Foresight

Infectious Diseases: preparing for the future

OFFICE OF SCIENCE AND INNOVATION

T7.1: Climate change and diseases of plants, animals and humans: an overview

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Introduction

Change is disease's friend. Change throws unfamiliar hosts together and allows their pathogens to jump from one to the other. Change enables diseases to explore new means of getting to populations that were previously beyond reach. Change hinders us from applying the control or avoidance measures that we have learned to use, over centuries or millennia, to keep diseases in abeyance.

Changes that facilitate the emergence and spread of infectious disease include altered landscapes, which bring hosts into contact with new pathogens; greater population densities, which facilitate their rapid spread; faster, longer-distance travel and trade, which carry diseases to new populations; and natural disaster or war, which disrupt our ability to keep diseases in check, at least temporarily. Climate change, of natural or anthropogenic origin, is also a major driver of infectious disease.

This paper provides a brief overview of key conclusions from three state-of-science reviews that considered the effects of climate change on infectious diseases of animals, humans and plants in the UK and sub-Saharan Africa by the 2020s and 2080s. Foresight commissioned reviews of the following topics (see links to full reports):

- the effects of climate change on infectious diseases of plants [T7.2]
- the effects of climate change on infectious diseases of animals [T7.3]
- the effects of climate change on infectious diseases of humans [T7.4]

The three reviews take a unique approach, focusing on the full range of infectious diseases that are of greatest current importance to the UK and Africa rather than on those that, *a priori*, are most likely to be affected by climate change. In this way, the reviews assess the impact of climate change on the diseases 'that matter' and, by so doing, assess whether climate change's effects on infectious diseases will matter too. Key findings of the reviews are summarised in Table 1.

The future climate of the UK and Africa

The three reviews draw on current predictions of our future climate in the 2020s and 2080s. Uncertainties in these predictions are recognised, but common assumptions are that the UK will have warmed by 0.5–1.5 °C by the 2020s and 2–4 °C by the 2080s (Figure 1A). Warming patterns in Africa are more spatially diverse, given its size and the greater number of forces acting on its climate, but are of broadly similar magnitude to those predicted for the UK (Figure 2). Rainfall predictions are more varied and less precise. The UK is predicted to experience drier summers and wetter winters, with little or no net change overall (Figure 1B); the UK's climate, then, will become increasingly Mediterranean as we move through the 21st century. Much of Africa is expected to become significantly drier at the same time as it gets warmer; some regions, however, such as parts of east, central and west Africa, will experience greater rainfall.

Climate and disease

The three reviews argue that we must understand how climate affects infectious diseases today before we can predict the impact climate change will have in the future.

Climate affects certain pathogens directly. In order to get from one host to another, many pathogens must spend a period of time in the environment, exposed to the weather. The time period can be as long as months/years (for example, spores of many fungal plant diseases, and spores causing anthrax in animals and humans) or as short as seconds/minutes (for example, human cold and influenza viruses, and rinderpest virus in animals). In most cases, climate and weather affect the ability of the pathogen to survive or reach and enter a new host. These effects rarely limit where a particular disease can occur as transmission is usually possible at some time or other, but such effects can determine the seasonal distribution often observed for directly transmitted diseases and, therefore, how many cycles of infection are possible in a year.

Climate is known to affect hosts, particularly plants, directly. For example, some plants lose their resistance to certain pathogens above threshold temperatures.

Many pathogens employ the use of intermediate hosts (vectors) to facilitate transmission between primary hosts: mosquitoes, fleas and ticks are among the most important vectors of human disease; mosquitoes, midges, non-biting flies and ticks are vectors of many animal diseases; while aphids and leaf hoppers are important vectors of plant diseases. The huge abundances attainable by such vectors and their finely tuned delivery mechanisms (preferential feeding on specific host types combined with insertion of mouthparts directly into blood/phloem) makes the use of vectors a highly successful transmission route for pathogens. However, vector-borne pathogens are then limited to the spatial and seasonal distributions of the intermediate host. In the case of arthropod vectors, climate often plays a dominant role in determining where and when they occur and, accordingly, vector-borne diseases are often climatically restricted in both time and space.

