

# Climate change impacts and risks for animal health in Asia

S. Forman<sup>(\*, 1)</sup>, N. Hungerford<sup>(2)</sup>, M. Yamakawa<sup>(3)</sup>, T. Yanase<sup>(3)</sup>, H.-J. Tsai<sup>(4)</sup>, Y.-S. Joo<sup>(5)</sup>, D.-K. Yang<sup>(5)</sup> & J.-J. Nha<sup>(5)</sup>

\* The points of view expressed in this paper are those of the author and not the official position of the World Bank

(1) World Bank, 1818 H Street NW, Washington, DC 20433, United States of America

(2) World Organisation for Animal Health (OIE) Southeast Asia Foot and Mouth Disease Campaign, c/o Department of Livestock Development, 69/1 Phaya Thai Road, Ratchathewi 10400, Bangkok, Thailand

(3) Kyushu Research Station, National Institute of Animal Health, Chuzan, Kagoshima Kagoshima, 891-0105 Japan

(4) Department of Veterinary Medicine, National Taiwan University, 1 Sec 4 Roosevelt Road, Taipei 106, Chinese Taipei

(5) National Veterinary Research and Quarantine Service, 480 Anyang 6- dong Anyang, Gyeonggi-do 430-824, Republic of Korea

## Summary

The threat of climate change and global warming is now recognised worldwide and some alarming manifestations of change have occurred. The Asian continent, because of its size and diversity, may be affected significantly by the consequences of climate change, and its new status as a 'hub' of livestock production gives it an important role in mitigating possible impacts of climate variability on animal health.

Animal health may be affected by climate change in four ways: heat-related diseases and stress, extreme weather events, adaptation of animal production systems to new environments, and emergence or re-emergence of infectious diseases, especially vector-borne diseases critically dependent on environmental and climatic conditions. To face these new menaces, the need for strong and efficient Veterinary Services is irrefutable, combined with good coordination of public health services, as many emerging human diseases are zoonoses. Asian developing countries have acute weaknesses in their Veterinary Services, which jeopardises the global surveillance network essential for early detection of hazards. Indeed, international cooperation within and outside Asia is vital to mitigating the risks of climate change to animal health in Asia.

## Keywords

Animal disease – Animal health – Asia – Climate change – Impact – Surveillance – Vector-borne disease – Veterinary Services.

## Introduction

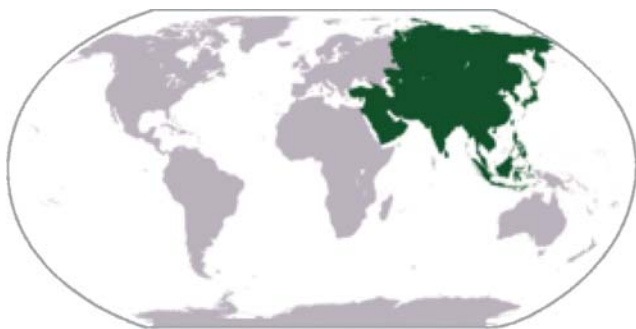
The threat of global warming is real, and already the consequences of climate change phenomena are numerous and alarming (23). Climate change is considered by many to be the most serious long-term threat to agriculture (1). The faster climate change occurs, the greater will be the

risk of damage to the Earth. The extent of such damage may exceed our ability to cope with the consequences (42). Numerous studies and reviews have addressed the effect of climate change on the physical environment and on human health over the past two decades (11). However, consideration of the actual and potential effects of climate change on animal health remains limited, particularly in Asia.

While future changes in climate systems are uncertain, the vast majority of the scientific community agree that these changes are real, and that the potential consequences of such changes would be dire. Over the next century and beyond, the changing climate will result in a broad range of consequences for most regions of the world, including Asia (35, 44, 58). Climate change is a major factor that is likely to affect significantly the future of animal production, health and welfare in the Asian region. Importantly, livestock systems are susceptible to changes in the severity and distribution of livestock diseases and parasites as a potential consequence of global warming (42).

### Asian context

Asia contains some of the greatest cultural, economic and ecological diversity in the world. It is the world's largest and most populous continent, with almost four billion people (over 60% of the world's population) living in the region, and with more than half its population located in coastal zones. Asia covers nearly 9% of the Earth's total surface area, which is nearly 30% of the world's land area (Fig. 1). The region has an estimated collective economic activity of approximately 25% of the global gross domestic product (GDP) (44). A wide range of climates are represented in Asia, ranging from continental, with high seasonal variation, in northern China, to a cool temperate climate in Japan and Korea, subtropical in Chinese Taipei, and hot tropical in Thailand or Vietnam (54, 55), southern India and Indonesia. Asia covers an enormously diverse area (Fig. 1).



**Fig. 1**  
**Land area covered by the Asian continent**

The majority of Asia's population is rural, with agriculture being the main sector of activity in several Asian countries. The combination of the overuse of natural resources, rapid urbanisation, industrialisation, and economic development has led to increased environmental problems, and climate change represents a further stress (24).

Due to existing levels of poverty and population density in the region, even small changes in land area or crop

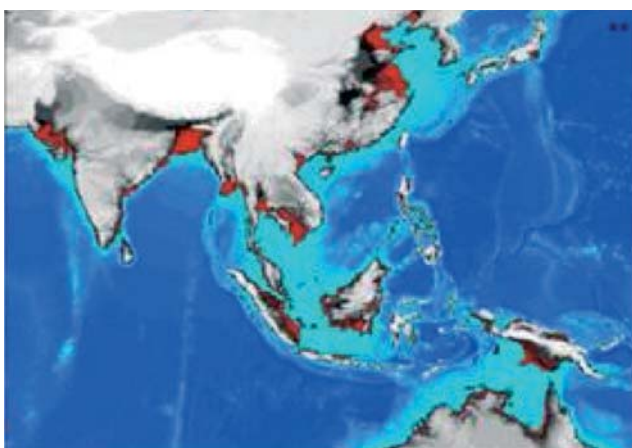
productivity may have serious social consequences (53). It is estimated that 60.9% of the world's malnourished people (529.8 million) live in South and Southeast Asia and China (32). Already, many farmers in Southeast Asia struggle for their daily existence and do not have the resources to adapt to climate change or to relocate. Countries that are characterised by high population density and low rates of economic growth are vulnerable to the consequences of extreme climate events such as cyclones and floods. A change in climate could exacerbate these vulnerabilities (23, 24).

### Climate change and variability

In 2001, research on the impacts of climate change was conducted for the Intergovernmental Panel on Climate Change Working Group on Impacts, Adaptation and Vulnerability (24). A number of risks linked to changes in climate and its variability were identified for Asia. The developing countries of temperate and tropical Asia are already vulnerable to extreme climate events such as droughts and floods. Climate change and its variability could exacerbate this vulnerability. Large deltas and low-lying coastal areas of Asia would be inundated by a rise in sea level (8) (Fig. 2) and increased precipitation intensity (particularly during the summer monsoon); such a change would increase the area prone to flooding throughout these delta and coastal regions. Conversely, climate change could produce drier conditions in arid and semi-arid regions of Asia during the summer, leading to more severe droughts. Availability of fresh water is expected to be highly vulnerable to any climate change, and tropical cyclones or typhoons would not necessarily increase in frequency but would become more intense (8). Warmer and wetter conditions would increase the incidence of heat-related and infectious diseases.

A study by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) on climate change in the Asia/Pacific region (44) indicated that the sea level may rise by 3 cm to 16 cm by the year 2030, and by 7 cm to 50 cm by 2070, in conjunction with regional variability in sea level. A 30 cm to 50 cm rise in sea level would affect over 100,000 km of coastline in Asia. Tens of thousands of square kilometres of land would be lost and tens of millions of individuals would be displaced (Fig. 2).

The global average surface temperature is now about 0.8°C above its level in 1750. It is not known whether this 0.8°C rise above the 1750 level will result in unmanageable consequences, but it is believed that a rise of 2°C to 2.5°C above the 1750 level would culminate in a situation of intolerable impacts on both humans and animals, despite feasible attempts at adaptation to the climate change (45). Recent projections suggest that the average temperature of the Earth's surface could increase by



**Fig. 2**  
**Vulnerability of the Asia/Pacific region to sea-level rise**  
 Land areas in red are below 20 m in elevation, highlighting the most low-lying areas

1.4°C to 5.8°C by 2100. If such a change occurs it would represent the highest ever increase in temperature in one century since recording began (47).

