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Leptospirosis: Epidemiology and Public Health Significance

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ABSTRACT

Climate change is a complex problem involving varied interactions between the environment, natural resources (land, crops, animals and water) and peoples. Global climate change poses the threat of serious social upheaval, population displacement, economic hardships and environmental degradation (ESAP, 2009). Agriculture and livestock are amongst the most climate sensitive economic sectors in the developing countries whilst the rural poor communities are more vulnerable to the adverse effects of the climate change (Kimaro and Chibinga, 2013). Climate change may affect livestock disease through several pathways both direct and indirect. It may facilitate establishment of novel imported infectious diseases in regions that were previously unable to support endemic transmissions. Most vector borne diseases that are expected to emerge because of climate change are zoonotic diseases. Climate change may cause amplification of the parasite population and have profound effects on the host-parasite assemblages. Another aspect of climate change is that an effect on the pathogen microorganism by increasing their virulence. Climate change also modify the disease ecology by complicating the life cycles of the different hosts and vectors and the microorganism, that make vector borne diseases difficult to predict and control. Stress caused due to the effect of climate change e.g. increased temperature, increased population density; high density of biting insects or lack of food may induce suppression of the immune response and lead to increased susceptibility of organisms to opportunistic pathogens.

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Introduction

Climate change is the 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. Climate change effects include among other things i.e. sea level rise, changes in the intensity, timing and spatial distribution of precipitation, changes in temperature and the frequency, intensity and duration of extreme climate events such as droughts, floods, and tropical storms (IPCC, 2007).

Climate change is a complex problem involving varied interactions between the environment, natural resources (land, crops, animals and water) and peoples. These interactions are likely to change the ecological and agricultural landscape, and therefore influence agricultural production Analyses of the issues involved and well informed opinions clearly indicate that the looming effects of climate change are potentially awesome. The predictable effects of increased temperature are apparently varied and many, whose impacts directly concern the biophysical environment, use of natural resources, productivity, research and development capacity, health and human welfare.

According to the IPCC, the agriculture sector contributes between 10% and 12% of global emissions of greenhouse gases, in terms of CO_2 equivalent. It contributes 40% of the total of anthropic emissions of CH_4 (from enteric fermentation, decomposition of manure and flooded rice fields) and 65% of the total of anthropic N_2O (agricultural land, use of nitrogenous fertilisers, spreading manure and burning biomass) (IPCC, 2007).

Storing and disposing vast quantities of manure can produce anthropogenic methane and nitrous oxide emissions (U.S. 2007). The amount of methane produced by animals and their manure is largely determined by the animals' feed quality, digestive efficiency, body weight, age, and amount of exercise (Paustian *et al.*, 2006). Ruminants emit methane during digestion, (U.S. 2006) which involves microbial (enteric) fermentation of fibrous feeds and grains (Steinfeld *et al*., 2006). This digestive process enables cattle, goats, buffalo, sheep, and other ruminants to consume plants that monogastric animals are unable to digest. Ruminant animals naturally consume grass and forage; however, when they are fed a low-fiber, corn based diet, fermentation acids can accumulate in the animal's rumen (Clancy K., 2006).

The standard diet of most industrial farm animal production systems is comprised of highly unnatural rations of concentrated, high-protein feeds made from corn and soybeans. For ruminants, eating corn and soybeans does not come naturally. For cattle in particular, the effects of a grain-fed diet can be devastating. Although cattle can gain weight quickly on this diet, (Radostits *et al*., 2000) grain consumption can cause a range of illnesses (Russell and Rychlik, 2001) and possibly more methane emissions (Paustian *et al*., 2006).

Livestock systems directly support the livelihoods of at least 600 million smallholder farmers, mostly in sub-Saharan Africa and South Asia (Thornton P.K., 2010). It is a rapidly-growing agricultural subsector and its share of agricultural GDP is 33 % and rising, driven by population growth, urbanization and increasing incomes in developing countries. Demand for all livestock products is expected to nearly double in sub-Saharan Africa and South Asia by 2050 (Alexandratos and Bruinsma, 2012). On the other hand, changes in climate over the last 30 years have already reduced global agricultural production in the range 1-5 % Climate change influences the emergence and per decade (Thornton *et al*., 2015).

