Journal of Aquatic and Terrestrial Ecosystems
2(1)
Received: January 28, 2024
Accepted: March 27, 2024
Published: April 27, 2024

Incidences and Impacts of Climate-Induced Vector Borne Diseases in Arid and Semi-Arid Regions of Kenya

Kipkorir K. G. Kiptoo

School of Environmental and Natural Resources, University of Eldoret, P.O Box 1125, Eldoret, Kenya

Abstract

Vector-borne diseases (VBD) remain a major threat to human and animal health, particularly in tropical and subtropical regions. The disease account for more than 17% of all infectious diseases, causing more than 700 000 deaths annually. Kenya, like many other regions, is largely affected by VBD. Over the past few decades, epidemics of VBDs in the country have been rising due to multiple driving forces, including socioeconomic factors, environmental changes, global warming, and climate change. Climate change is significantly impacting the epidemiology of these, particularly in Arid and Semi-Arid regions (ASALs) of Kenya. These regions, already characterized by harsh climatic conditions and fragile ecosystems, are experiencing shifts in temperature and precipitation patterns that are altering the distribution and behavior of disease vectors such as mosquitoes and ticks. The pastoralist communities inhabiting these regions, who rely heavily on livestock and subsistence agriculture, are especially vulnerable. Hence, assessing the prevalence and impacts of these diseases in ASALs is indispensable to develop targeted, sustainable interventions to protect vulnerable populations from climate-induced VBDs health risks. Academia, Research Gate, African Journal Online, ScienceDirect, Scopus, PubMed, Google Scholar and Web of Science, were used to conduct an exhaustive bibliographic search for scientific and technical articles as well as government documents on the prevalence of VBDs in ASAL regions and documented impacts. The findings were presented thematically. Infectious diseases including malaria, dengue, chikungunya Rifty Valley Fever and yellow fever have risen markedly, with numerous researchers attributing this trend to climate change. Changes in climate, including rising temperatures, altered rainfall patterns, and increased frequency of extreme weather events, have significant impacts on the distribution and proliferation of vectors like mosquitoes, ticks, and sandflies. These climatic changes extend the geographical range and breeding season of vectors, leading to a higher incidence of VBDs in regions that were previously less affected. The spread of VBDs exacerbates existing health challenges in these regions, which often suffer from limited healthcare infrastructure and resources. Further, increased incidence of these VBD diseases have led to higher morbidity and mortality rates. It also places a significant economic burden on families The cost of treatment, loss of productivity due to illness, and the diversion of resources to combat outbreaks hinder overall economic development. Engaging local populations in vector control measures, such as the proper use of insecticide-treated nets and eliminating stagnant water sources, can significantly reduce disease incidence. Also, enhancing the capacity of healthcare facilities and infrastructure in arid and semi-arid regions is key.

Keywords: Pastoralist communities, ASALs, climate change, vector borne diseases, incidences, impacts

Correspondence: kipkorirk@gmail.com

Copyright © 2024 Kipkorir. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY).

Competing interests: The authors have declared that no competing interests exist

Introduction

The Arid and Semi-Arid Lands (ASALs) of Kenya covers more than 80% of the country's land area and it's characterized by relatively low annual rainfall (Ouma et al., 2018; Marigi, 2019). Geographically, the ASALs are situated in the northern and eastern parts of Kenya, extending from the border with Somalia and Ethiopia in the north to the arid regions of the Rift Valley in the west (Lemenih, 2011). The ASALs covering 29 counties are inhabited predominantly by agro-pastoralists and nomadic pastoralists, with a population of approximately 16 million people (Njoka et al., 2016; Otolo & Wakhungu, 2013). The arid areas are characterized by severe living conditions, with little annual rainfall of between 150 and 550 millimeters and high temperatures. Garissa, Mandera, Isiolo, Marsabit, Baringo, Turkana, Tana River, Samburu and Wajir are the 9 counties that are found in arid regions. The semi-arid ones are Embu, Kajiado, Kilifi, Kitui, Kwale, Laikipia, Lamu, Makueni, Meru, Narok, Nyeri, Taita Taveta, Tharaka Nithi and West Pokot. The annual rainfall in the semi -arid areas is between 550-850mm.

ASALs areas in Kenya are particularly susceptible to droughts and flooding, and with increasing impacts from climate change (Koech, Makokha & Mundia, 2020; Kalele et al., 2021; Mabhuye et al., 2015). The regions are also characterized by widespread livestock theft, animal diseases, conflicts over the animals and their diminishing pastures and water, and a poor exposure to markets for their livestock (Sax et al., 2022; Rashid, 2014; Schilling, Opiyo & Scheffran, 2012). Extreme weather patterns in ASALs areas in Kenya, combined with socio-economic vulnerabilities, make these regions particularly susceptible to the impacts of climate change (Opiyo et al., 2015; Kagunyu, 2014). Further, climate change is significantly increasing incidence of VBDs in the region, a phenomenon well-documented by various researchers (Onyango, 2021; Achola, 2021; Morris, 2022).

A vector is an organism (most often an arthropod) that transmits an infectious pathogen from an infected human or animal host to an uninfected human (Meena et al., 2019; Rocklöv &

Dubrow, 2020). According to World Health Organization (2017) the major global VBDs include malaria, dengue, chikungunya, yellow fever, Zika virus disease, lymphatic filariasis, schistosomiasis, onchocerciasis, Chagas disease, leishmaniasis and Japanese encephalitis. Other VBDs of regional importance include African trypanosomiasis, Lyme disease, tick-borne encephalitis and West Nile fever (Rocklöv & Dubrow, 2020). These diseases are caused by viruses, bacteria and parasites which are transmitted by vectors (Müller et al., 2019; Chala & Hamde, 2021). VBDs account for more than 17% of all infectious diseases, causing more than 700,000 deaths annually (Tozan, Branch & Rocklöv, 202; Ma et al., 2022; Khan et al., 2023). Major diseases such as malaria and dengue fever are associated with the largest burden, affecting millions of people worldwide (Shah et al., 2020; Mitra & Mawson, 2017).