The Scientific Expert Group Report for the United Nations Foundation (45) noted that even the modest changes in the average temperature experienced over the 20th Century have been accompanied by significant increases in the incidence of floods, droughts, heat waves and wildfires. The CSIRO Report on Climate Change in the Asia/Pacific region (44) indicated that an increase in temperature of less than 2°C would lead to a decrease in rice yields in Asia of between 7% and 26%, wheat yields in South Asia would decline by 0.45 tonnes per hectare, and, specifically, rice yields would decrease by 20% to 40% in the Philippines. The report showed that an increase in temperature of 2°C to 4°C would have a significant deleterious impact on the Asia/Pacific region, and tens of thousands of kilometres of coast and between 69% and 91% of the land area in the Mekong Delta would be affected by the rise in sea level, particularly during the flood season.

## Animal production in Asia

In Asia, livestock currently provide the livelihood support for over 35% of the poor (people living on less than US\$ 2 per day). Livestock rearing does not require formal education, large amounts of capital, or land ownership. Consequently, livestock rearing is one of the only economic activities available to poor people in developing countries, including those in Asia (47). Furthermore, there has been an observed shift in the geographical location of livestock production, which will culminate in the emergence of Asia as the world centre for livestock

production. It is estimated that by 2020, 31% to 40% of global milk and meat production will occur in Asia. India is already the largest producer of milk and China is the largest pig producer in the world (21). Both China and India have contributed to what is widely known as the 'Livestock Revolution' (7). There has been a dramatic increase in demand for livestock products in Asia, largely due to the combination of population growth and urbanisation. The growth in poultry meat production between 1989 and 1999 has been remarkable in both East Asia (11.7%) and South Asia (7.2%) (46).

Livestock production is seen as one of the key sectors for poverty alleviation in Asia. Most of the production occurs on smallholder and backyard farms, which provide the farmer with a minimum livelihood but often ensure food security for poor people. In some of the poorest countries in Southeast Asia (Lao People's Democratic Republic [PDR], Cambodia and Myanmar), over 80% of the population are still linked to agriculture. In Lao PDR, 80% of rice culture is still dependent on animal draught power (National Statistic, 2005), and 90% of draught power in Myanmar comes from livestock (statistic from the Livestock Breeding and Veterinary Department, Myanmar). In Viet Nam in 2005, 21% of the GDP was generated by agriculture, and of this almost 30% came from animal production (Department of Animal Health, Ministry of Agriculture statistic).

While livestock production is very important in many developing Asian countries, their access to the global market is often limited by trade barriers. Trade barriers to livestock and their products are mainly due to regulations related to animal health status. However, traditional movements and trade of animals and animal products between neighbouring countries in Asia (e.g. between China and Viet Nam) occur at high volumes and are dependent on the demand and price trends acting at any given time.

In contrast to the dominant smallholder systems of Southeast Asia, some industrialised Asian countries such as Japan and South Korea rely largely on commercial farms with high biosecurity for their livestock production. In such systems, contagious diseases affecting animals are a major risk, given the vulnerability of the system and the potential impact of disease.

## Veterinary Services and the animal health situation in Asia

The size of the Asian continent, as well as the diversity of its populations, landforms, geographical and climatic regions, cultures and husbandry practices, makes it

impossible to describe a single animal health situation for the entire Asian region. Asian countries rely on their Veterinary Services, which are often under the Ministry of Agriculture, to control the main contagious and zoonotic animal diseases. The quality of these Veterinary Services is greatly variable between different countries of the region. They range from very weak with a crucial lack of resources (e.g. Cambodia, Lao PDR and Sri Lanka) to highly efficient (e.g. Japan and the Republic of Korea). The highly pathogenic avian influenza (HPAI) crisis highlighted the need to strengthen national Veterinary Services and emphasised this effort to strengthen Veterinary Services as a 'Global Public Good'. Many countries in Asia have made significant efforts, with the assistance of the international community, to improve their Veterinary Services. Notable progress has been made in a number of countries, including Thailand, Viet Nam and India.

Most of the animal diseases of highest economic or zoonotic importance are present and endemic in mainland Asia. In particular, HPAI, foot and mouth disease (FMD), classical swine fever, haemorrhagic septicaemia, Newcastle disease and rabies are of concern for farmers and for the veterinary and public health services in Asian countries. It is indeed a major challenge for countries free from one or several diseases listed by the World Organisation for Animal Health (OIE) to maintain their status (e.g. Indonesia for FMD and the Philippines for HPAI).

In Asia, high animal densities and urbanisation create a close relationship between humans, domestic animals and wildlife. This has been one of the causes of recent emergence or re-emergence of zoonotic animal diseases including HPAI, severe acute respiratory syndrome (SARS) and Nipah virus (Malaysia).

With respect to animal health, national Veterinary Services are usually responsible for defining policies and regulations, reporting notifiable diseases, developing information systems, and establishing and enforcing quarantine control. This is often done at the local level and authority delegation has progressively been privatised for specific tasks.

According to OIE standards for the quality of Veterinary Services in the *Terrestrial Animal Health Code*, early detection and rapid response capacities are key components in the control of emerging diseases, but these important factors differ enormously from one country to another in Asia. For example, the limited human resources, weak staff education and technical skills, as well as insufficient laboratory diagnostic capability, of the Veterinary Services in some countries have a major impact on the capacity of the country to detect newly introduced animal diseases.

## New threats generated by climate change

It has been suggested that climate change will have a significant effect on livestock and other animals through its impact on diseases (15). Many diseases are transmitted by vectors such as ticks, mosquitoes and flies, the developmental stages of which are often heavily dependent on temperature and humidity. Sheep, goats, cattle and horses are also vulnerable to an extensive range of nematode infections, most of which have developmental stages that are influenced by climatic conditions. Any change in climatic conditions could thus affect such agents, either positively or negatively, and therefore influence livestock health.

Climate change is expected to affect animal health in Asia in a variety of ways, including the occurrence of heat-related diseases, extreme weather events, future changes in animal production systems to minimise climate change and environmental damage, and the emergence or re-emergence of infectious diseases.

### Heat-related diseases

Following the increase in frequency and intensity of heat waves, the risk of death and serious illness is expected to increase and will be exacerbated by increased temperature and humidity (35). For pigs, if the temperature rises by 1°C above their optimal growth temperature, feed intake decreases by 5%, and activity decreases by 7.5%. Pigs subjected to excessively high temperatures are likely to suffer heat stress. Heat stress not only causes suffering, but also reduces productivity and fertility. It can lower the feed intake of lactating sows, thereby reducing their milk production and culminating in adverse effects on their piglets. For example, the summer in Chinese Taipei is hot and long. It is estimated that in each year adult pigs suffer from heat stress for 7 months in the north of the country and 8.5 months in the south.

Heat stress also represents a serious problem in dairy farming in Chinese Taipei. Livestock growth, reproductive ability and temperature are closely related. The thermoneutral zone for dairy cattle is -4°C to +18.5°C. When the ambient temperature increases to 27°C, more heat accumulates than the cow is able to dissipate and heat stress occurs. Under heat stress the oestrous cycle of dairy cows is prolonged, signs of oestrus are weakened, the oestrus period shortened, gestation rate decreased, and fetal death rate increased. Thus heat stress significantly affects reproduction, milk yield and health in dairy cows, with a subsequent loss of economic potential. These effects are demonstrated in Chinese Taipei, where the hot season (between June and September) represents a period of low

productivity for dairy cattle. In a study by the Livestock Research Institute in the Hsing Chu area of northern Chinese Taipei, for 13 years (1974 to 1986) the average conception rate of dairy cattle was 65% in February and only 28% in August (27). With the predicted change in climate, particularly with the rising temperature, the time periods or geographical locations that may induce heat stress in livestock will increase.

### Extreme weather events

The Asian continent has been, and continues to be, affected by extreme weather events. Over the past 100 years a distinct trend of increases in the intensity and frequency of events such as storms, typhoons, droughts, sandstorms and floods has been observed in different areas and seasons in Asia (3). The related changes in rainfall, humidity and the El Niño/Southern Oscillation (ENSO) may alter the quality and availability of some vector breeding sites. For example, an outbreak of bovine ephemeral fever (BEF) was observed after a typhoon episode in August 1996 in Chinese Taipei, and resulted from a proliferation of biting midges (28). Investigation of the impact of typhoon Nari (which occurred on 6 September 2001 in Chinese Taipei) on communicable diseases indicated that the resulting floods actually caused the outbreaks of dengue fever (57). Increased frequency and intensity of extreme weather events brought about by climate change can thus affect animal health through a variety of mechanisms.

### Future changes in animal production systems to minimise climate change and environmental damage

The impact of animal production on the environment and the climate is now recognised. Livestock production systems can be seen as one of the factors contributing to current changes in the environment. Furthermore, it is likely that climate change will have an impact on animal production and, consequently, on animal health. An estimated 35% of global greenhouse gas emissions that are derived from agriculture and land use originate from livestock production (36). Livestock currently use almost one third of the world's entire land surface, mostly as permanent pasture, while one third of the world's arable land provides livestock feed (44).

