequencies and percentages. Continuous performance scores were summarised using means, medians, interquartile ranges and score ranges, depending on the distribution of the data. Performance scores were calculated for each surveillance domain and scaled from 0 to 100, with higher scores indicating stronger surveillance performance. Respondents were further classified as high-performing if their overall score was 80% or above, moderate-performing if their score was 60% to 79%, and low-performing if their score was below 60%. Geographic summaries were also produced at province and district levels

to show spatial variation in mean performance and the proportion of respondents classified as high-performing.

Bivariate analysis was conducted to examine how surveillance performance varied across respondent and programme characteristics. For each predictor variable, the median overall performance score and interquartile range were calculated across response categories. The proportion of respondents classified as high-performing was also estimated for each group, together with 95% confidence intervals using binomial methods. Differences in the prevalence of high performance across categorical groups were assessed using chi-square tests, while differences in median performance scores were assessed using the Kruskal-Wallis test because performance scores were not assumed to be normally distributed. Variables examined in the bivariate analysis included province, health-system level, job title, years of experience, awareness of the malaria surveillance system, frequency of malaria surveillance plan review, availability of guidelines or standard operating procedures, external oversight, data validation performance, timeliness of report submission and average time from diagnosis to reporting.

Multivariable and predictive analyses were then conducted to identify factors associated with strong malaria surveillance performance and to assess whether high-performing respondents could be distinguished from lower-performing respondents using the available surveillance indicators. The main regression outcome was high malaria surveillance performance, coded as 1 for respondents with an overall score of 80% or higher and 0 for those below 80%. Candidate predictors were entered as categorical variables, and variables with only one observed category were excluded from the model because they provided no meaningful variation. A multivariable logistic regression model was fitted, followed by AIC-guided model selection to retain the most informative predictors. Results were presented as odds ratios with 95% confidence intervals and p-values, and visualized using a forest plot. For predictive analytics, numeric domain scores were used to train and test two models: LASSO logistic regression and random forest. The dataset was split into a 70% training set and a 30% testing set, and synthetic minority oversampling was applied to the training data to reduce class imbalance. Model performance was evaluated on the test set using the area under the receiver operating characteristic curve, accuracy, sensitivity and specificity, while random forest variable importance was used to identify the domains contributing most strongly to prediction.

Ethical consideration

Ethical approval to conduct the study was granted by the University of Zambia Biomedical Research Ethics Committee (Ref. No. 7544-2025) and the National Health Research Authority (NHRA-3188/28/01/2026). All participants provided informed consent before taking part in the study. Participation was voluntary, and respondents were informed about the purpose of the study, the nature of the questions, and their right to decline or withdraw without any penalty. Confidentiality was maintained throughout data collection, storage and analysis. No personal identifiers were used in the analysis, and results were reported in aggregate form only to ensure that individual respondents, facilities or staff members could not be identified from the findings.

RESULTS

Characteristics of the respondents

A total of 452 health workers participated in this survey across three levels of the health system in Zambia. Both demographic and professional characteristics of the respondents were analyzed. Environmental Health Technologists constituted the largest proportion of respondents (50.0%; n=226), followed by Community Health Assistants (17.0%; n=77) and District Surveillance Officers (9.3%; n=42). The majority of respondents (78.8%; n=356) were from health facilities, followed by district health offices (19.7%; n=89) and provincial health offices (1.5%; n=7). Southern Province had the highest representation (32.7%; n=148), followed by Luapula Province (22.1%; n=100) and Eastern Province (15.3%; n=69). Northern Province had the fewest respondents (0.7%; n=3). The largest proportion of respondents had more than 6 years of experience (39.8%; n=180), suggesting a relatively experienced cadre of health workers engaged in malaria surveillance. Only 6.6% (n=30) had less than one year of experience. Overall, 88.7% (n=401) of respondents were aware of the national malaria surveillance system. Provincial health office staff demonstrated the highest awareness (100.0%) and training rates (85.7%), while formal training coverage was comparably lower at health facility level (62.6%) and district level (66.3%). Despite the training gap, the median knowledge performance score was 100.0% across all levels, reflecting that those who were trained and aware scored correctly on both knowledge items. (Table 1).

Table 1: Demographic and professional characteristics of the respondents

Demographic and professional characteristics	N=452	(%)
Positions		
Environmental Health Technologist	226	50.0
Community Health Assistant	77	17.0
District Surveillance Officer	42	9.3
Malaria Elimination Officer	37	8.2
Facility In charge	28	6.2
Environmental Health Officer	10	2.2
Public Health Nurse	8	1.8
Public Health Officer	7	1.5
Clinical Officer General	6	1.3
Other positions	11	2.5
Level of Health System		
Health Facility	356	78.8
District Health Office	89	19.7
Provincial Health Office	7	1.5
Provinces		
Southern	148	32.7
Luapula	100	22.1
Eastern	69	15.3
Copperbelt	41	9.1
Northwestern	34	7.5
Muchinga	20	4.4
Western	20	4.4
Central	11	2.4
Lusaka	6	1.3
Northern	3	0.7
Experience in Malaria Surveillance		
Less than 1 year	30	6.6

1 – 3 years	149	33.0
4 – 6 years	92	20.4
More than 6 years	181	40.0
Received Formal Training in Surveillance		
Yes	288	63.7
No	164	36.3
Aware of Malaria Surveillance System used in Zambia		
Yes	401	88.7
No	51	11.3

Others: Chief Environmental Health Officer, Provincial Surveillance Officer, District Epidemiologist

Assessment of Attributes for Malaria Surveillance System Performance

A total of 452 health workers participated in the survey across all ten provinces of Zambia. Most respondents were based at health facility level, followed by district health offices and provincial health offices. Respondent distribution varied by province, with Southern, Luapula and Eastern provinces contributing the largest proportions of participants, while Northern, Lusaka and Central provinces had smaller numbers. Of the ten surveillance attributes evaluated, five met or exceeded the 80% performance benchmark. The attribute-level mean performance score was 80.4%, indicating that the system marginally met the predefined benchmark. However, the respondent-level median overall performance score was 76.9%, showing that individual-level performance was more modest than the aggregate attribute score. This distinction is important because the overall mean reflects performance across surveillance attributes, while the median reflects the distribution of performance scores across respondents.

Table 2: Means of Measurement of Malaria Surveillance System Attributes

Attributes	Indicator (Survey Question)	Score (%)	Status
Simplicity	System is easy to understand and use	85.4	Met
	Case definition easily understood by staff	99.1	Met
	Case definition standardized and uniformly applied	97.8	Met
	Reporting forms/tools are user-friendly	93.1	Met
	Simplicity Composite Score	93.8	Meets 80%
Acceptability	Stakeholders willing to participate in surveillance	79.6	Not Met
	Surveillance considered part of routine duties	98.4	Met
	Acceptability Composite Score	89.0	Meets 80%
Completeness	All malaria cases and deaths accurately captured	94.0	Met
	All expected reporting units submitting reports	94.7	Met
	Average $\geq 90\%$ of reports submitted (last 3 years)	72.7	Not Met
	Completeness Composite Score	87.1	Meets 80%
Sensitivity	System detects most malaria cases in the population	87.6%	Met
	Mechanisms to capture community-level cases	87.8%	Met
	Mechanisms to detect outbreaks early	79.4	Not Met
	Sensitivity Composite Score	84.9	Meets 80%
Usefulness	Surveillance data used for decision-making	94.5%	Met
	Feedback received on submitted reports	73.4%	Not Met
	Usefulness Composite Score	84.0%	Meets 80%
Attributes	Indicator (Survey Question)	Score (%)	Status
Timeliness	Reports submitted on time to the next level	91.1%	Met
	No delays when accessing surveillance data	77.2%	Not Met
	No significant delays in report submission	70.7%	Not Met
	Timeliness Composite Score	79.7%	Below 80%
Data Quality	All facilities submitting complete reports	87.6%	Met
	No errors in surveillance data	69.4%	Not Met
	Routine data verification/validation system	86.3%	Met
	Surveillance data always complete	78.5%	Not Met
	Surveillance data always accurate and reliable	71.4%	Not Met
	Data Quality Composite Score	78.6%	Below 80%
	Most reported cases are laboratory-confirmed	73.6%	Not Met
Positive Predictive Value	System represents all population groups	82.7%	Met
	Positive Predictive Value Composite Score	78.2%	Below 80%
Stability	Reporting tools always or often available	94.2%	Met
	System disruptions are rare or never	59.9%	Not Met
	Diagnostic tools often available	61.0%	Not Met
	Trained staff for surveillance adequate	67.2%	Not Met
	Stability Composite Score	70.6%	Below 80%
Flexibility	System accommodates new diseases without structural change	37.5%	Not Met
	New staff trained quickly to operate the system	72.7%	Not Met
	Staff can adapt without extensive retraining	40.8%	Not Met
	Software updates possible without interrupting activities	84.7%	Met
	System integrates with other health information systems	52.5%	Not Met
	Flexibility Composite Score	57.6%	Below 80%

Governance Performance by Level of Health System

Governance performance was strong across all levels of the health system. The majority of respondents confirmed that roles and responsibilities were clearly defined (97.3% overall), with the highest clarity reported at the provincial level (100.0%). Standard operating procedures and guidelines were available and accessible to 90.3% of all respondents, with slightly higher availability at district (93.3%) and provincial (100.0%) levels compared to health facilities (89.3%). Regarding the review frequency of

surveillance plans: 50.9% of respondents reported annual reviews, 35.8% bi-annual, 3.8% more than once per year, while 9.5% reported that plans were never reviewed. The median governance score was 100.0% across all levels [95%CI: 100.0–100.0%], reflecting near-universal positive responses on the binary governance indicators.

