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Original Research Article

The influence of enhanced vegetation index, proximity to national borders, proximity to protected areas, and proximity to water on malaria case prevalence in Sub-Saharan Africa, 2000-2020

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ABSTRACT

Background: This study aimed to assess the effect of enhanced vegetation index, proximity to national borders, proximity to protected areas, and water on malaria morbidity in Sub-Saharan Africa.
Methods: Data were pooled from the Demographic and Health Surveys (DHS) conducted in 32 Sub-Saharan African countries spanning 2000 to 2020. Women's standard weights were denormalized and bivariate analyses were conducted to identify potential confounders. Two models were fitted; model 1 involved primary exposure variables and model 2 involved primary exposure variables adjusted for significant confounders. The final interpretation of the results was based on model 2.
Results: The prevalence of malaria cases was 23.1%, The risk of children suffering malaria in households that belong to the 3rd quantile of the vegetation index is 27% less compared to children that belong to the households in the 1st quantile of the vegetation index [aOR=0.73, 95%CI: 0.55-0.99; p-value<0.05]. Children belonging to households in the 4th quantile of proximity to water have a 33% higher risk of suffering from malaria compared to households that are closer to water [aOR=1.33, 95%CI:1.08-1.63; p-value<0.01].
Conclusions: Environmental factors have been found to influence malaria morbidity among children in SSA. Intervention should be targeted at households especially those that are closer to water with more children under five to ensure full access and use of ITNs among all children under five as part of the overall goal of achieving the health-related SDGs.

Keywords: Enhanced vegetation index, Proximity to protected areas, Proximity to national borders, Proximity to water, Sub-Saharan Africa, Malaria

INTRODUCTION

In the last two decades, malaria remains a major global public health challenge, especially in low- and middle-income countries.[1] Over 210 million estimated cases of malaria were reported in 2015 with over 450,000 deaths worldwide.[2,3] The number of malaria cases rose to about

300 million in 2018 and in 2019, the estimated malaria cases from 87 countries were nearly 230 million.[3,4]

Globally, there was a decline in the number of deaths that resulted from malaria cases from about 730, 000 in 2000 to over 400,000 in 2019.[3,5] Out of the 430,000 deaths resulting from malaria in 2017; Sub-Saharan Africa (SSA) accounted for about 90% of the global malaria deaths with about 260,000 being children under five years of age.[2,6] The burden of malaria cases among children under five years differs across the countries in SSA. More than 30% and 10% of children under five mortalities in Nigeria and Tanzania respectively were a result of malaria cases alone and it is the second largest contributor to childhood morbidity and mortality.[2,5,7] Ethiopia is amongst the countries with the highest under-five mortality in SSA, with most cities and villages being malaria endemic.[8,4] Malaria infection is said to be more prevalent in rural areas than in urban centers.[9]

Malaria was believed to be a rural disease because the transmitting vectors are said to breed more in rural areas.[9] However, malaria had remained a serious public health concern in urban areas as observed by.[10] Unfortunately, this is not the situation for most African countries with limited resources to provide adequate infrastructure amenities that cope with the rate of urbanization experienced, resulting in poor housing, sanitation, and, drainage systems, which could increase the vector breeding and human contact.[9] Research scientists have attributed the prevalence of malaria in SSA to several factors including medical conditions, seasonal influences, age, gender, pregnancy, socioeconomic status, and demographic and environmental factors.[4,11]

METHODS

Data source

This study involved data that were pooled from the Demographic and Health Surveys (DHS) conducted in 32 Sub-Saharan African countries spanning 2000 to 2020 with a total population of 736,487. These countries included Ghana, Nigeria, Kenya, Senegal, Tanzania, Burkina Faso, and Zambia. The DHS data are generated from household surveys conducted in over 90 countries every three to five years. These surveys are nationally representative and primarily provide data for monitoring and impact assessment of population, health, and nutrition indicators for individual countries as well as for cross-country comparative analyses. These surveys use standard data definitions and data collection procedures across countries.

Geospatial covariates

The following geospatial covariates were obtained from the Spatial Data Repository under the DHS program (https://spatialdata.dhsprogram.com/covariates/): enhanced vegetation index, proximity to national borders, proximity to protected areas, proximity to water.