Kenya, like many other regions, is largely affected by VBDs such as malaria, dengue fever and Rift Valley fever (Ondiba, 2018; Githeko, 2024; Blaylock et al., 2011). Climate change has been implicated in the changing patterns of these diseases, influencing the distribution and transmission dynamics of their respective vectors (Martens et al., 1995; Sutherst, 2004; Parham et al., 2015). For example, rising temperatures and altered rainfall patterns can create favorable breeding conditions for mosquitoes, leading to increased malaria transmission in previously non-endemic areas (Kimuyu, 2021). Similarly, changes in temperature and humidity impact the prevalence of other VBDs, such as Rift Valley fever, which is transmitted by mosquitoes and affects both humans and livestock (Bett, Lindahl & Delia, 2019). Malaria, a major health concern in these areas, is transmitted by Anopheles mosquitoes, and climate change is likely to expand the geographical range of these vectors, increasing the disease's incidence (Githeko et al., 2000). Additionally, diseases such as dengue fever, transmitted by Aedes mosquitoes, and Rift Valley fever, linked to heavy rainfall and flooding, are becoming more prevalent due to climate-induced changes in the environment (Anyamba et al., 2012). Leishmaniasis, spread by sandflies, is another vector-borne disease whose transmission dynamics are influenced by environmental changes affecting sandfly habitats (Tonui, 2006).

The transmission of VBDs requires an established vector population, a pathogen, and suitable environmental and climatic conditions (LaDeau et al., 2015). Climate change is expected to have the greatest impact on diseases such as dengue fever, West Nile fever, chikungunya, malaria, leishmaniasis, tick-borne encephalitis, Lyme disease, Crimean-Congo haemorrhagic fever, spotted fever rickettsioses, yellow fever, and Rift Valley fever (El-Sayed & Kamel, 2020; Baylis, 2017; World Health Organization, 2011; Medlock & Leach, 2015). Climate change can impact pathogens both directly and indirectly. Direct effects include alterations in the survival, reproduction, and life cycle of pathogens. Indirect effects involve changes in habitat, environment, and competition among pathogens, as well as modifications in human-pathogen and human-vector contact patterns (Chala & Hamde, 2021; Wu et al., 2016). Many parasitic, viral, and bacterial diseases respond to variations in the climate whether through their geographic distribution, seasonality, inter-annual variability, or temporal and spatial trends.

Diseases such as malaria, dengue fever, and Rift Valley fever are increasingly affecting populations in ASAL areas that have previously had limited exposure. Further, indirect effects such as changes in the ecosystem, water availability, and human migration patterns further exacerbate the spread and incidence of these diseases. The communities in these regions often lack the necessary resources and infrastructure to effectively combat the increasing prevalence of VBDs. Traditional knowledge and practices may not be sufficient to address the new challenges posed by climate change. Therefore, there is an urgent need to develop and implement community-based adaptation measures that can mitigate the impacts of these diseases. Therefore, this study evaluated Climate-Induced Vector Borne Diseases in Arid and Semi-Arid Regions in Kenya while focusing on impacts and community-based adaptation measures.

Methodology

Study area

The study was conducted ASAL areas in Kenya as indicated in figure 1. The main livelihood activities include pastoralism, agro-pastoralism, mixed farming, marginal mixed farming, and some irrigated cropping.