In order to minimise the effects of livestock production on the environment, changes in production systems are necessary. Such changes may have repercussions on animal health. Policies of intensification of dairy production in India, pig rearing in China and poultry production in Viet Nam will need to adapt to this trend to avoid increases in climate and environmental alterations, which may lead in turn to new animal health challenges.

### Emergence or re-emergence of infectious diseases

A report of the Food and Agriculture Organization of the United Nations (FAO) (12) on the impact of climate change on agriculture in Asia and the Pacific suggested that livestock diseases are strongly influenced by climate change-induced modification of environmental conditions. It noted that, in particular, the transmission of wind-borne diseases such as FMD, and infections transmitted by ticks, flies, mosquitoes, midges and other arthropods, may be of great concern with respect to the changing climate. The migration and spread of birds may change and affect the geographical coverage of diseases such as HPAI and West Nile virus. The transmission cycle of most parasitic infestations is vulnerable to climate change and therefore could become altered. The report concluded that climate change brings disease, and while the pattern of such disease will be difficult to predict, epidemics are a certainty.

## Case studies in three Asian countries

### Important veterinary arthropod-borne viruses in Japan

Various arthropod-borne viruses (arboviruses), such as Akabane, Aino (genus *Orthobunyavirus*, family *Bunyaviridae*), Chuzan, Ibaraki (genus *Orbivirus*, family *Reoviridae*) and BEF (genus *Ephemerovirus*, family *Rhabdoviridae*) viruses have been isolated repeatedly and are recognised as major obstacles to the production of beef and dairy cattle, mainly in the south-western part of Japan (Table I, Fig. 3). Akabane, Aino and Chuzan viruses cause epizootic and/or sporadic outbreaks of abortion, stillbirth, premature birth and congenital abnormalities in cattle (13, 19, 37, 52). It is known that Ibaraki virus causes a disease similar to bluetongue, with fever, anorexia and deglutition disorders (41, 42). Interestingly, numerous abortions and stillbirths were reported among cattle, in addition to the typical clinical signs, in the 1997 epidemic (38, 39). Although bluetongue virus (*Orbivirus*), an OIE listed agent, appears to be prevalent in Japan, almost all the cases in sheep and cattle have been mild or subclinical (14). Bovine ephemeral fever is characterised by the sudden onset of fever, rapid breathing, lameness and reduction of milk production. It seems that recent outbreaks of BEF have been restricted to the southernmost area of Japan and are related to those in Chinese Taipei. Akabane virus (AKAV) is considered to be the most important veterinary arbovirus in Japan because it has caused extensive damage at least five times, and a significant prevalence of the virus was detected almost every year over the four decades from 1959 by virus isolation and serological surveillance. It is

estimated that more than 42,000 abnormal calves were born during the largest outbreak, in 1972 to 1975, in

Japan, associated with economic losses of more than five billion Japanese Yen.

**Table I**  
**Incidents of bovine arboviral diseases in Japan, 1972-2007**

Year	Area *	No. of cases	Clinical signs	Causes
1972-1975	Kyushu, Chugoku, Shikoku, Kinki, Hokuriku, Chubu, Kanto, Tohoku	Approx. 42,000	Abortion, stillbirth, premature birth, AH syndrome	Akabane virus
1976	Okinawa	576	Fever	Bovine ephemeral fever virus
1979-1980	Kanto	Approx. 3,800	Abortion, stillbirth, AH syndrome	Akabane virus
1982	Kyushu	32	Deglutitive disorder	Ibaraki virus
1985-1986	Tohoku	Approx. 7,000	Stillbirth, AH syndrome	Akabane virus
	Okinawa, Kyushu	Approx. 2,400	HCH syndrome	Chuzan virus
1987-1988	Okinawa, Kyushu, Chugoku, Shikoku	270	Deglutitive disorder	Ibaraki virus
1988	Kyushu	372	Fever	Bovine ephemeral fever virus
1989	Okinawa	333	Fever	Bovine ephemeral fever virus
1991	Kyushu, Shikoku	6	Fever	Bovine ephemeral fever virus
1995-1996	Kyushu, Chugoku, Shikoku, Kinki	Over 700	Stillbirth, AHCH syndrome	Aino virus
1997	Kyushu	Approx. 1,000	Abortion, stillbirth, deglutitive disorder	Ibaraki virus
1998-1999	All area	1,085 (confirmed)	Abortion, stillbirth, AH syndrome	Akabane virus
	Kyushu, Chugoku, Shikoku, Kinki	148 (confirmed)	Abortion, stillbirth, AHCH syndrome	Aino virus
2001	Okinawa	1,413	Fever	Bovine ephemeral fever virus
2001-2002	Kyushu	13 (confirmed)	HCH syndrome	D'Aguilar virus**
2002	Kyushu, Chugoku, Shikoku	Approx. 90	Abortion, stillbirth, AHCH syndrome	Aino virus
2004	Okinawa	4	Fever	Bovine ephemeral fever virus
2005-2006	Kyushu, Chugoku, Kinki	17	Abortion, stillbirth, AHCH syndrome	Aino virus
2006	Kyushu	Approx. 250	Encephalomyelitis of calves	Akabane virus
2006-2007	Kyushu	16 (confirmed)	Abortion, stillbirth, AH syndrome	Akabane virus
2007	Okinawa	2	HCH syndrome	Chuzan virus

\* see map in Fig. 3

\*\* D'Aguilar virus belongs to the Palyam serogroup of the genus *Orbivirus*

AH: arthrogryposis and hydranencephaly

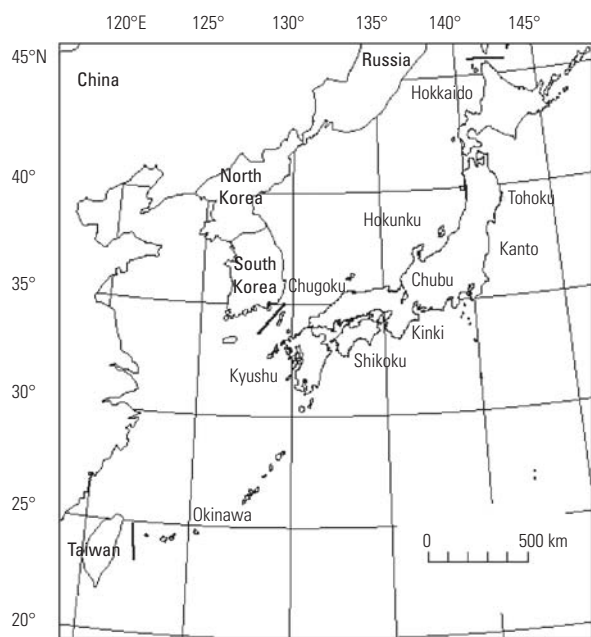
HCH: hydranencephaly-cerebellar hypoplasia

AHCH: arthrogryposis, hydranencephaly and cerebellar hypoplasia

### Epidemiology of bovine arthropod-borne viruses in Japan

Seroconversion of sentinel calves has always been confirmed after the rainy season in Japan (June to July) by nationwide serological surveillance and epidemiological investigation of arboviruses. Entomological investigations in southern Japan over two decades indicate that *Culicoides oxystoma* is the principal vector (Fig. 4) and that bovine arboviruses have been isolated between summer and autumn (August to November) when adult midges are abundant (64). Molecular analyses of the field isolates collected in Japan from 1959 to the present, and phylogenetic comparisons among the isolates derived from various countries in Asia, Oceania and Africa have demonstrated that arboviruses circulating widely in Asia

seem to have evolved in a common gene pool and can clearly be differentiated from strains existing in Oceania and Africa (20, 40, 61, 62). These findings suggest that bovine arboviruses have not become established in Japan and are introduced repeatedly from lower latitude areas (tropical and subtropical zones) in Asia, where the climatic conditions are more suitable, by infected *Culicoides* biting midges carried on the seasonal winds over long distances. Certain viruses that can adapt to the Japanese environment may spread transiently and cause disease between summer and autumn (in the case of congenital abnormalities, between autumn and spring) at intervals of 5 to 15 years. It is unlikely that arboviruses are persistent during the winter season. However, the possibility of viral overwintering in *Culicoides* larvae by vertical transmission should be confirmed by further investigations of



**Fig. 3**  
**Map of Japan**

virus–vector interactions. Retrospective serological analyses and chronological comparisons of viral genes have verified that some of these arboviruses invaded the main island via Okinawa district (Fig. 3), the southernmost islands of Japan. The Okinawa district is probably one of the gateways for virus incursions from overseas (13, 62).

