

# Eight-year Retrospective Analysis of Malaria Trends in Gedeo Zone, South Ethiopia (2012-2019)

Eshetu Molla (✉ [eshetmolla@gmail.com](mailto:eshetmolla@gmail.com))

Dilla University, College of Health Sciences and Medicine <https://orcid.org/0000-0001-8262-0622>

**Sinknesh Wolde Behaksra**

Armauer Hansen Research Institute

**Fitsum G Tadesse**

Addis Ababa University College of Law and Governance Studies

**Sisay Dugassa**

Aklilu Lemma Institute of Pathobiology, Addis Ababa University

**Endalamaw Gadisa**

Armauer Hansen Research Institute

**Hassen Mamo**

Addis Ababa University

---

## Research

**Keywords:** Malaria, retrospective, spatiotemporal trend, meteorological factors, Gedeo zone

**Posted Date:** August 17th, 2020

**DOI:** <https://doi.org/10.21203/rs.3.rs-59521/v1>

**License:**  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

---

# Abstract

**Background:** Informed decision making is underlined by all level of the tiers in the health system. Poor data record system coupled with under- (over)-reporting of malaria cases affects the country's elimination activities. Thus, malaria data at health facilities and health offices are important particularly to monitor and evaluate malaria elimination progresses. This study was intended to assess overall reported malaria cases, spatiotemporal trends and factors associated in Gedeo zone, South Ethiopia, and compare malaria case reports by the health centers and health offices.

**Methods:** Past eight years retrospective data stored in 17 health centers and 5 district health offices in Gedeo Zone were extracted. Malaria cases data at each health center with sociodemographic information, between 2012 and 2019, were included. Meteorological data were obtained from the national meteorology agency. The data were analyzed using Stata 13.

**Results:** A total of 485,414 clinical suspects were examined for malaria during the previous 8 years at health centers. Of these suspects, 57,228 (11.79%) were confirmed malaria cases. We noted, an overall under reporting of malaria, 3,758 clinical suspects and 467 confirmed malaria cases were not captured at the health offices level. Based on the health centers records, *Plasmodium falciparum* (49.74%) was slightly higher ( $p = 0.795$ ) than *P. vivax* (47.59%). The majority of cases were found in adults ( $\geq 15$  years of age) that accounted for 11.47% of confirmed malaria cases ( $p < 0.0001$ ). There was high spatiotemporal variation: highest cases record was during autumn (12.55%) ( $p < 0.0001$ ) and, the highest (18,150, 13.17%) and lowest (5,187 (10.44%)) malaria cases were reported from Dilla town and Yirgacheffe rural district, respectively ( $p = 0.0002$ ). Monthly rainfall and minimum temperature exhibited strong positive associations with the number of confirmed malaria cases.

**Conclusion:** A notable decline in malaria cases was observed over the eight-year period. Both *P. falciparum* and *P. vivax* co-exist; hence, control measures should continue targeting both species. The high malaria burden in urban (Dilla town) and suburban (Dilla zuria district) settings and autumn season need spatiotemporal consideration by the elimination program.

## Background

In Ethiopia, *Plasmodium falciparum* (*P. falciparum*) and *P. vivax* are the predominant causative species of malaria. The two coexist in almost all malarious areas at different levels of co-endemicity. Overall, large proportion of infections reported is due to *P. falciparum* (~60%) followed by *P. vivax* (~40%) [1, 2] with micro-epidemiological and seasonal variation. Such co-endemicity makes malaria control and elimination more complicated in Ethiopia than in most other areas where the later species is very low [2, 3].

Malaria transmission in Ethiopia is seasonal associated with precipitation and temperature changes; peaking from September to November following the large rainy season [4]. However, construction of

dams and irrigation-based agricultural activities sometimes modify malaria seasonal trend in Ethiopia [5, 6].

The past decades witnessed a sharp decline in morbidity and mortality, putting Ethiopia among the few African countries on track to meet the global 2020 milestone of cutting incidence by 40% or more [7]. These successes, encouraged the Ethiopian national malaria control program (NMCP) to stratify the country's malaria transmission into four based on annual parasite incidence (API); malaria free (API~0 cases/1,000 population/year), low (API>0 and<5), moderate (API≥5 and <100) and high (API≥100) [4], as a preparation to embark on nationwide malaria elimination. The policy and strategy shift to elimination requires data-driven decision making to tailor interventions [8, 9]. Thus, policy makers should be provided timely with quality and relevant data to inform national programs.

In Ethiopia, malaria data is captured through the health management information system (HMIS) at different tiers of the healthcare delivery systems. The hierarchy of data flow is from Health Posts (at *kebele* level) and Health Centers (HCs) to district health offices (HOs) which in turn channels to Zonal Health Departments, then to Regional Health Bureaus and finally to the Federal Ministry of Health [10]. Therefore, health post and HC data that are organized and archived at respective district HOs are the ones that are analyzed to evaluate the spatial and temporal changes, local malaria dynamics and *Plasmodia* species distribution.

Although understanding malaria trend could help to recognize the progress of elimination activities, under- (over)-reporting of malaria cases could affect the country's elimination efforts. Yet, validation studies comparing data from the different tiers of the health care delivery system hardly exist in most settings and at micro-epidemiological level. Although the six malarious districts of Gedeo Zone are stratified as elimination targeted low transmission districts by NMCP [4], little information is available to understand the overall trend of malaria and the above issues in the area. Thus, we assessed the species composition, malaria data quality, spatiotemporal trend and associated socio-demographic and climatic variables. Further, the accuracy of HO malaria records (HMIS data) was checked against the HC data (source document).

## Methods

### Study setting

Based on the Gedeo Zone health department report, 36.31% (423,411/1,166,163) of the population is at risk of malaria. Malaria transmission in the zone is seasonal with peak from September to November. The API of the zone in 2019 was close to 2.0. The zone is sub-divide into six districts and two town administrations [11]. Districts, also known as "*woredas*" in Ethiopia, are the third level administrative divisions of the country, following regional states and zones and are further sub-divided into "*kebeles*" (the smallest administrative unit with its own jurisdiction). Six elimination-targeted settings, low transmission, by the NMCP; Dilla and Yirgacheffe towns, and Dilla zuria, Wonago, Kochore and Yirgacheffe rural districts were included [4].

## Data collection

Eight-year (from 2012 to 2019) data were collected from malaria laboratory registration logbooks in the HCs and HMIS of the district HOs. Six district HOs and seventeen public HCs with at least 8 years of service which report them were covered. HC records with missing information of cases; address (*kebele*/district), dates of HC visit, age, sex or results of malaria diagnosis were excluded from the main part analysis. Data on malaria diagnosis results (negative, or positive, and infecting *Plasmodium* species for positives), time of diagnoses (date/month/year) and socio-demographic data (*kebele*/district, age and sex) were collected. In addition, meteorological data; station level monthly and annual precipitation, maximum and minimum temperatures and relative humidity was obtained from the national meteorology agency of Ethiopia. Data collectors attended adequate training to assure quality. Further, the consistency and completeness of the extracted data was checked for each HC and district.

## Data analysis

Microsoft office excel worksheet 2019 and the Stata data software 13 (College Station, Texas 77845 USA) were used for data entry and analysis. Descriptive statistics was used to show the distribution of malaria cases with respect to months, years, sex, age, *Plasmodia* species and district. Pearson's chi-square ( $\chi^2$ ) test was used to determine the association of the different variables with confirmed malaria cases. Logistic regression was also performed to assess the association of malaria cases with socio-demographic variables, seasons and districts. Odds ratio (OR) with the corresponding 95% confidence interval (CI) was used to assess the differences in malaria prevalence with selected predictors. Spearman correlations were used to measure the strength of association of monthly malaria cases with meteorological variables. P-value of less than 0.05 was taken as statistically significant.