Table 3: Governance Performance by Level of Health System in Zambia

Level	N	Roles Defined	SOPs Available	Frequent Review of Surveillance Plan	
		(%)	(%)	Response	(%)
Health Facility	356	98.6	89.3	Annually	51.7
				Bi-annual	34.8
				>1 year	3.4
				Never	10.1
District Health Office	89	92.1	93.3	Annually	47.2
				Bi-annual	40.4
				>1 year	4.5
				Never	7.9
Provincial Health Office	7	100.0	100.0	Annually	57.1
				Bi-annual	28.6
				> 1 year	14.3
Overall	452	97.3	90.3	Annually	50.9
				Bi-annual	35.8
				>1 year	3.8
				Never	9.5

Performance varied by level of the health system. The median overall performance score was 76.9% among health facility respondents and 76.9% among district health office respondents, compared with 92.3% among provincial health office respondents. This suggests that respondents at higher levels of the health system perceived stronger surveillance performance, possibly reflecting better access to supervision, reporting tools, technical support and decision-making structures. However, the provincial-level estimate should be interpreted cautiously because only seven provincial respondents were included. The findings therefore point to a likely performance gradient across the health system, but the strength of this pattern should be confirmed in future assessments with larger provincial-level samples.

Table 4: Overall Median Performance Score by Level of Health System

Level of Health System	N	%	Median Overall Performance Score (%)	Confidence Interval
Health Facility	356	78.8	76.9	76.9–76.9
District Health Office	89	19.7	76.9	76.9–84.6
Provincial Health Office	7	1.5	92.3	84.6–100.0
Overall	452	100.0	76.9	76.9–76.9

High-performing provinces concentrated in the north-central region (Central, Muchinga, and Northern) whilst the Low-performing provinces clustered in two distinct belts namely the northern border (Luapula, Copperbelt) and the southern/urban corridor (Lusaka, Southern). Moderate-performance was recorded in Eastern Province as an isolated outlier (Figure 4).

Logistic regression of determinants of high surveillance performance

The stepwise logistic regression analysis identified several factors associated with high malaria surveillance performance. Districts in Copperbelt Province were significantly more likely to demonstrate high surveillance performance compared with the reference province (OR = 5.35, 95% CI: 1.17–24.16, $p = 0.028$). Regular review and updating of malaria surveillance plans was also an important predictor, with districts that reviewed their plans more frequently having over three times higher odds of achieving high surveillance performance (OR = 3.14, 95% CI: 1.41–7.77, $p = 0.008$). In contrast, health facilities had substantially lower odds of high surveillance performance compared with higher health system levels (OR = 0.16, 95% CI: 0.09–0.29, $p < 0.001$). Although higher odds of surveillance performance were observed in Lusaka, Muchinga, Eastern, Luapula, and Southern provinces, these associations were not statistically significant. Overall, the findings suggest that provincial context and the routine review of surveillance plans play important roles in strengthening malaria surveillance performance (Figure 5).

There was a wide disparity in predicted surveillance performance across Zambian provinces, ranging from very high (85%) in Central Province to very low (22%) in Luapula Province. Other provinces such as Muchinga, Northern, and Eastern had a predicted surveillance performance ranging from moderate high (75%) to moderate low (45%).

Both LASSO and Random Forest models demonstrate Near-Perfect sensitivity across all specificity thresholds, with both achieving 1.00 (100%) sensitivity at low thresholds and maintaining 0.99 (99%) sensitivity across the mid-range (0.2 to 0.8).

Surveillance Performance Vs Budgetary Allocation by Province

Malaria surveillance budget allocation by province (ZMW millions), 2017–2025, were modelled using historical financing trends, malaria burden, population size, and programme priorities. This covered surveillance only. Provinces were ordered by total 9-year allocation. These estimates were developed

because complete province-specific budget data were not publicly available. The modelled allocations were intended to support comparative analyses (Table 5).

Table 5: Provincial Modelled Malaria Surveillance Budget, 2017 – 2025, (ZMW Millions)

Province	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
Northern	10.2	11.0	12.0	12.9	13.9	15.1	16.3	17.6	19.0	128.0
Eastern	9.5	10.4	11.3	12.0	13.1	14.2	15.3	16.6	17.9	120.3
Luapula	8.8	9.6	10.4	11.2	12.1	13.2	14.2	15.3	16.5	111.3
North-Western	8.6	9.4	10.2	11.0	11.9	12.9	14.0	15.2	16.4	109.6
Western	7.8	8.5	9.3	10.0	10.8	11.7	12.7	13.8	14.9	99.5
Muchinga	7.2	7.9	8.5	9.2	10.0	10.8	11.7	12.7	13.7	91.7
Central	6.2	6.8	7.4	7.9	8.5	9.2	9.8	10.6	11.2	77.6
Southern	5.6	6.1	6.6	7.1	7.7	8.4	9.0	9.8	10.5	70.8
Lusaka	4.8	5.2	5.6	6.0	6.4	6.9	7.4	8.0	8.6	58.9
Copperbelt	4.1	4.4	4.8	5.1	5.5	6.0	6.5	7.0	7.5	50.9

Performance vs Budget

The budget allocation did not track closely with performance, Northern had the lowest composite score (74.8%) but the highest budget (ZMW 128.0M), while Copperbelt had the highest score (83.9%) with the smallest budget (ZMW 50.9M).

Establishing the relationship between surveillance performance and budgetary allocation

The correlation between malaria surveillance performance and budgetary allocation was weak to moderate and negative ($r = -0.475$). Provinces with larger cumulative surveillance budgets scored slightly lower on performance compared to provinces with smaller cumulative budgets. At $p = 0.1656$ ($p > 0.05$), this was not statistically significant (Figure 9)

DISCUSSION

The system was evaluated against ten CDC surveillance attributes [23]. Five attributes met the 80% performance benchmark; five fell below it, pointing to structural and infrastructural constraints that require targeted intervention. The overall mean performance score of 80.4% indicates that Zambia's malaria surveillance system marginally meets the minimum acceptable performance benchmark. However, this aggregate figure masks significant heterogeneity across individual attributes, with five of ten falling below threshold. The performance profile where high simplicity and acceptability alongside

low flexibility and stability is characteristic of a surveillance system that has succeeded in embedding basic reporting practices but has not yet achieved the systems maturity required for adaptive, integrated, and reliable operation.

Simplicity was the strongest attribute with a composite score of 93.8%, exceeding comparable results of 91.0% from Kano State, Nigeria [24] and much higher than 80.0% recorded from Ebonyi State, Nigeria [25]. Near-universal understanding of case definitions (99.1%) and standardized application across reporting levels (97.8%) indicate that the Malaria Rapid Reporting System (MRR) and DHIS2 are operationally intuitive for frontline staff. This is a genuine asset for elimination where a simple, well-understood reporting structure makes high-volume, granular, facility-level case reporting sustainable, and granular case data is the raw material where elimination phase analysis depends on. However, the gap between case definition understanding (99.1%) and reported ease of use (85.4%) points to a residual digital literacy bottleneck. This matters because elimination of malaria depends on the easy and simple of case based reporting system, foci registers, GIS-linked mapping and reactive case detection logs than aggregate monthly reporting. Zambia's malaria surveillance system need to absorb this added complexity without eroding the simplicity that currently drives high compliance; digital literacy gaps identified here are the most likely point of strain as that transition occurs.

In this study, acceptability had an average score of 89.0% far much higher than 79.0% reported in South Africa [26], driven by near-universal agreement that surveillance is part of routine duty (98.4%). Active participation, however, scored notably lower at 79.6%, just below threshold, a gap between normative compliance and intrinsic motivation. This distinction is consequential for elimination specifically, because elimination phase surveillance asks more of health workers than routine reporting such that active case detection, household level investigation, and reactive case detection around confirmed cases become additional non-routine tasks. A workforce that reports out of duty rather than intrinsic motivation may comply with passive reporting but be slower to take up these more demanding, elimination specific activities. Strengthening recognition, feedback loops, and incentive structures are therefore not just a general system-strengthening measure but a specific precondition for elimination phase of case investigation work.

Even though completeness scored 87.1% in this study, exceeding the benchmark, it fell short of the 100% reported in Benue State, Nigeria [27] and in Ethiopia [28] and comparable completeness gaps have been documented in Kenya's DHIS2 based malaria reporting system [29]. Case capture (94.0%) and reporting unit submission (94.7%) were strong, but only 72.7% of respondents reported consistent 90% and above submission over the preceding three years, indicating episodic reporting gaps linked to staff turnover, network downtime, and commodity shortages. In a control setting, episodic gaps are a data quality concern but in an elimination setting, they are a structural risk in the sense that each unreported period is a window in which a genuine transmission focus could emerge undetected. Because elimination reclassification of a Health Facility Catchment Area (HFCA) as malaria-free depends on a credible history of zero locally transmitted cases, any gap in reporting continuity weakens confidence in that history and

could delay or invalidate elimination verification for an area that may, in fact, have already interrupted transmission.

Sensitivity was at 84.9% composite score above benchmark of 80.0%, supported by community level case capture (87.8%), but outbreak detection (79.4%) was its weakest sub indicator. The system's continued reliance on passive routine surveillance is a known limitation in low endemic settings. This is because as transmission falls, care-seeking for mild illness declines and a growing share of infections including asymptomatic and low-density infections that still contribute to transmission also go undetected by passive systems. WHO elimination guidance therefore recommends active case detection (ACD) and reactive case detection (RACD) around confirmed cases rather than passive surveillance [30], [31] [7]. Similar reliance on passive detection alone, rather than active or reactive case detection, has been documented in other elimination phase settings in Asia and East Africa [32], [33]. Zambia's below the benchmark outbreak-detection sub-score suggest the early warning and epidemic threshold mechanisms needed to trigger this kind of targeted response are not yet consistently in place.

