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Half-decade of scaling up malaria control: malaria trends and impact of interventions from 2018 to 2023 in Rwanda

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Abstract

Background Rwanda has made significant strides in malaria control. This study reviews malaria epidemiology and control strategies in Rwanda from 2018 to 2023, documenting their impact, persistent gaps and emerging challenges.

Methods Data on Rwanda's malaria context from 2018 to 2023 were obtained through a literature review of peer-reviewed articles and grey literature, including annual reports from the malaria programmes, partners, the African Union, and the World Health Organization (WHO). Specific keywords used for the search included "malaria", "Rwanda", "case management", "control", "treatment", and "prevention". Moreover, epidemiological data for this period was extracted from the Health Management Information System (HMIS). Data analysis was done using R & R-Studio, ANOVA to assess the statistical significance ($P < 0.05$) of observed trends and T-test to compare the focal and blanket IRS techniques.

Results/Discussion Between 2018 and 2023, all malaria indicators showed improvement. Malaria incidence dropped from 345 to 40 cases per 1000 persons ($P = 0.00292$), the severe malaria rate decreased from 112 to 10/100,000 persons ($P = 0.018$), and the mortality rate fell from 2.72 to 0.258 deaths /100,000 persons ($P = 0.00617$). Among children under 5 years of age, incidence decreased significantly from 331 to 52/1,000 persons ($P = 0.00123$), the severe malaria rate dropped from 214 to 29/100,000 persons ($P = 0.00399$), and mortality declined from 5 to 0.453/100,000 persons ($P = 0.00504$). Over the same period, key malaria interventions expanded. The proportion of cases treated by CHWs increased significantly, improving access to early diagnosis and treatment (from 13 to 59%), and the new generations of ITNs (PBO and dual-active ingredient nets) were deployed in 9 districts. Since 2019, a blanket spraying technique has been adopted in 12 IRS districts replacing the focal spraying technique contributing to the significant decrease of malaria incidence from 2019 to 2023 ($P = 0.0025$). However, new challenges have emerged, including the rise of the *K13* R561H mutation associated with artemisinin resistance, the spread of insecticide resistance, and limited intervention coverage due to resource constraints.

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Conclusion To sustain the progress achieved, it is essential to intensify malaria control efforts, foster compliance with intervention strategies, enhance surveillance systems for timely and effective responses, and secure long-term funding to sustain these measures.

Keywords Malaria, Rwanda, Interventions, Challenges, Trends, Epidemiology and malaria control

Background

Malaria continues to be a significant public health challenge, particularly in sub-Saharan Africa, where the burden of the disease remains disproportionately high. Over the past two decades, substantial efforts to control malaria have led to a 38% reduction in incidence and a 60% reduction in mortality [1]. However, by 2022, global malaria cases had risen to an estimated 249 million, 5 million more than in 2021, with 94% occurring in sub-Saharan Africa [2].

In Rwanda, malaria is a leading cause of morbidity and mortality [3], affecting the entire population, with pregnant women, children under five years of age, and refugees at highest risk [4]. The Malaria and Other Parasitic Diseases Division (MOPDD) within the Rwanda Biomedical Centre (RBC) oversees malaria control efforts, which are decentralized through referral and district hospitals, health centres, health posts and integrated community based management by trained health workers countrywide [5, 6]. Malaria endemicity varies across four zones, defined by the Annual Parasite Incidence (API): High (>450 API per 1000), Moderate (250–450 API per 1000), Low (100–250 API per 1000) and Very Low (<100 API per 1000). Of the 30 districts in Rwanda, 19 are located in the Eastern and Southern provinces that account for 70% of the malaria burden in the country [4, 6]. Transmission occurs year-round, peaking during the rainy seasons (May–June and November–December), with *Anopheles arabiensis* as the primary vector [7] and *Plasmodium falciparum* as the dominant species [8].

Rwanda's malaria control history saw substantial progress in the 2000s [9], supported by the strengthening of the health system, and the scale-up of malaria control interventions such as home-based malaria management by community health workers (CHWs) [10], the rollout of standard insecticide-treated nets (ITNs) at the community level [11, 12] and the introduction of Artemisinin-based Combination Therapy (ACT). These efforts were supported by increased external funding from international partners (i.e. Presidents Malaria Initiative, WHO, Global Fund and Roll Back Malaria) [13]. Parasitological diagnosis before administration of ACT became mandatory with the use of light microscopy (LM) at health facilities, and *P. falciparum* histidine-rich protein based rapid diagnostic test (*pfHRP2*-RDT) at the community level by CHWs [14]. By 2010, malaria prevalence among children aged 6 to 59 months was halved, reflecting effective early intervention efforts [14, 15].

Despite this progress, between 2012 and 2018, incidence rose sharply from 48 to 403 cases per 1000 [4], driven by factors including climatic shifts, expanded irrigation, vector resistance to pyrethroids, shifts in mosquito behaviour, and insufficient coverage of interventions [3]. In response, Rwanda implemented two Malaria Strategic Plans [6, 14] to expand community-level testing and treatment to adults, increase ITN distribution to achieve universal coverage, and implement indoor residual spraying (IRS). IRS and ITNs were implemented in high burden districts, with ITNs provided routinely to vulnerable groups [13] through antenatal care (ANC), the Expanded Programme on Immunization (EPI) [16], and periodic household campaigns [17, 18]. In 2016, Rwanda introduced the Malaria Communication Strategy to increase awareness among communities and promote prevention and prompt treatment [14, 19]. In addition, and to enhance data-driven interventions, the Ministry of Health launched the Rwandan Health Management Information System (HMIS) in 2012, as a tool to standardize the health data collection system [16]. The HMIS was later adopted by the RBC to monitor intervention effectiveness and identify districts with the highest increase in malaria cases [20].

