



Research Paper

Urban Populations Facing Malaria: A Geographical Approach to Determining the Importance of Environmental Factors in Its Continued Existence in The City of Man (Côte D'ivoire)

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ABSTRACT: Malaria remains a major public health concern, even in urban environments where its persistence poses a significant challenge. Using a household questionnaire and interviews with officials from the town council, the regional council and the Institute of Public Hygiene in the town of Man, we examine the factors interacting to influence the prevalence of malaria in this specific urban environment. The environmental factors that contribute to the persistence of malaria in the city of Man are natural factors that take into account the climate, the presence of vegetation and soil around houses, and anthropogenic activities such as the presence of wastewater, stagnant water and the presence of household waste.

KEYWORDS: Man, malaria, environmental factors, geographical approach

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I. INTRODUCTION

Malaria is now a major public health problem, threatening many people around the world. According to the latest WHO World Malaria Report, there will be an estimated 263 million cases of malaria and 597,000 deaths from the disease worldwide in 2023. This represents around 11 million more cases than in 2022 [1]. Past and current data leave no room for doubt as to the endemic nature of malaria in Côte d'Ivoire [2]. According to [2] reports from the colonial health service dating back to the 1940s already point to the ravages of this endemic within the colony's populations, particularly the Europeans most affected by the endemic. Statistics on the extent of this disease, which must be taken with great caution, show that between 1940 and 1943, malaria morbidity increased among the European population, rising from 875 cases to 2,434, i.e. more than double [3]. Although there was a drop in 1944, it still accounted for 21% of malaria morbidity in the available data. Moreover, malaria was the main cause of medical repatriations from the colony during this period. Among the indigenous population, 44,241 were diagnosed with malaria in 1944 [3].

After independence, the seriousness of malaria in terms of mortality and morbidity was real: in a document published as part of the five-year plan to combat malaria, it is noted that malaria remains one of the leading causes of morbidity and mortality in Côte d'Ivoire, particularly among children under five (Five-year plan to combat malaria 1996-2001). Infant mortality accounted for 10% of deaths among children in 1985. In 1991, morbidity in paediatric wards at referral hospitals was 9% at Treichville University Hospital, 20.7% at Yopougon University Hospital and 54% at Cocody University Hospital. In 2006, 3.3 billion people and around 247 million people contracted malaria. Approximately 665,000 of these, with around 90% occurring mainly in sub-Saharan Africa [4]. Of these, 33% died. In 2023, malaria will account for around 30% of hospital consultations, with an incidence of 233 per 1,000 in the general population and 709 per 1,000 in children under the age of 5 [1].

Overall, malaria remains a dangerous endemic for the Ivorian population. It is considered a major cause of mortality and morbidity, especially in children under five, and is currently the main reason for consultations in primary care health facilities. Côte d'Ivoire is rightly regarded as a malaria-endemic country.

In response to this scourge, Côte d'Ivoire has implemented a malaria eradication policy dating back to 1955 and since 2010 has had a malaria control strategy with the ambition of achieving zero indigenous cases by 2020. Faced with this major political ambition, the Ivorian government has sought financial support from its multi- and bilateral partners. The Global Fund (97.8%) and the WHO (2.2%) have released more than US\$4.5 million for the fight against malaria. Various control measures have been put in place since 2010, including mass distribution campaigns for insecticide-treated mosquito nets, indoor insecticide spraying and mass treatment with artemisinin. These control measures have had a greater impact in the west of than in Côte d'Ivoire, especially in the town of Man. Despite all these efforts, malaria persists in Côte d'Ivoire and especially in the town of Man, where certain factors, especially environmental ones, contribute to its development.

In this study, we will attempt to identify the environmental factors that contribute to the persistence of malaria in the town of Man. Our problem can be summarised as follows: how do environmental factors contribute to the persistence of malaria in the town despite all the efforts made?

II. METHODS AND DATA

This section is structured around three points: presentation of the study area, selection method and data acquisition.

2.1 Presentation of the study area.

Man is a large town in western Côte d'Ivoire and the capital of the Tonkpi region (Figure 1). The town is nicknamed "The town of 18 mountains", and is located in a basin surrounded by a mountain range. It takes its name Man from the sacrifice of the Gbê patriarch, head of the Gbêpleu canton at the end of the 19th century. He sacrificed his only daughter, Manlé, who was buried alive in the sacred forest of Gbêpleu, for the development and harmonious growth of the new town. The Gbêpleu forest is now protected and is home to sacred monkeys. The town of Man is located 570 km from Abidjan (the economic capital of Côte d'Ivoire) and 330 km from Yamoussoukro (the political capital). Man is one of the largest towns in Côte d'Ivoire and the largest town in western Côte d'Ivoire, with a population of 241,969. According to the 2021 Ivorian population census. The city has an equatorial climate with a marked rainy season, creating conditions conducive to the proliferation of malaria-carrying mosquitoes.

