

Will climate change cause a geographical expansion of Dengue in Mediterranean Europe?

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Abstract. As the climate changes a lot of concerns take places in the scientific world, especially the ones regarding global health. The possibility of a Dengue geographical expansion is real as the environment changes drastically, although its intensity and range depends on how damaging the change is becoming. Mediterranean Europe is one of the most suitable and probable places for the disease expansion, once it was already a carrier of Dengue infection cases before its eradication in the beginning of the 20th century. Now scientists wonder about the virus being re-introduced as the temperatures slowly suits its biological demandings for surviving and adapting. The outbreak that happened in the Madeira island in 2012 is a proof of how *Aedes* mosquitos populations are spreading around those lands. The virus, however, is believed to be brought mainly with travelers coming from endemic countries, as the flow of people and products became more intense and fast with globalisation. The climate approach was focused on the comparison of past, current and future temperature of Mediterranean countries. The results obtained were mostly correlated to seasonality, this meaning that the projections point to a rise of vulnerability during the summer time, independly of the intensity of future climates yet its expansion clearly depends on it.

Keywords. Dengue, *Aedes albopictus*, *Aedes aegypti*, Mediterranean Europe, dengue expansion, climate change, rising temperature.

1. Introduction

As it is well known, Dengue is a global widespread arbovirus disease caused by four serotypes of the DENV virus (DENV-1, DENV-2, DENV-3 and DENV-4) [1], transmitted by different mosquitos species depending on climate and geographic location variables. There are two mosquitos in special that are mostly associated with Dengue epidemics, along with some others when carrying different viruses (yellow fever, chikungunya, zika, etc.). The *Aedes aegypti* mosquito, originally from west Africa, is by far the one that causes more Dengue outbreaks around the world, especially among tropical and subtropical urban areas, causing more damage once affects a bigger amount of people. Furthermore, coming from southeast Asia, the *Aedes albopictus* is the second most important mosquito related to Dengue, causing frequent epidemics in subtropical peripheral areas [2].

It is a known fact that Dengue's report is associated with climate and temperature, together with many other aspects of an environment and society, such as

socio-economic conditions, control measures, warning systems, public health care, urban and peri-urban flows and structure, humidity, precipitation, seasonality and so on [3]. As the climate becomes more unstable and changeable, the worries about an unpredictable and fragile global environment grows, especially regarding global health. Because Dengue is directly related to the climate system, is important to wonder about its future progress in the world, not only within the areas it already exists but also its expansion throughout areas that, with a possible change of climate variables, will become suitable for its survival and reproduction.

Bhatt et al. (2013) estimates that approximately 390 million people gets infected with Dengue's virus per year, which is three times more than the World Health Organization (WHO) estimates at their 2012 Global Strategy data [3]. Along with the effect of globalisation (mostly rapid types of flows and exchange such as turistic travels by airplanes and importation/exportation through shipping), the climate and temperature changes can cause a significant grow of infections and mosquitos

populations, that are able to easily adapt to different environments and natural disturbances [3]. Therefore, it is predictable that the percentage of people with risk of infection by 2050 increases between 8% to 12%, depending on the climate change alone. When combined with population growth and rise of underdeveloped social conditions, the percentage of people living under risk of Dengue increases up to 127% to 134%.

This paper aims to analyze the probability and projections for Dengue expansion throughout Mediterranean Europe, since studies already shows that this is the most likely part of the continent to be affected by the virus, because of how close its seasonal climate can get to a tropical and subtropical climate, especially if rising. The main approach that will lead this review is based on a climatological analyzes of the viruses transmission and spread of *Aedes* mosquitos. Despite considering the fact that others aspects already cited are as important as the climate when it comes to the progress and impact of Dengue, which makes them correlated and dependent of each other.

2. Dengue's historical records in Europe

2.1 Past-19th century

The possible future presence of Dengue in Europe and especially Southern Europe wouldn't be news to those lands, considering that until the 1930s some frequent outbreaks happend across the countries, proving that this climate itself can be suitable for dengue dissemination if not prevented. Researchs are not able to go back in those early days regarding Dengue records, seeing that before the end of the 18th century it was not even recognised as a proper disease [2]. Therefore, it is estimated that it was regularly mistaken by other viruses diseases, like chikungunya, once their respective symptoms are very similar [2].

