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CLIMATE CHANGE AND THE INCREASE IN INCIDENCE OF MALARIA CASES IN THE DVOKOLWAKO AREA OF SWAZILAND FROM 1990-2004

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ABSTRACT

The study examines the factors that account for the increase in malaria cases in Dvokolwako area (Swaziland), which in the past was generally malaria free. The two main aspects examined in the study area are climate change patterns and sugar cane cultivation under irrigation. Climatic data of the area was obtained from the Mbabane National Meteorological Service, whilst retrospective inpatient malaria data was obtained from Dvokolwako and Mliba clinics. Data on sugar cane growing was collected from the farmers through face-to-face questionnaire interviews. A field observation guide was used to collect information on the status of the sugar cane fields. The results clearly show that average temperatures have increased during the past fifteen years. It, therefore, appears that changes in climate parameters, especially maximum and minimum daily temperatures, have created conducive ecological conditions for mosquito breeding, thereby resulting in the increased incidence of reported malaria cases in the Dvokolwako area.

Keywords: Swaziland climate change, malaria incidence, epidemic, climate parameters, sugar cane irrigation, Dvokolwako area, and environmental factors

INTRODUCTION

Malaria is one of the world's leading epidemic killers. It is estimated that globally a population of about 500 million is affected, with resulting deaths of between 1 to 2.7 million a year. Many developing countries, particularly in sub-Saharan Africa, have experienced outbreaks of malaria in the past 10 to 20 years, thereby creating major obstacles to social and economic development. Malaria has been estimated to cost African countries more than USD 12 billion every year in GDP losses (United Nations, 2003). In Southern Africa, the epidemic has resurfaced causing many deaths in Swaziland, South Africa, Zimbabwe, and Mozambique.

Known environmental factors, such as floods, high temperatures, seasonal rainfall, deforestation, as well as agricultural activities, promote the transmission of the pandemic. Malaria is associated with irrigated areas where the flooded condition provides suitable habitat for mosquitoes and serve as transmission sites (FAO, 1996). Another environmental factor that has been responsible for the transmission of the disease in many tropical areas has been change in local climatic conditions. Studies that have been conducted on the impact of climate change on malaria transmission in Zimbabwe, Ethiopia, and Rwanda have discovered that mean temperature, night-time temperature, and temperature in combination with rainfall were found to be related to the transmission of malaria (Freeman and Bradley, 1996). Climate change could be helping to fuel a rise in malaria transmission in the region.

According to Packard (1986), in Swaziland, malaria was successfully eradicated in the 1950's through a successful campaign, which involved spraying with DDT, which is a malaria fighting insecticide. The change from DDT to synthetic parathyroid for intradomicillary residual spraying in South Africa may have been a contributory factor to the increase in malaria incidence in that country. On the other hand, the absence of a similar trend in neighbouring Swaziland, where DDT continues to be used, adds weight to the ecological association between change in the use of insecticide and increase in malaria cases.

However, malaria resurfaced in Swaziland in the late 1980's following the introduction of sugar cane irrigation projects. These sugar cane growing projects created ideal ecological conditions favourable for malaria breeding. Additional factors, such as anti-malarial drug resistance, insecticide resistance, and human behaviour, have all been cited as accounting for the resurgence of malaria in Swaziland (Govere et al., 2002). These findings support other studies, especially by Ijumba et al. (2002), which indicate that irrigation in much of sub-Saharan Africa largely influences the breeding of the mosquito. There is growing concern that crop irrigation results in increased numbers of vector mosquitoes, which lead to a rise in malaria in local communities. In sub-Sahara Africa, more than 90% of malaria cases are caused by the plasmodium falciparum parasite. Swaziland uses chloroquine as the first-line therapy for uncomplicated plasmodium falciparum (Govere et al., 2002).

Thirty percent of Swaziland's population of 1.13 million is at risk, especially in the low-lying Lubombo district where 45,000 inhabitants are under the age of five while an additional 10,200 are pregnant women. Estimates show that about 3% of all the deaths in the country are attributed to malaria (WHO, 2002). According to Dvokolwako health centre clinical records that serve the community of Dvokolwako, malaria cases have increased rapidly in the past five years in this area previously thought to be malaria free. This begs two questions: Which current factors that were not there previously account for the increase in malaria incidence in the Dvokolwako area? Are the new sugar cane plantation areas responsible for the spread of the disease? In Dvokolwako, farmers associations that cannot afford the necessary infrastructure, such as modern irrigation equipment and the recommended insecticides to stop the spread of diseases, practice sugar cane cultivation.