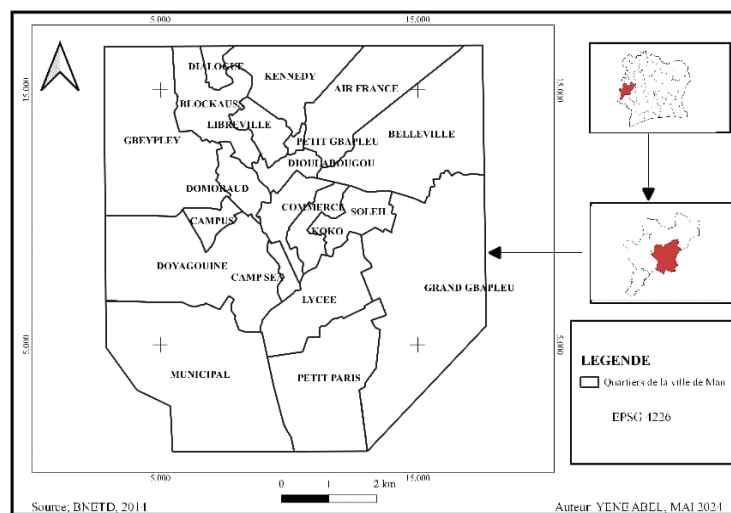


Figure 1: Presentation of the study area

2.2 Data acquisition method.

The data required for this study were collected by means of a questionnaire administered to a sample of households and interviews with officials from the town hall, the regional council and the Institute of Public Hygiene.

The questionnaire focused on the management of households' immediate environment. This survey phase was carried out among households in the various districts of the city of Man and enabled us to carry out more in-depth research and provide answers to certain questions.

With regard to the survey design, the town of Man has 20 neighbourhoods and we decided to carry out an exhaustive survey of the neighbourhoods.

Given the cost of the survey and the size of the study area, we decided to survey 20 households per neighbourhood in the town of Man, i.e. a total of 400 households taken at random from the total number of households (40,000 households). We decided to survey the head of household or a spouse in the event of the head's absence.

III. RESULTS

The results section is structured around two main points. The first presents the two types of environmental factors that are responsible for the persistence of malaria, natural factors that take into account the climate and the presence of vegetation, and the second presents the human activities linked to the persistence of malaria, such as the presence of waste water, the presence of stagnant water and the presence of household waste.

3.1 Prevalence of malaria in the town of Man

According to surveys in the town of Man, health officials have confirmed that malaria is endemic and the entire population is exposed to the disease. Transmission occurs throughout the year, with a peak in incidence from April to July.

According to surveys, parasite prevalence is 64% in the town of Man. The number of people who contracted malaria in households in the town of Man in the 6 months preceding the survey reveals that the lowest parasite prevalence is found in the Air France, Domoraud, Camp séa, Lycée and Municipal neighbourhoods, with 33%, 0%, 0%, 0% and 33% cases of malaria respectively (Table 1).

NEIGHBOURHOOD	average number of people in the household	number of people who have contracted malaria	Percentage of people who have contracted malaria
Dialogue	11	9	82%
Kennedy	9	9	100%
Air France	6	2	33%
Blockauss	12	7	58%
Libreville	5	1	20%
Gbeypley	11	11	100%
Petit Gbapleu	10	6	60%
Belleville	5	2	40%
Dioulabougou	9	9	100%
Domoraud	3	0	0%
Retail	4	2	50%
Sun	7	7	100%
Campus	8	5	63%
Koko	7	5	71%
Doyagouiné	7	6	86%
Camp Séa	3	0	0%
Lycée	4	0	0%
Grand Gbapleu	5	2	40%
Petit Paris	5	2	40%
Municipal	3	1	33%

Table 1: Prevalence of malaria in the different neighbourhoods of the city of Man

The highest prevalence of malaria was found in the Kennedy, Gbeypley, Dioulabougou, Soleil and Doyagouin neighbourhoods, with respectively 100%, 100%, 100% and 86% of people having contracted malaria in the household. Paradoxically, the neighbourhoods with the highest prevalence of malaria are the ones that use mosquito nets the most. Are these mosquito nets from the malaria control programme impregnated mosquito nets, or is there a problem with their use? The high prevalence of malaria in these neighbourhoods can be explained by the fact that these are the neighbourhoods that consult the fewest doctors in the event of illness, and in these neighbourhoods, drinking water from taps is rarely used.