By the end of 2017, following the implementation and improving of all these response strategies, malaria incidence and related deaths had dropped [21], however new challenges like anti-malarial and insecticide resistance [22], and increasing pfhrp2/3 genes deletions emerged that continue to hinder progress [23]. This paper examines malaria trends and control strategies in Rwanda from 2018 to 2023, focusing on current challenges and their contributing factors.

Methods

Literature search

Data on the epidemiology of malaria in Rwanda from 2018 to 2023 was extracted from literature, through a search of peer-reviewed articles and grey literature including (annual) reports from MOPDD, MOH, Rwanda Demographic Health Survey (DHS), WHO, African Union (AU) and President's Malaria Initiative (PMI). Databases searched are PubMed, Cochrane, Web of Science, Embase, and Scopus using the search

terms: ("Rwanda" AND "malaria" AND "prevention") or ("Rwanda" AND "malaria" AND ("control" OR "intervention")) or ("Rwanda" AND "Malaria" AND ("treatment" OR "case management")). The inclusion criteria consisted of any articles or documents that included Rwanda, malaria, and any of the search terms mentioned above, written in either French or English. The exclusion criteria consisted of articles published before 2018.

Epidemiological data analysis

Aggregated epidemiological data for the period between 2018 and 2023 was extracted from the HMIS, the annual reports from the MOPDD, and the Rwanda DHS conducted in 2019–2020 into a Microsoft Excel sheet. Data analysis was done using R (version 4.3.3) & R-Studio with the dplyr package for data handling, and Analysis of Variance (ANOVA) to assess the statistical significance ($P < 0.05$) of the malaria trends using various malaria indicators across different years. The indicators analyzed included incidence rate, death rate, and severe malaria rate in both the total population and children under 5 years of age in Rwanda. Yearly incidence maps were generated in R using the packages "sf", "ggplot2", "stringr" while the malaria intervention strategies map was generated using the packages "sf", "dplyr", "ggplot2". The base maps were retrieved from Rwanda National institute of Statistics publicly available shape files. Moreover, t-test was used to compare the mean malaria cases when using focal and blanket technique for IRS in the 12 districts where IRS was implemented.

Results and discussion

The literature review identified 37 peer-reviewed articles and 15 grey literature documents meeting the inclusion criteria. This study examines Rwanda's malaria context through three phases: (1) analysis of malaria trends from 2018 to 2023, (2) an overview of major malaria control interventions implemented, and (3) discussion of challenges for malaria control and elimination in the country.

Malaria trends in Rwanda from January 2018 to December 2023

Nationwide malaria incidence in Rwanda decreased significantly from 345 cases per 1000 persons in 2018 to 40 cases per 1000 persons in 2023 ($P = 0.00292$) (Fig. 1). In 2018, 23/30 districts recorded incidence rates above the national average of 100 cases per 1000 population (Fig. 1). The Eastern province had the highest burden, with Ngoma and Kayonza districts reporting incidences exceeding 1000 cases per 1000 population (1270 and 1469, respectively). In contrast, provinces in the North exhibited the lowest incidence rates. Overall, from 2019 to 2023, incidence rates decreased across most districts (Fig. 1).

By 2023, the Southern province emerged as the region with the highest malaria burden, followed by the Eastern province and the Kigali City. However, the Northern provinces continued to exhibit relatively low incidence. Only Nyamagabe and Gisagara districts in the Southern province reported incidence rates above the national average, demonstrating significant improvement since 2018.

According to the 2022 WHO malaria report, Rwanda achieved a reduction in malaria-related morbidity and mortality compared to neighbouring countries such as Uganda and Democratic Republic of Congo (DRC), which collectively accounted for nearly half of global malaria cases and deaths in 2021 [2]. The persistently high malaria burden in the districts in the Southern province can be attributed to the presence of water sources from irrigation projects that provide mosquito breeding grounds, cross-border movement, and poor housing wall materials that include sprawling human settlements near the marshlands [24]. Conversely, the Northern province higher altitudes and volcanic landscapes create less favorable conditions for *Anopheles* mosquitoes, reducing malaria risk. These findings align with the Rwanda Malaria Indicator Survey of 2017 [25].

The severe malaria rate also declined significantly, from 112 cases per 100,000 persons in 2018 to 10 cases per 100,000 persons in 2023 ($P = 0.018$), while the mortality rate decreased from 2.72 per 100,000 persons in 2018 to 0.258 per 100,000 persons in 2023 ($P = 0.00617$). Among children under 5 years, malaria incidence decreased from 331 cases per 1,000 persons in 2018 to 52 per 1,000 persons in 2023 ($P = 0.00123$). The severe malaria rate in children decreased from 214 per 100,000 persons to 29 per 100,000 persons ($P = 0.00399$), and mortality rate decreased from 5 to 0.453 per 100,000 persons ($P = 0.00504$) (Fig. 2). These reductions represent an overall decrease in malaria incidence by 88% across the total population and by 84% among children under 5, highlighting substantial progress between 2018 and 2023.