# Results

## Year-based data with missing variables at HCs

In respective order 1852 (0.38%) and 249 (0.43%) of clinical suspects and confirmed malaria cases were excluded from the downstream analysis due to incompleteness. Overall, there was a significant reduction in missing data between 2012 and 2019 ( $p = 0.001$ ). During the first two years there were more numbers of both suspected and confirmed cases of missing variables. Specifically, the highest data with missing variables (413 clinically suspected and 76 confirmed cases) occurred in 2012. Whereas, the lowest records of missing variables with 107 clinically suspected and 10 confirmed cases were reported in 2019 and 2018 respectively. Generally, the number of clinical suspects with missing variable declined from 413 in 2012 to 107 in 2019 by approximately 4-fold and confirmed cases from 76 in 2012 to 11 by 7-fold in 2019 (Table 1).

## Annual clinical suspects and confirmed malaria cases based on HC versus HO records

There is an evidence of statistically significant inconsistency ( $p = 0.041$ ) in both clinical and confirmed malaria case reports between HCs and HOs, overall, the 8-years period (2012-2019). Higher clinical suspects (485,414) were recorded at HCs compared to the HOs (481,656). Similarly, the corresponding confirmed malaria cases were 57,228 (11.79%) at the HCs and 56,761 (11.78%) at HOs although establishing which one is more accurate is rather not easy. With this, the number of clinical suspects recorded by the HCs was higher by 3758. The data kept by the HOs was lower on average by about 470 each year (except 2012, 2018). This difference was pronounced in 2016. During 2012 and 2018 the numbers of clinical suspects recorded at HCs were consistent with HO data. In addition, the HMIS captured on average 58 less confirmed malaria cases each year except in 2012 and 2018. In 2012 and 2018 the numbers of confirmed cases were higher at HO records than at HC records (Table 2).

Overall, a notable decline in malaria, HCs (source data), was observed during the eight-year period, except in 2016 and between 2018 and 2019. The number of confirmed malaria cases declined from 11607 in 2012 to 2857 in 2019, an 8.34% reduction from the baseline. Maximum and minimum numbers of confirmed cases were documented during 2013 and 2018 respectively. The case burden due to *P. falciparum* (49.74%) was comparable to *P. vivax* (47.59%) ( $p = 0.795$ ). Yet, *P. vivax* overtook *P. falciparum* in cases burden ( $p = 0.588$ ) during 2013, 2014 and 2017. Mixed species infections, *P. vivax* and *P. falciparum*, accounted a low proportion (2.67%) (Table 2).

### **Diagnostic performance; data from HCs**

Regarding the diagnostic performance, the yearly trend of clinical suspects was directly proportional to the confirmed cases in each year. But the proportions of examined clinical suspects against confirmed cases were increased from 6.91 in 2012 to 16.32 in 2019. The highest proportion (16.32) was recorded in 2019, whilst the lowest (5.59) was during 2013. This shows the proportion of 'non-malarial' febrile cases were increasing from 2012 to 2019 except in 2016 (Table 3).

### **Malaria cases number by sex and age; data from HCs**

Slightly more males (29,480 (11.34%)) were malaria positive ( $p = 0.236$ ) than females (27,748 (12.30%)) (Fig. 2). The above 15 years age group was the most affected (30,406, 11.47%) than the other age groups, followed by under 5 children which accounted for 15116 (13.83%) of the cases. The above 15 years age group was twice more likely (OR = 2.00, 95% CI: 1.90, 2.11,  $p < 0.0001$ ) to have malaria compared to the under 5 (Table 4).

### **Spatiotemporal distribution of malaria cases**

The peak confirmed case load (12.55%) was during autumn followed by spring (12.05%), summer (11.05%) and winter (11.32%) (Fig. 3). In autumn the likelihood of having malaria is 1.53 times more than winter (OR = 1.53, 95% CI: 1.37, 1.70,  $p < 0.0001$ ) (Table 4). Similarly, the highest proportions of both *P. falciparum* (8445 (50.21%)) and *P. vivax* (7911 (47.03%)) were noted during autumn particularly in April. On the other hand, in winter the proportion of infection due to the two species, *P. falciparum* (5451

(49.51%)) and *P. vivax* (5312 (48.25%)) was relatively lowest (Fig. 3). Although *P. falciparum* was higher than *P. vivax* in all seasons, the difference was the smallest (1.26%) during winter, while in autumn it is 3.17%. The number of mixed infections also had same pattern throughout the four seasons.

Overall, based on the HC records, the highest malaria case burden reported was from Dilla town (18,150 (13.17%)) from a total of 137,860 clinical suspects followed by the adjacent district, Dilla zuria (12,588 (10.56%)) from 119,207 tested suspects. The lowest was from Yirgacheffe rural district (5,187 (10.44%)). Dilla town annual malaria cases remained the highest throughout the 8-year period except in 2013 and 2019 (OR = 3.16, 95% CI: 2.11, 4.22,  $p = 0.0002$ ) (Table 4). The highest confirmed cases during these two years were reported by Kochore (4390 (19.78%)) and Dilla zuria districts (1178 (8.04%)) from 22197 and 14648 clinical suspects respectively. Although there was an overall declining trend of confirmed malaria cases from 2012 to 2019, there were peaks in Kochore during 2013, Dilla town and Dilla zuria in 2016.

Yirgacheffe rural district had the highest variation (376 (80.51%)) in terms of confirmed malaria records between HC and HO data (HC-HO) followed by Dilla town (164 (35.12%)) and Dilla zuria district (-138 (29.55%)), data obtained by HC-HO. Whereas, Wonago district had the lowest (-6 (1.28%)) deviation of malaria data recording between HC and HO (Fig. 4).

The monthly total confirmed malaria cases showed a strong and positive association with monthly rainfall (Spearman's  $\rho = 0.895$ ,  $p < 0.0001$ ) and monthly minimum temperature (Spearman's  $\rho = 0.671$ ,  $p = 0.017$ ). Nevertheless, the maximum monthly temperature was negatively and weakly associated with the monthly confirmed malaria cases. Relative humidity seems not to have an effect on malaria transmission in the study area (Fig. 5).

## Discussion

In the present study there was a significant reduction in data incompleteness; with missing variables between 2012 and 2019. Specifically, the number of clinical suspects with missing data variables declined between 2012 and 2019 by approximately 4-fold and confirmed cases with about 7-fold. Decreasing trend in data incompleteness overtime, is plausible indication of huge improvement in data quality which thereby an implication for improving programmatic performance over the years.

There was an overall notable difference in both total number of clinical suspects (3758) and confirmed malaria cases (467) recorded at HCs (source data) and HOs (HMIS data). For the 8-years period, discrepancies in clinically suspected and confirmed cases were observed between the HOs compared to the HCs. During 2012 and 2018 the numbers of clinical suspects recorded at HCs were consistent with HO data. In these years the numbers of confirmed cases were higher at HO records than HC records. Yirgacheffe rural district had the highest deviation in terms of confirmed malaria records between HC and HO data followed by Dilla town and Dilla zuria district, whereas Wonago district was the least. Similar to our finding, a three-month facility-based study comprising of various settings conducted in southern Ethiopia showed that majority of facilities under-reported total malaria (both confirmed and clinical malaria) cases [10]. This in malaria data between the two systems, HC and HO, could be due to errors

during entering the data from the sources (HCs) into recording formats of HMIS, lack of cross-checking and proofing habits, training gaps on HMIS data use and unintentional/intentional false reports. In addition, limited computer access and skill, inadequate technical support [12], poor data management skills and limited functionality of electronic data management systems [13] might be the likely reasons for HMIS implementation challenges.

