European Journal of
Health Sciences
(EJHS)

Spatiotemporal Variation of Malaria Transmission in Different Altitudes of Lower Lake Victoria Basin, Kenya

Samwel Odhiambo Olela, George L. Makokha, and Kennedy Obiero

AJP

European Journal of Health Sciences
ISSN 2520-4645 (online)
Vol.7, Issue 6, pp 1 - 24, 2022
www.ajpojournals.org

Spatiotemporal Variation of Malaria Transmission in Different Altitudes of Lower Lake Victoria Basin, Kenya

Samwel Odhiambo Olela[1*], Prof. George L. Makokha[2], and Dr. Kennedy Obiero[3]

[1]Post Graduate Student: School of Humanities and Social sciences, Kenyatta University, Kenya

[2]Senior Lecturer, School of Humanities and Social sciences, Kenyatta University, Kenya

[3]Lecturer, School of Humanities and Social sciences, Kenyatta University, Kenya

[*]Corresponding Author's Email: samwelodhiambo@students.ku.ac.ke

Abstract

Purpose: Malaria transmission is one of the consequences of climate variability and change. The burden is greatest in the developing countries of the tropics especially Africa south of the Sahara. In Kenya, particularly the Lower Lake Victoria Basin (LLVB), it is blamed on the historical high rainfall, temperature and relative humidity. This study sought to determine spatiotemporal variation of malaria transmission in different altitudes of the LLVB, Kenya.

Methodology: The study relied on data from routine malaria case transmission records archived by the Health Information System for ten years. Data for Kakamega, Kisumu and Migori Counties were obtained from the Kenya Health Information System (KHIS) through Sub-County Health Facilities. Pearson's Product Moment Correlation Coefficient was used to correlate the suspected and confirmed transmission cases. ANOVA was used in testing the variability of transmission, Time Series to determine transmission characteristics while malaria case transmission tables and Tukeys Honest Significance Difference (HSD) were for testing the significance of the distribution of malaria.

Findings: The suspected cases were found to have been overstated in Migori and Kakamega Counties. Malaria transmission varied by altitude, space and time during the study period. Trends increased in Kisumu and Kakamega Counties while it decreased in Migori County. Transmission depicted both endemic and epidictic characteristics in the study area.

Unique Contribution to Theory, Policy and Practices: Health facilities in the LLVB, Kenya should be equipped with more modern laboratory equipment to improve confirmation of transmission so as to reduce suspicions. Since most of the observations confirmed the varying nature of malaria transmission in relation to altitude, the aspect of blanket assumption concerning malaria transmission in the LLVB, Kenya should be stopped. LLVB, Kenya should be zoned by altitudes for effective mitigation and eradication strategies. The reduction of malaria case transmission in Migori County was an indication of possible future eradication. Its cause should be investigated and inferred to other counties. More research is necessary to establish situations elsewhere for effective management and control of transmissions. The revelations and recommendations were expected to enhance malaria eradication in the LLVB, Kenya and subsequently promote the realization of Kenya's vision 2030.

Keywords: *Spatiotemporal variation, malaria transmission, different altitudes, Lower Lake Victoria Basin*

1.0 INTRODUCTION

One of the consequences of climate variability and change is malaria transmission [1]. Malaria is a threatening disease caused by parasites transmitted to people through bites of infected female *Anopheles* mosquitoes whose distribution may be influenced by altitude, temperature, relative humidity and rainfall. From their report, half of the world's population including 3.4 billion people in 92 countries was at risk. 1.1 billion People at high risk. That meant more than one malaria case per 1000 members of the population per year. The hope is that malaria is preventable and is curable [22]. In the year 2018, 228 million cases and 405 000 deaths of which 67% (272 000) were children under 5 years of age occurred in the world [19]. [22]Talked of 229 million cases and 409 000 deaths in 2019. This was an increase of 1 million cases and 4 000 deaths respectively. Older adults, pregnant women, infants, children 5 years and below, HIV/AIDs patients and non-immune migrants were at higher risk.

The most vulnerable were those in the third world countries [9]. Though previously widely spread, malaria was found to be mainly confined to Africa (where 91% of the malaria related deaths occurred, 60% of them being children under five years), Asia and Latin America [8]. Of the 228 million cases in the world, 93% were found in the WHO African region, 3.4 in South East Asia and 2.1% in Eastern Mediterranean Region [19]. They further claimed that WHO African region accounted for 94% of the world's malaria cases and deaths [22]. According to [18], many countries in Africa South of the Sahara had weak surveillance systems and were not well positioned to assess disease distribution and trends making it difficult to optimize responses.

Occurrences of climate extremes had increased in East Africa. The worst case regional scenario of climate change predicted an additional 75.9 million people at risk from endemic (10 – 12 months) exposure to malaria in Eastern and Southern Africa by 2080 with the greatest population at risk being in Eastern Africa. Hot spots of endemic suitability included East African highlands and the Lake Victoria region [18]. Malaria in Kenya accounted for 18% of out–patient consultations and 10% of hospital admissions [16]. By the year 2019, Kenya had 29% (14.4 million) of her population living in malaria endemic areas with 9.8 million living in eight counties of the Lower Lake Victoria Basin [20]. Although there was increasing use of many interventions, many areas in Western Kenya were experiencing malaria transmission dynamics [9]. It was a threat with a prevalence rate of 27% while varying between 4% and 8% in the rest of the country [8].

[16] Identified the Lower Lake Victoria Basin (LLVB), Kenya, which included eight counties with a total population of more than 8.7 million to bear the highest brunt of malaria in the country. From his 2016 report, these counties combined had 38/1000 cases as compared to 6/1000 elsewhere. They showed 26.7% parasitemia as compared to 8.2% elsewhere. Malaria transmission in Kenya is largely determined by altitude, rainfall, and temperature. Kenya's altitude is naturally varied even at micro levels. Such variations create contrasts in the country's climate which ranges from tropical at the coast, temperate in the interior and to very dry in north and north east [4]. Under these assumptions, LLVB, Kenya has always been given a blanket consideration under the Lake Basin endemic. Based on such observations, the study sought to investigate variability of malaria transmission and trends in different altitudes of Lower Lake Victoria basin (LLVB), Kenya.

2.0 METHODOLOGY

2.1 Study Area

The study was carried out in the Lower Lake Victoria Basin, Kenya covering eight counties of Migori, Homabay, Kisumu, Vihiga, Siaya, Kakamega, Bungoma and Busia (Figure 1). From the eight, only three (Migori, Kisumu and Kakamega) were sampled for the study (Figure 3.1). The LLVB counties are located between latitudes 1.15^0N and 1.75^0S, and longitudes 33.95^0E and 35.05^0E [6]. The Basin covers an area of about 17,723km^2 [6] and [11]. The land covering this area slopes from an altitude of 1550m in Migori County down to 1100m at its lowest in Siaya County, and then rises again to 1535m in Kakamega and 1559m in Vihiga County [14] and [11].

The major health facilities are Migori, Homabay, Kisumu, Kakamega, Busia, Mbale, Bungoma and Siaya (Figure 1). An area of 3,549 km^2 is covered by L. Victoria. The inhabitants include Suba - Luos, Luos, Kurians, Nandis, Luhyas, Somalis, and small pockets of Indians, Arabs and Nubians [7]. The LLVB, Kenya was preferred for this study because from the literature review, the area was malaria endemic and despite malaria transmission reduction in most parts of Kenya, here (LLVB), the prevalence rate remained high. On the other hand, most of the studies carried out in this area hardly paid attention to the influence of the existing altitude variations on climate variability, vector distribution, and hence malaria transmission. It is from such reasons that this study sought to analyze malaria transmission variability and trends in different altitudes of lower Lake Victoria Basin, Kenya.

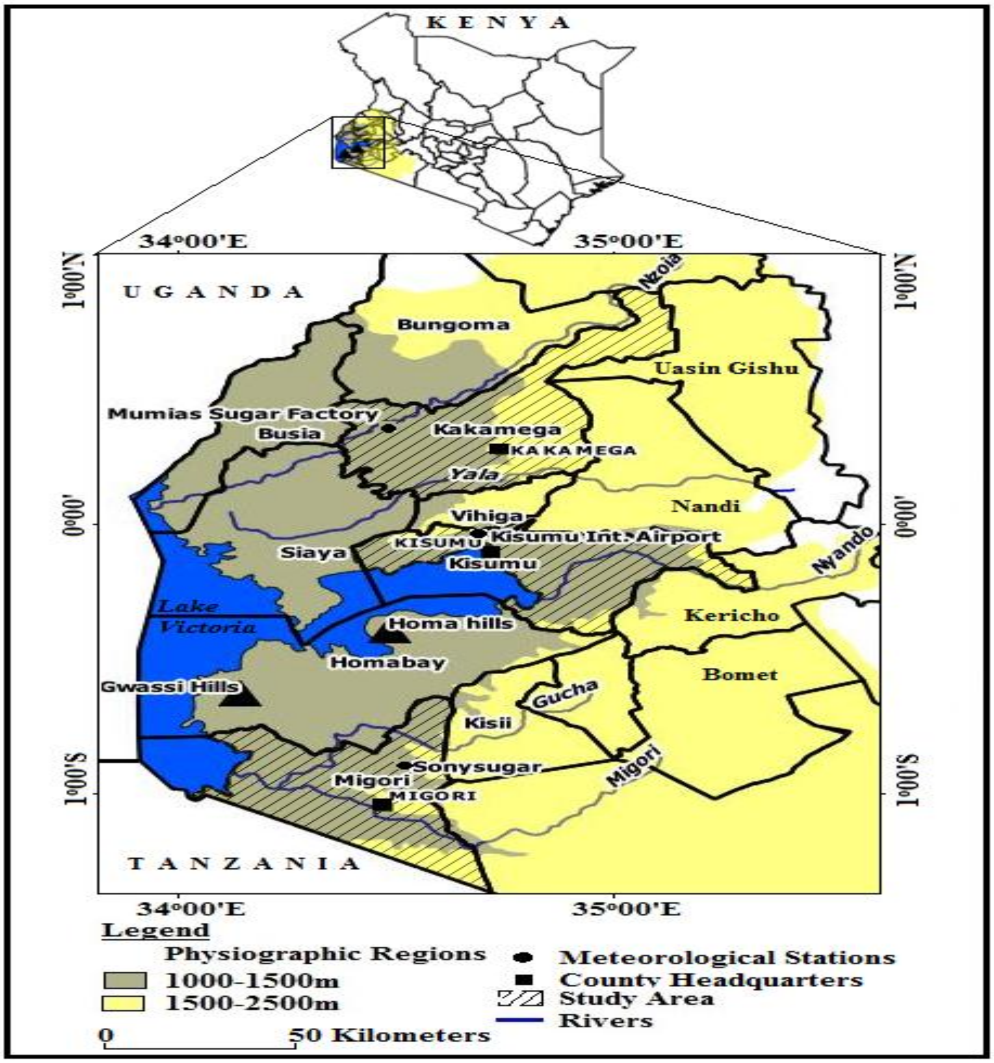

Figure 1: Map of the study area

Source: [10]

