Climate change and animal health

Juan Lubroth
Animal Health Service, FAO, Rome

INTRODUCTION

Systematic reviews of empirical studies provide the best evidence for the relationships between the health of humans, animals and plants, and weather or climate factors. Regarding the public health sector, Chapter 8 of the Working Group II report of the Intergovernmental Panel on Climate Change (IPCC) for 2007 comprises an update on the state of knowledge of the associations between weather/climatic factors and public health outcomes for human populations concerned (Patz *et al.*, 2005). Direct exposure to climate change comprises changing weather patterns (increasing temperatures, more precipitation, rising sea-level and more frequent extreme events). Indirect exposure comprises changes in water, air and food quality, vector ecology and changes in ecosystems, agriculture, industry and settlements. Additional indirect exposure may result from social and economic disruption. Possibilities for adaptation extend to concurrent direct-acting and modifying (conditioning) influences of environmental, social and health system factors. How critical global warming could become a threat to public health has been studied for several risk settings, comprising malaria, water shortage, famines and coastal flooding. Water shortage is often associated with unsanitary water conditions and therefore with a major impact of climate change on health, for example, through diarrhoeal disease.

Unfortunately, in the animal health realms, comprehensive, formal reviews are rare (de la Rocque, Rioux and Slingenbergh, 2008). Climate change and general anthropogenic factors together alter both the farming and the natural landscapes and in the process impact the health of animals in multiple ways. This paper is primarily concerned with the effects of climate change on disease ecology and transmission dynamics. Importantly, changes in host distribution, density and their availability to existing pathogens may translate in disease emergence in animals and at the animal-human interface. A pathogen may: (i) find access to new territories and host landscapes; or (ii) turn more host aggressive in settings where the hosts have become more abundant and/or immune-compromised; or (iii) perform a host species jump, possibly in response to enhance host species mixing or contacts. Geographic spread or invasion may entail a range expansion or, in case of saltation dispersal, kick-start a complete pathogen genetic remake (see Figure 1). The disease emergence category featuring an expansion of the geographic range is both relatively common and also more likely

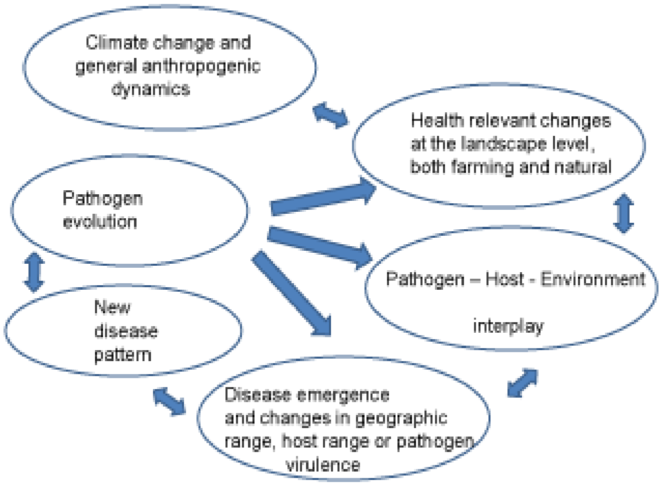

Figure 1. Effects of climate change on disease emergence

to be affected by climate change, and for this reason is the main focus of this paper. This group of disease complexes comprises insect pests, ecto-parasites, endo-parasites, arthropod-borne disease complexes and pathogens carried by foods and fomites. A set of global factors is believed to drive a worldwide redistribution of hosts, vectors and pathogens. Climate change clearly plays a role in this regard, enhancing or decreasing the introduction and invasions of disease agents, even when primarily caused by other factors such as the demography of humans and animals, encroachment of the natural resource base, land use, agriculture, the greater mobility of people, and the enhanced trade and traffic volumes. When it comes to the role of climate change in disease ecology and pathogen evolution, there is a need to duly consider the collective host–pathogen–environment interplay. In a stable environment, a situation of relative evolutionary stasis, host–pathogen–environment complexes tend to become more entrenched, with location-bound pathogen traits selected for. Conversely, in a rapidly changing environment, it is pathogen opportunism and generalist type versatility that matters.