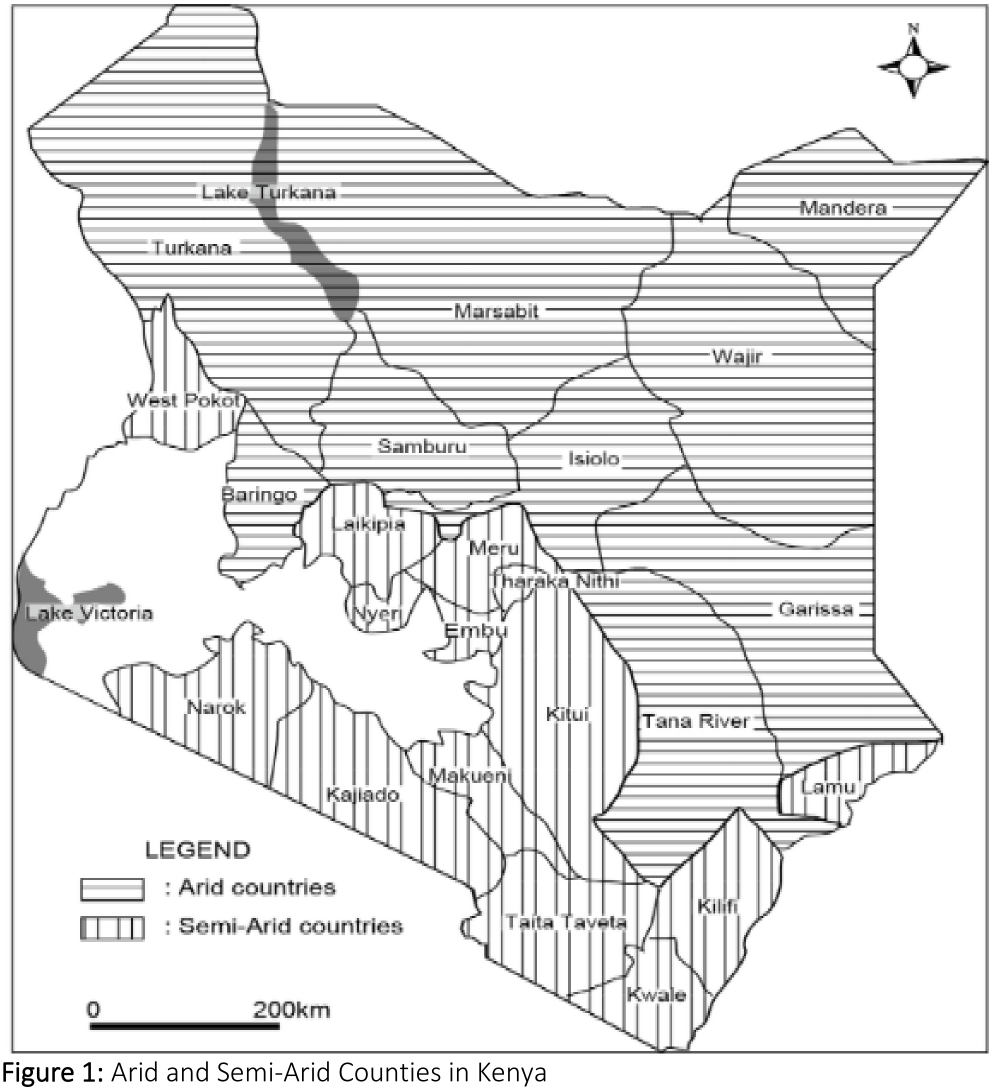

Figure 1: Arid and Semi-Arid Counties in Kenya
Source: *Nyanjom (2014)*

The study adopted a desktop literature review method. This involved an in-depth review of studies related to the impacts of climate variability on VBDs in arid and semi-arid regions (ASALs) of Kenya. The review process was conducted in three stages to ensure the relevance and quality of the selected literature. An initial search was performed to identify all articles related to the impacts of climate variability on VBDs in ASALs. The search included keywords in the article titles, abstracts, and keywords sections, focusing on terms such as "climate variability," "ASALs," and "infectious diseases." The second stage involved filtering the results to include only fully accessible publications. This step ensured specificity and allowed the researcher to concentrate on articles directly related to the impacts of climate variability on VBDs in ASALs. In the third stage, an in-depth search using the refined keywords led to the identification of four articles suitable for detailed analysis. Academia, Research Gate, African Journal Online, ScienceDirect, Scopus, PubMed, Google Scholar and Web of Science, were used to conduct an exhaustive bibliographic search for scientific and technical articles as well as government documents published between 2014 and 2024. Only empirical research with full-text availability published in peer-reviewed journals was included, excluding dissertations, conference proceedings, reviews, and commentary papers. The review considered all climate-related factors and health outcomes, without limitations on population or research methods, to comprehensively summarize the research progress. The findings from selected articles were analysed thematically.

Findings and discission

Malaria

Malaria remains one of the most pressing global health challenges, significantly impacting populations worldwide, particularly in tropical and subtropical regions. UNICEF (2023) reported 249 million malaria infections and 608,000 fatalities between 2020 and 2022. Some 76% of these fatalities were children under 5. In warm, humid climates, female Anopheles mosquitoes carry Plasmodium parasites that cause malaria (Townson, 2017; Tananchai et al., 2019; Msugh-Ter, Gbilekaa & Nyiutaha, 2014).

The African Region saw the highest malaria burden in 2022, accounting for 94% of worldwide cases and 95% of global fatalities. This translates to 233 million malaria cases and 580,000 deaths (WHO, 2022). Over 90% of all malaria deaths occur in Sub-Saharan Africa. The region's climate and socio-economic conditions create ideal breeding grounds for malaria vectors. The use of strategies such as insecticide-treated bed nets (ITNs), indoor residual spraying (IRS), and artemisinin-based combination treatments (ACTs) has led to a decline in both the occurrence and death rate of malaria in Africa within the last twenty years (Bhatt et al., 2015).

In Kenya, malaria is a major public health issue, with significant regional variation in transmission intensity (Kapesa et al., 2018). Several other studies in Kenya have shown that there is a resurgence of the malaria parasite despite the control measures that have been put in place (Chen et al., 2006; Zhou et al., 2011; Githeko et al., 2012). The country experiences four malaria epidemiological zones: endemic, epidemic-prone, seasonal, and low-risk areas (Wathondu, 2016). Approximately 70% of the inhabitants of Kenya is susceptible to malaria. Based on the Kenya Economic Survey (2023), malaria constituted the 2nd highest number of sickness cases, amounting to 11.7% in 2022. The endemic regions, particularly around Lake Victoria and the coastal areas, experience year-round transmission, whereas the ASALs have traditionally been considered low-risk areas due to their dry climate, which is less conducive to mosquito breeding (Snow et al., 1998). However, climate change is altering this dynamic, with increasing temperatures and changing precipitation patterns potentially transforming ASAL regions into more favorable environments for malaria vectors. Studies indicate that even slight increases in temperature and rainfall can lead to higher mosquito densities and extended transmission seasons in these typically dry areas (Githeko et al., 2000). For instance, Ototo et al. (2017) observed that malaria incidences in Kenya's ASAL regions are rising, attributed to anomalous weather patterns and increased human mobility, which facilitate the spread of both vectors and parasites. Higher temperatures (19°C-30°C) accelerate parasite and vector growth, whereas high temperatures (31°C-40°C) kill Anopheles mosquitoes. Temperature shortens the blood meal cycle (gonotrophic cycle). Minimum temperature increases influence cooler locations more (Githeko et al., 1996). Thus, a slight temperature increases from 19°C to 21°C shortens the gonotrophic cycle from 4 to 3 days and boosts mosquito vectoriality (Lindsay and Birley, 1996).

Historical malaria in Kenya was mostly documented in Western Kenya's lowlands near Lake Victoria and coastal regions. In other areas, malaria was unknown (Roberts, 1964; Malakooti et al., 1998). In the 1920s, malaria was first recorded in Rift valley. From 1941-1944, malaria outbreaks plagued the region into the 1950s. Insecticide residual spraying was used to minimise malaria cases. These controls kept malaria cases low into the 1980s. In 1901, increased land transport and railway from the Kenyan coast to the highlands to Lake Victoria caused these epidemic outbreaks (Shanks et al., 2005a). Increased land travel let affected individuals relocate from low-lying hyper-endemic-disease locations to the Rift valley highlands. Malaria outbreaks have plagued the East African Highlands since the late 1980s. North Kenya, an arid area, had a significant malaria outbreak during the 1997-8 El Niño owing to persistent floods. The same locations have acute Rift Valley Fever (Githeko, 2009).

Research conducted in ASAL areas of Kenya has highlighted the link between climate variability and the incidence of malaria. For example, a study by Githeko and others (2000) found that fluctuations in temperature and rainfall were associated with variations in malaria transmission rates in these regions. During periods of heavy rainfall, which can create stagnant water pools ideal for mosquito breeding, malaria cases tend to increase. Conversely, prolonged droughts can lead to water scarcity, reducing mosquito breeding sites but potentially driving humans and animals to congregate around remaining water sources, thereby increasing the risk of malaria transmission.