Climate change and disease

The three reviews suggest that climate change will affect a wide range of diseases, but they highlight in particular the strong impact expected on vector-borne diseases. The changing spatiotemporal map of temperature and moisture will lead to latitudinal and altitudinal shifts in the distribution of certain vectors, potentially exposing naive populations to new diseases. Warmer winters may allow more vectors to survive from one season to the next, leading to faster and earlier disease development. In some cases, warmer temperatures allow non-vector species to become vectors. In general, warmer temperatures in the UK, with no net change in rainfall, will be favourable to arthropod vectors and we may face greater challenge from vector-borne diseases. New human vector-borne infections do not appear imminent. This includes malaria, which was endemic until the mid-20th century but is considered unlikely to return: land-use changes have deprived the vectors of their breeding sites and better human housing has reduced our exposure to hungry mosquitoes. Ruminant livestock, however, are at considerable risk of bluetongue, a viral disease of cattle and sheep that has already spread into southern Europe because of recent climate warming in the region giving rise to spread in vector distribution and the appearance of novel vectors. Plants will also be at greater risk, as mild winters and warm springs favour the survival and early development of aphid vectors of numerous diseases. In some instances, however, very hot and dry summers may impact negatively on certain vectors: excessive water stress in summer may reduce threats to animals in the UK from the liver fluke (fascioliasis), which is vectored by water-sensitive lymneid snails, and may cause enhanced mortality of the aphid vectors of plant diseases.

Climate change’s impacts on vector-borne diseases will be greater in Africa than the UK, if only because they are already more significant causes of suffering. For example, vector-borne diseases are a negligible cause of human mortality in the UK, but five – malaria, sleeping sickness, leishmaniasis, schistosomiasis and filariasis – are major causes of human suffering in Africa. Tsetse- and tick-borne diseases are major constraints on livestock production in Africa. Climate change is expected to alter the distributions of some or all of these diseases.

While many climate change effects are common to animals, humans and plants, some are largely restricted to just one group of organisms. Livestock is at particular risk of acquiring novel infections from altered contact patterns with wild animals. An increased likelihood of flooding by sea water presents a particular risk to humans from cholera. Plants, being unable to alter their behaviour in order to avoid extremes of temperature and moisture, are particularly susceptible to the direct effects of climate change on their populations. In many instances, higher temperatures may favour plants, as their faster growth can help them outrun their pathogens. Plants’ resistance to disease can be related to temperature. Finally, plant fungal diseases are, uniquely, affected by rain ‘quality’ – the rate of fall rather than the total amount.

Future prospects

As climate change intensifies, its disease-related effects will be felt on at least three levels. First, climate change will act directly on pathogens, hosts or vectors, as described above. Second, climate change will affect the habitats present in a region, the community of hosts that can live in them and the lifecycles, or lifestyles, of those hosts and, thereby, shape indirectly the types of pathogen that occur. Third, climate change will act indirectly on other drivers of disease. In response to our future warmer world, landscapes will be altered, transport patterns will change, populations will move, and humans may fight over vital water or food resources. We can be confident that infectious diseases will take advantage of the opportunities presented.

A recurrent theme in the three reviews is the difficulty of predicting the future for infectious diseases in a warmer world. There is considerable uncertainty arising from the many, often conflicting, forces that climate imposes on infectious diseases, the complex interaction between climate and other drivers of change, and uncertainty in climate change itself. Effects of climate change that act indirectly on infectious diseases, via effects on other drivers, are particularly hard to predict. Nevertheless, there is consensus that some, and possibly many, infectious diseases of animals, humans and plants will be affected by climate change. Many of the diseases that we commonly face are kept at least partly in check by lifestyles, behaviours, farming systems or control measures that we have learned to use, sometimes over millennia, to help keep us, our livestock and our crops healthy. By contrast, when a new disease emerges or a familiar disease spreads to a new region, there is a long lead-in time before we know its significance and how it can be controlled or avoided. In terms of preventing suffering, therefore, change to infectious disease *per se* is bad: one disease eradicated, and another gained, is a net loss. Climate change will undoubtedly be an important cause of such suffering in the future.

