Climate change and animal health in Africa

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Summary
Climate change is expected to have direct and indirect impacts on African livestock. Direct impacts include increased ambient temperature, floods and droughts. Indirect impacts are the result of reduced availability of water and forage and changes in the environment that promote the spread of contagious diseases through increased contact between animals, or increased survival or availability of the agent or its intermediate host. The distribution and prevalence of vector-borne diseases may be the most significant effect of climate change.

The potential vulnerability of the livestock industry will depend on its ability to adapt to such changes. Enhancing this adaptive capacity presents a practical way of coping with climate change. Adaptive capacity could be increased by enabling the African livestock owner to cope better with animal health problems through appropriate policy measures and institutional support. Developing an effective and sustainable animal health service, associated surveillance and emergency preparedness systems and sustainable disease control and prevention programmes is perhaps the most important strategy for dealing with climate change in many African countries.

Keywords
Africa – Climate change – Control – Disease – Health – Livestock.

Climate change in Africa

Current climatic zones

Africa is a vast continent with a wide variety of climate regimes. The continent is predominantly tropical, hot and dry but there are small regions of temperate, rather cool climate in the extreme north and south and at higher altitudes. Large parts of West and Central Africa are humid throughout the year. North and south of these areas are sub-humid regions with seasonal rainfall. Polewards from this zone is a large area of semi-arid climates, where rainfall is unreliable and water sources are scarce. Most of the human and animal populations occur in the sub-humid and semi-arid zones. The African continent can be divided into climate-related, eco-climatic zones and their associated livestock production systems. These livestock production systems are usually shaped by prevailing biophysical and socio-cultural conditions and most of them are in equilibrium with their environment (38).

Climate change and variability

There is great uncertainty about how climate might change at the sub-regional level in parts of Africa and, especially, how this might be influenced by human-associated and other factors (20). Moreover, the size and geographical diversity of sub-Saharan Africa make climate change predictions particularly challenging. Nevertheless, observations show that the African continent is warmer than 20 years ago, with an average rate of warming of about 0.05°C per decade (17). Moreover, the African climate has, during the 20th Century, experienced wetter and drier intervals than during previous centuries. Projections for the rates of change in temperature and precipitation for the 21st Century vary but, irrespective of this uncertainty, future annual warming is expected to be highest in the interior of the semi-arid regions of Saharan and central southern Africa, resulting in desertification. Future changes in rainfall are more uncertain (5, 16). Despite this, there is general consensus that East Africa will become wetter, south-east Africa will become dryer and there is a poorly specified outcome for the Sahel region (16).

Climate has always been and will continue to be variable. Changes in climate variability and extreme weather events have received increased attention in the last few years. Such extremes are a key aspect of climate change. Changes in their frequency (increases or decreases) can be surprisingly large for seemingly modest mean climate changes and often cause the most disruption in ecosystems and human society, including livestock production systems. Climate variability can be expressed using various time scales and is a normal characteristic of climate, whether or not the system is subjected to change. The El Niño-Southern Oscillation (ENSO) and North Atlantic Oscillation are the most important perturbing factors for interannual climate variability in eastern and southern Africa and northern Africa, respectively (26, 45). The effect of climate change on the frequency of El Niño and its amplitude is not clear. However, climate change is expected to increase the risks of drought and floods that occur with El Niño.

Expected impacts of climate change

Africa probably contributes the least of any continent to global warming. Nevertheless, the people living in Africa may be the hardest hit. This is because the effects of climate change on, for example, livestock production and health are significant additions to the already impressive list of constraints that impede African livestock development. Indeed, climate change is a complex environmental hazard with a range of side effects that are often difficult to predict. Consequently, the overall impact of climate change on animal production and health is expected to be much higher than the individual impact of, for example, the increase in the annual average temperature. Unfortunately, there is little empirical research exploring whether climate change over the past three decades has directly affected animal health in Africa and, if so, in what ways. Furthermore, the indirect effects of climate change on economic, social and demographic sectors and their impact on the African livestock sector have hardly been investigated.

Vulnerability to climate change

The impact of climate change on livestock production and health in Africa is determined largely by the vulnerability of African livestock production systems. There are many definitions of vulnerability. In the context of this paper, vulnerability is defined as the degree to which African livestock production systems are susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and weather extremes. Vulnerability varies in space and time. Generally speaking, developing countries are more vulnerable to the impacts of climate change because they are more exposed and sensitive to such change, on the one hand, and they have more limited capacity to adapt to it, on the other (22). Africa is considered to be particularly vulnerable because of:

– its diversity of climate, vegetation, culture and economic circumstances

– a heavy reliance on natural resources

– its poor development status

– associated weaknesses in its science and technology infrastructure

– institutional weaknesses

– political and social instability.

All of these disadvantages seriously hamper the capacity of Africa to respond (22, 43, 44). The same applies to the African livestock sector. Moreover, the high burden of disease from which the livestock population already suffers exacerbates any other direct or indirect health problems caused by climate change. Although it is clear that this sector is vulnerable, it is very difficult to accurately assess to what degree. Nevertheless, certain assumptions can be made about the differences in vulnerability between the various livestock production systems, based on their particular characteristics, their associated exposure and sensitivity to climate change and their ability to adapt to those changes.