Concerning the diagnostic performance, the proportions of clinically suspected cases against confirmed cases were increased from 6.91 in 2012 to 16.32 in 2019. The highest proportion was recorded in 2019, whilst the lowest was during 2013. This revealed that the 'non-malarial' febrile cases were increasing from 2012 to 2019, which can be an indication of declining lab capacity of detecting malaria parasites. This declining lab capacity of detecting malaria might be due to the fact that the increased false negative reports associated with reduced sensitivity of microscopy with decreasing parasite densities [14], unable to detect sequestered *P. falciparum* parasites [15] and low competency of microscopists [16]. In the other way, such increased number of non-malarial febrile illnesses might be related to other febrile cases including yellow fever virus [17, 18] and typhoid fever [19] infections, as per the studies conducted in southern Ethiopia. In addition, this high number of non-malarial febrile illness might be due to fevers among positive individuals with malaria where the fever is coexisted with but not caused by the *Plasmodia* infection [20]. If laboratory performance percent confirmed declines it means; laboratory performance was decreasing over the years or something causing febrile illness in the area is increasing. Misdiagnosis and incorrect treatment of such non-malarial febrile illnesses with antimalarial drugs is possibly to contribute to rapid emergence of antimalarial drug resistance [21, 22] in the study area.

There was an overall reduction of malaria case from 2012 to 2019. According to data from HCs (source data), a maximum of 16,037 and a minimum of 2,546 of cases were observed during 2013 and 2018, respectively with 8.34 percent reduction. 2013 and 2016 were the exceptions to the declining trend as there were small epidemics in these periods in some parts of the Zone. Over the eight years period, overall, there was malaria positivity rate of 11.79%, data from the HCs. This positivity rate was comparable with certain studies done in Ethiopia including from Batu town (12.43%) [23], Arsi Negelle (11.40%) [24] and Halaba special district (9.47%) [25]. In contrast, higher overall malaria positivity rates were reported from related studies conducted in south-central Ethiopia [26], southern Ethiopia [27] and abroad in Dakar, Senegal [28] with 33.83%, 21.79% and 19.68% respectively. On the other hand, the present figure was higher than records in other local studies [29, 30]. These differences might be due to the variation in quality of laboratory diagnoses, difference in intervention measures, micro-climatic/altitudinal differences, and presence of constructions responsible for occurrence of temporary and permanent dams and drug and insecticide resistances. The possible contributing factors for the peaks/epidemics of malaria cases in 2013 and 2016 could be associated with feeble intervention activities in certain areas of the Zone.

1. *falciparum* and *P. vivax* were detected where equivalent; congruent results were reported in some other parts of Ethiopia [26, 27]. While other local studies [23, 25, 31] documented that the dominant species was *P. vivax*. The proportion of mixed infection in this study was congruent with other

studies [26, 30], whereas inconsistent with other reports [27, 31]. The likely reason for the slightly higher proportion of *P. falciparum* over *P. vivax* could be related to temperature; that is temperatures more than 18°C for *P. falciparum* and more than 15°C for *P. vivax* is suitable for the growth of these two species in human host and mosquito vectors [32, 33]. Apparently, in the current study area the average mean temperature during the eight years period found to be above 18°C. The higher proportion of *P. vivax* against the national figures could also be an implication for the ability of repeated relapse cases and early emergence of gametocytes during blood-stage infection. In addition, there could be heterogeneity of the Duffy phenotype and the high number of vulnerable Duffy-positive individuals that associated with population movement [34] in the study area. Environmental fluctuations that change target mosquito species abundance might have an impact on *Plasmodia* species occurrence [35]. The issue demands additional study. The possible reason for scarcity of mixed infections in this co-endemic area might be a competitive or an antagonistic effect of one *Plasmodium* species over the other within the human host during co-infection [26, 35].

Males were slightly more infected (51.51%) by malaria than females (48.49%) over the eight-year period. This was paralleled with other studies conducted in different parts of Ethiopia [23, 26, 27, 31]. However, this finding was not consistent with other reports in southern Ethiopia [25] and elsewhere in Mozambique [36] where higher malaria cases in females were documented. Individuals in the age group of 15 and above were also more significantly affected. This was in line with other local studies [23, 31]. Inconsistent result was observed in southern Ethiopia [24] arguing that malaria cases cluster among the under-5. And a finding in Metema, northwest Ethiopia by Ferede et al. [37] showed that 5-14 years old were more infected. Possible justifications for the higher occurrence of malaria among males and older age group could be their engagement in various outdoor activities and staying outdoors during the nights [38]. Apart from outdoor exposures, differences in treatment-seeking behavior, access to health facilities and travel history [39] might be the possible contributors for the sex- and age-based variations of malaria cases. In addition, a review report revealed that adult females are better protected from parasitic diseases than males due to genetic and biological (hormonal) factors [40].

The peak number of confirmed malaria cases was recorded during autumn followed by spring, summer and winter with a statistically significant variation. This seasonal peak in malaria cases in autumn deviates from various studies in Ethiopia which is during spring after the main rain season [24, 26, 27, 31]. In addition, nationally the main malaria transmission season is from September to December following the peak rain season [1, 4]. This trade-off in seasonal peak of malaria cases might be as a result of varying climatological conditions (rainfall pattern and temperature changes) in the area against other settings. Despite the high prevalence of malaria cases during the three seasons, there were a substantial number of confirmed malaria cases in the dry (winter) season in this study. These, absence of significant variation in the proportion of the *P. vivax* and *P. falciparum* burden and almost, year-round presence of malaria might suggest the presence of suitable local environments for mosquitoes. The comparable proportion of *P. vivax* against *P. falciparum* in winter might be explained by the fact that *P. vivax* has ability to relapse rather than new infections. Since such traits could affect the temporal patterns of *P. vivax* infections.

Overall, high number of clinical suspects and confirmed malaria cases were documented in Dilla town (urban) and Dilla zuria district (sub-urban) as compared to other districts. Except in 2013 and 2019, Dilla town annual malaria cases remained the highest all over the 8-year period. The highest confirmed cases during these two years were overtaken by Kochore in 2013 and Dilla zuria districts in 2019. While the lowest was from Yirgacheffe rural district. In general, though an overall declining trend of confirmed malaria cases from 2012 to 2019, peaks were recorded in Kochore during 2013 and Dilla town in 2016. Although there is expectation of a better documentation, treatment-seeking behavior, access to health facilities, community knowledge and coverage of intervention activities in urban settings, the current data pointed to the contrary. Thus, in this study, high burden of urban and suburban malaria was noted. This could be because of massive construction activities (like road, house and small dams) and presence of coffee processing sites in Dilla town and its vicinity that could create suitable habitat for mosquito breeding. Travel history [39], differences in the competence and skills of the laboratory personnel and relatively good reporting system might also be the main responsible factors influencing the prevalence of malaria in Dilla town compared to rural districts. There have been healthy ongoing malaria control activities incorporating environmental management, indoor residual spraying (IRS), long-lasting insecticide-treated nets (LLINs) and artemisinin-based combination therapy in the area. These intervention activities could be attributed for the decreasing trends of malaria in other sites of the Zone. In addition, micro-environmental variations, micro-climatic situations [35] and changes in intervention (like IRS and LLINs) periods might have effect for these spatial differences of malaria cases.

Monthly rainfall and minimum temperature demonstrated statistically significant positive correlation with malaria cases. Previous studies in Ethiopia [41, 42] and elsewhere [43,44] documented similar findings. However, the result of the current study on the association of rainfall and malaria cases was deviating from previous findings, stating higher rainfall does not necessarily influence the malaria changes [45, 46]. In contrast to our finding, minimum temperature was weakly correlated with malaria cases in southeast Ethiopia [42]. Ideally, rainfall and minimum temperature play a vital role in breeding and survival of malaria vectors and the respective parasites. Moreover, average monthly maximum temperature and relative humidity were weakly correlated with malaria cases. In disagreement to our finding, studies conducted in Jimma, Ethiopia by Alemu and others [41] and Sena and colleagues [42] in Gilgel-Gibe, southwest Ethiopia reported that inter-monthly relative humidity was significantly associated with monthly malaria cases.

The limitation of this study was incompleteness of patient data in the register with missed variables and only 8-year data were available during the data collection time at the HCs. Missing of asymptomatic cases and poor competence of the laboratory personnel at HCs could be the other limitations. Furthermore, clinically treated patients' (without laboratory confirmation) data and malaria mortality data were not recorded in the laboratory registration logbooks. Hence, interpretation of the finding should be with caution.