Sampling design

The demographic and health survey was based on a multi-stage stratified cluster sampling. The countries were first stratified by regions and counties and urban and rural areas. Sample enumeration areas (EA's) were selected independently in each stratum in two stages. In the first stage of obtaining the samples, EA's (residential households) were selected with probability proportional to the EA size (number of residential households) and with independent selection of each of the sampling stratum. The EA sizes were obtained from the immediate past population and housing census of each country. The sampling frames for the survey were obtained by conducting household listing operations in all the selected EAs, and the resulting lists of households served as a sampling frame for the selection of households in the second stage. In the second stage of the selection, a fixed number of households per cluster (EAs) were selected with an equal probability systematic selection from the newly created household listing. The trained interviewers visited and interviewed only the selected households.

Statistical methods

The study employed five stages of pooling the data together. Stage 1 involved appending all kids datasets from different countries for different survey periods. Stage 2 involved appending all environmental datasets for different survey periods for different countries. In stage 3, the kids' dataset and environmental datasets were merged. Stage 4 involved merging datasets obtained in Stage 3 with women 14 to 49 population dataset. In the final stage (i.e., stage 5), the dataset obtained from stage 4 was merged with women sample dataset. The final data analyses were carried out using the final merged dataset obtained in stage 5.

Outcome variables

The study investigated malaria case prevalence in SSA. Children who had fever for the past two weeks were used as proxies for malaria cases and classified as such.

Primary exposure variables

The primary exposure variables involved in the analyses were enhanced vegetation index, proximity to protected areas, proximity to national borders, and proximity to water.

Enhanced vegetation index

This measures the density of green leaves within a specified geographic region.

Proximity to national borders

This measures how close people in a geographical area are to a national border. It is a measure of straight-line distance to the nearest international border.

Proximity to protected areas (meters)

This is a straight-line distance to the nearest protected area.

Proximity to water (meters)

This is a straight-line distance to the nearest major water body.

All the primary exposure variables were grouped into 4 quantiles (i.e., 1st, 2nd, 3rd, and 4th quantiles). The 1st quantile of the enhanced vegetation represents low density of green leaves in a particular geographic area whiles 4th quantile represents high density of green leaves in a particular geographic area. The 1st quantile of proximity to national borders represents how close households are to national or international borders and the 4th quantile represent how far households are to national or international borders. The 1st quantile of proximity to protected area represents how close households are to the nearest protected area and the 4th quantile represents how far households are to the nearest protected area. Similarly, the 1st quantile of proximity to water represents how close households are to the nearest major water body and the 4th quantile represent how far households are to the nearest major water body.

The countries were also grouped into four regions for descriptive analysis as follows: East Africa, West Africa, Central Africa, and Southern Africa. Angola, Madagascar, Kenya, Rwanda, Tanzania, and Uganda were grouped as East Africa. West Africa group was made up of Benin, Burkina Faso, Ivory Coast, Gambia, Ghana, Guinea, Liberia, Mali, Nigeria, Senegal, and Togo. The Central Africa group was made up of Burundi, Cameroun, Chad, The Democratic Republic of Congo, and Gabon. Estwani, Lesotho, Malawi, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe were also grouped as Southern Africa.

Potential confounders

Factors such as age of household head, place of residence, household utility, wealth index, main floor material, multiple births, sex of child (male or female), mothers age at first birth, parity, mothers' highest educational level, currently using contraceptive, total children ever born, place of delivery, currently breastfeeding, type of delivery, number in co-wives, Antenatal Care (ANC) visits, household ownership of bed net, sanitary facility, wealth index, main floor material and properties (i.e. electricity, water, car, and motorbike), have been identified to independently influence malaria prevalence.[12,13] Other studies have linked environmental factors such as rainfall to malaria.[14] These factors were grouped into household characteristics, child-related characteristics, maternal factors, and environmental factors (see supplementary file).

Statistical analyses

The analysis was restricted to women who had children in the last 5 years preceding the survey. The sample contains the total number of children under-five born in the 5 years preceding the survey, and the data contain information on their respective mothers and households. Such data include place of residence, household wealth, and household size.

