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Supplementary Material

Investigating the Resurgence of Malaria Prevalence in South Africa Between 2015 and 2018: A Scoping Review

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SUPPLEMENTARY TABLE

Table 1. Characteristics of the studies (place of study conduction, type of study conducted, instrument used, population used).

Authors	Article title	Year of public-cation	Study location	Study population	Aims of the study	Methodology/instruments	Outcome measure	Important of the result
Abiodun, G.J., Maharaj, R., Witbooi, P. and Okosun, K.O.	Modelling the influence of temperature and rainfall on the population dynamics of Anopheles arabiensis	2016	Dondotha village, KwaZulu-Natal Province, South Africa	An. *arabiensis* mosquito population in the study region	To examine the impact of climatic factors on the gonotrophic cycle and the dynamics of the mosquito population over the study region	A climate-based, mathematical model was used. The model was driven by rainfall and temperature data of the study region.	Impact of temperature and rainfall on population dynamics of An. *arabiensis*	Temperature and rainfall affect *An. arabiensis* populations with a peak in summer and minimal in winter
Abiodun, G.J., Witbooi, P. and Okosun, K.O.	Modelling and analysing the impact of temperature and rainfall on mosquito population dynamics over Kwazulu-Natal, South Africa	2017	Amajuba District, KwaZulu-Natal Province, South Africa	*An. arabiensis* mosquito population in the study region	To explore in detail the connections between meteorological factors and their importance on mosquito population dynamics	A climate-based, mathematical model was used. The model was driven by rainfall and temperature data of the study region.	Impact of temperature and rainfall, population dynamics of *An. arabiensis* at both aquatic and adult stage over the study region.	Temperature and rainfall play a significant role in both aquatic and adult stages of the *Anopheles* mosquitoes.

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Abiodun, G.J., Witbooi, P. and Okosun, K.O.	Modelling the impact of climatic variables on malaria transmission	2018a	Limpopo Province, South Africa	*An. arabiensis* and malaria-infected human population of the study region	To explore the impact of climate variability on malaria transmission over the study region.	A climate-based, mathematical model was used. The model was driven by rainfall and temperature data of the study region.	Impact of temperature and rainfall on malaria transmission over the study region	Malaria transmission in the province is seasonal with epidemic peak between December-February when temperature and rainfall are relatively high
Abiodun, G.J., Witbooi, P.J., Okosun, K.O. and Maharaj, R.	Exploring the impact of climate variability on malaria transmission using a dynamic mosquito-human malaria model	2018b	KwaZulu-Natal Province, South Africa	*An. arabiensis* and malaria-infected human population of the study region	To investigate the impact of climate variability on malaria transmission over KwaZulu-Natal province during the period 1970-2005	A climate-based, mathematical model was used. The model was driven by rainfall and temperature data of the study region.	Impact of temperature and rainfall on malaria transmission over the study region	Malaria transmission is more tightly coupled with temperature than with rainfall over the study region
Abiodun, G.J., Njabo, K.Y., Witbooi, P.J., Adeola, A.M., Fuller, T.L., Okosun, K.O., Makinde, O.S. and Botai, J.O	Exploring the Influence of Daily Climate Variables on Malaria Transmission and Abundance of Anopheles arabiensis over Nkomazi Local Municipality,	2018c	Nkomazi, Mpumalanga Province, South Africa	*An. arabiensis* and malaria-infected human population of the study region	To investigate the influence of climatic factors on malaria transmission over the study regions	A climate-based, mathematical model was used. The model was driven by rainfall and temperature data of the study region. The output of the model was validated by malaria data of the study region.	Impact of rainfall, relative humidity, abundant of *An. arabiensis* on malaria transmission over the study region.	Rainfall was confirmed as the major driver of malaria over the region, followed by an abundance of *An. arabiensis* and relative humidity. Temperature was found to be less significant on the transmission of malaria in the municipality over the study period
Adeola, A.M., Botai, J.O., Olwoch, J.M., Rautenbach, H.C.D.W., Kalumba, A.M., Tsela, P.L., Adisa, M.O., Wasswa, N.F., Mmtoni, P. and Ssentongo, A.	Application of geographical information system and remote sensing in malaria research and control in South Africa: a review.	2015	South Africa	Malaria-infected human population of the study region	To present a review of numerous items of published literature on the use of spatial technology for malaria epidemiology in South Africa between 1930 and 2013	Review	The use of geographic information science (GIS) and remote sensing (RS) technology for malaria research	Remote sensing (RS) and global positioning systems (GPS) ought to be integrated into a GIS system, in order to have a core spatial technology for understanding the epidemiological processes of malaria
Adeola, A.M., Botai, O.J., Olwoch, J.M., Rautenbach, C.D.W., Adisa, O.M., Taiwo, O.J. and Kalumba, A.M.	Environmental factors and population at risk of malaria in Nkomazi municipality, South Africa	2016	Nkomazi, Mpumalanga Province, South Africa	Malaria-infected human population of the study region	To examine the influence of environmental factors on population (age group) at risk of malaria incidence over the study region.	R software was used to statistically analyse both malaria and environmental data of the study region	Impact of environmental factors on population at risk of malaria	Malaria incidence was highly associated with irrigated land, water body and altitude ≤400m areas of the study region.
Adeola, A.M., Olwoch, J.M., Botai, J.O., Rautenbach, C.D., Kalumba, A.M., Tsela, P.L., Adisa, O.M. and Nsubuga, F.W.N.	Landsat satellite derived environmental metric for mapping mosquitoes breeding habitats in the Nkomazi municipality, Mpumalanga Province, South Africa	2017	Nkomazi, Mpumalanga Province, South Africa	An. *arabiensis* mosquito population in the study region	To identify the potentially favourable breeding habitats of the mosquito using environmental metric parameters derived from Landsat satellite imagery over the study region.	Erdas Imagine 9.1 raster-based software was used for image processing and analyse normalized difference vegetation index (NDVI) and normalized difference water index (NDWI) and land surface temperature (LST) of the study region.	Impact of NDVI, NDWI and LST over mosquito habitation over the study region.	NDVI, NDWI and LST are considered as key environmental factors that influence the mosquito habitation over the study region
Adeola, A., Botai, J., Rautenbach, H., Adisa, O., Ncongwane, K., Botai, C. and Adebayo-Ojo, T.	Climatic variables and malaria morbidity in Mutale Local Municipality, South Africa: A 19-year data analysis	2017	Mutale local municipality, Limpopo Province, South Africa	Malaria-infected human population of the study region	To determine the role of each of the local climatic variables (monthly: total rainfall, mean maximum temperature (Tmax), mean minimum temperature (Tmin), and mean temperature (Tavg), and mean relative humidity (RH)) on malaria occurrence over the study region	Seasonal Autoregressive Integrated Moving Average (SARIMA) was used. The model was driven by climate and malaria data from the study region	Impact of monthly total rainfall, Tmax, Tmin, Tavg and RH on malaria occurrence over the study region	Monthly total rainfall and monthly Tmin at a two-month lagged effect, are the most significant climatic predictors of malaria transmission in the study region.