Vulnerability of African livestock production systems

Farming livestock is the most important industry in sub-Saharan Africa, contributing about 25% to the gross domestic product of the region.

The livestock sub-sector can be divided into several types of small- and large-scale production systems (23). The large-scale production system contributes a relatively small proportion of the agricultural output in sub-Saharan Africa. The bulk of production occurs in the small-scale or smallholder production system. Smallholder farming in Africa is carried out predominantly by small autonomous family units and is fundamentally different in its objectives and function from large-scale commercial farming. This small-scale production can be classified according to the degree of commercialisation and the integration of livestock and crops (23, 27).

Subsistence-oriented producers are usually found in remote areas and are resource-poor farmers who consume the majority of their production. Capital investment is limited and an increase in production depends largely on the climate and factors such as additional labour, animal manure and livestock management practices.

Semi-subsistence producers are located closer to main roads and urban markets. Subsistence farming remains their main activity but surpluses are frequently sold. Access to inputs that would improve production is usually low but the more products are sold, and the more income generated for the farmer, the more they will invest back into production. Thus, the greater the impact of the monetary circuit and the higher the demand for more inputs.

Commercial producers are close to or within urban markets. Most of what they produce is sold at the market. Inputs are available and purchased. Based on the degree of integration with crops, smallholder livestock production systems can also be defined broadly as grazing or mixed farming systems (36). The grazing production system or pastoralism is based almost entirely on livestock production, with little or no integration with crops. These systems are found mainly in arid or semi-arid zones and are characterised by high animal mobility.

Mixed (livestock and crops) sedentary production systems are systems in which livestock and crop production are integrated on the same farm. These production systems are not mobile and are found mainly in humid lowlands and cool highlands.

Finally, urban production systems meet the increasing demand for animal products in urban areas. They comprise the entire range of landless livestock production systems, from subsistence to commercial producers.

Considering the specific characteristics of the most important African livestock production systems, and their high dependence on the environment, the majority of African livestock seems to be highly exposed and sensitive to climate change. This situation is aggravated by:

– the often low knowledge levels of farmers/producers

– low input/low output production methods

– the risk averseness of most livestock owners

– ineffective private and public animal health and laboratory services.

All these factors leave the African livestock industry even less able to deal with climate change.

Climate change and animal health

Climate change, including climate variability, has direct and indirect impacts on livestock production.

Direct impacts

Most direct effects of climate change on animal health, wellbeing and production (e.g. growth, reproduction, milk production) are the result of increased ambient temperature and concurrent changes in heat exchanges between the animal and its environment (28). The resulting heat stress adversely affects production (for example, reproductive performance in dairy animals), and hence reduces the total area in which high-yielding livestock can be reared economically. Animals are somewhat able to adapt to higher ambient temperatures with prolonged exposure but production losses will occur (1, 33). African cattle from the *Bos indicus* line are much more tolerant to heat than the European *B. taurus* breeds. Nevertheless, extremely hot temperatures will also be beyond the climatic envelope for *B. indicus*, resulting in reduced milk and meat production and reduced time for foraging because the animals prefer to remain in the shade (29).

Extreme weather events, such as droughts or floods, will also have considerable direct impacts on livestock in Africa. Although many of the pastoralist societies in the Horn of Africa living on arid land are used to droughts, changes in the frequency and magnitude of these events, as the result of climate change, have on several occasions resulted in very high mortality in the livestock population.

Indirect impacts

The indirect effects of climate change on animal health and production include those changes that influence the quantity and quality of food and water and the distribution and prevalence of disease. As a result of the threat of devastating diseases such as trypanosomiasis, most of the domestic livestock in Africa are concentrated in the arid and semi-arid zones of the continent, where they feed predominantly off natural grasslands and savannahs. They are thus very dependent on the quantity and quality of natural resources for their survival. Not surprisingly, and despite the interannual variability in rainfall, there is a strong relationship between the mean annual precipitation and long-term, area-wide herbivore mass in production systems which are so dependent on natural resources (6). Thus, the grazing capacity of the natural grassland and savannah areas will be affected largely, but not solely, by changes in annual rainfall. Those African regions that are becoming drier, and will continue to do so due to climate change, will have a reduced growing season, resulting in a fundamental change to the ecosystem structure and function. In some areas, this could lead to a forage shortage which may be exacerbated by increased weather extremes (droughts) and major anthropogenic factors, such as unsustainable agricultural practices, overgrazing and deforestation, that contribute to desertification. At the same time, water sources are likely to become intermittent or disappear.

The relationship between climatic conditions and the presence or absence of certain livestock diseases is well known. In Africa, there is also much evidence of associations between climatic conditions and infectious diseases. However, estimating the real impact of climate change on livestock health over a long period of time is challenging. It is, for example, difficult to separate non-climatic from climatic influences. Indeed, within a climate range that limits the transmission and distribution of a disease, many other economic, social, cultural, institutional and environmental factors also affect disease occurrence (24). Moreover, the repercussions of changes in the distribution and prevalence of certain diseases on regional and international trade are difficult to assess. The best estimate of the future impact of climate change is based on empirically observed relationships between climatic conditions and their effects on the biological processes that determine disease transmission in space and/or in time (30, 31). Unfortunately, these models cannot be generalised and do not take account of concomitant changes in factors that are not related to climate change, but may have important repercussions on disease transmission or impact (4).