2.2 Data Collection and Data Characteristics

The study relied on secondary data from routine malaria case transmission records archived by the Kenya Health Information System (KHIS) through Sub-County Hospitals for ten years. The case transmission data for Kakamega County was obtained from Mumias West Sub-County, Kisumu County -Seme Sub-County and Migori County - Awendo Sub-County. Data included suspected (clinical) and confirmed (laboratory tested) cases for the < 5 years in age, the > 5 years in age, and malaria in pregnancy. The study focused on the < 5 and the > 5 suspected and confirmed cases separately. All data collected were harmonized before being used. The following tools were used: Mean Annual and Monthly Malaria Case Transmission Tables to show the totals and the means, Pearson's Correlation Coefficient was used to establish the relationship between the suspected and confirmed cases, Descriptive Time Series Analysis was used to show the trends, seasonal variations and monthly cyclic characteristics of the transmissions. ARIMA Time Series was used because of its Auto – Regressive (AR) component to account for the resultant patterns such as growth or decline. After correlating the suspected and the confirmed cases, the researcher concentrated on the total confirmed cases of malaria transmission to determine the spatiotemporal variability using ANOVA. The means were separated using Tukeys Honest Significance Difference.

After correlating the suspected and the confirmed cases, the researcher later concentrated on the total confirmed cases of malaria transmission to determine the variability.

3.0 RESULTS

3.1 Kakamega County (Mumias West Sub-County)

3.1.1 Relationship between Suspected and Confirmed Cases of Malaria Transmission

To determine the relationship between suspected and confirmed malaria cases in Kakamega County among the < 5 and the > 5 years, Pearson's moment correlation analysis was carried out at 95% confidence interval (CI). The finding showed that there was a negative relationship between the number suspected and the number confirmed among the < 5 and the > 5 populations (r = -0.043, P = 0. 907and r = -0.297, P = 0.405 respectively) (Tables 1and 2). It was observed that over the years, there were more suspected cases than confirmed. Some of the years registering the highest suspected cases happened to register the lowest confirmed cases.

Table 1: Correlations for Kakamega County (< 5 years), Mumias West Sub – County

		Suspected	Confirmed
Susp	Pearson Correlation	1	-.043
	Sig. (2-tailed)		.907
	N	10	10
Con	Pearson Correlation	-.043	1
	Sig. (2-tailed)	.907	
	N	10	10

Table 2: Correlations for Kakamega County (> 5 years), Mumias West Sub – County

		Suspected	Confirmed
Susp	Pearson Correlation	1	-.297
	Sig. (2-tailed)		.405
	N	10	10
Con	Pearson Correlation	-.297	1
	Sig. (2-tailed)	.405	
	N	10	10

3.1.2 Annual Trends of Malaria Cases in Kakamega County (Mumias West Sub-County)

Annual Confirmed cases among the > 5 year olds were highest in the year 2019 with a mean of 3904 ± 491 cases and lowest in the year 2012 with a mean of 873.8 ± 43.6. Among the < 5 year olds, transmissions were highest in the year 2015 at a mean of 1670 ± 188 and lowest in the year 2012 at a mean of 514.9 ± 46.6 Malaria among the pregnant women was highest in the year 2020 at a mean of 105.0 ± 28.9 and lowest in the year 2014 which had a mean of 34 ± 5.27. From the available records, malaria among the pregnant had only confirmed cases. These confirmed the aspect of temporal variation of malaria case transmission in the county as shown in figure 2.

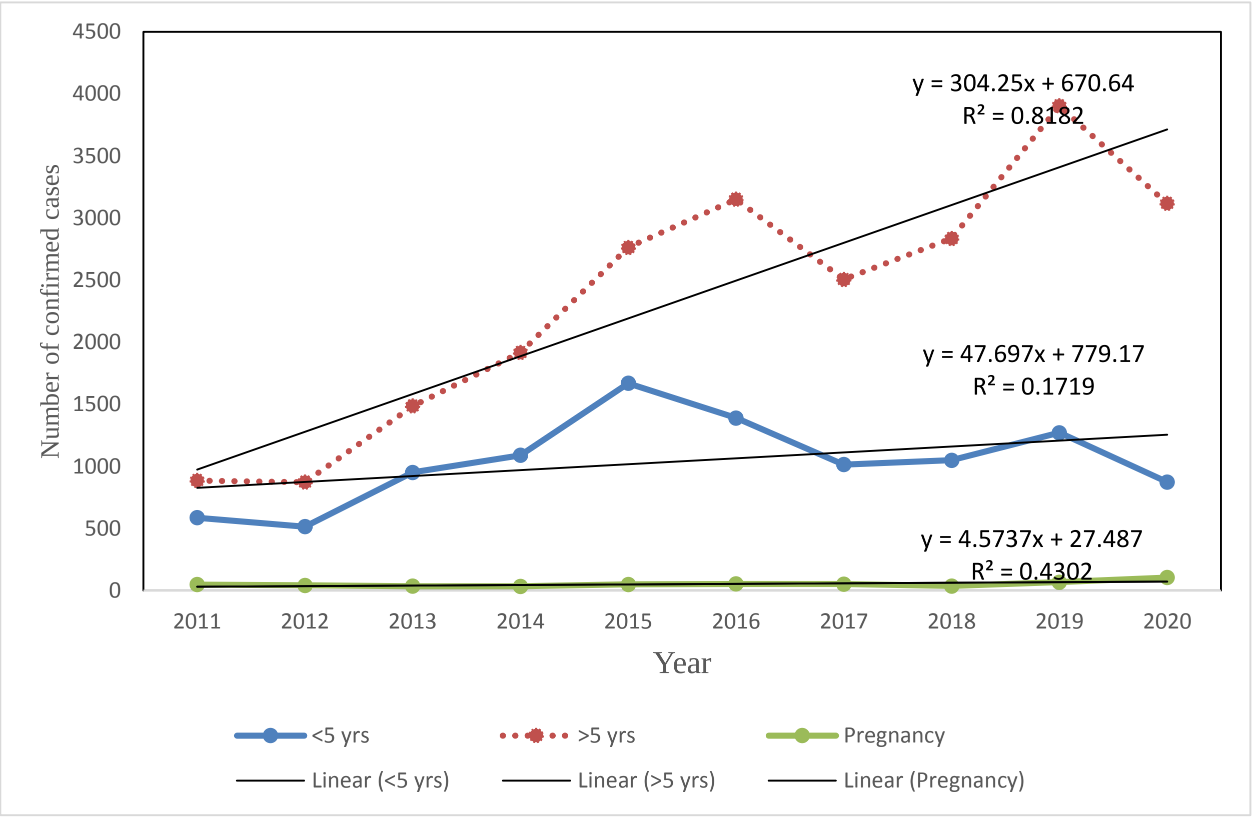

Figure 2: Mean malaria case transmission trends for the < 5, > 5 and the pregnant mothers in Kakamega County, Mumias West Sub – County

"ARIMA" Model Analysis of time series for confirmed cases of malaria in Kakamega County showed that there were significant positive changes in malaria case transmissions among the people who were > 5 years of age with a z value of 5.60 and a P value of 0.000**.**Pregnant mothers had positive changes which were not significant at z value of 0.39 and P of 0.694.On the other hand, transmission among the < 5 indicated negative changes that were not significant at a z value of -1.75 and p value of 0.081 (Table 3).

Table 3: ARIMA Regression for Kakamega County, Mumias West Sub-County

```
. arima Year Mumiasless Mumiasmore Mumiaspregn

(setting optimization to BHHH)
Iteration 0:   log likelihood = -11.820827
Iteration 1:   log likelihood = -11.820827

ARIMA regression

Sample:  1 - 10                                 Number of obs     =        10
                                                Wald chi2(3)      =    128.07
Log likelihood = -11.82083                      Prob > chi2       =    0.0000
```

Year	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
Year						
Mumiasless	-.0036795	.0021076	-1.75	0.081	-.0078102	.0004512
Mumiasmore	.0035024	.0006253	5.60	0.000	.0022768	.0047281
Mumiaspregn	.0075206	.019086	0.39	0.694	-.0298873	.0449285
_cons	.7264946	1.599001	0.45	0.650	-2.407491	3.86048
/sigma	.7891051	.4383031	1.80	0.072	-.0699532	1.648163

Considering the entire study period and working only with the mean total confirmed malaria transmission cases, a rising trend was established (Y = 351.9x + 1450, R^2 value= 68.3%). It showed that case transmissions were highest in the year 2019, mean5176±628 and lowest in the year 2012, mean 1388.75 (Figure 3).