Global climate change poses the threat of serious social upheaval, population displacement, economic hardships and environmental degradation (ESAP, 2009). Furthermore, Climate change and global warming now being accepted facts have affected all the ecosystems and will do so if left uncontrolled (Yatoo *et al*., 2012). Agriculture and livestock are amongst the most climate sensitive economic sectors in the developing countries whilst the rural poor communities are more vulnerable to the adverse effects of the climate change (Kimaro and Chibinga, 2013). Impacts on some components have gained more attention while others have been neglected. Animals belong to later. Even among the aspects relating to impacts of climate change on animals, production related impacts have gained attention when the impacts on health in general and on infectious diseases in particular are neglected (Yatoo *et al*., 2012). Climate change influences the emergence and proliferation of disease hosts or vectors and pathogens and their breeding, development and disease transmission. Consequently, it affects distributions and host –parasite relationships and its assemblages to new areas (ESAP, 2009).

Climate Change and Animal Diseases Linkage

The distribution of infectious diseases, (human, animal and plant) and the timing and intensity of disease outbreaks are often closely linked to climate. Climate change may affect livestock disease through several pathways both direct and indirect. The direct effect s of climate on animal disease are likely to the most pronounced for diseases that are vector-born, soil associated, water or flood associated, rodent associated or air temperature/humidity associated and sensitive to climate (Grace *et al*., 2015). These directly or indirectly effects by weather and climate may be spatial, with climate affecting distribution, temporal with weather affecting the timing of an outbreak, or relate to the intensity of an outbreak. Global climate change alters ecological construction which causes both the geographical and phonological shifts (Slenning, B., 2010). These shifts affect the efficiency and transmission pattern of the pathogen and increase their spectrum in the hosts (Brooks and E.P. Hoberg, 2007).

The increased spectrum of pathogens increases the disease susceptibility of the animal and thus, supports the pathogenicity of the causative agent. The livestock systems are susceptible to changes in severity and distribution of livestock diseases and parasites as potential consequences. Incidence of external parasite (43.3%) was first ranked as the problem in the warm temperate (Dhakal *et al*., 2013). Vector-borne diseases are especially sensitive to climate change. Changes in rainfall and temperature regimes may affect both the distribution and the abundance of disease vectors, as can changes in the frequency of extreme events. Arthropod vectors tend to be more active at higher temperatures; they therefore feed more regularly to sustain the increase in their metabolic functions, enhancing chances of infections being transmitted between hosts. Small changes in vector characteristics can produce substantial changes in disease (Grace *et al*., 2015).

There is a link between climate and epidemiological conditions of disease agents. Temperature, precipitation, humidity and other climatic factors are known to affect the reproduction, development, behavour and population dynamics of the helminthes, arthropod vectors and the pathogen they carry. Climate change influences the emergence and proliferation of disease hosts or vectors and pathogens and their breeding, development and disease transmission (ESAP, 2009). The OIE Scientific Commission has concluded that climate changes are likely to be an important factor in determining the spread of some diseases, especially those that are vector-borne. The two most mentioned emerging and re-emerging cattle diseases in a recent OIE survey are Catarrhal fever (Bluetongue) and Rift Valley fever (OIE, 2008). The global distribution of Bluetongue virus infection changed drastically in recent years and climate change may be partly responsible for this profound change in the global distribution of the Bluetongue virus (Wilson and Mellor, 2008). Studies have demonstrated that the vectors of the disease are affected by temperature and have indicated a possible role of humidity (Wittmann *et al*., 2002) and precipitation (Wilson and Mellor, 2008).