## Conclusion

Over the entire period, 2012 to 2019, the program data quality improved over the years; underreporting and proportion of data incompleteness declined significantly, and the burden dropped continuously except in 2016. Yet, equivalent *P. falciparum* and *P. vivax* malaria existed, thus intervention actions should target both species. The high malaria prevalence in urban setting (Dilla town) and its vicinity and in autumn season necessitates spatiotemporal consideration by the control campaign. The intervention strategies need also consider older age groups. In general, malaria still remains a public health problem in the area, which demands strengthening of interventions and short-term forecasting based on local meteorological factors to achieve elimination goals in the area. In addition, the data recorded at the HCs and district HOs should be monitored for consistency.

## Abbreviations

*Pf. Plasmodium falciparum*; *Pv. Plasmodium vivax*, NMCP: national malaria control program; API: annual parasite incidence; HMIS: health management information system; HC: health center; HO: health office; OR: odds ratio; CI: confidence interval; IRS: indoor residual spraying; LLINs: long-lasting insecticide-treated nets

## Declarations

### Acknowledgments

would like to thank heads of HOs and HCs for their willingness to provide the retrospective malaria data and the national meteorology agency of Ethiopia for providing meteorological data of the study area. We are also grateful to Mr Eyuel Asemahegn for constructing the study area map.

### Authors' contributions

EM designed the study, involved in data collection, analyzed and interpreted the data, and drafted the manuscript. SWB contributed in data analysis works. FGT initiated the idea, involved in the data entry template development and gave feedback on the data collection protocol. SD was responsible for revising the draft manuscript. EG initiated the idea, guided the process of data collection and substantively revised the manuscript. HM participated in guidance of the data collection progresses and critically commented the whole section of the paper. All authors read and approved the final manuscript.

## Funding

This study was partially funded by Dilla and Addis Ababa Universities. But the funders have no role in the study design, data collection, analysis, interpretation of data and in writing the manuscript.

### Availability of data and materials

All data generated or analyzed during this study are included in this manuscript.

## Ethics approval and consent to participate

Ethical approval was obtained from Department of Microbial, Cellular and Molecular Biology and College of Natural and Computational Sciences Ethical Review Committee, Addis Ababa University (CNSDO/318/11/2019).

## Consent for publication

Not applicable.

## Competing interest statement

The authors declare that they have no competing interests.

## References

1. Ethiopian Public Health Institute. Ethiopia National Malaria Indicator Survey 2015. Addis Ababa, 2016.
2. Taffese HS, Hemming-Schroeder E, Koepfli C, Tesfaye G, Lee M, Kazura J, et al. Malaria epidemiology and interventions in Ethiopia from 2001 to 2016. *Infect Dis Poverty*. 2018;7:103.
3. Gari T, Lindtjørn B. Reshaping the vector control strategy for malaria elimination in Ethiopia in the context of current evidence and new tools: opportunities and challenges. *Malar J*. 2018;17:454.
4. President's Malaria Initiative Ethiopia. Malaria Operational Plan FY 2019; 2019.
5. Kibret S, Wilson GG, Ryder D, Tekie H, Petros B. Malaria impact of large dams at different eco-epidemiological settings in Ethiopia. *Trop Med Int Health*. 2017;45:4.
6. Chung B. Impact of irrigation extension on malaria transmission in Simret, Tigray, Ethiopia. *Korean J Parasitol*. 2016;54(4):399-405.
7. World malaria report 2019. Geneva: World Health Organization; 2019.
8. Moonen B, Cohen JM, Tatem AJ, Cohen J, Hay SI, Sabot O, et al. A framework for assessing the feasibility of malaria elimination. *Malar J*. 2010;9:322.
9. From malaria control to malaria elimination: a manual for elimination scenario planning. Geneva: World Health Organization; 2014.
10. Endriyas M, Alano A, Mekonnen E, Ayele S, Kelaye T, Shiferaw M, et al. Understanding performance data: health management information system data accuracy in Southern Nations Nationalities and People's Region, Ethiopia. *BMC Health Serv Res*. 2019;19:175.
11. Gedeo zone health department. Gedeo zone health department annual report 2019. Dilla, 2019.
12. Kiberu VM, Matovu JK, Makumbi F, Kyoziira C, Mukooyo E, Wanyenze RK. Strengthening district-based health reporting through the district health management information software system: the Ugandan experience. *BMC Med Inform Decis Mak*. 2014;14:40.

13. Ledikwe JH, Grignon J, Lebelonyane R, Ludick S, Matshediso E, Sento BW, et al. Improving the quality of health information: a qualitative assessment of data management and reporting systems in Botswana. *Health Res Policy Syst.* 2014;12:7.
14. Wongsrichanalai C, Barcus MJ, Muth S, Sutamihardja A, Wernsdorfer WH. A review of malaria diagnostic tools: microscopy and rapid diagnostic test (RDT). *Am J Trop Med Hyg.* 2007;77 Suppl 6:119-127.
15. Leke RF, Djokam RR, Mbu R, Leke RJ, Fogako J, Megnekou R, et al. Detection of the *Plasmodium falciparum* antigen histidinerich protein 2 in blood of pregnant women: implications for diagnosing placental malaria. *J Clin Microbiol.* 1999;37:2992-2996.
16. Nega D, Abebe A, Abera A, Gidey B, G/ Tsadik A, Tasew G. Comprehensive competency assessment of malaria microscopists and laboratory diagnostic service capacity in districts stratified for malaria elimination in Ethiopia. *PLoS ONE.* 2020;15(6):e0235151.
17. Lilay A, Asamene N, Bekele A, Mengesha M, Wendabeku M, Tareke I, et al. Reemergence of yellow fever in Ethiopia after 50 years, 2013: epidemiological and entomological investigations. *BMC Infect Dis.* 2017;17:343.
18. Nigussie E, Shimelis T, Eshetu D, Shumie G, Chali W, Aseffa A, et al. Seropositivity of yellow fever virus among acute febrile patients attending selected health facilities in Borena district, southern Ethiopia. *Ethiop Med J.* 2020;58:57-62.
19. Habte L, Tadesse E, Ferede G, Amsalu Typhoid fever: clinical presentation and associated factors in febrile patients visiting Shashemene Referral Hospital, southern Ethiopia. *BMC Res Notes.* 2018;11:605.
20. Dalrymple U, Cameron E, Arambepola R, Battle KE, Chestnutt EG, Keddie SH, et al. The contribution of non-malarial febrile illness co-infections to *Plasmodium falciparum* case counts in health facilities in sub-Saharan Africa. *Malar J.* 2019;18:195.
21. Onchiri FM, Pavlinac PB, Singa BO, Naulikha JM, Odundo EA, Farquhar C, et al. Frequency and correlates of malaria over-treatment in areas of differing malaria transmission: a cross-sectional study in rural Western Kenya. *Malar J.* 2015;14: 97.
22. Nyaoke BA, Mureithi MW, Beynon C. Factors associated with treatment type of non-malarial febrile illnesses in under-fives at Kenyatta National Hospital in Nairobi, Kenya. *PLoS ONE.* 2019;14(6):e0217980.
23. Hassen J, Dinka H. Retrospective analysis of urban malaria cases due to *Plasmodium falciparum* and *Plasmodium vivax*: the case of Batu town, Oromia, Ethiopia. *Heliyon* 6. 2020;e03616.
24. Hailemariam M, Gebre S. Trend analysis of malaria prevalence in Arsi Negelle health center southern Ethiopia. *J Infect Dis Immun.* 2015;7(1):1-6.
25. Shamebo T, Petros B. Trend analysis of malaria prevalence in Halaba special district, Southern Ethiopia. *BMC Res Notes.* 2019;12(1):190.
26. Yimer F, Animut A, Erko B, Mamo H. Past five-year trend, current prevalence and household knowledge, attitude and practice of malaria in Abeshge, south-central Ethiopia. *Malar J.* 2015;14:230.