Arid and semi-arid parts of Central and North Eastern Kenya are classified under the seasonal malaria transmission areas. This is because short periods of intense malaria transmission are usually experienced in the rainy seasons. Baringo and Marsabit counties, are some of the counties that experience seasonal malaria transmission (National Malaria Control Programme, 2016). Morris (2022) reported a significant number of cases in the arid and semi-arid regions of Northern Kenya, specifically in the counties of Garissa, Mandera, and Baringo. This increase could be attributed to climate change, particularly the rise in temperature due to prolonged drought. Kipruto et al. (2017) found that malaria transmission in these arid and semi-arid regions, such as Baringo County, is seasonal and often influenced by climatic factors. They identified two malaria peak seasons in the lowland zone and three in other zones, which largely follow the climatic seasons in the study area. Other research conducted in ASAL areas of Kenya has also highlighted the link between climate variability and the incidence of malaria (Amadi, 2018; Nyagechanga, 2020; Odhiambo, 2013).

The impact of climate change on malaria in ASAL areas of Kenya is compounded by socio-economic factors. Communities in these regions often have limited access to healthcare services, inadequate housing, and poor sanitation, which further exacerbate the risk of malaria transmission (Mutero et al., 2004). Moreover, poverty and food insecurity can force individuals to engage in activities that increase their exposure to malaria vectors, such as working in fields or sleeping outdoors, particularly during periods of intense heat.

Rift Valley Fever

The Rift Valley Fever (RVF) first emerged in Kenya's Rift Valley in 1912. Since 2007, most instances have been documented in the north-eastern area, starting in Baringo County (Ondiba, 2018; Nanyingi, 2018). RVF epidemics occur irregularly every 5-15 years (Sumaye, 2019). Flooding induced by heavy rainfall and mosquito populations rising causes epidemics (Sang et al., 2017). RVF a viral zoonotic illness that mostly affects cattle, affects population health and economic stability in Africa's Rift Valley. The Phlebovirus genus spreads to humans by contact with infected animals or mosquito bites, especially Aedes and Culex species causing febrile illness, hemorrhagic fever, and in severe cases, encephalitis or death (WHO, 2020). In addition, RVF outbreaks often have devastating consequences for livestock populations, resulting in high mortality rates among animals such as sheep, goats, cattle, and camels (Kasye et al., 2016).

Studies have demonstrated that climate variability, including changes in temperature and rainfall, affects the prevalence and transmission dynamics of RVF in these regions. Research in the ASAL areas of Kenya has shown a connection between climatic factors and RVF outbreaks. For example, heavy rainfall and flooding, which create ideal breeding conditions for mosquitoes, are often followed by increased RVF activity (Anyamba et al., 2012). During these periods, the virus can quickly spread among livestock herds, leading to extensive transmission to humans through mosquito bites or contact with infected animal tissues. Conversely, drought periods following heavy rainfall can also contribute to RVF outbreaks by concentrating susceptible hosts around scarce water sources, thereby enhancing virus transmission (Anyamba et al., 2012).

Njenga, Akoko, and Mulwa (2023) reported that Isiolo County, located in the arid and semi-arid region of Kenya, is facing an increase in diseases such as yellow fever, malaria, dengue, and Rift Valley fever due to rising global temperatures and erratic rainfall. For instance, there was a rise in yellow fever cases between February and March 2022, following intense rains earlier in the year. Additionally, the county experienced multiple Rift Valley fever outbreaks from December 2020 to January 2021, particularly affecting low-lying regions along the Ewaso Nyiro river basin, which are prone to flooding and favorable for mosquito breeding. Kenyan authorities issued an alert for Rift Valley fever (RVF) on January 24, 2024, after a human case was confirmed in Marsabit County, prompting preparations in neighboring Isiolo County (Njenga & Slator, 2024). This outbreak is linked to the end of El Niño rains, which have caused a surge in the mosquito population and increased transmission of vector-borne diseases (VBDs). Other studies have linked climate change and RVF increased incidence in ASALs areas in Kenya (Nafula et al., 2023; Ondiba, 2018).

The impact of climate change on RVF in ASAL areas of Kenya extends beyond direct environmental influences to encompass socio-economic factors. Livestock farming is a major livelihood activity in these regions, and RVF outbreaks have significant economic consequences due to livestock losses and trade restrictions imposed to prevent the spread of the disease (Anyamba et al., 2012). For instance, in Kenya during 1997, within a span of just three months, around 90,000 individuals fell ill, resulting in nearly 500 fatalities. Additionally, Kenyan livestock keepers suffered significant losses, with approximately 70% of their sheep and goats and 20–30% of their cattle and camels perishing. Furthermore, the country encountered agricultural difficulties as several nations imposed stringent bans on livestock imports. (Rogers, 2022). The disease poses a considerable risk to the country's agricultural sector, which heavily relies on livestock for food security and livelihoods. The impact of RVF extends beyond the immediate health implications, affecting trade, tourism, and food security in affected regions. Efforts to control RVF in Kenya include surveillance and early detection of outbreaks, vaccination campaigns for livestock, vector control measures, and public health education to raise awareness about RVF transmission and prevention (Lichoti et al., 2014).

Yellow Fever

Yellow fever (YF) is a viral acute hemorrhagic illness caused by infected mosquitoes of the flavivirus family (Uwishema, et al., 2022). Yellow Fever virus is endemic in parts of sub-Saharan Africa and South America, where outbreaks occur periodically, posing risks to unvaccinated populations (Uchenna Emeribe et al., 2021). In Africa, the disease is transmitted primarily by Aedes mosquitoes, with urban outbreaks often linked to the Aedes aegypti vector (Agha et al., 2022). Outbreaks can spread rapidly, fueled by factors such as urbanization, deforestation, and population movement. Despite the availability of a safe and highly effective vaccine, yellow fever vaccination coverage remains inadequate in many at-risk African countries, leaving populations vulnerable to outbreaks (WHO, 2021).

In Kenya, the first yellow fever outbreak in Kenya was in 1992. Similar outbreaks were recorded in the western part of the country in 1993, 1995, and 2011, particularly in the Rift Valley province of Kenya (Uwishema, et al., 2022). ASAL regions in Kenya, characterized by low and erratic rainfall, high temperatures, and sparse vegetation, provide suitable ecological conditions for the proliferation of mosquitoes, particularly Aedes species, which are vectors for yellow fever virus transmission. Changes in climatic factors, such as temperature and rainfall patterns, can directly impact mosquito abundance, behavior, and distribution, thereby influencing the risk of yellow fever transmission in these areas (Patz et al., 2005).