Infectious Diseases

For both domestic animals and wildlife, new infectious diseases are a serious threat. Introduction of new infective agents may entail disastrous effects for a large proportion of individuals in an immunologically naive population and, in extreme cases, lead to extinction of entire populations. Globalisation with increased movement of animals, people and goods facilitates dispersal of disease agents far from their endemic regions (Mintiens *et al*., 2008). As infectious diseases today are spreading geographically much faster than at any previous time, an epidemic or epizootic disease outbreak in any part of the world is not far away from becoming a threat somewhere else. Consequently, new diseases can arrive from ‘anywhere’, while climate change may facilitate establishment of novel imported infectious diseases in regions that were previously unable to support endemic transmissions (Dufour *et al*., 2008). The mechanisms by which climate change affects disease transmission have often been oversimplified, as many other factors also influence the environment and the behaviour of populations and individuals (Randolph, 2008). For example, human activities such as change of land use and fragmentation of habitats can enhance the dispersal of disease agents. Extreme weather events such as flooding, storms, droughts, etc. are associated with an increased disease risk. Such events may influence infectious diseases more profoundly and acutely than the ongoing climate change (Hubalek *et al*., 2004).

In terms of climate change, vector borne diseases are a special concern (de La Rocque *et al*, 2008). The transmission of vector borne diseases is closely linked to nature and ecosystem structure and therefore to a large extent dependent on processes in a specific ecosystem (Hales *et al*., 2006). Most vector borne diseases that are expected to emerge because of climate change are zoonotic diseases. Compared with ‘human-only’ diseases, zoonoses are in general more difficult to control with vaccination, education of populations and medical checks of travellers, etc. In an attempt to identify animal infectious diseases of importance whose introduction or distribution in France could be affected by climate change, five out of six prioritised diseases were vector borne diseases and five of these six were also zoonoses (Dufour *et al*., 2008).

Although the introduction of exotic diseases to new regions is a concern, geographical and seasonal patterns of endemic infectious diseases may also be altered due to climate change. It is possible that well-known, persistent diseases will change character in respect of severity, epidemiology, incidence etc. The seasonality of outbreaks of a certain disease has long been commonly recognised. The same has been observed for periodic epidemics and disease outbreaks of less frequent or more irregular intervals. Knowledge of the mechanisms triggering epidemics with inter annual cycles is in most cases sparse. Most epidemiological data concerning infectious diseases are restricted to certain periods of time or to specific countries or regions. The identification and relative importance of climatic factors for disease dynamics on a longer timescale is therefore still a controversial topic (McMichael *et al*., 2006). Other non-climatic aspects such as environmental disturbances and pollution, land use changes, habitat fragmentation, effects of altered behaviour, etc. Also affect the incidence of diseases. These factors may have either cumulative or opposing effects on disease occurrence. For example, effects of climate change in promoting the dispersal of 'human-only' vector borne diseases such as malaria and denguefever from more tropical ranges to temperate areas have been observed (Patz *et al*., 1996). Another interesting example of climate effects on the incidence of human infections is the El Niño Seasonal Oscillation effect (ENSO). This semi-regular climate cycle, although not perfect, can be used as an analogue for the effects of global climate change (Cazalles and Hales, 2006). The ENSO even has been associated with an increase in diarrhoea in Peru, cholera epidemics in Peru and Bangladesh and denguefever and malaria epidemics in several tropical and subtropical countries (Cazalles and Hales, 2006). El Niño Seasonal Oscillation events are predicted to become a more frequent and severe phenomenon as global warming progresses (IPCC, 2007), which would further facilitate local epidemics of certain diseases.

Another aspect of climate change is that an effect on the pathogen microorganism itself may be seen. This has been speculated to cause an increase in the virulence of pathogens in some cases (Marcogliese, 2008). To fit a dynamic environment such as that induced by climate change, a generalist strategy is favourable. A generalist organism displays pioneer behaviour and is ready to encroach or occupy any novel ecological vacuum that may present itself. For example, the ability to infect multiple host species makes it possible for a pathogen to overcome temporary shortfalls in host availability. A pathogen with a flexible host-occupancy pattern is also an effective transmitter of infection to new species. Vector-borne viruses are often RNA viruses, which are known for their variability and limited specificity of hosts (de La Rocque *et al*., 2008).