Key malaria interventions and challenges

Case management: diagnosis and treatment

Between 2018 and 2023, Rwanda implemented two strategic plans to control malaria that focused on enhancing case management (prioritizing early, and accurate diagnosis and prompt treatment with effective anti-malarial drugs), vector control interventions and surveillance. The first Extended Malaria Strategic Plan (EMSP) 2013–2020 aimed to reduce malaria mortality by 30% compared to 2015/2016 baseline levels [14], a goal exceeded by 2018/2019 with 61% reduction [6]. Similarly, the second

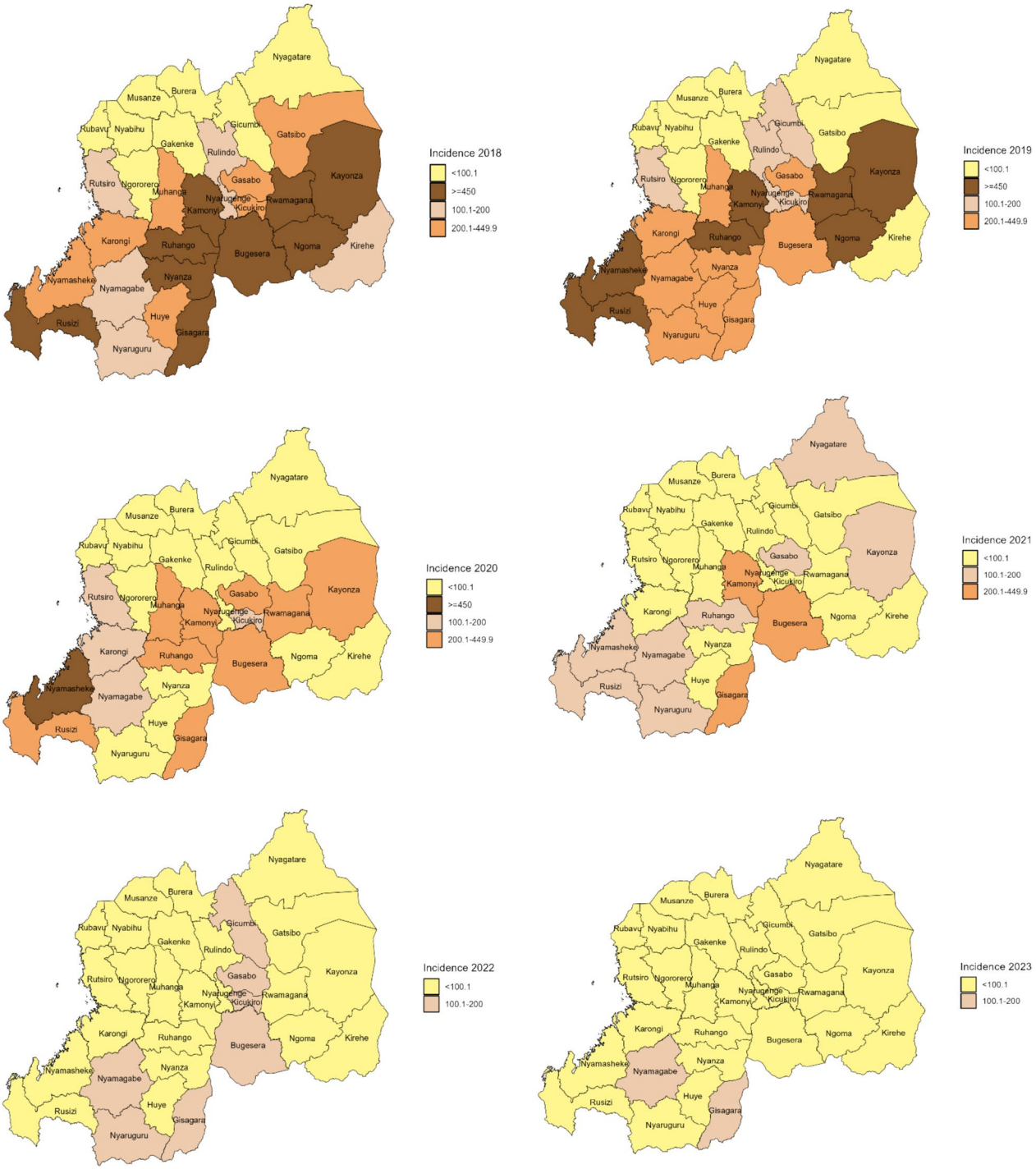

Fig. 1 Malaria incidence rate (per 1000 populations) per district in Rwanda from 2018 to 2023. In brown are districts with malaria incidence ≥ 450/1000 populations and in yellow districts with malaria incidence < 100.1/1000

Malaria Strategic Plan (MSP) 2020–2024 set a target of 50% reduction in malaria morbidity and mortality compared to 2018/2019 levels, achieving an 80% reduction in deaths by 2022/2023.