Generally, the usefulness of the malaria surveillance system was at 84.0%, supported by strong data utilisation rate of 94.5%, exceeding 90.0% recorded in Ebonyi State, Nigeria [25] and much higher than 70.0% reported in Benue State, Nigeria [27]. This is encouraging for elimination in principle because data used for decisions at facility and district level can support the targeted elimination by directing intervention measures such as indoor residual spraying (IRS), net distribution, or case investigation to specific localities rather than broad administrative areas. However, this study did not establish whether utilization extended to elimination specific decisions such as foci classification or HFCA reclassification, which typically require province and national level analytic capacity beyond routine facility or district decision-making.

Timeliness recorded an average score of 79.7%, failing slightly below the threshold of 80.0% and far much below 95.0% in a study conducted in Nigeria [25] and 97.0% in Ethiopia [28], though above 70.0% in a study conducted in India [3]. This study further established that 91.1% of respondents self-reported submitting reports on time, yet 22.8% reported access delays and 29.3% reported significant submission delays, a substantial contradiction likely reflecting network connectivity issues, DHIS2 downtime, and inconsistent data-bundle availability, or inconsistent interpretation of what counts as “on time.” This gap posed a direct consequence for elimination strategy. WHO's 1-3-7 approach for elimination settings specifies that a confirmed case should be notified within 1 day, investigated within 3 days, and any associated focus responded to within 7 days [34], [35], [36] [7], consistent with Thailand and Cambodia experience in implementing the similar approach [2], [8]. A system in which nearly a third of respondents report significant submission delays cannot reliably support a 1-day notification standard; delayed reporting directly translates into delayed investigation and delayed response, allowing continued transmission during exactly the window elimination strategy is designed to close.

Data quality scored 78.6%, below the threshold and further below South Africa's 88.9% [26]. Validation systems (86.3%) and report completeness (87.6%) were reasonably strong, but 30.6% of respondents

acknowledged data errors, and only 71.4% rated surveillance data as always accurate and reliable, the weakest sub-indicators in this domain alongside error free reporting (69.4%). Data quality is arguably the most consequential below-threshold attribute for elimination decision-making specifically, because elimination relies on case-level data being trustworthy enough to classify each case as indigenous, imported, or introduced, a distinction with no equivalent in control phase surveillance, where aggregate burden estimates are sufficient. Errors at the rate identified in this study risk misclassifying foci, distorting burden estimates in exactly the low-case-count settings where estimates are most sensitive to individual errors, and weakening the historical case-data record that WHO elimination certification dossiers require.

The positive predictive value (78.2%) in this study substantially exceeded the 44.4% recorded in Ankober Woreda, North Shewa, Ethiopia [28], but remained below the 80% benchmark. While 82.7% of respondents felt the system adequately represented all population groups, only 73.6% agreed that most reported cases were laboratory-confirmed, pointing to persistent clinical (non-parasitological) diagnosis in some settings. This has a direct bearing on elimination because it runs counter to WHO's Test-Treat-Track (T3) initiative [37], which calls for parasitological confirmation of every suspected case before treatment and reporting. Unconfirmed clinical diagnoses inflate case counts, reduce the specificity of surveillance data and cannot therefore be used in elimination verification or HFCA reclassification, which require confirmed case histories. As Zambia moves towards subnational elimination, closing this confirmation gap is a prerequisite for trusting the case counts elimination decisions.

Stability (70.8%), while below threshold, compared favorably with 57.0% in Punjab, India[3] and 51.9% in Chipinge district, Zimbabwe [38]. Diagnostic tool availability of 94.2% was reported, though the composite stability sub-score for this was only 61.0% and trained staff adequacy (67.2%) were the weakest components, alongside the finding that only 59.9% of respondents reported rare or no system disruptions. Stability gaps carry outsized risk in elimination settings because they are most likely to bite exactly where elimination is closest to being achieved. A previously malaria-free or near-eliminated area that experienced an imported case depends on an uninterrupted surveillance and diagnostic capacity to detect and respond before onward transmission re-establishes local malaria. A stock-out of rapid diagnostic tests or an untrained replacement staff member during that narrow window can allow a single imported case to seed a new focus, a failure mode with far higher consequence in an elimination district than in a high-burden control district, where individual case detection delays have proportionally less impact on overall transmission.

Flexibility was markedly lower (57.6%) than the 85.9% reported in Punjab, India [3], and was the lowest-scoring attribute in this study. Only 37.5% of respondents believed the system could accommodate new diseases without structural change, only 40.8% felt staff could adapt without extensive retraining, and integration with other health information systems scored just 52.5%. This is arguably the single most consequential below-benchmark finding for elimination. Just as the COVID-19 pandemic exposed the rigidity of vertical, single-disease surveillance systems worldwide, Zambia's malaria surveillance system showed the similar pattern. Elimination phase surveillance is an evolution away from a fixed and vertical

reporting structure to a case-based, foci-level and cross-programme surveillance that must interoperate with eIDSR, HMIS, and STEP-D, and also taking into account the cross-border transmission, with the data systems of neighbouring Elimination 8 (E8) countries [39]. A system architecture that struggles to absorb a new case definition without structural change will struggle far more with the shift to foci classification, reactive case detection registers, and genomic or cross-border data sharing that elimination requires. This is a design level constraint rather than an operational one, and this study flagged it as warranting architectural review rather than incremental fixes.

The evaluation identified a negative correlation between provincial funding and surveillance performance: the four lowest-performing provinces (Western, Central, North-Western, and Northern) received the largest financial allocations, while six provinces that received below-threshold funding (Copperbelt, Luapula, Lusaka, Eastern, Muchinga, Southern) still achieved 80% or higher performance. The most plausible reading is reverse causality where funding responding to poor performance rather than driving it, which implies that the binding constraints are non-financial and may include staffing levels, network/DHIS2 infrastructure, and terrain or accessibility. This has direct relevance for elimination financing. As international donor contributions to malaria programmes in the region come under pressure [40], the marginal cost of finding and responding to each remaining case rises as burden falls, making efficient targeting of resources more important than the total volume of funding. If the constraints limiting Western, Central, North-Western, and Northern provinces are structural (staffing, connectivity, and terrain) rather than financial, continued proportional budget increases to these provinces are unlikely to close the performance gap. Targeted technical investments in offline reporting fallbacks, staff deployment, and connectivity infrastructure are more likely to move these provinces toward elimination readiness than additional funding alone.

The WHO Global Technical Strategy (GTS) names surveillance as one of its three core pillars and calls for surveillance to be treated as a core intervention capable of detecting cases early, tracking trends, and guiding a targeted response. The 80.4% overall performance score in this study validates and mirrors the GTS concern that surveillance systems in transitioning countries often achieve basic functionality without reaching the maturity needed to safely support elimination. Weaknesses in flexibility and stability directly undercut the GTS requirement that surveillance systems be able to detect, verify and respond to changing transmission patterns, including resurgence risk as burden falls. Low positive predictive value (78.2%) and reliance on clinical (unconfirmed) diagnosis run counter to the GTS's emphasis on high-quality, trustworthy data as the basis for elimination verification and reclassification of transmission areas.

Africa CDC has increasingly framed surveillance and data systems as “sovereign infrastructure” central to continental health security, and has prioritized digitally enabled, epidemic-ready primary health care systems built around community health workers, alongside a dedicated roadmap for strengthening malaria surveillance (including genomic surveillance) across the continent [41]. In this study, the strong role of community health workers in case detection (simplicity 93.8%, acceptability 89.0%) is consistent with Africa CDC's emphasis on leveraging community health workers as the frontline of surveillance and

primary health care integration [42], [43]. In addition, the flexibility and interoperability gaps identified, particularly weak integration between DHIS2, eIDSR, MRR and other platforms (52.5%) are precisely the kind of fragmentation Africa CDC's continental health-intelligence agenda seeks to overcome; disconnected national systems limit the region-wide data sharing Africa CDC is pushing for. Further, data quality and diagnostic confirmation weaknesses reinforce Africa CDC's broader argument that surveillance cannot be strengthened in isolation from laboratory systems and commodity security, both flagged in this study as constraints on stability and PPV.

Zambia's NMESP 2022–2026, aligned with the WHO GTS and the Southern Africa Elimination 8 (E8) initiative, sets out to reduce national malaria incidence while pursuing subnational elimination, maintaining malaria-free status in Health Facility Catchment Areas (HFCAs) that have already eliminated transmission, and preventing reintroduction, while strengthening surveillance as a strategic pillar [44]. The results of this study speak directly to whether the surveillance backbone required for this dual strategy is currently in place. For instance, subnational elimination and HFCA-level stratification, as pursued under the NMESP, depend on precisely the case-based, foci-level, and interoperable surveillance capacity that this study finds weakest (flexibility 57.6%, PPV 78.2%). Without reliable case confirmation and system adaptability, HFCAs cannot be confidently reclassified as malaria-free or monitored for reintroduction risk [45]. The NMESP's ambition to raise intervention implementation from 72% to 95% by 2026 assumes a surveillance system that can reliably track where interventions are and are not reaching target coverage; the completeness gaps identified here (72.7% of respondents reporting consistent 90%+ submission over three years) suggest this tracking capacity is not yet fully dependable. The province-level disconnect between funding and performance identified in this study is directly relevant to NMESP implementation planning, which operates under Medium-Term Expenditure Framework budget ceilings; it suggests that closing performance gaps may require targeted technical and structural investment (staffing, network infrastructure, commodity supply) rather than proportional budget increases alone. The heterogeneous transmission landscape described in the NMESP with some areas ready for elimination, focused strategies and others still needing control phase strengthening, matches this study's own finding that national averages mask meaningful subnational variation in surveillance performance.

Strengths of the study

National coverage: The study included 452 health workers across facility, district and provincial levels in all ten provinces, a breadth rarely achieved in comparator studies from other regions.