Parasitic Infections

For domestic animals a prolonged grazing period has several advantages, but a negative health effect may follow from prolonged exposure to parasite infections. Warmer and more humid climates, especially in temperate and colder northern latitudes and in areas of high altitude, may shorten generation time and increase the survival and population density of parasites (van Dijk *et al*., 2008). On the other hand, e.g. a sparse protective layer of snow during the winter or less protective vegetation during drought may reduce the survival of free-living stages of the parasite or of intermediate hosts. Intermediate hosts are common in the development cycle of many parasitic organisms and play an important role in disease transmission dynamics (Feachem *et al*., 1983). Therefore, an expansion of suitable habitats, e.g. damp areas, for invertebrate hosts may favour the existence of parasitic organisms.

Zoonotic parasites such as *Cryptosporidia, Giardia* and *Toxoplasma* can be water-borne and are suggested to cause increasing problems in the developed world, in part due to climate change (Mas-Coma *et al*., 2008). The ability of these parasites to survive for long periods of time in the environment and resist many natural and artificial conditions makes them most difficult to control (Feachem *et al*., 1983).

In a British study, 430, 000 samples of faeces from sheep with gastroenteritis symptoms were analysed for the presence of parasites during the period 1975-2006 (van Dijk *et al*., 2008). A highly significant increase in the rate of parasitic gastroenteritis was observed during this period and climate change was suggested to be the most likely explanation for this increase. Possible sources of bias such as reporting bias, changes in husbandry patterns and antihelminthic resistance were also evaluated (van Dijk *et al*., 2008).

Under optimal conditions for an individual, many parasitic infections may not provoke any negative effect on the physiology of the host. However, under certain environmental conditions involving stress, the effects may become negative. Intestinal parasites may cause protein losses in the intestine, resulting in decreased digestive ability and increased nitrogen in the manure. Parasitic diseases, especially helminthiases, have a great impact on animal health. Under certain conditions they can also influence wild animal populations and in that way affect whole ecosystems (Mas-Coma *et al*., 2008). Climate change may cause amplification of the parasite population and have profound effects on the host-parasite assemblages. This in turn can have large impact on the health and survival of wild animal populations. Kutz *et al*. (2001) gives an example of this effect on a Canadian musk ox population. This population was decimated to about half during a six-year period due to an unusual genus of a protostrongylid lung nematode. Even though this parasite did not kill the animals, it lowered their lung capacity and made them more vulnerable to predators.

Vector-borne Disease

The concern today is for increased incidence of vector borne diseases is due to climate change. Environmental conditions are important for the presence of many vectors (ticks, mosquitoes, sand flies, etc.), as well as the mammalian or avian host species they use to feed on or which act as reservoir species for the disease agent. The transmission cycle for infectious agents carried by vectors can be complex, and it is especially important to understand this cycle for any given agent and its geographical context in order to understand how climate plays a role. In general, vectors are favoured by increased temperature and high humidity. However, increasing precipitation is not always favourable for vectors. Heavy rainfall may wash away breeding sites, while drought, on the other hand, may slow rapid streams and create pools of stagnant water.

It is the complexity involved with the life cycles of the different hosts and vectors and the microorganism that make vector borne diseases difficult to predict and control, and this complexity also results in a disease ecology that can be modified due to climate change. The distribution and size of populations of vectors and hosts will respond to changes in temperature and precipitation and these can often produce an outcome of changing disease patterns (Daniel *et al*., 2003).

An attempt has been made to simulate the influence of climate change on replication and population size of ticks and the secondary effect on disease transmission of three different pathogens by using a mathematical model (Ogden *et al*., 2008). The seasonal synchrony of different development stages of ticks is important for the population biology and this is to a large extent temperature-dependent and therefore may be altered by climate change. However, the results from the mathematical modelling were difficult to interpret, since the influence of climate change was different between different tick species and geographical locations and even amongst different populations of the same species, as an effect of evolutionary processes (Ogden *et al*., 2008). In addition, the relationship between ambient weather conditions and vector ecology is complicated by the natural tendency for arthropod vectors to seek out the most suitable microclimates for their survival. Example of this is resting under vegetation or in pit latrines during dry or hot conditions or in culverts during cold conditions (Gubler *et al*., 2001).