The proportion of malaria cases managed by CHW increased from 13% in 2015/2016 to 59% in 2022/2023 [26], with over 99% of malaria cases receiving quality diagnosis and treatment at both health facilities and in

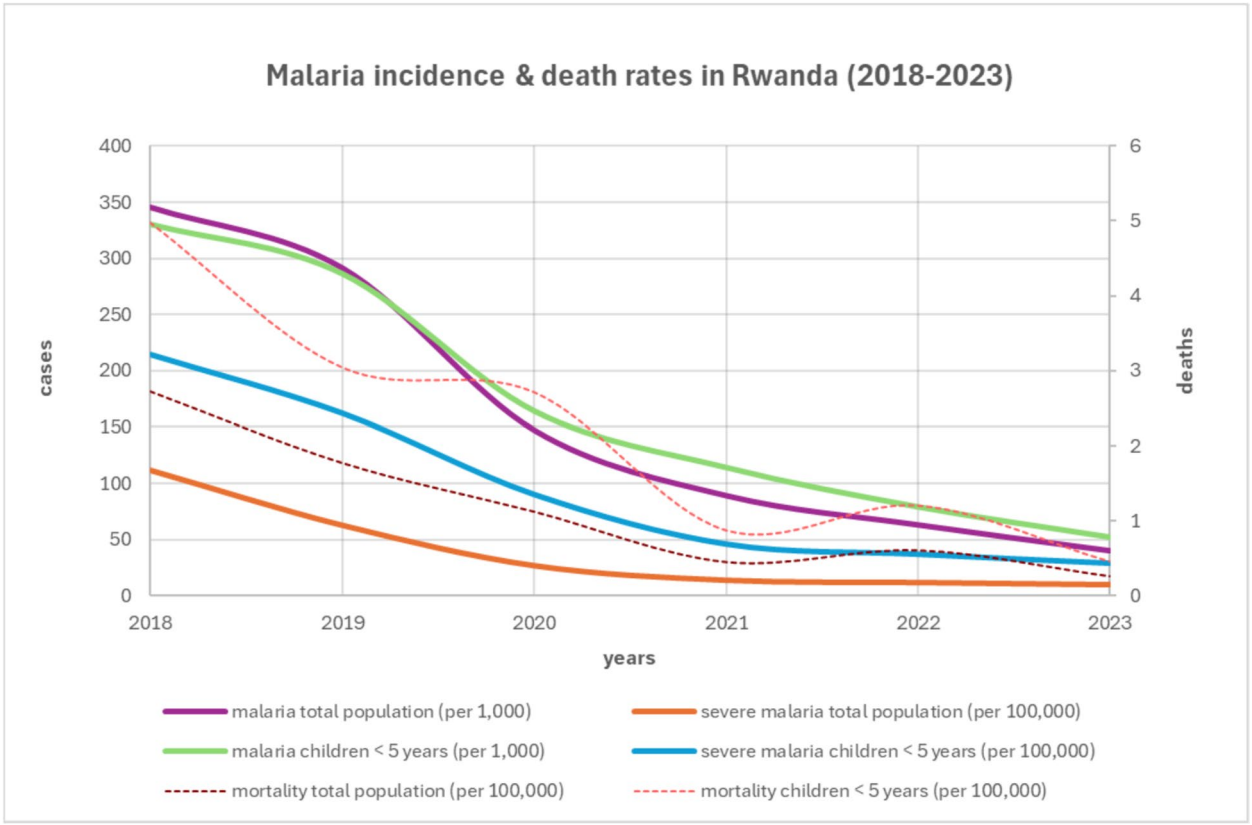

Fig. 2 Shows the decrease in trends of incidence, severe malaria and mortality rates from 2018 to 2023 in all population and children under 5 years of age

the community [27]. Timely treatment-seeking behaviour, defined as seeking care within 48 h of the onset of symptoms at the community level, remained fairly stable across age groups between 2018 and 2023 [26, 28]. This stability can be attributed to three key factors: the establishment of home-based malaria treatment by community health workers, ensuring accessible diagnosis and treatment within communities; increased accessibility of healthcare facilities, strategically located near the population to provide consistent healthcare access; and the implementation of community-based health insurance (Mutuelle de Santé), which has made healthcare affordable and minimized cost-related barriers to seeking timely care. This increase in access to early diagnosis and treatment, coupled with CHWs' education efforts, has significantly contributed to the reduction in malaria morbidity and mortality.

Vector control: ITNs and IRS

Key components of the vector control strategy include mass and routine distribution of ITNs and IRS (Fig. 3). In 2018, the Ministry of Health implemented regulations to distribute free ITNs to lower socioeconomic households (Ubudehe categories 1 and 2) and subsidized ITNs to others [19]. Routine distribution through ANC and EPI ensured coverage for pregnant women and children under one year, thought COVID-19 disrupted procurement and distribution in 10 districts (Rusizi, Gisagara, Huye, Bugesera, Rwamagana, Kayonza, Gatsibo, Nyamasheke, Muhanga and Karongi) in 2020 [29]. In addition, ITN distribution to households through mass campaigns covered 23 districts while 7 districts (Rusizi, Gisagara, Huye, Bugesera, Rwamagana, Kayonza, and Gatsibo) were left out. Districts missed in 2020 were covered in subsequent campaigns by 2021 [30].