Non-vector-borne diseases

The effect of climate change on the distribution and prevalence of non-vector-borne diseases varies greatly. Changes in environmental conditions, as a direct or indirect consequence of climate change, can increase or reduce the survival of the infectious agent in the environment or predispose the susceptible animal to infection. A changing environment may also result in increased or reduced contact between infected and susceptible animals and thus affect transmission.

Temperature and humidity changes will affect the spatial and temporal distribution of the pathogens of non-vector-borne diseases that spend a period of time outside the host and are thus very sensitive to such changes. These pathogens include:

– the infective spores of anthrax and blackleg

– the viruses causing peste des petits ruminants (PPR) and foot and mouth disease (FMD), contained in wind-borne aerosol droplets

– the agents causing dermatophilosis, haemorrhagic septicaemia, coccidiosis and haemonchosis.

The prevalence of infections with *Fasciola hepatica* may increase in areas of Africa where rainfall increases, creating temporary water bodies in which the intermediate snail host of *F. hepatica* survives. The creation of permanent water bodies for irrigation in drier areas may facilitate the survival of the intermediate snail host of *F. gigantica*.

Although diseases transmitted directly between animals in close contact are less related to climate, changes in the ecosystem resulting in the disappearance or intermittent availability of water resources or grazing land can cause mass movements of livestock and wildlife in search of water or grazing. This migration increases the contact between livestock from different areas, and between game and livestock, and may result in the transmission of pathogens (25). Such mass movements, animal congregations and sharing of water and food resources are known to contribute substantially to the spread of important African transboundary diseases, such as FMD, PPR and contagious bovine pleuropneumonia. In the past, mass migrations due to droughts in eastern Africa have been important factors in the 'flare up' of rinderpest in stressed cattle and wildlife populations (18, 40).

Drought, overgrazing and severe environmental stress as the result of climate change, and/or mass migrations, may become an important trigger mechanism for epidemics of soil-borne diseases, such as anthrax. Anthrax spores can, under certain circumstances, remain dormant and viable in the soil for several decades. Spores are concentrated in the upper few centimetres and can infect susceptible animals when they graze close to the soil. This is especially the case in overgrazed or very dry areas. Similarly, scarce water sources may become contaminated with anthrax spores and epidemics can occur when animals are concentrated around contaminated watering points.

Dermatophilosis is already most prevalent in humid tropical and subtropical regions where predisposing factors are present, such as:

– high rainfall

– high humidity and ambient temperature

– skin lesions due to ectoparasites, such as ticks

– malnutrition

– stress

– intercurrent diseases (46).

Excessive rainfall, due to climate change, and concomitant severe wetting or saturation of the hair and skin for several days or weeks may result in higher prevalences of this disease. Similarly, outbreaks of blackleg, an acute infectious clostridial disease, mostly of young cattle, are often associated with heavy rainfall.

Foot rot is a flood-related bacterial disease affecting the interdigital tissue of ruminants. Changes in the integrity of the interdigital skin, due to exposure to wet conditions during floods, provide a favourable environment for the growth of the bacteria and the development of foot rot.

Changes in the ecosystem as a result of climate change can also influence the migratory routes of a wide variety of bird species, both within Africa and between continents. Such alterations in migration routes can play a role in the spread and distribution of avian influenza and West Nile virus.

Vector-borne diseases

There is ample literature on the effects of climate change and the epidemiology of several vector-borne animal and especially human diseases (e.g. 15, 19). In Africa, vector-borne livestock diseases fall into three main categories. They are:

– the arboviral diseases transmitted by mosquitoes, midges or biting flies

– tsetse-transmitted trypanosomiasis

– ticks and tick-borne diseases.

The mechanisms involved in the climate-related emergence or resurgence of such diseases are complex. Vector-borne diseases are typically transmitted through contact between hosts and the infected vectors. The prevalence of infection depends on the inter-relationship between hosts, pathogens and vectors. Any climate-related factor that affects this triangular relationship will affect the epidemiology of the vector-borne disease. Of particular importance, in this respect, are:

– the survival of the vector, its reproduction and, hence, its distribution and density

– the biting rate of the vector

– the incubation rate of the pathogen within the vector.

In areas with sufficient rainfall, an increase in temperature will cause certain vector-borne diseases to spread. Indeed, in the absence of effective Veterinary Services, the spread of vector-borne diseases is determined largely by a natural boundary, where ecological or climatological conditions limit the distribution of the vector and, hence, the pathogen. At the fringes of this natural distribution, small changes in climatic conditions can have substantial repercussions for disease transmission and interfere with endemic stability.

An important arboviral disease already associated with climate change is Rift Valley fever (RVF). It is a peracute or acute, mosquito-borne zoonotic disease of domestic ruminants in Africa. It is most severe in sheep and goats, resulting particularly in mortality in new-born animals and abortion in pregnant animals (39). Apart from outbreaks in Sudan, Egypt, Senegal and Mauritania, epidemics tend to occur in eastern and southern Africa, and have been associated with above-average rainfall at irregular intervals of five to 15 years. Such excessive rainfall causes the flooding of sometimes dry areas and results in the hatching of dormant, drought-resistant, infected eggs of the mosquito (*Aedes*) responsible for maintaining the infection in dambos (shallow, seasonally inundated wetlands). These mosquitoes infect an amplifying host (ruminant), which serves as a source of infection for many other genera of mosquitoes that rapidly spread the disease.