Bluetongue virus, a disease transmitted by *Culicoides* midges, has had devastating effects on livestock throughout Africa, the Middle East, Asia, Australia, the United States, and the Mediterranean. In 2006, the disease spread to Central Europe for the first time (Mehlhorn *et al*., 2007) through interplay of factors that included an expansion of the range of the primary *Culicodes* vector, temperature dependence of virus replication in the vector (Wittmann *et al*., 2002), and overlap with a new *Culicodes* species whose range extended 800 km further North than outbreaks had previously been reported (Purse *et al*., 2005).

Rift valley fever is a viral disease that affects domestic animals and humans and is spread by several mosquito species, some of which can transmit the virus directly to their offspring (Linthicum *et al*., 1999). The relationship between Rift valley fever outbreaks and heavy rains that create mosquito breeding sites is well established (Linthicum *et al*., 1985).

Opportunistic Pathogens

Commensals or opportunistic microorganisms cause no harm when present in healthy animals. Stress caused by e.g. increased temperature, increased population density, high density of biting insects or lack of food may induce suppression of the immune response and lead to increased susceptibility of organisms to opportunistic pathogens. An example of this is an outbreak of fatal pneumonia caused by an opportunistic bacterium (*Pasteurellaceae* or *Mannheimia* spp.), which occurred in a musk ox population of Dovrefjell in Norway. A large proportion of the animals died during a period of extraordinarily warm and humid weather during early autumn 2006 (Ytrehus *et al*., 2008). Musk ox, like other Arctic species are adapted to extreme cold and therefore regarded as vulnerable to the impacts of climate change (ACIA, 2005). Dovrefjell is a rather southerly habitat for this cold-adapted species and during early autumn the animals have a well-developed winter coat and a thick layer of subcutaneous fat, which makes them especially vulnerable to heat stress (Ytrehus *et al*., 2008).

Ecosystem Health

Changes in ecosystems as a consequence of climate change will have a profound impact on ecosystem health. Today an obvious effect of climate change has been observed on the distribution of vertebrates, invertebrates and plant species, on timing of seasonal activities of species and on physiological responses in both terrestrial and aquatic organisms (Marcogliese, 2008). Ecosystems with a low biodiversity, e.g. in Arctic and sub-Arctic climate zones, are more sensitive to changes (ACIA, 2005) that the more diverse systems (Parmesan, 2006). Continuous and systematic assessment of wildlife health can provide a means to estimate ecosystem health, e.g. infectious diseases are one manifestation of deteriorating ecosystems. New diseases may cause epizootics, especially if the native biota is immunologically naive to the new agent.

Sudden, fundamental changes (threshold changes) in ecosystems can already be observed today and further anthropogenic changes can magnify the health effects of climate change and extreme weather events. Taken together, the present and coming changes in ecosystems will have profound implications for epidemiology and animal health.

A shift in distribution by migration to areas of more suitable climate has been a common historical way of survival. Temporary establishment in refugee areas has often been practised, together with downsizing in population numbers and in distribution area. However, a higher density of an animal population, as may follow migration, can create an opportunity for density-dependent pathogens to cause disease outbreaks. (Lovejoy, 2008)

In general, vector borne diseases today are more prevalent in the tropics, since the warm and humid climate there provides ideal conditions for vectors. However, the large diversity and abundance of different infections in the tropics is most likely buffered by the large biodiversity, causing a 'dilution effect'. Through this, the presence of incompetent disease reservoirs decreases the impact of highly competent reservoirs and reduces the disease risk (Marcogliese, 2008). Vectors can only bite a limited number of times during their lifetime. If some bites are spent on individuals that are non-competent to either amplify or transmit the pathogen, those bites are wasted. If vector borne diseases disperse to higher latitudes and altitudes under warmer climate conditions, they will invade ecosystems in which the natural level of biodiversity is relatively low. If the most competent vector or reservoir host becomes dominant, the risk for a high prevalence of the infection will increase (Schmidt and Ostfeld, 2001). Furthermore, some host species may also spread from the tropics into the temperate zones. However, larger species typically spread at a slower rate than smaller, so for a significant time vector borne diseases will be moving down a gradient of biodiversity (Dobson *et al*., 2006). Therefore, it may be wise to conserve biological diversity for the purely selfish reasons of protecting human and domestic animal health.