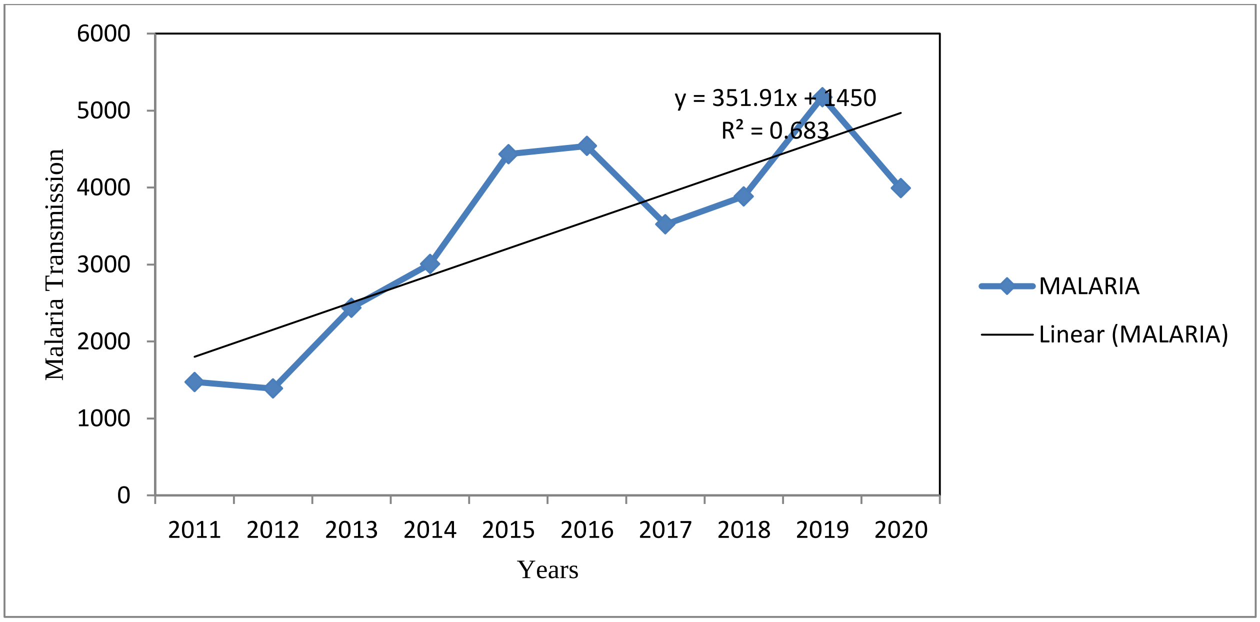

Figure 3: Annual total confirmed malaria transmission trends in Kakamega County, Mumias West Sub-County

3.1.3 Monthly Trends of Confirmed Mean Malaria case transmission in Kakamega County, Mumias West Sub -County

Monthly trends of confirmed cases of malaria transmission in Kakamega County, Mumias West Sub -County among those < 5 years and those > 5 years during the period (2011 – 2021) were highest in the month of May after which both declined towards September. From September, both cases slightly increased with the > 5 being highest in October and the < 5 in November. For the two populations, malaria was highest in May and lowest in December, otherwise both the < 5 and the > 5 indicated decreasing trends towards the end of the year (Y = -39.88x + 1296 and -82.05x + 2880 respectively)(Figure 4).

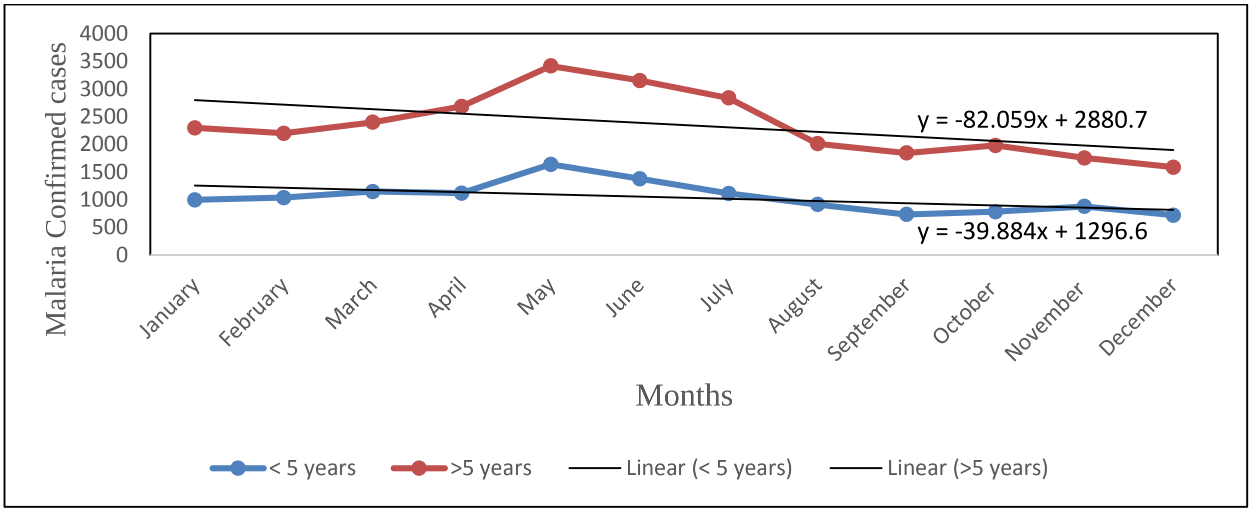

Figure 4: Confirmed mean malaria case transmission in Kakamega County, Mumias West Sub –County (2011 – 2021)

During the study period, total confirmed monthly mean malaria transmission in Kakamega County, Mumias West Sub -County indicated a decreasing trend towards the end of the year (Y = -123.0x + 4185). The highest case transmissions were observed in May (5053.3) while the lowest were in December (2305.4) (Figure 5).

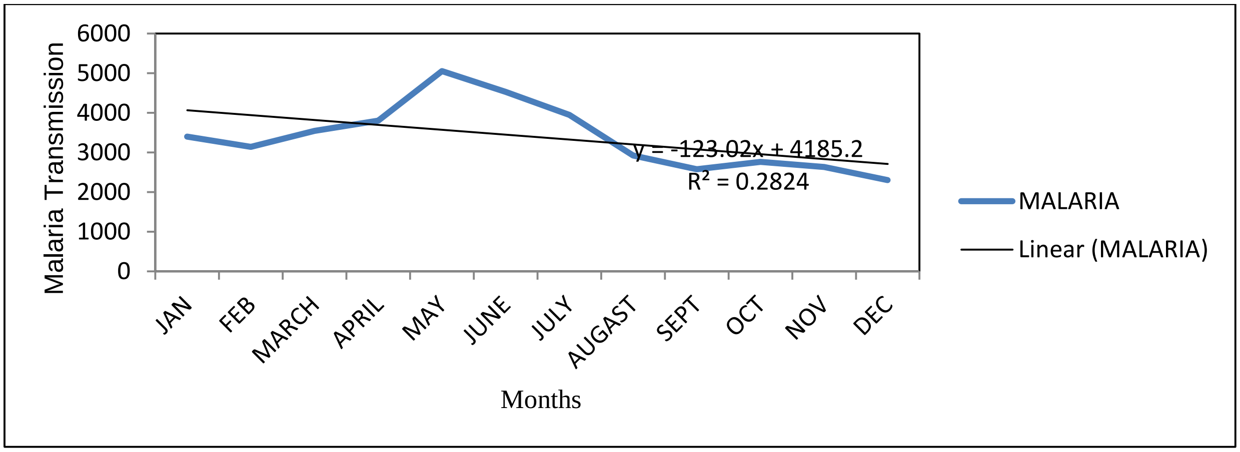

Figure 5: Total Mean Malaria Monthly transmission trends in Kakamega County, Mumias West Sub-County

3.2 Kisumu County, Seme Sub-County

3.2.1 Relationship between Suspected and Confirmed Cases of Malaria Transmission

The number of suspected and confirmed cases were both high in Kisumu County, Seme Sub-County, hence a positive correlation (r = 0.211, P = 0.559) among the < 5 years. Similarly, cases of suspected and confirmed malaria among those > 5 years of age were both high and again positively correlated (r = 0.370, P = 0.292) (Tables 4 and 5). This indicated that, the suspicion parameters used had substantial components for predicting malaria transmission.

Table 4: Correlations for Kisumu County (< 5 years), Seme Sub-County

		Suspected	Confirmed
Susp	Pearson Correlation	1	.211
	Sig. (2-tailed)		.559
	N	10	10
Con	Pearson Correlation	.211	1
	Sig. (2-tailed)	.559	
	N	10	10

Table 5: Correlations for Kisumu County (> years), Seme Sub-County

		Suspected	Confirmed
Susp	Pearson Correlation	1	.370
	Sig. (2-tailed)		.292
	N	10	10
Con	Pearson Correlation	.370	1
	Sig. (2-tailed)	.292	
	N	10	10

3.2.2 Annual Malaria Trends Kisumu County, Seme Sub-County

Using time series over the study period, confirmed malaria transmission cases among the < 5, > 5 and the pregnant mothers all indicated increasing trends (Y = 56.96x + 990.3 – R^2 Value = 17.2%,Y = 327.1x + 798.2 – R^2 Value = 68%, Y = 0.625x + 42.94 – R^2 value = 2.5% respectively). The lowest cases for all were observed in the years 2012; the highest were in 2019 for the > 5 and, 2014 for the< 5 and the pregnant mothers. All were increasing (Figure 6).