Outbreaks of RVF follow sudden heavy rains and floods, often triggered by El Niño (21). For example, the 1997-1998 El Niño event has been linked to very heavy rainfall in north-eastern Kenya and southern Somalia, resulting in a severe outbreak of RVF. The outbreak killed more than 500 people and large numbers of, in particular, small ruminants, with some livestock owners losing up to 70% of their animals. A similar large outbreak of RVF occurred in 2007. Outbreaks of RVF in North and West Africa are not associated with excessive rainfall but with the presence of large rivers and dams that provide suitable breeding sites for the mosquito vectors. In such areas, increasing water-storage capacity for agricultural development and irrigation, in response to a drying environment, is likely to provide new suitable breeding sites for mosquitoes transmitting the RVF virus, and may make such areas more prone to RVF epidemics. Moreover, RVF can become endemic in areas where the disease has not previously been reported. For example, it is believed that RVF is now endemic in Egypt and possibly in the Arabian Peninsula.

Wesselsborn disease (WSL) is another mosquito-borne viral infection of sheep, cattle and goats that depends largely on the presence of floodwater-breeding *Aedes* spp. mosquitoes, and has epidemiological features very similar to those of RVF.

African horse sickness (AHS) and bluetongue (BT) are caused by viruses transmitted by *Culicoides* biting midges. The distribution of both diseases is thus very much affected by the presence of favourable conditions for the breeding and spread of midges. For example, large outbreaks of AHS in South Africa have been associated with the combination of drought and heavy rainfall caused by the warm phase of ENSO (2). Some global climate models predict that ENSO will occur more frequently in future. Thus, epidemics of these vector-borne diseases may become more frequent in certain parts of North Africa, as

Culicoides extends its range. Such areas may constitute serious threats for the spread of the infection into the Middle East and Mediterranean.

Lumpy skin disease is an economically important cattle disease in Africa, causing severe losses, such as damage to hides, mortality and losses in production and reproduction. The disease is more prevalent under wet conditions or conditions that favour the breeding of biting flies (e.g. *Stomoxys* and *Tabanus* spp.).

The direct and indirect effects of climate change on the distribution and density of tsetse flies will help to determine the future distribution and prevalence of livestock trypanosomiasis. (Although a recent study modelling the expected impact of climate change on the distribution of tsetse flies suggested that the influence of climate change is limited compared to the effects of population growth and the concomitant changes in land-use and the natural habitat of the tsetse [41].) The largest changes in the distribution of the tsetse fly are expected in the drier areas of West, East and southern Africa. Humid areas of the African tsetse belt will be less affected by climate change. However, the possible effects of increased temperatures and changes in habitat suitability on the vector capacity of the tsetse fly are not known and require further investigation.

Ticks spend a large part of their life living off their host(s) and are thus subject to ambient temperature and humidity. Climatic conditions and vegetation influence the ecosystem and largely determine the distribution of ticks and their density. Increasing temperature, as a result of climate change, may shorten their life cycle but increase their reproductive rate. Very high temperatures are likely to reduce their survival and mortality will increase under drier conditions. A model developed for the brown-ear tick (*Rhipicephalus appendiculatus*), the primary vector of East Coast fever (ECF), predicts that, by the 2050s, suitable habitats for the tick will have disappeared in most of the south-eastern part of its range. Conversely, more suitable areas for tick survival will appear in the western and central parts of southern Africa (30). In southern Zambia, a positive association was found between El Niño events and an increased ECF seroprevalence, as a result of the increased survival of the tick vector, *R. appendiculatus* (11). Hence, climate clearly influences the dynamics of the tick population and of the diseases they transmit by affecting the distribution of ticks and their seasonal occurrence.

In large areas of Africa, the control of major tick-borne diseases is based on the maintenance of an endemic stable situation. Endemic stability is the epidemiological state of a population in which clinical disease is rare, despite high levels of infection (7). It can develop in circumstances where young animals are exposed to infection but do not become diseased because of maternal or age resistance. As a result of this infection, they develop a long-lasting immunity. Conversely, when animals are not exposed to the disease agent during the 'protected' period, they will become susceptible to infection and may develop severe disease when challenged. Endemic stable situations are known to occur in the cases of heartwater, babesiosis and anaplasmosis. The development and maintenance of endemic stability for tick-borne diseases in cattle are thus dependent on an optimal relationship between cattle, the disease agent and ticks. Disruption of this optimal relationship, as a result of climate changes and subsequent alterations in the distribution and density of certain tick species, is likely to affect endemic stability and may result in outbreaks of disease.

Adaptation to climate change

Although the large majority of the African livestock population is exposed and sensitive to the direct and indirect impacts of climate change, much of its ultimate vulnerability will depend on the ability of the production system to adapt to such changes. Adaptations vary according to the system in which they occur, who undertakes them, the climatic changes or events that prompt them, their timing, functions, forms and effects. In most African livestock production systems, adaptation is likely to be autonomous and reactive. Nevertheless, adaptations can be undertaken consciously, or be planned and supported by, for example, the government or a veterinary infrastructure on behalf of the livestock owners. Autonomous adaptations often mask the important role such institutions could or should play in the long term, when dealing with animal health issues related to climate change.