3.2 natural factors determining the endemic nature of the town of Man

A climate favourable to exposure to the risk of malaria. The Man region is located in Côte d'Ivoire, on the borders of Guinea and Liberia. A mountainous region, with many peaks exceeding 1,000 m, extends to the north of Man, divided into nine massifs isolated by deep ravines at an altitude of 500 to 600 m. Geologically, the mountains are made up of gneiss and granite of the magnesian series. When decomposed, they produce fertile soils overall. They have two shortcomings: the slope in the northern region - an average gradient of 450 m - and the decomposition into granitic arenas in certain localised areas. Man's climate is tropical with only one rainy season, similar to that of Bouaké, but the differences in daily and seasonal temperature and humidity make it a typical mountain transition climate, very similar to the Guinean climate. Due to the proximity of the mountains,

temperatures are a little lower and rainfall a little heavier than in other Côte d'Ivoire towns located at the same latitude.

The region's climate is characterised by

- rainfall of around 2 metres
- a single dry season from November to March
- fairly constant temperatures hovering around 25°C
- very heavy cloud cover during the rainy season
- micro-climates due to the mountainous terrain in the north.

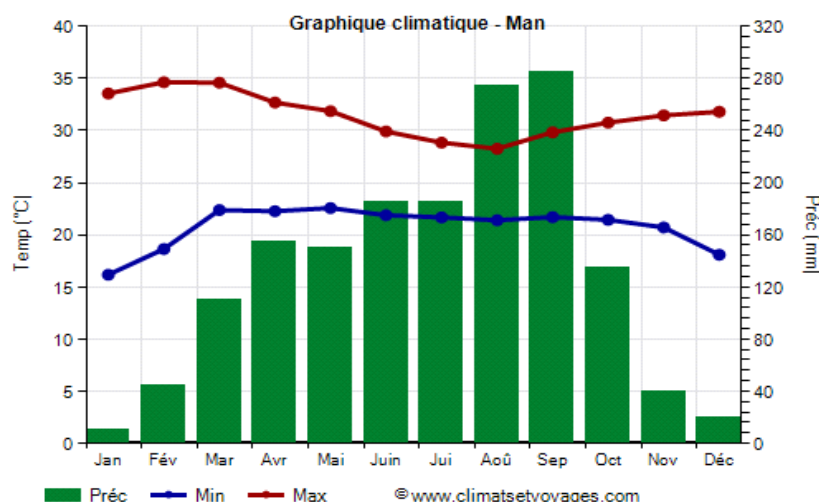


Figure 2: Umbro-thermal curve for the town of Man in 2020

Rainfall in Man increases steadily from east to west, and also increases with altitude. Figure 2 shows the number of rainy months and the annual rainfall, maximum, minimum and average. These figures show that the rainfall pattern is highly irregular: indeed, a maximum rainfall of 282 mm was recorded at Man in 2020.

The rainy season lasts 7 to 8 months, beginning in March and ending in October. September is the wettest month. The dry season lasts three to four months, from November to February. The driest months, December and January, receive less than 40 mm of rainfall.

Rainfall totals 1,590 millimetres per year, making it abundant. In the least rainy month (January) it amounts to 11 mm, in the wettest month (September) it amounts to 285 mm.

This rainfall is good for mosquitoes, as it feeds the ponds and pools used for breeding.

The average temperature is around 25^(o) C. The average temperature difference between the hottest and coldest months is only 3.7^(o) C. It is in the dry season that the highest maxima are observed, as well as the greatest amplitudes of daily variation. Finally, the region is very cloudy during the rainy season, with less than 3 hours of sunshine a day in July and August. The average temperature in the coldest month (August) is 26°C, while the average temperature in the hottest month (March) is 28.5°C. These are the average temperatures.

These temperatures are linked to higher malaria transmission. This favours the spread of anopheles, providing them with a favourable biotope.

Maintained urban vegetation conducive to malaria transmission. According to our observations in the field, the town of Man is covered in abundant vegetation. There is the sacred forest of Gbèpleu, not far from the campus 2 district, and the waterfall not far from Mont Gla. All the city's districts have green spaces, with the exception of the commercial district (figure 3). On top of the mountains, you'll find a variety of plant species in a landscape that's as magnificent as it is varied. We're in a dense forest on top of the mountains, as well as cultivated areas. In this town, we saw some areas occupied by fields.