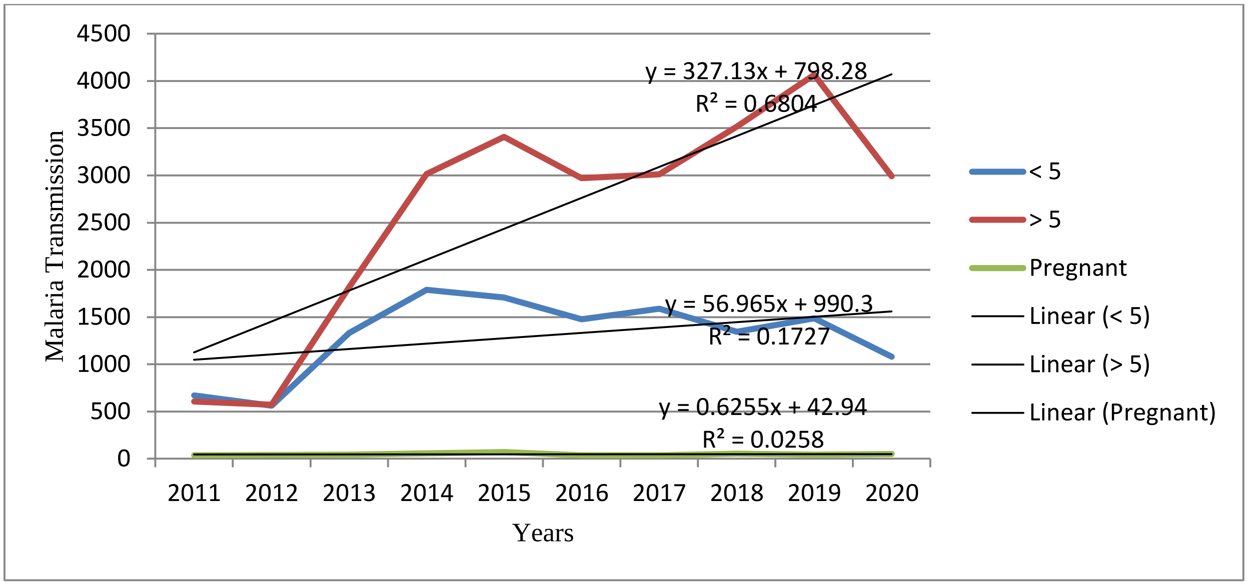

Figure 6: Mean malaria case transmission trends for the < 5, > 5 and the pregnant mothers inSeme Sub-County

In Kisumu County, Seme Sub-County, malaria case transmission had negative significant changes over the years among the < 5 year olds with a z value of -5.15 and a P Value of 0.000. However, there were significant positive changes in the cases among those > years with a z value of 2.61 and a P Value of 0.009 (Table 6).

Table 6: ARIMA Regression for Kisumu County, Seme Sub-County

```
. arima Year kombless kombmore kombpregnancy

(setting optimization to BHHH)
Iteration 0:   log likelihood =  -13.35297
Iteration 1:   log likelihood =  -13.35297

ARIMA regression

Sample:  1 - 10                                 Number of obs     =        10
                                                Wald chi2(3)      =     36.07
Log likelihood = -13.35297                      Prob > chi2       =    0.0000
```

Year	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
Year						
kombless	-.0360646	.0070063	-5.15	0.000	-.0497966	-.0223325
kombmore	.0301954	.0115534	2.61	0.009	.007551	.0528397
kombpregna~y	-.0152506	.2754825	-0.06	0.956	-.5551864	.5246851
_cons	7.132843	3.01057	2.37	0.018	1.232234	13.03345
/sigma	.9197609	.3511897	2.62	0.009	.2314416	1.60808

Considering the entire study period and working only with the total confirmed malaria transmission cases, an increasing trend was established (Y = 384.41x + 1788, R^2 value = 55.6%). It showed that case transmissions were highest in the year 2019 (5553±1156) and lowest in the year 2012 (1135.7±99.1) (Figure 6 and Table 5).

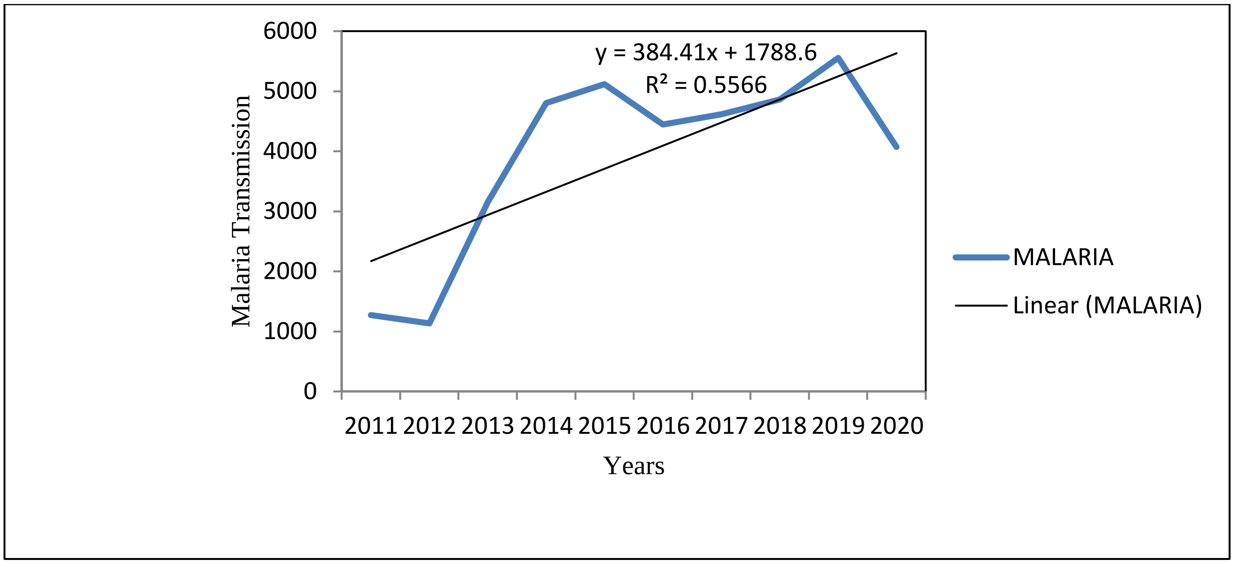

Figure 6: Total confirmed annual malaria transmission trends in Kisumu County, Seme Sub-County

3.2.3 Monthly Trends of Confirmed Cases of Malaria in Kisumu County, Seme Sub-County

Monthly trends of mean total malaria cases for the < 5 and the 5 > in Kisumu County, Seme Sub-County during the period 2011 – 2021 showed general decline from the month of July to December. High numbers of malaria case transmissions were observed in the month of July and the lowest in December. From July, there other declines were observed towards December (Figure 7).

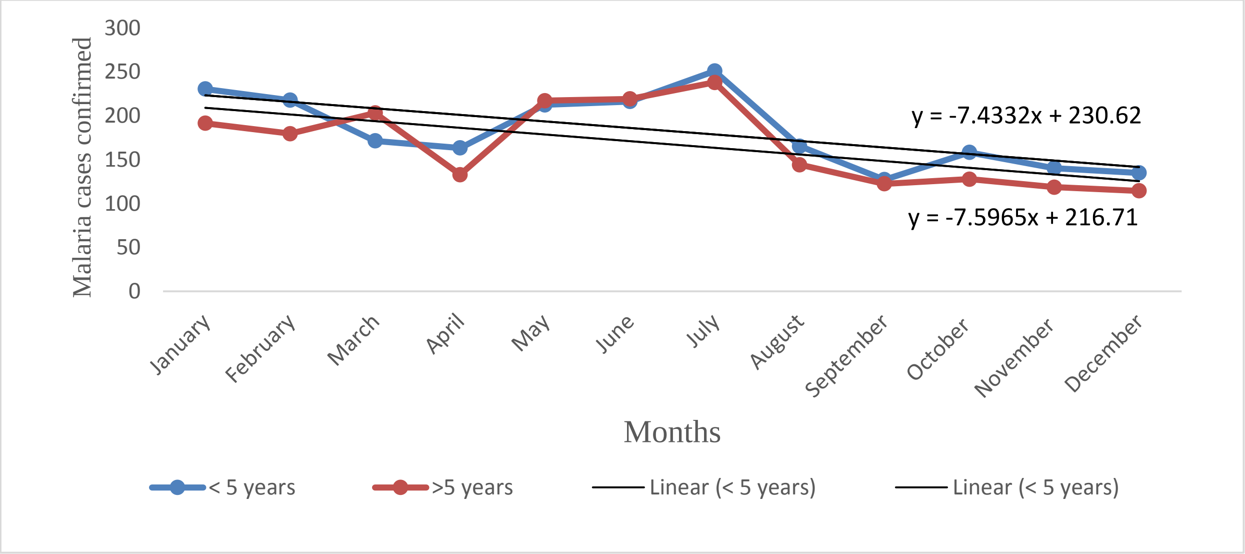

Figure 7: Monthly mean confirmed malaria case transmission for the < 5 and the > 5 in Kisumu, Seme Sub-County (2011 – 2021)

Mean total confirmed malaria case transmissions in Kisumu County, Seme Sub-County fell from January (5107.8) to April (3430.8) then rose again from April to July (5936.4). From July, the trend drastically fell to October (2473.9) from which it then stabilized towards December. Mean total case transmission was highest in the month of July (5936.4) and lowest in the month of October (2473.5) (Table 7 and Figure 8).

Table 7: Monthly total confirmed malaria transmission 2011-2020 for Kisumu, Kakamega and Migori Counties

	Kakamega	Kisumu	Migori
January	3399.1	5107.8	2624.6
February	3140.5	3941.3	2916.4
March	3545.6	3833.3	2913.6
April	3803	3430.8	2097
May	5053.3	5702.9	2536
June	4532.6	4993.4	2437.9
July	3950.1	5936.4	2522.5
August	2924	3283.3	1676.9
September	2578.7	2518.9	1387.6
October	2762.5	2473.5	1619
November	2631.6	2801	1422.4
December	2305.4	2811.8	1410.8

