



Infectious Diseases and Climate Change in Morocco

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Abstract

Climate change has emerged as a significant threat to ecosystems, exerting both direct and indirect impacts on human and animal health. The alterations in climate patterns disrupt the distribution, abundance, and spatial dynamics of vector species and reservoirs, consequently disturbing the balance of ecosystem composition and the reproductive cycles of vectors and reservoirs.

The impact of climate change exacerbates the burden of infectious diseases, affecting different populations unequally. Morocco serves as an example of the severe dangers that climate change and inadequate adaptation pose to human health, as evidenced by available data from past decades. Morocco should engage with the United Nations Framework Convention on Climate Change and develop plans and projects that aim to mitigate, counter, and prevent the devastating health impacts of climate change nationwide.

Keywords: Climate change; Infectious disease; Morocco-Africa

Introduction

Climate change has emerged as a significant threat to ecosystems, exerting both direct and indirect impacts on human and animal health. The alterations in climate patterns disrupt the distribution, abundance, and spatial dynamics of vector species and reservoirs, consequently disturbing the balance of ecosystem composition and the reproductive cycles of vectors and reservoirs. Additionally, climate change acts as a driving force for the adaptation and selection of pathogens, including viruses, bacteria, and parasites, favouring populations that are better suited to the changing environmental conditions [1]. From a Moroccan standpoint, climate change poses substantial health vulnerabilities. These include the reactivation risk of climate-sensitive diseases like malaria, bilharzia, typhoid, leishmaniasis, dengue, and cholera. Furthermore, there is a possibility of the re-emergence of infectious diseases, particularly vector-borne diseases, along with an increased incidence of diseases and fatalities associated with extreme weather events. Vulnerable groups are particularly susceptible to these risks, which also contribute to the rise of water and foodborne illnesses [2].

The environmental modifications resulting from climate change have a profound influence on vector and reservoir populations, consequently altering the epidemiology of diseases. While certain species that serve as potential vectors or reservoirs may decline or disappear, others may experience population increases. Moreover, the behavioural patterns and geographical ranges of migrating host species are subject to modification due to changing environmental conditions linked to climate change. Consequently, the distribution and prevalence of vector-borne diseases such as leishmaniasis and malaria, as well as waterborne diseases like schistosomiasis, are expected to be impacted. Despite their hidden nature, these neglected diseases continue to inflict significant harm on populations worldwide [2]. In Morocco, infectious diseases such as leishmaniasis, malaria, and schistosomiasis continue to pose public health challenges, and the impact of climate change on these diseases adds complexity to the situation, despite the implementation of a national program to combat parasitic diseases. These diseases are currently designated as federally reportable, and the number of reported cases, both indigenous and imported, is on the rise. According to the Moroccan Ministry of Health, between 2005 and 2014, 2,086

Received date: 07 June 2023; **Accepted date:** 14 June 2023; **Published date:** 21 June 2023

Citation: Addi RA, Benksim A, Cherkaoui M (2023) Infectious Diseases and Climate Change in Morocco. SunText Rev Case Rep Image 4(4): 187.

DOI: <https://doi.org/10.51737/2766-4589.2023.087>

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cases of malaria were imported into the country [3]. The risk of indigenous malaria resurgence is significant in Morocco due to the potential presence of carriers of malaria gametocytes in the last known malaria focus [4]. The spatial distribution and incidence of leishmaniasis in Morocco exhibit notable variations, with an increase in the number of recorded cases in recent years [5]. The Moroccan Ministry of Health reported a total of 43,163 cases of leishmaniasis (41,867 cases of cutaneous leishmaniasis (CL) and 1,296 cases of visceral leishmaniasis) between 2005 and 2014 [3]. Schistosomiasis, which has significant health impacts and socioeconomic consequences in developing countries, recorded 39 cases in Morocco between 2005 and 2014 [3]. The emergence, re-emergence, outbreaks, spatial distribution limits, and seasonal activity of these diseases remain sensitive to climate factors, as well as the local disease control capacity. This paper aims to identify vector-borne diseases highly sensitive to climate change in Morocco, assess the risks of their re-emergence in vulnerable regions, and emphasize the urgent need for a better understanding of the dynamics of these diseases, particularly in a context with limited and uncertain scientific evidence on the health vulnerability to climate change. It also highlights the challenges associated with health adaptation to climate change and evaluates Morocco's adaptive capacity from a health perspective.