Although all statistical analyses for survey data adjusted for weighting, clustering, and stratification at the individual analysis, traditional regression models assume that both geospatial and non-geospatial covariates are identically and independently distributed over the geographical area. The study employed three-staged statistical analyses. In the first stage, the women's standard weights were denormalized to obtain one pooled dataset for all the demographic and health surveys (2000-2020) since the study pooled data from different DHS data from different countries at different survey periods in SSA. The second stage involved bivariate analyses of potential confounders. Simple logistic regression was used to determine potential confounders for malaria case prevalence. Thirdly, each covariate's effect was assessed by fitting a logistic regression model that includes the primary exposure variables adjusted for potential confounders and the country-fixed effect. Two different logistic regression models were fitted to assess the multivariable effect of the primary exposure variables on malaria prevalence. Model 1 assessed the effect of only primary exposure variables on malaria prevalence and model two assessed the effect of primary exposure variables adjusted for maternal factors, child-related factors, household factors, and environmental factors on malaria prevalence.

Mean and standard deviation was reported for continuous variables whiles proportions were reported for categorical variables. All statistical analyses were conducted using Stata 14 (StataCorp, College Station, Texas, USA) and p-value less than 0.05 were considered statistically significant. The final interpretation of the results was based on the adjusted models, however, in some instances, references were made to the unadjusted models to highlight those interesting findings.

RESULTS

Descriptive statistics

The average age of the head of household was approximately 41±12.9 years (range = 12-98), and females headed 17.3% of households with an average household size of 2.1±0.8. The percentage of households in rural areas was 69%. Male and female children born in the 5 years preceding the survey have almost equal percentages (male = 50.6%, female = 49.4%). The prevalence of multiple births was 3.5% and 54.8% of women had 4 or more Antenatal Care (ANC) visits. The percentage of women who did not deliver in a recommended facility (home delivery) was 47.5% and about 4% of all delivery were conducted through caesarian section. Fifty-one percent (51%) of the women breastfed their children after 1 hour after delivery.

Approximately 60% of households have mosquito bed nets for sleeping. The percentage of children under-five who did not sleep under mosquito bed net the night preceding the survey was 59.7%. Thirty-three percent (33%) of respondents had no formal education and 3% completed higher level of education. The percentage of households that belonged to the poorest category of wealth index was 22.9%, 20.1% belonged to the middle category and 16.2% belonged to the richest category of the wealth index.

Table 1: Description of the data source used for the study.

Years of survey	Countries	Data Source	Number of children born 5 years preceding the survey	
			Male	Female
2000	Malawi	DHS	5939	5966
	Namibia		1966	1971
	Uganda		3027	3070
2001	Benin	DHS	2647	2590
	Mali		6567	6448
2003	Burkina Faso	DHS	5424	5147
	Ghana		1920	1850
	Kenya		3003	2914
	Nigeria		3037	2952
2004	Cameroon	DHS	4041	4030
	Lesotho		1771	1715
	Malawi		5519	5385
2005	Guinea	DHS	3174	2993
	Rwanda		2758	2669
	Rwanda		4334	4223
	Senegal		5291	5007
	Zimbabwe		2614	2590
2006	Eswatini	DHS	1388	1373
	Mali		7170	7024
	Namibia		2595	2424
	Uganda		3805	3829
2007	Democratic Republic	DHS	4372	4380
	Liberia		2884	2705
	Zambia		3181	3220
2008	Ghana	DHS	1482	1419
	Kenya		3073	2898
	Madagascar		6206	5915
	Nigeria		14592	14029
	Sierra Leone		2721	2696
2009	Lesotho	DHS	1994	1967
2010	Burkina Faso	DHS	7219	6940
	Burundi		3928	3799
	Malawi		9735	9755
	Rwanda		4586	4416
	Senegal		6076	5691
	Tanzania		3800	3815
	Zimbabwe		2718	2654
2011	Cameroon	DHS	5788	5895
	Mozambique		5511	5426
2012	Benin	DHS	6737	6379
	Comoros		1380	1348

Continued.