Table 1. *Summary of the effects of climate change on infectious diseases of animals, humans and plants in the UK and Africa*

	Effects in the UK	**Effects in Africa**
Animal diseases	Increased risk of invasion of insect vectors of bluetongue, West Nile virus, canine leishmania Reduced risk of airborne spread of foot-and-mouth disease Possible reduction in fascioliasis Unpredictable change in risk of anthrax, haemonchosis, summer mastitis Little or no change in risk of avian influenza, brucellosis, bovine spongiform encephalopathy, classical swine fever, local spread of foot-and-mouth disease, mastitis, Newcastle disease, rabies, salmonelloses	Moisture-sensitive diseases will be affected, including anthrax, blackleg, dermatophilosis, haemorrhagic septicaemia, peste des petits ruminants, haemonchosis and vector-borne diseases; these diseases may decline in some areas and spread to others Increase in fascioliasis hepatica in central, east and parts of west Africa; decline in fascioliasis hepatica and gigantica in northern and southern Africa, depending on measures to preserve water supplies Possible increase in frequency of epidemics of diseases linked to the El Niño Southern Oscillation (i.e. Rift Valley fever, bluetongue) Possible increase in pathogen transmission between wildlife and livestock
Human diseases	Uncertain impact on acute respiratory infections Increased impact of diarrhoeal diseases Possible increased risk of West Nile fever Possible increased risk of Lyme disease and leptospirosis No impact expected on HIV/AIDS and tuberculosis	Uncertain impact on acute respiratory infections Possible increase in cholera in response to more coastal flooding Increased impact of diarrhoeal diseases Greater areas at risk of vector-borne diseases, such as dengue fever, leishmaniasis, malaria, Rift Valley fever, schistosomiasis, West Nile fever Uncertain effect on meningococcal meningitis, filariasis, sleeping sickness No impact expected on HIV/AIDS and tuberculosis
Plant diseases	Uncertain but possible increase in risk of root and stem base fungal pathogens of crops (e.g. take-all, eye spot).	Possible reduction in southern and northern leaf blights, cowpea mosaic disease and groundnut rosette in areas with more drought

	Decrease in some stem and leaf fungal pathogens (leaf blotch, net blotch, yellow rust, late blight, light leaf spot, phoma stem canker), although this may be countered in some cases by earlier disease onset Increased risk of powdery mildew Unpredictable change in brown rust Milder winters may favour development of vector-borne viral diseases (e.g. barley yellow dwarf virus)	Possible increase in sorghum head smut Possible increase in vector-borne diseases such as maize streak virus, cassava mosaic disease, sweet potato virus complex, feathery mottle virus and chlorotic stunt virus

Figure 1. *Change in average winter and summer (A) temperatures and (B) precipitation for the 2020s and 2080s for the low-emissions and high-emissions scenarios*

Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP).

