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Infectious diseases and climate: Case of Morocco

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ABSTRACT

It is predicted that the life cycle, incidence and spread of several infectious diseases will be increasingly and adversely affected by climate change. Morocco, designated as an area of significant impact by numerous reports of Intergovernmental Panel on Climate Change, is notably susceptible to such drastic climate-related health consequences. The present work thus examines the increasing risk of vector-borne diseases in hazard-prone localities, while also highlights the current lack of dedicated scientific research in this critical area. It further identifies the severe challenges both of health adaptation to climate change and of consequent policy responses, before providing a more detailed overview of Morocco's adaptive capacity to such crises.

1. Introduction

Climate change is affecting ecosystems and may have direct or indirect effects on human and animal health. This change affects the distribution and abundance as well as the spatial dynamics of vector species and reservoirs, which in turn disrupts ecosystem composition, vector and reservoir reproduction cycles. Climate change also acts on viruses, bacteria or parasites pathogens, forcing a selection of populations better adapted to environmental conditions[1].

Within a Moroccan perspective, the main health vulnerabilities to climate change include the following: risk of reactivation of certain diseases sensitive to climate change, such as malaria, bilharzia, typhoid, leishmaniasis, dengue and cholera; possibility of reemergence of infectious diseases, vector-borne diseases as well as diseases and deaths related to extreme weather events, especially among the most vulnerable groups and increased water and food-borne diseases.

Changing environmental conditions caused by climate change often have an enormous influence on vector and reservoir populations and consequently, on the epidemiology of disease. While some species of potential vector and reservoir may disappear, others may become more abundant. Changing environmental conditions, linked to climate change, also modify the behavior and areas inhabited by migrating host species. In this context, climate change is expected to affect the distribution and prevalence of vector-borne diseases such as leishmaniasis and malaria, as well as waterborne diseases such as schistosomiasis. These neglected diseases still ravage lives covertly in the world[2].

In Morocco, infectious diseases such leishmaniasis, malaria and schistosomiasis are still a public health problem and the situation may be more complicated in light of climate change despite the adoption of a domestic program to fight against these parasitic diseases. Currently, they are a federally reportable disease and the number of reported cases -indigenous and -imported is increasing.

According to the Moroccan Ministry of Health, 2 086 cases of malaria were imported between 2005 and 2014[3]. The risk of autochthonous malaria resumption is important in Morocco because of the possible presence of gametocytes carriers in the last malaria focus[4].

Leishmaniasis in Morocco shows significant variations in its spatial distribution and forms with an increase in the number of recorded cases during the last couple of years[5]. A total of 43 163 cases of

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leishmaniasis (41 867 cases of cutaneous leishmaniasis (CL) and 1 296 cases of visceral leishmaniasis) were recorded between 2005 and 2014 by Moroccan Ministry of Health[3].

While schistosomiasis has major health impacts and socio-economic consequences in developing countries and 39 cases were reported in Morocco between 2005 and 2014[3].

For all these diseases, the emergence, reemergence, outbreak, spatial limits of their distribution and the seasonal activity remain sensitive to climate factors, as well as to the control capacity of local disease.

This paper aims to identify vector-borne diseases that are highly sensitive to climate change in Morocco, the risks of their reemergence in vulnerable regions, highlights the pressing need to understand the dynamics of these diseases, especially in a context marked by limited and uncertain scientific evidence regarding the health vulnerability to climate change, underlines the problematic aspects of health adaptation to climate change and finally undertakes an assessment of Morocco's adaptive capacity within a health perspective.

2. Eco-epidemiological context of parasitic diseases in Morocco

In Morocco, parasitic diseases pose a public health challenge. Their spread is very closely tied to risk factors (climatic, ecological, and socioeconomic) and other factors, such as urbanization and agricultural practices, beyond health authorities' traditional sphere of influence. Climate change is imposing a burden that is unevenly distributed across populations. The most vulnerable populations are in worse positions to effectively face these challenges to the extent that they have a limited ability to adapt to changing conditions. Therefore, a particular case of vulnerability in this context is the emergence of vector-borne-diseases (leishmaniasis, malaria and schistosomiasis). In view of life threatening nature of most of these diseases, there is need for understanding having eco-epidemiological approach in respect of each disease with emphasis on habitats of reservoirs of infection, micro niche of arthropod/insect vectors and understanding life cycle of each disease.