The adoption of new-generation piperonyl butoxide (PBO) nets and Chlorfenapyr combined with alpha-cypermethrin interceptor G2 (IG2) nets in high-burden districts (non-IRS districts) with resistance to standard ITNs significantly reduced malaria cases from 2020 to 2022 ($P=0.013$) (Fig. 2) [31]. Since then the PBO nets have been distributed across all non-IRS districts except 3 with low endemicity (Musanze, Burera and Nyabihu) that still use standard ITNs. Despite these efforts, ITN ownership declined from 84% in 2017 to 66% in 2019–2020, while utilization increased from 64 to 71% [32, 33].

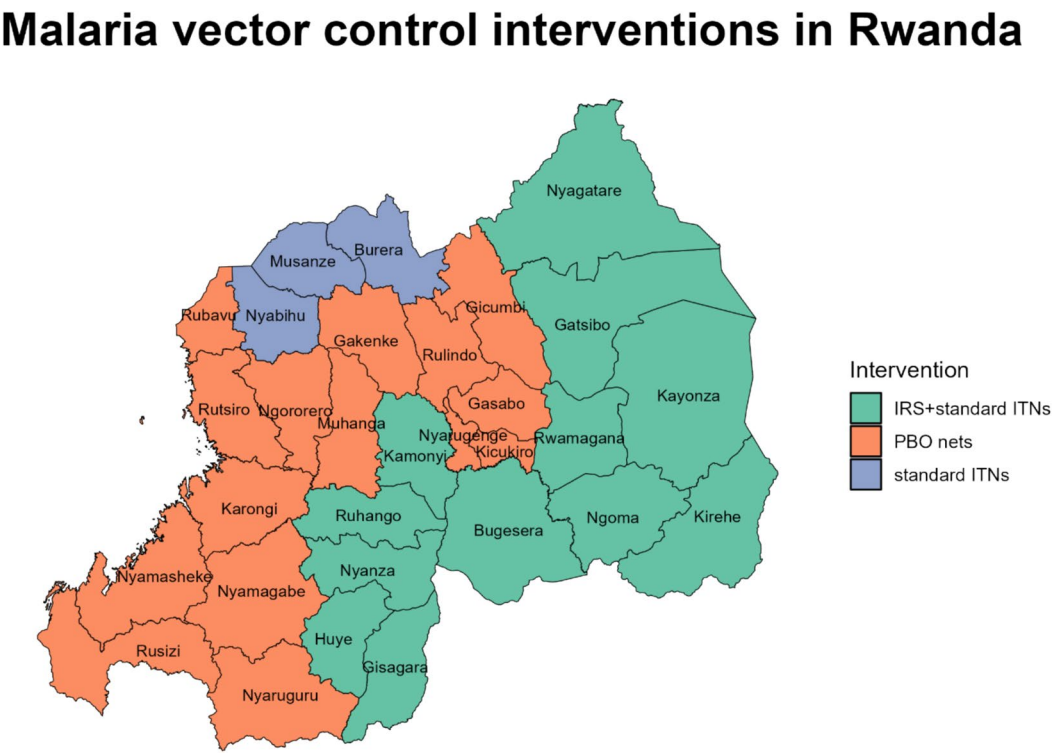

Fig. 3 The Malaria Vector Control Intervention map illustrates how the interventions currently being deployed in Rwanda. ITNs are distributed both mass and routinely in all districts and IRS is conducted in 12 high endemic districts. Districts where standard nets are distributed alongside IRS activities (represented in Green). In non-IRS districts, Piperonyl Butoxide (PBO) nets (Orange) are the ones used. Only 3 districts in the non-IRS zone continue to use standard nets (Blue). Geospatial data is from the National Institute of Statistics of Rwanda and intervention data is from Rwanda Biomedical Center-Malaria programme

Disparities in ITN ownership and usage are influenced by socioeconomic status, education and urban/rural residence [34]. In the lowest quintile of wealth, ITN ownership was 46%, while in the highest quintile it reaches 82%. Similarly, ITN usage increases with household wealth ranging from 29% among households in the lowest wealth quintile to 65% among those in the highest quintile. Urban households exhibit higher ownership than rural households (76% compared to 64% respectively) [33]. There is a need to investigate why people are reluctant to use ITNs and to educate them about the importance of sleeping under an ITN.

IRS has been implemented in 13 high-endemic districts alongside ITNs, with the insecticide rotated biennially to prevent the development of resistance. From 2018 to 2020, Fludora Fusion, a combination of deltamethrin (a pyrethroid) and clothianidin (a neonicotinoid) was used [28, 29] and from 2021 to 2023, Actellic 300CS, a micro-encapsulated formulation of the organophosphate class pirimisphosmethyl [30, 34]. This insecticide has also proved to be effective in reducing malaria cases in Kenya, where its use in IRS halved malaria incidences at several health facilities [35].