**Characteristics of the recent prevalence of arthropod-borne viruses in Japan**

Patterns of the prevalence of arboviruses in Japan have been changed recently, probably as a result of global warming. Although the number of clinical cases caused by arboviruses has been reduced in the south-western region of Japan, not only by use of attenuated and inactivated vaccines but also because of more frequent exposure to the viruses, the epidemic areas have tended to expand to cover the whole country except the most northerly regions. For example, from 1998 to 1999 Akabane disease spread to Hokkaido (Fig. 3), the northernmost district, in which no outbreaks of arboviral diseases had been observed



**Fig. 4**  
***Culicoides oxystoma* (Diptera: Ceratopogonidae), an important vector in East Asia**

previously. The presence of arboviruses since 1995 has led to the emergence of antigenic and/or pathogenic variants as a result of genetic mutations such as reassortment among field isolates (38, 39, 40). As described above, new clinical signs of abortion and stillbirth associated with a variant of Ibaraki virus were reported in western Japan in 1997 (38, 39). When a large-scale epidemic of encephalomyelitis of calves occurred in southern Japan in 2006, immunohistochemical and virological diagnoses demonstrated that the disease was caused by a variant of AKAV. Congenital malformations associated with this variant were also observed from autumn 2006 through spring 2007. Furthermore, Peaton, Sathuperi, and Shamonda viruses, which belong to the same genus as AKAV and Aino viruses, have been newly detected one after another in Japan (Table II, Fig. 3) (34, 63, 65). These rare arboviruses were initially isolated from cattle, *Culicoides* biting midges and/or mosquitoes from 1957 to 1976 in Asia (India), Africa (Nigeria) and Australia (2, 5, 49). Peaton virus has been recognised as a teratogenic pathogen similar to Akabane and Aino viruses by experimental infection of sheep (43), while the disease potential of the other two orthobunyaviruses in domestic animals remains unknown. Peaton and Sathuperi viruses

**Table II**  
**Bovine arboviruses that have recently emerged in Japan**

Virus	First isolation year (place)	Vector insect	Vertebrate host	Isolation year (place*)
Peaton	1976 (Australia)	<i>Culicoides</i> midges	Cattle, sheep	1999 (Kyushu), 2001 (Okinawa), 2005 (Okinawa), 2006 (Kyushu)
Sathuperi	1957 (India)	<i>Culicoides</i> midges, mosquitoes	Cattle	1999 (Chugoku), 2006 (Okinawa)
Shamonda	1965 (Nigeria)	<i>Culicoides</i> midges	Cattle	2002 (Kyushu)

\* see map in Fig. 3

have invaded repeatedly after 1999 but, fortunately, large-scale outbreaks of disease associated with these viruses have not yet been observed in Japan.

## Case studies in the Republic of Korea

### Seroprevalence of some arthropod-borne diseases in South Korea

In the framework of national surveillance and vaccination programmes for vector-borne diseases affecting livestock, yearly sero-epidemiological surveys of Japanese encephalitis virus (JEV) in pigs (since 2001) and of AKAV, Aino virus (AIV) and Chuzan virus (CHUV) in cattle (since 1993) have been conducted. The results are presented in Figure 5 and show an endemic status for these four diseases in South Korea. For AKAV, AIV and CHUV, the virus circulation seems to fluctuate in a 5-year cyclical periodicity. Among other reasons, this could be due to changes in the biting habits or population of vectors such as *Culicoides* spp., which may be associated with climate change in Korea.

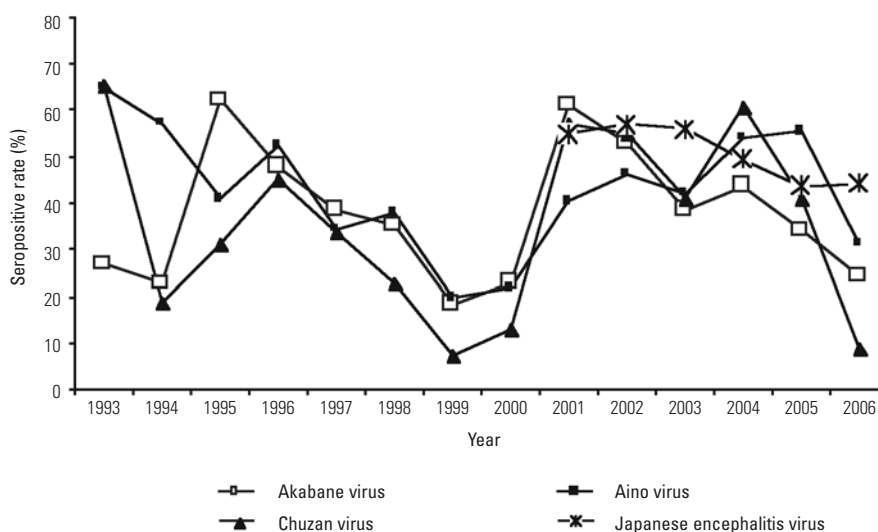
### Detection of vector-borne viruses in Korea

Many cases of Japanese encephalitis (JE, an OIE-listed disease with serious zoonotic impact) with clinical signs of stillbirth and abortion were reported in pigs during the 1950s. In 1980, an attenuated JE vaccine was developed and a massive vaccination programme targeting pigs was undertaken; JE outbreaks in Korea decreased sharply as a result of the vaccination campaign. However, Japanese encephalitis virus (JEV) infection in pigs has continued to be reported, with several cases still occurring every year. Moreover, a phylogenetic analysis to elucidate the genetic

relationships of JEV isolates revealed that Korean JEV isolates have changed from genotype III to genotype I since 1991 (66, 67). The reasons for this genotypic change in JEV may include alterations in agricultural practices, such as the advent of large-scale intensive farms, or an influx of new migratory bird species.

Following the first detection of AKAV infection in cattle in 1980 and its isolation from aborted bovine fetuses in 1993 (4, 31), an attenuated vaccine against AKAV was introduced in the 1990s to help prevent reproductive disorders in cattle. However, the disease continues to be detected in ruminants, including goats. An AIV designated as strain KSA9910 was isolated from the blood of a healthy cow in 1999. Few AIV infections have been detected recently. Infection with CHUV, which is associated mainly with the birth of weak calves, was first detected on Jeju Island in the southern part of the Korean peninsula. Subsequently, CHUV spread throughout much of Korea in 1993. However, only a few sporadic CHUV infections have been detected in recent years. An inactive multivalent vaccine against AKAV, AIV and CHUV was developed for prevention of reproductive failure in cattle in 2005. Since the single epidemic of Ibaraki virus (IBAV) infection in cattle, which was reported in 1991, there has been no further report of IBAV infection in the Republic of Korea (Table III). A study to determine the species of mosquito associated with arboviral transmission in Korean ruminants began in 2007 and is in progress.

Arthropod-borne viral agents such as JEV, AKAV, AIV and CHUV are mainly transmitted by vectors such as *Culex* spp. and *Culicoides* spp. in the field. The rise of temperatures in Korea may favour the development cycle of the vectors and facilitate disease transmission to



**Fig. 5**  
Yearly seropositive rates for Japanese encephalitis virus in pigs, and Akabane virus, Aino virus and Chuzan virus in cattle in the Republic of Korea



**Table III**  
**Annual incidence of vector-borne diseases in Korea, 2002-2006**

Year	Vector-borne viruses: outbreaks (number of cases)					
	JEV	AKAV	AIV	CHUV	IBAV	BEFV
2002	1 (4)	8 (25)	*	–	–	0
2003	1 (10)	2 (2)	2 (4)	13 (47)	0	1 (1)
2004	1 (1)	0	2 (4)	0	0	0
2005	4 (27)	2 (7)	3 (7)	1 (1)	0	0
2006	1 (7)	2 (2)	6 (6)	1 (1)	0	0
Total	8 (49)	14 (36)	13 (21)	15 (49)	0	1 (1)

\* data unavailable

JEV: Japanese encephalitis virus

AKAV: Akabane virus

AIV: Aino virus

CHUV: Chuzan virus

IBAV: Ibaraki virus

BEFV: bovine ephemeral fever virus

Source: Disease statistics from National Veterinary Research and Quarantine Service (NVRQS)

JEV, AKAV, BEFV: <http://aims.nvrqs.go.kr>

CHUV, AIV, IBAV: results from diagnostic services of NVRQS during 2003 to 2006

domestic animals. First, because several JEV genotypes have been reported in Southeast Asia and China, the different genotypes spreading across Asia may be found in the future in the Korean Peninsula as a result of ecological changes. Second, the 5-year cycle of recurrence of described vector-borne viruses in cattle might be shortened. Another possibility is that climate change may increase the occurrence of JEV, AKAV, AIV or CHUV infection, and IBAV and BEFV infections, which have not occurred recently in Korea.