Conclusion and Recommendations

Climate change has negative effect on livestock health in many aspects. It may influence livestock health through a number of factors, including the range and abundance of vectors and wildlife reservoirs, the survival of pathogens in the environment. Climate change can exacerbate disease in livestock and some diseases are especially sensitive to climate change. Indeed, a better understanding of the effect of climate change on animal health is crucial and good for recommendations on how to lessen its potential impact. Unfortunately, the determinants of resilience and adaptation that already reduce this impact are often poorly understood even though they are not unique but are needed regardless. For example, adaptive capacity could be increased in the broader context of developing appropriate policy measures and institutional support to help the livestock owners to cope with all livestock 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 programme is perhaps the most important and most needed adaptive strategy. This will safeguard livestock populations from the threats of climate change and climate variability. Therefore, successful adaptations may be shown as better way of coping with the negative consequences of climate change and associated drivers of disease.

Depending on the above conclusion, I recommend the concerning body these recommendations:

Every country should have to aware about climate change and make policies that regulate carbon emission that cause climate change

REFERENCES

1 ACIA, (Arctic Climate Impact Assessment) (2005). Scientific report: Impact of a warming arctic. Cambridge University Press, Cambridge, UK, Pp. 1042.

2 Alexandratos, N. and Bruinsma, J. (2012). World agriculture towards 2030/2050: the 2012 revision. FAO, Rome, Italy.

3 Brooks, D. and Hoberg, E. (2007). How will global climate change affect parasite host assemblages. Trends in Parasitology, 23: 571-574.

4 Cazelles, B. and Hales, S. (2006). Infectious diseases, climate influences, and non-stationary. In: *Plos Medicine* **3**, pp. 328 http://www.plosmedicine.Org.

5 Clancy, K. (2006). Greener pastures: how grass-fed beef and milk contribute to healthy eating, p.13.www.ucsusa.org/assets/documents/food_and_environment/greener-pastures.pdf. Accessed April 23, 2008.

6 Daniel, M., Danielova, V., Kríz, B., Jirsa, A. and Nozicka, J. (2003). Shift of the tick Ixodesricinus and tick borne encephalitis to higher altitudes in central Europe. In: *Eur J Clin Microbiol Infect Dis* **22**, pp. 327-328.

7 de La Rocque, S., Rioux, J. and Slingenbergh, J. 2008. Climate change: effects on animal disease systems and implications for surveillance and control. In: *Rev Sci Tech* **27**(2): pp. 339-54.

8 Dhakal, C., Regmi, P., Dhaka, M., Khanal, B., Bhatta, U., Barsila, S., and Acharya B., (2013). Perception, Impact and Adaptation to Climate Change: An Analysis of Livestock System in Nepal. *J. Anim. Sci. Adv* **3**(9): 462-471.

9 Dobson, A., Cattadori, I., Holt, R., Ostfeld, R., Kessing, F., Krichbaum, K., Rohr, J., Perkins, S. and Hudson, P. (2006). Sacred cows and sympathetic squirrel: the importance of biological diversity to human health. In: *PloS Medicine* **3**, pp.231 http://www.plosmedicine.org

10 Dufour, B., Moutou, F., Hattenberger, A. and Rodhain, F. (2008). Global change: impact, management, risk approach and health measures – the case of Europe. In: De La Rocque, S., Hendrickx, G. and Morand, S. (eds.) *Climate*

change: impact on the epidemiology and control of animal diseases. *Rev. Sci. Tech. Off. Int. Epiz* **27**(2), pp. 529-550.

11 ESAP (Ethiopian Society of Animal Production), (2009). Climate change, livestock and people: Challenges, opportunities and the way forward. Zelalem Yilma and Aynalem Haile (eds). Proceedings of the 17th Annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, September 24 to 26, 2009. ESAP, Addis Ababa, pp: 300.

12 Feachem, R., Bradley, D., Garelick, H. and Mara, D. (1983). *Sanitation and disease. Health aspects of excreta and waste water management*. World Bank studies in Water Supply and Sanitation 3, Bath, GB: Pitman Press.