Figure 3: Poorly maintained vegetation

In addition to vegetation, bare soil is a key factor in the spread of *Anopheles*. 91% of households surveyed had bare soil less than 3 metres from their house. 56% of households surveyed had unkempt grass less than 5 metres from their house. The persistence of malaria in the town of Man can be explained by the different types of soil found around houses. Bare soil and herbs are all factors in the persistence of malaria insofar as they retain sufficient water during the rainy season (Figure 4).



Figure 4: Stagnant water in the Camp séa neighbourhood

This water is a breeding ground for the female *Anopheles* mosquito. Speaking of the soil around the houses, the earthen floors are exposed to erosion, which will cause holes where water will stagnate, and these spaces will be nests for *Anopheles* mosquitoes.

3.3human activities linked to the persistence of malaria

The presence of wastewater . Wastewater is water discharged by households after use. We observed a massive presence of wastewater in and around households in the town of Man. In fact, 34% of households surveyed dump wastewater in their homes, while 50% dump wastewater less than 10 metres from their homes. This is due to the fact that people do not have the means to build spaces to channel this water. A total of 652 sewage points were identified in the various districts of the town of Man (Table 2).

NEIGHBOURHOOD	number of wastewater points	
	frequency	percentage
Dialogue	15	2%
Kennedy	68	10%

Air France	8	1%
Blockauss	96	15%
Libreville	8	1%
Gbeypley	72	11%
Petit Gbapleu	69	11%
Belleville	11	2%
Dioulabougou	96	15%
Domoraud	6	1%
Retail	2	0%
Sun	52	8%
Campus	45	7%
Koko	32	5%
Doyagouiné	48	7%
Camp Séa	3	0%
Lycée	5	1%
Grand Gbapleu	3	0%
Petit Paris	8	1%
Municipal	5	1%
TOTAL	652	100%

Table 2: The number of wastewater points in the various districts of the town of Man

The neighbourhoods in the city of Man with the most wastewater points are Kennedy with 68 points, Blockauss with 96 points, Gbeypley with 72 points, Petit Gbapleu with 69 points and Dioulabougou with 96 points. The poor drainage of wastewater and rainwater in these neighbourhoods is at the root of the creation of ponds, which are breeding grounds for malaria mosquitoes.

The neighbourhoods in the town of Man with the fewest wastewater points are the Commerce neighbourhood with 2 wastewater points, the Camp Séa and Grand Gbapleu neighbourhoods with 3 points each, the Lycée and Municipal neighbourhoods with 5 points each and the Domoraud neighbourhood with 6 wastewater points. These neighbourhoods are less exposed to malaria because of the good drainage of waste water.

As for stagnant or dormant water, these are areas of fresh water where there is little or no water circulation. In the town of Man, 1070 stagnant water points have been identified (table 3). The neighbourhoods with the most stagnant water were Kennedy (92), Blockauss (115), Gbeypley (95), Petit Gbapleu (100), Dioulabougou (142) and Doyagouiné (92). It rains a lot in the town of Man, and this creates breeding grounds for malaria-carrying mosquitoes, which lay their eggs in stagnant water. These neighbourhoods are therefore the most exposed to malaria. The least exposed districts are Libreville, Commerce and Camp Séa, each with 11, 10 and 12 stagnant water points.

NEIGHBOURHOOD	number of stagnant water points	
	frequency	%
Dialogue	52	5%
Kennedy	92	9%
Air France	20	2%
Blockauss	115	11%
Libreville	11	1%
Gbeypley	95	9%
Petit Gbapleu	100	9%
Belleville	45	4%
Dioulabougou	142	13%
Domoraud	21	2%
Retail	10	1%
Sun	75	7%
Campus	52	5%
Koko	72	7%
Doyagouiné	92	9%
Camp Séa	12	1%
Lycée	18	2%
Grand Gbapleu	15	1%
Petit Paris	16	1%
Municipal	15	1%
TOTAL	1070	100%

Table 3: Number of stagnant water points in the different districts of the town of Man

During the survey, a woman from the Dioulabougou neighbourhood said that: The prevalence of malaria in our neighbourhood is really high because from 6pm onwards we can't sit outside because the mosquitoes come to bite us, so we have to stay in the house, and it's hot inside.