A study done by the World Health Organization, revealed that the Spread of malaria has invaded new regions in the Kingdom namely; the Middleveld and the Highveld where the transmission was not reported before, since the invasion of the outbreak of the disease in the Lubombo region in the early 1960's,WHO, (2002). The low lying and hot Lubombo region has been known to be the only ecological region in the country with suitable conditions for the transmission of malaria and various control measures have been undertaken by the Malaria Unit to eradicate the disease in the region.

In Dvokolwako, commercial agriculture under irrigation is practiced by four sugar cane growing associations. Such agricultural projects normally have a negative effect on the health of the local people because they have the potential to provide good ecological conditions for the breeding of mosquitoes as they use a lot of water for irrigation purposes.

The effects of temperature on both the vectors and parasites of malaria are seen in the latitudinal and altitudinal boundaries to malaria transmission. However, these boundaries seem to be changing as many highland areas have experienced malaria epidemics in the past few years. This is typical of the spatial spread of malaria in Swaziland, where new areas have been affected. It is hypothesized in this paper that increasing temperatures could be part of the reason why malaria is now observable at higher altitudes. However, as Patz and Lindsay (1999) caution, many other confounding factors could be causing the increase in malaria in the previously non-malaria areas. Mean temperature, night-time temperature, temperature in combination with rainfall, and mean November and December temperature were found to be related to malaria incidence in several countries including Zimbabwe, Ethiopia, Rwanda, and Pakistan (Freeman and Bradley, 1996).

Several factors affect malaria transmission in the sub-region. The chief determinant is climate, which affects both the life of the anopheles mosquito and the development of malaria parasites. The development of the malaria parasite is greatly retarded below 20 degrees Celsius and ceases to develop below 16 degrees Celsius. In addition, relative humidity of over 80% lengthens the life of the mosquito, thereby enabling it to transmit infections (WHO, 2002). The development of P. falciparum in the female adult Anopheles mosquito requires a minimum temperature of 19°C. Above this temperature, the development of the parasite in the vector quickens. During the summer months of December to March in Swaziland temperature rises above 20 degrees Celsius, thereby creating suitable ecological conditions for the breeding of the mosquito in several regions of the country.

Against the above backdrop, this study examines the relationship between temperature changes and the increased incidence of malaria cases in the Dvokolwako area of Swaziland. The research questions formulated to guide the study are: Is there a relationship between temperature changes and the increased incidence of malaria cases in the Dvokolwako area? Is there a relationship between sugar cane cultivation under irrigation and the increased incidence of malaria cases in the Dvokolwako area? The study focuses on the increased incidence of malaria cases in the area because Swaziland, just like several other countries in the region, is experiencing resurgence in malaria cases. The main purpose of the study was to investigate factors accounting for the increased incidence of Malaria cases in the Dvokolwako area of Swaziland, traditionally thought to be malaria free. The two main factors studied were namely climate and irrigation agriculture sugar cane growing.

STUDY AREA

Climate

The study was undertaken in the Dvokolwako area of Manzini district in the Kingdom of Swaziland. Swaziland is a small landlocked country of 17,400 km^2, which is located in the Southern African region and is bounded by the Republic of South Africa in the north, west, and south and by Mozambique on the East. Dvokolwako is a peri-urban area which is situated between 31°34' north and 26°09' south of the equator (Figure 1). The area receives an average of 650 mm of rainfall per year with rains rising to 1,350 mm in some years and its long term mean monthly maximum temperature is 31°C, although in extreme cases it may rise to over 35°C. Minimum temperatures are experienced in winter and they average 9°C in June, but may drop to 4°C in extreme cold days.