Since 2017, IRS implementation has targeted high endemicity districts, starting with 5 in 2017/2018, and achieving implementation in all 13 planned districts by 2022/2023. The implementation of IRS in all planned districts faced challenges due to budget constraints, which were resolved in 2022 with support from PMI and Global Fund [3, 4]. Pyrethroid resistance, first detected in Rwanda in 2012, prompted a switch to non-pyrethroid insecticides for IRS. In 2019, a blanket spraying technique -where all houses in a given area are sprayed regardless of malaria incidence- was adopted in 12 IRS districts (Fig. 3) with the exception of Rusizi district, where focal spraying remains in use in 9 of the 18 sectors with high malaria incidence or transmission. From 2019 to 2023, malaria cases decreased significantly compared to 2015–2018, when focal spraying was still in use (P-value = 0.0025; Fig. 4). This suggests that the blanket spraying technique has contributed to more effectively reducing malaria cases than focal

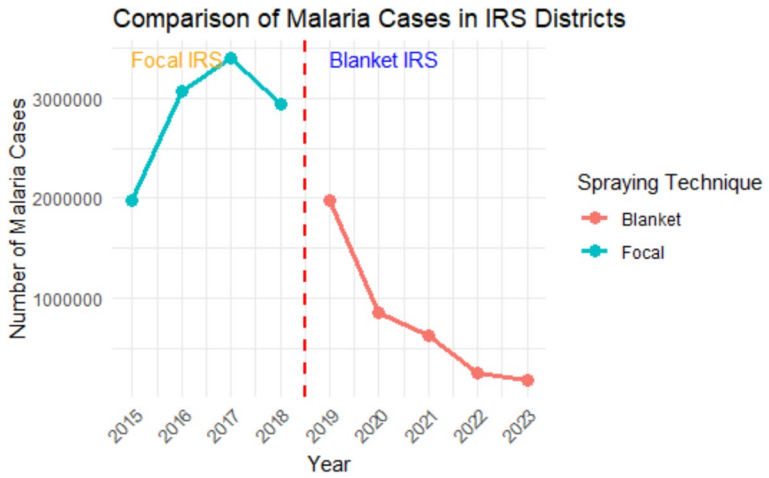

Fig. 4 Comparison of malaria cases in 12 districts where blanket and focal IRS spraying technique were implemented. From 2015 to 2018 the spraying technique that was used was focal IRS spraying targeting selected high endemic sectors in IRS districts only (blue line). From 2019, the malaria program changed from focal technique to blanket technique targeting the whole district (red line). This intervention also contributed to the significant decrease of malaria cases in those districts (P = 0.0025)

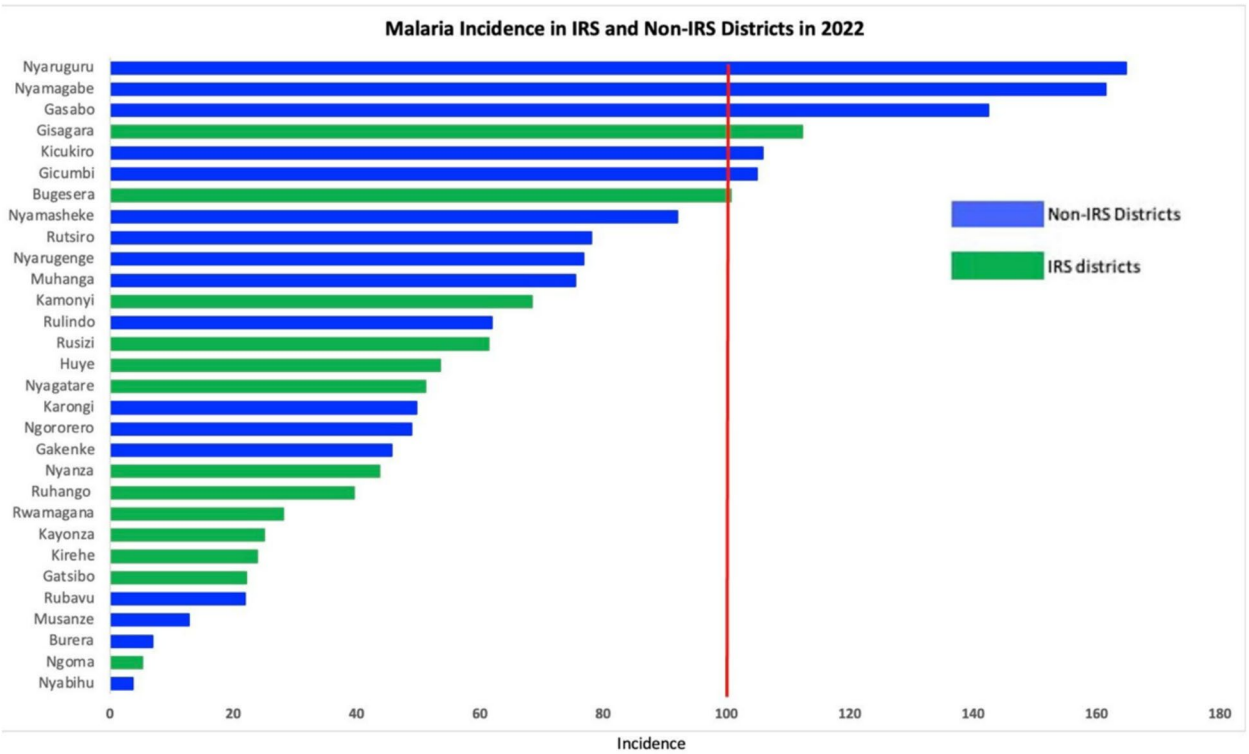

Fig. 5 Malaria incidence was compared in both IRS (green) and non IRS districts (blue). From the 7 districts that had an incidence above 100/1000 populations (red line) in 2022, 5 districts were from a non-IRS zone

spraying. Notably, of the 7 districts with a malaria

incidence above 100 cases per 1000 population in 2022, 5 are located in non-IRS zone (Fig. 5).