Years of survey	Countries	Data Source	Number of children born 5 years preceding the survey	
	Cote D'Ivoire		3770	3711
	Gabon		2896	2888
	Guinea		3581	3319
	Mali		5324	5002
	Senegal		6734	6688
2013	Democratic Republic	DHS	8525	8674
	Liberia		3822	3673
	Namibia		2452	2502
	Nigeria		15841	15384
	Sierra Leone		5946	5921
	Togo		5946	5921
	Zambia		3519	3460
2014	Chad	DHS	9472	9151
	Ghana		3006	2771
	Kenya		10528	10220
	Lesotho		1555	1583
	Rwanda		3978	3878
	Senegal		3251	3252
2015	Angola	DHS	14112	14184
	Malawi		8580	8495
	Senegal		3395	3400
	Tanzania		5082	4998
	Zimbabwe		3024	3108
2016	Burundi	DHS	6607	6456
	Senegal		3408	3198
	Uganda		7545	7375
2017	South Africa	DHS	1832	1715
2018	Cameroon	DHS	4928	4781
	Guinea		4050	3806
	Nigeria		16767	16233
	Zambia		4826	4872
2019	Gambia		4057	3734
	Liberia		2720	2795
	Sierra Leone		4767	4574

DHS Demographic and Health Survey

Table 2: Average temperature and rainfall in sub-Saharan Africa (2000-2020).

Regional groups	Variables	
	Temperature	Rainfall
	Mean (SD)	Mean (SD)
East Africa	22 (2.6)	1124.6 (363)
West Africa	27.4 (1.1)	1217.2 (635.8)
Central Africa	24.6 (2.6)	1429 (463.1)
Southern Africa	21.7 (2.4)	846.4 (263.1)

West Africa recorded the highest temperature (27.4ºC±1.1). This was followed by Central Africa (24.6ºC±2.6) with Southern Africa recording the least temperature (21.7ºC±2.4). East Africa recorded 1124.6mm±363 of rainfall, 1217.2mm±635.8 of rainfall was recorded in West Africa, and 846.4mm±263.1 of rainfall was recorded in Southern Africa over the period (2000-2020) (Table 2).

The description of the data source used for the study can be found in Table 1.

The influence of enhanced vegetation index, proximity to national borders, proximity to protected areas, and proximity to water on malaria cases prevalence in SSA from 2000 to 2020

Table 3 shows the factors that influence malaria case prevalence in SSA from 2000 to 2020. Enhanced vegetation index has a significant association with malaria case prevalence. In the unadjusted model, children belonging to households with higher vegetation indices have significant risks of suffering from malaria. Children in households in the 3rd quantile have a 15% higher risk of suffering from malaria [COR=1.15, 95%CI: 1.09-1.22; p value<0.001] compared to children belonging to households with lower vegetation index (1st quantile) and children in households in the 4th quantile have 34% higher risk of suffering malaria [COR=1.34, 95%CI: 1.27-1.41; p-value<0.001] compared to children belonging to households with lower vegetation index (1st quantile). After adjusting for other covariates, only children in households belonging to the 3rd quantile of enhanced vegetation index have a significant risk of suffering from malaria. The risk of children suffering malaria in this household is 27% less compared to children that belong to households that belong to the 1st quantile of vegetation index [aOR=0.73, 95%CI: 0.55-0.99; p-value=0.050].

Table 3: The effect of enhanced vegetation index, proximity to national borders, proximity to protected areas, and proximity to water on malaria case prevalence in Sub-Saharan Africa (2000-2020) (N= 664,850).

