Current Tropical Medicine Reports (2023) 10:47–70
https://doi.org/10.1007/s40475-023-00283-y

TROPICAL MEDICINE IN THE MEDITERRANEAN REGION (F BRUSCHI, SECTION EDITOR)

Multisectoral Perspectives on Global Warming and Vector-borne Diseases: a Focus on Southern Europe

Oluwafemi A. Adepoju[1] · Olubunmi A. Afinowi[2] · Abdullah M. Tauheed[3] · Ammar U. Danazumi[4] · Lamin B. S. Dibba[5] · Joshua B. Balogun[6] · Gouegni Flore[1,7] · Umar Saidu[1,7] · Bashiru Ibrahim[1] · Olukunmi O. Balogun[8] · Emmanuel O. Balogun[1,7]

Accepted: 4 January 2023 / Published online: 28 January 2023

Abstract

Purpose of Review The climate change (CC) or global warming (GW) modifies environment that favors vectors' abundance, growth, and reproduction, and consequently, the rate of development of pathogens within the vectors. This review highlights the threats of GW-induced vector-borne diseases (VBDs) in Southern Europe (SE) and the need for mitigation efforts to prevent potential global health catastrophe.

Recent Findings Reports showed astronomical surges in the incidences of CC-induced VBDs in the SE. The recently (2022) reported first cases of African swine fever in Northern Italy and West Nile fever in SE are linked to the CC-modified environmental conditions that support vectors and pathogens' growth and development, and disease transmission.

Summary VBDs endemic to the tropics are increasingly becoming a major health challenge in the SE, a temperate region, due to the favorable environmental conditions caused by CC/GW that support vectors and pathogens' biology in the previously non-endemic temperate regions.

Keywords Climate change · Disease transmission · Emerging diseases · Temperates · Tropics

Introduction

Global warming (GW) and climate change (CC) are two closely related terms that are often used interchangeably, although the former is only one aspect of the latter. GW refers to persistent heating of the Earth, measured as the average increase in the global surface temperature of the Earth relative to the pre-industrial period (1850–1900) [1]. Anthropogenic activities, especially the burning of fossils, which raises the level of greenhouse gases, are the main driver of GW. While CC is defined according to the Intergovernmental Panel on Climate Change (IPCC)—as "a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period" [2]. These changes

Oluwafemi A. Adepoju, Olubunmi A. Afinowi and Abdullah M. Tauheed contributed equally to this work.

✉ Emmanuel O. Balogun
eobalogun@abu.edu.ng; oluwadareus@yahoo.com

1 Department of Biochemistry, Ahmadu Bello University, Zaria 2222, Kaduna State, Nigeria

2 Department of Private and Property Law, University of Lagos, Lagos, Nigeria

3 Department of Veterinary Pharmacology and Toxicology, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria 2222, Kaduna State, Nigeria

4 Faculty of Chemistry, Warsaw University of Technology, Warsaw, Poland

5 Department of Physical and Natural Sciences, School of Arts and Sciences, University of the Gambia, Serrekunda, The Gambia

6 Department of Biological Sciences, Federal University Dutse, Jigawa State, Dutse, Nigeria

7 Africa Centre of Excellence for Neglected Tropical Diseases and Forensic Biotechnology (ACENTDFB), Ahmadu Bello University, Zaria 2222, Kaduna State, Nigeria

8 Department of Health Policy, National Center for Child Health and Development, Tokyo, Japan

include increased sea level, precipitation, temperature, wind patterns, melting of ice, shrinking mountain glaciers, and extreme weather events such as hurricanes, heatwaves, wildfires, droughts, and floods. People living in poor regions, who contributed the least to climate problems, suffer the most devastating effect of CC [3].

Anthropogenic activities are a major factor contributing to CC and GW. The excessive production of greenhouse gasses from human activities over the years through the emission of huge amounts of CO_2 gas from industries have continued to negatively impact global temperature. It is predicted that the average global temperature will increase by 2–5 °C in the next few decades. This change is significant enough to potentially bring about climatic changes characterized by extreme weather events in the coming decades [4]; such adverse environmental changes will further disrupt the ecological balance. Living things and, most importantly, disease vectors respond to harsh environmental changes by modifying their breeding patterns and other activities such as migrating to more favorable habitats for their survival and continuity. This is the way GW and CC continue to contribute to the spread of disease vectors/emergence and re-emergence of VBDs [5].

The spread of VBDs is on the rise globally, and the globalization of infectious diseases is becoming a palpable threat to global health [6, 7]. This situation calls for urgent attention as millions of people around the world are continuously at risk of infection with emerging and re-emerging vector-transmitted diseases. The spread and transmission of VBDs is largely driven by CC and GW. GW impacts on temperature and humidity which are major factors determining disease vectors' habitats and behavior. CC causes extreme weather events and disrupts the habitats of living organisms. Consequently, human and animal health suffer greatly because of the spread and distribution of vectors harboring infectious pathogens. Disease vectors become more widely spread and with increased potential to transmit infectious pathogens in warmer temperatures [8]. The spread of VBDs has a far-reaching effect on global health and economy [9].

CC and/or GW is correlated with the incidence of VBDs and is a matter of concern in many regions of the world. The warm Mediterranean climate of Southern Europe provides a flourishing environment and habitats for the survival of disease vectors. Several transcontinental activities between Africa and Europe take place around the Mediterranean region. These have tremendous potential to facilitate the transborder spread of infectious pathogens across these continents. In a recent report in January 2022, the first case of African swine fever virus (ASFV) was detected in the Piedmont region in Northern Italy. The Zooprophylactic Institute Umbria and Marche, the National Reference Center for Pestiviruses, confirmed ASFV in a dead wild boar found in Ovada, Province of Alessandria. This is the first case of the disease in the Piedmont region. ASFV can be transmitted by Ixodes ticks. Climate change and GW play a major role in the distribution of Ixodes ticks and, thus, their rate of transmission of infectious pathogens [10]. There are several reports of the emergence and/or re-emergence of VBDs transmitted by mosquitoes, sand flies, and other insects in Southern Europe [11].

To achieve global health, multidimensional and multidisciplinary approaches are needed. The one health concept, which is based on the premise that the health of animals, humans, and the environment are linked and interdependent; hence, an imbalance in one affects the others provides an insight to managing global health. From the standpoint of one health, to achieve global health, multisectoral approaches are needed for the implementation of policy design and public health interventions for combating VBDs. This will require the urgent participation of governments, policy makers, stakeholders, and individuals to achieve a healthy society and, by extension, global health [12]. The issue of GW and CC is a global emergency that requires the participation of governments at different levels, health organizations, and individuals. The impacts of GW and CC on VBDs in Southern Europe are discussed in this review, as well as how relevant stakeholders in global health should react and respond to this situation in order to mitigate the potential consequences.

Drivers of Global Warming

The principal cause of GW is the greenhouse effect, which occurs when there is an increase in the atmospheric concentration of greenhouse gases such as CO_2, which trap heat from the sun and prevent it from escaping back into space. Greenhouse gases exist naturally, but the atmospheric concentration of some of them is significantly increased by anthropogenic activities. For example, the atmospheric level had risen to 48% above the pre-industrial level [13]. Other potent greenhouse gases include methane, nitrous oxide, water vapor, and fluorinated gases. Global warming can result from natural or human-induced forces. The term total GW is therefore used to refer to the combined effect of both natural forces and anthropogenic activities. The difference between total GW and human-induced GW is minimal, and the two have been indistinguishable since 2000 [2]. From 2006 to 2015, the world has warmed relative to pre-industrial time to 1 °C in 2017 and is expected to reach 1.5 °C by 2040 [2].

Natural Causes

Natural forces such as volcanic eruption, sun's intensity, changes in naturally occurring greenhouse gas concentration, changes in Earth's orbit and rotation, changes in Earth's reflectivity, and variation in solar activity have resulted in the warming and cooling phase of the Earth long before humans existed (Fig. 1). However, these changes were slow and subtle as opposed to the much faster GW occurring since the mid-twentieth century. These natural causes continue to play today, but their impact is very little or too slow to account for the rapid heating of the Earth observed in recent decades [14].

Anthropogenic Activities

Anthropogenic activities are undeniably the cause of present-day GW, with fossil fuels burning being by far the major contributor. The burning of fossil fuels such as coal, crude oil, and natural gas is associated with the high emission of greenhouse gases, especially CO_2 which traps heat in the atmosphere [15] (Fig. 1). Greenhouse gases can remain trapped in the atmosphere for centuries and the consequence of this is an overall increase in Earth's average air temperatures. Agricultural activities such as large-scale animal production and farming release methane into the atmosphere. In addition, the application of nitrate fertilizers also results in the release of nitrous oxide from the soil. Furthermore, modern agricultural machinery operates directly by burning fossil fuels [16]. Therefore, the agricultural sector is also a key contributor to greenhouse emissions. Another anthropogenic activity that is harmful to the environment is deforestation. The consequences of deforestation on GW are twofold; cutting down trees reduces the number of plants that can sequester atmospheric CO_2, while burning or decay of the cut trees directly releases and nitrous oxide into the atmosphere [17]. Domestic and industrial wastes are also important sources of greenhouse gases. Fluorinated gases (hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride), for example, are emitted from refrigerators, air conditioners, heat pumps, and fire extinguishers. Industrial processes depend heavily on burning fossil fuels for energy, while some manufacturing processes, such as cement production from limestone, produce CO_2 and nitrous oxide [18].

Influence of Global Warming on Human and Animal Health

According to the World Health Organization (WHO), CC influences social and environmental health determinants, and the direct economic cost on health can exceed \$ 2–4 billion per year by 2030 (Fig. 2). It is further claimed that CC is the greatest health risk threatening humanity [19]. The effects of CC on human and animal health can be direct or indirect, both of which are primarily due to increased temperature, as well as the frequency and intensity of heatwaves. High temperature can directly result in metabolic imbalance, oxidative stress, immunosuppression, increased susceptibility to infection, and ultimately death of humans and animals [20]. In 2003, for example, an extreme heat wave in the summer claimed about 35,000 lives across a large area of Europe, and the probability of the occurrence of such an event has been presumably doubled by GW [21]. Animals are equally not spared from this catastrophe. For example, the 2003 heat wave led to the loss of thousands of domestic animals in the French regions of Brittany and Pays-de-la-Loire [20]. Additionally, dairy cattle mortality is also reported to be higher on summer days with recorded heatwaves [22]. Other extreme weather events, such as

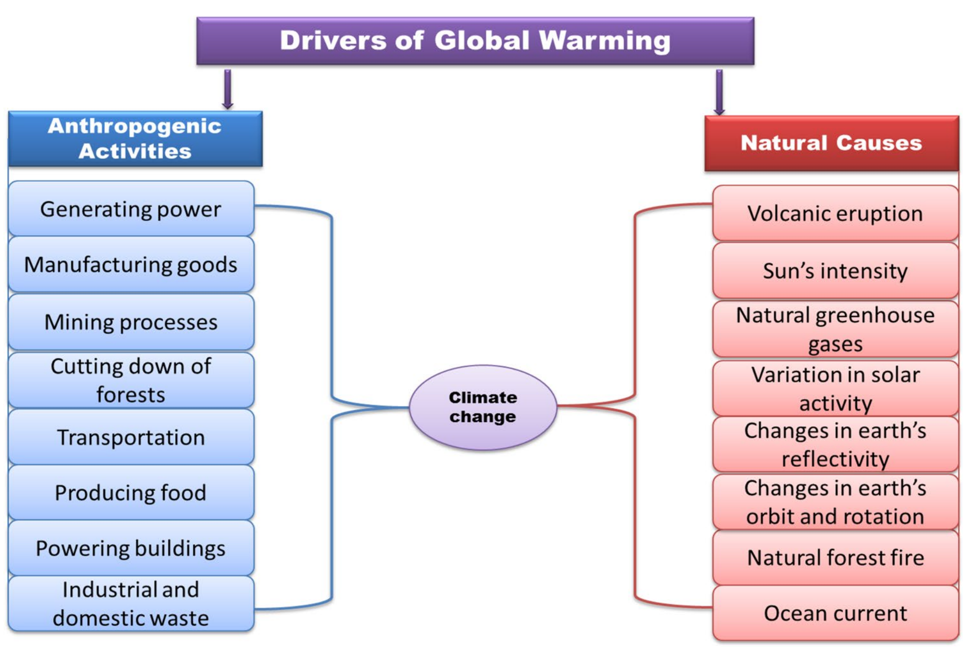


Fig. 1 Human and natural causes of global warming

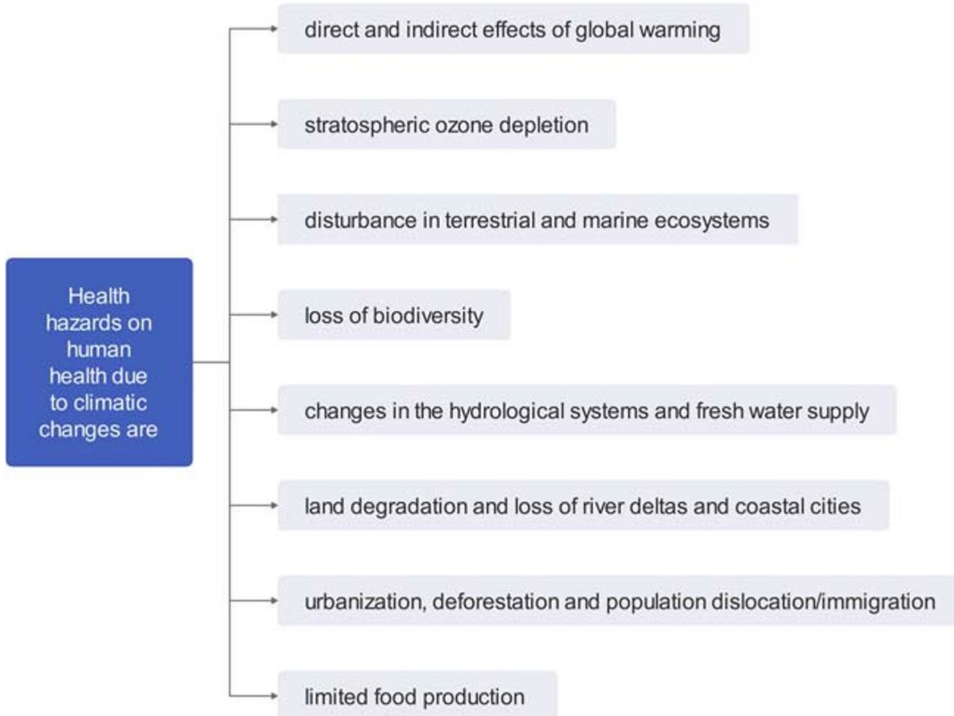


Fig. 2 Health hazard on human health due to climate change

cyclones and floods facilitated by increased temperature, can directly destroy the lives of humans and animals [23•]. In 2019 alone, natural calamities accounted for the loss of 11,755 human lives and additionally affected 95 million people, with floods and storms responsible for 68% of affected individuals [24].

Adulteration of air quality because of GW is another major problem that poses a great health risk. Temperature rise can generally be associated with an increase in ozone formation, although this association should be taken with caution since the ozone level is also dependent on the interaction between temperature, water vapor levels, and air circulation patterns [25, 26]. Be that as it may, ozone smog is formed when pollutants from industrial or other anthropogenic sources react with sunlight, a process that can be speeded up by high temperatures. Consequently, ozone can interfere with lung function and cause inflammation of the airways, resulting in respiratory complications or aggravating existing respiratory diseases [27]. The incidence of skin cancer has also increased globally at an alarming rate since the mid-twentieth century, and this new trajectory has been directly related to increased exposure to ultraviolet radiation due to GW [28].