Parasitological and entomological surveillance

Rwanda's malaria surveillance strategy primarily involves collecting data on malaria cases and deaths from all public health facilities. These data are reported weekly through the Health Management Information System (HMIS) to monitor the effectiveness of control interventions and support evidence-based decision-making. In 2018, Rwanda introduced the "Système d'Information Sanitaire Communautaire (SISCOM)" to independently track malaria cases managed in the community [36]. CHWs manually record uncomplicated cases in provided registers, and submit it to the health centres where data managers integrate it into SISCOM. Key indicators reported include malaria cases, malaria-related deaths, inpatient cases, diagnostic testing, and treatments.

To avoid stock outs at the community level, Rwanda also initiated the RapidSMS notification system [28]. CHWs use this system to report stock shortages promptly, ensuring timely drug replenishments. RapidSMS is also used to notify health centres and district hospitals about confirmed severe malaria cases, facilitating prompt interventions and preventing fatalities [29].

Monitoring anti-malarial drug efficacy and resistance Therapeutic Efficacy Studies (TES), conducted every two years at sentinel sites as recommended by WHO, monitor the efficacy of antimalarial drugs and detect resistance [37]. In 2018, TES was conducted at 3 sentinel sites (Bugarama, Ngoma and Masaka) to evaluate artemether-lumefantrine (AL) efficacy. Participants included febrile children aged 6–59 months with confirmed parasitaemia (500–200,000 parasites/µl) and haemoglobin levels > 7 g/dl. PCR-corrected cure rates demonstrated 96% efficacy at 28 days [28]. A subsequent TES in 2020 aimed to test the efficacy of AL and dihydroartemisinin-piperaquine (DP) across the same sites, involving 264 patients (88 per site per treatment arm). However, due to COVID-19 pandemic and declining malaria incidence, recruitment was delayed, and the study concluded in 2023. Data analysis is ongoing.

In 2018, nonsynonymous Kelch 13 (*K13*) mutations associated with artemisinin resistance -R561H and P574L- were detected in 2 sentinel sites, with R561H being the most prevalent (7.4% in Masaka, 0.7% in Kigali city and Rukara) [38]. By 2019, *K13* mutations were found in 12.1% of isolates at Sovu, Huye district in the Southern province, with the R561H mutation present in 4.5% of cases, alongside candidate mutations C469F and A675V [39, 40]. These mutations, located in the *K13* gene's propeller domain, are associated with partial artemisinin, characterized by delayed parasite clearance (day 3) after ACT [41–43]. However, no evidence of treatment failure has been reported, indicating that AL remains effective [44]. Similar *K13* mutations have also emerged in neighboring countries, including DRC and Uganda [45, 46]. These findings underscore the importance of strengthening drug resistance surveillance using early detection tools to mitigate the potential spread of resistant strains.

Diagnostic challenges: pfhrp2/3 gene deletions RDTs used in Rwanda detect *P. falciparum* pfHRP2 antigen. Parasites with deletions in the *pfhrp2/3* genes can evade detection, leading to false negative RDT results, delayed treatment and poor outcomes [47]. A 2014–2015 observational study at three health centres found that 23% of false-negative HRP2-RDT results were linked to *pfhrp2* deletions confirmed by PCR [48]. Other African countries have reported high rates of *pfhrp2/3* deletions. For example, already in 2016, Eritrea transitioned away from *pfhrp2*-based RDTs after detecting 62% false-negative results [23], and recent surveys in Ethiopia found > 50% of *P. falciparum* parasites lacked these genes [49]. These findings highlight the need for a nationwide survey in Rwanda to evaluate *pfhrp2*/3 deletions following WHO-recommended protocols [50].

Although current RDTs remain effective, establishing a malaria molecular surveillance (MMS) system integrated within the MOPDD is critical. This system will enable timely detection of drug- and diagnostic-resistant parasites, ensuring evidence-based updates to malaria control policies. Such a system is especially valuable in low endemic settings where TES studies face logistical and financial challenges due to low case numbers.

Entomological surveillance and insecticide resistance Entomological surveillance in Rwanda assesses vector bionomics, including mosquito's behaviour, life cycle, habitat, and insecticide susceptibility. Two key methods are employed: human landing catches and indoor resting catches using the pyrethrum spray technique [21]. Insecticide resistance is monitored annually at 30 sentinel sites using WHO cylindrical tubes or CDC bottles assays. Eight insecticides spanning four WHO-approved classes are tested: carbamates (bendiocarb 0.1%), organophosphates (fenitrothion 1%, pirimiphosmethyl 0.25%), organochlorines (DDT 4%), pyrethroids (deltamethrin 0.05%, permethrin 0.75%, alpha-cypermethrin 0.05%), and the pyrrole chlorfenapyr (200 µg) [51] (Table 1). Resistance levels are categorized as full susceptibility (98–100% mortality), possible resistance (90–97% mortality and requiring confirmation), and confirmed resistance (< 90% mortality) (30). Table 1 details the insecticides tested and the observed percentage of confirmed insecticide resistance.