CLIMATE CHANGE AND TRANSMISSION ECOLOGY

From a climate change perspective, it is important to assess the extent to which a pathogenic agent is exposed to the conditions outside the host body. A free-living pathogen stage plays a role even in the direct transmission of respiratory diseases. The survival of the common flu virus on doorknobs or during aero-gene transmission or by means of handshakes is influenced by ambient temperature and humidity (Lowen *et al*., 2007). The role of environmental pathogen load is perhaps more obvious still in the case of faecal-oral or water-borne transmission. Food poisoning usually entails faecal contamination of food items. Environmental robustness is a prominent feature in certain stages of the life history of larger parasites, including in nematodes, with larvae surviving for weeks or more outside the host on pastures. The natural cycle of avian influenza viruses in mallard ducks, its foremost natural host, involves ingestion of water containing the virus. Natural avian influenza virus replication occurs mainly in the distal end of the enteric duck tract (Jourdain *et al.,* 2010). Viruses deposited by migratory waterfowl during summer breeding at higher latitudes may be stored in permafrost conditions in subarctic regions and survive for centuries (Zhang *et al*., 2006). Likewise does the anaerobe *Bacillus anthrax* bacterium survive for decades in the form of spores in the soil (Dragon and Rennie, 1995).

Disease agents transmitted by arthropods form a distinct, albeit related category. Indirect transmission of protozoan disease agents may be facilitated by three-host ticks. Soft ticks feeding on warthogs play a role in the transmission of African swine fever (ASF) (Kleiboeker and Scoles, 2001). The causative agent of ASF, a DNA virus, may survive for eight years in the tick vector. There are also a number of midge- or mosquito-borne disease complexes that involve a dormant pathogen stage. For example, Rift Valley fever (RVF) virus may survive in mosquito eggs for years, until a prolonged heavy rainfall facilitates an awakening of *Aedes* mosquitoes, feeding on ruminants and thus kick-starting a RVF outbreak (Mondet *et al*., 2005; Anyamba *et al*., 2009). Infected ruminants that end up in densely populated irrigation schemes may also attract mosquitoes feeding on humans and thus contribute to the transmission of RVF among humans.

Midges are sometimes blown by wind across wider geographic areas. This is probably what happened with bluetongue virus (BTV8) introduction in the United Kingdom, in the summer of 2006, after the virus had first spread westwards across Belgium (Gloster *et al.,* 2008). It is very possible that also the flare up of the Schmallenberg virus (SBV) in the United Kingdom in early 2012 resulted from wind-carried infected midges arriving from mainland Europe (Gibbens, 2012).

In the direct-indirect transmission spectrum, directly, swiftly transmitted common flu, short-lived fevers, faecal–oral, food and vector-borne transmission to more prominent free-living parasite stage can be noted. In this regard, ecto-parasites and myiasis-causing insects should also be considered. Arthropod pests are strongly modulated by climatic and weather conditions. For example, both the Old World screwworm fly (OWS), *Chrysomya bezziana*, and the New World screwworm fly, *Cochliomyia hominivorax*, feature a prominent free-living stage. The adult female fly deposits eggs in open wounds and also minor skin lesions or on mucous membranes, providing access for the evolving larval stages to life tissue of warm blooded hosts (Spradbery, 1991). The latter is obligatory for this life cycle stage. Hundreds of larvae may result from a single egg batch, producing an ever-larger wound. Additional screwworm flies are lured to the scene, and death of the affected host may eventually result. The larvae leaving the wound fall to the soil and bury themselves 2 cm deep, to turn into a pupa for about a period of one week until a new fly emerges. Adult flies feed on nectar and rely on adequate vegetation.

As shown in Figure 2, substantial areas of the Arabian Peninsula today provide suitable conditions for OWS persistence. OWS flare-up in the Gulf countries has been reported since the 1980s. Apart from rather small foci in Oman, Saudi Arabia and Iran, OWS myiasis did not pose a serious problem to livestock production until a major outbreak erupted in the mid-1990s in Iraq. As a result of the United Nations sanctions, the country ran out of acaracide supplies required to keep the sheep flocks free from ticks. With the higher number of skin lesions, also the vulnerability to OWS incursions increased. An FAO study

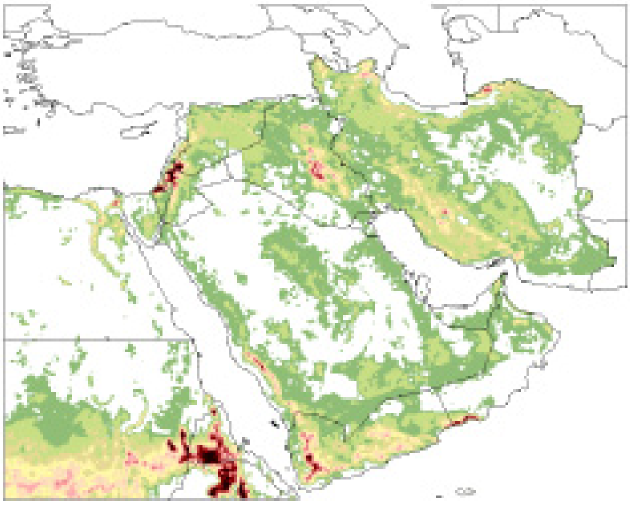

Figure 2. Areas where the risk of Old World screwworm is relatively high (dark shade)
Source: Gilbert and Slingenbergh (2008).

predicted OWS suitability across the Arabian Peninsula on the basis of satellite-derived proxies for soil temperature and presence of vegetation. The results suggested Yemen as a potential area where OWS might flare-up and turn endemic. Indeed, large areas of southwestern Yemen have turned OWS endemic during the 2000s, with ever prominent, mostly springtime, disease outbreaks.