On the other hand, GW can indirectly influence human and animal health. One way is through the eutrophication of water bodies and the growth of harmful algae, which eventually compromise the quality of drinking water for humans and animals [29]. Global warming–induced adulteration of air quality can also have indirect repercussions, as prolonged warm season translates to longer pollen seasons, resulting in increased pollen allergies and asthma episodes [30]. Furthermore, the growth of mycotoxin-producing fungi, often growing on cereals, is also promoted with high temperatures. Their growth and distribution depend on their exposure to moisture, which in turn depends on the weather conditions at harvest. Therefore, this increases the risk of mycotoxins being consumed by animals through feed or directly by humans through the consumption of cereals [31]. Nevertheless, GW can also have some positive benefits, such as reduced cold-related mortality and increased crop yield in temperate regions. Overall, the impact of CC on human health is significantly harmful [32]. Owing to the immense global health relevance of insect-transmitted diseases (i.e., VBDs) and the established fact that insects thrive best at elevated temperatures, the interrelatedness of GW and VBDs has become an important research focus. In general, the epidemiology and distribution of VBDs are remarkably enhanced by CC. Increased temperature and precipitation provide an ambient environment for the proliferation of insects. As a result, disease-transmitting insects are blossoming, migrating to previously non-endemic areas, and consequently expanding the transmission foci of VBDs [20]. In fact, major VBDs such as neglected tropical diseases (NTDs), including Chagas disease, leishmaniasis, chikungunya, and dengue, have recently emerged in some countries in Southern Europe [33].

Global Warming and VBDS

Disease vectors are mostly arthropods (such as mosquitoes, flies, and ticks) that transmit pathogens from an infected host to another host. They are cold-blooded animals (ectotherms) that rely exclusively on the ambient temperature to maintain their optimal body temperature for growth and reproduction. Consequently, hot temperature and high humidity of the tropics favors them, and this explains why arthropods and the diseases they transmit are more abundant in the tropics than in the temperate regions. Malaria, yellow fever, chikungunya, dengue, Zika virus disease, lymphatic filariasis, Chagas disease, leishmaniasis, schistosomiasis, onchocerciasis, and Japanese encephalitis are the major global VBDs [34]. Other VBDs of global economic importance include Lyme disease, tick-borne encephalitis, West Nile fever, and African trypanosomiasis.

The gradual increase in mean global temperature by 1 °C above the pre-industrial levels is referred to as CC [2, 35]. The effect of CC causes a decrease in the number of cold days and nights, an increase in the number of warm days and nights, and the more significant warming of land over the ocean, especially along the arctic [36••], and this has profound effects on the redistribution of vectors and VBDs. The gradual warming up of the planet means that the temperature of the temperate region is increasingly becoming more conducive to most of the vectors that hitherto thrive only in the tropics. The impact of CC on the incidence, transmission, and redistribution of VBDs represents a major threat among the effects of CC [2]. This is because the abundance, survival, feeding, and reproduction of vectors which are ectotherms, will increase with increasing temperature and, consequently, the rate of development of the pathogen within the vectors. For example, the extrinsic incubation period (the time between ingestion of the pathogen by the vector and the time the vector becomes infective) for the dengue virus is inversely associated with the ambient temperature [37]. These could explain the numerous outbreak of chikungunya transmitted by *A. albopictus* in Southern Europe notably in Italy and France [38]. An infected vector cannot become a competent vector (capable of transmitting infection) if the rate of development of the pathogens within it is too slow or the survival of the vector is too short that the vector dies before it even becomes infective [36••]. Studies to demonstrate the influence of GW on vector dynamic shows that the survival of the dengue disease vector *Aedes aegypti* from egg to adult increases arithmetically from 0% at 15 °C to about 90% at 20 °C and then slowly falls to about 60% at 35 °C. Similarly, the time of development from egg to adult drops sharply from about 60 days at 15 °C to 12 days at 20 °C and then declines further to about 6 days at 27–34 °C; and the percentage of mosquitoes that complete a blood meal within 30 min after a host is made available plateaus at about 50% between 22 and 28 °C and then declines to almost 0% at 33 °C [39]. Furthermore, precipitation also influences VBDs dynamics for diseases transmitted by vectors that have aquatic developmental stages [40].

It has been observed that the geographic range of *Ae. aegypti* and other vectors is limited by cooler ambient temperatures. However, as the Earth warms, there is the possibility of the mosquito and virus to spread to higher latitudes and altitudes, increasing the incidence of disease transmission and lengthening the transmission season in some endemic areas [36••]. Accordingly, Colón-González et al. [41] indicate an increase suitability for Malaria and dengue transmission will be observed in the highlands of the Eastern Mediterranean region of Southern Europe.

GW is playing a significant role in the emerging or re-emerging of VBDs in Europe. Southern Europe is prominent in this CC-mediated transmission dynamics of VBDs in Europe. This is due to the unique position of Southern Europe in terms of closeness to the Tropics and as the region of Europe that is most affected GW [33]. In the whole of Europe, Southern Europe has the warmest climate with high frequency of heatwaves all due to GW, and the effect of this warming is proposed to be much more severe in term of human death due VBDs [42, 43]. This warm climate means longer summer and warmer winter and it has been leading to high cases of VBDs in Southern Europe. In fact, Southern Europe is a considered as the entry point for VBDs to Europe. Due to GW, VBDs are first established in Southern Europe before distributing or invading other regions of Europe [33, 44]. Many of the important vector-borne pathogens have been reported in Southern Europe (Fig. 3). Based on the vector involved in the transmission of VBDs, we grouped VBDs into diseases transmitted by arthropod vectors: mosquitoes, ticks, sandflies, and flea; and non-arthropod vectors: rodents. Table 1 shows notable diseases that are emerging or re-emerging in Southern Europe due to the impact of CC (GW).

Important VBDS Posing Threats to the Mediterranean Region

Mosquitoes

Mosquitoes are the most significant vector that can transmit a wide range of diseases including malaria, dengue, Chikungunya, and Rift Valley fever (RVF). Malaria is a life-threatening protozoan disease caused mainly by *Plasmodium falciparum* and *P. vivax* and transmitted between humans

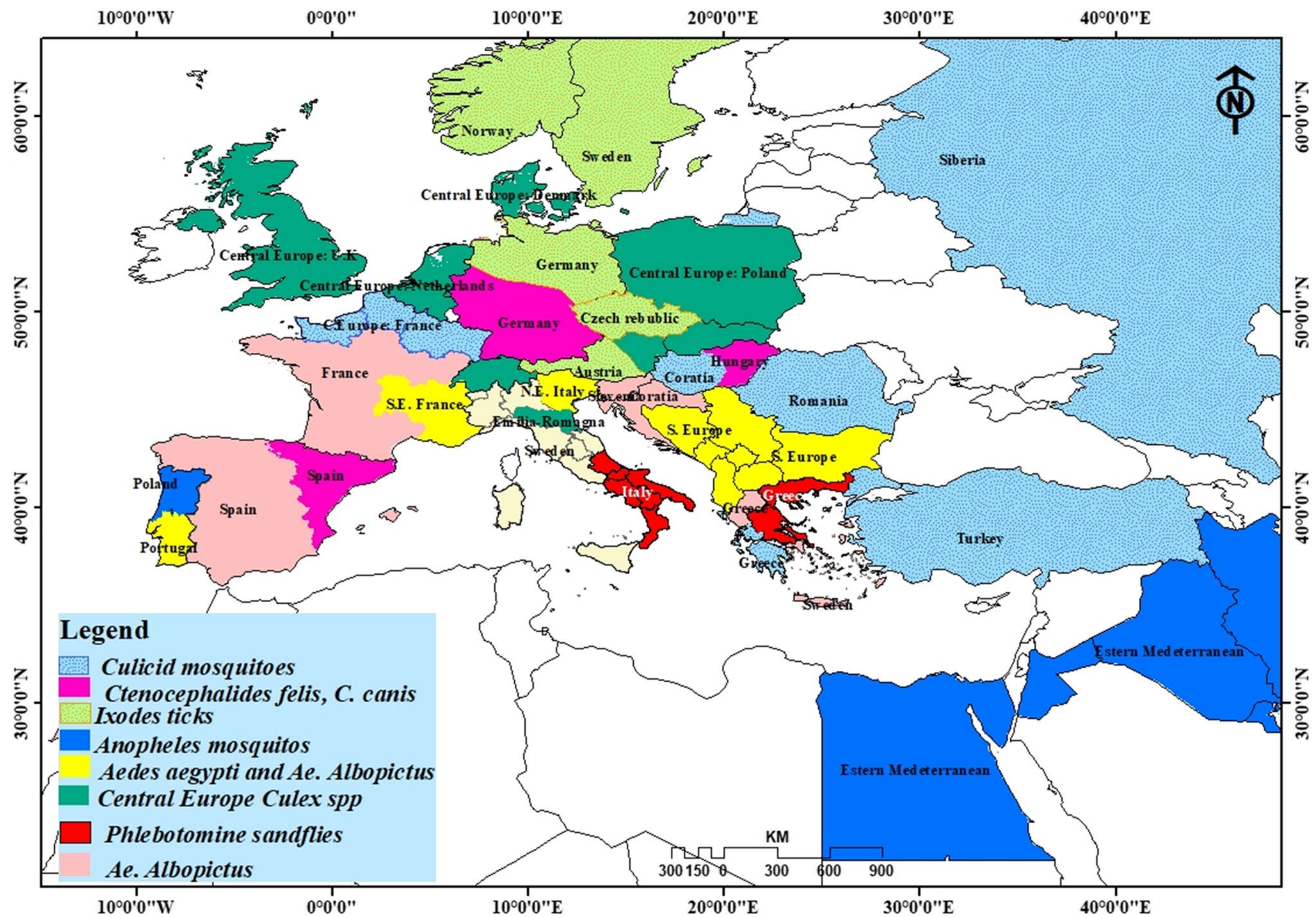


Fig. 3 Distribution of disease vectors in Southern Europe and neighboring countries

Table 1 Notable climate change-driven emerging and re-emerging vector-borne diseases in Southern Europe

Disease	Etiology (pathogen)	Vector(s)	References
Malaria	*Plasmodium* sp.	*Anopheles mosquito*	[45]
Dengue	*Flavivirus* sp.	*Aedes aegypti* and *Ae. albopictus*	[46, 47, 48••]
Chikungunya	*Alphavirus* sp.	*Ae. aegypti* and *Ae. albopictus*	[49–51]
Rift valley fever	*Phlebovirus* sp.	*Culex pipiens complex*, *Ae.* sp., and *Mansoni* sp.	[52]
West Nile virus	*Flavivirus* sp.	*C.* sp.	[53, 54]
Heartworm (dirofilariasis)	*Dirofilaria immitis*	*C.* sp., *Ae.* sp., and *Anopheles* sp.	[55]

by the bite of female *Anopheles species*. These vectors are mainly found in tropical and subtropical regions, but some species are now being found in higher latitudes due to GW [41]. *Anopheles* spp. are ubiquitous in rural areas, but the establishment of *A. stephensi* in Eastern Africa has raised concern about the incidences of urban and peri-urban malaria [56, 57]. Eastern Mediterranean and Western Pacific regions have seen a mild increase in the incidence of malaria in recent time, while the regions of the Americas have reported a moderate rise in the number of new cases due to the unprecedented spike in new cases in Venezuela from 41,749 cases in 2007 to 411,586 in 2017 [58]. Similarly, climate suitability for malaria transmission is pushing malaria to higher altitudes, including the African highlands [59].

Mosquito-transmitted Diseases

Dengue

This is the fastest-growing mosquito-borne viral disease in the world, with an expanded spatial range in the past few decades. The disease is caused by an arbovirus in the family

Flaviviridae and genus *Flavivirus*. There are four strains of dengue virus (DENV) codenamed DENV1–4 serotypes. Clinical manifestations of dengue range from mild cases of dengue fever to severe cases of dengue hemorrhagic fever and/or dengue shock syndrome. *Aedes aegypti* is the main vector of DENV, but the infection may also be transmitted by *Ae. albopictus* [60] (Fig. 4). Since the first outbreak of dengue in Europe (Athens) in 1889, sporadic cases were reported up to 1910, and a major outbreak occurred in the summer or early fall of 1924 in Athens and neighboring areas of Greece [61]. The reports of autochthonous cases of the disease in France [47], Croatia [62], Portugal (Madeira) [46], and the USA [63] raised concerns for the effect of CC. Recently, sporadic autochthonous cases of dengue were reported in southern countries, Spain (Catalonia) and France in September 2019 and France and Italy in summer 2020 [48••].

Chikungunya

This is also caused by an arbovirus in the family Togaviridae and genus *Alphavirus*. Chikungunya virus (CHIKV) was first isolated in the Newala district of Tanzania in 1952 [64], and it is transmitted by the bite of *Ae. aegypti* and *Ae. Albopictus* (Fig. 4). Three different genotypes of CHIKV have been identified: the western African, the east-central-south African (ECSA), and the Asian genotype [65]. The evidences suggesting the paradigm change in the relationship between the virus and the victor include the outbreak of chikungunya fever in North-Eastern Italy in 2007 [66], the autochthonous transmission of CHIKV in south-eastern France in 2010 [50] and 2014 [51], the outbreak of CHIKV strains in the Indian Ocean area belonging to the ECSA genotype [67], and the circulation of CHIKV A226V variant in La Reunion and Kerala [68].