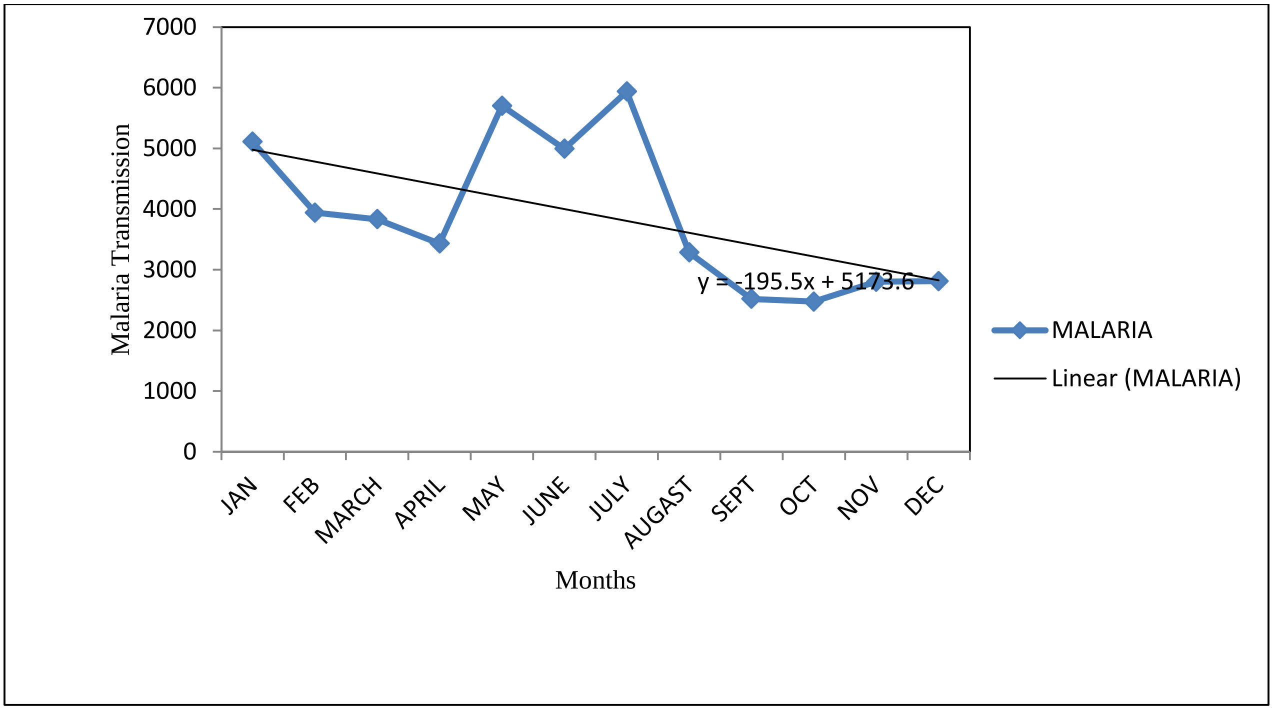

Figure 8: Total Confirmed Monthly Malaria transmission trends in Kisumu County, Seme Sub-County.

3.3 Migori County, Awendo Sub-County

3.3.1 Relationship between Suspected and Confirmed Cases of Malaria Transmission

A comparison of suspected malaria cases with the confirmed cases among the < 5 in Migori County, Awendo Sub-County was done and the results showed that more cases of malaria were suspected than confirmed, hence a negative correlation (r = -0.239, P = 0.506). The negative relationship was also found between the suspected and confirmed malaria cases in those > 5 years (r = -0.070, P = 0.847) (Table 8 and 9). As was the case in Kakamega County, the suspected cases in Migori County, Awendo Sub-County, were overstated.

Table 8: Correlations for Migori County (< 5 years), Awendo Sub-County

		Suspected	Confirmed
Susp	Pearson Correlation	1	.239
	Sig. (2-tailed)		.506
	N	10	10
Con	Pearson Correlation	-.239	1
	Sig. (2-tailed)	.506	
	N	10	10

Table 9: Correlations for Migori County (> 5 years), Awendo Sub-County

		Suspected	Confirmed
Susp	Pearson Correlation	1	-.070
	Sig. (2-tailed)		.847
	N	10	10
Confirm	Pearson Correlation	-.070	1
	Sig. (2-tailed)	.847	
	N	10	10

3.3.2 Annual Malaria Trends in Migori County, Awendo Sub-County

During the study period, the highest confirmed case transmission was observed in the year 2014 (1660 ± 138) for both the < 5 (1660 ± 138) and the > 5(2736 ± 259) followed by the year 2016 (2675 ±414) for the > 5 only. The lowest was in the year 2020 for the <5 (243.3 ± 29.3), for the >5, 2012 (453 ± 26.2) and for the pregnant 2018 (23.5 ± 4.23). A very sharp rise was observed between the year 2012 and the year 2014 followed by diminishing trends from the year 2014 to the year 2020. All the cases indicated general diminishing trends towards the end of the study period (Y = -44.24x + 962, Y = -24.22x + 1536 and Y = - 4.625x + 82.98) (Figure 9).

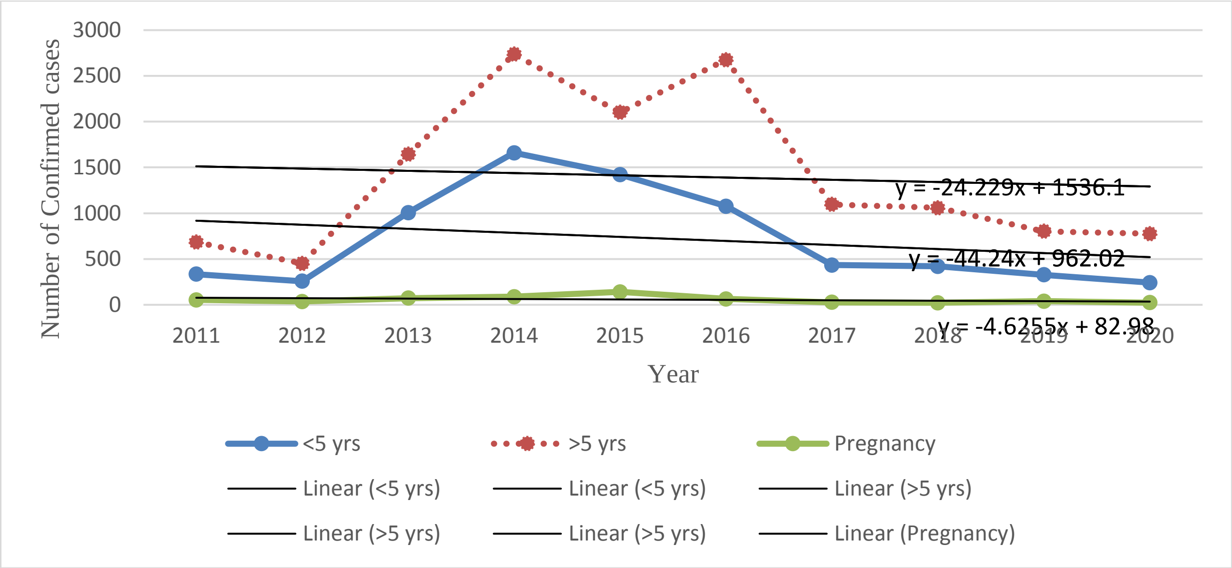

Figure 9: Malaria trend in Migori County, Awendo Sub-County

Among the persons < 5 years, >5 years and the pregnant women, in Migori County, Awendo Sub-County, there were no significant variations in malaria trends over the study period. This was confirmed by the ARIMA (Table 10).

Table 10: ARIMA Regression for Migori County, Awendo Sub-County

```
. arima Year Awendoless Awendomore Awendopregn

(setting optimization to BHHH)
Iteration 0:   log likelihood = -23.360072
Iteration 1:   log likelihood = -23.360072

ARIMA regression

Sample:  1 - 10                                 Number of obs     =        10
                                                Wald chi2(3)      =      2.11
Log likelihood = -23.36007                      Prob > chi2       =    0.5493
```

Year	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
Year						
Awendoless	-.0056879	.0152058	-0.37	0.708	-.0354906	.0241149
Awendomore	.003488	.0054465	0.64	0.522	-.0071869	.0141628
Awendopregn	-.0160254	.1034095	-0.15	0.877	-.2187043	.1866534
_cons	5.616726	3.077053	1.83	0.068	-.4141877	11.64764
/sigma	2.501946	1.15535	2.17	0.030	.2375016	4.766389

Total Annual Confirmed malaria transmissions during the study period (2011-2020) were observed to be generally decreasing in Migori County – Awendo Sub County given the trend equation (Y = -73.3x + 2533). Transmission was lowest in the year 2012 at a mean of 712.1±28.6 and highest in the year 2014 at a mean of 4397±329 (Figure 10 and Table 7).

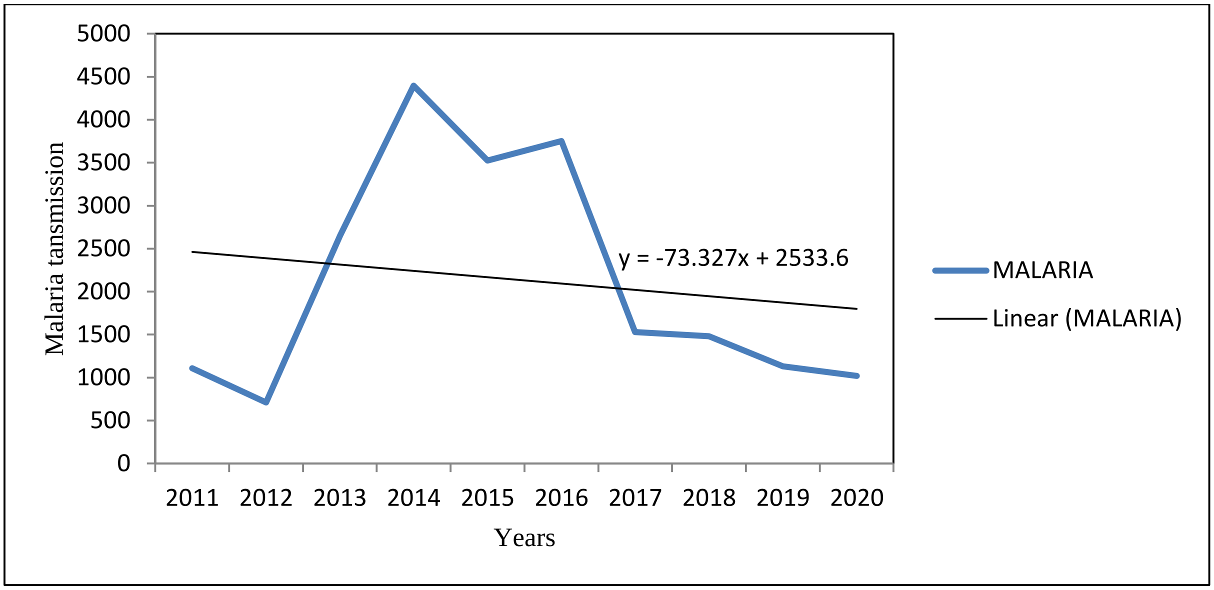

Figure 10: Total annual malaria transmission trends in Migori County, Awendo Sub-County

3.3.3 Monthly Trends of Confirmed Cases of Malaria in Migori County, Awendo Sub-County

Monthly trends of confirmed cases of malaria in Migori County, Awendo - Sub -County among those < 5 years, > 5 years and the pregnant during the period (2011 – 2021) showed general decrease (Y = - 44.94x + 1010, Y = - 100.6x + 2061 and Y = - 2.487x + 74.07 respectively) with a lot of fluctuations from the beginning of the year towards the end. Peak periods occurred in the months of February and March after which both declined towards December. The< 5, the > 5 and the pregnant all indicated negatively (Figure 10), an indication that malaria is higher early in the year and cyclically reduces towards the end of the year.