The adaptive capacity of African livestock production systems is thus defined as the ability of those systems:

– to adapt to climate change and climate variability and moderate the potential damage

– to take advantage of opportunities, or

– to cope with the consequences (37).

Enhancing the adaptive capacity of the African livestock sector is a practical way of coping with climate change.

Since many African livestock systems are already very exposed and sensitive to climate in one way or another, and since climate is inherently variable for natural reasons, many of these systems have evolved to accommodate normal climate variations and, to a lesser extent, extreme weather events.

Transhumance, the moving of animals within a seasonal range or to and from seasonal pastures, is being applied particularly in West and East Africa to avoid adverse effects of climate on livestock health. Similarly, many pastoralist societies of arid or semi-arid regions in eastern and southern Africa have responded to interannual variations in rainfall by migration into wetter or more productive areas, in search of new seasonal grazing and water sources (35). Such examples of autonomous adaptation or coping ability contribute to the robustness or resilience of many African livestock production systems to climate change. Other coping strategies include:

– more efficient management of resources

– diversification of economic strategies

– the keeping of mixed herds to take advantage of the heterogeneous nature of the changing environment

– the intensification of resource use (9, 10, 13).

Making use of such processes, pastoralists in the Sahel region of West Africa have adapted to a reduction in rainfall of 25% to 30% over the last century (e.g. 32). In southern Kenya, Maasai herders have ultimately adopted crop farming to supplement or replace livestock keeping (3). Nevertheless, this ability to adapt autonomously can vary considerably in place and time. For East African pastoralists, for example, the strategies that have been used to cope with intra- and interannual droughts and floods are currently not working very well partly due to problems associated with their reduced ability to move (8). Moreover, although the pastoralist system has an inbuilt resilience to climate variability, the nature of this variability may change and the system may not be able to adapt to these new circumstances. In this regard, the key features of climate change that may increase the vulnerability of African livestock keepers are expected to be those related to variability and extreme weather events, rather than gradual changes in average conditions.

Key determinants of the adaptive capacity of a system are:

– economic resources

– technology

– information and skills

– infrastructure

– institutions

– equity.

Advances in technology (such as effective vaccination against some diseases) will greatly increase the ability to deal with climate-associated animal health problems, since many adaptive strategies, such as early warning systems or vector or disease control measures, are technology driven. For example, satellite images of vegetation can play a role in predicting outbreaks of vector-borne diseases.

Similarly, the capacity to adapt depends on having informed, trained and skilled personnel, who are capable of recognising, reporting and responding to animal health problems or threats associated with climate change. This requires a sound political, regulatory, technical and human basis for surveillance and response and an effective veterinary infrastructure, working alongside functional institutions that can support such interventions. Finally, the social and political environment may also seriously affect adaptive capacity. Political upheaval and the associated social, political and economic instability will constrain adaptation.

The capacity to adapt to climate change and extreme events is thus a function of a range of resources, and the ability of individuals and/or a community to call on these resources. Poverty and marginalisation are key drivers of vulnerability and reduce this capacity to adapt. Wealthier societies, on the other hand, have a greater adaptive capacity because they can afford and are willing to invest in adaptive measures.

It is not surprising that, for African livestock producers, the ability to adapt to livestock problems caused by climate change varies across geographical regions and, within those regions, between livestock production systems over time. To develop appropriate strategies to deal with the adverse effects of climate change it is essential to understand that vulnerability and adaptive capacity vary greatly in different areas and over different time periods. Generally speaking, it can be concluded that, at present, the ability of the African livestock keeper to adapt, and his/her choice of possible solutions, are very limited, due to:

– the limited financial resources available to most African livestock production systems

– the lack of technology and poorly developed or inappropriate infrastructure

– the lack of trained personnel

– the inequitable distribution of resources

– a lack of or limited information on potential adaptation options.

Failure to appreciate these limitations may reduce the ability to cope even more.

Coping with climate change

Although much is uncertain, some of the effects of climate change on African livestock can be predicted with relative certainty. These could form the basis for the development of general policies on how to prevent any adverse effects or, alternatively, exploit positive effects. Livestock owners could be made more aware of climate change and variability; surveillance systems could be established or improved, and the capacity of the production system to deal with such changes could be increased.

The development and implementation of strategies to specifically support adaptation remains a complex and continuous process that requires contributions from all participants, from the livestock owner and the local community to the government and regional or international organisations. To support informed decision-making at each of those levels, updated and relevant information is required.

Thus, further research will be needed. More attention could be paid to evidence from the recent past of the relationship between climate variability and animal health. For example, the association between excessive rainfall and the occurrence of some diseases is well known. Thus, areas that are more vulnerable to the influence of the El Niño cycle are also likely to be more vulnerable to those specific animal health problems, and local animal disease control strategies, based on climate forecasts, can be adapted accordingly (12, 14, 35, 42).

Unfortunately, there are few reports on the effect of long-term climate change on animal health in Africa. Monitoring its impact is a challenging task. Indeed, changes in livestock health due to climate are often difficult to distinguish from other confounding influences. The same applies to the spread of, for example, vector-borne diseases, where the distribution of the vector may be attributed to changes in the climate and/or other changes in environmental conditions (e.g. suitable habitat).

Models based on a range of climate scenarios are used to clarify, quantify and qualify those future effects, assist in the identification of scientific uncertainties and help to focus research activities. An assessment of climate change impact on livestock health should also attempt to integrate any physical, biological and societal confounding factors, as such integrated models will be far more useful in making policy decisions.