27. Dabaro D, Birhanu Z, Yewhalaw D. Analysis of trends of malaria from 2010 to 2017 in Boricha district, southern Ethiopia. *Malar J.* 2020;19:88.
28. Diallo MA, Badiane AS, Diongue K, Sakande´ L, Ndiaye M, Seck MC, et al. A twenty-eight-year laboratory-based retrospective trend analysis of malaria in Dakar, Senegal. *PLoS ONE.* 2020;15(5):e0231587.
29. Derbie A, Alemu M. Five years malaria trend analysis in Woreta health center, Northwest Ethiopia. *J Health Sci.* 2017;27(5):465.
30. Yimer M, Hailu T, Mulu W, Abera B, Ayalew W. A 5 year trend analysis of malaria prevalence with in the catchment areas of Felegehiwot referral hospital, Bahir Dar city, northwest-Ethiopia: a retrospective study. *BMC Res Notes.* 2017;10:239.
31. Solomon A, Kahase D, Alemayehu M. Trend of malaria prevalence in Wolkite health center: an implication towards the elimination of malaria in Ethiopia by 2030. *Malar J.* 2020;19:112.
32. Bodker E. Relationship between altitude and intensity of malaria transmission in the Usambara Mountains, Tanzania. *Med Entomol.* 2003;40:706-17.
33. BradfieldLyon E. Temperature suitability for malaria climbing the Ethiopian highlands. *Environ Res Lett.* 2017;12:064015.
34. Howes RE, Battle KE, Mendis KN, Smith DL, Cibulskis RE, Baird JK, et al. Global epidemiology of *Plasmodium vivax*. *Am J Trop Med Hyg.* 2016;95 Suppl 6:15-34.
35. Phimpraphi W, Paul RE, Yimsamran S, Puangsa-art S, Thanyavanich N, Maneeboonyang W, et al. Longitudinal study of *Plasmodium falciparum* and *Plasmodium vivax* in a Karen population in Thailand. *Malar J.* 2008;7:99.
36. Temu A, Coleman M, Abilio P, Kleinschmidt I. High prevalence of malaria in Zambezia, Mozambique: the protective effect of IRS versus increased risks due to pig-keeping and house construction. *PLoS ONE.* 2012;7:e31409.
37. Ferede G, Worku A, Getaneh A, Ahmed A, Haile T, Abdu Y, et al. Prevalence of malaria from blood smears examination: a seven-year retrospective study from Metema hospital, northwest Ethiopia. *Malar Res Treat.* 2013;2013:704-30:5.
38. Kigozi SP, Kigozi RN, Epstein A, Mpimbaza A, Sserwanga A, Yeka A, et al. Rapid shifts in the age-specific burden of malaria following successful control interventions in four regions of Uganda. *Malar J.* 2020;19:128.
39. Mathanga DP, Tembo AK, Mzilahowa T, Bauleni A, Mtimaukenena K, Taylor TE, et al. Patterns and determinants of malaria risk in urban and peri-urban areas of Blantyre, Malawi. *Malar J.* 2016;15:590.
40. Krogstad DJ. Malaria as a re-emerging disease. *Epidemiol Rev.* 1996;18:77-89.
41. Alemu A, Abebe G, Tsegaye W, Golassa L. Climatic variables and malaria transmission dynamics in Jimma town, Southwest Ethiopia. *Parasit Vectors.* 2011;4:30.

42. Sena L, Deressa W, Ali A. Correlation of climate variability and malaria: a retrospective comparative study, southwest Ethiopia. *Ethiop J Health Sci.* 2015;25:2.
43. Gunda R, Chimbari MJ, Shamu S, Sartorius B, Mukaratirwa Malaria incidence trends and their association with climatic variables in rural Gwanda, Zimbabwe, 2005-2015. *Malar J.* 2017;16:393.
44. Nanvyat N, Mulambalah CS, Barshep Y, Dakul DA, Tsingalia HM. Retrospective analysis of malaria transmission patterns and its association with meteorological variables in lowland areas of Plateau state, Nigeria. *Int J Mosq Res.* 2017;4(4):101-106.
45. Haque U, Hashizume M, Glass GE, Dewan AM, Overgaard HJ, Yamamoto T. The role of climate variability in the spread of malaria in Bangladeshi highlands. *PLoS ONE.* 2010;5(12):1-9:e14341.
46. Singh N, Sharma VP. Patterns of rainfall and malaria in Madhya Pradesh, central India, *Ann Trop Med Parasitol.* 2002;96(4):349-359.

## Tables

Table 1 Number of missing data on clinical suspects (N) and confirmed malaria cases (n) by year, Gedeo zone, South Ethiopia, 2012-2019

| Year         | Grand total clinical suspects (N) | Excluded clinical suspects n (%) | Grand total confirmed cases (N) | Excluded confirmed cases n (%) | P-value |
|--------------|-----------------------------------|----------------------------------|---------------------------------|--------------------------------|---------|
| 2012         | 80601                             | 413 (0.51)                       | 11683                           | 76 (0.65)                      | 0.001   |
| 2013         | 89979                             | 320 (0.36)                       | 16075                           | 38 (0.24)                      |         |
| 2014         | 37076                             | 224 (0.60)                       | 4450                            | 40 (0.90)                      |         |
| 2015         | 58788                             | 311 (0.53)                       | 5042                            | 24 (0.48)                      |         |
| 2016         | 74693                             | 182 (0.24)                       | 10384                           | 19 (0.18)                      |         |
| 2017         | 61395                             | 186 (0.30)                       | 4419                            | 31 (0.70)                      |         |
| 2018         | 38006                             | 109 (0.29)                       | 2557                            | 10 (0.39)                      |         |
| 2019         | 46728                             | 107 (0.23)                       | 2867                            | 11 (0.38)                      |         |
| <b>Total</b> | <b>487266</b>                     | <b>1852 (0.38)</b>               | <b>57477</b>                    | <b>249 (0.43)</b>              |         |

*N, n: number of cases; %: percentage (n/N\*100); Grand total: quantitatively analyzed + excluded data (missing data that analyzed separately)*

Table 2 Numbers of clinical suspects (N) and confirmed malaria cases (n) by year; HCs and HOs data, Gedeo zone, South Ethiopia, 2012-2019

| Year         | Data from HCs         |                       |                       |                     |         | Data from HOs         |                       |                       | P-value      |
|--------------|-----------------------|-----------------------|-----------------------|---------------------|---------|-----------------------|-----------------------|-----------------------|--------------|
|              | Clinical suspects (N) | Confirmed             |                       |                     | P-value | Clinical suspects (N) | Confirmed             |                       |              |
|              |                       | Pf n (%)              | Pv n (%)              | Pf/Pv mixed n (%)   |         |                       | Pf n (%)              | Pv n (%)              |              |
| 2012         | 80188                 | 5921 (51.01)          | 5403 (46.55)          | 283 (2.44)          | 0.795   | 80188                 | 5785 (48.40)          | 6168 (51.60)          |              |
| 2013         | 89659                 | 7386 (46.06)          | 8168 (50.93)          | 483 (3.01)          |         | 89298                 | 7876 (49.48)          | 8041 (50.52)          |              |
| 2014         | 36765                 | 2110 (47.85)          | 2199 (49.86)          | 101 (2.29)          |         | 36649                 | 2277 (52.13)          | 2091 (47.87)          |              |
| 2015         | 58564                 | 2642 (52.65)          | 2232 (44.48)          | 144 (2.87)          |         | 58455                 | 2289 (46.52)          | 2631 (53.48)          |              |
| 2016         | 74511                 | 5660 (54.61)          | 4450 (42.93)          | 255 (2.46)          |         | 71502                 | 4937 (49.55)          | 5027 (50.45)          |              |
| 2017         | 61209                 | 2014 (45.90)          | 2242 (51.09)          | 132 (3.01)          |         | 61049                 | 1928 (45.18)          | 2339 (54.82)          |              |
| 2018         | 37897                 | 1298 (50.98)          | 1182 (46.43)          | 66 (2.59)           |         | 37897                 | 1313 (51.47)          | 1238 (48.53)          |              |
| 2019         | 46621                 | 1437 (50.30)          | 1359 (47.57)          | 61 (2.13)           |         | 46618                 | 1442 (51.12)          | 1379 (48.88)          |              |
| <b>Total</b> | <b>485,414</b>        | <b>28,468 (49.74)</b> | <b>27,235 (47.59)</b> | <b>1,525 (2.67)</b> |         | <b>481,656</b>        | <b>27,847 (49.06)</b> | <b>28,914 (50.94)</b> | <b>0.041</b> |