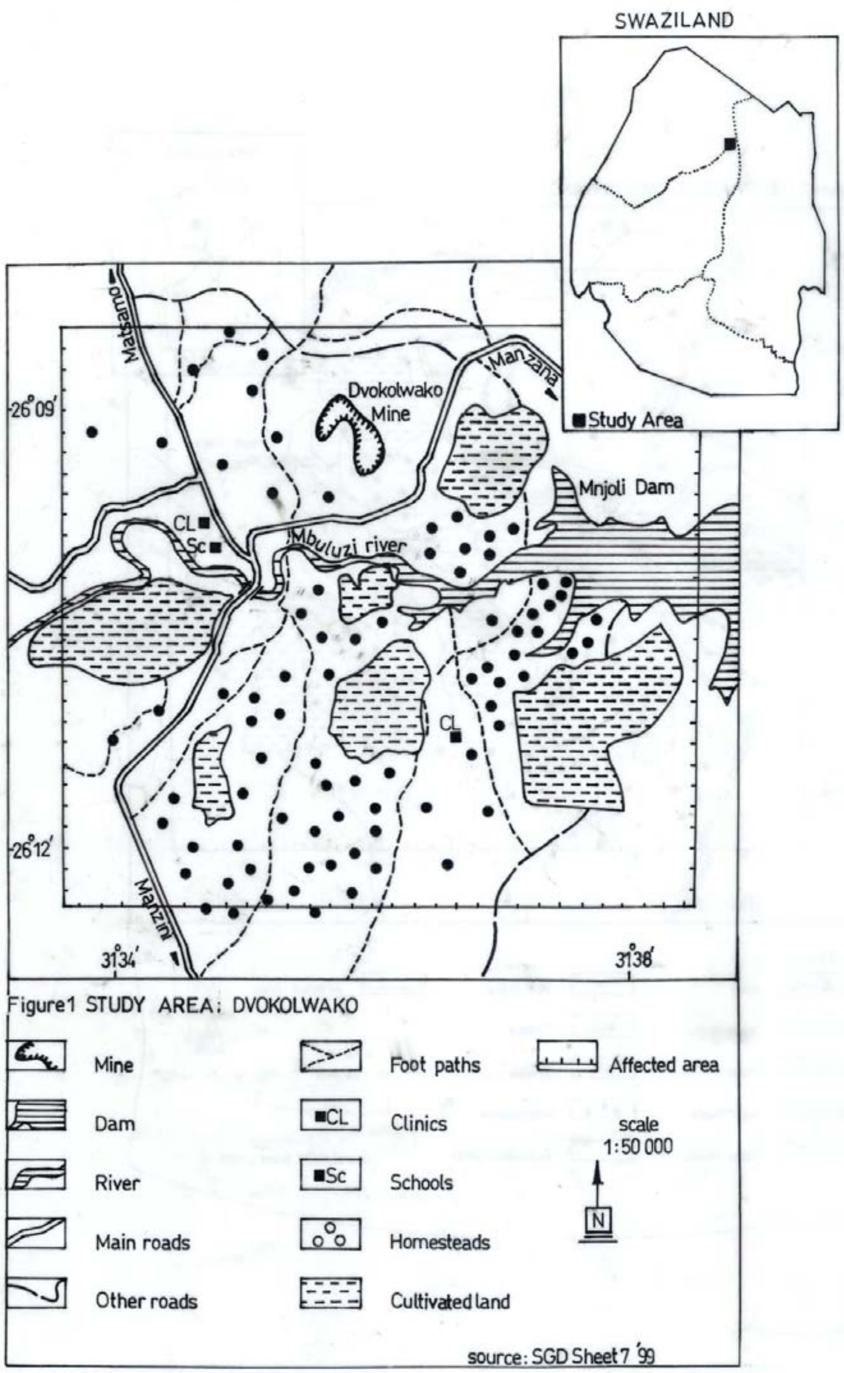

Figure 1: Detailed map of study area

Population Trends and Major Economic Activity

According to the national statistical bulletin of 1997, in 1986 the population of Dvokolwako area was 1,105 but by 1997 had risen sharply to 2,036, thereby, making it one of the fastest growing peri-urban centers in Swaziland. There are 97 sugar cane growing farmers, who grow sugar cane on 358 hectares of land. In total, there are 280 homesteads, and 350 households (Central Statistical Office, 1997).

The major form of economic activity today is sugar cane growing, which is practiced on a commercial scale and employs most of the local population and maize growing. Maize growing has been greatly reduced in the area with more focus on sugar cane growing. There are four sugar cane growing associations that have been formed recently, growing sugar cane on a total of 354 hectares of land. Sugar cane took over from the Dvokolwako diamond mine, which used to employ about 70% of the local population but has since closed down (Ministry of Enterprise and Employment, 1998).

MATERIALS AND METHODS

Retrospective malaria inpatient study data was extracted from Dvokolwako and Mliba clinic monthly reports, which included all confirmed malaria laboratory inpatients cases since 1990 to 2004, specifically for Dvokolwako area. The Mbabane Meteorological Weather Service made temperature and rainfall data for Dvokolwako area for the period 1980 to 2004 available, which is the headquarters of all weather stations in the country. The reason why such a long time frame (24 years) was considered because good interpretation of the climate data was necessary to obtain a concrete analysis. Sugar cane growing information was gathered from sugar cane growing farmers and from the sugar cane fields themselves. Data on malaria cases for the area were obtained from Dvokolwako Health Centre and Mliba Nazarene Clinic. In addition, field visits were made to the four sugar cane plantations in the area (Manzana Cooperative, Kwasa Farmers, Phinduvuke Farmers, and Lilunga Farmers). Observations on the prevailing agronomic methods were made and unstructured interviews were made with the sugar cane farmers.