However, the available evidence indicates that the relationship between climate and animal health depends largely on context, and varies between different livestock populations and production systems. Hence, these models must also be based on data from the relevant livestock populations. Such information can be acquired nationally or, in areas with similar climatic conditions and livestock production systems (and vulnerabilities), regionally. A regional approach may be the most useful to co-ordinate relevant research activities.

Direct associations between long-term climate change and livestock health will probably be seen most clearly in production systems where adaptive capacity is lowest or where the relationship between the exposure and the outcome is straightforward.

A sound understanding of how climate change affects livestock health is crucial in making recommendations on how to reduce its potential impact. Unfortunately, the determinants of resilience and adaptation that already reduce this impact are often poorly understood. Indeed, lessons can be learned from case studies of past and present responses and adaptations, or from livestock production systems in regions that already experience similar climatic conditions (e.g. 41). In some cases, it is also useful to see how policy has been influenced by these experiences.

Many possible adaptive measures are not unique to climate change but are needed regardless, and indeed benefit the livestock sector as a whole (34). For example, adaptive capacity could be increased in the broader context of developing appropriate policy measures and institutional support to help the African livestock owner cope with all animal health problems. In fact, the development of an effective and sustainable animal health service, with associated surveillance and emergency preparedness systems and sustainable animal disease control and prevention programmes (e.g. vaccination campaigns against RVF, AHS and bluetongue), is perhaps the most important and most needed adaptive strategy in many African countries, and may, to a considerable extent, safeguard livestock populations from the threats of climate change and climate variability. Such a holistic approach is likely to be more acceptable, and probably more sustainable, since it is consistent with or can be integrated into programmes that address wider livestock production and rural development issues in Africa.

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Le changement climatique et la santé animale en Afrique

P. Van den Bossche & J.A.W. Coetzer

Résumé
En Afrique, le changement climatique aura certainement des conséquences directes aussi bien qu'indirectes sur les animaux d'élevage. Parmi les conséquences directes figurent principalement le réchauffement de la température, les inondations et les sécheresses. Les conséquences indirectes résulteront de la raréfaction de l'eau et des fourrages et de changements environnementaux qui favoriseront la propagation de maladies contagieuses en intensifiant le contact entre animaux ou en renforçant la capacité de survie ou d'activité de l'agent pathogène ou de son hôte intermédiaire. Les conséquences les plus significatives du changement climatique concerneront probablement la distribution et la prévalence des maladies à transmission vectorielle.
La vulnérabilité de l'industrie de l'élevage à cette menace dépendra de sa capacité de s'adapter à ces changements. L'amélioration de la capacité d'adaptation est l'un des moyens concrets de faire face au changement climatique. En Afrique, cette capacité d'adaptation peut être favorisée en permettant aux propriétaires de bétail de s'attaquer plus efficacement aux problèmes de santé animale, ce qui exige des mesures adéquates et un soutien institutionnel approprié. Le développement de services de santé animale efficaces et durables, parallèlement aux systèmes de surveillance et de préparation aux urgences sanitaires et aux programmes durables de prophylaxie et de prévention constituent sans aucun doute la meilleure stratégie pour faire face au changement climatique dans bien des pays d'Afrique.

Mots-clés
Afrique – Animal d'élevage – Changement climatique – Maladie – Prophylaxie – Santé.

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Cambio climático y sanidad animal en África

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Resumen
Según las previsiones, el cambio climático ejercerá efectos tanto directos como indirectos sobre el ganado africano. Entre las causas de los primeros se cuentan el aumento de la temperatura ambiente, las inundaciones y la sequía. Los efectos indirectos son resultado de la disminución de las reservas de agua y forrajes y de cambios en el entorno que favorecen la propagación de enfermedades contagiosas por la vía de un mayor contacto entre animales o de una mayor supervivencia o abundancia del agente o su hospedador intermedio. Quizá la consecuencia más importante del cambio climático vaya a ser la modificación de la distribución y prevalencia de enfermedades transmitidas por vectores.

La eventual vulnerabilidad de la industria ganadera dependerá de su capacidad para adaptarse a todas esas transformaciones. Una forma práctica de afrontar el cambio climático estriba en mejorar esa capacidad de adaptación, para lo cual cabría preparar a los ganaderos africanos para que sepan manejar mejor los problemas zoosanitarios mediante las oportunas medidas normativas y de apoyo institucional. Quizá en muchos países africanos la mejor estrategia para adaptarse al cambio climático pase por crear un servicio de sanidad animal eficaz y duradero, establecer sistemas conexos de vigilancia y preparación para emergencias y aplicar programas a largo plazo de control y prevención de enfermedades.

Palabras clave
África – Cambio climático – Control – Enfermedad – Ganado – Salud.

References

1. Adams R.M., McCarl B.A., Segerson K., Rosenzweig C., Bryant K.J., Dixon B.L., Conner R., Evenson R.E. & Ojima D. (1998). – The economic effects of climate change on US agriculture. *In* The economics of climate change (R. Mendelsohn & J. Neumann, eds). Cambridge University Press, Cambridge.