Exposure variables	Model 1			Model 2		
	Crude OR	95%CI	P value	aOR	95%CI	P value
Enhanced vegetation index						
1	1			1		
2	1	[0.94, 1.07]	0.996	0.8	[0.64, 1.00]	0.054
3	1.15	[1.09, 1.22]	<0.001	0.73	[0.55, 0.99]	0.04
4	1.34	[1.27, 1.41]	<0.001	0.86	[0.61, 1.19]	0.36
Proximity to national borders						
1	1			1		
2	1.09	[1.02, 1.15]	0.005	1	[0.81, 1.24]	0.974
3	1.04	[0.98, 1.11]	0.189	0.87	[0.71, 1.06]	0.166
4	1.02	[0.96, 1.09]	0.483	0.97	[0.80, 1.17]	0.726
Proximity to protected areas						
1	1			1		
2	0.99	[0.93, 1.04]	0.628	0.96	[0.81, 1.14]	0.631
3	0.87	[0.83, 0.92]	<0.001	0.86	[0.68, 1.10]	0.243
4	0.9	[0.85, 0.94]	<0.001	0.82	[0.62, 1.07]	0.145
Proximity to water						
1	1			1		
2	1.05	[0.99, 1.11]	0.126	1.09	[0.88, 1.36]	0.414
3	0.9	[0.85, 0.95]	<0.001	1.22	[1.00, 1.49]	0.053
4	1.17	[1.10, 1.24]	<0.001	1.33	[1.08, 1.63]	0.007
Child related factors						
Child Sex						
Male				1		
Female				1	[0.90, 1.12]	0.982
Birth order						
Ist child				1		
2nd child				0.99	[0.77, 1.27]	0.922
3rd child				0.9	[0.70, 1.15]	0.383
4th+ child				1	[0.81, 1.24]	0.968
ANC visits						
No ANC visit				1		
1-3 visits				1.01	[0.86, 1.20]	0.879
4 and above visit				1.08	[0.93, 1.26]	0.336
Place of delivery						
Home				1		
Government				0.97	[0.85, 1.12]	0.716
Private				1.14	[0.88, 1.47]	0.33
Slept under a bed net						
No				1		
All children				0.85	[0.72, 1.00]	0.05
Some children				0.96	[0.79, 1.15]	0.636
No net in household				0.86	[0.72, 1.04]	0.113
Early breastfeeding						
Within one hour				1		

Continued.

Exposure variables	Model 1			Model 2		
	Crude OR	95%CI	P value	aOR	95%CI	P value
After one hour or over				1.4	[1.22, 1.60]	<0.001
Mothers' factors						
Mother's age at first birth						
less than 20yrs				1		
20 - 29yrs				0.85	[0.75, 0.96]	0.008
30 - 39yrs				0.78	[0.47, 1.28]	0.323
At least 40yrs				4.51	[0.69, 29.57]	0.116
Owns a mobile phone						
No				1		
Yes				0.94	[0.83, 1.07]	0.329
Co-wives						
One				1		
More than one				0.91	[0.82, 1.01]	0.079
Currently working				1.03	[0.72 1.47]	0.872
No				1		
Yes				1.41	[1.24, 1.60]	<0.001
Highest educational level						
No education				1		
Primary				1.02	[0.89, 1.18]	0.74
Secondary				0.88	[0.71, 1.07]	0.198
Higher				0.78	[0.49, 1.26]	0.312
Contraceptive use						
No contraceptive use				1		
Uses at least one method				1.21	[1.04, 1.41]	0.014
Husband educational level						
No education				1		
Primary				1.08	[0.92, 1.28]	0.331
Secondary				1.16	[0.98, 1.36]	0.078
Higher				1.17	[0.87, 1.57]	0.306
Don't know				1.29	[0.85, 1.94]	0.235
Household factors						
Household wealth index						
Poorest				1		
Poorer				1	[0.86, 1.15]	0.979
Middle				0.79	[0.65, 0.97]	0.022
Richer				0.75	[0.58, 0.98]	0.038
Richest				0.7	[0.48, 1.02]	0.065
Household electricity						
No				1		
Yes				0.96	[0.78, 1.19]	0.726
Household television						
No				1		
Yes				0.84	[0.68, 1.04]	0.113
Household fridge						
No				1		
Yes				1.13	[0.88, 1.45]	0.326
Household bike						
No				1		
Yes				0.98	[0.87, 1.11]	0.74
Household car						
No				1		
Yes				1.05	[0.84, 1.33]	0.662

Continued.