Research suggests that climate variability plays a significant role in shaping the epidemiology of yellow fever in ASAL areas of Kenya. Fluctuations in temperature and rainfall can create favorable conditions for mosquito breeding and survival, leading to increases in vector populations and disease transmission. For instance, periods of heavy rainfall followed by warm temperatures may stimulate mosquito breeding, resulting in higher vector densities and elevated transmission rates of yellow fever virus (Patz et al., 2005). Conversely, drought conditions can lead to the formation of stagnant water bodies, providing additional breeding sites for mosquitoes and further amplifying the risk of yellow fever transmission. In 2022, the viral acute illness resurfaced and hit Kenya killing at least six people (Uwishema, et al., 2022). The first reports of the illnesses originated in Merti Sub County, which is located inside Isiolo County. The sub-County is situated in the northern region of Isiolo, next to Wajir, Marsabit, and Samburu counties. It is also bordered by Garbatulla Sub County to the south. Both sub-counties, Merti and Garbatulla, are inhabited by people of Cushitic descent whose livelihoods rely on pastoralism. The Cherrab ward often has unpredictable rainfall patterns and a prolonged dry season. In December 2021, the region saw typical levels of precipitation, resulting in a surge in the mosquito population. This rise in mosquitoes may have played a role in the increased incidence of fever episodes (IRFC, 2022).

The impact of climate-induced yellow fever cases in ASAL areas of Kenya is compounded by socio-economic factors. Limited access to healthcare services, inadequate housing, and poor sanitation in these regions exacerbate the vulnerability of communities to VBDs. ASAL populations often face challenges in accessing yellow fever vaccination due to logistical barriers and low awareness of the disease. Moreover, poverty and food insecurity can force individuals to engage in activities that increase their exposure to mosquito bites, such as outdoor work or sleeping in unprotected areas, further heightening the risk of yellow fever transmission (Mutero et al., 2004).

Chikungunya

Chikungunyais an acute febrile illness caused by an arthropod-borne alphavirus (Staples, Breiman & Powers, 2009). The virus is primarily transmitted to humans via the bite of an infected *Aedes* species mosquito. This viral disease was first described during an outbreak in southern Tanzania in 1952, where it derived its name from the Makonde language. ‘Chikungunya’ means ‘that which bends up’, which describes the stooped walking posture of sufferers with joint pain (arthralgia). Chikungunya is characterised by an abrupt onset of fever, often accompanied by severe joint pain. The joint pain is often very incapacitating and unbearable, but usually lasts for a few days or may be prolonged to weeks.

Chikungunya is a viral infection transmitted to people by mosquito bites, much like dengue and Zika viruses (Patterson, Sammon & Garg, 2016; Silva Jr et al., 2018; Shanmugaraj, Malla & Ramalingam, 2019). This disease was first documented during an epidemic in the southern region of Tanzania in 1952, and it acquired its name from the Makonde language (Ritz, Hufnagel, & Gérardin, 2015). The term 'Chikungunya' refers to the bent posture seen in those experiencing joint discomfort (arthralgia). Chikungunya is defined by a sudden beginning of fever, often accompanied by intense joint discomfort. The pain in the joints may be very debilitating and intolerable, but often subsides after a few days or may last for many weeks (Ntagereka, 2015).

Chikungunya resurfaced in Kenya in 2004 and then moved towards the east, resulting in millions of cases of the illness across many countries (Staples, Breiman & Powers, 2009). Climate change influences the distribution and activity of mosquito vectors, potentially expanding the geographical range of chikungunya transmission in ASAL regions. A Chikungunya epidemic has been observed in North Eastern Kenya. The Ministry of Health recorded 777 instances of the illness in Mandera between May and early June 2016, but no fatalities. Chikungunya has been found in over 60 Asian, African, European, and American nations. Mid-February 2022 saw the first occurrences in Kotulo, Wajir County. According to the Ministry of Health fast assessment report, 23 suspected case samples were collected and analysed at KEMRI Nairobi laboratory between February 10 and 24. Five of these samples proved positive for Chikungunya. The latest epidemic in mid-2016 began in Mandera and expanded to other counties, including Mombasa, between late 2017 and mid-2018. A Chikungunya fever outbreak occurred in Mombasa. Even if no instances are reported in Mandera or Mombassa, Wajir's county is nearby. From past outbreaks, 58% of cases are female and most are between 2-33 years old (IRFC, 2022). The impact of chikungunya in ASAL areas is compounded by factors such as poverty, food insecurity, and population displacement, which increase the vulnerability of communities to VBDs (Nanyingi et al., 2015).

Dengue

Dengue, carried by mosquitoes and family Flaviviridae, class Flavivirus, is common in tropical and subtropical regions (Senthilkumar, 2015). The most established sickness may have been originally described in a Chinese clinical reference book in 992 (Evelyn Angel, 2015). The illness became tolerable during the rise of global transportation and port cities in the 18th and 19th centuries. The slave trade may have carried dengue virus to the Americas via infected African slaves, according to later investigations. Most dengue cases occurred in 2023, impacting approximately 80 countries in all WHO regions. Since 2023, continued transmission and an unexpected surge in dengue infections have led to a record 6.5 million illnesses and nearly 7300 dengue-related fatalities (WHO, 2024). The disease is now endemic in more than 100 countries in the WHO Regions of Africa, the Americas, the Eastern Mediterranean, South-East Asia and the Western Pacific. The Americas, South-East Asia and Western Pacific regions are the most seriously affected, with Asia representing around 70% of the global disease burden (WHO, 2024).

Climate change is associated with the increasing risk of spread of the dengue epidemic. Dengue cases emerged in Kenya in early March 2021, with 24 out of 47 (51% positivity rate) recorded by the Mombasa County health department. Another 305 of 315 cases tested positive in April (97%). The nearby Lamu county has recorded 224 positive cases from health institutions, including 59 children under 5. In January, February, March, and April, 553 instances were recorded, peaking in April. No fatalities have been recorded in the two counties. (WorldAid (2021).