2.1. Leishmaniasis

Leishmaniasis is a complex disease caused by *Leishmania* species and transmitted by a phlebotomine sand fly (Diptera: Psychodidae). Two forms are known, cutaneous and visceral leishmaniasis. The main reservoirs are dogs for zoonotic visceral leishmaniasis (ZVL), rodents for zoonotic cutaneous leishmaniasis (ZCL) and human for anthroponotic cutaneous leishmaniasis (ACL)[5,6].

Actually, three parasite species co-exist in Morocco. *Leishmania infantum* causes mainly ZVL and is transmitted by species of the subgenus *Larroussius*. It is widespread in the whole country and is more frequent in its northern part[5,7]. *Leishmania infantum* can cause CL as well even if it is a rare condition with a few sporadic cases in the North of the country (especially in Sidi Kacem Province) with little epidemiological data available[6]. *Leishmania major* causes ZCL with *Phlebotomus papatasi* as the vector in pre-Saharan area and *Leishmania tropica*, causative agent of ACL is widespread in northern and central areas, especially in semi-arid regions with *Phlebotomus sergenti* as the vector[1,5,8].

2.2. Malaria

Malaria is a mosquito-borne infectious disease caused by

parasitic protozoans of the genus *Plasmodium* (*Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium ovale* and *Plasmodium falciparum*) and is transmitted by female mosquito vectors of the *Anopheles* species. The cycle of *Plasmodium* is carried out in several stages which spread between mosquitoes and humans.

Malaria raged in Morocco for centuries and was an endemic disease in the majority of provinces. In 1960, a domestic program to fight the disease was launched. It allowed to control the situation after 40 years of bitter struggle. By 1999, malaria was occurring as sporadic cases of *Plasmodium vivax* in some residual foci in the north. The epidemiological assessment undertaken by the Moroccan Ministry of Health showed a shift towards the elimination of indigenous cases and the last indigenous case was reported in 2004. Malaria is now certified free in Morocco by World Health Organization but imported cases are reported constantly.

In Morocco, *Anopheles labranchiae* is the main vector of malaria. In common with leishmaniasis, it is the female vector that bites people when it needs a blood meal before laying eggs. The vectorial capacity of *Anopheles labranchiae* is considerably high during the summer which corresponds to the rice cultivation period in Northern Morocco[4]. The north center area is a high risk of transmission reported by Moroccan Ministry of Health[9,10].

The risk of malaria resurgence in Morocco is higher because of the possible presence of parasite in human and invertebrate hosts in the last malaria foci, numerous imported cases and the presence of the main vector of malaria in Morocco.

2.3. Schistosomiasis

Schistosomiasis is a disease caused by parasitic worms belonging to the class of trematodes and genus *Schistosoma* [*Schistosoma haematobium* (*S. haematobium*), *Schistosoma mansoni*, *Schistosoma japonicum* and *Schistosoma intercalatum*]. The parasite develops successively in two hosts: mollusk and human. This parasite is commonly found in ponds, streams and irrigation canals, housed in freshwater mollusks, and infests humans through the skin via contact with contaminated water.

In Morocco, the disease had spread in the oases in the south and along the southern side of the Atlas. The majority of cases have been filed in the Province of Tata, Chtouka, Taroudant, and Errachidia[11]. In recent years, many *S. haematobium* foci are proved to be unstable and some even disappeared. However, creating large water supply for irrigation may lead to the onset of new foci.