### Case studies in Chinese Taipei

Global warming is likely to reshape the ecology of many arthropod vectors of medical importance. Warmer temperatures have been shown to directly increase mosquito and tick vector reproduction, biting, and pathogen transmission despite reduced mean daily survivorship (68). Chinese Taipei, which is in the subtropical and tropical zone with high temperature and humidity, provides an appropriate environment for reproduction and growth of organisms, including hazardous insects such as mosquitoes, biting midges, fleas and flies. Effects of climate change on animal diseases, especially vector-borne diseases, are expected to occur in this territory. A recurring difficulty in identifying such impact is that the causation of most infectious diseases is multifactorial, and the 'background' husbandry system, vaccination programme, and environmental context change significantly over time. Three endemic vector-borne animal diseases are discussed below.

#### Canine heartworm disease

Heartworm disease (or dirofilariasis) in dogs is caused by a filarial nematode, *Dirofilaria immitis*, a parasite that in rare instances affects humans. The mosquito is the only natural agent of transmission for canine heartworm, which is why

heartworm disease occurs worldwide in tropical, subtropical, and some temperate regions.

Two studies, one conducted in northern Chinese Taipei and the other in the centre, demonstrated natural infection with *D. immitis* in two species of mosquitoes, *Aedes albopictus* and *Culex quinquefasciatus* (22, 59). A survey performed in 2002 in the Zhu-Nan area of northern Chinese Taipei showed that the density grade of *Aedes* spp. mosquito larvae reached peaks in July to September (density grades 2 to 5, Breteau Index 8 to 46) and contributed 80% of the total *Aedes* spp. mosquito larvae positive container count in the whole year. In another study, the *D. immitis* infection rate in mosquitoes was highest in June (11%) and lowest in January (0.9%) in northern Chinese Taipei (59).

In Chinese Taipei, where mosquitoes are present year round, the threat of heartworm disease is constant. Canine heartworm infection is widely distributed on the island. The results of many studies have indicated that canine dirofilariasis among stray or domestic dogs in the northern, central and southern parts of the island has increased rapidly over the past ten years (9, 10, 26, 51, 56, 60). The prevalence has been shown to be related to wind speed, temperature, relative humidity and altitude in the different areas surveyed (60). It is expected that warmer temperatures will result in an earlier and higher infection rate, especially in the northern part of the territory.

#### Bovine ephemeral fever

Bovine ephemeral fever is caused by a virus and the disease is widespread in Chinese Taipei. It is generally believed that the virus that causes ephemeral fever is transmitted between cattle by flying insects. Spread of BEF depends on the season and weather conditions; rain and prevailing easterly and southerly winds are necessary for the survival and dispersal of vectors. The BEF virus has been isolated

from *Culicoides* spp., *Anopheles* spp., *Culex* spp., *Aedes* spp. and *Uranotaenia* spp. (6, 48, 50). Results of a survey carried out from 1991 to 1996 in southern Chinese Taipei indicated that *Culicoides oxystoma* (Fig. 4) and *C. nipponensis* are the prevalent species affecting cattle herds. The results also showed a higher density of *Culicoides* spp. from May to October, when the temperature is above 25°C with high precipitation (18). In another survey conducted in southern Chinese Taipei in 2006, six species of *Culicoides* (including *C. oxystoma* and *C. nipponensis*) were found around cattle farms, with a similar pattern of seasonal fluctuation. The midges begin to increase in number from February/March to June/July, when the maximum prevalence is observed. The highest density was found in August and was maintained until October (W.C. Tu, Department of Entomology, National Chung Hsing University, personal communication).

Bovine ephemeral fever is a common disease in summer and early autumn, because of the heavy rainfall in these seasons. In the past 40 years, Chinese Taipei has suffered seven BEF epizootics (1967, 1983 to 1984, 1989 to 1990, 1996, 1999, 2001, and 2004), despite the use of annual single-dose vaccination with inactivated virus since 1984 (17). The epizootics of BEF often started in the Chiayi and Kaoshung area (Southern Territory) and spread to other parts of the island. It is concluded that the warm temperature and the large area of swamps, in addition to the high humidity during the rainy season in April/May, facilitated the multiplication of the vector (33). With the trend for increased rainfall in the north and decreased rainfall in the south, it is expected that the epidemic centre of BEF may gradually move northwards.

### Leucocytozoonosis

Leucocytozoonosis, caused by *Leucocytozoon caulleryi*, is a significant disease that is prevalent in open chicken houses in Chinese Taipei. *Leucocytozoon caulleryi* is transmitted by *Culicoides arakawae*. In central and southern Chinese Taipei, *C. arakawae* can be found year round, and the density of *C. arakawae* begins to increase in February, reaches a peak in March, and remains high until October (29, 30). In the northern island, the density of *C. arakawae* peaks in May to September and it can be found year round with the exception of January (25).

The prevalence of leucocytozoonosis is influenced by vector population succession. It has been reported that chicken leucocytozoonosis begins at the end of April, and the mortality and morbidity are highest from the end of April to the middle of June in the northern island (25). It has also been shown that the density of *C. arakawae* is positively related to outbreaks of leucocytozoonosis in open chicken houses in the south (69). In southern Chinese Taipei, leucocytozoonosis incidents begin in early April (69), earlier than in the northern region, where they begin at the end of April (25). Constant high humidity is

important for the development and fecundity of *C. arakawae* (70). Thus, the fact that *C. arakawae* is more active and productive in spring than in autumn in Chinese Taipei is probably due to humidity more than temperature. Changes in the distribution and abundance of insects are likely to be among the most important and immediate effects of climate change. It is expected that warmer temperatures will eventually result in year-round *L. caulleryi* infection in northern Chinese Taipei.

## Foreseeing and detecting emerging animal health events due to climate change in Asia: policy and strategy

The Asian region is characterised by a large and growing human population, urbanisation, high and increasing animal density, a close human–animal interface, and diverse climates and environments. Such factors suggest a vulnerability of this region to future threats to animal health caused by climatic and environmental changes. Some Asian countries are better prepared for climate change ‘events’, but most countries in Asia need to put more emphasis on climate change and combine this with improvements in the preparedness of their National Animal Health Services, to be able to react promptly.

Since the avian influenza crisis, which started in 2003, good quality national Veterinary Services have been recognised to be a crucial factor in early detection and avoidance of the spread of any emerging diseases. Events that could occur due to climate changes in the future are no exception and will not be controlled without strong Veterinary Services.

Some evaluations of Veterinary Services have been conducted in developing and in-transition Asian countries since 2004, using the new tool adopted by the OIE, the Performance of Veterinary Services (PVS) Tool. These evaluations generally highlight issues such as lack of resources (human, financial and material) and lack of technical expertise in key domains required to tackle climate change and related animal health problems. The knowledge fields outlined are mainly policies and regulations, surveillance and diagnosis, risk analysis, research and innovation, and addressing the human–animal interface.

### Policies and regulations

To enable animal health and partner services of a given country to detect and manage any new events related to

climate change, the concept of emerging threats must be integrated into National Animal Health regulations and should be included in the remit of the Veterinary Services. The World Animal Health Information System (WAHIS) of the OIE recently modified its policy in order to allow countries to immediately notify 'a sudden and unexpected increase in the distribution, incidence, morbidity or mortality of a listed disease prevalent within a country, a zone or a compartment; **or** an emerging disease with significant morbidity or mortality, or zoonotic potential; **or** evidence of change in the epidemiology of a listed disease (including host range, pathogenicity, strain) in particular if there is a zoonotic impact'. These different cases for immediate reporting cover any unexpected events that could occur due to climate or environmental changes. However, although some countries may include such notifications in their national regulations and strategies, many Asian developing countries do not have the capacity to do so, which leaves a worrying gap in this domain. For instance, the Animal Health Law in Cambodia is rather weak and does not give the means or power to the Veterinary Authorities to survey and manage such risks. There is a critical need for governments of the poorest Asian countries to build a structure of law and regulations in order to be able rapidly to deal with such hazards. This will require technical support from the international community.

## Surveillance and diagnosis

The need to strengthen surveillance and diagnostic capacities of Asian developing and in-transition countries has been highlighted over the past few years. This concerns both endemic diseases (especially those that are arthropod-borne) for which the pattern may become modified by climate change and exotic or emerging diseases that may appear in such a favourable environment as Asia. Appropriate technical skills (epidemiological and laboratory techniques), as well as human and financial resources, are often lacking in the poorest Asian countries. Potential impacts of climate change on animal diseases need to be monitored attentively, by both passive and active surveillance programmes. Developed or in-transition neighbouring countries with such capabilities should take an interest in assisting the poorest countries to develop and implement surveillance programmes for emerging threats. A 'South-South' cooperation is strongly encouraged, as some countries such as China, India and Thailand now have the technical and financial means to support neighbouring countries in a win-win process.