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Agusto, F.B., Gumel, A.B. and Parham, P.E.	Qualitative assessment of the role of temperature variations on malaria transmission dynamics.	2015	West Africa, Central Africa, East Africa, South Africa	Malaria-infected human population of the study regions	To develop a new temperature-dependent deterministic model to gain qualitative insight into the effects of temperature variability on malaria transmission dynamics	A climate-based, mathematical model was used. The model was driven by temperature data of the study regions.	Impact of temperature on mosquito population dynamics and malaria occurrence over the study regions.	Malaria burden increases with increasing temperature in the range 16–28°C and decreases for temperature values above 28°C in West Africa, 27°C in Central Africa, 26°C in East Africa and 25°C in South Africa
Burke, A., Dandalo, L., Munhenga, G., Dahan-Moss, Y., Mbokazi, F., Ngxongo, S., Coetzee M, Koekemoer, L. and Brooke, B.	A new malaria vector mosquito in South Africa	2017	Vlakbult and Block A in Ehlanzeni District of Mpumalanga province and Mamfene in KwaZulu-Natal Province, South Africa	*Anopheles* mosquito's population in the study regions.	To assess whether *An. vaneedeni*, a member of the *An. funestus* species, contributes to residual malaria transmission in South Africa	Adult *Anopheles* mosquitos were collected using traditional ceramic pots and modified plastic buckets	Mosquito collection over a long period helps detect a new mosquito species transmitting malaria over the study regions.	A new malaria vector mosquito (*An. vaneedeni*) found in Mpumalanga and KwaZulu-Natal provinces, South Africa
Behera, S.K., Morioka, Y., Ikeda, T., Doi, T., Ratnam, J.V., Nonaka, M., Tsuzuki, A., Imai, C., Kim, Y., Hashizume, M. and Iwami, S	Malaria incidences in South Africa linked to a climate mode in south-western Indian Ocean	2018	Vhembe district, Limpopo province, South Africa	Malaria-infected human population of the study region	To present evidence of a new mode of climate variation in the Indian Ocean that could explain the inter-annual variation of malaria incidences in South Africa	Statistical analysis were performed on malaria data from the study region and climate data (SST anomalies, 850 hPa winds, Monthly-averaged SST, Sea surface height (SSH), Precipitation anomalies, monthly precipitation) of the study region.	Impact of rainfall and temperature and other large-scale climate phenomena such as El Niño/La Niña and sea surface temperature (SST) on malaria transmission over the study region.	Malaria incidences in South Africa is linked to rainfall and temperature, El Niño/La Niña and sea surface temperature (SST) from the south-western Indian Ocean.
Davies, C., Coetzee, M. and Lyons, C.L.	Effect of stable and fluctuating temperatures on the life history traits of *Anopheles arabiensis* and *An. quadriannulatus* under conditions of inter-and intra-specific competition	2016	North-eastern South Africa	*Anopheles arabiensis* and *An. quadriannulatus* mosquito population of the study region	To determine the outcome of inter and intra-specific competition on the development rate and survival of An. arabiensis and An. quadriannulatus larvae by controlling ecological variables (competitive scenario and temperature)	Parametric ANOVAs were used	Impact of competitive scenario and temperature on *Anopheles arabiensis* and *An. quadriannulatus*	Temperature significantly influenced the measured life-history traits of *Anopheles arabiensis* and *An. quadriannulatus*
Hlongwana, K.W. and Tsoka-Gwegweni, J	From malaria control to elimination in South Africa: The researchers' perspectives	2016	South Africa	Malaria researchers in South Africa	To investigate the malaria researchers' knowledge, understandings, perceived roles, and their perspectives on the factors influencing implementation of a malaria elimination policy in South Africa	The study was a descriptive cross-sectional survey conducted through an emailed self-administered semi-structured questionnaire amongst malaria researchers who met the set selection criteria and signed informed consent	The perspective of malaria researchers in South Africa over South Africa's 2018 malaria elimination	Majority of the targeted researchers believe that South Africa's 2018 elimination target was not realistic due to lack of new tools, resources, and capacity to fight malaria; poor cross-border collaborations; overreliance on partners to implement; poor community involvement; and poor surveillance