Table 1 Insecticide resistance monitoring assessed per insecticide product used every fiscal year in 30 entomological sentinel sites

Insecticide class	Insecticide	2018–2019	2019–2020	2020–2021	2021–2022	2022–2023
Carbamates	Bendiocarb 0.1%	1%	8%	7%	0%	8%
Organophosphates	Fenitrothion 1%	0%	0%	0%	0%	0%
	Pirimiphos methyl 0.25%	10%	0%	3%	40%	7%
Pyrethroids	Permethrin 0.75%	77%	72%	83%	70%	84%
	Deltamethrin 0.05%	47%	64%	37%	60%	40%
	Lambdacyalothrin 0.05%	77%	60%	–	–	–
	Alpha cypermethrin 0.05%	–	–	50%	80%	78%
Organochlorines	DDT 4%	53%	20%	20%	26%	18%
Neonicotinoid	Clothianidin 4 µg	–	0%		22.3%	0%
Pyrrole	Chlorfenapyr 100 µg	–	–	0%	15.4%	22%

This table shows the Level of confirmed insecticide resistance (%) per insecticide tested in sites tested. 0% indicates 100% susceptibility to the insecticides. The hyphen indicates that the insecticides were not tested in that year. A fiscal year runs from July to June the next year

Additionally, Rwanda adopts the WHO recommendation to alternate insecticides every two years, a strategy that has likely contributed to malaria incidence reductions [52].

While vector control measures have significantly decreased malaria incidence in Rwanda and other African countries [53, 54], insecticide resistance threatens their effectiveness, increasing costs and the health care burden [55]. Strengthened surveillance and strategic insecticide rotation remain essential for sustaining malaria control gains.

Other challenges

Climatic change significantly impacts malaria transmission, as it is closely tied to temperature and rainfall patterns. Malaria incidence is predominantly higher in low altitude areas (< 1700 m above mean sea level (asl)), which accounts for 82.4% of confirmed cases in Rwanda [32]. However, due to climate change, transmission is increasing in higher altitude areas (≥ 1700 m asl) [9]. Conditions such as high temperatures (≥ 18 °C), annual rainfall exceeding > 800 mm, and relative humidity around 60% favour the proliferation of *Anopheles* mosquitoes, maintaining a persistent malaria transmission risk as temperatures rise [28, 30].

As a resource-limited country, Rwanda faces challenges in securing stable and timely funding for malaria interventions, compounded by inadequate resource allocation to sustain adequate coverage of planned interventions [9]. Nevertheless, the introduction of CHWs has been pivotal in maintaining cost-effectiveness malaria control [56]. By decentralizing health services to the community level, CHWs have increased access to diagnosis and treatment, leading to a reduction in the costs associated with care at formal healthcare facilities [57].

Conclusion

Over the past 5 years, Rwanda's malaria control programme has made significant progress in reducing the national malaria burden, particularly among vulnerable populations. Key strategies include integrating community-based management of malaria, ensuring early access to diagnosis and treatment, scaling up IRS with non-pyrethroid insecticides, and distributing non-pyrethroid insecticide-treated nets. Despite these achievements, several challenges persist. The high malaria burden among children under 5, emerging drug and insecticide resistance, and the presence of *pfhrp2/3* deletions threaten progress. Furthermore, the sustainability of funding remains a critical obstacle, limiting the implementation of core interventions and delaying the adoption of advanced technologies, such as molecular tools for enhanced surveillance. To sustain and enhance these gains, it is imperative to strengthen routine surveillance systems by integrating cutting-edge technologies, particularly molecular techniques, to complement traditional methods like TES. Community participation and education must also be prioritized to raise public awareness and acceptance of interventions. Finally, intensifying research to address existing knowledge gaps is essential. This approach will enable evidence-based decision-making by the MOPDD and ensure continued advancements in malaria control.

Abbreviations

ACT	Artemisinin-based Combination Therapy
AL	Artemether-Lumefantrine
ANC	Antenatal care
ANOVA	Analysis of Variance
API	Annual Parasite Incidence
asl	Above mean sea level
AU	African Union
CHWs	Community Health Workers
DHS	Rwanda Demographic Health Survey
DP	Dihydro-Artemisinin Piperaquine
EPI	Expanded Programme on Immunization

HBM	Home-based management of malaria
HMIS	Health Management Information System
IRS	Indoor Residual Spraying
ITNs	Insecticide-treated nets
LM	Light microscopy
MOPDD	Malaria and Other Parasitic Diseases Division
PBO	Piperonyl Butoxide
pfHRP2-RDT	P. falciparum histidine-rich protein based rapid diagnostic test
PMI	President's Malaria Initiative
RBC	Rwanda Biomedical Center
RBM	Roll Back Malaria
RDT	Rapid Diagnostic Test
SISCOM	Système d'Information Sanitaire Communautaire
TES	Therapeutic Efficacy Studies
WHO	World Health Organization

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Author contributions
Conception of ideas for the paper, AR-U, AU, EH. Study design, AU, AR-U, MM. Provision of epidemiological data, AM and MK. Data analysis ER, TK, GR, and HM. Writing first draft manuscript, AU, MM, AR-U. Generating the maps included in the manuscript, MM, GR, HM. Review of the different versions of the manuscript, AR-U, EH, AU, MM, JHK, JCSN, AA and CN. Supervision, AR-U, EH. All authors contributed to the interpretation of findings and reviewed the final version of the manuscript.

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Availability of data and materials
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Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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