Moreover, the ongoing cooperation of international organisations such as the OIE and FAO is crucial to enhance the surveillance and diagnostic capabilities of Asian developing countries. It is important to note that even the most developed Asian countries have been led to

adapt their national animal health surveillance systems to the new threats occurring due to climate change.

## Case study in the Republic of Korea

It has been observed that the temperature of the Korean Peninsula has increased by approximately 1.5°C over the last century, and that the climate is evolving to become similar to that in subtropical regions. Therefore, control policies and research into animal diseases are increasingly concerned with exotic vector-borne diseases for which the distribution is closely related to climate change. There are several important arthropod-borne diseases, such as bluetongue, African horse sickness, vesicular stomatitis and Rift Valley fever, that are among the exotic notifiable animal diseases in the Republic of Korea. Additionally, it is viewed with apprehension that West Nile fever (a recent emerging disease that has caused significant human mortality in North America) has a high outbreak potential in Korea because of the early and high distribution of its mosquito vectors (e.g. *Culex tritaeniorhynchus*) during the summer season. In order to be prepared for such threats and the risk of occurrence of these diseases in historically free countries such as Korea, the National Veterinary Research and Quarantine Service (NVRQS) has been implementing surveillance programmes to detect suspicious cases and is attempting to establish or improve its diagnostic capabilities for exotic diseases.

## Risk analysis, research and innovation

In the context of new and unknown threats, the importance of risk analysis and research is growing significantly. Due to its characteristics, Asia is recognised as a risk area for emerging animal diseases, and past incidents of HPAI, SARS and Nipah virus confirm this hypothesis. However, risk analysis and development of innovative tools are very complicated processes requiring considerable resources (human, material and financial) that some of the poorest Asian countries cannot afford. The need for multidisciplinary teams with precise technical skills often makes these tasks unattainable for developing countries of the region. Therefore, international cooperation and local support, as well as sharing of the findings of studies undertaken abroad, will be a key component to ensure that any hazards are recognised.

## Case study in Thailand

The work undertaken by the Center for Vectors and Vector-borne Diseases of the Mahidol University in Thailand, in collaboration with the Institute for Research and Development, France, is a good example of international cooperation. This collaboration has introduced innovative techniques that have increased capacity to detect new hazards by foreseeing changes in the environment, ecological niches and behaviours of vectors such as

rodents. The use of Geographical Information Systems to delineate possible habitats and increase understanding of animals and associated pathogenic agents in their environment (land and water use, human settlement, etc.) is a powerful tool for predicting new health threats to animals or humans (such as hantaviruses), that could be generated by climate variability (16).

### Human–animal interface

The lack of coordination between environmental, animal health and public health services has been shown to be one of the major constraints on efficiency and effectiveness in early detection and control of emerging diseases. It has been demonstrated that 75% of the new diseases affecting humans come from animals. Indeed the concept of ‘One Health’ is now strongly promoted by international organisations such as the OIE, FAO, World Health Organization (WHO) and World Bank. Asian countries, like the rest of the world, should be actively encouraged to integrate this approach into their own National Strategies.

## Conclusion

The authors of this paper have attempted to demonstrate how complicated it is to evaluate and foresee what will be the impacts of climate and environmental changes on animal health in such an enormous continent as Asia, which is characterised by large and growing populations, high animal densities and very diverse climate zones, landforms, cultures and practices. The predicted changes of a rise in sea-level – resulting in a huge loss of land – combined with changes of temperature and humidity, and more frequent extreme weather events, will significantly affect agricultural systems and water availability in Asia, as well as animal diseases. The already changing pattern of some animal and human diseases (particularly arthropod-borne diseases) highlights the urgent need to undertake action in response to a series of events that may be

attributed, among other factors, to climate variability. These include:

- expansion of epidemic areas to the northern part of Asia
- increase of the incidence of some agents, especially vector-borne pathogens
- changes in the clinical signs caused by variant viruses
- incursions of unexpected agents into historically free areas of Asia.

Moreover, it has been outlined that some developing countries in Asia are not yet ready to face such a threat and need to be part of a ‘win-win’ process with the support of international organisations such as the OIE, FAO, WHO and World Bank. Developed countries in Asia and other continents need to support them with technical assistance and financial and material support. A ‘South-South’ cooperation is strongly encouraged as emerging countries such as China, India and Thailand are now capable of offering these services to neighbouring countries. Asian industrialised countries need to consolidate their animal and public health systems and maintain a strong surveillance network incorporating innovative risk analysis tools.

Finally the vision of Veterinary Services as a ‘Global Public Good’ has never been more accurate than it is today, and Asian Governments, like others, must put more focus and resources into strengthening these services in order to be able to respond to the new challenges that climate change imposes on animal and public health.

## Acknowledgements

The authors wish to thank Polly Cocks from Murdoch University, Australia, for having reviewed and commented on this paper.



## Le changement climatique : impacts et risques pour la santé animale en Asie

S. Forman, N. Hungerford, M. Yamakawa, T. Yanase, H.-J. Tsai, Y.-S. Joo, D.-K. Yang & J.-J. Nha

### Résumé

La menace que le changement climatique et le réchauffement planétaire font peser sur le monde est désormais reconnue et confirmée par des phénomènes alarmants déjà perceptibles. Du fait de ses dimensions et de sa diversité, le continent asiatique risque d'être considérablement affecté par les conséquences du changement climatique ; l'Asie est devenue un grand centre mondial de production d'animaux d'élevage et devrait donc jouer un rôle important dans les efforts pour atténuer les effets potentiels des variations climatiques sur la santé animale.

Les conséquences du changement climatique sur la santé animale sont de quatre ordres : les maladies et le stress liés à la chaleur ; les événements climatiques extrêmes ; l'adaptation des systèmes de production animale aux nouveaux environnements ; et l'émergence ou la réémergence de maladies infectieuses, en particulier celles à transmission vectorielle, qui sont extrêmement sensibles aux conditions environnementales et climatiques. Pour faire face à ces nouvelles menaces, il est impératif que les pays se dotent de Services vétérinaires puissants et efficaces travaillant en collaboration avec les services de santé publique, dans la mesure où un grand nombre de maladies humaines sont des zoonoses. Or, en Asie, les Services vétérinaires des pays en développement présentent de graves déficiences qui compromettent l'efficacité globale du réseau de surveillance requis pour détecter rapidement les nouveaux dangers. De fait, la coopération internationale, aussi bien en Asie même qu'avec les autres régions du monde est une condition essentielle pour atténuer les risques que le changement climatique représente pour la santé animale en Asie.

### Mots-clés

Asie – Changement climatique – Impact – Maladie à transmission vectorielle – Maladie animale – Santé animale – Services vétérinaires – Surveillance.



## Efectos del cambio climático y riesgos zoonosarios en Asia

S. Forman, N. Hungerford, M. Yamakawa, T. Yanase, H.-J. Tsai, Y.-S. Joo, D.-K. Yang & J.-J. Nha

### Resumen

En todo el mundo se reconoce ya que el cambio climático y el calentamiento planetario traen consigo una amenaza real, una transformación de la que ya se han producido algunas manifestaciones alarmantes. Por su tamaño y diversidad, el continente asiático puede verse sensiblemente afectado por las consecuencias del cambio climático, y su nueva condición de "centro neurálgico" de la producción ganadera le otorga un papel importante a la hora de atenuar los posibles efectos de la variabilidad del clima en la sanidad animal. El cambio climático puede incidir en la salud de los animales de cuatro formas:

enfermedades y estrés relacionados con las altas temperaturas; fenómenos meteorológicos extremos; adaptación a un medio nuevo de los sistemas de producción animal; y aparición o reaparición de enfermedades infecciosas, en especial afecciones transmitidas por vectores que dependen sobremanera de las condiciones ambientales y climáticas. Es innegable que para hacer frente a estas nuevas amenazas se requieren Servicios Veterinarios sólidos y eficaces, así como una buena coordinación de los Servicios de salud pública, toda vez que muchas enfermedades humanas emergentes son en realidad zoonosis. Los Servicios Veterinarios de los países asiáticos en desarrollo presentan agudas carencias, que ponen en peligro el funcionamiento de la red mundial de vigilancia, indispensable para detectar rápidamente las amenazas. Para atenuar los riesgos que el cambio climático entraña para la sanidad animal en Asia es en efecto vital la cooperación internacional dentro y fuera del continente asiático.

#### Palabras clave

Asia – Cambio climático – Efecto – Enfermedad animal – Enfermedad transmitida por vectores – Sanidad animal – Servicios Veterinarios – Vigilancia.