13 Grace, D., Bett, B., Lindahl, J. and Robinson, T. (2015). Climate and Livestock Disease: assessing the vulnerability of agricultural systems to livestock pests under climate change scenarios. CCAFS Working Paper No. 116. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

14 Gubler, D., Reiter, P., Ebi, K., Yap, W., Nasci, R. and Patz, J. (2001). Climate variability and change in the United States: potential impacts on vector- and rodent-borne diseases. In: *Environ. Health Persp* **109**, pp. 223-233.

15 Hales, S., Kovats, S. and Woodward, A. (2006). What El Niño can tell us about human health and global climate change. In: *Global change& human health* **1**. pp. 66-77.

16 Hubalek, Z., Zeman, P., Halouzka, J. and Juricova Z. et al. (2004). [Article in Czech] Antibodies against mosquito-borne viruses in human population of an area of Central Bohemia affected by the floodof 2002. In: *Epidemiol Microbiol Imunol* **53**, pp. 112-120.

17 IPCC. (2007). *Climate change: Impacts, adaptation and vulnerability. Working group II contribution to the Intergovernmental Panel on Climate Change, Fourth assessment report*. Cambridge University Press. http://www.ipcc.ch/ipccreports/ar4-syr.htm

18 Kimaro, E. and Chibinga, O. (2013). Potential impact of climate change on livestock production and health in East Africa: A review. Livestock Res. Rural Develop, 25(7): 116.

19 Kutz, S., Hoberg, E., Polley, L. (2001). A new lungworm in musk oxen: an exploration in arctic parasitology. In: *TRENDS in Parasitology* **6**, pp 276-280.

20 Linthicum, K., Anyamba, A., Tucker, C., Kelley, P., Myers, M., Peters, C. (1999). Climate and satellite indicators to forecast Rift Valley fever epidemics in Kenya. *Science* **285**:397-40

21 Linthicum, K., Davies, F., Kairo, A., Bailey, C. (1985). Rift Valley fever virus (family Bunyaviridae, genus Phlebovirus). Isolations from Diptera collected during an inter-epizootic period in Kenya. *The J Hyg* **95**:197–209

22 Lovejoy, T. (2008). Climate change and biodiversity. In: De La Rocque,S., Hendrickx, G. and Morand, S. (eds.) *Climate change: impact onthe epidemiology and control of animal diseases*. *Rev. Sci. Tech. Off. Int. Epiz* **27** (2), pp. 331-338.

23 Marcogliese, D. (2008). The impact of climate change on the parasites and infectious diseases of aquatic animals. In: De La Rocque, S. Hendrickx, G. and Morand, S. (eds.) *Climate change: impact on theepidemiology and control of animal diseases*. *Rev. Sci. Tech. Off.Int. Epiz* **27** (2), pp. 467-484.

24 Mas-Coma, S., Valero, M.and Bargues, M. (2008). Effect of climate change on animal and zoonotic helminthiases. In: De La Rocque, S., Hendrickx, G. and Morand, S. (eds.) *Climate change: impact on the epidemiology and control of animal diseases*. *Rev. Sci. Tech. Off. Int. Epiz* **27**, pp. 443-458.

25 McMichael, A., Woodruff, R. and Hales, S. (2006). Climate change and human health: present and future risks. In: *Lancet* **367**, pp. 859-69.

26 Mehlhorn, H., Walldorf, V., Klimpel, S., Jahn, B., Jaeger, F., Eschweiler, J. (2007). First occurrence of Culicoidesobsoletus-transmitted bluetongue virus epidemic in Central Europe. *Parasitol Res* **101**: pp. 219–228

27 Mintiens, K., Meroc, E., Faes, C., Abrahantes, J., Hendrickx, G., Staubach, C., Gerbier, G., Elbers, A., Aerts, M. and Clercq, K. (2008). Impact of human interventions on the spread of bluetongue virus serotype 8 during the 2006 epidemic in north-western Europe. In: *Prev Vet Med* **87**, pp. 145-61.