The effects of climate change on tsetse flies, the vector of human and animal African trypanosomiases, is rather different, despite certain similarities between the tsetse and the screwworm fly life history. The tsetse fly also features a pupal stage in the soil. However, whereas a single screwworm fly egg batch may yield over 200 larvae, the female tsetse fly produces only one larva every nine days. During its total lifespan, a female tsetse fly may produce six to eight larvae, each of which undergo a pupal development period of about three weeks depending on ambient temperatures (Ford, 1971). Unlike screwworm flies, dispersing over hundreds of kilometres within weeks, tsetse flies sit and wait for the host to show up. Tsetse fly activity is restricted to 15 to 20 minutes a day.

From the above examples, it becomes clear that the effects of climate change on disease complexes may take many different forms, complicating comparison and generalization. Whereas the tsetse fly distribution in Ethiopia entails a gradual encroachment of the country's central highland plateau (Slingenbergh, 1992.), recorded since the 1960s, the Old World Screwworm fly rather abruptly colonized the Arabian peninsula, first the Mesopotamia valley in Iraq and later parts of Yemen, within the course of just two decades (Siddig *et al*., 2005).

A disease complex may also change the transmission mode or pattern. For example, ASF virus circulates in the form of at least 22 different genotypes in its sylvatic cycle – the warthogs as distributed in the miombo woodlands of southern Africa. Yet, in 2007, genotype II found its way to central Europe, starting in Georgia, in a Black Sea port. It is believed that meat products containing ASF virus were shipped from Mozambique or Madagascar and disposed of in Georgia as food scraps and fed to local pigs. Today ASF is progressively colonizing higher latitude areas of eastern Europe, propagated by people transporting contaminated pig meat products, through pig production, and also involving the Eurasian wild boar, *Sus scrofa.*

RESILIENCE IN ANIMAL HEALTH

Basically, there are three distinct entry points that may lead to a better way of coping with the negative consequences of climate change and associated drivers of disease, pest dynamics and the overall health status of animals.

Preventive veterinary medicine

As has been shown by the FAO Emergency Prevention System (EMPRES), since its creation in 1994, early warning, early detection, and early response have been key to the prevention and control of both old and new pests and diseases in animal and crop production. Prevention and curtailing the spread of disease across country boundaries has become the credo of the FAO/World Organisation for Animal Health (OIE) initiative, Global Framework for the Progressive Control of Transboundary Animal Diseases (GF-TAD). Progressive control pathways and regional roadmaps are being designed to counter the spread of high-impact infectious livestock diseases such as foot-and-mouth disease (FMD), peste des petits ruminants (PPR) and ASF.

Early detection and early response were also key to the success of the Global Rinderpest Eradication Programme. Following years of vaccination of the entire national cattle herd, countries gradually replaced the blanket vaccination by early detection and early response, in the process consolidating and expanding the rinderpest-free areas. In mid-2011 both OIE and FAO proclaimed the world free from rinderpest.

Yet the flare-up of new disease and the persistence of chronic disease burden remain considerable, particularly in the developing world. Climate change-modulated vector-borne disease (VBD) complexes would appear to become more dynamic globally, especially in the temperate climate zones of the northern hemisphere. In many countries, the expertise in entomology and disease ecology within public veterinary services is inadequate to mount early warning and response mechanisms in the face of novel VBD emergencies. Improvements are required also in terms of a further integration of field veterinary work, laboratories and detection of critical control points further along the food chain.

A “One Health” approach conveniently deals with the collective risk factors acting at the level of natural and farming landscapes, on-farm, in slaughterhouses and processing and distribution circuits. “One Health” brings together health professionals engaged as veterinary practitioners and food inspectors, working in fisheries health, forestry, plant protection, natural resource management and, of course, food safety and public health.

Removing the divides separating today disciplines, sectors, institutions and political boundaries, undoing the compartmentalization as prevailing in government organizational structures, presents the major challenge under the “One Health” umbrella. For FAO, the “One Health” notion extends to the Food Chain Crisis Management Framework, a platform for all health professionals within the Organization (Figure 3) (Tekola *et al.,* 2012).