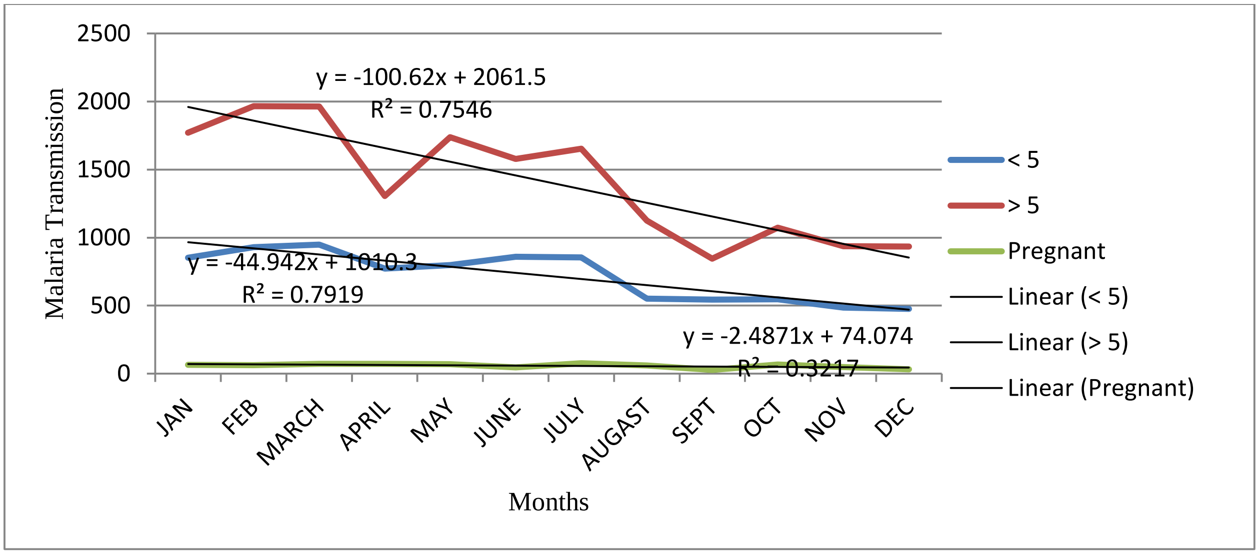

Figure 10: Total monthly malaria transmission trends in Migori County, Awendo Sub-County

European Journal of Health Sciences
ISSN 2520-4645 (online)
Vol.7, Issue 6, pp 1 - 24, 2022
www.ajpojournals.org

Total monthly Confirmed malaria cases in Migori County, Awendo Sub-County during the period (2011 – 2021) showed a decline in the months of September and December. The highest mean of total malaria case transmission was realized in the month of February (2916.6) and lowest in September (1387.6). Case transmission generally indicated a diminishing trend being very high at the beginning of the year and very low at the end of the year (Figure 11).

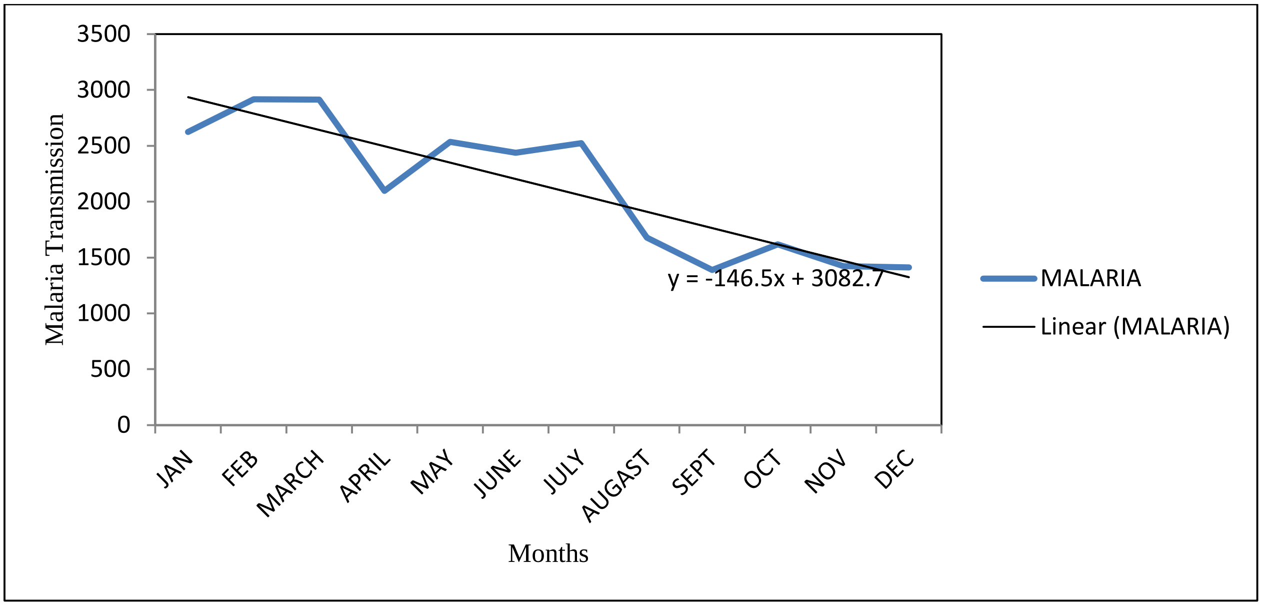

Figure 11: Total monthly Malaria transmission trends in Migori County, Awendo Sub-County

3.4 Total Confirmed Malaria Transmission in Kakamega, Kisumu and Migori

3.4.1 Analysis of Variance (ANOVA)

Spatiotemporal variability of total malaria transmission over the period, 2011 – 2020 in Kisumu, Migori and Kakamega Counties were compared using Analysis of Variance (ANOVA) at 95% confidence interval (CI) and the means were separated using Tukey's range test at $P \leq 0.05$. The findings showed there was a significantly higher malaria transmission in Kisumu County (3902.87 ±493.3) followed by Kakamega County (3385.53 ± 407.7) then Migori County (2130.330 ± 422.3) (F =4.240, P = 0.025), (Tables 11 and 12).

Table 11: ANOVA table for malaria in Kisumu, Kakamega and Migori Counties

Malaria cases Total confirmed	Mean SE	Minimum	Maximum
Kisumu County	3902.87 ±493.3	1135.67	5552.75
Kakamega County	3385.53 ± 407.7	1388.75	5175.50
Migori County	2130.330 ± 422.3	712.08	4397.08
F value	4.240		
P Value	0.025		

Mean separated using Tukeys Honest Significance Difference (HSD) at $P \leq 0.05$.

Table 12: Mean monthly total malaria confirmed cases (2011 -2020)

Year	Kisumu County	Kakamega County	Migori County
2011	1274.2 ± 92.1	1473 ± 103	1108 ± 123
2012	1135.7±99.1	1388.8±82.4	712.1±28.6
2013	3148±330	2438± 233	2651±204
2014	4805±611	3007 ±180	4397±329
2015	5116±541	4434±478	3523±481
2016	4447±671	4541±362	3752±574
2017	4618±783	3521±434	1530±340
2018	4863±540	3885±327	1480±104
2019	5553±1156	5176±628	1132±108
2020	4070±516	3992±222	1019±132
Mean	**3902.87 ±493.3**	**3385.53 ± 407.7**	**2130.330 ± 422.3**
F-Value	4.240		
P-Value	0.025		

Malaria total confirmed cases in Kisumu, Kakamega and Migori Counties.

3.4.2 Total Annual Malaria Transmission Trend Analysis (Kisumu, Kakamega Migori)

Total malaria transmission trends during the study period revealed that mean annual malaria transmission was highest in Kakamega County (5176±628) in the year 2019 and lowest in the year 2012 (1388.8±82.4). It was highest in Migori County in the year 2014 (4397±329) and lowest in 2012 (712.1±28.6). In Kisumu County, mean annual malaria transmission was highest in the year 2019 at a mean of 5553±1156 and lowest in 2012 (1135.7±99.1) Table 422.

The trend during the study period further revealed that transmission increased in Kakamega and Kisumu Counties while it decreased in Migori County. In Kakamega County, the increase was $Y = 351.9x + 1450$, R^2 value = 68.3% (Where Y = malaria transmission and x = years). In Kisumu County, the increase was $Y = 384.4x + 1788$, R^2 value = 55.6% while in Migori County the decrease was $Y = -73.32x + 2533$, R^2 value = 2.7. Interestingly the lowest events occurred in the same year (2012). It should also be observed that the highest events for Kakamega and Kisumu Counties occurred in 2019 while Migori County's highest was in 2014 after which transmission took a decreasing trend to the year 2020 (Figure 12).