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Hlongwana, K.W. and Tsoka-Gwegweni, J.	Towards the implementation of malaria elimination policy in South Africa: the stakeholders' perspectives	2017	South Africa	Malaria stakeholders in South Africa	To investigate the stakeholders' understanding of the malaria elimination policy in South Africa, including their perceived barriers and facilitators to effective policy implementation.	The study followed a constructivist epistemological approach. Interview were conducted using semi-structured approach. The hybrid approach was used to perform thematic data analysis.	The perspective of stakeholders' in South Africa over South Africa's 2018 malaria elimination	Malaria remains a problem in South Africa, exacerbated by staff attitudes and poor capacity, lack of resources, lack of new effective intervention tools, lack of intra- and inter-departmental collaboration, poor cross-border collaboration and weak stakeholder collaboration. Informants were concerned about the target year (2018) for elimination, and about the process followed in developing the policy, including the perceived malaria epidemiology shortfalls, regulatory issues and political context of the policy.
Ikeda, T., Behera, S.K., Morioka, Y., Minakawa, N., Hashizume, M., Tsuzuki, A., Maharaj, R. and Kruger, P.	Seasonally lagged effects of climatic factors on malaria incidence in South Africa	2017	Limpopo province, South Africa	Malaria-infected human population of the study region	To investigate the impact of local and regional climate on malaria transmission over the study region.	Correlation analysis were performed on the climate and malaria data of the study region by with R version 3.2.2. Self-Organizing Maps (SOMs) SOMs were used to analyse spatio-seasonal malaria incidence anomaly patterns in Limpopo at the municipality level by SOM_PAK Version 3.1.	Impact of rainfall, temperature and migration on malaria transmission over the study region.	Rainfall, temperature and migration from neighbouring countries were found to be the cause of malaria over the study region. The findings highlight the need to Strengthen cross-border control of malaria to minimize its spread.
Kapwata, T. and Gebreslasie, M.T.	Random forest variable selection in spatial malaria transmission modelling in Mpumalanga Province, South Africa	2016	Mpumalanga Province, South Africa	Malaria-infected human population of the study region	To assess the relationship between climatic variables and malaria transmission by determining the variable importance of each climatic variable, as well as to evaluate what combination of climatic factors is the most associated with malaria	Random forest for regression analysis was performed on malaria data and environmental data (land surface temperature (LST), monthly rainfall, humidity and altitude, normalized difference vegetation index (NDVI)) from the study region.	Impact of land surface temperature (LST), monthly rainfall, humidity and altitude, normalized difference vegetation index (NDVI) on malaria transmission over the study region.	Altitude, NDVI, and temperature have high predictive capabilities in relation to malaria transmission over the study region.
Komen, K., Olwoch, J., Rautenbach, H., Botai, J. and Adebayo, A.	Long-run relative importance of temperature as the main driver to malaria transmission in Limpopo Province, South Africa: A simple econometric approach	2015	Limpopo Province, South Africa	Malaria-infected human population of the study region	To examines the distribution of malaria at district level in the province, and to determine the direction and strength of the linear relationship between malaria and meteorological variables (rainfall and temperature) and ascertains their short- and long-run variations.	Spatio-temporal method, Correlation analysis and econometric methods were applied on malaria and climate data (temperature and rainfall) of the study region.	Impact of temperature and rainfall on malaria transmission over the study region.	Temperature is more important in influencing malaria transmission in Limpopo Province