*N, n: number of cases; %: percentage (n/N\*100), Pf: Plasmodium falciparum; Pv: Plasmodium vivax*

Table 3 Proportion of clinical suspects against confirmed malaria cases, Gedeo zone, South Ethiopia, 2012-2019

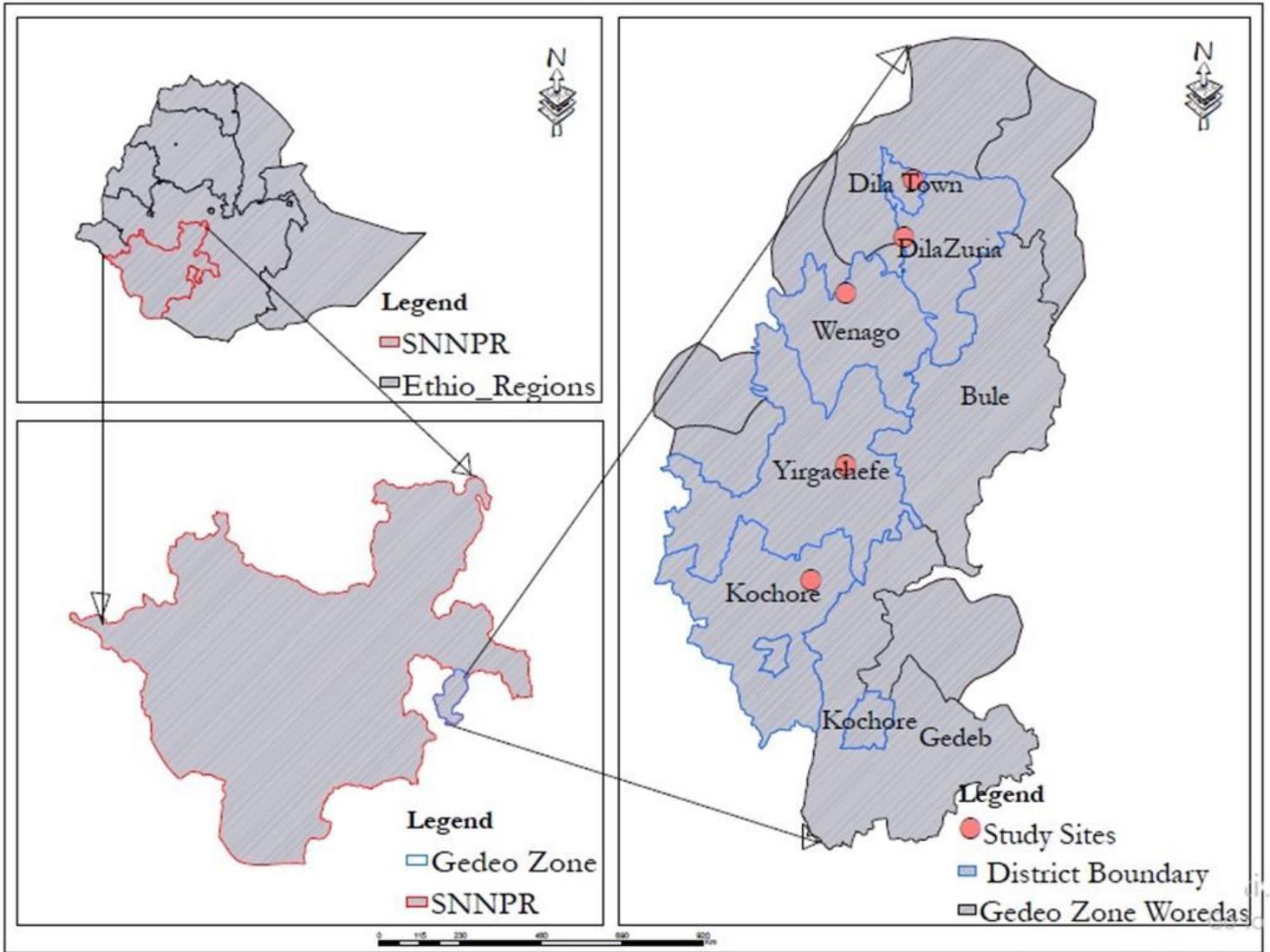
| <b>Year</b>  | <b>Clinical suspects (N)</b> | <b>Confirmed (n)</b> | <b>Proportion (N/n)</b> |
|--------------|------------------------------|----------------------|-------------------------|
| 2012         | 80188                        | 11607                | 6.91                    |
| 2013         | 89659                        | 16037                | 5.59                    |
| 2014         | 36765                        | 4410                 | 8.34                    |
| 2015         | 58564                        | 5018                 | 11.67                   |
| 2016         | 74511                        | 10365                | 7.19                    |
| 2017         | 61209                        | 4388                 | 13.95                   |
| 2018         | 37897                        | 2546                 | 14.88                   |
| 2019         | 46621                        | 2857                 | 16.32                   |
| <b>Total</b> | <b>485,414</b>               | <b>57,228</b>        | <b>8.48</b>             |

Table 4 Logistic regression analysis of factors associated with malaria at HCs in Gedeo zone, South Ethiopia, 2012-2019

| Variable                     | Clinical suspects N (%) | Confirmed n (%) | OR (95% CI)       | P-value |
|------------------------------|-------------------------|-----------------|-------------------|---------|
| <b>Sex</b>                   |                         |                 |                   |         |
| Male                         | 259906 (53.54)          | 29480 (11.34)   | 1.0               |         |
| Female                       | 225508 (46.46)          | 27748 (12.30)   | 1.02 (0.97, 1.08) | 0.236   |
| <b>Age category</b>          |                         |                 |                   |         |
| <5                           | 109302 (22.52)          | 15116 (13.83)   | 1.0               |         |
| 5-14                         | 111028 (22.87)          | 11706 (10.54)   | 1.33 (1.29, 1.37) | <0.0001 |
| 15+                          | 265084 (54.61)          | 30406 (11.47)   | 2.00 (1.90, 2.11) | <0.0001 |
| <b>Season</b>                |                         |                 |                   |         |
| Winter                       | 97227 (20.03)           | 11010 (11.32)   | 1.0               |         |
| Autumn                       | 134054 (27.62)          | 16820 (12.55)   | 1.53 (1.37, 1.70) | <0.0001 |
| Summer                       | 123200 (25.38)          | 13618 (11.05)   | 1.24 (1.19, 1.29) | <0.0001 |
| Spring                       | 130933 (26.97)          | 15780 (12.05)   | 1.42 (1.34, 1.51) | <0.0001 |
| <b>District/urban center</b> |                         |                 |                   |         |
| Yirgacheffe rural            | 49684                   | 5187 (10.44)    | 1                 |         |
| Dilla town                   | 137860                  | 18150 (13.17)   | 3.16 (2.11, 4.22) | 0.0002  |
| Dilla zuria                  | 119207                  | 12588 (10.56)   | 2.30 (1.82, 2.78) | <0.0001 |
| Wonago                       | 71689                   | 7427 (10.36)    | 1.40 (1.21, 1.60) | <0.0001 |
| Yirgacheffe town             | 60531                   | 6271 (10.36)    | 0.24 (0.07, 1.42) | 0.780   |
| Kochore                      | 46443                   | 7605 (16.37)    | 1.59 (1.20, 1.98) | <0.0001 |