Recognized evaluation framework: Use of the CDC framework for surveillance system evaluation anchors the assessment in ten internationally recognized attributes enabling structured and comparable scoring.

Transparent analysis: A reproducible R/Quarto workflow, standardized 0–100 domain scoring, and appropriate non-parametric statistics (Kruskal-Wallis, chi-square with 95% confidence intervals) support replicability.

Depth beyond description: Bivariate and multivariable/predictive analyses allowed the study to identify which respondent and system characteristics are associated with high performance, not merely describe the scores.

Engaging with counter-intuitive findings: The inverse relationship between provincial budget allocation and performance is examined analytically rather than omitted, with a defensible reverse-causality interpretation offered.

Programme relevance: Findings are translated into a concrete, attribute-linked table of challenges and recommended actions, making the study directly useful for programme planning rather than purely academic.

Limitations of the study

Cross-sectional design: A single time window (2022–2024) cannot establish trends over time including the budget-performance association, which remains correlational only.

Reliance on health-worker perception: Almost all attributes were assessed based on health workers' perception on the performance of the surveillance system

Instrument validation not reported: There was no pilot testing or reliability testing of the adapted questionnaire

Recall bias: Three-year retrospective questions (e.g. on completeness) are vulnerable to recall bias, particularly among staff with high turnover.

Cross-country comparisons are descriptive only: Comparisons with Nigeria, Ethiopia, South Africa, India and Zimbabwe are useful context but are not statistically tested, and differences in questionnaire design and health-system context limit direct comparability.

Proxy measure of PPV: Positive predictive value, as measured, is a proxy based on respondent perception of laboratory confirmation rather than a calculated epidemiological PPV against confirmed/unconfirmed case data, worth flagging given the term's specific technical meaning.

CHALLENGES AND RECOMMENDATIONS

Challenges

This study established the following challenges in the quest to enhance the performance of malaria surveillance system in Zambia: Low laboratory confirmation capacity in districts; Network system disruption; Disintegration of malaria reporting systems; Poor feedback from districts to facilities; Irregular data quality audits at facility and district levels; Low mentorship based training for new staff

and community health workers; Stock outs of RDTs and antimalarial in peripheral facilities and Inadequate assessment on malaria system flexibility.

Recommendations

Based on the performance findings, the following evidence-based recommendations are proposed to strengthen Zambia's malaria surveillance system: Enhance laboratory confirmation capacity by expanding access to RDTs and microscopy and integrating results directly into digital reporting platforms to improve PPV; Develop offline-capable or SMS-based reporting fallback mechanisms to address timeliness and stability gaps caused by network disruptions; Implement interoperability frameworks linking DHIS2, eIDSR, MRR, and StepD to close flexibility gaps and advance integrated disease surveillance goals; Institutionalize structured feedback loops from district to facility level for all surveillance reports to improve usefulness and long-term acceptability; Conduct routine data quality audits and implement real-time error-flagging in DHIS2 to address the 30.6% data error rate; Strengthen mentorship-based training for new staff and community health workers to sustain sensitivity and reduce retraining burdens when system changes occur; Ensure buffer stocks of RDTs and antimalarial at peripheral facilities to maintain stability and uninterrupted case confirmation; Commission a dedicated flexibility assessment using event simulation exercises to test system adaptability to outbreak scenarios beyond malaria.

Conclusion

This evaluation shows that Zambia's malaria surveillance system has a strong foundation but is not yet fully elimination-ready. The system achieved an attribute-level mean performance score of 80.4%, marginally meeting the 80% benchmark, with strong performance in simplicity, acceptability, completeness, sensitivity and usefulness. However, important weaknesses were observed in flexibility, stability, data quality, timeliness and positive predictive value. These gaps point to structural and operational limitations that may affect the reliability, adaptability and epidemiological precision of routine malaria surveillance data. Strengthening diagnostic confirmation, data quality assurance, system interoperability, feedback mechanisms, workforce capacity and reporting continuity should be treated as urgent programme priorities if Zambia is to generate the surveillance intelligence needed to reach its 2030 malaria elimination targets.

Declarations

Clinical Trial

This study was a non-clinical trial study

Consent for publication

The consent to publish the findings of this study was granted by the author.

Availability of data and material

The data and materials used in this study are available on this link attached: <https://docs.google.com/spreadsheets/d/12rb3UpKJxgR8ffTXyvXmOLMT-WTI-4nu/edit?usp=sharing&ouid=104928340185415046610&rtpof=true&sd=true>

Conflict of interest

All the authors declared no conflict of interest regarding this work.

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Authors' contribution

WFN, WN and CZ conceptualized and designed the study. AM and WN were involved in data collection whilst WFN and WN performed the analysis. WFN drafted the manuscript. WN, CZ and WFN edited and reviewed the manuscript. All the authors have read and agreed to the final manuscript.

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References

1. W. Han *et al.*, "Performance and feasibility of reactive surveillance and response strategies for malaria elimination in Vietnam: a mixed - methods study," *Malar. J.*, pp. 1–13, 2023, doi: 10.1186/s12936-023-04660-w.
2. S. T. Kheang *et al.*, "Malaria elimination using the 1-3-7 approach: lessons from Sampov Loun, Cambodia," no. 2020, pp. 1–7, 2025.
3. S. Sharma, K. Goel, K. Kaushal, G. S. Grover, T. Dikid, and G. B. Singh, "An Evaluation of Malaria Surveillance System in Punjab, India, 2020," pp. 407–412, 2023, doi: 10.4103/ijcm.ijcm.
4. J. Kaur, R. Baharia, and M. Dattani, "Assessment of the quality of malaria surveillance and laboratory services for diagnosis in three districts of Gujarat state, India," vol. 2000, no. 1, 2000.
5. E. K. Aidoo *et al.*, "Reactive Case Detection Strategy for Malaria Control and Elimination: A 12 Year Systematic Review and Meta-Analysis from 25 Malaria-Endemic Countries," 2023.

6. D. K. Sarma, P. K. Mohapatra, D. R. Bhattacharyya, N. S. Kumar, A. P. Dash, and A. Prakash, "Malaria in North-East India: Importance and Implications in the Era of Elimination," vol. 2016, pp. 1–21, 2019.
7. WHO, *Global Technical Strategy for Malaria 2016–2030*. 2021.
8. C. Lertpiriyasuwat *et al.*, "Implementation and success factors from Thailand's 1-3-7 surveillance strategy for malaria elimination," *Malar. J.*, pp. 1–12, 2021, doi: 10.1186/s12936-021-03740-z.
9. A. Mon *et al.*, "'Alert-Audit-Act': assessment of surveillance and response strategy for malaria elimination in three low-endemic settings of Myanmar in 2016," pp. 1–9, 2018.
10. WHO, *World malaria report 2022*. 2022.
11. J. Gerardin *et al.*, "Effectiveness of reactive case detection for malaria elimination in three archetypical transmission settings: a modelling study," *Malar. J.*, pp. 1–17, 2017, doi: 10.1186/s12936-017-1903-z.
12. D. A. Larsen *et al.*, "Location, location, location: environmental factors better predict malaria-positive individuals during reactive case detection than index case demographics in Southern Province, Zambia," *Malar. J.*, pp. 1–9, 2017, doi: 10.1186/s12936-016-1649-z.
13. K. M. Searle *et al.*, "Evaluation of the operational challenges in implementing reactive screen-and-treat and implications of reactive case detection strategies for malaria elimination in a region of low transmission in southern Zambia," *Malar. J.*, pp. 1–14, 2016, doi: 10.1186/s12936-016-1460-x.
14. MoH, "Zambia National Malaria Indicator Survey 2021," 2021.
15. C. B. Mandyata, L. K. Olowski, and W. Mutale, "Challenges of implementing the integrated disease surveillance and response strategy in Zambia: a health worker perspective," pp. 1–12, 2017, doi: 10.1186/s12889-017-4791-9.
16. WHO, "World malaria report 2016," Geneva, 2016.
17. E. E. Agbemaflle *et al.*, "Public Health in Practice Evaluation of the malaria surveillance system – Adaklu District, Volta Region, Ghana, 2019," *Public Heal. Pract.*, vol. 6, no. June 2022, p. 100414, 2023, doi: 10.1016/j.puhip.2023.100414.
18. SADC, *Assessment Report on the Status of HIV and AIDS, Tuberculosis and Malaria Surveillance Systems in the SADC Region*. 2009.
19. Gitta *et al.*, "Proceedings of the African Field Epidemiology Network (AFENET) Scientific Conference 17-22 November 2013 Addis Ababa, Ethiopia: plenaries and oral presentations," *PanAfrican Med. J.*, vol. 8688, pp. 1–66, 2015, doi: 10.11604/pamj.2015.21.208.7258.
20. Jailos Lubinda, Y. B. Id, B. Hamainza, and U. H. Id, "Modelling of malaria risk, rates, and trends: A spatiotemporal approach for identifying and targeting sub-national areas of high and low burden," pp. 1–23, 2021, doi: 10.1371/journal.pcbi.1008669.
21. J. Karuri, P. Waiganjo, D. Orwa, and A. Manya, "DHIS2: The Tool to Improve Health Data Demand and Use in Kenya," *J. Health Inform. Dev. Ctries.*, vol. 8, no. 1, pp. 38–60, 2014.