2. Baylis M., Mellor P.S. & Meiswinkel R. (1999). – Horse sickness and ENSO in South Africa. *Nature*, **397**, 574.

3. Campbell D.J. (1999). – Response to drought among farmers and herders in southern Kajiado District, Kenya: a comparison of 1972-1976 and 1994-1995. *Human Ecol.*, **27**, 377-416.

4. Campbell-Lendrum D.H. & Woodruff R. (2006). – Comparative risk assessment of the burden of disease from climate change. *Environ. Hlth Perspect.*, **114**, 1935-1941.

5. Carter T.R., Hulme M., Crossley J.F., Malyshev S., New M.G., Schlesinger M.E. & Tuomenvirta H. (2000). – Climate change in the 21st Century: interim characterisations based on the new IPCC emissions scenarios. Finnish Environment Institute (FEI) Report No. 433. FEI, Helsinki.

6. Coe M.J., Cumming D.H. & Phillipson J. (1976). – Biomass and production of large African herbivores in relation to rainfall and primary production. *Oecologia*, **22**, 341-354.

7. Coleman P.G., Perry B.D. & Woolhouse M.E.J. (2001). – Endemic stability – a veterinary idea applied to human public health. *Lancet*, **357**, 1284-1286.

8. Cousins B. (1996). – Conflict management for multiple resource users in pastoralist and agro-pastoralist contexts. *IDS Bull.*, **27**, 41-54.

9. Davies S. (1996). – Adaptable livelihoods: coping with food insecurity in the Malian Sahel. Palgrave Macmillan, London.

10. Downing T.E., Ringus L., Hulme M. & Waughray D. (1997). – Adapting to climate change in Africa: prospects and guidelines. *Mitig. Adapt. global Change*, **2**, 19-44.

11. Fandamu P., Duchateau L., Speybroeck N., Marcotty T., Mbao V., Mtambo J., Mulumba M. & Berkvens D. (2005). – *Theileria parva* seroprevalence in traditionally kept cattle in southern Zambia and El Niño. *Int. J. Parasitol.*, **35**, 391-396.

12. Galvin K.A., Boone R.B., Smith N.M. & Lynn S.J. (2001). – Impacts of climate variability on East African pastoralists: linking social science and remote sensing. *Climate Res.*, **19**, 161-172.

13. Galvin K.A., Thornton P.K., Boone R.B. & Sunderland J. (2004). – Climate variability and impacts on East Africa livestock herders. *Afr. J. Range Forage Sci.*, **21**, 183-189.

14. Hales S., Edwards S.J. & Kovats R.S. (2003). – Impacts on health of climate extremes. *In* Climate change and human health. Risks and responses (A.J. McMichael, D.H. Campbell-Lendrum, C.F. Corvalan, K.L. Ebi, A.K. Githeko, J.D. Scheraga & A. Woodward, eds). World Health Organization, Geneva, 79-102.

15. Hay S.I., Rogers D.J., Randolph S.E., Stern D.I., Cox J., Shanks G.D. & Snow R.W. (2002). – Hot topic or hot air? Climate change and malaria resurgence in East African highlands. *Trends Parasitol.*, **18**, 530-534.

16. Hulme M., Doherty R., Ngara T., New M. & Lister D. (2001). – African climate change: 1900-2100. *Climate Res.*, **17**, 145-168.

17. Intergovernmental Panel on Climate Change (2001). – Climate change 2001: impacts, adaptation and vulnerability (J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken & K.S. White, eds). Cambridge University Press, Cambridge.

18. Kock R.A., Wambua J.M., Mwanzia J., Wamwayi H., Ndungu E.K., Barrett T., Kock N.D. & Rossiter P.B. (1999). – Rinderpest epidemic in wild ruminants in Kenya 1993-1997. *Vet. Rec.*, **145**, 275-283.

19. Kovats R.S., Campbell-Lendrum D.H., McMichael A.J., Woodward A. & Cox J.S. (2001). – Early effects of climate change: do they include changes in vector-borne disease? *Philos. Trans. roy. Soc. Lond., B, biol. Sci.*, **356**, 1057-1068.

20. Kurukulasuriya P., Mendelsohn R., Hassan R., Benhin J., Deressa T., Diop M., Eid H.M., Fosu K.Y. *et al.* (2006). – Will African agriculture survive climate change? *World Bank econ. Rev.*, **20**, 367-388.

21. Linthicum K.J., Anyamba A., Tucker C.J., Kelley P.W., Myers M.F. & Peters C.J. (1999). – Climate and satellite indicators to forecast Rift Valley fever epidemics in Kenya. *Science*, **285**, 397-400.

22. McCarty J.J., Canziani O.F., Leary N.A., Dokken D.J. & White K.S. (2001). – Climate change 2001: impacts, adaptation, and vulnerability. Cambridge University Press, Cambridge.

23. McDermott J.J., Randolph T.F. & Staal S.J. (1999). – The economics of optimal health and productivity in smallholder livestock systems in developing countries. *In* The economics of animal disease control (B.D. Perry, ed.). *Rev. sci. tech. Off. int. Epiz.*, **18** (2), 399-424.

24. McMichael A.J. (2004). – Environmental and social influences on emerging infectious diseases: past, present and future. *Philos. Trans. roy. Soc. Lond., B, biol. Sci.*, **359**, 1049-1058.