Rift Valley Fever (RVF)

A zoonotic viral disease of domestic ruminants and humans caused by the arbovirus in the family Bunyaviridae and genus *Phlebovirus*. It causes high mortality in newborn ruminants and abortion in pregnant animals. Human infection results from the bite of a mosquito, exposure to body fluids of livestock, or to carcasses and organs during necropsy, slaughtering, and butchering [69]. Although RVF is not yet a problem in Europe, humid areas with a large population of ruminants are thought to contribute to the possibility of its outbreak in Europe [70]. For example, the reports of RVF in the French island of Mayotte [52] and

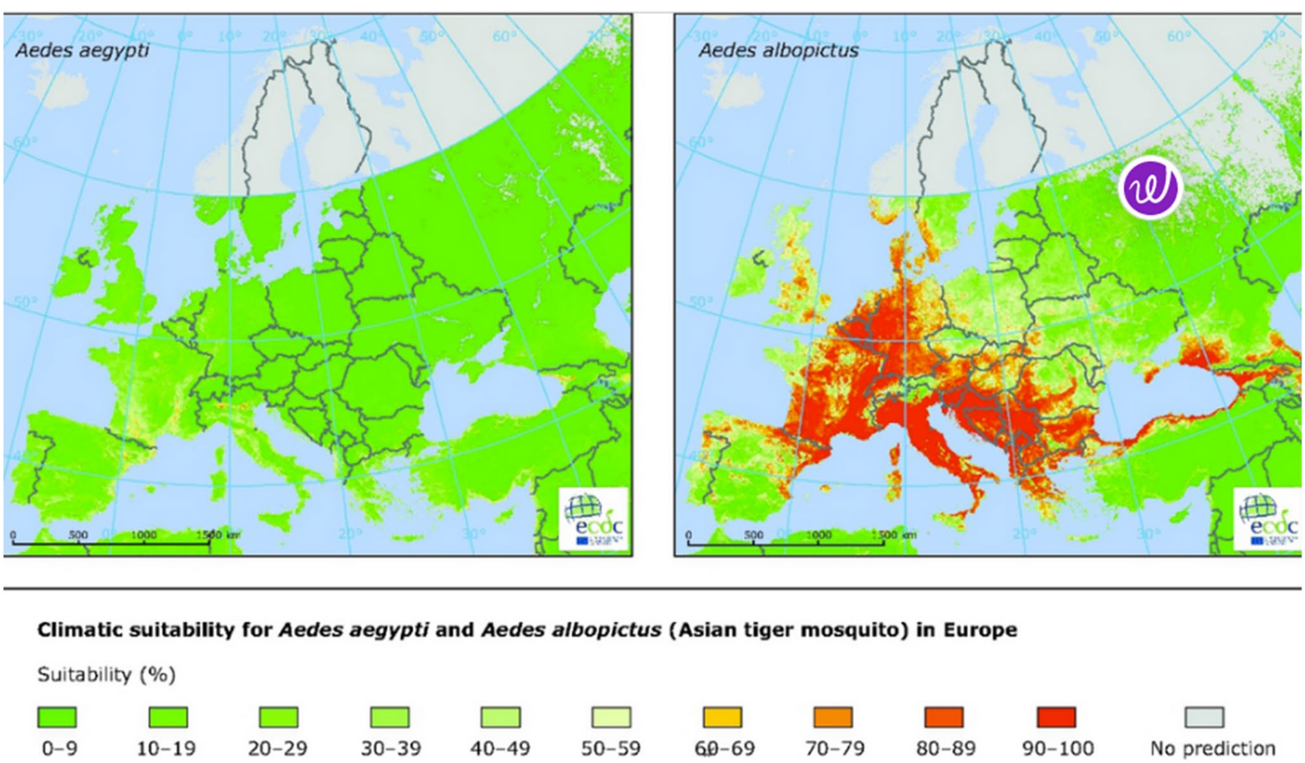


Fig. 4 Climatic suitability for the mosquitoes Aedes aegypti and Aedes albopictus in Europe. Note: Yellow to red designates conditions that are increasingly suitable for the vector, whereas darker to lighter green designates conditions not suitable for the vector. Gray indicates that no prediction is possible. Source: Copyright © European Centre for Disease Prevention and Control, 2012

Northern Egypt [70] indicate encroachment of the virus into the Europe zone.

West Nile Virus (WNV)

It is the most widely distributed virus of the encephalitic flaviviruses. It is a mosquito-borne viral disease caused by *Flavivirus* spp. (family Flaviviridae and a member of the Japanese encephalitis serocomplex). The enzootic cycle is driven by continuous virus transmission to susceptible bird species through adult mosquito blood meal feeding [40]. WNV is mostly transmitted by *Culex* mosquitoes (Fig. 5) which is one of the common mosquitoes of Europe [71]. WNV was introduced into Europe by migratory birds from sub-Saharan Africa, North Africa, or Middle East, whereupon the virus overwinters in *Culex* spp. of mosquitoes widely distributed in Europe [54]. Weather conditions have been shown to influence vector competence of mosquitoes, vector population dynamics, and viral replication within the mosquitoes [72, 73]. These factors favor disease transmission. An increase in ambient temperature and fluctuations in rainfall caused by CC have contributed to the endemicity of WNV in Southern Europe, the Eastern Mediterranean, Western Asia, Canadian Prairies, Australia, and some parts of the USSA [74, 75]. Recent surveys in Europe showed that 2083, 463, and 336 autochthonous cases of WNV were recorded in 2018, 2019, and 2020, respectively. Southern and Central Europe alone accounted for the high cases reported in 2018, and it was linked to higher temperatures in early spring that favored the vector and the virus [53]. The Netherlands recorded the first case of WNV in birds and consequently in humans in the summer of 2020 [76]. Besides high temperature, high precipitation in late winter or early spring is also known to strongly influence the outbreak of WNV in Europe [77].

Heartworm (Dirofilariasis)

A parasitic nematode infection of both domestic and wild canines and felines caused by *Dirofilaria immitis*. It is transmitted by the bite of culicid mosquitoes- *Culex* sp., *Aedes* sp., and *Anopheles* sp. [78]. It is a zoonotic disease found in temperate, tropical, and subtropical regions [79]. In Europe, the parasite persists mainly in endemic southern countries with a Mediterranean climate [55]. However, the spread of heartworms from these countries towards the northern regions has been observed [55, 79, 80]. Recently, rapid spread of heartworm in Hungary has been linked to CC [81].

Tick

With its warm climate compared to other regions in Europe, Southern Europe has been home to number of vector-borne diseases, of which ticks and tick-borne pathogens are part of [33]. Ticks are poikilothermic and the most important vector arthropod with worldwide distribution [82, 83]. Ticks are known for transmitting a wide range of pathogens including viruses, protozoan parasites, and bacterial parasites. Thus, their medical and veterinary importance [84, 85]. Ticks, like mosquitoes, cannot regulate their body

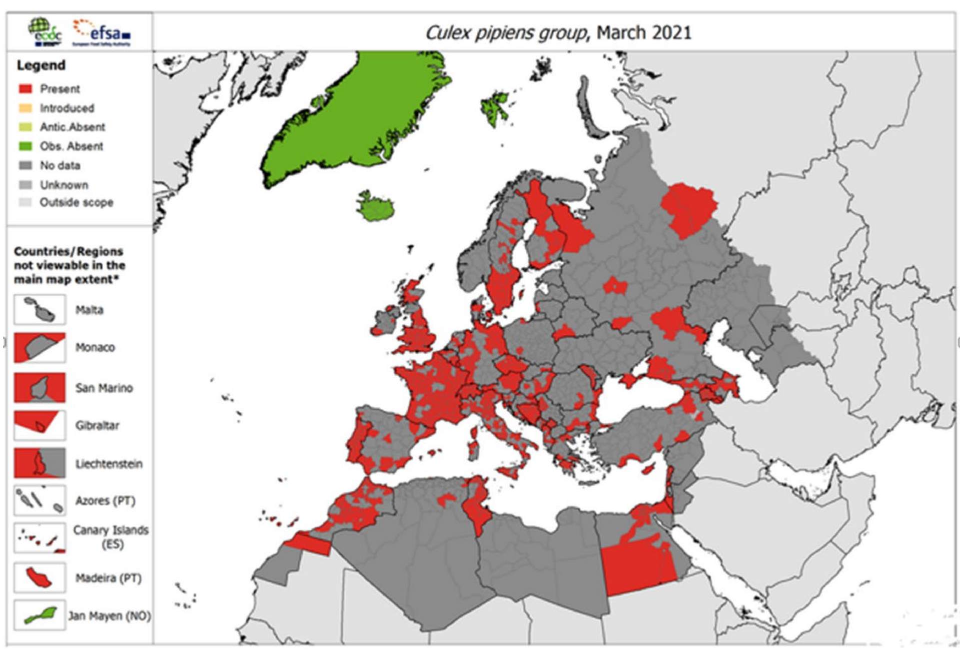


Fig. 5 Current known distribution of the Culex pipiens group (Culex pipiens and Culex torrentium) in Europe at "regional" administrative level, as of March 2021. https://ecdc.europa.eu/en/disease-vectors/surveillance-and-disease-data/mosquito-maps

ECDC and EFSA map produced on 26 Mar 2021 (Adapted from VectorNet project).*Countries/Regions displayed at different scale to facilitate their visualisation temperature internally and are therefore greatly affected by environmental temperature, hence influenced by GW [86]. Increasing reports worldwide are showing links between the spread, distribution, and invasion of new areas by ticks and ticks-borne diseases (TBDs) with increase in environmental temperature [87]. GW leads to extreme heat, heat waves, longer summer and spring, and less winter. All of which is good for the development of ticks and spread of TBDs [88]. A recent report from 30 years of surveillance studies of ticks have shown that GW leads to the expansion and emergence of ticks and TBDs [89].

In Southern Europe, TBDs are becoming a major public health concern with increasing reports of emerging and/or re-emerging of TBDs in the region [90–92]. Global warming is partly or wholly the driving force behind the emergence and re-emergence of ticks and TBDs in Southern Europe. Zoonotic tick-borne pathogens of importance in Southern Europe are tick-borne encephalitis virus, *Borrelia* spp., *Babesia* spp., *Rickettsia* spp., *Anaplasma phagocytophilum*, Crimean-Congo hemorrhagic fever virus, and *Coxiella burnetii* [93, 94]. *C. burnetii*, which causes *Q* fever, is highly prevalent in Southern Europe, and it is said to be due high abundance of *Hyalomma* spp. and *Rhipicephalus* spp. tick species [93]. Considering that GW leading to warmer autumns increases the survival, proliferation, and expansion of *Hyalomma* spp. tick, it is not difficult to see the link between the high prevalence of *Q* fever in Southern Europe and GW. Crimean-Congo hemorrhagic fever (CCHF) is also another TBDs that have emerged or re-emerge in some countries in Southern Europe with sign showing an expansion of the disease to new area in line with warmer climate due to GW [95, 96].

In France, Lyme borreliosis is the most prevalent TBDs, and it is transmitted by *Ixodes ricinus* (*I. ricinus*) tick, a tick whose expansion and distribution have been shown to be influenced by global warming [97] at least in Canada and the USA [89]. *Dermacentor* and *Rhipicephalus* genera tick are the next most prevalent in France and they do better in warmer climates [98]. Their expansion from the Mediterranean region of France to colder part of France (Northern) can be attributed to GW as Northern France is witnessing warmer climate than before due to CC. In a study by Fanelli and Buonavoglia [95], France is one country at high risk of entry of CCHF, a TBD transmitted by *Hyalomma marginatum* species. Though this risk of entry was attributed to migratory birth [82, 99]. However, we should be asking what the effect of GW is on the migration of migratory birds. Is global warming indirectly contributing to the expansion of ticks and TBDs in France by influencing the migration of birds? Furthermore, even if the entry of the *H. marginatum* species might not be due to GW, the establishment of this tick will depend on be enhanced by GW since the ticks thrive in warmer climate. Italy is also another country in Southern Europe at high risk of exposure to CCHF [95]. The emergence or introduction of *H. marginatum* and many other tick species in Italy is also mostly ascribed to migratory birds from Africa {Pascucci, 2019 #543. However, the establishment of these ticks will be influenced by GW as the indigenous countries for the ticks have warmer climate [100]. Reports on the emerge of many of TBDs in Italy [84, 101] are accumulating. Similar situation of emergency and establishment of tick-borne pathogen is reported in Greece, Portugal, and Spain [102, 103]. As of Greece two fatal cases of TBDs were reported with report of increase of tick bite and TBDs in 2007–2008 because of GW [104]. A recent survey of ticks in Spain reveals an increasing number of tick vector with CCHF. Dermacentor-borne necrosis erythema and lymphadenopathy are becoming an emerging disease in Spain [105]. Furthermore, tick bites have become frequent in spring and winter in Spain, in line with warmer winter due to GW over the years [103, 105]. In Portugal, Mediterranean spotted fever (MSF) is the most important TBD with several fatal outcomes since year 2000 [106]. Although we have not come across report of the influence of GW on this TBDs in Portugal but the principal tick vector, *Rhipicephalus* spp. have been shown to be affected by GW [98]. Slovenia is another Southern European country having one of the highest incidences of Lyme disease and tick-borne encephalitis in Europe [107, 108]. Diseases are transmitted by *I. ricinus*, a tick that its activity, survival, and expansion are greatly influenced by GW [97, 109]. Several TBDs have been reported to be endemic in Montenegro, Serbia, and Croatia [110–112]. In a climate change and communicable diseases manual for health workers in North Macedonia, TBDs have been reported as concern with their occurrence in future being very high in North Macedonia, with Lyme borreliosis being endemic and GW will likely lead to increase cases of the disease in North Macedonia [113]. Several tick species have been reported to present in Bosnia and Herzegovina with some like *Dermacentor reticulatus* showing sign of expansion in Bosnia and Herzegovina [114]. This have led to the emerges of zoonotic bacteria in Bosnia and Herzegovina [115]. Interestingly, tick species reported in Bosnia and Herzegovina are common to countries in the Mediterranean Region of Europe [114]. Albania is one country in Southern Europe with report of outbreak of CCHF and the country is endemic to this TBD. The CCHF outbreak occur during warmer weather [116]. It is clear from numerous reports coming out of Southern Europe there is an emergence of TBDs, establishment, and expansion of tick in this part of Europe, and it is linked to GW.

Sandflies

Sandflies are an important vector for the transmission of leishmaniasis (or "leishmaniosis") and several viral and bacterial pathogens including summer meningitis, sandfly fever, Chandipura virus encephalitis, Carrión's disease, and vesicular stomatitis [117–119]. According to WHO, leishmaniasis disease is underestimated with an increasing prevalence globally and about one million cases annually Worldwide including in Southern Europe [119]. Due to GW, leishmaniasis is an emerging disease in Europe and indicating the expansion of sand flies in the continent [120]. The risk of leishmaniasis spreading across Southern Europe is real and most worrying is the lack of an institutionalized surveillance system of sand fly-borne pathogens in Europe [120]. The several human outbreaks of leishmaniasis in Spain and Italy are an example of the threat of the disease in Southern Europe [121–123]. In the Mediterranean areas of Southern Europe, there are 1200–2000 cases of visceral leishmaniasis and 239,500–393,600 of cutaneous leishmaniasis annually as of 2012 [46].

Furthermore, other sandfly-borne diseases (SBDs) like sandfly fever and Chandipura have been shown to be more prevalent in the Mediterranean region of Southern Europe than previously thought. Sandflies are thermophilic and studies have shown that the females responsible for sandfly-borne diseases do die below 15 °C. Temperature is thus a vital factor for the survival and distribution of sandfly and SBP [124–126]. As such, GW influences the distribution and emergence or re-emergence of ssandfly-borne diseases (SBD) in Southern Europe. The Mediterranean region of Southern Europe is endemic to sandfly with signs showing its expansion northward which is associated with GW [120, 127, 128]. A study by Chalghaf et al. [43] has clearly shown that GW will enhance the distribution of sandflies from the Mediterranean region and cause the spread to new areas in Southern Europe with potential expansion toward Northern Europe. In countries like Italy, Spain, France, and Portugal, an increased incidence of SBDs has been reported with the invasion of new areas in these countries by sandfly. The observed phenomenon is partly attributed to GW [128–134]. In the Balkan region of Southern Europe, a number of reports are suggesting the re-emergence of leishmaniasis [135–138], and this is taking place with a concomitant increase of average temperature increased by 1.2 °C in the Balkans [139]. It is certain from the number of data coming out of Europe that the increased prevalence, distribution, and invasion of new areas by sandfly and SBDs across Southern Europe toward the North is in line with effects of GW.

Fleas

Fleas are another group of vectors of public health importance because they parasitize companion animals in addition to other domestic and wild animals. Fleas belong to the family Pulicidae and genus *Ctenocephalides*. While *C. canis* and *C. felis* are the important fleas of companion animals, *C. felis* is the predominant flea found on companion animals in Europe and other regions [140]. Fleas tolerate a wide range of environmental conditions and, therefore, have worldwide distribution. These factors make fleas important in disease transmission. Nonetheless, climatic variables influence their life cycle, which could also affect their distribution [141]. Because fleas are not host-specific, their distribution pattern is more dependent on habitat than host. This may explain why different species of fleas are seen in different geographical areas [142].