22. A. Many, J. Braa, L. Øverland, O. Titlestad, J. Mumo, and C. Nzioka, "National Roll out of District Health Information Software (DHIS 2) in Kenya , 2011 – Central Server and Cloud based Infrastructure," *IIMC Int. Inf. Manag. Corp.*, pp. 1–9, 2012.
23. R. R. German *et al.*, "Updated guidelines for evaluating public health surveillance systems: recommendations from the Guidelines Working Group.," *MMWR. Recomm. reports Morb. Mortal. Wkly. report. Recomm. reports*, vol. 50, no. RR-13, pp. 1–35; quiz CE1-7, 2001, [Online]. Available: <http://www.ncbi.nlm.nih.gov/pubmed/18634202>
24. T. I. Visa, O. Ajumobi, E. Bamgboye, I. Ajayi, and P. Nguku, "Evaluation of malaria surveillance system in Kano State , Nigeria , 2013 – 2016," pp. 1–9, 2020.
25. A. Joseph, N. Patrick, N. Lawrence, O. Lilian, and A. Olufemi, "Evaluation of Malaria Surveillance System in Ebonyi," pp. 101–104, 2017.
26. M. Mabona, T. Zwane, J. Raman, L. Kuonza, and B. Mhlongo, "Evaluation of the malaria case surveillance system in KwaZulu - Natal Province , South Africa , 2022: a focus on DHIS2," *Malar. J.*, pp. 1–13, 2024, doi: 10.1186/s12936-024-04873-7.
27. P. O. Amede *et al.*, "Evaluation of malaria surveillance system in Benue State , Nigeria," *Malar. J.*, pp. 1–14, 2022, doi: 10.1186/s12936-022-04367-4.
28. W. N. Shewa, A. Region, T. Abye, B. Hailegiorgis, B. Taye, and T. Abera, "Malaria Surveillance System Evaluation in Ankober," vol. 2, no. 3, pp. 8–21, 2024.
29. S. Githinji *et al.*, "Completeness of malaria indicator data reporting via the District Health Information Software 2 in Kenya , 2011 – 2015," *Malar. J.*, pp. 1–11, 2017, doi: 10.1186/s12936-017-1973-y.
30. H. J. W. Sturrock *et al.*, "Reactive Case Detection for Malaria Elimination : Real-Life Experience from an Ongoing Program in Swaziland," *PLoS One*, vol. 8, no. 5, 2013, doi: 10.1371/journal.pone.0063830.
31. H. J. W. Sturrock *et al.*, "Targeting Asymptomatic Malaria Infections : Active Surveillance in Control and Elimination," *PLoS One*, vol. 10, no. 6, pp. 1–8, 2013, doi: 10.1371/journal.pmed.1001467.
32. C. S. Gueye *et al.*, "Active case detection for malaria elimination : a survey among Asia Pacific countries," *Malar. J.*, vol. 12, no. 358, pp. 1–9, 2013.
33. T. Van Der Horst, B. S. Fakih, L. Stuck, A. Ali, J. Yukich, and M. W. Hetzel, "Operational Coverage and Timeliness of Reactive Case Detection for Malaria Elimination in," *Am. J. Trop. Med. Hyg.*, vol. 102, no. 2, pp. 298–306, 2020, doi: 10.4269/ajtmh.19-0505.
34. S. Zhou *et al.*, "China ' s 1-3-7 surveillance and response strategy for malaria elimination : Is case reporting , investigation and foci response happening according to plan?," *Infect. Dis. Poverty*, pp. 1–9, 2015, doi: 10.1186/s40249-015-0089-2.
35. B. Yi, L. Zhang, J. Yin, S. Zhou, and Z. Xia, "in malaria elimination : China ' s practice and global adaptations," *Malar. J.*, vol. 22, no. 1, pp. 1–9, 2023, doi: 10.1186/s12936-023-04580-9.
36. J. Cao *et al.*, "Communicating and Monitoring Surveillance and Response Activities for Malaria Elimination: China ' s "" 1-3-7 "" Strategy," vol. 11, no. 5, pp. 1–6, 2014, doi: 10.1371/journal.pmed.1001642.

37. WHO, "Test. Treat. Track. Scaling up diagnostic testing , treatment and surveillance for malaria," 2012.
38. T. Kureya, E. Chadambuka, M. Mhlanga, and A. Ndaimani, "An Evaluation of the Malaria Surveillance System of Chipinge District , Manicaland Province," vol. 7, no. 3, pp. 197–209, 2017.
39. C. H. Sikaala, B. Dlamini, A. Lungu, P. Fakudze, and M. Chisenga, "Malaria elimination and the need for intensive inter - country cooperation : a critical evaluation of regional technical co - operation in Southern Africa," *Malar. J.*, pp. 1–11, 2024, doi: 10.1186/s12936-024-04891-5.
40. Akros, "Bridge the Gap Initiative. A Data-Driven Call to Action: Sustaining Zambia's Malaria Response," 2025.
41. Africa CDC, "Roadmap for the Implementation of Malaria Genomic Surveillance in Africa," 2023.
42. C. Tusiime, "Community Health Workers: Key Drivers in Malaria Community Case Management in Zambia," *Texila Int. J. Public Heal.*, 2024, doi: 10.21522/TIJPH.2013.12.04.Art063.
43. J. B. Christopher, A. Le May, S. Lewin, and D. A. Ross, "Thirty years after Alma-Ata : a systematic review of the impact of community health workers delivering curative interventions against malaria , pneumonia and diarrhoea on child mortality and morbidity in sub-Saharan Africa," *Hum. Resour. Health*, vol. 9, no. 1, p. 27, 2011, doi: 10.1186/1478-4491-9-27.
44. Ministry of Health, "National Malaria Elimination Strategic Plan 2022 - 2026," 2022.
45. WHO, "A framework for malaria elimination," 2017.

Figures

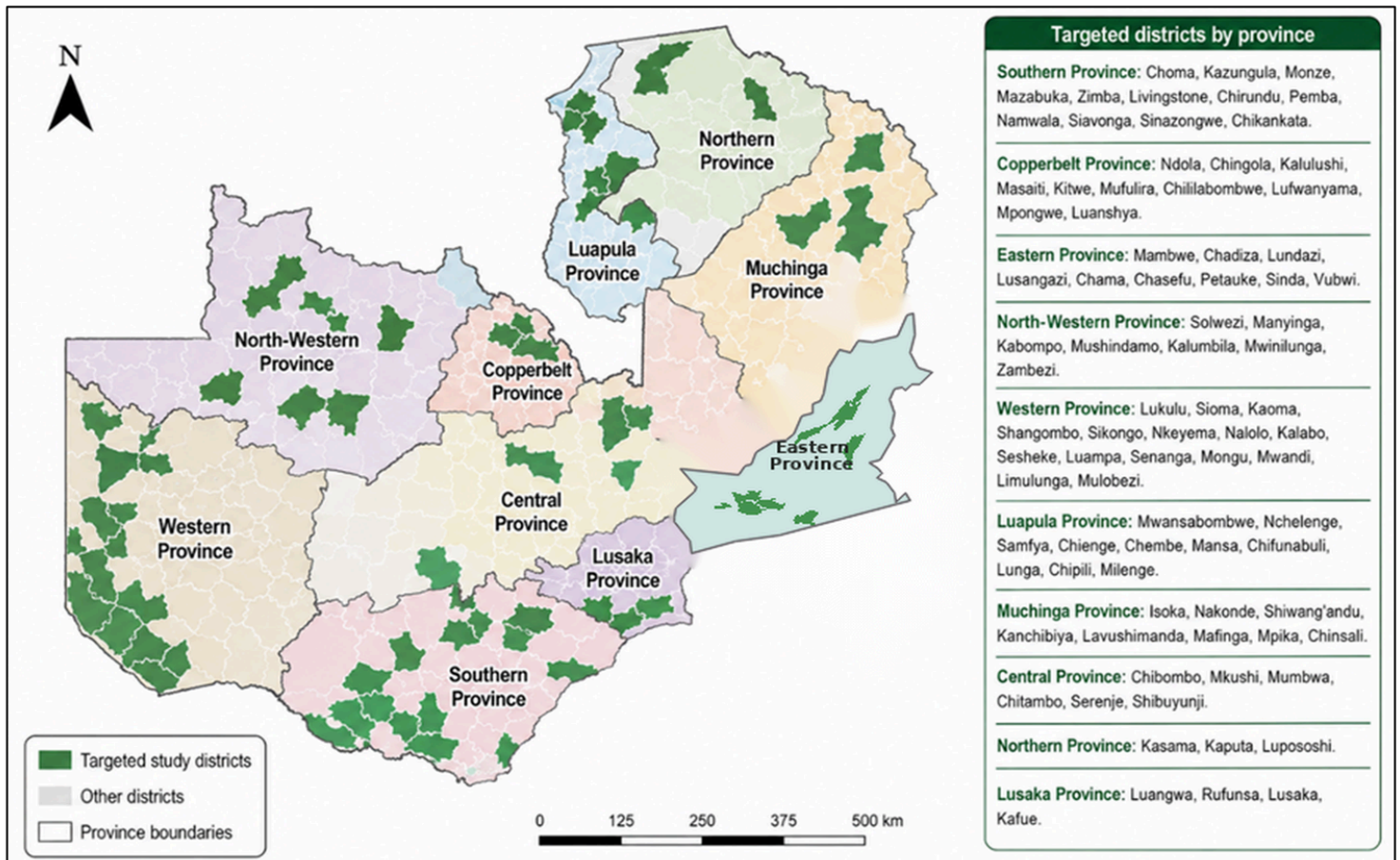


Figure 1

Map of Zambia showing districts targeted for the malaria surveillance system performance assessment, 2022 to 2024