Studies made by the WHO points that during the 18th and 19th century many Dengue epidemics happened around Europe, more expressly in the Mediterranean's port cities (of Spain, Portugal, Italy, Greece, Turkey, etc.) where the main flow of people and products were concentrated [2]. Reports indicates that those epidemics happened mostly because *Aedes aegypti* was imported from South American and Asian countries.

2.2 20th century

The first three decades of the 20th century were crucial to the current development of Dengue in Europe. Some small outbreaks were happening throughout the continent but the biggest epidemic event that lead to a major concern between governments was the outbreak of 1927-1928 in the territories of Greece and Turkey, affecting approximately 1 million people, among them 90% of Athens's habitants, resulting in up to 1500 deaths [2].

This ongoing situation lead to an "international convention for mutual protection against dengue fever" between 13 mediterranean countries in 1935 [2], what seemed to have worked, once the disease was eradicated up until the beginning of the 21st century.

Although no epidemics or serious cases of Dengue were reported after the agreement, some sporadically cases of infections happend between 1960 and 2001, indicating the presence of small populations of some *Aedes* mosquitos. The reported cases were: one in Italy (1972), one in Israel (1974) and five in Turkey (1961, 1984, 1992, 1993, 2001) [2].

2.3 21st century

Dengue's reappearance in the southern part of the continent makes scientists wonder how related is the climate change with the new presence of a disease that was already overcome, since the temperature and other climate variables tend to behave differently over the years.

Only two decades of this century have passed and a concerning amount of dengue reports have been filled, including a major outbreak in the autonomous archipelago of Madeira, Portugal, that is located in the Atlantic Ocean on the same latitude as the northwest coast of Africa [4].

Other cases not as meaningful were reported in France and Croatia, besides the reports of *Aedes* population rising in Europe, which can be seen by the chikungunya outbreak in Italy (2007) and surveillance records of small populations on the Black Sea and Mediterranean coast [2]. Their reentrance in Europe most likely comes with the dynamic of turistic traveling, either by local europeans that get infected in endemic countries or by turistics from tropical and subtropical countries that visit the continent. See Fig. 1 for historical reports for *Aedes aegypti*'s presence in Europe.

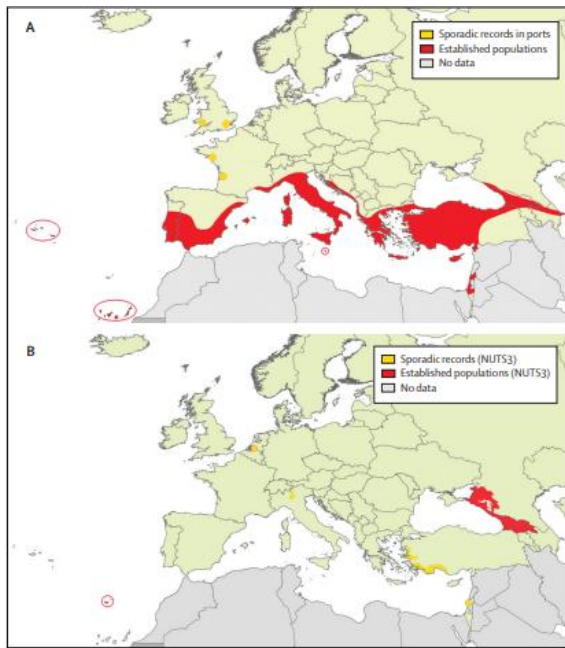


Fig. 1 – “Distribution of *Aedes aegypti* in the WHO European region.” (Schaffner F., Mathis A., 2014). A being the mosquito’s distribution up until 1960 and B being its current distribution [2].

3. Madeira’s outbreak

So far, the first and only Dengue outbreak to happen in Europe since its eradication was the 2012-2013 event in Madeira, Portugal in which more than 2100 people got infected on the island [4]. The importance of this case to this study is such that it can possibly represent the start of Dengue’s significant re-introduction in the continent [5].