Eco-Epidemiological Context of Parasitic Diseases in Morocco

Parasitic diseases pose a significant public health challenge in Morocco. The transmission and spread of these diseases are closely linked to various risk factors, including climatic, ecological, and socioeconomic factors, as well as other factors such as urbanization and agricultural practices. These factors extend beyond the traditional scope of influence of health authorities. The impact of climate change further exacerbates the burden of these diseases, affecting different populations unequally [6]. Among the most vulnerable populations, the ability to effectively address these challenges and adapt to changing conditions is limited. This creates a specific case of vulnerability, particularly in relation to the emergence of vector-borne diseases such as leishmaniasis, malaria, and schistosomiasis. Given the life-threatening nature of most of these diseases, it is crucial to adopt an eco-epidemiological approach to understand and address each disease. This approach involves studying and understanding the habitats of reservoirs of infection, identifying the micro-niches of arthropod/insect vectors, and comprehending the life cycle of each disease. By gaining insights into these ecological and epidemiological aspects, it becomes possible to develop targeted strategies for disease control and prevention.

Leishmaniasis

Leishmaniasis is a complex disease caused by various species of the *Leishmania* parasite and transmitted by phlebotomine sand flies. In Morocco, three parasite species coexist, namely *Leishmania infantum*, *Leishmania major*, and *Leishmania tropica* [7]. *Leishmania infantum* is the main species responsible for both zoonotic visceral leishmaniasis (ZVL) and anthroponotic cutaneous leishmaniasis (ACL) in Morocco. It is primarily transmitted by sand fly species belonging to the subgenus *Larrousius*. *L. infantum* is widespread throughout the country, with higher frequency observed in the northern regions [8]. *Leishmania major* is the causative agent of zoonotic cutaneous leishmaniasis (ZCL) in Morocco, and it is transmitted by *Phlebotomus papatasi*, a sand fly species found in the pre-Saharan area [9]. *Leishmania tropica*, another species found in Morocco, is responsible for anthroponotic cutaneous leishmaniasis (ACL). It is widespread in the northern and central areas of the country, particularly in semi-arid regions. The sand fly vector associated with *L. tropica* transmission is *Phlebotomus sergenti*. The reservoir hosts for zoonotic forms of leishmaniasis in Morocco are primarily dogs for ZVL and rodents for ZCL, while humans serve as the reservoir for anthroponotic cutaneous leishmaniasis (ACL). It is important to note that the epidemiology of leishmaniasis in Morocco is dynamic, and the distribution and prevalence of different species may vary over time. Ongoing surveillance and research efforts are essential to monitor and understand the eco-epidemiological dynamics of leishmaniasis in the country.

Malaria

Malaria is an infectious disease caused by parasitic protozoans of the *Plasmodium* genus, including *Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium ovale*, and *Plasmodium falciparum*. It is transmitted by female mosquito vectors of the *Anopheles* species. The transmission cycle of *Plasmodium* involves several stages that occur between mosquitoes and humans [10]. Historically, malaria has been endemic in Morocco for centuries, affecting the majority of provinces. In 1960, a domestic program was initiated to combat the disease, leading to significant progress after a challenging 40-year battle. By 1999, malaria was limited to sporadic cases of *Plasmodium vivax* in residual foci in the northern regions. The efforts of the Moroccan Ministry of Health resulted in a shift towards the elimination of indigenous cases, and the last indigenous case was reported in 2004. Morocco has been certified as malaria-free by the World Health Organization, but imported cases continue to be reported [8].

In Morocco, the main vector of malaria is *Anopheles labranchiae*. Similar to leishmaniasis, female mosquitoes bite humans to obtain a blood meal before laying eggs. *Anopheles labranchiae* exhibits high vectorial capacity during the summer season, which

coincides with rice cultivation periods in northern Morocco. The north-central area of the country is considered a high-risk region for malaria transmission, as reported by the Moroccan Ministry of Health. Risk of malaria resurgence in Morocco remains a concern due to the possible presence of parasites in human and invertebrate hosts within the last malaria foci, the continuous occurrence of imported cases, and the presence of the primary malaria vector in the country.

Schistosomiasis

Schistosomiasis is a parasitic disease caused by trematode worms belonging to the genus *Schistosoma*, including *Schistosoma haematobium*, *Schistosoma mansoni*, *Schistosoma japonicum*, and *Schistosoma intercalatum*. The parasite undergoes successive development stages in both mollusk and human hosts. It is commonly found in freshwater habitats such as ponds, streams, and irrigation canals, where it infects freshwater mollusks and subsequently enters humans through skin contact with contaminated water [9]. In Morocco, schistosomiasis has been prevalent in the oases in the south and along the southern side of the Atlas Mountains. The majority of reported cases have been documented in provinces such as Tata, Chtouka, Taroudant, and Errachidia. In recent years, some *Schistosoma haematobium* foci have been found to be unstable or even disappeared. However, the development of large-scale water supply systems for irrigation purposes may lead to the emergence of new foci [10]. Despite the implementation of monitoring programs and adequate healthcare services, cases of malaria, leishmaniasis, and schistosomiasis are still recorded in Morocco. Indigenous cases of leishmaniasis are more frequently reported, while all malaria cases are imported. The occurrence of indigenous schistosomiasis cases is rare and often associated with the introduction of new species through travellers or immigrants from countries where the disease is endemic [11].