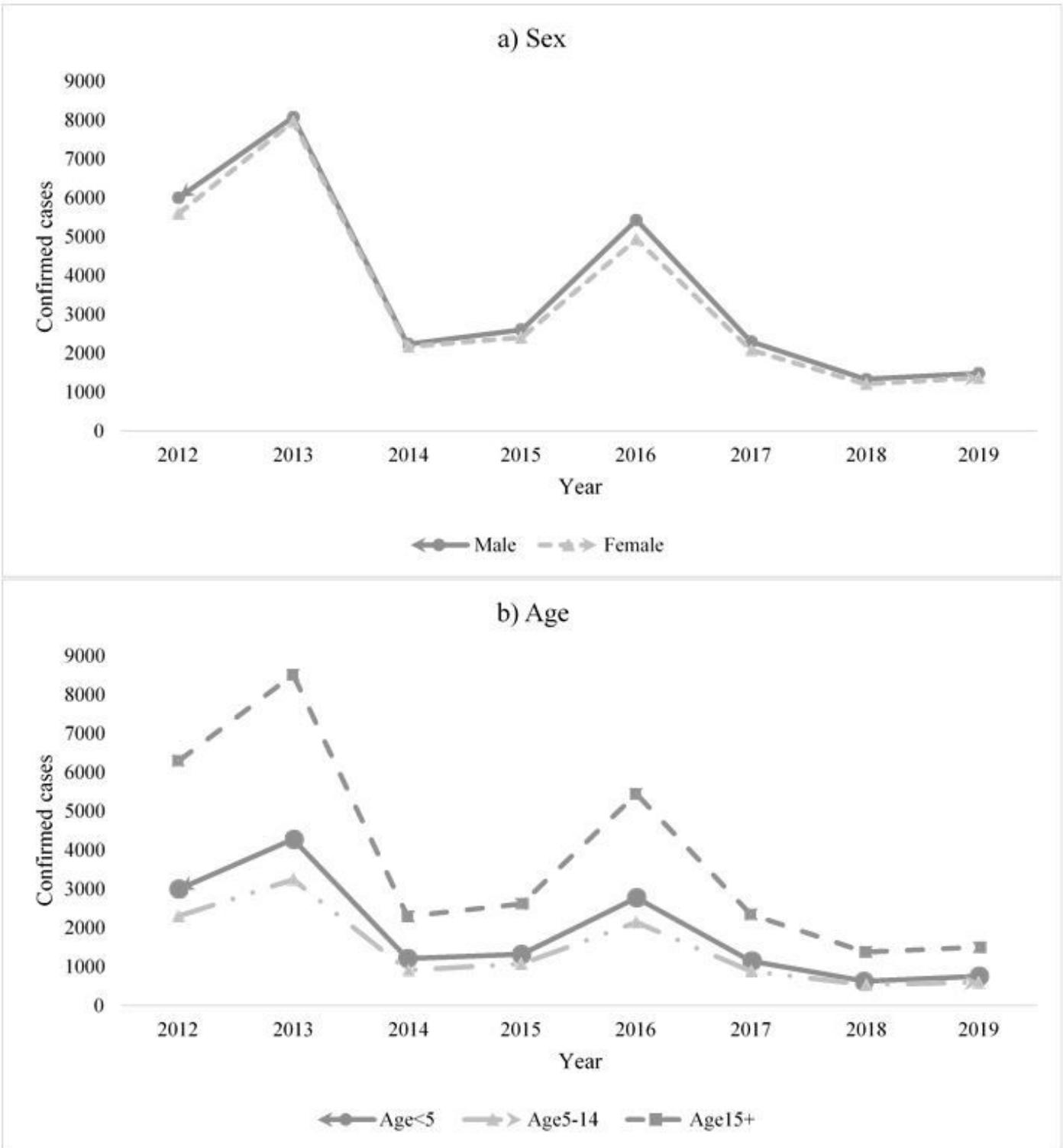
%.: *percentage (n/N\*100)*

## Figures



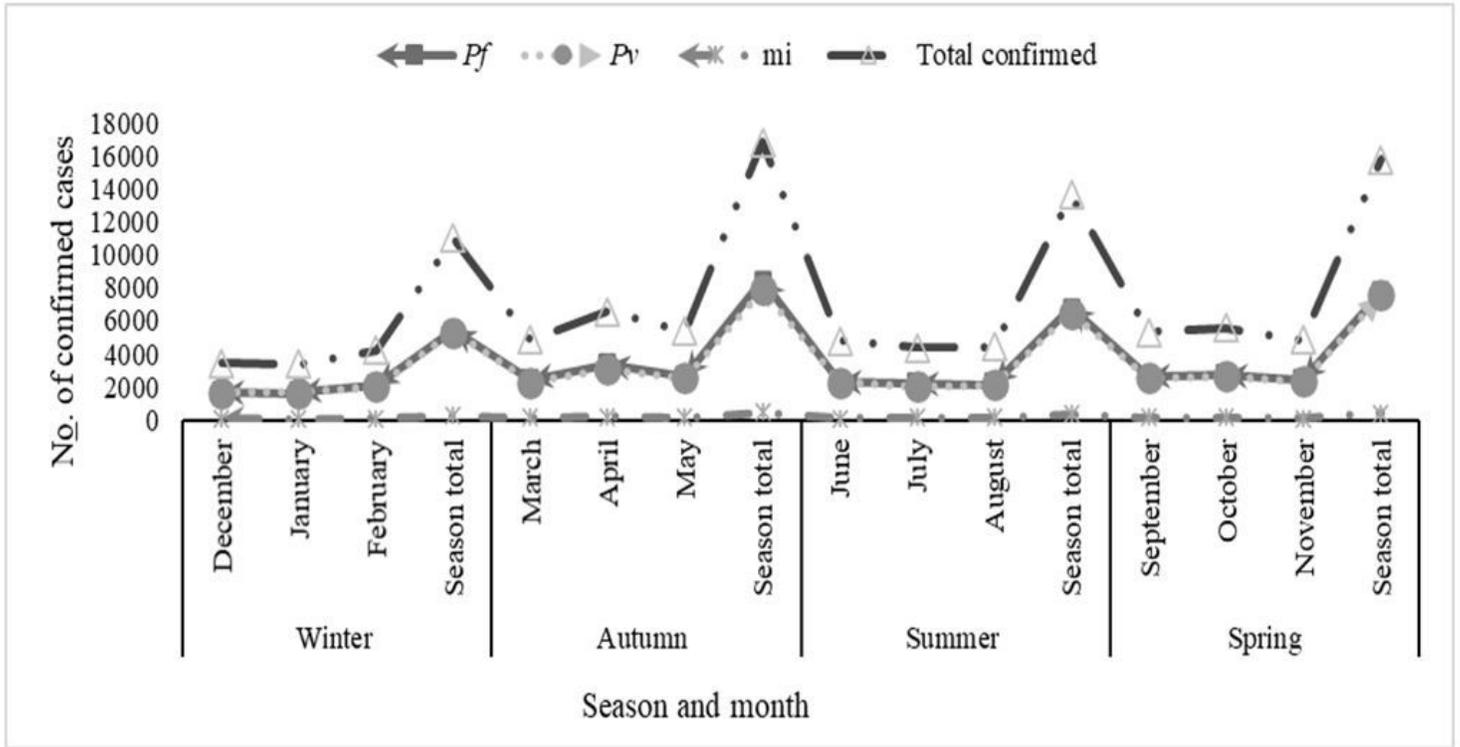
**Figure 1**

Map of the study districts; Gedeo Zone Southern Nationals Nationalities and Peoples Regional state, Ethiopia.