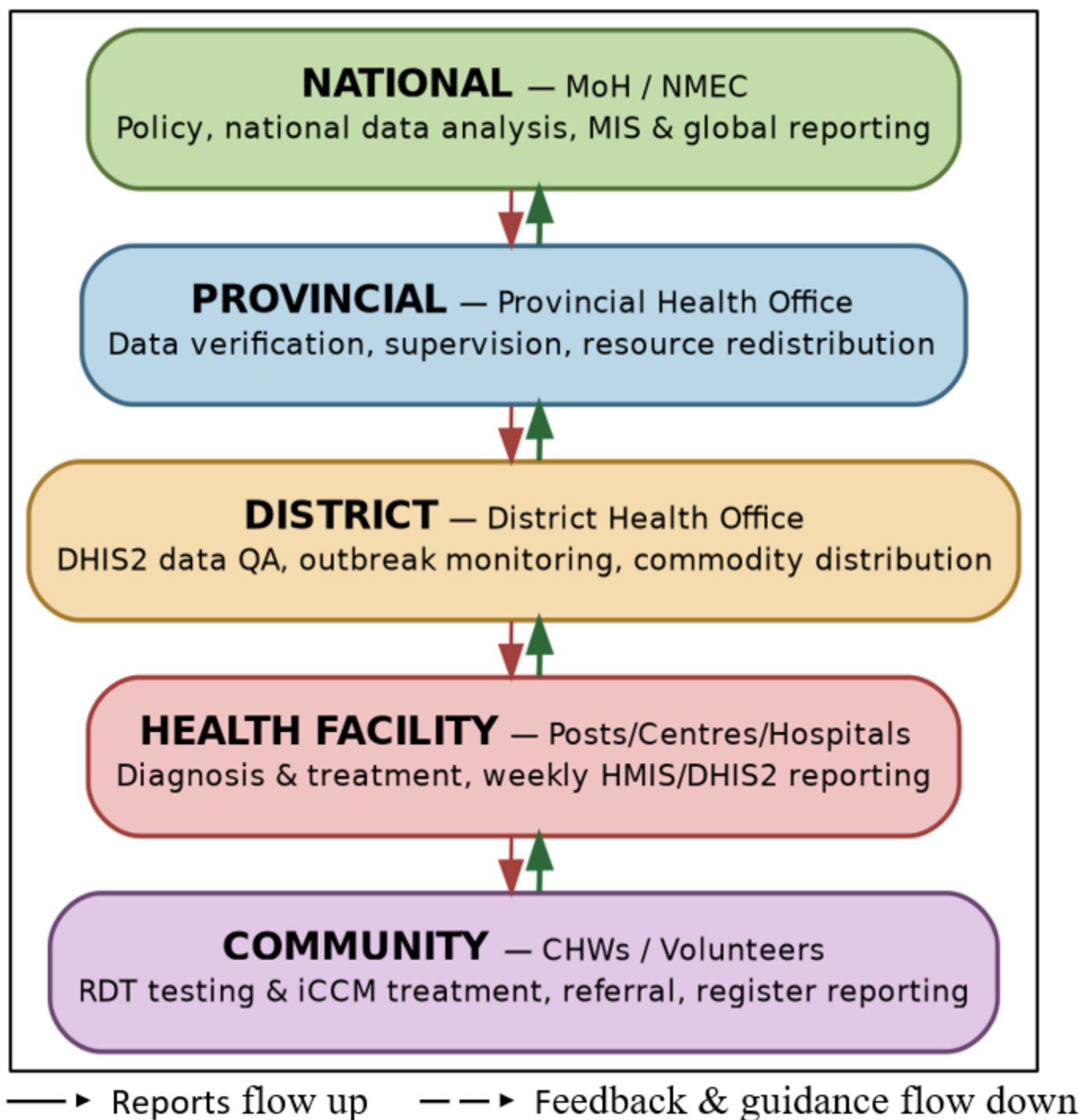


Figure 2

Implementation of the malaria surveillance system in Zambia

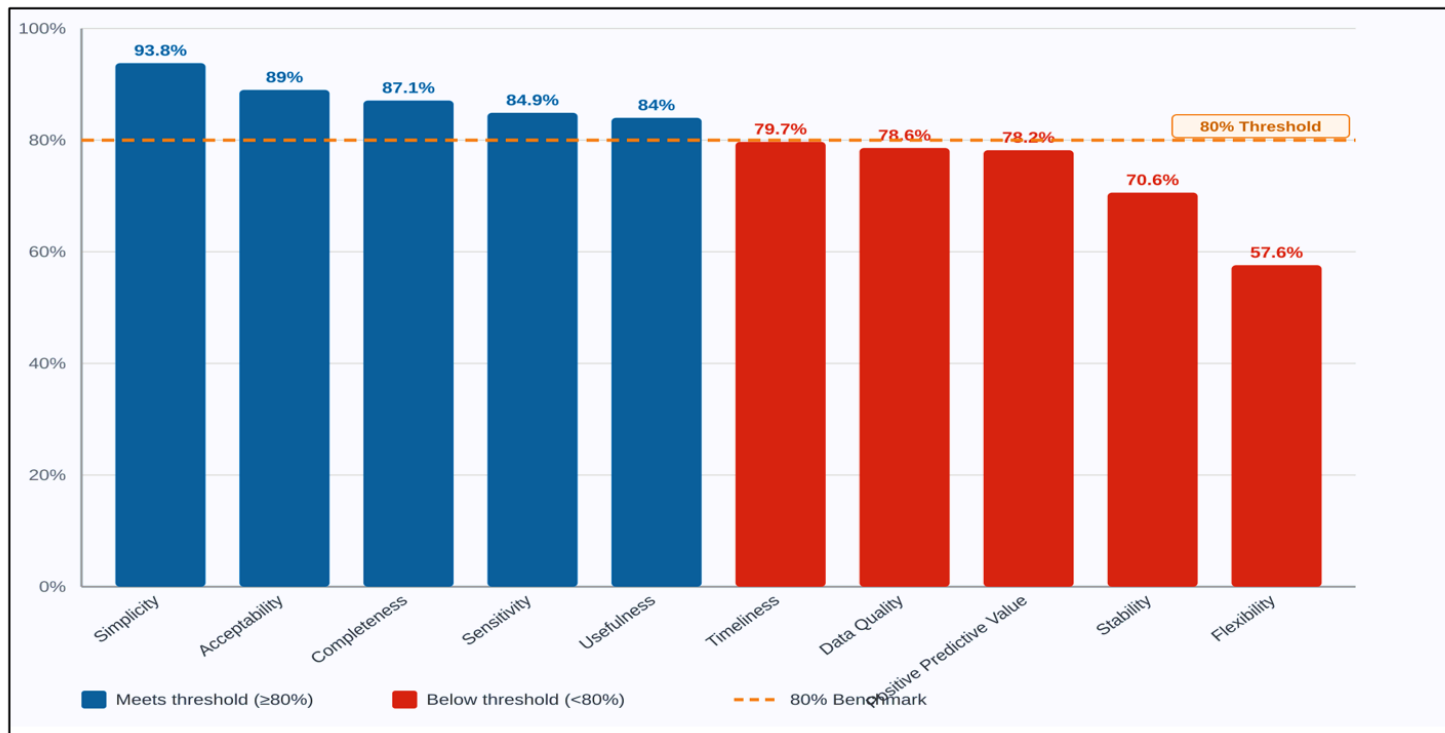


Figure 3

Summary of Malaria Surveillance System Performance against the 80% Threshold (N = 452)

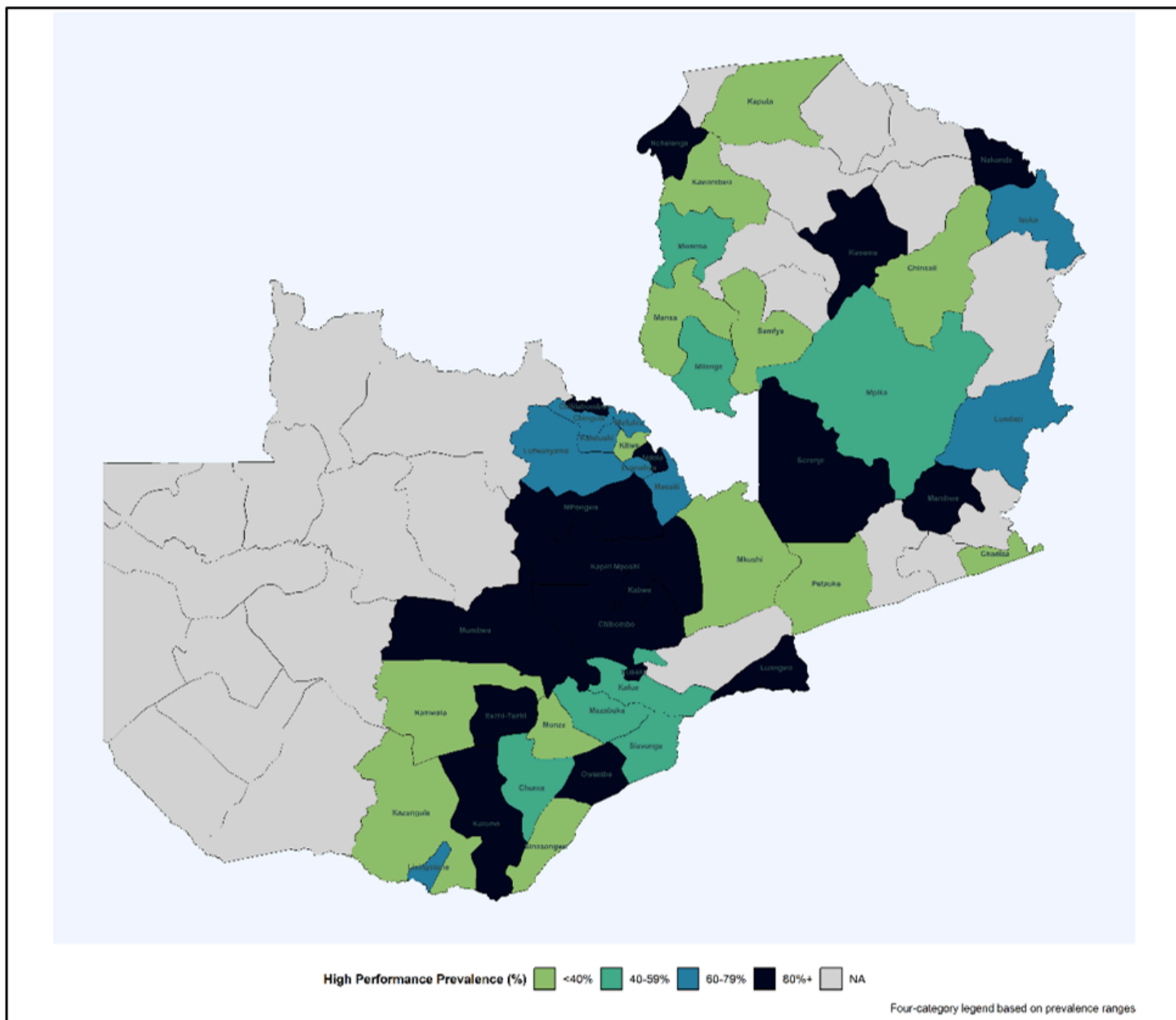


Figure 4

Prevalence of High Malaria Surveillance Performance (Score ≥ 80) across Key Survey Characteristics