Exposure variables	Model 1			Model 2		
	Crude OR	95%CI	P value	aOR	95%CI	P value
Household age						
<30 years				1		
30-39 years				0.91	[0.74, 1.11]	0.345
40-49 years				0.84	[0.67, 1.04]	0.102
50-59 years				0.87	[0.68, 1.11]	0.253
60+ years				0.68	[0.52, 0.89]	0.005
Unknown				1.05	[0.25, 4.48]	0.942
Environmental factors						
Average aridity				0.99	[0.98, 1.00]	0.222
Global human footprint				1	[1.00, 1.01]	0.468
Slope				1.02	[0.96, 1.10]	0.514
Drought				0.97	[0.94, 0.99]	0.015
Average rainfall				1.04	[0.92, 1.18]	0.536
Average temperature				1.01	[0.97, 1.05]	0.566

OR Odds Ratio; aOR Adjusted Odds Ratio; NB: significant p-values are in bold

Among households that are closer to national borders (i.e., those in the 2nd quantile), the risk of children suffering malaria is 9% higher compared to children who belong to households that are very close to national borders (1st quantile) [COR=1.09, 95%CI: 1.02-1.15; p-value=0.005] in the crude analysis. However, after adjusting for potential confounders, the risk of suffering malaria between children of households in the 2nd quantile and children of households in the 1st quantile is the same [aOR=1.00, 95%CI: 0.81-1.14; p-value=0.974].

In the unadjusted model, children who belong to households that are not close to protected areas (3rd and 4th quantiles) have significant risks have suffering malaria. Those in the 3rd quantile have 13% less risk compared to households in the 1st quantile [COR=0.87, 95%CI: 0.83-0.92; p-value<0.001], and children belonging to households in the 4th quantile have 10% less risk of suffering malaria compared to households in the 1st quantile [COR=0.90, 95%CI: 0.85-0.94; p-value <0.001]. After adjusting for other covariates, the risks were almost the same as previously determined in the unadjusted model, however, these estimates were no longer significant; children belonging to households in the 3rd quantile have 14% less risk of suffering malaria compared to children belonging to households in the 1st quantile [aOR=0.86, 95%CI: 0.68-1.10; p=0.243] and those belonging to household in the 4th quantile have 18% less risk of suffering malaria compared to children belonging to households in the 1st quantile [aOR=0.82, 95%CI: 0.62-1.07; p-value=0.145].

Proximity to water is significantly associated with malaria case prevalence. In the unadjusted model, children belonging to households that are not closer to water (i.e., those belonging to 3rd) have 10% less risk of suffering malaria compared to children in households closer to water (1st quantile) [COR=0.90, 95%CI; 0.85-0.95; p-value<0.001] and those belonging to the 4th quantile (i.e., far from water) have 17% higher risk of suffering malaria compared to households in the 1st quantile [COR=1.17, 95%CI=1.10-1.24; p-value<0.001]. After adjusting for potential confounders, only households in the 4th quantile remained significant. Children belonging to this household, have 33% higher risk of suffering malaria compared to households that are closer to water [aOR=1.33, 95%CI:1.08-1.63; p-value=0.007].

DISCUSSION

This study sought to determine the factors that influenced malaria case prevalence in sub-Saharan Africa from 2000 to 2020. We were specifically interested in the role environmental factors such as enhanced vegetation index, proximity to water, proximity to national borders, and proximity to protected areas played in increasing or decreasing malaria prevalence in sub-Saharan Africa. This objective was achieved by modeling the joint effect of these environmental factors using the logistic regression approach. This is critical to understanding other environmental factors that promote or prevent malaria infections among households and communities in sub-Saharan Africa.

The prevalence of malaria cases was 23.1%. The plausible reason for this high prevalence could be that some households may not have enough ITNs for all the children under five, and therefore priority is given to the youngest among all the children. Another explanation that could be given is that information regarding malaria prevention may not be properly understood by the households because it may not be culturally sensitive and may not be based on already existing positive beliefs and behaviour.