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Komen, K.	Could Malaria Control Programmes be Timed to Coincide with Onset of Rainfall?	2017	Limpopo province, South Africa	Malaria-infected human population of the study region	To examine how variation in rainfall and temperature impacts on malaria cases and to test the sensitivity of malaria cases to the onset of rainfall season	This paper applies statistical methods: regression analysis and impulse response function on climate and malaria data over the study region	Impact of temperature and rainfall on malaria transmission over the study region.	The onset of rainfall triggers a malaria season that lasts for 3 months over the study region.
Malahlela, O.E., Olwoch, J.M. and Adjorlolo, C.	Evaluating Efficacy Of Landsat-Derived Environmental Covariates For Predicting Malaria Distribution In Rural Villages Of Vhembe District, South Africa	2018	Vhembe district, Limpopo province, South Africa.	Mosquito (*An. arabiensis*) and Malaria-infected human population of the study region	To evaluate environmental covariates (vegetation moisture and vegetation greenness) associated with malaria vector distribution for better predictability towards rapid and efficient disease management and control.	Malaria incidence data combined with Landsat 5 ETM were used in this study.	Impact of vegetation moisture and vegetation greenness vector distribution and malaria transmission over the study region.	Malaria vector (*An. arabiensis*) prefer productive and greener vegetation.
Manana, P.N., Kuonza, L., Musekiwa, A., Mpangane, H.D. and Koekemoer, L.L.	Knowledge, attitudes and practices on malaria transmission in Mamfene, KwaZulu-Natal Province, South Africa 2015	2018	Mamfene, KwaZulu-Natal Province, South Africa	Community of the study region.	To assess knowledge, attitudes, and practices regarding malaria transmission to inform a public awareness campaign for Sterile Insect Technique (SIT) in the study region.	Cross-sectional survey were conducted. A structured field piloted questionnaire was administered to Descriptive statistics were used to summarize data with STATA Version 13.	Awareness of Sterile Insect Technique (SIT) on malaria transmission over the study region.	The existing communication channels used by the malaria control program can be used; however additional channels should be investigated.
Mutegeki, E., Chimbari, M.J. and Mukaratirwa, S.	Assessment of individual and household malaria risk factors among women in a South African village	2016	Mgedula Village, KwaZulu-Natal Province, South Africa	Among women living in the study region	To understand how various malaria risk factors interact at the individual, household and community levels, as well as wider contexts, in order to guide the design and implementation of effective and more comprehensive control strategies	Close-ended questionnaires and a multivariable logistic regression model was used on the data collected from the study region.	Impact of individual, household and community levels on malaria risk over the study region.	Practicing animal husbandry, residing in household structures that had not been sprayed, and cross-border movement were greatly associated with malaria infection over the study region.
Okuneye, K. and Gumel, A.B.	Analysis of a temperature-and rainfall-dependent model for malaria transmission dynamics	2016	KwaZulu-Natal Province, South Africa	Human and mosquito population of the study region.	To assess the impact of variability in temperature and rainfall on the transmission dynamics of malaria in a population	A non-autonomous mathematical model was used. Climate and malaria data of the study region was used to run the model.	Impact of temperature and rainfall on mosquito population dynamics and malaria transmission was investigated.	Malaria transmission over the study region is maximized for mean monthly temperature and rainfall in the ranges [21 –25]$^{\circ}$C and [95 –125] mm
Tusting, L.S., Bottomley, C., Gibson, H., Kleinschmidt, I., Tatem, A.J., Lindsay, S.W. and Gething, P.W.	Housing improvements and malaria risk in sub-Saharan Africa: a multi-country analysis of survey data.	2017	21 Sub-Sahara Africa (SSA) countries including South Africa.	Human population of SSA	To test the hypothesis that the odds of malaria infection are lower in modern, improved housing compared to traditional housing in SSA	Conditional logistic regression was used. Individual survey odds ratios (ORs) were combined to determine a summary OR using a random effects meta-analysis.	Impact of housing quality on malaria transmission was investigated over SSA.	Housing quality is an important risk factor for malaria infection across the spectrum of Malaria endemicity in sub-Sahara Africa.