In Europe, the prevalent fleas-borne diseases (FBDs) are plague, murine typhus, flea-borne spotted fever, and cat scratch disease [143]. Furthermore, the prevalence and distribution of FBDs depends on flea prevalence which is influenced by climatic factors like temperature and precipitation [144]. In Greece, Christodoulopoulos et al. [145] have shown high prevalence of fleas (human flea) during summer. Likewise, the FBD murine typhus is reported to be high in Greece during summer as of 2012 [146]. In Spain, there is also increasing incidence of fleas-borne murine typhus over the years mostly during summer [147]. Another emerging FBD around the world is flea-borne spotted fever, and it has been reported in Southern European countries of Portugal, Spain, and France [148, 149]. A study on flea abundance and prevalence in the Balkan country of Serbia, Macedonia, Bosnia, Herzegovina, and Montenegro in Southern Europe have revealed an increase prevalence of flea during warm period (summer and spring) [150]. These studies have clear shown relationship between flea prevalence, fleas-borne disease, and the ambient temperature. GW increases length and severity of summer. Thus, with the increasing trend of GW, the incidence and prevalence of FBDs will likely increase in Southern Europe.

Rodents

Rodents are an important reservoir and vector for several zoonotic diseases, which can be transmitted directly by contact with rodent feces, urine, saliva and bites or indirectly through ticks, mites and fleas [151]. Data from Europe are showing the emergence or re-emergence of rodent-borne diseases (RBDs) such as hantavirus disease, leptospirosis, and lymphocytic choriomeningitis (LCM) with the LCM been under-reported [152–154]. Of all the rodents, rats are of most significant to humans in terms of being vectors for zoonotic pathogens. The risk of transmission of rat-borne diseases depends on the likelihood of contact between rats and humans, which also depends on rat population [155]. Environmental temperature influences the population of rats and other rodents. Thus, the prevalence of RBDs like hantavirus can be influenced by GW [156]. GW can lead to short and milder winter and frequent occurrences of heat waves. According to ECDC [157], milder winter drives high rodent population, while heat waves can force rodents to move indoors looking for water, thus increasing contact between humans and rodents. This will translate to an increased incidence of RBDs. With milder winter and more frequent heatwaves in Southern Europe over the decade due to GW, it is not surprising, of recent outbreaks of RBDs in some countries of Southern Europe [157, 158].

In the Balkan area of Southern Europe, rodent-borne disease caused by hantavirus is epidemic with several outbreaks in many countries in the region [158]. As for the Mediterranean region of Southern Europe, several rodent-borne diseases and pathogens such as arenavirus, hantavirus, and leptospirosis have been reported in Italy, France, Portugal, and Spain [159–163]. In Italy, a study by Tagliapietra et al. [164] has observed an increase in the seroprevalence of pathogenic hantavirus of Dobrava-Belgrade virus (DOBV) from 2002 to 2015 with the first report of the pathogenic Puumala strain of hantavirus in the country. Recently, an outbreak of RBD leptospirosis was reported in France with the outbreak occurring during an unusual warmer summer of 2016 [165]. In addition, rat-bite fever was for the first time diagnosed in humans from Portugal [166]. All these show an increasing threat of emergence or re-emergence of rodent-borne diseases in Southern Europe with the possibility of introduction and establishment of new rodent-borne diseases. These developments are taking place against the backdrop of frequent heatwave in Southern Europe due to GW which increases contact between rodents and humans necessary for the transmission of RBDs [157, 167].

Indicators of Climate Change Effects on Vector-borne Disease Transmission in Traditionally Non-endemic Areas

The progressive increase in the monthly incidences of malaria cases in the highlands of Colombia and Ethiopia were reported to be due to the shift in the altitudinal distribution of malaria toward higher altitudes in warmer years and, therefore, more likelihood of malaria burden at higher elevations as the climate warms up further [2]. Global CC results in habitat alteration, which in combination with urbanization and agricultural practices are key to mediating regional environmental changes that paves way to ecosystem modifications and habitat expansion for disease vectors, and eventually leads to the emergence of diseases in areas that were previously free of the diseases (Fig. 6).

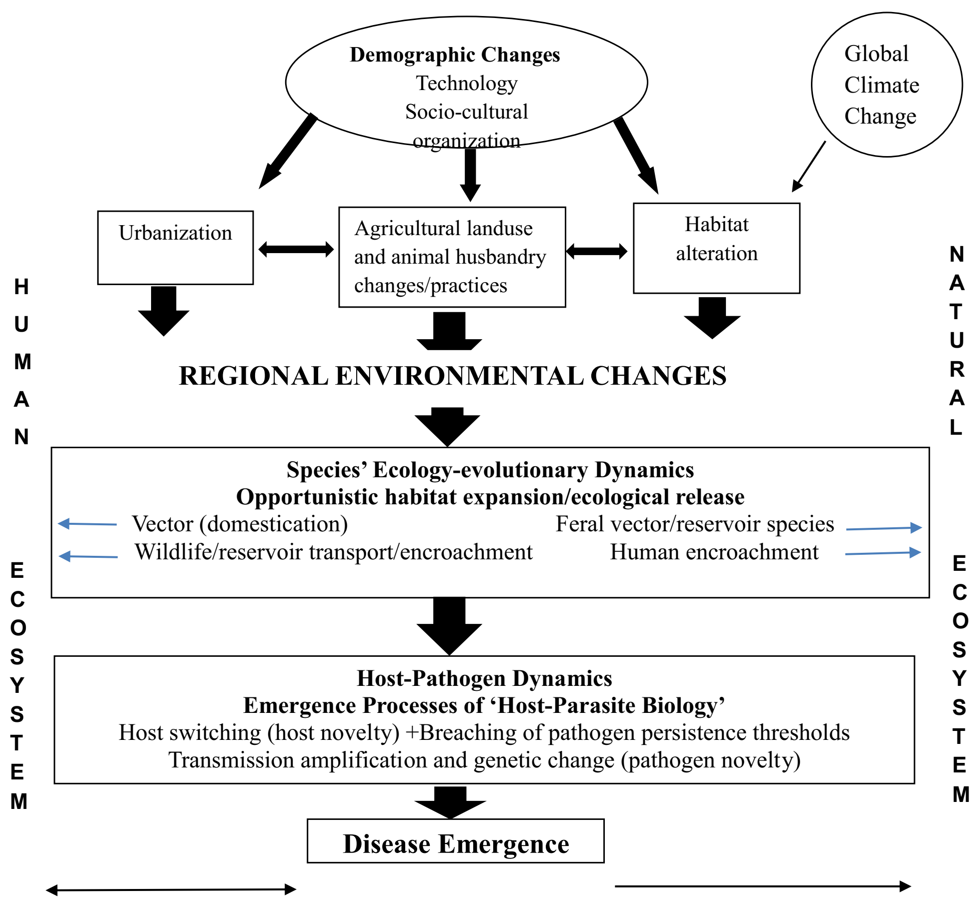


Fig. 6 Epidemiological effects of urbanization and environmental change. Adapted from [182] with permission from the Japanese Society for Hygiene

Another factor that contributes to the presence of pathogens in non-endemic areas is travel (trade or migration). Semenza et al. [168] reported a strong correlation between the number of dengue cases imported into Europe and the number of travelers arriving from the endemic areas. The establishment of *Ae. albopictus* vector in Southern Europe was initially due to the autochthonous (local) outbreaks of dengue and chikungunya in the region when infected travelers pass the pathogen to the vector. This, in turn, causes secondary cases of human infection [169]. Although the risk of such outbreaks is presently very low, vigilance is still needed to prevent sustained outbreaks or the establishment of endemicity of these pathogens in the future as the climate warms [36••]. Despite the role of travel in these incidences, a favorable environmental temperature is crucial for the survival of the vector and viability of the pathogen to be infective. These favorable environmental conditions, such as higher temperature and precipitation, are being aided by changing climatic variables caused by CC. The 2017 outbreaks of chikungunya (transmitted by *Ae. albopictus*) in Europe and the 2015–2016 Zika virus (transmitted by *Ae. aegypti* and *Ae. albopictus*) epidemic in South America [170] could be explained by warmer temperature condition that favors vectorial capacity—a measure of the capacity of a vector to transmit disease, considering information on vector abundance, survival, competence, and feeding rate and the length of the extrinsic incubation period. In the latter case, temperature conditions associated with the 2015–2016 El Niño/Southern Oscillation favor Zika virus transmission [36••]. Globally, the vectorial capacity for the dengue vectors (*A. aegypti* and *A. albopictus*) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000 [59].

Impact of Climate Change on Epidemiology of Zoonotic Diseases

Zoonoses are diseases that are transmitted from vertebrate animals to humans. For this to occur, humans must be in close contact with these vertebrates harboring some of these pathogens. Human activities, such as mining, agriculture, and urbanization, aid proximity of humans with other vertebrate animals (Fig. 6). This contact at the animal-human interface is affecting the emergence and spread of zoonoses worldwide [171]. According to Taylor et al. [172], about 60% of emerging infectious diseases (EIDs) are zoonotic, and they exist in wildlife. The emergence of these diseases is often due to dynamic interactions between humans, wildlife, livestock populations, and the rapidly changing environments [173] (Figs. 4 and 6). Emerging zoonoses due to globalization, through CC/GW are a threat to global health, economy, and safety [174] (Fig. 7). One important weather condition that greatly contributes to extreme weather events,

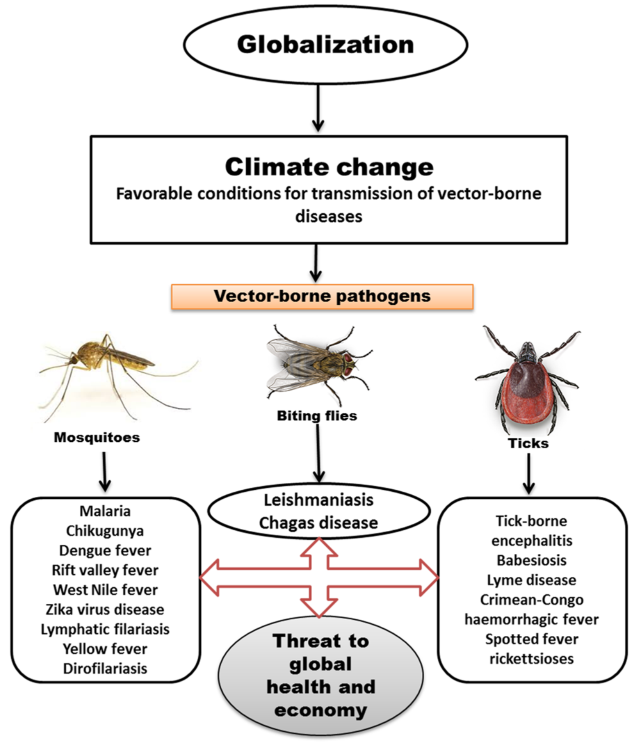


Fig. 7 Effect of climate change on transmission of vector-borne diseases

such as floods, tornadoes, heavy precipitation, droughts, heat waves, and hurricanes, is El Niño-Southern Oscillation (ENSO). ENSO, which has two components: El Niño (the warming phase) and La Niña (cooling phase), is the irregular, periodic fluctuations in the equatorial Pacific Ocean surface temperature and atmospheric pressure [173, 175]. Other oscillations, such as North Atlantic Oscillation (NAO), Pacific Decadal Oscillation, and Antarctic Oscillation, are also linked with extreme events [176]. GW and its consequential geo-climatic variations influence the epidemiology of zoonotic diseases by altering the dynamics of hosts, vectors, and pathogens interactions. This has been demonstrated in the case of ENSO/extreme weather events and outbreaks of rift valley fever (RVF), malaria, cholera, plague, hantavirus, and several emergent diseases [177]. Similarly, NAO was linked with zoonoses like Lyme borreliosis and tularemia [178, 179]. A retrospective study of the West Nile virus (WNV) outbreak in Southern France in 2000 showed that the vector aggressiveness (biting rate of *Culex modestus*) was positively linked with temperature and humidity and associated with heavy rainfall and sunshine [180]. *Ae. aegypti* and *Ae. albopictus* transmit more than 22 arboviruses to humans [181]. The presence of these vectors in Southern Europe and the conducive environment being provided by GW pose a great threat to the inhabitant of this region. Both the *Aedes* and *Culex* mosquitoes are widely distributed across different countries of Southern Europe (Figs. 4 and 5).

Climate Change's Impact on Food and Nutrition Security in Europe

According to a comprehensive investigation by the European Environment Agency, CC, precipitation, and weather extremes are already affecting crop yields and animal production in the EU [183]. Climate change is anticipated to improve the suitability of Northern Europe for growing cereal crops, while reducing crop yield in significant sections of Southern Europe [184]. However, the growing season in Southern Europe may move towards winter as a partial compensation. Among the many possible concerns caused by GW, the threats to global agriculture stand out as one of the gravest. Long-term variations in temperature, humidity, rainfall patterns, and the frequency of extreme weather events are already affecting farming practices, crop productivity, and the nutritional value of food crops. Due to the sensitivity of germs, potentially toxin-producing bacteria, and other pests to climatic circumstances, CC may influence the prevalence and intensity of many foodborne illnesses. Climate change, particularly GW, may also facilitate the spread of invasive alien species that are harmful to plant and animal health. The development of toxin-producing algae because of increasing fertilizer input and surface seawater warming, culminating in outbreaks of seafood contamination, is another major negative impact of CC on human nutrition and wellbeing.

Furthermore, as earlier predicted by Cline [185], baseline GW by the 2080s will result in a 16% decline in agricultural productivity (output per hectare) without carbon fertilization (Fig. 8), and a 3%t drop if carbon fertilization benefits are realized (Fig. 9). The developing countries will bear a disproportionate share of the losses. Developing country regions incur losses of roughly 25% without carbon fertilization and 10–15% if carbon fertilization is incorporated, whereas industrial countries experience outcomes ranging from 6% losses without carbon fertilization to 8% gains with it. Germany has minimal losses without carbon fertilization but moderate gains with it in Europe. The results are less beneficial in Spain, reflecting the country's latitudinal location. Without carbon fertilization, Russia's productivity falls by 8%; with it, Russia's productivity rises by 6% (Fig. 8 and Fig. 9).