The study data are presented in graphical form and summary explanations are used where necessary. Seeing that the study involves both qualitative and quantitative research methods, a Spearman's Rank correlation coefficient statistical calculation was used to find the strengths of relationships between malaria cases and rainfall and temperature, respectively.

RESULTS AND DISCUSSION

Malaria Cases

According to clinical records from Dvokolwako and Mliba, malaria was not a problem in the area until the beginning of the 1990s when increased malaria cases were reported, particularly towards the end of the 1990s. Figure 2 shows confirmed laboratory malaria cases versus time of the area of Dvokolwako from 1990 to 2004. According to clinical records, malaria rarely occurred in the 1980s, as revealed by clinical documentations in the area of Dvokolwako. It was noted that in the late 1990s, more malaria cases were reported. Figure 2 shows that during the early 1990s until the mid 1990s, there were very few numbers of malaria cases reported. The highest numbers of malaria cases were documented in 1990 when 35 malaria patients were treated. However, beginning from 1996 to 2004, a substantial increase in malaria cases was witnessed. The substantial increase of the malaria cases is continuous throughout the latter part of the 1990s until 2004 when 412 malaria cases were reported.

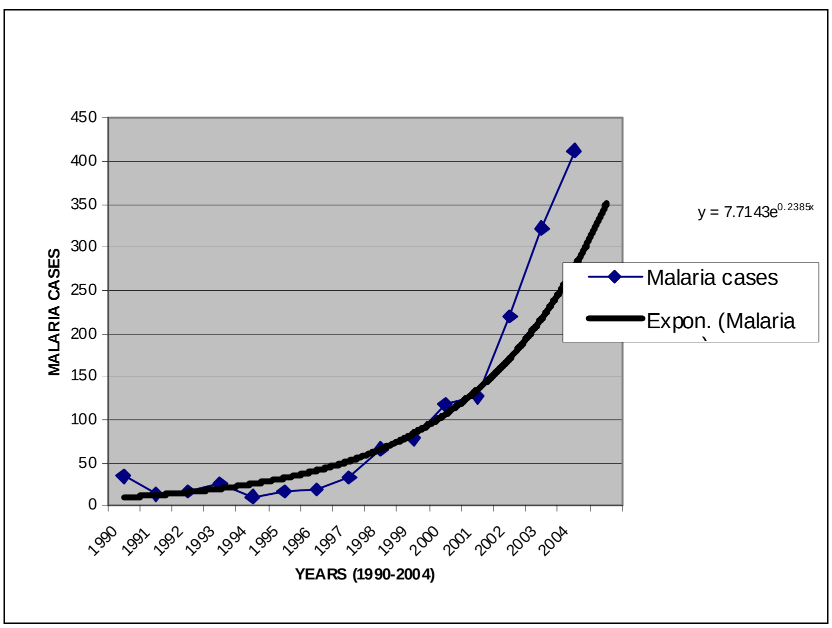

Figure 2: Confirmed Laboratory Malaria Cases Reported from 1990-2004

Source: Dvokolwako and Mliba Clinics, 2004

It is also very important to take note of when the increase in malaria cases began to take place, so as to be able to identify the main factor(s) responsible for the increase. According to clinical records, only 20 malaria cases were documented between 1980 and 1990. More malaria cases began to occur at the beginning of the 1990s with substantial increases starting in the middle of the 1990s. The increase grew exponentially at a graphical equation rate of $y = 7.7143e^{0.2385x}$ per year through to 2004.

Temperature and Rainfall Trends from 1980-2004

Mean monthly temperatures (average maximum and minimum temperatures) for the area of Dvokolwako were computed. The mean temperature was computed by averaging the maximum and minimum temperatures for each given month and further computed for the twelve months of the year to come out with one mean temperature of that specific year. Figure 3 shows that between 1980 and 1990 the maximum temperature fluctuated from a low of 22ºC to a high of 28ºC, whilst the minimum temperature fluctuated from a low of 8ºC to a high of 15ºC, yielding a maximum mean temperature of 15ºC. It is important to note that during this period only 20 malaria cases were reported. What we observe here is that the mean temperature, which is the critical temperature variable that influences the breeding of mosquitoes, was far below the normal mean temperature of 20ºc, which favors the breeding of mosquitoes. This could be attributed to the fact that both the maximum and the minimum temperatures were not high enough to create a good ecological region for the habitation of mosquitoes in the 1980s. Figure 3 shows an analysis of the temperature trends of the 1980s. From the data presented in Figure 3, it is clear that temperatures in the 1980s were not high enough to encourage the breeding of mosquitoes.