Despite the existence of monitoring programs and adequate health services, cases of malaria, leishmaniasis and schistosomiasis are still recorded in Morocco. As shown in Table 1, leishmaniasis is the most reported disease and all cases are indigenous. In contrast, all malaria cases are imported. For schistosomiasis, the number of indigenous cases is rarely associated with the risk of introduction of new species, which is linked to travelers or immigrants from countries where these species are endemic.

These diseases constitute a real social problem in Morocco because they disproportionately affect the poor, particularly those in vulnerable housing and environmental conditions. Loss of income and healthcare costs exacerbate the economic situation of already-disadvantaged households[12]. Urban population growth, responsible for the spatial expansion of cities, creates enormous need for community facilities and equipment related to decent housing, access to clean water and sanitation and environmental preservation. The vulnerability of populations to these disease risks varies across spatial and temporal scales in response to environmental change, economic development dynamics, social capital, demographics and population structure. Understanding

Table 1

Annual evolution of parasitic diseases in Morocco between 2005–2014[3].

Parasitic diseases	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Malaria (imported cases)	100	83	100	142	145	218	312	364	314	308
Schistosomiasis	13	4	8	2*	2*	1*	5 (3 ^o)	0	3	1
Leishmaniasis	ZVL	114	170	160	163	134	139	107	111	85
	ACL	865	1 197	1 938	1 697	1 611	2 263	2 100	2 055	2 081
	ZCL	2 174	2 164	1 352	3 431	4 402	6 444	2 219	740	460

*: Imported cases.

the interactions between human health and the environment is quite complex. In fact, the very term environment can be confusing because it is used in various acceptances. The ecosystem approach to human health is distinguished from traditional approaches by integrating all determinants of health, namely economic and environmental factors and community needs.

3. Climate change impacts on infectious diseases - Morocco case

Anthropogenic climate change may directly affect the behavior and geographical distribution of mosquito vectors and the lifecycle of the parasite, and thus change the incidence of the disease. Indirectly, climate change could also have various effects by influencing environmental factors such as climate variables, soil PH and the availability of breeding sites[13].

As the climate has an important influence on environmental and socio-economic components, the juxtaposition of many of socio-economic factors *e.g.*, poverty, economic degradation over time may convincingly increase as result to climate change. This change could, depending on the region, have adverse impacts on water resources, agriculture, biodiversity, ecosystems, food and health security.

A wide range of infectious diseases may change their geographic range, seasonality and incidence due to climate change, but there is still limited and uncertain scientific evidence about the extent of health vulnerability to climate change. For example, over the past decade, the epidemiological situation of CL has changed significantly. It is acquiring an increasingly epidemic status with geographic expansion to previously free areas and the emergence of new foci in several provinces of Morocco. A total of 24 804 cases of zoonotic *Leishmania major* CL and 16 852 cases of *Leishmania tropica* anthroponotic CL were recorded between 2004 and 2013 in Morocco[6]. ZCL acquires an increasingly epidemic status with geographic expansion into previously free areas in several provinces of South-East Morocco[12]. Whereas, ACL has an extensive geographical distribution[6].

The leishmaniasis lifecycle, parasite-reservoir-vector, evolves depending on geographic regions and is sensitive to environmental changes that can affect the parasite, the reservoir and the vector, as well as their dynamic interaction and territorial expansion[1]. Seasonal patterns and the correlation between the vector density and the number of cases have been documented[1]. Weather and climate variables also play an important role in leishmaniasis incidence as they can constrain or exacerbate favorable conditions for the disease, such as an acceleration of the development of the parasite or synergistic changes in reservoir and vector populations that cause an explosion in the vector population. For example, increase in precipitation may increase the vegetation foliage, and thus the number and quality of breeding sites for both rodents and sandflies[1].