28 Ogden, N., Bigras-Poulin, M., Hanincova, K., Maarouf, A., O´Callaghan, C. and Kurtenbach, K. (2008). Projected effects of climate change on tick phenology and fitness of pathogens transmitted by the North American tick Ixodesscapularis. In: *J. Theor. Biol* **254**, pp. 621-632.

29 OIE (2008). Report of the Meeting of the OIE Scientific Commission for Animal Diseases. http://www.oie.int/downld/SC/2008/A_SCAD_feb2008.pdf.

30 Parmesan, C. (2006). Ecological and evolutionary responses to recent climate change. In: *Annual*

Review of Ecology, Evolution and Systematics **37**, pp. 637-669.

31 Patz, J., Epstein, P., Burke, T. and Balbus, J. (1996). Global climate change and emerging infectious diseases. In: *JAMA* **275**, pp. 217-223.

32 Paustian, K., Antle, J., Sheehan, J. and Paul, E. (2006). Agriculture's role in greenhouse gas mitigation. Pew Center on Global Climate Change, pp. 3.

33 Purse, B., Mellor, P., Rogers, D., Samuel, A., Mertens, P., Baylis, M. (2005) Climate change and the recent emergence of bluetongue in Europe. *Nat Rev Microbiol* **3**: pp.171–181

34 Radostits, O., Gay, C., Blood, D., and Hinchcliff, K. (2000). Veterinary Medicine: A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses, 9th edition (China: W.B. Saunders, pp. 285).

35 Randolph, S. (2008). Dynamics of tick-borne disease systems: minor role of recent climate change. In: *Rev. Sci. Tech. Off. Int. Epiz* **27**(2), pp. 367-81.

36 Russell, J. and Rychlik, J. (2001). Factors that alter rumen microbial ecology. *Science* **292**: pp. 1119-22.

37 Schmidt, K. and Ostfeld, R. (2001). Biodiversity and the dilution effect in disease ecology. In: *Ecology* **82**(3), pp. 609-619.

38 Slenning, B. (2010). Global climate change and implications for disease emergence. Veterinary Pathology, 47(1): 28-33.

39 Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., and de Haan, C. (2006). Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 82.

40 Thom, E. (1959). *The discomfort index*. Weather wise. 12, pp. 57-59. (USDC-ESSA, 1970).

41 Thornton, P. (2010). Livestock Production: Recent trends, future prospects. Philosophical Transactions of the Royal Society Series B, 365: 2853-2867.

42 Thornton, P., Boone, R. and Ramirez-VillegasJ. (2015). Climate change impacts on livestock. CCAFS Working Paper No. 120. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

43 U.S. Environmental Protection Agency. (2006). Methane: sources and emissions. www.epa.gov/methane/sources.html. Accessed April 23, 2008.

44 U.S. Environmental Protection Agency. (2007). Inventory of U.S. greenhouse gas emissions and sinks: 1990-2005, p.6-6. www.epa.gov/climatechange/emissions/downloads06/07CR.pdf. Accessed April 23, 2008.

45 Van Dijk, J., David, G., Baird, G. and Morgan, E. (2008). Back to the future: Developing hypotheses on the effects of climate change on ovine parasitic gastroenteritis from historical data. In: *Vet. Parasit* **158**, pp. 73-84.

46 Wilson, A. and Mellor, P. (2008). Bluetongue in Europe: Vectors, epidemiology and climate change. Parasitology Research, 103: 69-77.

47 Wittmann, E., Mello, P., Baylis, M. (2002). Effect of temperature on the transmission of orbiviruses by the biting midge, Culicoidessonorensis. Med Vet Entomol 16:147–156.

48 Yatoo, M., Kumar, P., Dimri, U. and Sharma, M. (2012). Effects of climate change on animal health and diseases. International Journal of Livestock Research, 2(3): 15-24.

49 Ytrehus, B., Bretten, T., Bergsjö, B. and Isaksen, K. (2008). Fatal pneumonia epizootic in musk ox (Ovibusmoschatus) in a period of extraordinary weather conditions. In: *Eco Health*., pp. 213-223.