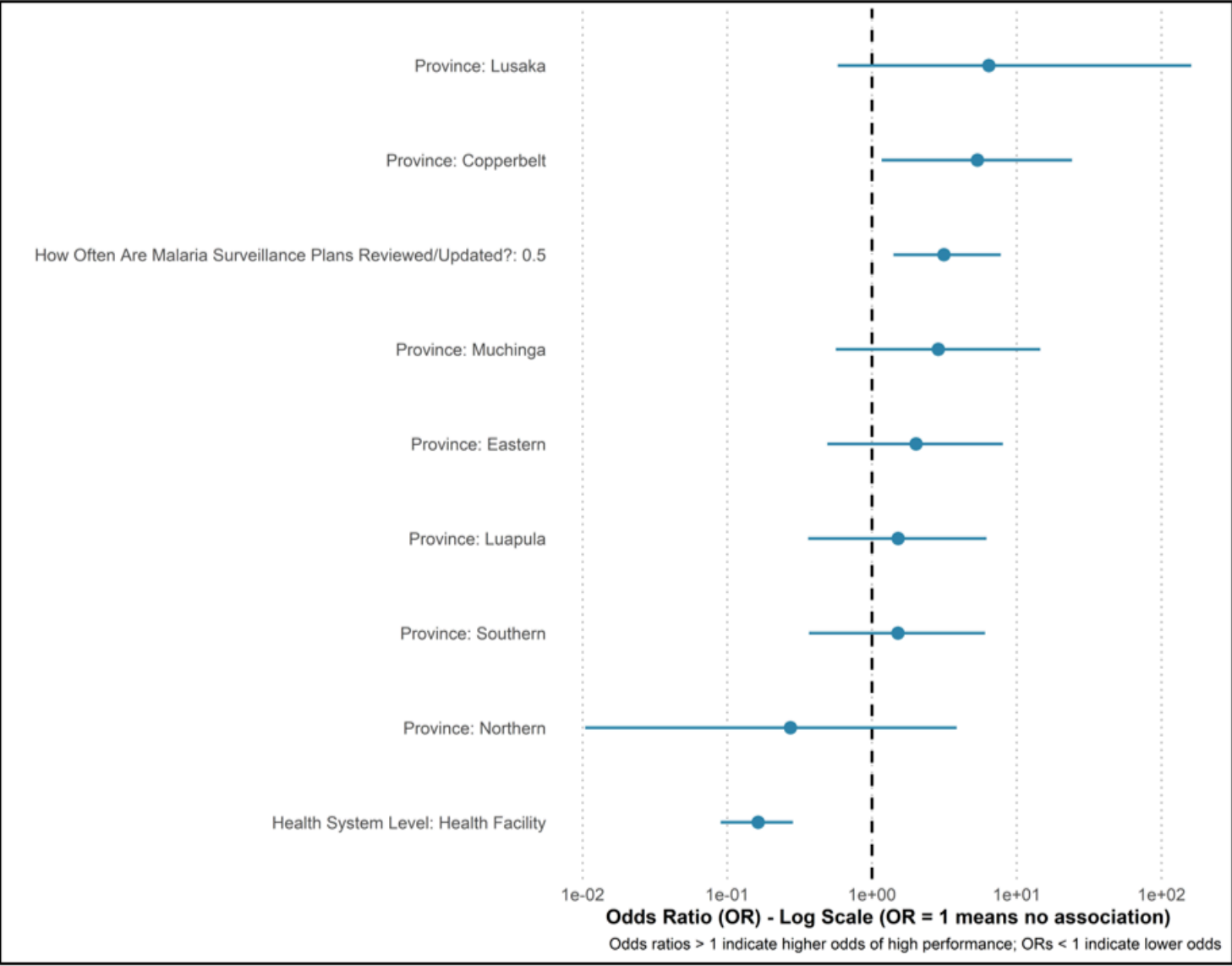


Figure 5

Determinants of high performance of malaria surveillance in Zambia, 2022-2024

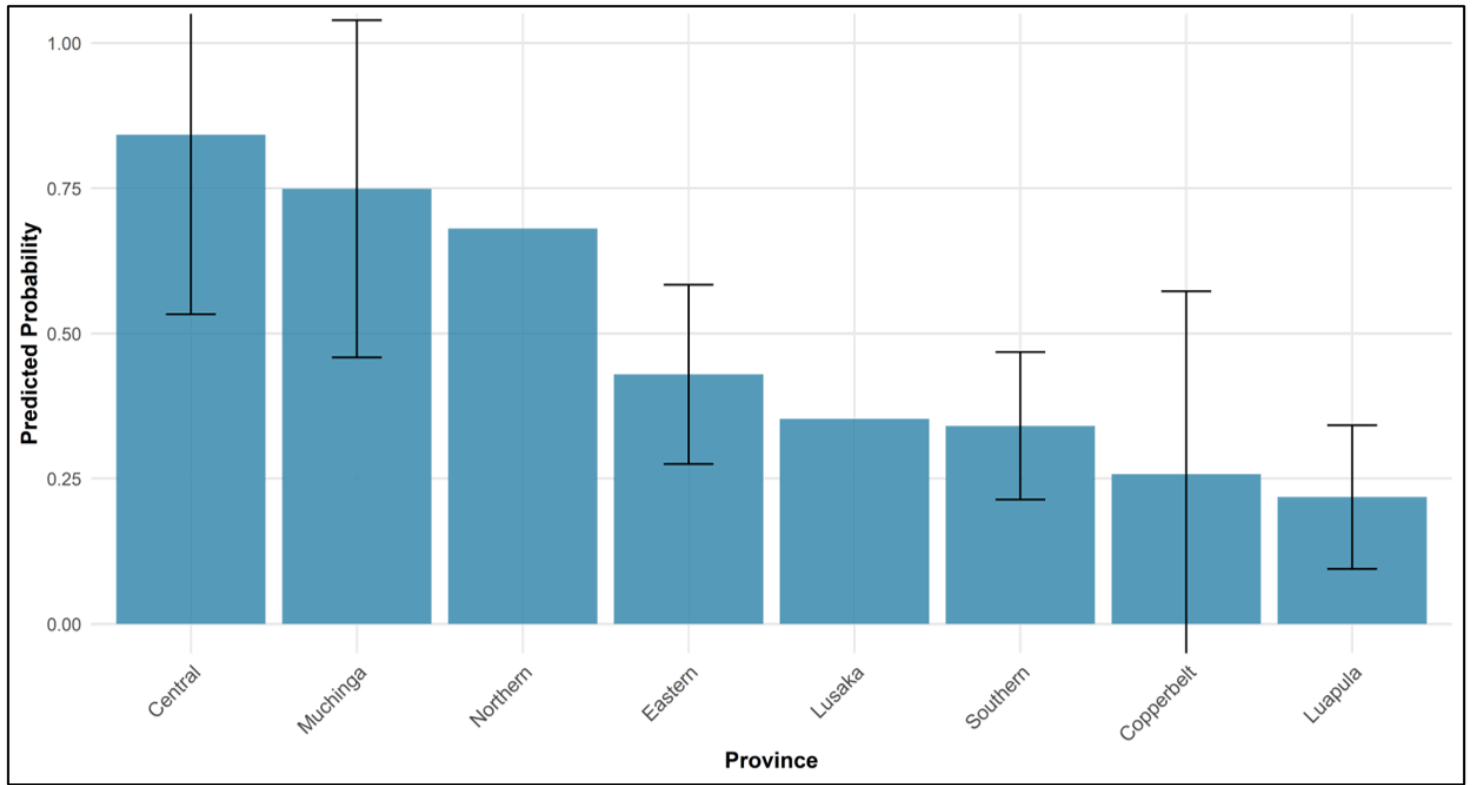


Figure 6

Predicting probability of high surveillance performance in Zambia

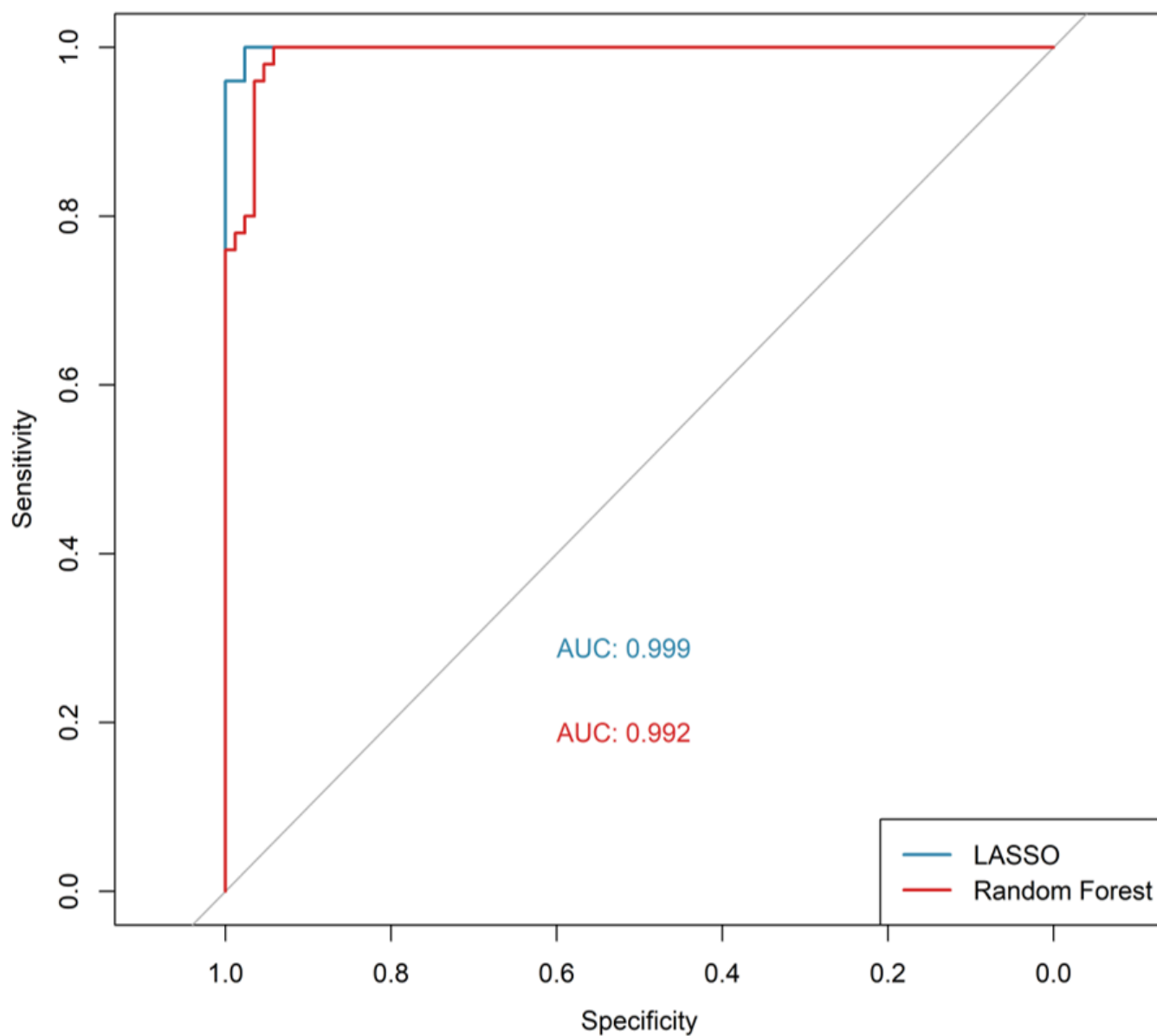