Public Health and Social Policies on Global Warming IN Southern Europe

European Center for Disease Prevention and Control

The European Center for Disease Prevention and Control (ECDC) is an agency of the European Union (EU) whose mission is to strengthen Europe's defenses against infectious diseases. ECDC covers a wide spectrum of activities with national public health institutions across Europe to strengthen and develop Europe-wide disease surveillance and early warning systems, provides EU-level infectious disease surveillance, epidemic intelligence, early warning and

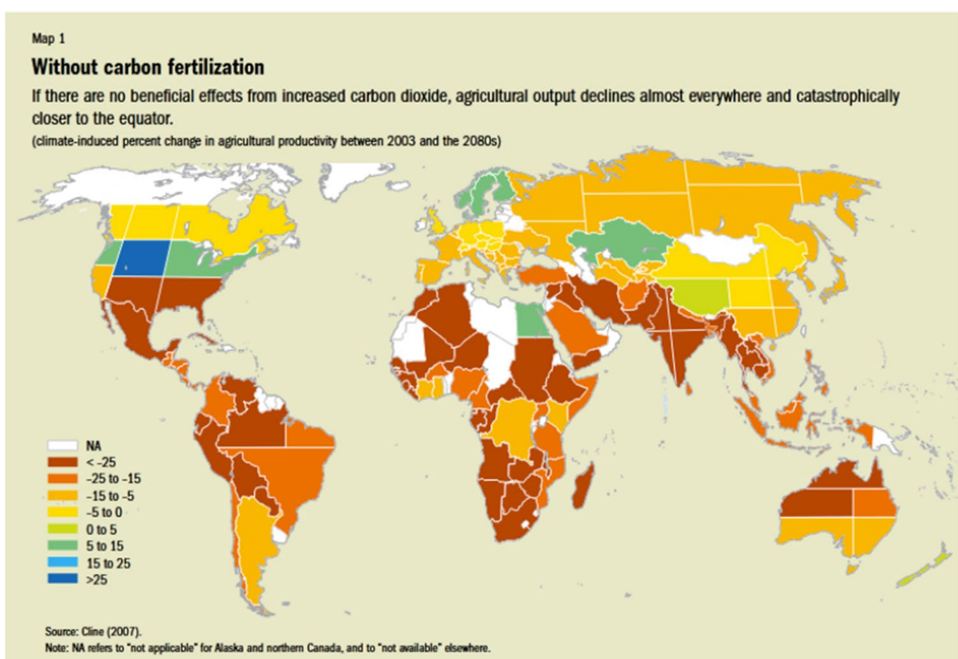


Fig. 8 Climate-induced percent change in agricultural productivity between 2003 and the 2080s without carbon fertilization Source: [185]. NA: not applicable for Alaska and Northern Canada, and not available for elsewhere

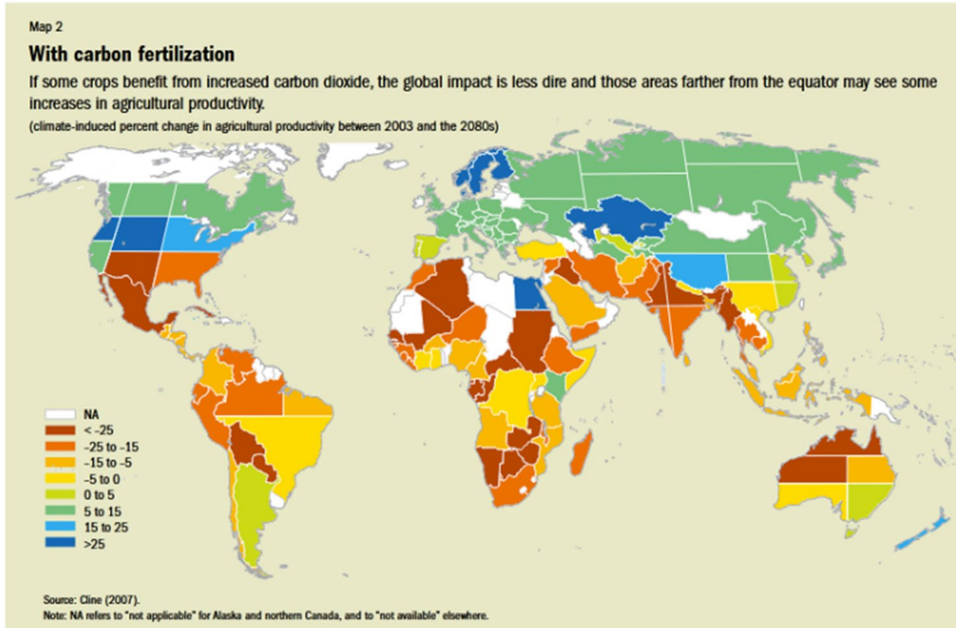


Fig. 9 Climate-induced percent change in agricultural productivity between 2003 and the 2080s with carbon fertilization. Source [185]. NA: not applicable for Alaska and Northern Canada, and not available for elsewhere. If some crops benefit from increased carbon dioxide, the global impact is less dire and those areas farther from the equator may see some increases in agricultural productivity

response, and searches for, collects, collates, evaluates and disseminates relevant scientific and technical data, providing scientific risk assessments and opinions, scientific and technical assistance including training, timely information to the Commission. It coordinates the European networking of bodies operating in the fields, including networks arising from public health activities supported by the Commission and operating dedicated networks for surveillance, information exchange, expertise, and best practices, and facilitates joint actions (https://www.ecdc.europa.eu/en/about-ecdc).

ECDC has developed the European Environment and Epidemiology (E3) Network with the goal of monitoring climatic and environmental precursors of epidemics and providing predictions that can be used to develop intervention [156].

European Environment and Epidemiology (E3) Network

The E3 Network was established by the ECDC to monitor environmental and climatic conditions of epidemic events which include VBD outbreaks to facilitate a more effective public health response [73]. The E3 Network provides technical support for the reporting, monitoring, analysis, and mapping of data and enhances the analytical capacity of existing resources in Europe. The network has compiled and processed data on European environmental, demographic, and climatic situation that are available for epidemiological analysis and prediction modeling, which is hosted at the E3 Geoportal (https://geoportal.ecdc.europa.eu/e3-network/generaldescription). For instance, data from the E3 Geoportal was used to inform effective public health action to address these VBDs successfully in the following instances:

1. E3 Geoportal was used to develop a multivariate model to identify areas at risk for transmission based on climatic and environmental conditions during the reintroduction and autochthonous transmission of malaria in Greece in 2009–2012. The models enable public outreach and dedicated surveillance that led to the end of the outbreak in 2013 [186].
2. Environmental data from E3 Geoportal was used to identify the risk of transmission of tick-borne encephalitis (TBE) in certain areas of southern Sweden by delineating these areas suitable for transmission through vaccination campaigns.
3. Environmental and Meteorological data from the E3 Geoportal were used to develop a predictive model of West Nile Virus (WNV) that can now be used to predict potential outbreaks in the future. The correlation between temperature deviations from the mean and WNV infections were assessed during the WNV outbreaks in 2010 in Europe [187, 188].
4. Dengue importation was modeled in 2010 from dengue active areas using air passenger volume. This can also be used to predict potential airports at risk and timing of transmission in the destination country in future [189].
5. Identify spatiotemporal risk parameters for chikungunya import into Europe from the Americas.

United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC acknowledges that CC impacts adversely affect human health and welfare [190] and requires member States to take necessary steps through policies and climate action to build resilience and minimize its adverse effects on public health amongst other areas (Art 4(1)(f) UNFCCC). This is iterated in the Paris Agreement and the Cancun Adaptation Framework which requires nations to act in addressing CC, including in the areas of health and human wellbeing (Preamble to the Paris Agreement; Para 14(a) of the Cancun Agreement).

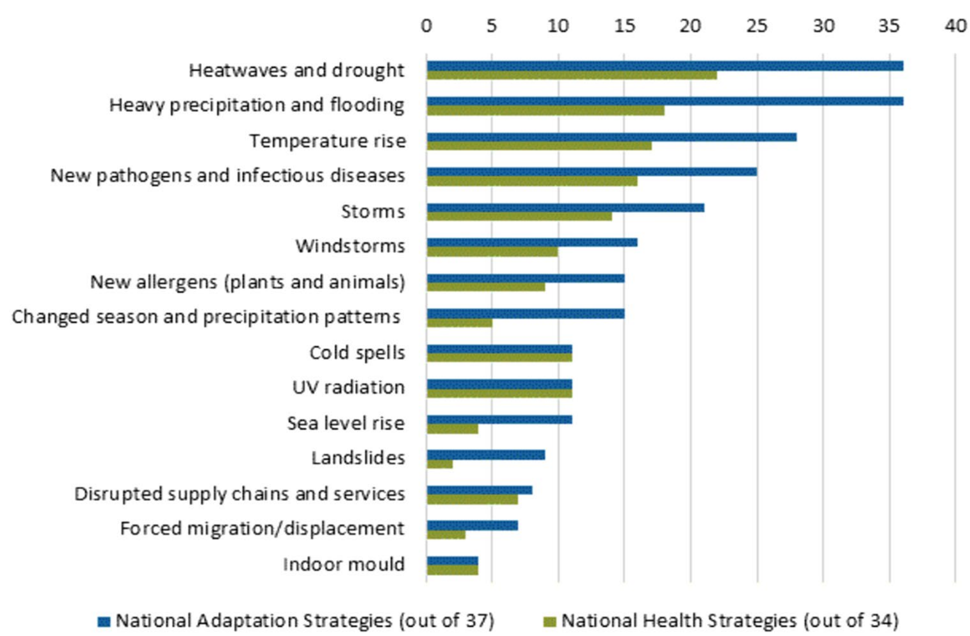
Specifically, reports by the WHO and the UN show that CC portends several health risks from extreme weather conditions, food scarcity, and other adverse effects. Of importance to this research is the point that CC would increase the propensity of infectious, vector-borne diseases (*Climate Change and Health*, n.d.; *The Health Effects of Global Warming: Developing Countries Are the Most Vulnerable | United Nations*, n.d.). As with other adverse effects of CC, the likely impacts on human wellbeing and public health have far-reaching implications of vulnerabilities, and it is necessary (in line with international frameworks acceded to) for individual states and regions to take necessary steps to identify these health vulnerabilities and establish adaptation strategies.

In view of the above, this section discusses the social vulnerabilities linked to public health, especially as it relates to the spread of vector-borne diseases in southern Europe. It also examines the various laws and policies by European Union and individual countries of Southern Europe and the extent to which these frameworks integrate health concerns. Furthermore, it seeks to examine the public health strategies to adapt to the health risks and hazards of CC. Climate change impacts raise new issues of vulnerabilities not only regarding the natural or biophysical environment but social vulnerabilities which put many human systems, including public health, at great risks and require streamlined and coordinated efforts at adaptation [191]. Socio-economic vulnerabilities to CC pose a varied form of threat as these aggravate the preexisting socio-economic weaknesses of societies and their inability to cope with the impacts of CC. For instance, in relation to Southern Europe, research shows a predisposition to social vulnerabilities due to an aging population and the geographical make up of most of the countries in the region. Specifically, the impact assessment showed that the sub regional experiences (European Commission Staff Working Document, 2021, p 14) and will continue to experience (ibid) significant negative social and economic losses, including vulnerabilities to climate health hazards (Fig. 10).

The European Climate Law and Policy Responses

In a bid to address the growing concerns around the negative impacts of CC on human health especially because of rising temperatures and the emergence of infectious diseases in the EU, the European Union Climate Change Law requires member States to build up adaptive capacity and strengthen resilience (Art 5, Climate Law Regulation (EU) 2021/1119). In adapting to CC, member States are required to ensure cross-sectoral integration of adaptation policies and to particularly identify areas of vulnerability

Fig. 10 Climate-related hazards to health included in the national policies reviewed



in various sectors (Art 5 (3) & (4) Climate Law). In furtherance of the goals of the EU in relation to identifying and building resilience to the health risks of CC, the EU Climate Law reiterates the intercepting role of science and governance through the collaborative work of the *European Environment Agency (EEA)*, the *European Centre for Disease Prevention and Control (ECDC) through the European Environment and Epidemiology (E3) Network*, the *European Climate and Health Observatory*, and the *Climate-Adapt*.

The health adaptation strategies of the EU are in line with the precautionary principle required in climate action to "better understand, anticipate and minimize threats of CC" to human and public health (Article 191 of the Treaty on the Functioning of the EU; Preamble to the EU Climate Law). Such collaborative and cross-sectoral health-related adaptation strategies are required in the southern Europe subregion where assessments have shown a predisposition and exposure to health hazards based on identified social vulnerabilities within the demographics such as age, low-income, and rural dwelling (Impact Assessment accompanying the Document: Forging a Climate-Resilient Europe-The New EU Strategy on Adaptation to Climate Change, n.d.).

A significant aspect of climate action anywhere in the world is the Adaptation initiatives available to build resilience and adapt to the negative impacts of CC. The EU Strategy on Adaptation to Climate Change (EU-SACC) reiterates the need to promote public health in view of the recent experiences with the COVID-19 pandemic (SWD (2021) 26 Forging a Climate-Resilient Europe—the New EU Strategy on Adaptation to Climate Change, p 1). In this regard, the EU-SACC prioritize the need for further research and expanding the knowledge base of CC health-related hazards such as the increase of infectious diseases within the Region (Ibid, 7). To this end, the EU aims to "…pool and connect data, tools, and expertise to communicate, monitor, analyze and prevent the effects of CC on human health," (ibid). Also, considering the transborder implications of infectious diseases, the EU-SACC highlights the need for a region-wide health vulnerabilities risk assessment to ascertain the level of preparedness to respond to climate-related health hazards (ibid, 15).

In implementing the EU-SACC, the Climate-ADAPT Strategy 2022 to 2024 outlines the roadmap for climate adaptation within the Region. A significant aspect of the Strategy is the consideration of adaptation to the climate health risks and hazards which aims at extending the scope of adaption and involving new stakeholders in adaption actions (Climate-ADAPT Strategy 2022–2024, p, 8). Specifically, Objective 4 of the Climate-Adapt Strategy aims at engendering regional and community resilience by providing information and sharing knowledge on various vulnerabilities, including health hazards, and providing guidelines for viable adaption action across member countries (Climate-ADAPT Strategy, p. 12).

The Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCCAR5) identifies three distinct pathways through which CC impacts human health negatively [192]. These are through direct impacts of extreme weather conditions, through natural systems media such as disease vectors, water-borne diseases, and air pollution, and through socio-economic drivers of man-made systems such as occupational impacts, undernutrition, and mental stress [192]. The IPCC AR5 Report also emphasizes that the lack or cut-back in public infrastructure such as health care could lead to the spread of certain infectious diseases which have rebounded because of CC. It is worthy of note that within Europe, Southern Europe is projected to be most likely affected by health-related CC impacts due to the increased warming within the subregion.

The Intergovernmental Panel on Climate Change Special Report (IPCCSR) on the impacts of GW pointed out that the global temperature is 1.5 °C above pre-industrial levels and attributed it to global greenhouse gas emissions. To curb the potential impacts of GW, IPCCSR suggested the need for strengthening the global response to the threat of CC and promotion of sustainable development activities [193]. The 2018 IPCCSR on impacts of GW notes that increase in temperature leads to higher vulnerability to diseases and reduces the capacity of human health systems to manage such climate related impacts [194]. In relation to the spread of vector-borne diseases, there are positive projections that 1.5 to 2 °C warming in parts of Europe will lead to the greater transmission and spread, as well as extend the geographic range (ibid).

In view of the high probability of increase in the spread of vector-borne diseases globally, especially in the Mediterranean and Southern Europe (which have been described as climate hot spots), the IPCCS Global Warming 1.5° notes the importance of emergency public health measures as a form of adaptive action to prevent or reduce morbidity and mortality from the spread of vector-borne diseases [2]. These public health adaptation measures would include improved human health management systems and health infrastructure to cater for hitherto uncommon or unknown diseases within the region; and an early advisory system to detect such climate sensitive diseases as is already in place with the Observatory.

Framing Climate Change Adaptation as a Public Health Issue

While there are various adaptation strategies, this paper limits itself to the analysis of public health laws as the viable adaptation strategy to tackle the risks of spread of diseases exacerbated by CC [195]. The health implications of CC make it a matter of public health concern, especially in relation to the likelihood of proliferation of VBDs in Southern Europe. In essence, public health policies and legislation become a viable adaptation tool. Public health policies and legislation have been concerned among other things, with intelligence and response, education and advocacy concerning various forms and classes of diseases [196]. Greer and Jarman further posit that framing a problem as a public health concern engenders collaborative action across connected sectors in response to the health implications of the identified problem [196]. Eleanor Brooks and Anniek de Ruijter also clarify public health laws as regulating relationships between citizens, state, and non-state actors to protect and promote the health of the general population [197].