The virus is widespread in the counties of Kwale, Kilifi, Mandera, Lamu, Taita-Taveta, and Mombasa in Kenya. Dengue virus outbreaks have been recurrent since 2004, with the most recent one taking place in 2017. The incidence of Dengue virus among feverish patients in Mombasa County was found to be 41% based on an epidemiological investigation that used IgM as a marker (Mulakoli et al., 2024).

Conclusion and recommendation

As climate change continues to alter environmental conditions, these ASALs regions are becoming increasingly vulnerable to diseases transmitted by vectors such as mosquitoes, ticks, and flies which causes malaria, dengue, chikungunya Rifty Valley Fever and yellow fever. The convergence of factors such as rising temperatures, changing precipitation patterns, and ecological disruptions creates favorable conditions for vector proliferation and disease transmission. The consequences of climate-induced VBDs extend beyond public health, affecting livelihoods, food security, and economic development in ASAL communities. Malaria, dengue fever, Rift Valley fever, and other VBDs impose a heavy burden on already marginalized populations, exacerbating existing socio-economic disparities and hindering progress towards sustainable development goals. Without effective intervention, the cycle of poverty and disease in ASAL regions is likely to perpetuate, further compromising the well-being of vulnerable populations. Enhancing the capacity of healthcare facilities and infrastructure in arid and semi-arid regions is key. Also, continuous education of communities to improve their knowledge on VBDs causes, symptoms, risk factors and prevention should be carried out by the public health and veterinary departments in collaboration with relevant stakeholders.

References

Achola, J. Y. (2021). *Assessing Sustainability of Pastoralism Under a Changing Climate in Kajiado County, Kenya* (Doctoral dissertation, University of Nairobi).

Agha, S. B., Tchouassi, D. P., Turell, M. J., Bastos, A. D., & Sang, R. (2022). Risk assessment of urban yellow fever virus transmission in Kenya: is Aedes aegypti an efficient vector?. *Emerging Microbes & Infections*, *11*(1), 1272-1280.

Amadi, J. A. (2018). *Effects of climate variability on ecohydrological conditions and their influence on malaria risk in Baringo County, Kenya* (Doctoral dissertation).

Anyamba, A., Linthicum, K. J., Small, J., Britch, S. C., & Tucker, C. J. (2012). Remote sensing contributions to prediction and risk assessment of natural disasters caused by large-scale Rift Valley fever outbreaks. *Proceedings of the IEEE*, *100*(10), 2824-2834.

Baylis, M. (2017). Potential impact of climate change on emerging vector-borne and other infections in the UK. *Environmental Health*, *16*, 45-51.

Bett, B., Lindahl, J., & Delia, G. (2019). Climate change and infectious livestock diseases: the case of rift valley fever and tick-borne diseases. *The Climate-Smart Agriculture Papers: Investigating the Business of a Productive, Resilient and Low Emission Future*, 29-37.

Blaylock, J. M., Maranich, A., Bauer, K., Nyakoe, N., Waitumbi, J., Martinez, L. J., & Lynch, J. (2011). The seroprevalence and seroincidence of dengue virus infection in western Kenya. *Travel medicine and infectious disease*, *9*(5), 246-248.

Chala, B., & Hamde, F. (2021). Emerging and re-emerging vector-borne infectious diseases and the challenges for control: a review. *Frontiers in public health*, *9*, 715759.

El-Sayed, A., & Kamel, M. (2020). Climatic changes and their role in emergence and re-emergence of diseases. *Environmental Science and Pollution Research*, *27*(18), 22336-22352.

Evelyn Angel, S. (2015). *Dengue: A Clinicohaematological Profile and Role of Platelet Transfusion in its Management* (Doctoral dissertation, Sree Mookambika Institute of Medical Sciences, Kulasekharam).

Githeko, A. K. (2009). Malaria and climate change: special feature. In *Commonwealth health ministers' update 2009*. Commonwealth Secretariat: Pro-Brook Publishing, GB.

Githeko, A. K. (2024). Responding to Climate Change in the Health Sector, Kenya. In *Climate Change and Human Health Scenarios: International Case Studies* (pp. 303-316). Cham: Springer Nature Switzerland.

Ignareki, D. D., Dadji, G. A. F., Baudelaire, E. N., Dicko, A., Younoussa, L., Wangrawa, D. W., ... & Fomena, A. Adulticidal Activities and Synergistic Effects of Citrus Aurantiifolia Peels and Hyptis spicigera Leaves Essential Oils against Anopheles gambiae sl (Diptera: Culicidae).

IRFC (2022). Kenya: Integrated Vector Borne Diseases Outbreak - Emergency Plan of

Action (EPoA) DREF n° MDRKE050. https://reliefweb.int/report/kenya/kenya-integrated-vector-borne-diseases-outbreak-emergency-plan-action-epoa-dref-n

Kagunyu, A. W. (2014). *Effects of climate variability on the livelihoods and coping strategies of the Borana community in Isiolo county, Northern Kenya* (Doctoral dissertation, University of Nairobi).

Kalele, D. N., Ogara, W. O., Oludhe, C., & Onono, J. O. (2021). Climate change impacts and relevance of smallholder farmers' response in arid and semi-arid lands in Kenya. *Scientific African*, *12*, e00814.

Kapesa, A., Kweka, E. J., Atieli, H., Afrane, Y. A., Kamugisha, E., Lee, M. C., ... & Yan, G. (2018). The current malaria morbidity and mortality in different transmission settings in Western Kenya. *PloS one*, *13*(8), e0202031.

Kasye, M., Teshome, D., Abiye, A., & Eshetu, A. (2016). A Review on Rift Valley Fever on Animal, Human Health and its Impact on Live Stock Marketing. *Austin Virol. Retrovirol*, *3*, 1020.

Khan, A., Yasin, M., Aqueel, M. A., Farooqi, M. A., Akram, M. I., Yousuf, H. M. B., ... & Maqsood, A. (2023). Vector-Borne Disease and Climate Change. In *Arthropods-New Advances and Perspectives*. IntechOpen.

Kimuyu, J. S. (2021). Comparative spatial–temporal analysis and predictive modeling of climate change-induced malaria vectors' invasion in new hotspots in Kenya. *SN Applied Sciences*, *3*(8), 741.

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*, 1-11.