However, from 1990 we observe that maximum temperature increased substantially reaching 26ºC in 1994 and continued to increase to about 37 degrees Celsius in 2004. When you compare the differences of the maximum temperatures between 1986 of 28ºC and that 0f 2004 of 37ºC, you get a difference of 9ºC. Similarly, after 1992, the minimum temperature increased substantially and exceeded 15ºC for the first time since 1980. The increases in both maximum and minimum temperature brought a significant change to the mean temperature as well, which is the critical temperature parameter that influences the breeding of mosquitoes. From 1990-2004 the temperature was higher than normal.

Contrary to the substantial temperature increase since 1980, rainfall shows much fluctuation between 1980 and 2004. Between 1980 and 1990, the highest rainfall was recorded in 1985 when a total average rainfall of 1000 mm was recorded. From 1986 to 1990, rainfall declined considerably. During this time period, temperatures were also fluctuating at low levels (minimum and maximum temperatures), yielding mean temperatures below 16ºC, which were not conducive enough to influence mosquito breeding; hence, there was less malaria transmission in the area during this period. Between 1990 and 1998, rainfall continued to fluctuate at low levels, below 800 mm. However, temperature had started to increase by this time. More rainfall was recorded during the year 2000, where an average rainfall of (1400 mm) was recorded. Subsequent years have been characterized by meteorological droughts not just in Swaziland but in most of Southern Africa.

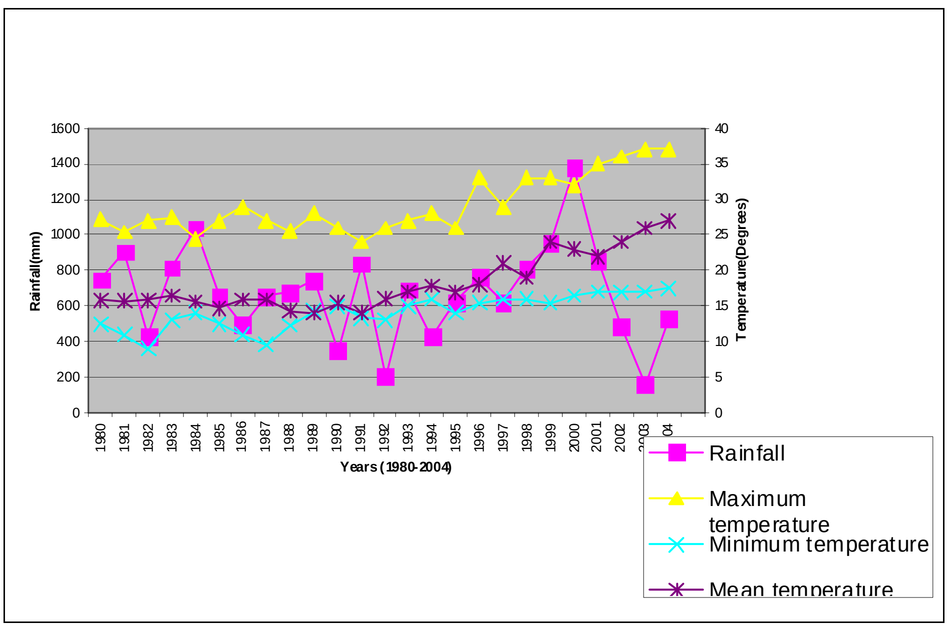

Figure 3: Maximum, Minimum, and Mean Temperatures and Rainfall from 1980 – 2004

Source: Mbabane Weather Service, 2004

Figure 4 shows a graphical relationship between the climate parameters and the occurrence of reported malaria cases. It is also worth noting that the change in climate triggered an increase in malaria cases in the Dvokolwko area. This suggests that there is a relationship between temperature increases and the increase in the incidence of malaria in the Dvokolwako area.