Seeing that CC has broad impacts on human health and health systems, it is essential to have an integrated governance approach which ensures that CC and health is a policy and action issue across spheres of governance (WHO). Such action has become pertinent as a public health concern as the health impacts of CC may likely throw even the most developed climes a few steps back in terms of human health systems and disease prevention. Thus, in line with the precautionary principle, effective public and thorough policy measures are necessary to protect the health and wellbeing and build resilience to the apparent and projected negative health impacts of CC. The EU has towed this path by establishing a cross-sectoral public health structure through the Health in All Policies (HIAP) approach on various issues of public health, including CC (Public health | Fact Sheets on the European Union | European Parliament (europa.eu).

Public *Health Laws* of Countries in Southern Europe

Public health laws and policies have always been tools adopted by governments to safeguard health and human wellbeing. In terms of CC, it is a viable cross-sectoral tool for climate action in safeguarding both human and public health. Public health laws have also been considered from a risk-based approach, that is, the legal powers and duties of the State to identify, prevent, reduce, and manage risks to public health [198]. While public health falls within the purview of national and sub-national jurisdictions, CC adaptation spans all levels of governance and requires collaborative action. In essence, adaptation to the health impacts of CC as a public health concern would require action at all levels of governance and entail the strengthening of health systems, provision of adequate warning systems, viable action plans and preparedness, monitoring and surveillance, and an integration of public health considerations across sectors. (*POLICY BRIEF: HEALTH AND CLIMATE ACTION*, n.d.)

The Treaty on the Functioning of the EU requires the Union and member States to take necessary action to prevent illnesses and diseases and to improve the quality of human health by taking necessary action to prevent, monitor, and combat various possible threats to public health (Article 168, Treaty on the Functioning of the European Union (TOFEU)). While this section makes no direct reference, CC-induced threats to human and public health will be given due consideration. Furthermore, the Treaty provides for the protection of human health as part of its environmental policies as well as combating problems related to CC. The joint reading of Articles 168 and 191 of the TOFEU is to the effect that necessary action is to be taken to preserve human and public health in the event of environmental or other threats such as CC.

Majority of the countries of Southern Europe have codified provisions safeguarding and promoting public health. In Spain for instance, the Law codifies the public health policy and establishes citizens' rights and duties as well as government obligations to protect and promote public health. A notable provision is the establishment of a "public health surveillance" which establishes a warning and rapid response system to detect and evaluate incidents, risks, and threats of diseases (Chapter 1, Article 12, Ley 33/2011, de 4 de octubre, General de Salud Pública). The Public Health Act of the Republic of Albania also entails an extensive framework on public health surveillance which includes investigating health problems and identifying risk factors: strengthening laws, regulations that protect and safeguard citizens, and public health guaranteeing continued research into solutions of health problems. Of utmost importance, however, is the provision on preparedness and taking measures to mitigate health impacts of natural and man-made disasters such as CC (Article 5 Public Health Act, Republic of Albania, n.d.) In Slovenia, the public health measures also extends to researching into protecting and monitoring the public state of health and taking necessary steps to safeguard against public health risks from a variety of sources including environmental and CC hazards (CoR—Slovenia Public health (europa.eu) (*Slovenia—Organization and Financing of Public Health Services in Europe—NCBI Bookshelf*, n.d.) The research shows some innovations in the public health laws of some countries which some other laws will require a level of reform to bring them up to date with the realities of contemporary health threats such as CC. The Croatian Health Care Act is a contemporary public health legislation which includes the rights, duties, and obligations of the government and citizens in relation to the safeguard of individual and public health. These measures include adopting social and economic policies and coordinated activities across spheres of government (Article 6) to ensure the protection of citizens' public health from environmental factors (Article 7) (*Health Care Act—Zakon.Hr*, n.d.).

National Adaptation Plans and Strategies

It is worthy of note that the EU-SACC highlights the need for urgent and intensified action in Southern Europe and the Mediterranean based on evidence that the subregion is a CC hotspot and is warming at a 20% rate faster than global trends (EU Strategy on Adaptation to Climate Change, p 18). Notably, while the EU has a detailed adaptation strategy on health and CC, this is quite lacking at the individual country levels (*Climate Change and Health: Overview of National Policies in Europe — European Climate and Health Observatory*, n.d.). A review of national adaptation policies in Europe shows that few countries (Finland, Ireland, Sweden, and North Macedonia) have a specific sectoral strategy for adaptation to climate health threats (*Climate Change and Health: Overview of National Policies in Europe — European Climate and Health Observatory*, n.d.). Other countries have National Adaptation Strategies which incorporate health considerations along with other sectors as against a specific health response strategy to climate risks (*Climate Change and Health: Overview of National Policies in Europe — European Climate and Health Observatory*, n.d.). Of all the Southern Europe Countries assessed by the European Climate and Health Observatory, Spain has the most comprehensive assessments including a National Adaptation Strategy (NAS), National Adaptation Plan (NAP), and sectoral vulnerability assessments and adaptation plans (*Country Profiles — Climate-ADAPT*, n.d.). A survey carried out by the European Climate and Health Observatory involving members of the European Environment Agency (European Climate and Health Observatory, CC and health: the national policy overview in Europe 2022) shows the status of countries in relation to their national adaptation strategies and national health strategies. The survey shows that in some Southern European countries, there is no distinct policy on national adaptation plans or strategies; most countries in Southern Europe have some form of policy or strategy statement on Adaptation; in some countries, there is no link established between CC and health (*Climate Change and Health: The National Policy Overview in Europe*, 2022, p 3).

Global Change Research Act and Law

Global Change Research Act (GCRA) is an establishment law enacted in 1990 by the government of the USA. The main purpose of the Law is to establish a US Global Change Research Program to study and understand GW and its effects on the physical, chemical, and biological processes of the environment, as well as on human health, and to "to promote discussions toward international protocols in global change research, and for other purposes" (Preamble and Sect. 101 of the US Global Change Research Act, 1990 USGCRA). The US Global Change Research Program (USGCRP) established under the Act is a cross-sectoral body which coordinates collaborative research across various agencies and departments of the government on GW, CC, and its impacts on human health and other aspects of the environment (Sect. 102, USGCRA). According to Gage et al. [199], research done under the auspices of the USGCRP confirm that the "seasonality, distribution, and prevalence of VBDs are influenced significantly by climate factors, primarily high and low temperature extremes and precipitation patterns" [199]. In essence, the functions of the USGCRP are like those performed by the *European Environment Agency (EEA)* in collaboration with other agencies at the regional level. As with other forms of adaptation however, action is most effective the closer it is to the people. Thus, viable health adaptation will require agencies similar to the USGCRP at the individual country levels in Southern Europe so that these agencies can collaboratively research into and address health risks that are peculiar to the subregion.

Conclusion

The impacts of CC and GW on our ecosystem is becoming very clear and felt across the globe, which manifests as abnormal surge in ambient temperature as that is presently experienced in Europe and other parts of the world, prolonged Summer in temperate climates, and unusual precipitations. These all contributes to ecological imbalance that results in habitat expansion for vectors of pathogens causing emergence of diseases in previously non-endemic regions. A good example is the report of the first case of African swine fever this year (2022) in Northern Italy and West Nile fever in Southern Europe. Both diseases are caused by viruses and transmitted by ticks and mosquitoes, respectively. Warmer ambient temperature is favorable to ticks and mosquitoes. Since the Intergovernmental Panel on Climate Change (IPCC) still predicts that the earth will continue to warm up, it is only wise to encourage formulation of policies at the national, regional, and global levels that will help to mitigate the potential health and economic hazards of the global spread of vector-transmitted infectious diseases. Commendably, Europe has set up regional agencies in this regard such as European Environment Agency (EEA), the European Centre for Disease Prevention and Control (ECDC), European Environment and Epidemiology (E3) Network, and the European Climate and Health Observatory and the Climate-Adapt. There is not much collaboration between these agencies in Europe with similar bodies in the neighboring tropical continent, African. We therefore recommend a better partnership between the European-related agencies with those of countries in Africa. We believe this will promote synergistic efforts for formulating more robust policies that will help Europe, Africa, and the world at large to combat the menace of emerging vector-borne diseases.

Acknowledgements EOB is a recipient of the Emerging Global Leader (K43) Award of the National Institutes of Health and supported by funding from the Fogarty International Center of the National Institutes of Health under Award Number K43TW012015. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Data Availability The data presented in this study are available on request from the corresponding author.

Declarations

Conflict of Interest The authors declare no competing interests.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. NASA. Vital signs of the planet. URL: https://climatenasagov/vital-signs/global-temperature/(dataobrashhenija:25122019). 2018.
2. IPCC. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. 2018.
3. NRDC. Global climate change: what you need to know 2021 [cited 2022 June 25]. Available from: https://climatenasagov/vital-signs/global-temperature/(dataobrashhenija:25122019). 2018
4. El-Sayed A, Kamel M. Climatic changes and their role in emergence and re-emergence of diseases. Environ Sci Pollut Res Int. 2020;27(18):22336–52.
5. Gubler DJ. The global threat of emergent/re-emergent vector-borne diseases. Vector Biology, Ecology and Control: Springer Netherlands; 2010. p. 39–62.
6. Balogun EO, Nok AJ, Kita K. Global warming and the possible globalization of vector-borne diseases: a call for increased awareness and action. Tropical Medicine and Health. 2016;44(1):1–3.
7. Christofferson RC, Parker DM, Overgaard HJ, et al. Current vector research challenges in the greater Mekong subregion for dengue, Malaria, and Other Vector-Borne Diseases: a report from a multisectoral workshop March 2019. PLoS Negl Trop Dis. 2020;14(7):e0008302–e0008302.
8. Dudley JP, Hoberg EP, Jenkins EJ, et al. Climate change in the North American Arctic: a one health perspective. EcoHealth. 2015;12(4):713–25.
9. Otranto D, Dantas-Torres F, Breitschwerdt EB. Managing canine vector-borne diseases of zoonotic concern: part one. Trends in Parasitology. 2009;4:157–63.
10. Ostfeld RS, Brunner JL. Climate change and Ixodes tick-borne diseases of humans. Philos Trans R Soc Lond B Biol Sci. 2015;370(1665):20140051.
11. Artigas P, Reguera-Gomez M, Valero MA, et al. *Aedes albopictus* diversity and relationships in south-western Europe and Brazil by rDNA/mtDNA and phenotypic analyses: ITS-2, a useful marker for spread studies. Parasit Vectors. 2021;14(1):333–333.
12 Shuman EK. Global climate change and infectious diseases. New Eng J Medicine. 2010;362(12):1061–3.
13. Betts R. Met Office: Atmospheric CO_2 now hitting 50% higher than pre-industrial levels. Carbon Brief. 2021.
14. IPCC. Climate change 2021: the physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change2021. p. 2.
15. Bach W. Fossil fuel resources and their impacts on environment and climate. Int J Hydrogen Energy. 1981;6(2):185–201.
16. Lynch J, Cain M, Frame D, et al. Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil CO_2-emitting sectors. Frontiers in sustainable food systems. 2021:300.
17. Bala G, Caldeira K, Wickett M, et al. Combined climate and carbon-cycle effects of large-scale deforestation. Proc Natl Acad Sci. 2007;104(16):6550–5.
18. Moomaw WR. Industrial emissions of greenhouse gases. Energy Policy. 1996;24(10–11):951–68.
19. WHO. Climate change and health 2021 [cited 2022 June 25]. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health
20. Lacetera N. Impact of climate change on animal health and welfare. Anim Front. 2019;9(1):26–31.
21. Luterbacher J, Dietrich D, Xoplaki E, et al. European seasonal and annual temperature variability, trends, and extremes since 1500. Science. 2004;303(5663):1499–503.
22. Vitali A, Felici A, Esposito S, et al. The effect of heat waves on dairy cow mortality. J Dairy Sci. 2015;98(7):4572–9.
23.• Ebi KL, Vanos J, Baldwin JW, et al. Extreme weather and climate change: population health and health system implications. Annual review of public health. 2021;42:293–315. **Describes the effects of extreme weather conditions on health system and concludes that the only panacea to climate change is the establishment of climate-resilient health systems with improved risk reduction, preparation, response, and recovery.**
24. Froment R, Below R. Disaster* year in review 2019. Centre for Research on the Epidemiology of Disasters (CRED) Louvain; 2020.
25. Langner J, Bergström R, Foltescu V. Impact of climate change on surface ozone and deposition of sulphur and nitrogen in Europe. Atmos Environ. 2005;39(6):1129–41.
26. Racherla PN, Adams PJ. Sensitivity of global tropospheric ozone and fine particulate matter concentrations to climate change. Journal of Geophysical Research: Atmospheres. 2006;111(D24).
27. NRC. Advancing the science of climate change. National Academies Press; 2011.
28. Parker ER. The influence of climate change on skin cancer incidence–a review of the evidence. Int J Women's Dermatol. 2021;7(1):17–27.
29. USEPA. Climate impacts on water quality 2022 [cited 2022 June 25]. Available from: https://www.epa.gov/arc-x/climate-impacts-water-quality