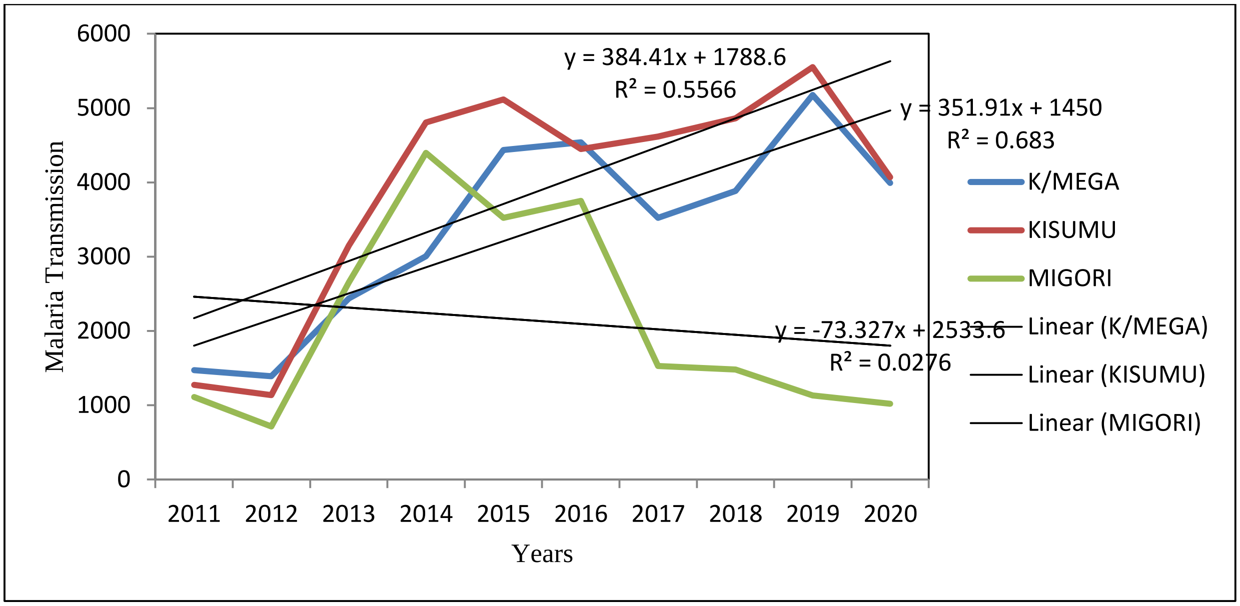

Figure 12: Total Annual Malaria transmission Trends in the Study Areas

During the study period (2011 – 2020) the mean monthly malaria transmission revealed decreasing trends in all the Counties. Migori County decreased at $Y = -146.5x + 3082$, Kisumu County, $Y = -123.0x + 4185$ and Kakamega County, $Y = -195.5x + 5173$. Elevated and suppressed transmissions varied from one place to another. In all the counties, malaria transmission peaks between May and July. It is then low between September and December (Figure 13).

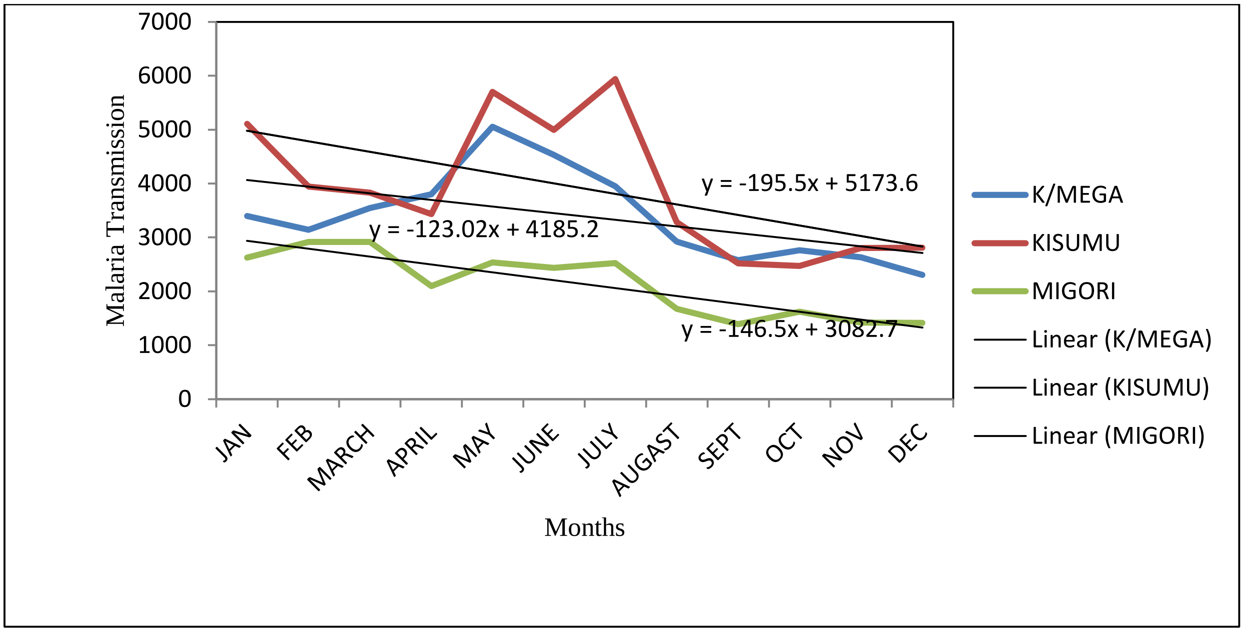

Figure 13: Total monthly Malaria transmission Trends in the Study Areas ARIMA model for malaria cases in Kakamega, Kisumu and Migori Counties

This model (ARIMA) established significant variations in total confirmed malaria cases in Migori County ($P = 0.014$) over the study period (2011 – 2020). The model was; $Y = 0.1930 + 0.0011X_1$

$+0.0011X_2 - 0.0012X_3$. Where Y =Year, X_1 = Malaria cases in Kakamega, X_2= Malaria cases in Kisumu, X_3 = Malaria cases in Migori. In Kakamega and Kisumu, malaria cases were not significantly changing as the year progressed towards the end. This further confirmed the spatiotemporal nature of malaria transmission variability (Table 13).

Table 13: ARIMA table showing change in malaria cases in Kakamega, Kisumu and Migori Counties over the 10 year period (2011 – 2020)

ARIMA regression

Sample: 1 - 10 | Number of obs = 10
Wald chi2(3) = 41.73
Log likelihood = -14.45572 | Prob > chi2 = 0.0000

Year	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
Year						
MalKakamega	.0010756	.0014455	0.74	0.457	-.0017574	.0039087
MalKisumu	.0010621	.0013026	0.82	0.415	-.0014909	.0036151
MalMigori	-.001164	.0004745	-2.45	0.014	-.0020941	-.000234
_cons	.1930146	1.987756	0.10	0.923	-3.702916	4.088945
/sigma	1.026992	.3172334	3.24	0.001	.4052257	1.648758

Considering confirmed malaria cases in a year (monthly), the model similarly showed significant variations in confirmed malaria cases in Migori County (P = 0.001) during the period (2011 – 2020). The model was; $Y = 17.7715 - 0.00023X_1 + 0.00069X_2 - 0.00617X_3$. Where Y = Year, X_1 = Malaria cases in Kakamega, X_2= Malaria cases in Kisumu, X_3 = Malaria cases in Migori (Table 14). The changes were significant in Migori County while in Kakamega and Kisumu Counties, the numbers of malaria cases were not significantly changing in a year during this study period.

Table 14: ARIMA table showing change in malaria cases in Kakamega, Kisumu and Migori Counties in a year over the period (2011 – 2020)

ARIMA regression

Sample: 1 - 12 | Number of obs = 12
Wald chi2(3) = 24.53
Log likelihood = -22.25052 | Prob > chi2 = 0.0000

Month	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
Month						
KakamegaMal	-.0002331	.0011663	-0.20	0.842	-.0025189	.0020528
Kisumumal	.0006867	.0006957	0.99	0.324	-.0006768	.0020503
migorimal	-.0061785	.0018289	-3.38	0.001	-.0097631	-.002594
_cons	17.77159	2.923951	6.08	0.000	12.04075	23.50243
/sigma	1.545383	.6020771	2.57	0.010	.3653332	2.725432

4.0 DISCUSSION

As was observed by [17], malaria is a common issue in many parts of the world including LLVB, Kenya. This study sought to determine spatiotemporal variation of malaria transmission in different altitudes of the LLVB, Kenya. Suspected and confirmed transmission cases were correlated and disproportionate relationships established in Kakamega and Migori Counties of the study area. The suspected were found to have been significantly higher than the confirmed cases hence overstated. This was not the case in Kisumu County where the relationship was positive (confirmed and suspected cases were proportionately high) implying that the suspicion parameters used had substantive components. Because of the overstated observations, the study opted to rely more on the total confirmed transmission cases for those < 5 and > 5 year olds. The pregnant cases were covered under the confirmed cases to give the total for malaria transmission from the sampled areas.

In Kakamega County, Descriptive Time Series established that transmission among the < 5 was highest in 2015 and lowest in the year 2012. The pregnant cases were highest in 2020 and lowest in 2014. All had increasing trends. ARIMA revealed significant positive changes in malaria transmission among the > 5 year olds. The < 5 year olds had negative changes which were not significant. The pregnant mothers also had positive changes that were not significant. Using descriptive time series, all cases in Kisumu were increasing with the lowest cases being observed in 2012 and the highest in 2019. ARIMA revealed that the < 5 had significantly negative changes while the > 5 had significantly positive changes. The pregnant had positive changes but were not significant. Using descriptive time series in Migori, all the cases were decreasing. By ARIMA, Migori County had no significant variations.

Total malaria transmission data was analyzed using one way ANOVA. The findings revealed significantly high mean malaria transmissions in Kisumu County (3902.87±493.3) followed by Kakamega County (3385.53±407.7) then Migori County (2130.33±422.3) (F = 4.240, P = 0.025). In Kakamega County, descriptive time series analysis revealed that annual total confirmed malaria transmission was highest in the year 2019 (5176 ± 628) and lowest in the year 2012 (1388.8 ± 82.4); monthly transmissions on the other hand cyclically peaked in May (5053.3) but were lowest in December (2305.4). The annual total confirmed transmissions were observed to be rising while monthly trends declined towards December. The trend was almost the same in Kisumu County where annual total confirmed transmission was highest in the year 2019 (5553 ± 1156) and lowest in 2012 (1135.7 ± 99.1). Monthly total confirmed transmissions were cyclically lowest in October (2473.5) and highest in July (5936.4). Again the annual total confirmed transmissions were observed to be rising while monthly trends declined towards December. The scenario in Migori County was rather different. While the lowest annual case transmission was observed in the year 2012 (712.1 ± 28.6), the highest was in 2014 (4397 ± 326). Monthly case transmissions were cyclically highest in February (2916.6) and lowest in September (1387.6). Annual total confirmed transmissions in Migori County were observed to be decreasing. Similarly monthly trends also cyclically decreased towards December. The monthly decline observed in all the sampled counties is an indication that transmissions are cyclically higher early in the year and decline toward the end of the year. The above observations confirm, "The wide variability, seasonality and cyclical patterns at different sites" as was predicted by [13].