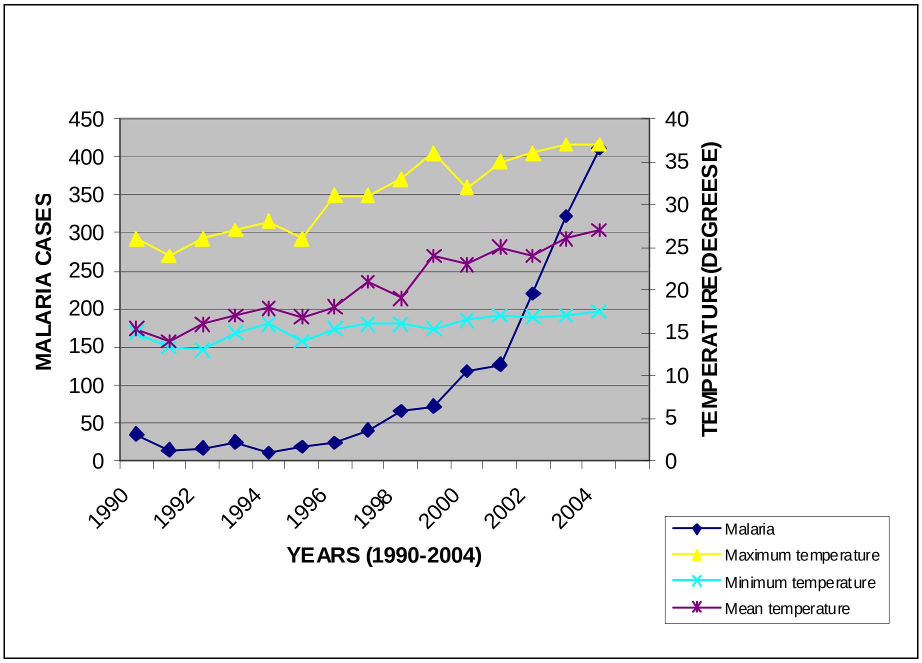

Figure 4: Trends in Maximum, Minimum, and Mean Temperatures against Trends in Confirmed-Laboratory Malaria Cases from 1990 to 2004

Source: Mbabane Weather Service, 2004

Relationship and Annual Cycle Occurrence of Malaria

The Spearman's Rank Correlation Coefficient was used to establish the strength of association between temperature changes and malaria incidence and between rainfall and malaria. The procedure below shows how the calculations of the association between temperature and malaria, rainfall and malaria cases were done:

a) Temperature and Malaria

$$rs = 1 - \frac{6\Sigma d^2}{n^3 - n}$$

$$rs = 1 - \frac{6 \times 76.5}{15^3 - 15}$$

$$rs = 1 - \frac{6 \times 76.5}{3375 - 15}$$

$$rs = 1 - \frac{459}{3360}$$

$$rs = 1 - 0.1366$$

$$rs = 0.86$$

b) Rainfall and Malaria

$$rs = 1 - \frac{6\Sigma d^2}{n^3 - n}$$

$$rs = 1 - \frac{6 \times 534.5}{15^3 - 15}$$

$$rs = 1 - \frac{3207}{3360}$$

$$rs = 1 - 0,95$$

$$rs = 0.05$$

A strong positive correlation of 0.86 was found between the Dvokolwako mean monthly temperatures and malaria cases. The positive correlation suggests that the warmer than average temperatures experienced have resulted in an increase of malaria cases. However, of interest to note has been the surprising correlation of 0.05 between rainfall and malaria indicates a weak positive association between rainfall and malaria cases. However, it is significant to note that the analysis has been based on the 1990 to 2004 period, during which rainfall was highly variable.

Figure 5 reveals that graphs for climate parameters (temperature and rainfall) and malaria incidence follow similar trends although they peak at different times. There is a three-month time lag between the peak rainfall and temperature season (November – February) and the peak of malaria from January to March. The figure shows that the level of malaria transmission is low during the cold months, especially between April and July. High malaria transmission occurs between January and March during the rainy and hot season.

The above findings suggest that the increase in the incidence of malaria cases in Dvokolwako is attributable to changes in climate parameters rather than the introduction of commercial sugar cane growing in the area in 1998. Had sugar cane growing been the critical contributing factor the rise in the incidence of malaria cases would not have been seasonal as it currently is but all year round, which is not the case according to the findings of the study.