25. Morgan E.R., Medley G.F., Torgerson P.R., Shaikenov B.S. & Milner-Gulland E.J. (2007). – Parasite transmission in a migratory multiple host system. *Ecol. Modell.*, **200**, 511-520.

26. Nicholson S.E. & Entekhabi D. (1986). – The quasi-periodic behavior of rainfall variability in Africa and its relationship to the Southern Oscillation. *J. Climate appl. Meteorol.*, **34**, 331-348.

27. Perry B.D., McDermott J. & Randolph T. (2001). – Can epidemiology and economics make a meaningful contribution to national animal-disease control? *Prev. vet. Med.*, **48**, 231-260.

28. Reilly J. (1996). – Agriculture in a changing climate: impacts and adaptation. *In* Climate change 1995: impacts, adaptations and mitigation of climate change: scientific-technical analyses. Contribution of Working Group II to the 2nd assessment report of the Intergovernmental Panel on Climate Change (R.T. Watson, M.C. Zinyowera & R.H. Moss, eds). Cambridge University Press, Cambridge, 429-467.

29. Robertshaw D. & Finch V. (1976). – The effects of climate on productivity of beef cattle. *In* Cattle production in developing countries (A.J. Smith, ed.). University of Edinburgh, Edinburgh, 132-137.

30. Rogers D.J. (1996). – Changes in disease vector distributions. *In* Climate change and southern Africa: an exploration of some potential implications in the SADC region (M. Hulme, ed.). Climate Research Unit, University of East Anglia, Norwich, 49-55.

31. Rogers D.J. & Randolph S.E. (2006). – Climate change and vector-borne diseases. *Adv. Parasitol.*, **62**, 345-381.

32. Roncoli C., Ingram K. & Kirshen P. (2001). – The costs and risks of coping with drought: livelihood impacts and farmers' responses in Burkina Faso. *Climate Res.*, **19**, 119-132.

33. Rötter R. & Van de Geijn S.C. (1999). – Climate change effects on plant growth, crop yield and livestock. *Climatic Change*, **43**, 651-681.

34. Scheraga J.D., Ebi K.L., Furlow J. & Moreno A.R. (2003). – From science to policy: developing responses to climate change. *In* Climate change and human health. Risks and responses (A.J. McMichael, D.H. Campbell-Lendrum, C.F. Corvalan, K.L. Ebi, A.K. Githeko, J.D. Scheraga & A. Woodward, eds). World Health Organization, Geneva, 237-266.

35. Scoones I. (1995). – Exploiting heterogeneity: habitat use by cattle in dryland Zimbabwe. *J. arid Environ.*, **29**, 221-237.

36. Seré C., Steinfeld S. & Groenewold J. (1996). – World livestock production systems: current status, issues and trends. Food and Agriculture Organization of the United Nations (FAO) Animal production and health paper No. 127. FAO, Rome.

37. Smit B. & Pilifosova O. (2003). – From adaptation to adaptive capacity and vulnerability reduction. *In* Climate change, adaptive capacity and development (J. Smith, R.T.J. Klein & S. Huq, eds). Imperial College Press, London, 9-28.

38. Steinfeld H., Wassenaar T. & Jutzi S. (2006). – Livestock production systems in developing countries: status, drivers, trends. *In* Animal production food safety challenges in global markets (S.A. Slorach, ed.). *Rev. sci. tech. Off. int. Epiz.*, **25** (2), 505-516.

39. Swaenepoel R. & Coetzer J.A.W. (2004). – Rift Valley fever. *In* Infectious diseases of livestock (J.A.W. Coetzer & R.C. Tustin, eds). Oxford University Press, Oxford, 1037-1070.

40. Taylor W.P., Roeder P.L., Rweyemamu M.M., Melewas J.N., Majuva P., Kimaro R.T., Mollel J.N., Mtei B.J. *et al.* (2002). – The control of rinderpest in Tanzania between 1997 and 1998. *Trop. anim. Hlth Prod.*, **34**, 471-487.

41. Thornton P., Robinson T., Kruska R., Jones P., McDermott J., Kristjanson P. & Reid R. (2006). – Cattle trypanosomiasis in Africa to 2030. *In* Infectious diseases: preparing for the future. Office of Science and Innovation, London.

42. Thornton P.K., Fawcett R.H., Galvin K.A., Boone R.B., Hudson J.W. & Vogel C.H. (2004). – Evaluating management options that use climate forecasts: modelling livestock production systems in the semi-arid zone of South Africa. *Climate Res.*, **26**, 33-42.

43. Thornton P.K., Jones P.G., Owiyo T., Kruska R., Herrero M., Kristjanson P.M., Notenbaert A., Bekele N. & Omolo A. (2006). – Mapping climate vulnerability and poverty in Africa. International Livestock Research Institute, Nairobi, Kenya.

44. Vincent K. (2004). – Creating an index of social vulnerability to climate change for Africa. Tyndall Centre for Climate Change Research working paper No. 56. University of East Anglia, Norwich.

45. Ward M.N. (1998). – Diagnosis and short-lead time predictions of summer rainfall in tropical northern Africa at interannual and multidecadal timescales. *J. Climate Change*, **11**, 3167-3191.

46. Zaria L.T. & Amin J.D. (2004). – Dermatophilosis. *In* Infectious diseases of livestock (J.A.W. Coetzer & R.C. Tustin, eds). Oxford University Press, Oxford, 2026-2041.