The very first cases of infection reported were during october of 2012, while the last ones were reported in march of 2013, even though the *Aedes aegypti* has been established since 2005 [4]. As for the climate background, according to Santos et al. (2004) the island is under the influence of a temperate mediterranean climate with not many temperature variation all year-round, well distributed precipitation controlled by topography (rugged volcanic terrain with various high peaks and deep ravines), in which is noticeable the difference between the amount of precipitation on both higher and lower lands, varying between 2000-3500 and 500-2000 mm per year, respectively. Several meteorological stations around the island were analyzed during the 20th century, leading to a result that shows the temperature steadily increasing from the 1970s [6].

A study made by Wilder-Smith et al. (2014) with the intentions of tracing the insertion of the virus in the island resulted in a bigger probability of importation through travelers from either Venezuela, Brazil or Colombia, respectively. The dengue virus DENV-1 sequence apointed to a higher proximity with serotypes frequently found in South America, as well as the analyze of the amount of flights coming from

endemic countries [4].

4. Projections of new risks

Liu-Helmersson et al (2016) studied the new Dengue epidemic potential (DEP) in Europe by “using vectorial capacity with increased range of climate scenarios and temporal resolution”, while focusing on 10 different europeans cities [7, p. 2]. It is known that *Aedes aegypti* can currently be found in the Black Sea and Madeira, meanwhile *Aedes albopictus* is spread throughout the Mediterranean and expanding to the northern part of the continent, as it can also be found in the Netherlands and France [2].

Another conclusion reached by some studies is that in current and future Europe the *Aedes* mosquitos potential is completely dependent on seasonality. That can be also a fact to tropical and subtropical countries, once Dengue epidemics are more common during summer, mostly for the higher temperatures and precipitation indices. However, as the annual temperature varies significantly more in temperate climates, so will the projections for future Dengue epidemics in Mediterranean Europe according to seasonality. The authors criated maps based on monthly temperatures where they compare the vectorial capacity of the two main kinds of *Aedes* mosquitos within different seasons of Europe. During the period of 2006-2015 (Fig. 2), it shows the higher vectorial capacity of *Aedes aegypti* as being approximately 0,6/day and *Aedes albopictus* as being 0,4/day in most parts of Mediterranean lands during summer, with extremily low or even zero capacity during other seasons of the year. This means that, according to those datas, some parts of Southern Europe is currently able to sustain seasonal epidemics [7].

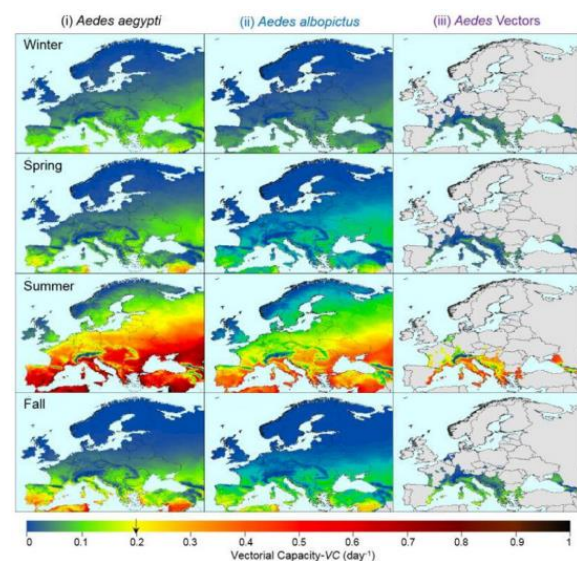


Fig. 2 – “Season stratified maps of VC for Europe for *Ae. aegypti* (i), *Ae. albopictus* (ii), and in those areas having recently established and/or introduced *Aedes* vectors (iii) (European Centre for Disease Prevention and Control (ECDC), 2015; Wilder-Smith et al., 2014b).” [7]

As for the a projection map now according to projected climate change (Fig. 3), a map with two different conceivable scenarios was created for the last decade of the 21st century: (i and iv) if the greenhouse gas emission was under RCP2.6; (i and iii) and the greenhouse gas emission under RCP8.5, two of some evaluations made by scientists on how will the climate behave in the next decades of this century.