Koech, G., Makokha, G. O., & Mundia, C. N. (2020). Climate change vulnerability assessment using a GIS modelling approach in ASAL ecosystem: a case study of Upper Ewaso Nyiro basin, Kenya. *Modeling Earth Systems and Environment*, *6*(1), 479-498.

LaDeau, S. L., Allan, B. F., Leisnham, P. T., & Levy, M. Z. (2015). The ecological foundations of transmission potential and vector-borne disease in urban landscapes. *Functional ecology*, *29*(7), 889-901.

Lemenih, E. M. (2011). Production, Value Addition And Marketing Of Non-Wood Forest Products (Nwfps) From Arid And Semi Arid Lands (Asals) Of Ethiopia. *Addis Ababa: ICPALD*.

Ma, J., Guo, Y., Gao, J., Tang, H., Xu, K., Liu, Q., & Xu, L. (2022). Climate change drives the transmission and spread of vector-borne diseases: An ecological perspective. *Biology*, *11*(11), 1628.

Mabhuye, E., Yanda, P., Maganga, F., Liwenga, E., Kateka, A., Henku, A., ... & Bavo, C. (2015). *natural capital endowments and dynamics of the changing climate in arid and semi-arid lands (ASALs): experiences from Africa and Asia*. PRISE working paper. http://prise. odi. org/wp-content/uploads/2015/12/Low-Resolution_Natural-capital-endowment-and-dynamics-of-thechanging-climate-in-ASALs. pdf.

Marigi, S. N. (2019). Hydrology and best practices for managing water resources in arid and semi-arid lands in Kenya. In *Hydrology and Water Resources Management in Arid, Semi-Arid, and Tropical Regions* (pp. 229-250). IGI Global.

Martens, W. J. M., Jetten, T. H., Rotmans, J., & Niessen, L. W. (1995). Climate change and VBDs: a global modelling perspective. *Global environmental change*, *5*(3), 195-209.

Medlock, J. M., & Leach, S. A. (2015). Effect of climate change on vector-borne disease risk in the UK. *The Lancet Infectious Diseases*, *15*(6), 721-730.

Meena, M., Swapnil, P., Barupal, T., & Sharma, K. (2019). A review on infectious pathogens and mode of transmission. *J. Plant Pathol. Microbiol*, *10*, 472.

Mitra, A. K., & Mawson, A. R. (2017). Neglected tropical diseases: epidemiology and global burden. *Tropical medicine and infectious disease*, *2*(3), 36.

Morris, M. J. (2022). *Spatial Modelling of Malaria Prevalence in Kenya* (Doctoral dissertation).

Msugh-Ter, M. M., Gbilekaa, V. C., & Nyiutaha, I. G. (2014). Sporozoite infection rates of female Anopheline mosquitoes in Makurdi, an endemic area for malaria in central Nigeria. *International Journal of Entomological Research*, *2*(2), 103-115.

Mulakoli, F., Gachara, G., Ndombi, E., & Khamadi, S. (2024). Prevalence of Dengue virus among healthy blood donors in Mombasa County, Kenya. *PAMJ-One Health*, *13*(6), 1.

Müller, R., Reuss, F., Kendrovski, V., & Montag, D. (2019). Vector-borne diseases. *Biodiversity and health in the face of climate change*, 67-90.

Nafula, P. K., Opiyo, T., Ndiao, E., & Dancea, L. (2023). Effects Of Climate Change and Variability On Pastoral Communities In Kenya. *Research Journal of Agricultural Science*, *55*, 4.

Nanyingi, M. O. (2018). *Spatial epidemiology and predictive modelling of Rift valley fever in Garissa County, Kenya* (Doctoral dissertation, University of Nairobi).

Njenga G. & Slator A., (April, 2024). Building resilience: Community-led response to Rift Valley fever in Isiolo County, Kenya. ILRI. https://www.ilri.org/news/building-resilience-community-led-response-rift-valley-fever-isiolo-county-kenya

Njenga L. G., Akoko J., & Mulwa F., (2023). Climate change, mosquitoes and disease: Battling a lethal trio in northern Kenya. ILRI. https://www.ilri.org/news/climate-change-mosquitoes-and-disease-battling-lethal-trio-northern-kenya

Njoka, J. T., Yanda, P., Maganga, F., Liwenga, E., Kateka, A., Henku, A., ... & Bavo, C. (2016). Kenya: Country situation assessment. *Pathways to Resilience in Semi-arid Economies (PRISE)*.

Ntagereka, P. B. (2015). *Mosquito abundance and molecular detection of arboviruses in Kyela district, Tanzania* (Doctoral dissertation, Sokoine University of Agriculture.).

Nyagechanga, O. E. (2020). *The Impact Of Climatic Variability And Malaria Control Interventions On Malaria Parasite Prevalence And Vector Abundance In Western Kenya* (Doctoral dissertation, KENYATTA UNIVERSITY).

Nyanjom, O. (2014). Remarginalising Kenyan pastoralists: the hidden curse of national growth and development. *African study monographs. Supplementary issue.*, *50*, 43-72.

Odhiambo, S. O. (2013). *Effects of Variability of Selected Climatic Elements on Malaria Prevalence in Awendo Division, Rongo District, Migori County, Kenya* (Doctoral dissertation, Kenyatta University).

Omosa, E., Bett, B., & Kiage, B. (2022). Climate change and Rift Valley fever disease outbreak: implications for the food environment of pastoralists. *The Lancet Planetary Health*, *6*, S17.

Ondiba, I. M. (2018). *Impact of Seasonal Changes on Malaria and Rift Valley Fever Vector Ecology and Infection Status in Baringo County, Kenya* (Doctoral dissertation, University of Nairobi).

Onyango, K. B. (2021). Climate Variability Effects On Vector-Borne Livestock Diseases In Narok South Sub-County, Narok County, Kenya.

Otolo, J. R. A., & Wakhungu, J. W. (2013). Factors influencing livelihood zonation in Kenya. *International Journal of Education and Research*, *1*(12), 1-10.

Ouma, J. O., Olang, L. O., Ouma, G. O., Oludhe, C., Ogallo, L., & Artan, G. (2018). Magnitudes of climate variability and changes over the arid and semi-arid lands of Kenya between 1961 and 2013 period. *American Journal of Climate Change*, *7*(01), 27.