Distribution and seasonal activity of malaria are also sensitive to climate factors and impact the local capacity to control the disease. Malaria is one of the few climate-sensitive diseases that has been modeled by many research groups, which facilitates a thorough

assessment of possible climate change effects using a multi-model inter-comparison[14]. The distribution and population dynamics of malaria are probably more governed by abiotic than biotic factors. Of the possible abiotic influences on the transmission cycle of malaria, temperature and rainfall are the most important; therefore the situation could be exacerbated by climate change. Although this linkage is still uncertain, an increase in the incidence of malaria has been identified as a potential impact of climate change in South America and Africa[15,16]. Climatic factors that feed into the phenomenon could have a direct bearing on the number of malaria cases. Actually, a number of studies have reported the association between malaria cases, rainfall and temperature[17]. For example, a study carried out in Ethiopia revealed an association of malaria with rainfall and minimum temperature and the strength of which varied with altitude[18]. In South Africa, variations in annual cases of malaria were shown to be related to rainfall and temperature patterns[19].

According to McCreesh and Booth, climate change will inevitably influence both the distribution of *Schistosoma* sp. and incidence of schistosomiasis in areas where it is currently endemic[20]. Global warming is expected to be accompanied by perturbations in the global hydrologic cycle, precipitation levels and pronounced changes in water availability[21,22]. However, only a few attempts have been made to predict changes in the spatial distribution of schistosomiasis due to global warming[13]. Thus, the nature and extent of climate change on the transmission of schistosomiasis remain poorly understood[23]. The lack of research in this field probably explains why climate change implications for schistosomiasis control and elimination have been largely ignored[24].

Snails of the genus *Bulinus* serve as the intermediate hosts of *S. haematobium* in Africa and the Eastern Mediterranean[2]. These aquatic snails breed in waters (barrages, irrigation canals...), contaminated with infected faeces or urine from infected person or by infected wastewater, was also used for irrigation. Water resources development schemes in certain areas, particularly irrigation schemes, can contribute to the introduction and spread of schistosomiasis. Consequently, intermediate hosts can determine the geographical area of schistosomiasis risk. In Morocco, the disease foci, especially in Beni Mellal, El Kelaa and Nador Provinces were linked to hydrologic programs for irrigation (barrages and irrigation canals and wells) in the 1970s[11].

Potential impact of climate change on the transmission of schistosomiasis and other diseases must be juxtaposed to profound ecological, demographic and socioeconomic changes. Also, it should be mentioned that in Morocco, there is no study that addresses the relationship between malaria or schistosomiasis and climate change.

4. The climate-health nexus: Morocco's adaptation potential and opportunities for action

Human health is ever-increasingly linked to climate change, particularly in areas with vulnerable populations. Adaptive capacity

in relation to this current and ongoing emergency is far from uniform, with wide disparities in strategy and response across and even within nations and states. In particular, developing countries rarely benefit from the expert knowledge, resources and infrastructure needed appropriately and efficiently to respond to climate-related health risks. Morocco's case is an object lesson in the grave dangers of climate change and inadequate adaptation pose to human health. During past decades, relevant data indicate the clear consequences in public health among other vital sectors[2,9].

In order to manage the ensuing and numerous threats to human health, an adequately defined yet flexible governance system must be devised. This will necessarily involve effective targeting of socio-economic and environmental health factors, including nutrition, level of financial stability, access to education, etc. In Morocco's case however, specific and targeted actions should include the reform of legal and policy responses to health and environmental challenges; the promotion of human rights in relation to health and the environment; the development of regional climate-health strategies; the prioritization within social and human sciences of the climate-health nexus; the bringing together of policy makers with health and climate specialists and the fostering of full civil society actor engagement in health policy making and enactment.

Moreover, Morocco's climate change adaptation in relation to health should concentrate on the following elements: adequate and equitable financial and human resource allocation across the regions; a robust and effective health infrastructure at the national level which simultaneously safeguards urban-rural equality of access and distribution; the promotion of good health governance through suitable management strategies; health institution reform and the prioritization of primary healthcare, compulsory medical coverage and investment in healthcare professions. In order to fulfil these criteria, Morocco should approach the United Nations Framework Convention on Climate Change with plans and projects which seek to mitigate, counter and where possible prevent the devastating health impact of climate change nationwide.

Conflict of interest statement

We declare that we have no conflict of interest.

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