Enhanced vegetation index was found to significantly influence malaria morbidity in SSA. The findings suggest that an enhanced vegetation index tends to negatively influence malaria morbidity in SSA. For instance, people located in areas with higher vegetation index have 27% less risk of recording malaria cases. This finding is interesting as opposed to the findings of other studies that suggest that higher vegetation index is positively associated with malaria cases.[15,16] The present finding that suggests a negative association could be because the plants located in the area may have some mosquito repellant properties as identified by.[17] This would mean that as such plants increased in population, the whole geographical area will be mosquito free and this may result in low malaria morbidity.

The study found higher odds of malaria infection among households who live far from major water bodies. For example, those who live close to major water bodies have 22% higher risk of malaria infection compared to those who live closer to major water bodies though not significant. This odds increased to 1.33 among those who live far from major water bodies compared to those who live closer to major water bodies. This is consistent with other studies that found presence of water bodies to be significantly associated with malaria transmission in Africa.[18] However, the interesting thing is that whiles this present study found that the longer the distance from major water bodies, the higher the risk of malaria infection, other studies have reported that the longer the distance from major water bodies, the less the risk of malaria infection.[19,20] Further studies in the form of evidence synthesis are however necessary to establish whether proximity to major water bodies results in a higher or lower risk of malaria infection.

Proximity to national borders was significantly associated with malaria prevalence in the absence of confounders. When the final analysis was adjusted for confounders, those who live far from national borders have a 3% reduced risk of being diagnosed with malaria compared to those who lived closer to national borders, though not significant. This is contrary to similar studies done in Africa and elsewhere. For example, a study conducted in The Gambia that sought to map malaria transmission risk using satellite imagery showed that malaria case prevalence was high among residents of villages that are closer to The Gambia- Senegal border compared to villages that were far away from the border.[21] Other publications have also indicated that the increasingly high incidence of malaria along the Indian national borders is creating real challenges in eliminating malaria in those areas.[22] The plausible explanation for this contradiction could be that the period within which data was collected for one study may be the peak season for malaria cases at the national and international borders although this theory seems unlikely. Further studies are thus needed to establish whether proximity to national borders increases or decreases malaria case prevalence.

Contrary to other studies, this study showed no significant influence of proximity to protected areas on malaria prevalence even though those who live far from protected areas have an 18% reduced risk of being diagnosed with of malaria. Even though not enough studies have been conducted on the effect of closeness to protected areas on malaria prevalence, some publications available suggest that proximity to protected area may be used to predict the rates of malaria especially in areas where the disease exist. Other studies have actually determined the influence of protected areas on malaria case prevalence, and the results from these studies are contrary to each other.[23–25] Whiles one study reports that proximity to protected area leads to a reduced risk of malaria infection others have reported otherwise.[23] Some of the protected areas that are forest reserves may have some reserves species with mosquito-repellant properties that led to reduce risk of malaria infection.[17] While other protected areas that are forest reserves may have ornamental plants such bromeliads which can serve as a good breeding place for mosquitoes leading to a higher risk of malaria infection.[26]

One main strength of the study is that the survey is nationwide and population-based with internationally approved survey methods. The procedures used to carry out the survey combined with large samples drawn nationally allow for the findings to be generalized to the population of children under-five in SSA, as well as other similar population worldwide. Sampling weights were adjusted for in the analysis, making the estimates more reliable and representative of the entire population. Despite these strengths, the study has some limitations which should be considered in interpreting the results. The data used in the study was based on cross-sectional survey design and cannot be used to conclude causative effect between the outcome and predictors. Just as with all other studies, this study did not account for all the factors that could predict malaria case prevalence among children under-five.

CONCLUSION

This study has a direct bearing on achieving SDG Target 3 which relates to a reduction in malaria incidence and malaria mortality rate to at least 90% each and to end the epidemic of malaria in at least 35 countries by 2030. The study has highlighted environmental factors as predictors of malaria incidence and demonstrated the utmost need to include these factors in the fight against malaria in SSA. Intervention should be targeted at households that are closer to water with more children under five to ensure full access and use of ITNs among all children under five as part of the overall goal of achieving health-related SGDs. Also, the contradictory findings relating to proximity to water, proximity to protected areas and proximity to national borders warrant further studies such as evidence synthesis to establish the actual effect of these environmental factors on malaria case prevalence.

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