Fig. 3 shows that under any of those scenarios (and consequently any scenario in between), the probability of *Aedes* expansion in Europe is almost certain. For the RCP2.6, it is estimated that *Aedes aegypti* have a capacity of around 0.9/day during summer. Not less important is the fact that the capacity during fall and spring got elevated, meaning that there would be potential for Dengue cases during those seasons. On the other hand, *Aedes albopictus* showed less intensity or expansion during summer, even if its capacity got higher than before.

As for the RCP8.5, the map shows, for both mosquitos, an expressly expansion around the continent, reaching even the northern countries where a medium vectorial capacity is estimated. *Aedes aegypti* shows to be stronger, wider and more resilient, being also the one that carries the responsibility of affecting and reaching more people in the whole continent. However, only in the Mediterranean territory that would be suitable for its survival also during fall and spring.

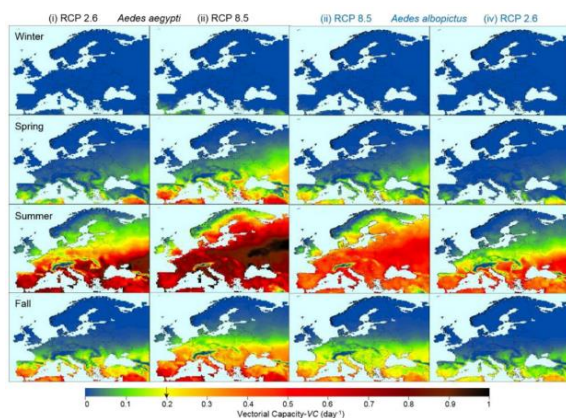


Fig 3 – “Season stratified maps of VC for Europe of the last decade of this century (2090–2099) under the greenhouse gas emission pathways RCP2.6 (i & iv) and RCP8.5 (ii & iii) for two *Aedes* vectors.” [7]

5. Discussion

By the climate dynamic point of view, results show that Dengue is most likely to become a concern in Mediterranean Europe in the close future as temperatures and other climate variables tend to change. As observed in Liu-Helmersson et al. (2016) study, with a rise of greenhouse gas emission the risk of geographical suitable areas for the development and reproduction of *Aedes* mosquitos will increase. This is not only a scientific hypothesis based on data and statistics but it is already being proved to be an

alarming problem once it is being re-introduced in the continent by different ways. The Madeira outbreak is important as it shows that even small populations of *Aedes* can be dangerous and evaluate to something bigger, like an outbreak or possible epidemics. Differently from other endemic countries, the main characteristic noticed about Dengue projections in Mediterranean Europe is the seasonality influence on the disease, once the low temperature months can stop or harm *Aedes* lifecycle development, consequently the risk of infections during European winters are nearly zero. On the other hand, there are many aspects avoiding those extreme situations in the continent, that plays a role as important as the climate impact.

Unfortunately there are still no cures or specific treatments for Dengue but for a very long time now scientists have been trying to develop vaccines since so many tropical countries suffer annually and at times all year-round with this disease. The closest thing to a solution is prevention and control of the vector by public health, public policies, warning systems and, of course, studies about the mosquitos lifecycle and transmission.

6. Conclusions

Dengue is a very important disease around the world and the changing climate opens possible doors to its future spread to other geographical areas that weren't or still aren't suitable for the mosquitos survival, causing a massive concern between scientists and governments.

One very relevant approach to this problem is the climate one, which can tell if or when an environment will be suitable for certain limitations of *Aedes* mosquitos biological requirements. But more than that, the expansion and spread of the disease they transmit is determined by several natural and anthropological factors combined, meaning that even if the climate is suitable for them, other aspects might not be favorable, causing a controlled dengue free environment.

What will define the intensity of the mosquitos survival, spread, expansion and diseases circulation within Mediterranean countries is the possibility to control and even further to revert climate change, since its future climate is being projected to bear the populations of mosquitos.

The past records can be a very powerful tool for future prevention, considering that Dengue was already a common disease around Mediterranean Europe until 1930s and yet was able to be eradicated by authorities control.

7. References

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