## References

1. Australian Centre for International Agricultural Research (ACIAR) (2007). – Climate change and agriculture. Australian Government. Available at: <http://www.aciar.gov.au/node/2391> (accessed on 18 September 2007).
2. Causey O.R., Kemp G.E., Causey C.E. & Lee V.H. (1972). – Isolations of Simbu-group viruses in Ibadan, Nigeria 1964-1969, including the new types Sango, Shamonda, Sabo and Shuni. *Ann. trop. Med. Parasitol.*, **66**, 357-362.
3. Chen P.S. & Li C.S. (2005). – The impact of climate change on public health. In *Global change and sustainable development* [in Chinese], 46, 21-24.
4. Cho J.J., Lee C.G., Park B.K., Chang C.H., Chung C.W., Cho I.S. & An S.H. (2000). – Isolation of Akabane virus and its molecular diagnosis by reverse transcription polymerase chain reaction. *Korean J. vet. Res.*, **40**, 42-48.
5. Dandawate C.N., Pajagopalan P.K., Pavri K.M. & Work T.H. (1969). – Virus isolations from mosquitoes collected in North Arcot district, Madras state, and Chittoor district, Andhra Pradesh between November 1955 and October 1957. *Indian J. med. Res.*, **57**, 1420-1426.
6. Davis F.G., Walker A.R., Ochieng P. & Shaw T. (1979). – Arboviruses isolated from *Culicoides* midges in Kenya. *J. comp. Pathol.*, **89**, 587-595.
7. Delgado C., Rosengrant M., Steinfeld H., Ehui S. & Courbois C. (1999). – Livestock to 2020: The next food revolution. Food, Agriculture and the Environment, Discussion Paper 28. Food and Agriculture Organization (FAO), Rome.
8. Department for International Development (DFID) (2004). – Climate change in Asia. Key sheet. DFID, United Kingdom. Available at: <http://www.dfid.gov.uk/pubs/files/climatechange/11asia.pdf> (accessed on 18 September 2007).
9. Fan C.K., Su K.E., Chung W.C., Tsai Y.J., Chang M.H., Lu J.L. & Chao P.H. (1998). – A parasitological survey among stray dogs in Taipei City with haematological findings [in Chinese with English abstract]. *J. Chin. Soc. vet. Sci.*, **24** (4), 288-294.
10. Fan C.K., Su K.E., Lin Y.H., Liao C.W., Du W.Y. & Chiou H.Y. (2001). – Seroepidemiologic survey of *Dirofilaria immitis* infection among domestic dogs in Taipei City and mountain aboriginal districts in Taiwan (1998-1999). *Vet. Parasitol.*, **102**, 113-120.
11. Food and Agriculture Organization (FAO) (2007). – Adaptation to climate change in agriculture, forestry and fisheries: perspective, framework and priorities. Departmental Working Group on Climate Change. FAO, Rome.

12. Food and Agriculture Organization (FAO) (2004). – Impact of climate change on agriculture in Asia and the Pacific. In 27th Food and Agriculture Organization of the United Nations Regional Conference for Asia and the Pacific, Beijing, China, 17-21 May 2004.
13. Goto Y., Miura Y. & Kono Y. (1988). – Epidemiological survey of an epizootic of congenital abnormalities with hydranencephaly-cerebellar hypoplasia syndrome of calves occurring in 1985/1986 and seroepidemiological investigations on Chuzan virus, a putative causal agent of the disease, in Japan. *Jpn. J. vet. Sci.*, **50**, 405-413.
14. Goto Y., Yamaguchi O. & Kubo M. (2004). – Epidemiological observations on bluetongue in sheep and cattle in Japan. *Vet. ital.*, **40**, 78-82.
15. Grasty S. (1999). – Agriculture and climate change. *TDRJ quart. Rev.*, **14** (2), 12-16.
16. Herbreteau V., Demoraes F., Hugot J.P., Kittayapong P., Salem G., Souris M. & Gonzalez J.P. (2006). – Perspectives on applied spatial analysis to animal health: a case of rodents in Thailand. *Ann. N.Y. Acad. Sci.*, **1080**, 17-29.
17. Hsieh Y.C., Chen S.H., Chung W.C., Lee Y.F., Tsai K.Y. & Tsai S.S. (2005). – Case report: bovine ephemeral fever [in Chinese with English abstract]. *Taiwan vet. J.*, **31** (3), 185-194.
18. Hsu H.S., Liao Y.K. & Hung H.H. (1997). – The seasonal successional investigation of *Culicoides* spp. in cattle farms of Pintung district, Taiwan. *J. Chin. Soc. vet. Sci.*, **23**, 303-310.
19. Inaba Y., Kurogi H. & Omori T. (1975). – Akabane disease: epizootic abortion, premature birth, stillbirth and congenital arthroglyposis-hydranencephaly in cattle, sheep and goats caused by Akabane virus. *Aust. vet. J.*, **51**, 584-585.
20. Kobayashi T., Yanase T., Yamakawa M., Kato T., Yoshida K. & Tsuda T. (2007). – Genetic diversity and reassortments among Akabane virus field isolates. *Virus Res.*, **130**, 162-171.
21. Kurup M.P.G. (2004). – Production structure and cost competitiveness of livestock production in Asia. In *Livestock and livelihoods: challenges and opportunities for Asia in the emerging market environment* (V. Ahuja, ed.), 10-12 November 2003, Anand, India, 132-152.
22. Lai C.H., Tung K.C., Ooi H.K. & Wang J.S. (2001). – Susceptibility of mosquitoes in central Taiwan to natural infections of *Dirofilaria immitis*. *Med. vet. Entomol.*, **15** (1), 64-67.
23. Lal M. (2002). – Regional climate scenarios – Future changes in variability and mean including extreme weather events: issues related to agriculture policy in South Asia. In *South Asia Workshop on 'Adaptation to Climate Change for Agriculture Productivity'*, May 2002, New Delhi.
24. Lal M., Harasawa H. & Murdiy Arso D. (2001). – Asia in climate change: impacts, adaptation and vulnerability. Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, chap. 11.
25. Lee Y.C., Chang C.H. & Fuh T.H. (1969). – Studies on leucocytozoonosis of chickens. V. Symptoms and damages caused by the infection of *Leucocytozoon* spp. *Mem. Coll. Agric. natl Taiwan Univ.*, **10**, 16-23.
26. Lee Y.M., Fan B.H., Chen B.C., Yang Y.J. & Shin J.W. (1995). – Epidemiological survey of intestinal and blood helminths of stray dogs in Tainan area [abstract in Chinese]. *Chin. J. Parasitol.*, **8**, 70.
27. Li G.F., Wen S.H. & Lee P.S. (1994). – Seasonal variations in plasma progesterone concentrations in cyclic Taiwan yellow cattle (*Bos indicus*). *Chin. J. Physiol.*, **37** (1), 15-19.
28. Liao Y.K., Inaba Y., Li N.J., Chain C.Y., Lee S.L. & Liou P.P. (1998). – Epidemiology of bovine ephemeral fever virus infection in Taiwan. *Microbiol. Res.*, **153** (3), 289-295.
29. Lien J.C. & Chen C.S. (1981). – Seasonal succession of some common species of the genus *Culicoides latreille* 1809 (Diptera: Ceratopogonidae) in central Taiwan. *J. Formosan med. Assoc.*, **80**, 673-682.
30. Lien J.C. & Chen C.S. (1981). – Seasonal succession of some common species of the genus *Culicoides latreille* 1809 (Diptera: Ceratopogonidae) in southern Taiwan. *J. Formosan med. Assoc.*, **81**, 514-523.
31. Lim S.I., Kweon C.H., Tark D.S., Kim S.H. & Yang D.K. (2007). – Sero-survey on Aino, Akabane, Chuzan, bovine ephemeral fever and Japanese encephalitis virus of cattle and swine in Korea. *J. Vet. Sci.*, **8** (1), 45-49.
32. Lobell D.B., Burk M.B., Tebaldi C., Mastrandrea M.D., Falcon W.P. & Naylor R. (2008). – Prioritizing climate change adaptation needs for food security in 2030. *Science*, **319**, 607-610.
33. Lu Y.S., Lee Y.L., Huang S.T., Tsai H.J., Liao Y.K. & Lin D.F. (1992). – The epizootiology of the bovine ephemeral fever in Taiwan 1989. *J. Chin. Soc. vet. Sci.*, **13**, 189-195.
34. Matsumori Y., Inai K., Yanase T., Ohashi S., Kato T., Yoshida K. & Tsuda T. (2002). – Serological and genetic characterization of newly isolated Peaton virus in Japan. *Arch. Virol.*, **147**, 401-410.
35. McCarthy J.J., Canziani O.F., Leary N.A., Dokken D.J. & White K.S. (2001). – Climate change: impacts, adaptation and vulnerability. Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press.
36. McMichael A.J., Powles J.W., Butler C.D. & Uauy R. (2007). – Food, livestock production, energy, climate change and health. *Lancet*, **370**, 1253-1263.