Adjustment of animal husbandry

Improvement in sanitation, hygiene or biosecurity may conveniently take a whole-of-society approach. Risk factors vary with animal production subsectors and systems. The management of animal genetic resources, feeding practices, housing and bio-containment

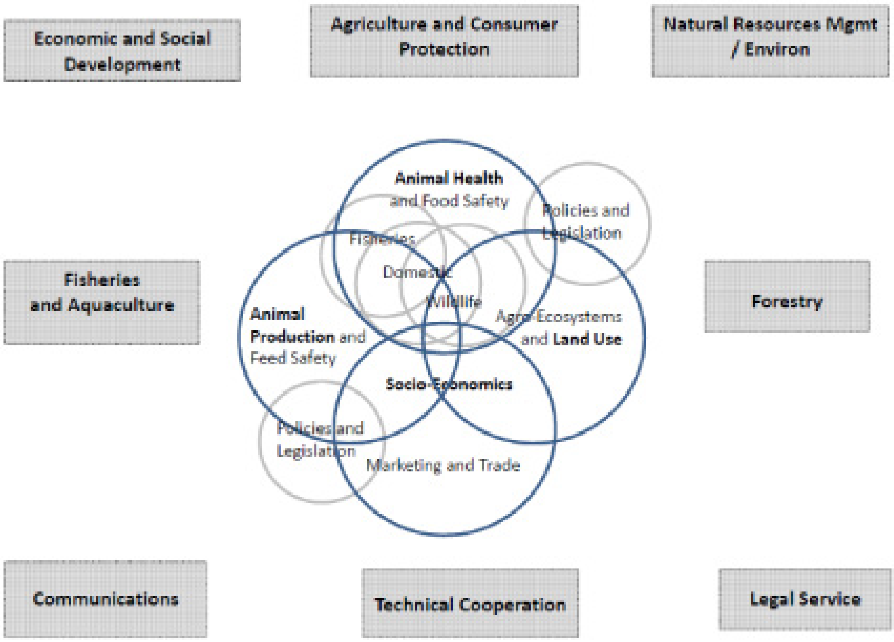

Figure 3. FAO Departments (rectangles) and intersecting thematic areas of work

together play a key role in the maintenance of robust, healthy and productive animals. Agro-ecological resilience matters most where production environments reflect the local conditions. Local breeds may harbour genetic disease resistance and other traits reflecting their adjustment to the locally prevailing conditions.

Ruminant grazing in the open brings exposure to multiple arthropod-borne diseases. A growing armoury of quality vaccines is required to confront a vast array of old and new diseases. Vaccination is particularly a priority in developing countries. Disease flare-ups at the human-animal-ecosystems interfaces are particularly prominent in pig and poultry production, with Influenza A as a primary example. A number of new emerging diseases, in part climate change modulated, are finding their way from wildlife reservoirs via pigs to humans. Fruit bats may transmit Henipah viruses (HeV) or Reston Ebola virus (REBOV). The management of this growing number of veterinary and medical threats requires adjustment of natural resource management practices, land use and food and agriculture. Safe and healthy food and agriculture requires re-definition.

Social resilience

Empowering the community regarding health protection presents the key priority. With health systems and infrastructures being weakest in remote rural areas and harsh environments where ruminant livestock production is the most prominent among the prevailing farming systems, self-help options supported by community animal health outreach are rapidly gaining in importance. This extends to participatory disease surveillance and control, relying also on syndromic surveillance. Where vaccination is integrated with adjustments in husbandry and increased off-take results, prospects evolve for sustainable improvements in food and income security, in turn paving the way for an upgrading of the livestock production and farming systems in settings today featuring major disease burdens and low levels of productivity.

As the experience with rinderpest eradication has shown, community-based health protection efforts stand a good chance of success provided livelihood sustenance is made both the entry point and the ultimate rationale for the collective stakeholder efforts.

CONCLUSIONS

There has been a tendency to oversimplify the mechanisms by which climate change affects disease transmission and animal health status. Indeed, only a limited number of studies present validation of the direct effects of climate change itself. Climate change is to be considered in conjunction with the set of global factors today altering the earth terrestrial surface area and associated global biophysical systems.

The flare-up of novel pests and diseases of wildlife and livestock origin, and also the surge of food safety hazards, is likely to continue for decades to come. Risk analysis highlighting the implications of climate change in its broader context relies on the full consideration of the transmission ecology of pests and diseases. Transmission involving prominent free-living parasite stages is arguably more likely to be modulated by environmental factors including temperature, humidity and seasonality.

Risk management of emerging disease complexes in which climate change plays a role is best addressed under a "One Health" umbrella. For FAO, these efforts are centred around the collective biological risks in food production and supply chains.

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