Household rubbish In general, there are six ways of collecting household rubbish in the town of Man: rubbish dumped in the open air, rubbish lorries, rubbish bins, pits and in water or ponds. 22% of households surveyed dump their household waste in pits, while 25% dump their waste in dump trucks. 27% dump their waste in bins or containers. The trucks that empty the bins come every fortnight. This causes real pollution in the neighbourhoods. 16% of households in Man dump their household waste in the open air. Finally, 10% of households in the town of Man use water or ponds to dispose of household waste (figure 5).

It is in the Dioulabougou, Kennedy, Blockauss and petit gbapleu neighbourhoods that we find the most open-air household waste collection. Every month, open-air rubbish dumps are created, and some disappear. All bare, undeveloped areas are potential locations for open-air collection points.



Figure 5: Rubbish under the bridge linking the Domoraud and Libreville neighbourhoods
The method of solid waste disposal shows that, on the whole, the choice of disposal method influences exposure to malaria.

IV. DISCUSSION

The research carried out here has shown that the persistence of malaria in Man is partly due to natural conditions that favour an increase in malaria transmission. The region's climate is characterised by rainfall of around 2 metres, a single dry season from November to March, fairly constant temperatures of around 25°C, very high cloud cover during the rainy season and the presence of micro-climates due to the mountainous terrain. These results confirm the findings of previous research on the link between climatic conditions and the presence of malaria in a given region, while acknowledging that the link is complex and difficult to establish. A number of studies, including one by [5] on the link between climate change and malaria in Colombia, state that higher temperatures, rainfall and humidity can lead to the proliferation of malaria-carrying mosquitoes in high-altitude regions, as was the case in our study, thereby increasing transmission. With regard to the health risks associated with household waste and insalubrity for the population, our study is in line with that of [6], on the health risks associated with household waste and insalubrity for the population of Anyama (Abidjan-Côte d'Ivoire), with regard to waste disposal methods. The results show that households that dump their solid waste in the street are more exposed to malaria than those that use the services of a pre-collection agent. In fact, the prevalence rates for malaria were 38%, 63% and 82% respectively for individuals who used pre-collectors, the rubbish bin and the street. Throwing rubbish out on the street leads to cohabitation with unauthorised rubbish dumps. The literature constantly reveals that these unauthorised dumpsites bathed in stagnant water are breeding grounds for vectors of all kinds of diseases ([7], [8] and [9]). This was borne out by an analysis of the spatial distribution of illegal rubbish dumps in the Anyama commune. The neighbourhoods where the highest rates of uncontrolled dumping were found, namely Derrière-Rails (43%) and Schneider (25%), also had the highest malaria prevalence rates 88% (Derrière-Rails) and 82% (Schneider). Several studies carried out in developing countries have revealed that, among environmental factors, the presence of stagnant water and weeds are risk factors for malaria ([10], [11], [12] and [13]). Our data concur with that of [13] in his study on Behavioural and environmental factors associated with malaria in Tourou (Benin) during a period of low endemicity. He states that among the environmental factors, the presence of stagnant water and weeds are risk factors for malaria. Proximity to stagnant water is a factor favouring the onset of malaria. These results are also reported by [10] in his study on the incidence of Plasmodium infections and determining factors in children in a district of north-west Ethiopia, by [11] in their study on the characterisation of spatial determinants and prevention of malaria in Kenya and finally [12] in their study on the

assessment of malaria as a health problem in and around the sugarcane plantation area of Arjo Didhessa in western Ethiopia.

The results of the study by [14] reported by [13] confirm that the occurrence of malaria depends on the vegetation index. The more poor vegetation is present, the more frequent malaria is. The risk of malaria transmission depends on the flight distance of the Anopheles, which is approximately 2 to 3 km. Habitats within 250 metres of forest or 200 metres of gardens are more at risk of malaria [15].

V. CONCLUSION

The aim of this research was to identify the environmental factors that contribute to the persistence of malaria in the city of Man. The study revealed that the town of Man is characterised by rainfall of around 2 metres, a single dry season from November to March, fairly constant temperatures of around 25°C and very heavy cloud cover during the rainy season. These factors favour the spread of Anopheles, providing them with a favourable biotope. In addition to these factors, there is the poor management of the environment due to human activities such as waste water discharged by households after use, and the presence of household rubbish in the vicinity of dwellings. All these factors interact to influence the prevalence of malaria in the town of Man.

It is essential to develop knowledge of the geographical variables associated with malaria transmission so that the Ivorian government and the many organisations involved can fulfil their objective of better controlling the spread of malaria. Although other factors such as social factors could be investigated further in this study, the results could nevertheless be used to guide malaria intervention programmes and improve their effectiveness in reducing malaria transmission.

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