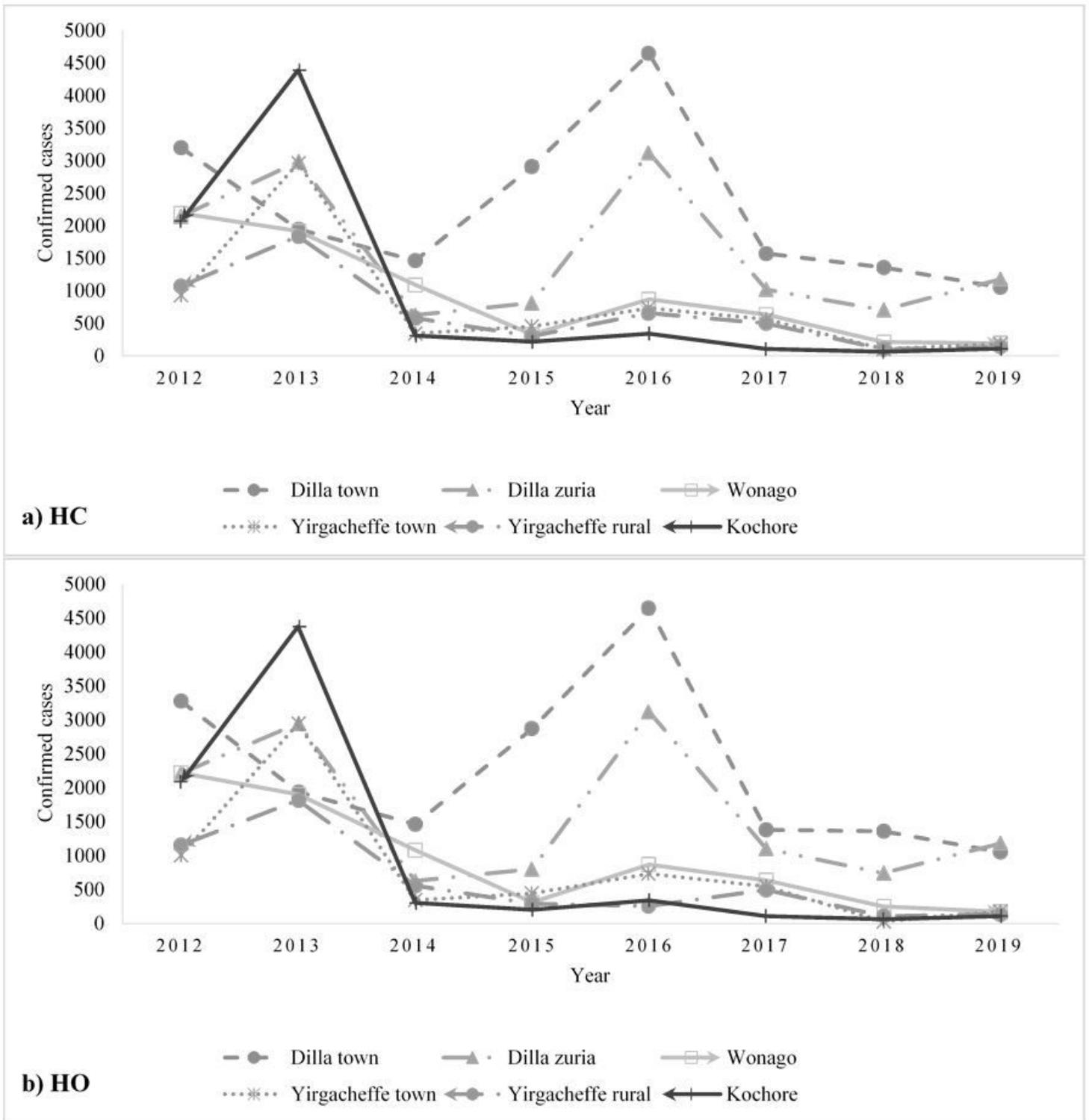
**Figure 2**

Annual clinical and confirmed malaria trend by sex and age in Gedeo zone, South Ethiopia from 2012-2019.



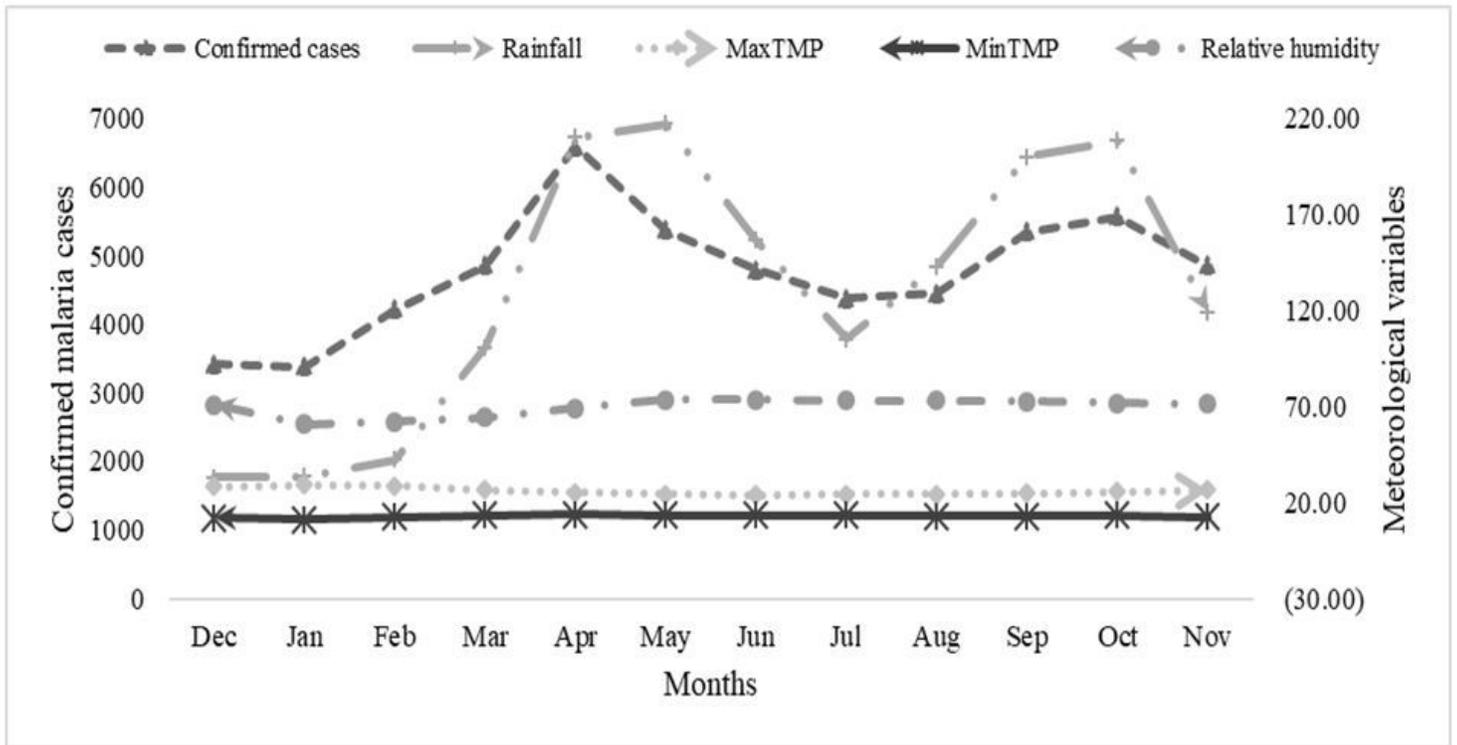
**Figure 3**

Seasonal trend of clinical and confirmed malaria cases based on HC data, Gedeo zone, South Ethiopia, 2012-2019.



**Figure 4**

Spatial distribution of confirmed malaria cases in HCs and HOs, Gedeo zone, South Ethiopia, 2012-2019.



**Figure 5**

Monthly HC-level confirmed malaria cases and meteorological data in Gedeo zone, South Ethiopia from 2012-2019.