Figure 7

Sensitivity analysis of the classification high performance of malaria surveillance

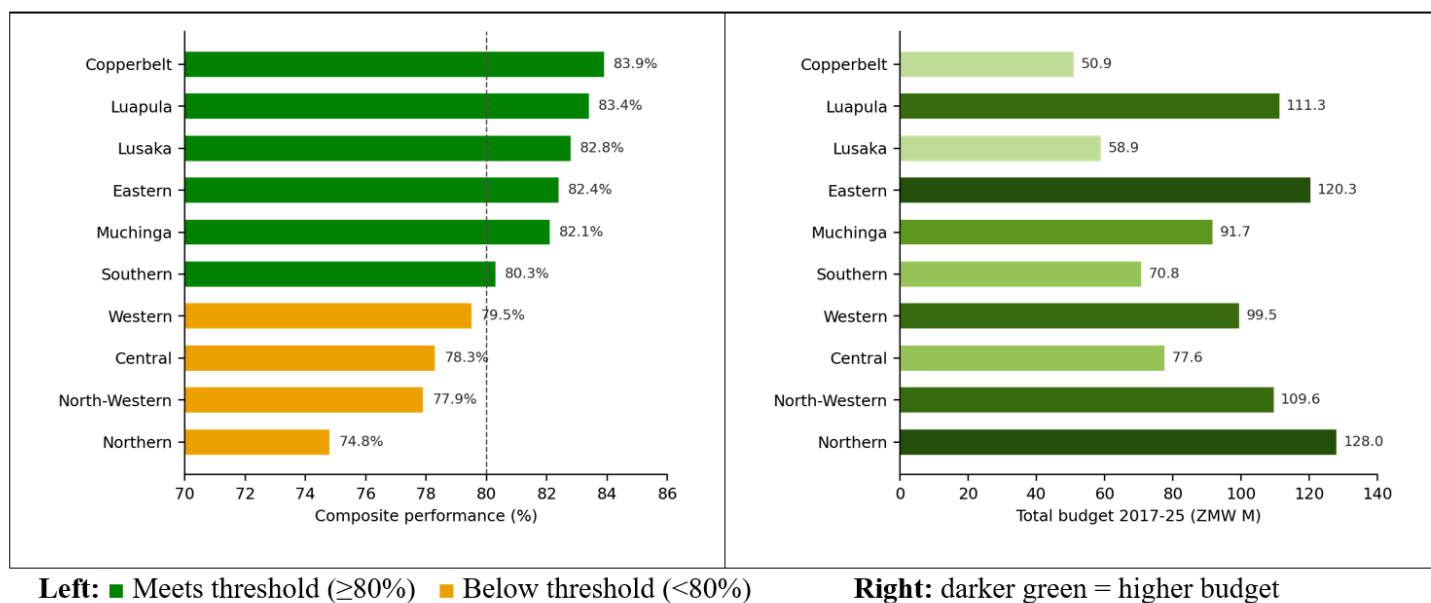


Figure 8

Surveillance Performance vs Budgetary Allocation by Province

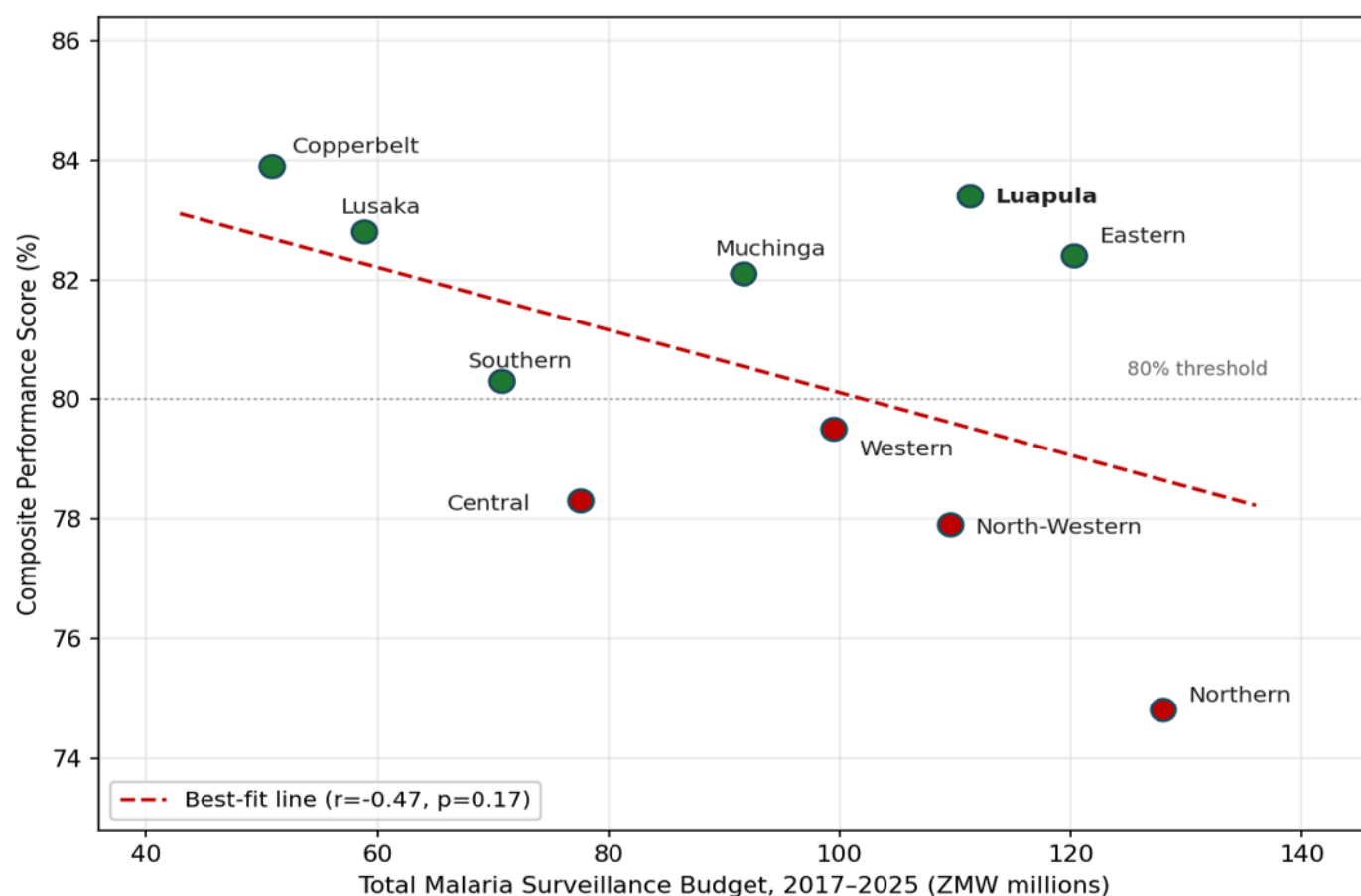


Figure 9