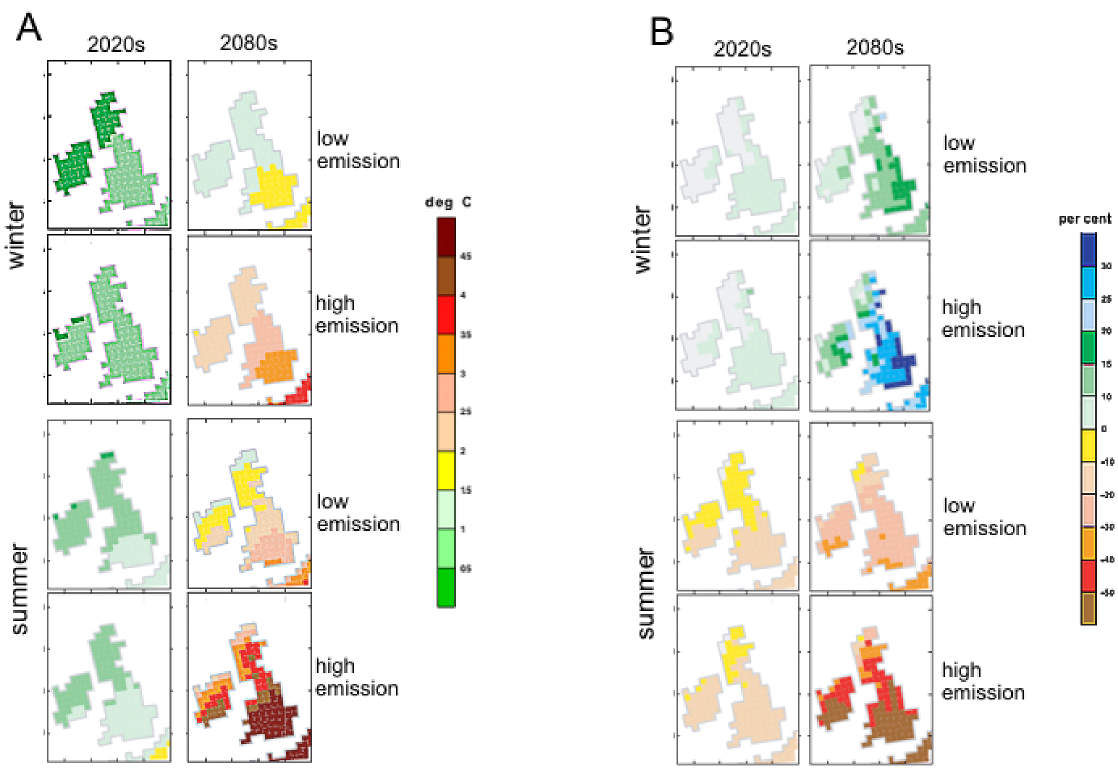
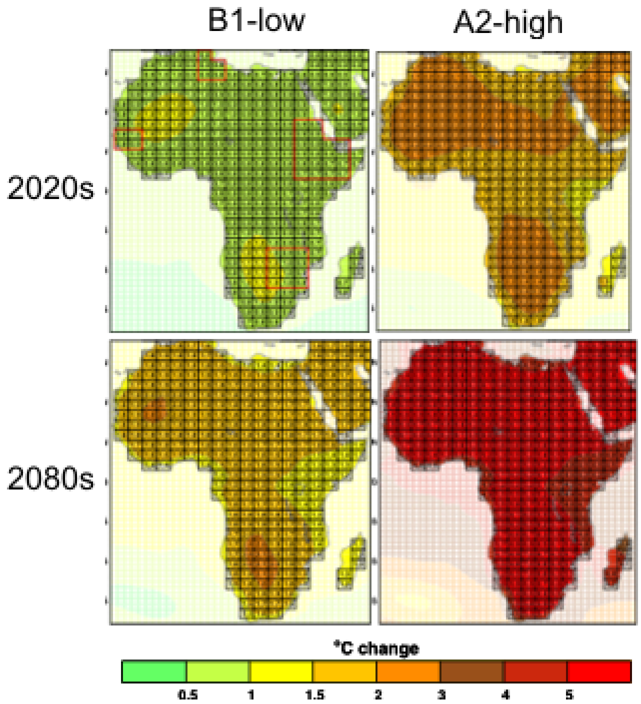


Figure 2. *Change in mean annual temperatures for the 2020s and 2080s (with respect to 1961–1990) for the B1 low- and A2 high-emissions scenarios*

Source: Hulme, M. et al. (2001). African climate change: 1900–2100. *Climate Research* 17, 145–168.



All the reports and papers produced within the Foresight project 'Infectious Diseases: preparing for the future,' may be downloaded from the Foresight website (www.foresight.gov.uk). Requests for hard copies may also be made through this website.

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