These diseases pose significant social challenges in Morocco, particularly affecting the poor and individuals living in vulnerable housing and environmental conditions. The economic burden, loss of income, and healthcare expenses further exacerbate the socioeconomic situation of disadvantaged households. The rapid urban population growth and expansion contribute to the increased demand for community facilities, access to clean water, sanitation, and environmental preservation [12]. The vulnerability of populations to these disease risks varies based on various factors such as environmental changes, economic development dynamics, social capital, demographics, and population structure. Understanding the complex interactions between human health and the environment requires adopting an ecosystem approach that integrates economic and environmental determinants of health and addresses community needs [13].

Climate Change Impacts on Infectious Diseases in Morocco

Anthropogenic climate change can directly impact the behaviour and geographical distribution of mosquito vectors and the lifecycle of parasites, potentially altering the incidence of diseases such as leishmaniasis and malaria. Additionally, climate change can indirectly influence disease transmission by affecting environmental factors like climate variables, soil pH, and the availability of breeding sites. The socioeconomic factors, including poverty and economic degradation, can exacerbate the impacts of climate change on water resources, agriculture, and biodiversity, ecosystems, and food and health security. In the case of leishmaniasis, the epidemiological situation has undergone significant changes in Morocco over the past decade, with an increasing number of cases and geographic expansion to previously unaffected areas. Leishmaniasis has two main forms in Morocco: zoonotic *Leishmania major* cutaneous leishmaniasis (ZCL) and *Leishmania tropica* anthroponotic cutaneous leishmaniasis (ACL). ZCL has been spreading to several provinces in Southeast Morocco, while ACL has a widespread distribution. The lifecycle of leishmaniasis, including the parasite, reservoirs, and vectors, is influenced by environmental changes, and weather and climate variables play a crucial role in disease incidence [14].

Malaria is another disease that is sensitive to climate factors, and its distribution and seasonal activity are influenced by climate change. Temperature and rainfall are key abiotic factors affecting malaria transmission, and climate change can potentially increase the incidence of malaria in South America and Africa. Studies have shown associations between malaria cases and rainfall and temperature patterns in various regions, emphasizing the impact of climate on disease dynamics [15]. The transmission and incidence of schistosomiasis, caused by the *Schistosoma* parasite, can also be influenced by climate change. Global warming and changes in the hydrologic cycle and water availability can affect the distribution of the disease. Aquatic snails of the genus *Bulinus* serve as intermediate hosts for *Schistosoma haematobium* in Africa and the Eastern Mediterranean. Water resource development projects, particularly irrigation schemes, can contribute to the introduction and spread of schistosomiasis. In Morocco, disease foci have been linked to hydrologic programs for irrigation in certain provinces [16]. It is important to note that the potential impact of climate change on the transmission of diseases like schistosomiasis and malaria should be considered within the context of ecological, demographic, and socioeconomic changes. Despite the significance of these issues, research on the relationship between climate change and malaria or schistosomiasis in Morocco remains limited.

The Morocco's Adaptation

Human health is increasingly being linked to climate change, especially in areas with vulnerable populations. However, there are significant disparities in adaptive capacity and response strategies across different nations and states. Developing countries, in particular, often lack the necessary resources and infrastructure to effectively respond to climate-related health risks [17]. Morocco serves as an example of the severe dangers that climate change and inadequate adaptation pose to human health, as evidenced by available data from past decades. To effectively manage the multiple threats to human health, a well-defined and flexible governance system is essential. This system should target socioeconomic and environmental health factors, including nutrition, financial stability, and access to education. In Morocco's case, specific actions should involve reforming legal and policy responses to health and environmental challenges, promoting human rights related to health and the environment, developing regional climate-health strategies, prioritizing the climate-health nexus in social and human sciences, facilitating collaboration between policymakers, health experts, and climate specialists, and ensuring active engagement of civil society actors in health policy-making. Furthermore, Morocco's climate change adaptation efforts in relation to health should focus on several key elements. These include equitable allocation of financial and human resources across regions, the establishment of a robust and effective national health infrastructure that ensures equal access in urban and rural areas, the promotion of good health governance through appropriate management strategies, reforming health institutions, prioritizing primary healthcare, implementing compulsory medical coverage, and investing in healthcare professions. To achieve these goals, Morocco should engage with the United Nations Framework Convention on Climate Change and develop plans and projects that aim to mitigate, counter, and prevent the devastating health impacts of climate change nationwide.

Conflict of Interest Statement

We declare that we have no conflict of interest.

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