European Journal of Health Sciences
ISSN 2520-4645 (online)
Vol.7, Issue 6, pp 1 - 24, 2022
www.ajpojournals.org

All low total annual case transmissions occurred in the same year (2012), while all the high case transmissions were in 2019 except for Migori County which was high in 2014. However none of the cyclic monthly highs and lows was observed to occur at the same place in the same month. From the ANOVA results, malaria transmission significantly declined with increase in altitude implying that altitude is a very important factor in determining malaria transmission in the study area. Were it not for the significant altitudinal differences and the varying monthly highs and lows, the similarities in the high and low annual transmissions might have undermined the spatiotemporal malaria transmission variation phenomenon.

[3] Determined malaria transmission hot spots in India based on altitude and temperature thresholds. In the LLVB case, the study determined them based on transmission ranking, altitude, temperature threshold, and proximity to the lake. Transmission ranking can be very important for determining necessary interventions in situations where variables other than climatic might have interfered with the natural transmission patterns. Kisumu County and areas with similar characteristics were therefore considered hot spots in the LLVB, Kenya "to be targeted for serious intervention" as [17], put it. This is based on the fact that Kisumu was the highest ranking in malaria transmission as has been established by this study. Kisumu was followed by Kakamega and Migori Counties in that order. From this finding, the study assumed that temperature, being a factor of altitude, and proximity to large masses of water have significant roles in determining variability of malaria transmission in the LLVB, Kenya. Where there are no large water bodies as were observed by [12], rainfall becomes responsible by being the main source of water hence the cyclic seasonality of transmission in an area.

Despite the altitudinal variations, all the sampled study sites indicated endemic and epidictic characteristics with malaria transmission being experienced throughout the year with no real free month while Transmission cyclically peaked in the months of May to July for Kakamega and Kisumu Counties and in the months of February to March for Migori County. [12] Established differing peaks for differing sites in a year defined by rainfall, temperature and altitude. Similar to the current study, they identified two insignificant malaria peak seasons in the lowland and riverine zones. Unlike in the current study, they established three significant peak seasons in the highland zones. According to them, all these cases were defined by rainfall, temperature and altitudinal variations. All these observations confirm the varying nature of malaria transmission in relation to altitude and climate elements.

[9] Confirmed that transmission varied from site to site with different sites responding to similar interventions differently such that while some areas were witnessing reduction, others did not. This could explain the increasing trends in Kisumu and Kakamega Counties against the decreasing trend in Migori County during the study period. This kind of observation was also made by [12] but in a different way. From their findings, malaria cases increased in the highland and mid altitude zones instead of the lowlands. This is a contradiction of what was observed by this study where increases were observed in the lowlands.

5.0 CONCLUSION

Suspected malaria cases were much higher than the confirmed malaria transmission cases in Kakamega and Migori Counties. The suspected cases must have been overstated. In Kisumu where the correlations were proportionately positive, the parameters used to determine the suspicions must have been substantive. Malaria transmission had annually increasing trends in the three counties except in Migori County where the trend was decreasing. Monthly Transmission trends were however found to be decreasing in all the sampled counties. This was an indication that transmissions are cyclically higher early in the year and decline as the year progresses. Monthly high and low transmission periods were found to differ. ANOVA results likewise revealed significantly different transmission means from the sampled study sites. Kisumu County at the lowest altitude had the highest mean followed by Kakamega and lastly Migori County at the highest altitude. There was enough evidence of significant variation in space and time during the study period and for that reason, it was summarily concluded that malaria transmission varied in space and time. Given that altitude defines temperature in many instances, this study blamed transmission variations in the LLVB – Kenya on altitude, temperature and proximity to the lake. This was a clear indication that malaria transmission is varied in all parts of the study area. The annual decreasing trend observed in Migori County was a clear indication that with concerted effort, malaria transmission can be eradicated in the LLVB, Kenya.

6.0 RECOMMENDATIONS

Since all the observations confirmed the varying nature of malaria transmission in relation to altitude, the aspect of blanket assumption concerning malaria transmission in the LLVB, Kenya should be stopped. LLVB, Kenya should be zoned by altitudes for effective mitigation and eradication strategies. The annual decreasing trend observed in Migori County should be investigated and the findings employed to help in reduction of transmissions elsewhere. Close attention to transmission reduction should focus on the early months of the year. This kind of study should be conducted to cover all the sites at different altitudes and at different proximities to the lake in the LLVB, Kenya. This will help reduce errors that may arise from blanket assumptions while increasing certainties in the eradication efforts. Emphasis of intervention should always strategize with the idea of altitude and proximity to the lake in mind.

7.0 ACKNOWLEDGEMENT

This study was conducted as a doctoral study program by the first author through the department of geography under the school of Humanities and Social Sciences, Kenyatta University, Kenya. Appreciations to the supervisors: Professor G. L Makokha and Doctor Kennedy Obiero. It was self - funded by the first author. Appreciations also go to the Kenya Health Information System through the sampled Sub – County Health Facilities in the study areas – Awendo, Mumias West and Seme (Kombewa).

REFERENCE

[1] Alonso, P., & Noor, A. M. (2017). The global fight against malaria is at crossroads. *The Lancet*, *390*(10112), 2532-2534.

[2] Bashir, I. M., Nyakoe, N., & van der Sande, M. (2019). Targeting remaining pockets of malaria transmission in Kenya to hasten progress towards national elimination goals: an assessment of prevalence and risk factors in children from the Lake endemic region. *Malaria Journal*, *18*(1), 1-10.

[3] Bhattacharya, S., Sharma, C., Dhiman, R. C., &Mitra, A. P. (2006). Climate change and malaria in India. *Current science*, *90*(3), 369-375.

[4] Davies, P., Tanner, M., Jemari, B., & Henderson-Howat, S. (2020). Cast the net wide: Assessing the root causes of malaria transmission through the knowledge, attitude and practice of treated inpatients in rural western Uganda. *Access Microbiology*, *2*(2), 150.

[5] De Alban, J., Connette, G., Oswald, P., & Webb, E. (2018). Combined Landsat and L-band SAR data improves land cover classification and change detection in dynamic tropical landscapes. *Remote Sensing*, *10*(2), 306.

[6] Emrouznejad, A., & Yang, G. L. (2018). A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016. *Socio-Economic Planning Sciences*, *61*, 4-8.

[7] Hamel, M. J., Adazu, K., Obor, D., Sewe, M., Vulule, J., Williamson, J. M., ...&Laserson, K. F. (2011). A reversal in reductions of child mortality in western Kenya, 2003–2009.*The American journal of tropical medicine and hygiene*, *85*(4), 597-605.

[8] Hemingway, J., Ranson, H., Magill, A., Kolaczinski, J., Fornadel, C., Gimnig, J., ...& Pickett, J. (2018). Averting a malaria disaster: will insecticide resistance derail malaria control?.*The Lancet*, *387*(10029), 1785-1788.

[9]Kapesa, A., Kweka, E. J., Zhou, G., Atieli, H. E., Kamugisha, E., Mazigo, H. D., ... & Yan, G. (2018). Utility of passive malaria surveillance in hospitals as a surrogate to community infection transmission dynamics in western Kenya.*Archives of Public Health*, *76*(1), 39.

[10] Kenya Government. (1970). National Atlas of Kenya.

[11] Kerandi, N. M., Laux, P., Arnault, J., &Kunstmann, H. (2017). Performance of the WRF model to simulate the seasonal and interannual variability of hydrometeorological variables in East Africa: a case study for the Tana River basin in Kenya. *Theoretical and Applied Climatology*, *130*(1-2), 401-418.

[12] Kipruto, E. K., Ochieng, A. O., Anyona, D. N., Mbalanya, M., Mutua, E. N., Onguru, D., ...&Estambale, B. B. (2017). Effect of climatic variability on malaria trends in Baringo County, Kenya.*Malaria journal*, *16*(1), 220.

[13] Lake Victoria Basin Commission (LVBC). (2018–2023). Climate Change Adaptation Strategy and Action Plan.

[14] Mwagiru, W. (1986). Planning for settlement in rural regions: the case of spontaneous settlements in Kenya,'.*Spontaneous Settlement Formation in Rural Regions, Volume TWo: Case Sntdies*, 3-12.

[15] Okuneye, K., Abdelrazec, A., &Gumel, A. B. (2018). Mathematical analysis of a weather-driven model for the population ecology of mosquitoes. *Mathematical Biosciences & Engineering*, *15*(1), 57-93.

[16] Oxborough, R. M. (2016). Trends in US President's Malaria Initiative-funded indoor residual spray coverage and insecticide choice in sub-Saharan Africa (2008–2015): urgent need for affordable, long-lasting insecticides. *Malaria journal*, *15*(1), 146.

[17] Roser, M., Ritchie, H., &Dadonaite, B. (2020). Child & Infant Mortality. *Our World in Data*.

[18] Ryan, S. J., Lippi, C. A., &Zermoglio, F. (2020). Shifting transmission risk for malaria in Africa with climate change: A framework for planning and intervention. *Malaria Journal*, *19*, 1-14.

[19] Teboh-Ewungkem, M. I., &Ngwa, G. A. (2020). COVID-19 in malaria-endemic regions: potential consequences for malaria intervention coverage, morbidity, and mortality. *The Lancet Infectious Diseases*.

[20] U.S. President's Malaria Initiative Kenya Malaria Operational Plan FY 2022. Retrieved from www.pmi.go

[21] World Health Organization. (2017). *Design of epidemiological trials for vector control products: report of a WHO expert advisory group, Château de Penthes, Geneva, 24-25 April 2017* (No. WHO/HTM/NTD/VEM/2017.04). World Health Organization.

[22] World Health Organization. (2021). WHO malaria policy advisory group (MPAG) meeting: meeting report, April 2021.