30. D'Amato G, Chong-Neto HJ, Monge Ortega OP, et al. The effects of climate change on respiratory allergy and asthma induced by pollen and mold allergens. Allergy. 2020;75(9):2219–28.
31. Perrone G, Ferrara M, Medina A, et al. Toxigenic fungi and mycotoxins in a climate change scenario: ecology, genomics, distribution, prediction and prevention of the risk. Microorganisms. 2020;8(10):1496.
32. Kim K-H, Kabir E, Ara JS. A review of the consequences of global climate change on human health. J Environ Sci Health C. 2014;32(3):299–318.
33. Hotez PJ. Southern Europe's coming plagues: vector-borne neglected tropical diseases. CA USA: Public Library of Science San Francisco; 2016. p. e0004243.
34. WHO. Global Vector Control Response 2017–2030. 2017.
35. Wuebbles D, Fahey D, Hibbard K, et al. US Global Change Research Program: Washington. DC, USA. 2017;1.
36.•• Rocklöv J, Dubrow R. Climate change: an enduring challenge for vector-borne disease prevention and control. Nat Immunol. 2020;21(5):479–483. **Triangulates how meteorological variables affect the incidence, transmission- season duration, and spread of vector-borne diseases; and models effects of future climate change that can aid long-term planning for the prevention and control of vector-borne diseases.**
37. Liu-Helmersson J, Stenlund H, Wilder-Smith A, et al. Vectorial capacity of *Aedes aegypti*: effects of temperature and implications for global dengue epidemic potential. PLoS ONE. 2014;9(3):e89783–e89783.
38. Rocklöv J, Tozan Y, Ramadona A, et al. Using big data to monitor the introduction and spread of Chikungunya, Europe, 2017. Emerg Infect Dis. 2019;25(6):1041–9.
39 Morin CW, Comrie AC, Ernst K. Climate and dengue transmission: evidence and implications. Environ Health Perspect. 2013;121(11–12):1264–72.
40 Paz S. Effects of climate change on vector-borne diseases: an updated focus on West Nile virus in humans. Emerging Topics in Life Sci. 2019;3(2):143–52.
41. Colón-González FJ, Sewe MO, Tompkins AM, et al. Projecting the risk of mosquito-borne diseases in a warmer and more populated world: a multi-model, multi-scenario intercomparison modelling study. Lancet Planet Health. 2021;5(7):e404–14.
42. Agency EE. Climate change, impacts and vulnerability in Europe 2016 : an indicator-based report. Publications Office; 2017.
43. Chalghaf B, Chemkhi J, Mayala B, et al. Ecological niche modeling predicting the potential distribution of Leishmania vectors in the Mediterranean basin: impact of climate change. Parasit Vectors. 2018;11(1):1–9.
44. Fros JJ, Geertsema C, Vogels CB, et al. West Nile virus: high transmission rate in north-western European mosquitoes indicates its epidemic potential and warrants increased surveillance. PLoS Negl Trop Dis. 2015;9(7):e0003956.
45. Casimiro E, Calheiros J, Santos FD, et al. National assessment of human health effects of climate change in Portugal: approach and key findings. Environ Health Perspect. 2006;114(12):1950–6.
46. Alves M, Fernandes P, Amaro F, et al. Clinical presentation and laboratory findings for the first autochthonous cases of dengue fever in Madeira island, Portugal, October 2012. Eurosurveillance. 2013;18(6):20398.
47. Marchand E, Prat C, Jeannin C, et al. Autochthonous case of dengue in France, October 2013. Eurosurveillance. 2013 18(50).
48.•• Semenza JC, Paz S. Climate change and infectious disease in Europe: impact, projection and adaptation. Lancet Reg Health Eur. 2021;9:100230–100230. **Discusses climate change–related hazards, exposures, and vulnerabilities to infectious disease in Europe and describes observed impacts, projected risks, and policy entry points for adaptation to reduce or avoid these risks.**
49 Fischer D, Thomas SM, Niemitz F, et al. Projection of climatic suitability for *Aedes albopictus* Skuse (Culicidae) in Europe under climate change conditions. Global and Planetary Change. 2011;78(1–2):54–64.
50. Grandadam M, Caro V, Plumet S, et al. Chikungunya virus, southeastern France. Emerg Infect Dis. 2011;17(5):910–3.
51. Rezza G. Dengue and chikungunya: long-distance spread and outbreaks in naïve areas. Pathog Glob Health. 2014;108(8):349–55.
52. Sissoko D, Giry C, Gabrie P, et al. Rift Valley fever, Mayotte, 2007–2008. Emerg Infect Dis. 2009;15(4):568–70.
53. Marini G, Calzolari M, Angelini P, et al. A quantitative comparison of West Nile virus incidence from 2013 to 2018 in Emilia-Romagna. Italy PLoS Negl Trop Dis. 2020;14(1):e0007953–e0007953.
54. Rudolf I, Betášová L, Blažejová H, et al. West Nile virus in overwintering mosquitoes, central Europe. Parasit Vectors. 2017;10(1):452–452.
55 Genchi C, Kramer LH. The prevalence of Dirofilaria immitis and D repens in the Old World. Veterinary Parasitology. 2020;280:108995.
56. Mathanga DP, Tembo AK, Mzilahowa T, et al. Patterns and determinants of malaria risk in urban and peri-urban areas of Blantyre. Malawi Malar J. 2016;15(1):590–590.
57. Takken W, Lindsay S. Increased threat of urban malaria from *Anopheles stephensi* mosquitoes. Africa Emerg Infect Dis. 2019;25(7):1431–3.
58. Grillet ME, Hernández-Villena JV, Llewellyn MS, et al. Venezuela's humanitarian crisis, resurgence of vector-borne diseases, and implications for spillover in the region. The Lancet Infect Dis. 2019;19(5):e149–61.
59. Watts N, Amann M, Arnell N, et al. The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. The Lancet. 2019;394(10211):1836–78.
60. WHO. Dengue: guidelines for diagnosis, treatment, prevention and control. Geneva. 2009.
61 Rosen L. Dengue in Greece in 1927 and 1928 and the pathogenesis of dengue hemorrhagic fever: new data and a different conclusion. Am J Trop Med Hygiene. 1986;35(3):642–53.
62. Schmidt-Chanasit J, Haditsch M, Schöneberg I, et al. Dengue virus infection in a traveller returning from Croatia to Germany. Eurosurveillance. 2010;15(40).
63. Adalja AA, Sell TK, Bouri N, et al. Lessons learned during dengue outbreaks in the United States, 2001–2011. Emerg Infect Dis. 2012;18(4):608–14.
64 Ross RW. The Newala epidemic III The virus: isolation, pathogenic properties and relationship to the epidemic. J Hyg (Lond). 1956;54(2):177–91.
65 Ng LC, Hapuarachchi HC. Tracing the path of Chikungunya virus—evolution and adaptation. Infect Genetics Evolution. 2010;10(7):876–85.
66 Rezza G, Nicoletti L, Angelini R, et al. Infection with chikungunya virus in Italy: an outbreak in a temperate region. The Lancet. 2007;370(9602):1840–6.
67. Njenga MK, Nderitu L, Ledermann J, et al. Tracking epidemic chikungunya virus into the Indian Ocean from East Africa. J Gen Virol. 2008;89(Pt 11):2754.
68. Kumar NP, Joseph R, Kamaraj T, et al. A226V mutation in virus during the 2007 chikungunya outbreak in Kerala. India J General Virology. 2008;89(8):1945–8.
69 EFSA. Opinion of the scientific panel on animal health and welfare (AHAW) on a request from the commission related to the aspects of the biology and welfare of animals used for

experimental and other scientific purposes. EFSA Journal. 2005;3(12):292.
70. Chevalier V, Pépin M, Plée L, et al. Rift Valley fever - a threat for Europe? Eurosurveillance. 2010;15(10).
71. Fortuna C, Montarsi F, Severini F, et al. The common European mosquitoes *Culex pipiens* and *Aedes albopictus* are unable to transmit SARS-CoV-2 after a natural-mimicking challenge with infected blood. Parasit Vectors. 2021;14(1):1–6.
72. Kilpatrick AM, Meola MA, Moudy RM, et al. Temperature, viral genetics, and the transmission of West Nile virus by *Culex pipiens* mosquitoes. PLoS Pathog. 2008;4(6):e1000092–e1000092.
73. Paz S, Semenza JC. Environmental drivers of West Nile fever epidemiology in Europe and Western Asia–a review. Int J Environ Res Public Health. 2013;10(8):3543–62.
74. May FJ, Davis CT, Tesh RB, et al. Phylogeography of West Nile virus: from the cradle of evolution in Africa to Eurasia, Australia, and the Americas. J Virol. 2011;85(6):2964–74.
75 Sambri V, Capobianchi M, Charrel R, et al. West Nile virus in Europe: emergence, epidemiology, diagnosis, treatment, and prevention. Clin Microbiol Infec. 2013;19(8):699–704.
76. Vlaskamp DR, Thijsen SF, Reimerink J, et al. First autochthonous human West Nile virus infections in the Netherlands, July to August 2020. Euro Surveill. 2020;25(46):2001904.
77 Cotar AI, Falcuta E, Prioteasa LF, et al. Transmission dynamics of the West Nile virus in mosquito vector populations under the influence of weather factors in the Danube Delta. Romania EcoHealth. 2016;13(4):796–807.
78. Morchón R, Carretón E, González-Miguel J, et al. Heartworm disease (*Dirofilaria immitis*) and their vectors in Europe - new distribution trends. Front Physiol. 2012;3:196–196.
79. Simón F, Siles-Lucas M, Morchón R, et al. Human and animal dirofilariasis: the emergence of a zoonotic mosaic. Clin Microbiol Rev. 2012;25(3):507–44.
80. Otranto D, Dantas-Torres F, Brianti E, et al. Vector-borne helminths of dogs and humans in Europe. Parasit Vectors. 2013;6:16–16.
81. Széll Z, Bacsadi Á, Szeredi L, et al. Rapid spread and emergence of heartworm resulting from climate and climate-driven ecological changes in Hungary. Veterinary Parasitology. 2020;280:109067.
82. Nuttall PA. Climate change impacts on ticks and tick-borne infections. Biologia. 2021:1–10.
83. Wikel SK. Ticks and tick-borne infections: complex ecology, agents, and host interactions. Veterinary Sci. 2018;5(2):60.
84. Cafiso A, Olivieri E, Floriano AM, et al. Investigation of tick-borne pathogens in *Ixodes ricinus* in a peri-urban park in Lombardy (Italy) reveals the presence of emerging pathogens. Pathogens. 2021;10(6):732.
85. Rochlin I, Toledo A. Emerging tick-borne pathogens of public health importance: a mini-review. J Med Microbiol. 2020;69(6):781.
86. Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. Nature. 2005;438:310–7.
87. Ogden NH, Ben Beard C, Ginsberg HS, et al. Possible effects of climate change on ixodid ticks and the pathogens they transmit: predictions and observations. J Med Entomol. 2021;58(4):1536–45.
88. Bush E, Lemmen D. Canada's changing climate report; Government of Canada. Ottawa, ON, Canada. 2019.
89. Guillot C, Badcock J, Clow K, et al. Surveillance sentinelle du risque de la maladie de Lyme au Canada, 2019: résultats de la première année du Réseau sentinelle canadien de surveillance de la maladie de Lyme (ReSCaL). Canada communicable disease report. 2020;46(10).
90. Vial L, Stachurski F, Leblond A, et al. Strong evidence for the presence of the tick *Hyalomma marginatum* Koch, 1844 in southern continental France. Ticks and Tick-borne Diseases. 2016;7(6):1162–7.
91. Stachurski F, Vial L. Installation de la tique *Hyalomma marginatum*, vectrice du virus de la fièvre hémorragique de Crimée-Congo, en France continentale. 2018.
92. Raghavan R, Barker S, Cobos M, et al. Potential spatial distribution of the newly introduced long-horned tick, *Haemaphysalis longicornis* in North America. Sci Rep. 2019;9(1):498.
93. Körner S, Makert GR, Ulbert S, et al. The prevalence of *Coxiella burnetii* in hard ticks in Europe and their role in Q fever transmission revisited—a systematic review. Front Vet Sci. 2021;8:655715.
94. Efstratiou A, Karanis P. Human tick-borne diseases in Southern Europe: present status and future challenges. 2019.
95. Fanelli A, Buonavoglia D. Risk of Crimean Congo haemorrhagic fever virus (CCHFV) introduction and spread in CCHF-free countries in southern and Western Europe: a semi-quantitative risk assessment. One Health. 2021;13:100290.
96. Gray J, Dautel H, Estrada-Peña A, et al. Effects of climate change on ticks and tick-borne diseases in Europe. Interdisciplinary perspectives on infectious diseases. 2009;2009.
97. Leighton PA, Koffi JK, Pelcat Y, et al. Predicting the speed of tick invasion: an empirical model of range expansion for the Lyme disease vector *Ixodes scapularis* in Canada. J Appl Ecol. 2012;49(2):457–64.
98. Figoni J, Chirouze C, Hansmann Y, et al. 2019 Lyme borreliosis and other tick-borne diseases Guidelines from the French Scientific Societies (I) prevention epidemiology diagnosis. Médecine et maladies infectieuses.49(5):318–334.
99. Estrada-Peña A, Fernández-Ruiz N. A retrospective assessment of temperature trends in Northern Europe reveals a deep impact on the life cycle of *Ixodes ricinus* (Acari: Ixodidae). Pathogens. 2020;9(5):345.
100. Battisti E, Urach K, Hodžić A, et al. Zoonotic pathogens in ticks from migratory birds, Italy. Emerg Infect Dis. 2020;26(12):2986.
101. Chisu V, Foxi C, Mannu R, et al. A five-year survey of tick species and identification of tick-borne bacteria in Sardinia. Italy Ticks and tick-borne Dis. 2018;9(3):678–81.
102. Papa A, Dalla V, Papadimitriou E, et al. Emergence of Crimean-Congo haemorrhagic fever in Greece. Clin Microbiol Infect. 2010;16(7):843–7.
103. Portillo A, Palomar AM, Santibáñez P, et al. Epidemiological aspects of Crimean-Congo hemorrhagic fever in Western Europe: what about the future? Microorganisms. 2021;9(3):649.
104. Parola P, Socolovschi C, Jeanjean L, et al. Warmer weather linked to tick attack and emergence of severe rickettsioses. PLoS Negl Trop Dis. 2008;2(11):e338.
105. Vieira Lista MC, Belhassen-García M, Vicente Santiago MB, et al. Identification and distribution of human-biting ticks in Northwestern Spain. Insects. 2022;13(5):469.
106. de Sousa R, Nóbrega SD, Bacellar F, et al. Mediterranean spotted fever in Portugal: risk factors for fatal outcome in 105 hospitalized patients. Ann N Y Acad Sci. 2003;990(1):285–94.
107. Grgič-Vitek M, Klavs I. High burden of tick-borne encephalitis in Slovenia—challenge for vaccination policy. Vaccine. 2011;29(32):5178–83.
108. Petrulionienė A, Radzišauskienė D, Ambrozaitis A, et al. Epidemiology of Lyme disease in a highly endemic European zone. Medicina. 2020;56(3):115.
109. Sprong H, Azagi T, Hoornstra D, et al. Control of Lyme borreliosis and other *Ixodes ricinus*-borne diseases. Parasit Vectors. 2018;11(1):1–16.