Owino, E. A. (2018). Aedes spp. mosquitoes and emerging neglected diseases of Kenya.

Oyas, H., Holmstrom, L., Kemunto, N. P., Muturi, M., Mwatondo, A., Osoro, E., ... & Njenga, M. K. (2018). Enhanced surveillance for Rift Valley Fever in livestock during El Niño rains and threat of RVF outbreak, Kenya, 2015-2016. *PLoS neglected tropical diseases*, *12*(4), e0006353.

Parham, P. E., Waldock, J., Christophides, G. K., Hemming, D., Agusto, F., Evans, K. J., ... & Michael, E. (2015). Climate, environmental and socio-economic change: weighing up the balance in vector-borne disease transmission. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1665), 20130551.

Patterson, J., Sammon, M., & Garg, M. (2016). Dengue, Zika and chikungunya: emerging arboviruses in the New World. *Western Journal of Emergency Medicine*, *17*(6), 671.

Rashid, H. H. (2014). *Land Use Conflicts and opportunities in a Livestock Market: Case study of Garissa Market* (Doctoral dissertation).

Ritz, N., Hufnagel, M., & Gérardin, P. (2015). Chikungunya in children. *The Pediatric infectious disease journal*, *34*(7), 789-791.

Rocklöv, J., & Dubrow, R. (2020). Climate change: an enduring challenge for vector-borne disease prevention and control. *Nature immunology*, *21*(5), 479-483.

Rogers J., (October, 2022). Rift Valley fever: What's next for the climate-driven disease with epidemic potential?. https://cepi.net/rift-valley-fever-whats-next-climate-driven-disease-epidemic-potential

Sang, R., Lutomiah, J., Said, M., Makio, A., Koka, H., Koskei, E., ... & Bett, B. (2017). Effects of irrigation and rainfall on the population dynamics of Rift Valley fever and other arbovirus mosquito vectors in the epidemic-prone Tana River County, Kenya.

Journal of medical entomology, *54*(2), 460-470.

Sax, N., Santa Cruz, L. M., Carneiro, B., Liebig, T., Läderach, P., & Pacillo, G. (2022). How does climate exacerbate root causes of livestock-related conflicts in Kenya? An impact pathway analysis. *Climate Security Observatory Series*.

Schilling, J., Opiyo, F. E., & Scheffran, J. (2012). Raiding pastoral livelihoods: motives and effects of violent conflict in north-western Kenya. *Pastoralism: Research, Policy and Practice*, *2*, 1-16.

Senthilkumar, V. (2015). *Epidemiological Analysis of Flavivirus Infections in Tamil Nadu with Specific Reference to Japanese Encephalitis, Dengue and West Nile Viruses. Development of a Novel Detection System* (Doctoral dissertation, King Institute of Preventive Medicine & Research, Chennai).

Shah, S., Abbas, G., Riaz, N., ur Rehman, A., Hanif, M., & Rasool, M. F. (2020). Burden of communicable diseases and cost of illness: Asia pacific region. *Expert review of pharmacoeconomics & outcomes research*, *20*(4), 343-354.

Shanmugaraj, B., Malla, A., & Ramalingam, S. (2019). Epidemiology, clinical features and transmission of re-emerging arboviral infection chikungunya. *Asian Pacific Journal of Tropical Biomedicine*, *9*(4), 135-139.

Silva Jr, J. V., Ludwig-Begall, L. F., de Oliveira-Filho, E. F., Oliveira, R. A., Durães-Carvalho, R., Lopes, T. R., ... & Gil, L. H. (2018). A scoping review of Chikungunya virus infection: epidemiology, clinical characteristics, viral co-circulation complications, and control. *Acta tropica*, *188*, 213-224.

Staples, J. E., Breiman, R. F., & Powers, A. M. (2009). Chikungunya fever: an epidemiological review of a re-emerging infectious disease. *Clinical infectious diseases*, *49*(6), 942-948.

Sultana M., Sheikh N., Mahumud R.A., Jahir T., Islam Z., Sarker A.R. Prevalence and associated determinants of malaria parasites among Kenyan children. Trop. Med. Health. 2017;45:25

Sumaye, R. D. (2019). Epidemiology of the inter-epidemic Rift Valley fever transmission of the kilombera valley, Tanzania.

Sutherst, R. W. (2004). Global change and human vulnerability to vector-borne diseases. *Clinical microbiology reviews*, *17*(1), 136-173.

Tananchai, C., Pattanakul, M., Nararak, J., Sinou, V., Manguin, S., & Chareonviriyaphap, T. (2019). Diversity and biting patterns of Anopheles species in a malaria endemic area, Umphang Valley, Tak Province, western Thailand. *Acta tropica*, *190*, 183-192.

Townson, H. (2017). The anopheles vector. In *Essential Malariology, 4Ed* (pp. 59-84). CRC Press.

Tozan, Y., Branch, O. L. H., & Rocklöv, J. (2021). Vector-borne diseases in a changing climate and world. *Climate Change and Global Public Health*, 253-271.

Uchenna Emeribe, A., Nasir Abdullahi, I., OR Ajagbe, O., Egede Ugwu, C., Oloche Onoja, S., Dahiru Abubakar, S., ... & Oyewusi, S. (2021). Incidence, drivers and global health implications of the 2019/2020 yellow fever sporadic outbreaks in Sub-Saharan Africa. *Pathogens and Disease*, *79*(4), ftab017.

Uwishema, O., Eneh, S. C., Chiburoma, A. G., Elhassan, W. A. F., Adekunle, A. A. R., Rogose, M. S., ... & Onyeaka, H. (2022). Yellow fever outbreak in Kenya: A review. *Annals of Medicine and Surgery*, *82*.

Wathondu, R. G. (2016). *Assessment of knowledge on Malaria epidemic monitoring indicators Among health care providers in Greater Nyando sub-counties* (Doctoral dissertation, Maseno University).

WHO (April. 2024). Dengue and severe dengue. https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue

World Health Organization (2017) *Global Vector Control Response 2017–2030*

World Health Organization. (2011). Climate change and communicable diseases: a manual for health workers.

WorldAid (2021). Dengue Outbreak. https://www.worldsaid.com/node/745

Wu, X., Lu, Y., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment international*, *86*, 14-23.