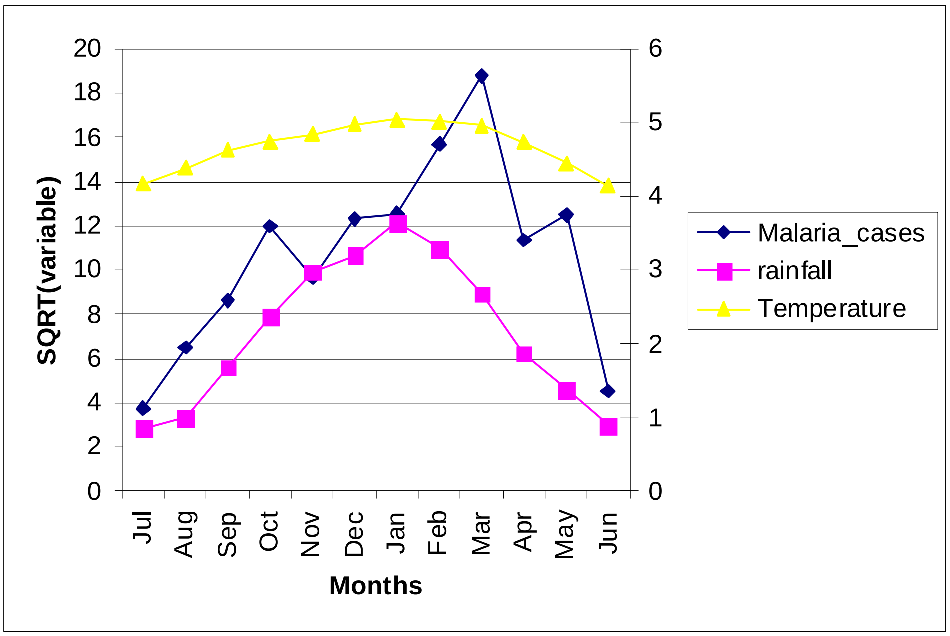

Figure 5: Annual Cycle of Malaria Occurrence and its Relationship between Climate Parameters (Temperature and Rainfall)

Source: Fieldwork

Sugar Cane Data Analysis

The study also wanted to find out if the spread of malaria in the area of Dvokolwako was as a result of the sugar cane growing projects, which started in 1998 in the area. As revealed in the literature review, unplanned irrigation agriculture has the capacity to create good ecological conditions for the breeding of mosquitoes.

The majority of the associations use the drip irrigation system in irrigating their sugar cane fields, whilst one of the four associations uses the sprinkler irrigation system. The association which uses the sprinkler irrigation system is the pioneer association which started growing the sugar cane in 1998, whilst the other three associations, which use the basin system, which is a modern system, started growing the sugar cane two years later (in 2000). When asked why they opted for the basin irrigation system instead of the sprinklers, they said that they were advised to install the basin irrigation system because it serves water by irrigating only the intended crop. Secondly, they opted for the basin irrigation system because it does not cause water logging which eventually creates good ecological conditions for the breeding of mosquitoes. The basin irrigation system does not cause water flooding in fields, as it is designed in such a way that it only irrigates the intended crop. This is contrary to the sprinklers, which irrigate every part of the field; hence, causing water flooding, thus, creating ideal ecological conditions for mosquito breeding.

The farmers were also asked if, according to their observations, there had been a change in the spread of malaria in the area since they started growing the sugar cane. From their responses, 91% said no whilst 9% were not sure. When asked if they experienced most malaria during the growing period of the sugar cane or not, they said no. The reasons they gave on both questions were that, according to their observations they do not think that it was the sugar cane growing that has caused the increase of malaria, since the increase of malaria started some time back even before they stared growing the sugar cane. They also alluded to the fact that whether there is sugar cane or not the effect of malaria is there, and the type of irrigation system they use does not promote mosquito breeding since it does not cause water flooding. However, the majority of them attributed the increase of the malaria in the area due to the changes in climate parameters that have occurred over the years. They said, since the beginning of the 1990s, temperatures have changed tremendously; hence, it has had an impact in so many things, one of which has been the creation of ideal ecological conditions of mosquitoes since mosquitoes require high temperatures to breed well.

All the associations confirmed to be using DDT (dichlorodiphenyltrichloroethane) as one of the chemicals they use to spray their sugar cane fields in an attempt not only to kill insects attacking their crops but also to stop mosquitoes and schistosomiasis from breeding. They said they were advised by Mhlume sugar company through various workshops which they held regularly to use DDT, since it kills not only insects attacking their sugar cane but mosquitoes as well which are a threat to human life. What is also important to note is that, the World Health Organization, recommended the use of the DDT in the early 1920s as a good chemical, which kills mosquitoes and has been effectively used by the Malaria Unit in the kingdom to kill mosquitoes since the 1960s, when a malaria out-break took place in the country in the Lubombo region. This is another strategy that was employed by the farmers in making sure that their sugar cane growing activities do not become a health hazard to the local people.