110 Andric B. Vector borne transmissible zoonoses in Montenegro Journal of IMAB–Annual. Proceeding Scientific Papers. 2012;18(1):220–5.
111. Banović P, Díaz-Sánchez AA, Simin V, et al. Clinical aspects and detection of emerging rickettsial pathogens: a "One Health" approach study in Serbia, 2020. Frontiers in Microbiology. 2021;12.
112. Mulić R, Petković B, Klišmanić Z, et al. 2011 Bolesti koje se prenose krpeljima na području Hrvatske. Liječnički vjesnik 133(3–4):0–0.
113. Organization WH. Climate change and communicable diseases: a manual for health workers. 2011.
114. Omeragić J, Šerić-Haračić S, Soldo DK, et al. Distribution of ticks in Bosnia and Herzegovina. Ticks and tick-borne diseases. 2022;13(1):101870.
115. Hodžić A, Alić A, Fuehrer H-P, et al. A molecular survey of vector-borne pathogens in red foxes (*Vulpes vulpes*) from Bosnia and Herzegovina. Parasit Vectors. 2015;8(1):1–7.
116. Papa A, Tsergouli K, Tsioka K, et al. Crimean-Congo hemorrhagic fever: tick-host-virus interactions. Front Cell Infect Microbiol. 2017;7:213.
117. Maroli M, Feliciangeli M, Bichaud L, et al. Phlebotomine sandflies and the spreading of leishmaniases and other diseases of public health concern. Med Vet Entomol. 2013;27(2):123–47.
118. Mehrabi-Tavana A. Sand fly fever with different names. J Arthropod Borne Dis. 2017;11(1):171.
119. WHO. Fact sheets - leishmaniasis 2022 [cited 2022 19th September]. Available from: https://www.who.int/news-room/fact-sheets/detail/leishmaniasis
120. ECDC. Phlebotomine sand flies - factsheet for experts 2022 [cited 2022 22 July]. Available from: https://www.ecdc.europa.eu/en/disease-vectors/facts/phlebotomine-sand-flies
121. González E, Molina R, Iriso A, et al. Opportunistic feeding behaviour and *Leishmania infantum* detection in *Phlebotomus perniciosus* females collected in the human leishmaniasis focus of Madrid, Spain (2012–2018). PLoS Negl Trop Dis. 2021;15(3):e0009240.
122. Remoli ME, Jiménez M, Fortuna C, et al. Phleboviruses detection in *Phlebotomus perniciosus* from a human leishmaniasis focus in South-West Madrid region. Spain Parasit Vectors. 2016;9(1):1–11.
123. Varani S, Cagarelli R, Melchionda F, et al. Ongoing outbreak of visceral leishmaniasis in Bologna Province, Italy, November 2012 to May 2013. Eurosurveillance. 2013;18(29):20530.
124. Kasap OE, Alten B. Laboratory estimation of degree-day developmental requirements of *Phlebotomus papatasi* (Diptera: Psychodidae) Journal of vector ecology: J Soc Vector Ecol. 2005;30(2):328–33.
125. Kasap OE, Alten B. Comparative demography of the sand fly *Phlebotomus papatasi* (Diptera: Psychodidae) at constant temperatures. J Vector Ecol. 2006;31(2):378–85.
126. Koch LK, Kochmann J, Klimpel S, et al. Modeling the climatic suitability of leishmaniasis vector species in Europe. Sci Rep. 2017;7(1):1–10.
127. Aspöck H, Gerersdorfer T, Formayer H, et al. Sandflies and sandfly-borne infections of humans in Central Europe in the light of climate change. Wien Klin Wochenschr. 2008;120(4):24–9.
128. Michelutti A, Toniolo F, Bertola M, et al. Occurrence of phlebotomine sand flies (Diptera: Psychodidae) in the northeastern plain of Italy. Parasit Vectors. 2021;14(1):1–7.
129. Alten B, Maia C, Afonso MO, et al. Seasonal dynamics of phlebotomine sand fly species proven vectors of Mediterranean leishmaniasis caused by Leishmania infantum. PLoS Negl Trop Dis. 2016;10(2):e0004458.
130. Ballart C, Alcover M, Portús M, et al. Is leishmaniasis widespread in Spain? First data on canine leishmaniasis in the province of Lleida, Catalonia, northeast Spain. Trans R Soc Trop Med Hyg. 2012;106(2):134–6.
131. Calzolari M, Chiapponi C, Bellini R, et al. Isolation of three novel reassortant phleboviruses, Ponticelli I, II, III, and of Toscana virus from field-collected sand flies in Italy. Parasit Vectors. 2018;11(1):1–11.
132. Dereure J, Vanwambeke SO, Malé P, et al. The potential effects of global warming on changes in canine leishmaniasis in a focus outside the classical area of the disease in southern France. Vector-Borne and Zoonotic Diseases. 2009;9(6):687–94.
133. Díaz-Sáez V, Corpas-López V, Merino-Espinosa G, et al. Seasonal dynamics of phlebotomine sand flies and autochthonous transmission of *Leishmania infantum* in high-altitude ecosystems in southern Spain. Acta Trop. 2021;213:105749.
134. Trájer AJ, Bede-Fazekas Á, Hufnagel L, et al. The effect of climate change on the potential distribution of the European Phlebotomus species. Appl Ecol Environ Res. 2013;11(2):189–208.
135. Ivović V, Kalan K, Zupan S, et al. Illegal waste sites as a potential micro foci of Mediterranean Leishmaniasis: first records of phlebotomine sand flies (Diptera: Psychodidae) from Slovenia. Acta Vet Brno. 2015;65:348–57.
136. Medenica S, Jovanović S, Dožić I, et al. Epidemiological surveillance of leishmaniasis in Montenegro, 1992–2013. Srp Arh Celok Lek. 2015;143(11–12):707–11.
137. Omeragić J, Hrvat H, Crnkić Ć, editors. Occurrence of protozoa in dogs in the area of Tuzla. International Congress on One World-One Health-One Vision; 2015.
138 Vaselek S, Ayhan N, Oguz G, et al. Sand fly and Leishmania spp survey in Vojvodina (Serbia): first detection of Leishmania infantum DNA in sand flies and the first record of Phlebotomus (Transphlebotomus) mascittii Grassi, 1908. Parasit Vectors. 2017;10(1):1–8.
139. Knez S, Štrbac S, Podbregar I. Climate change in the Western Balkans and EU Green Deal: status, mitigation and challenges. Energy, Sustainability and Society. 2022;12(1):1–14.
140 Beck W, Boch K, Mackensen H, et al. Qualitative and quantitative observations on the flea population dynamics of dogs and cats in several areas of Germany. Veterinary Parasitology. 2006;137(1–2):130–6.
141 Krasnov BR, Shenbrot GI, Khokhlova IS, et al. Diversification of ectoparasite assemblages and climate: an example with fleas parasitic on small mammals. Global Ecol Biogeography. 2005;14(2):167–75.
142. Gálvez R, Musella V, Descalzo MA, et al. Modelling the current distribution and predicted spread of the flea species *Ctenocephalides felis* infesting outdoor dogs in Spain. Parasit Vectors. 2017;10(1):428–428.
143. ECDC. Fleas (Siphonaptera) - Factsheet for health professionals 2022 [updated 9 Nov 2021; cited 2022 24 July]. Available from: https://www.ecdc.europa.eu/en/all-topics-z/disease-vectors/facts/fleas-siphonaptera-factsheet-health-professionals
144. Krasnov BR. Functional and evolutionary ecology of fleas: a model for ecological parasitology. Cambridge University Press; 2008.
145. Christodoulopoulos G, Theodoropoulos G, Kominakis A, et al. Biological, seasonal and environmental factors associated with *Pulex irritans* infestation of dairy goats in Greece. Vet Parasitol. 2006Apr 15;137(1–2):137–43.
146. Chaliotis G, Kritsotakis EI, Psaroulaki A, et al. Murine typhus in central Greece: epidemiological, clinical, laboratory, and therapeutic-response features of 90 cases. Int J Infect Dis. 2012;16(8):e591–6.
147 Rodríguez-Alonso B, Almeida H, Alonso-Sardón M, et al. Murine typhus How does it affect us in the 21st century? The

epidemiology of inpatients in Spain (1997–2015). Int J Infec Dis. 2020;96:165–71.
148. Rolain J-M, Franc M, Davoust B, et al. Molecular detection of Bartonella quintana, B. koehlerae, B. henselae, B. clarridgeiae, Rickettsia felis, and Wolbachia pipientis in cat fleas, France. Emerg Infect Dis. 2003;9(3):339.
149. Márquez FJ, Muniain MA, Pérez JM, et al. Presence of *Rickettsia felis* in the cat flea from Southwestern Europe1. Emerg Infect Dis. 2002;8(1):89.
150. Pavlović I, Jovčevski S, Rogožarski D, et al. Biodiversity of ticks and fleas of dogs in the Western Balkans—preliminary examinations. Bulletin UASVM Veterinary Medicine. 2016;73:2.
151. CDC. National center for emerging and zoonotic infectious diseases (NCEZID), division of high-consequence pathogens and pathology (DHCPP) 2022 [updated July 29, 2010; cited 2022 July 24].
152. Strand TM, Lundkvist Å. Rat-borne diseases at the horizon A systematic review on infectious agents carried by rats in Europe 1995–2016. Infec Ecol Epidemiology. 2019;9(1):1553461.
153. Verner-Carlsson J, Lõhmus M, Sundström K, et al. First evidence of Seoul hantavirus in the wild rat population in the Netherlands. Infec Ecol Epidemiology. 2015;5(1):27215.
154. Vilibic-Cavlek T, Oreski T, Korva M, et al. Prevalence and risk factors for lymphocytic choriomeningitis virus infection in continental Croatian regions. Tropical Med Infect Dis. 2021;6(2):67.
155. Meerburg BG, Singleton GR, Kijlstra A. Rodent-borne diseases and their risks for public health. Crit Rev Microbiol. 2009;35(3):221–70.
156 Semenza JC, Menne B. Climate change and infectious diseases in Europe. Lancet Infect Dis. 2009;9(6):365–75.
157. ECDC. Rodent-borne diseases 2022 [cited 2022 24 July]. Available from: https://www.ecdc.europa.eu/en/climate-change/climate-change-europe/rodent-borne-diseases
158. Županc TA, Korva M, Markotić A. HFRS and hantaviruses in the Balkans/South-East Europe. Virus Res. 2014;187:27–33.
159. Bourhy P, Septfons A, Picardeau M. Diagnostic, surveillance et épidémiologie de la leptospirose en France. Bull Epidémiol Hebd. 2017;8–9:131–7.
160. Herrero-Cófreces S, Mougeot F, Sironen T, et al. Viral zoonoses in small wild mammals and detection of hantavirus, Spain. Emerg Infect Dis. 2022;28(6):1294.
161. Rodríguez-Vidigal F, Vera-Tomé A, Nogales-Muñoz N, et al. Leptospirosis in South-western Spain. Revista Clínica Española (English Edition). 2014;214(5):247–52.
162. Vieira ML, Gama-Simoes MJ, Collares-Pereira M. Human leptospirosis in Portugal: a retrospective study of eighteen years. Int J Infect Dis. 2006;10(5):378–86.
163 Vitale M, Agnello S, Chetta M, et al. Human leptospirosis cases in Palermo Italy The role of rodents and climate. J Infect Public Health. 2018;11(2):209–14.
164. Tagliapietra V, Rosà R, Rossi C, et al. Emerging rodent-borne viral zoonoses in Trento. Italy EcoHealth. 2018;15(3):695–704.
165. Guillois Y, Bourhy P, Ayral F, et al. An outbreak of leptospirosis among kayakers in Brittany, North-West France, 2016. Eurosurveillance. 2018;23(48):1700848.
166. Pena E, Jordão S, Simões MJ, et al. A rare cause of vertebral osteomyelitis: the first case report of rat-bite fever in Portugal. Revista da Sociedade Brasileira de Medicina Tropical. 2019;53.
167. Picardeau M. Diagnosis and epidemiology of leptospirosis. Med Mal Infect. 2013;43(1):1–9.
168. Semenza JC, Sudre B, Miniota J, et al. International dispersal of dengue through air travel: importation risk for Europe. PLoS Negl Trop Dis. 2014;8(12):e3278–e3278.
169. Lillepold K, Rocklöv J, Liu-Helmersson J, et al. More arboviral disease outbreaks in continental Europe due to the warming climate? Journal of Travel Medicine. 2019;26(5).
170. Caminade C, Turner J, Metelmann S, et al. Global risk model for vector-borne transmission of Zika virus reveals the role of El Niño 2015. Proc Natl Acad Sci U S A. 2017;114(1):119–24.
171. Magouras I, Brookes VJ, Jori F, et al. Emerging Zoonotic diseases: should we rethink the animal-human interface? Front Vet Sci. 2020;7:582743–582743.
172. Taylor LH, Latham SM, Woolhouse ME. Risk factors for human disease emergence. Philos Trans R Soc Lond B Biol Sci. 2001;356(1411):983–9.
173 Rupasinghe R, Chomel BB, Martínez-López B. Climate change and zoonoses: a review of the current status, knowledge gaps, and future trends. Acta Tropica. 2022;226:106225.
174. Heymann DL, Chen L, Takemi K, et al. Global health security: the wider lessons from the west African Ebola virus disease epidemic. Lancet. 2015;385(9980):1884–901.
175 Kovats RS, Bouma MJ, Hajat S, et al. El Niño and health. The Lancet. 2003;362(9394):1481–9.
176. Machado CB, Campos TLOB, Abou Rafee SA, et al. Extreme rainfall events in the macro-metropolis of São Paulo: trends and connection with climate oscillations. Journal of Applied Meteorology and Climatology. 2021
177. Anyamba A, Chretien J-P, Britch SC, et al. Global disease outbreaks associated with the 2015–2016 El Niño Event. Sci Rep. 2019;9(1):1930–1930.
178 Hubalek Z, Halouzka J, Juricova Z. Longitudinal surveillance of the tick *Ixodesricinusforborreliae*. Med Veterinary Entomology. 2003;17(1):46–51.
179. Rydén P, Sjöstedt A, Johansson A. Effects of climate change on tularaemia disease activity in Sweden. Glob Health Action. 2009;2:https://doi.org/10.3402/gha.v2i0.2063.
180. Ludwig A, Bicout D, Chalvet-Monfray K, et al. Modélisation de l'agressivité de Culex modestus, vecteur potentiel de West Nile en Camargue, en fonction de données météorologiques. Environ Risques & Santé. 2005;4(2):109–13.
181 Medlock JM, Hansford KM, Versteirt V, et al. An entomological review of invasive mosquitoes in Europe. Bull Entomological Res. 2015;105(6):637–63.
182. Wilcox BA, Gubler DJ. Disease ecology and the global emergence of zoonotic pathogens. Environ Health Prev Med. 2005;10(5):263–72.
183. Jacobs C, Berglund M, Kurnik B, et al. Climate change adaptation in the agriculture sector in Europe. European Environment Agency (EEA); 2019.
184. Nilsson M, Ebi KL, Campbell-Lendrum D, et al. Covid-19-a rehearsal to build a greener and healthier society. BMJ. 2021;372:n127–n127.
185. Cline WR. Global warming and agriculture: end-of-century estimates by country. Peterson Institute; 2007.
186. Semenza JC, Sudre B, Oni T, et al. Linking environmental drivers to infectious diseases: the European environment and epidemiology network. PLoS Negl Trop Dis. 2013;7(7):e2323–e2323.
187. Paz S, Malkinson D, Green MS, et al. Permissive summer temperatures of the 2010 European West Nile fever upsurge. PLoS ONE. 2013;8(2):e56398–e56398.
188. Tran A, Sudre B, Paz S, et al. Environmental predictors of West Nile fever risk in Europe. Int J Health Geogr. 2014;13:26–26.
189. Semenza JC. Climate change and human health. Int J Environ Res Public Health. 2014;11(7):7347–53.
190. UNFCCC. United Nations framework convention on climate change. UNFCCC; 1992.
191 Bulkeley H, Tuts R. Understanding urban vulnerability, adaptation and resilience in the context of climate change. Local Environment. 2013;18(6):646–62.
192. Smith K, Woodward A, Campbell-Lendrum D, et al. Human health: impacts, adaptation, and co-benefits. Climate Change 2014: impacts, adaptation, and vulnerability. Part A: global and

sectoral aspects. Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change: Cambridge University Press; 2014. p. 709–754.
193. Masson-Delmotte V, Zhai P, Pörtner H, et al. Global warming of 1.5 C. An IPCC special report on the impacts of global warming of 1.5 c above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Press. Intergovernmental Panel on Climate Change (IPCC). . Press Intergovernmental Panel on Climate Change (IPCC). 2018.
194. Hoegh-Guldberg O, Jacob D, Bindi M, et al. Impacts of 1.5 C global warming on natural and human systems. Global warming of 15° C. 2018.
195. Hatzianastasiou S, Pavli A, Maltezou HC. Legal aspects of public health: how law frames communicable disease control in Greece. J Public Health Policy. 2011;32(4):445–57.
196 Greer SL, Jarman H. What is EU public health and why? Explaining the scope and organization of public health in the European Union. J Health Politics, Policy and Law. 2020;46(1):23–47.
197. Brooks E, de Ruijter A. Towards more comprehensive health law and policy research. Health Econ Policy Law. 2021;16(1):104–10.
198. Chichevalieva S. Developing a framework for public health law in Europe. 2017.
199 Gage KL, Burkot TR, Eisen RJ, et al. Climate and vectorborne diseases. Am J Preventive Med. 2008;35(5):436–50.