37. Miura Y., Goto Y., Kubo M. & Kono Y. (1990). – Hydranencephaly-cerebellar hypoplasia in a newborn calf after infection of its dam with Chuzan virus. *Jpn. J. vet. Sci.*, **52**, 689-694.
38. Ohashi S., Yoshida K., Watanabe Y. & Tsuda T. (1999). – Identification and PCR-restriction fragment length polymorphism analysis of a variant of the Ibaraki virus from naturally infected cattle and aborted fetuses in Japan. *J. clin. Microbiol.*, **37**, 3800-3803.
39. Ohashi S., Yoshida K., Yanase T. & Tsuda T. (2002). – Analysis of intratypic variation evident in an Ibaraki virus strain and its epizootic hemorrhagic disease virus serogroup. *J. clin. Microbiol.*, **40**, 3684-3688.
40. Ohashi S., Matsumori Y., Yanase T., Yamakawa M., Kato T. & Tsuda T. (2004). – Evidence of an antigenic shift among Palyam serogroup orbiviruses. *J. clin. Microbiol.*, **42**, 4610-4614.
41. Omori T., Inaba Y., Morimoto T., Tanaka Y., Ishitani R., Kurogi H., Munakata K. & Matsumoto M. (1969). – Ibaraki virus, an agent of epizootic disease of cattle resembling bluetongue I. *Jpn. J. Microbiol.*, **13** (2), 139-157.
42. Omori T., Inaba Y., Morimoto T., Tanaka Y., Kono M., Kurogi H. & Matsumoto M. (1969). – Ibaraki virus, an agent of epizootic disease of cattle resembling bluetongue II. *Jpn. J. Microbiol.*, **13** (2), 159-168.
43. Parsonson I.M. & McPhee D.A. (1985). – Bunyavirus pathogenesis. *Adv. Virus Res.*, **30**, 279-316.
44. Preston B.L., Suppiah R., Macadam I. & Bathols J. (2006). – Climate change in the Asia/Pacific region – A consultancy report prepared for the Climate Change and Development Round Table. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.
45. SIGMA XI, The Scientific Research Society (2007). – Confronting climate change: avoiding the unmanageable and managing the unavoidable. In Scientific Expert Group report on climate change and sustainable development. Prepared for the 15th Session of the Commission on Sustainable Development – United Nations Foundation.
46. Steinfeld H. & Gao Q. (2004). – The competitiveness of Asian livestock sectors. In *Livestock and livelihoods: challenges and opportunities for Asia in the emerging market environment* (V. Ahuja, ed.), 10-12 November 2003, Anand, India, 59-94.
47. Steinfeld H., Gerber P., Wassenaar T., Castel V., Rosales M. & de Haan C. (2006). – Livestock's long shadow: environmental issues and options. Food and Agriculture Organization (FAO), Livestock, Environment and Development Initiative (LEAD), Rome.
48. St George T.D., Standfast H.A., Christie D.G., Knott S.G. & Morgen I.R. (1977). – The epizootiology of bovine ephemeral fever in Australia and Papua-New Guinea. *Aust. vet. J.*, **53**, 17-28.
49. St George T.D., Standfast H.A., Cybinski D.H., Filippich C. & Carley J.G. (1980). – Peaton virus: a new Simbu group arbovirus isolated from cattle and *Culicoides brevitarsis* in Australia. *Aust. J. biol. Sci.*, **33** (2), 235-243.
50. St George T.D., Standfast H.A. & Dyce A.L. (1976). – Letter: the isolation of ephemeral fever virus from mosquitoes in Australia. *Aust. vet. J.*, **52** (5), 242.
51. Tsai I.D., Tung K.C., Lai C.H., Wu J.T., Wang J.S. & Cheng F.P. (2003). – Epidemiological survey of dirofilariasis of stray dogs in Taichung area [in Chinese, with English abstract]. *Taiwan vet J.*, **29** (1), 71-75.
52. Tsuda T., Yoshida K., Ohashi S., Yanase T., Sueyoshi M., Kamimura S., Misumi K., Hamana K., Sakamoto H. & Yamakawa M. (2004). – Arthrogryposis, hydranencephaly and cerebellar hypoplasia syndrome in neonatal calves resulting from intrauterine infection with Aino virus. *Vet. Res.*, **35**, 531-538.
53. United Nations Environment Programme (UNEP) (1993). – How climate change could impact Southeast Asia. Information Unit on Climate Change (IUCC). Available at: <http://www.cs.ntu.edu.au/homepages/jmitroy/sid101/uncc/fs121.htm> (accessed on 18 September 2007).
54. United Nations Environment Programme (UNEP) (1993). – What can Thailand do about climate change. Information Unit on Climate Change (IUCC). Available at: <http://www.cs.ntu.edu.au/homepages/jmitroy/sid101/uncc/fs272.htm> (accessed on 18 September 2007).
55. United Nations Environment Programme (UNEP) (1993). – Viet Nam and climate change. Information Unit on Climate Change (IUCC). Available at: <http://www.cs.ntu.edu.au/homepages/jmitroy/sid101/uncc/fs123.htm> (accessed on 18 September 2007).
56. Wang L.C. (1997). – Canine filarial infections in north Taiwan. *Acta trop.*, **68**, 115-120.
57. Wang T.L. & Chang H.C. (2002). – Do the floods have the impacts on vector-borne diseases in Taiwan? *Ann. Disaster Med.*, **1**, 43-50.
58. Watson R.T., Zinyowena M.C. & Moss R.H. (2002). – The regional impacts on climate change – an assessment of vulnerability. In *Special Report of the IPCC Working Group II*. Cambridge University Press.
59. Wu C.C., Chen C.C. & Fan P.C. (1997). – Natural infection of mosquitoes with *Dirofilaria immitis* in northern Taiwan. *J. Chin. Soc. vet. Sci.*, **23** (1), 12-20.
60. Wu C.C. & Fan P.C. (2003). – Prevalence of canine dirofilariasis in Taiwan. *J. Helminthol.*, **77** (1), 83-88.
61. Yamakawa M., Ohashi S., Kanno T., Yamazoe R., Yoshida K., Tsuda T. & Sakamoto K. (2000). – Genetic diversity of RNA segments 5, 7 and 9 of the Palyam serogroup orbiviruses from Japan, Australia and Zimbabwe. *Virus Res.*, **68**, 145-153.



62. Yamakawa M., Yanase T., Kato T. & Tsuda T. (2006). – Chronological and geographical variations in the small RNA segment of the teratogenic Akabane virus. *Virus Res.*, **121**, 84-92.
63. Yanase T., Fukutomi T., Yoshida K., Kato T., Ohashi S., Yamakawa M. & Tsuda T. (2004). – The emergence in Japan of *Sathuperi* virus, a tropical Simbu serogroup virus genus *Orthobunyavirus*. *Arch. Virol.*, **149**, 1007-1013.
64. Yanase T., Kato T., Kubo T., Yoshida K., Ohashi S., Yamakawa M., Miura Y. & Tsuda T. (2005). – Isolation of bovine arboviruses from *Culicoides* biting midges (Diptera: *Ceratopogonidae*) in southern Japan: 1985-2002. *J. med. Entomol.*, **42** (1), 63-67.
65. Yanase T., Maeda K., Kato T., Nyuta S., Kamata H., Yamakawa M. & Tsuda T. (2005). – The resurgence of Shamonda virus, an African Simbu group virus of the genus *Orthobunyavirus*, in Japan. *Arch. Virol.*, **150**, 361-369.
66. Yang D.K., Kim B.H., Kweon C.H., Kwon J.H., Lim S.I. & Han H.R. (2004). – Biophysical characterization of Japanese encephalitis virus (KV1899) isolated from pigs in Korea. *J. vet. Sci.*, **5** (2), 125-130.
67. Yang D.K., Kim B.H., Kweon C.H., Kwon J.H., Lim S.I. & Han H.R. (2004). – Molecular characterization of full-length genome of Japanese encephalitis virus (KV1899) isolated from pigs in Korea. *J. vet. Sci.*, **5** (3), 197-205.
68. Yoganathan D. & Rom W.N. (2001). – Medical aspects of global warming. *Am. J. ind. Med.*, **40**, 199-210.
69. Yu C.Y., Wang J.S. & Yeh C.C. (2000). – *Culicoides arakawae* (Diptera: *Ceratopogonidae*) population succession in relation to leucocytozoonosis prevalence on a chicken farm in Taiwan. *Vet. Parasitol.*, **93**, 113-120.
70. Yu C.Y., Wang J.S. & Yeh C.C. (1999). – Effect of humidity on development and fecundity of *Culicoides arakawae* (Diptera: *Ceratopogonidae*) [in Chinese with English abstract]. *Taiwan J. vet. Med. anim. Husb.*, **69**, 87-94.
-