The sugar cane fields are properly managed. There are clearly prepared irrigation canals. Weeds are removed from the irrigation canals to allow free movement of water, thus preventing water logging. Grass is either cut or sprayed to keep it short. One reason they keep the grass short was to prevent mosquito breeding, as mosquitoes breed well in damp tall grass. According to this information, it is clear that the farmers are practicing planned commercial agriculture. What was found on the status of the sugar cane fields is in agreement with what the farmers said when they were interviewed. This shows that indeed they took heed of the advices by the Mhlume Company.

DISCUSSION OF THE RESULTS

According to clinical records (both Dvokolwako and Mliba clinics), only 20 cases of malaria were recorded between 1980 and 1990. This means that during this period, the area was not conducive enough to be a host area for mosquitoes. This is attributable to a number of reasons. One of the reasons could be that climate parameters were not conducive enough to influence the breeding of mosquitoes. However, in the early 1990s, an increase in the number of malaria cases is clear from the Dvokolwako and Mliba clinical records, although the incidence of malaria remained relatively low until 1996. A substantial increase in the number of malaria cases occurred between 1997 and 2004. While there were only 145 recorded malaria cases between 1990 and 1996 the figure had sharply risen to 1,378 between 1997 and 2004. This is a significant finding which reveals that the 1,524 confirmed laboratory malaria cases by 2004 is considerably higher than the figures recorded during the 1980s.

The highest minimum temperature was recorded 14.0ºC between 1980-1990 periods, while the highest minimum temperature was recorded 18.0ºC between 1990 and 2004, showing an increase or difference of 4.0ºC. The increase in both the minimum and maximum temperatures brought an increase in the mean temperatures. Between 1980 and 1990, the maximum mean temperature was 16.0ºC, where as between the 1990 and 2004 period the maximum mean temperature was 27.0ºC, showing a substantial increase of 11.0ºC. It is worth noting that the changes in climate parameters occurred between 1990 and 2004, where malaria cases began to increase. However, during this time period (1990-2004) rainfall was highly variable. This period is characterized by highly variable rainfall due to the drought season that attacked the country since the early 1990s.

From this discussion then, it is clear that it is the changes in temperature, which has facilitated the increase in malaria in the Dvokolwako area, not the growing of sugar cane. This is because the increase of malaria cases started in the mid 1990s, which is about three years before the growing of sugar cane even started in the area. The increase in the number of cases seems to grow exponentially with the increase in temperatures of the area. The other important reason why it has been discovered that it could not be sugar cane that has caused the increase in the number of malaria cases, is because the occurrence of malaria is seasonal not annual. If the occurrence was annual then it could have been the sugar cane because it is grown all year round; however, the occurrence of the disease is seasonal with peak malaria occurrence in (January-March). The farmers have taken the necessary measures to ensure that their sugar cane growing does not cause mosquito breeding by applying drip irrigation system, which does not cause water flooding.

The farmers also use chemicals to spray their sugar cane fields. One chemical they use when spraying their fields is DDT, which kills mosquito vectors before they start breeding more vectors. In addition, data obtained from the sugar cane fields by means of observation guides on status of the fields, indicates that the sugar cane fields are properly managed. Irrigation canals are well managed with grass growing on the edges of irrigation dams is either cut or sprayed to keep if short.

CONCLUSION

This data documents the increase of epidemic malaria due to climate change, more particularly temperature. Although malaria in the area of Dvokolwako was not a problem in the 1980s, because of the absence of favorable environmental conditions to host mosquitoes; however, in the recent past, increased malaria cases have been reported. Several pertinent factors have remained stable or absent and, therefore, do not appear to explain the increase of malaria in this area. Firstly, climate data of the area show obvious change in average temperature over the past 10 to 20 years, which explains the present seasonal occurrence of malaria in the area. From the above discussion, it was concluded that increased temperature is the most dominant factor responsible for increased incidence of malaria in Dvokolwako area. A second factor that could lead to an impression of increasing malaria would be the growing of sugar cane. Some irrigation agricultural activities have the capacity to create good breeding sites for mosquitoes. However, the irrigation agriculture that is practiced at Dvokolwako is planned and the farmers are taking the necessary precautions to ensure that the sugar cane fields do not become breeding grounds for mosquitoes. The farmers spray the sugar cane fields with chemicals or insecticides and they properly manage their fields.

ACKNOWLEDGEMENTS

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