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HIGH-LEVEL CONFERENCE ON WORLD FOOD SECURITY: THE CHALLENGES OF CLIMATE CHANGE AND BIOENERGY

Rome, 3 – 5 June 2008

CLIMATE-RELATED TRANSBOUNDARY PESTS AND DISEASES

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I. Introduction

1. The Expert Meeting on *Climate-related transboundary pests and diseases, including relevant aquatic species* met in Rome, 25-27 February 2008. The agenda, list of participants and presentations made by experts are available on the High-Level Conference webpage http://www.fao.org/foodclimate/expert/em3.html. This document presents the state-of-art in this field: additional scientific details to this document are annexes which are available on the above-mentioned webpage only. Another document, *Climate change, bioenergy and food security: options for decision-making identified by expert meetings* (HLC/08/INF/5 paras. 51-81), contains the options for development proposed by this Expert Meeting.

II. Knowledge basis

2. The movement of plant pests, animal diseases and invasive alien aquatic organisms across physical and political boundaries threatens food security and creates a global public concern across all countries and all regions. Countries allocate large resources to limit the spread and control of transboundary pests and diseases[1] such as avian influenza, foot-and-mouth disease and locust. They also adapt animal and plant health services and activities and cooperate regionally and globally for prevention, early warning and control.

3. There is clear evidence that climate change is altering the distribution, incidence and intensity of animal and plant pests and diseases such as Bluetongue, a sheep disease that is moving north into more temperate zones of Europe. Cannon (see Annex 1) found examples of plant pests whose distribution is shifting in the United Kingdom and other parts of Europe, most likely due to climatic factors. For example, migrant moths of the Old World bollworm (*Helicoverpa armigera*) had a phenomenal increase in the United Kingdom from 1969-2004 and there have been outbreaks at the northern edge of its range in Europe; cottony cushion scale (*Icerya purchasi*) populations appear to be spreading northwards perhaps as a consequence of global warming; and cottony camellia scale (*Pulvinaria – Chloropulvinaria – floccifera*) has become much more common in the United Kingdom, extending its range northwards in England and increasing its host range

[1] Transboundary animal and plant pest and diseases and relevant aquatic species refer to organisms that spread across national or geographical (physical) boundaries, indicating that disease or pest events in one country may have direct effects or potential effects in another country).

Transboundary Animal Diseases (TADs) may be defined as those epidemic diseases that are highly contagious or transmissible and have the potential for very rapid spread, irrespective of national borders, and can have serious socio-economic and public health consequences (OIE, FAO).

Transboundary plant pests refer to quarantine pests. These include pests of potential economic importance to the area endangered, even if they are not yet present, pests that are present but not widely distributed and officially controlled, and migratory pests, in particular locusts, which have the ability to change from individual to collective behaviour in swarms that easily cross boundaries.

For aquatic species, the term primarily refers to invasive alien aquatic species.

in the last decade or so, which is almost certainly in response to climate change. In Sweden this species was previously only known as a greenhouse species, but is now established as an outdoor species. The range of the oak processionary moth (*Thaumetopoea processionea*) has extended northward from central and southern Europe into Belgium, Netherlands and Denmark.

4. Evans (see Annex 2) found that the oak processionary moth's northward progression was due to improved synchrony of egg hatch and reduction of late frosts. He also found that the massive population buildup of mountain pine beetle (*Dendroctonus ponderosae*) and its northward progression in the North American Pacific Northwest has most likely been due to a combination of warmer winter temperatures, reduced episodes of underbark mortality and increased drought which weakened the trees. Kiratani (2007)[2] reported on the polar extension of several plant pests in Japan over the period 1965 to 2000. Yukawa has found that about 40 of the 250 butterfly species in Japan have exhibited northward range extensions in recent years (see Annex 3). A particular case study reported by Yukawa showed that *Nezara viridula*, a tropical and subtropical crop pest, is gradually moving northward in southwestern Japan, possibly due to global warming, replacing the more temperate species *Nezara antennata*.

5. Major drivers for the spread of transboundary animal and plant pests and diseases and alien invasive aquatic species are international trade and traffic (except for migratory pests). Animal and plant pest and diseases are not evenly distributed over the globe, often because they are limited by physical barriers such as mountains, seas and deserts. The increase in movement of people, animals, plants, goods and conveyances has accelerated the redistribution of animal and plant pests and diseases and alien invasive aquatic species and climate change will create new ecological niches allowing for the establishment and spread of pests and diseases into new geographical areas and from one region to another. This expansion will continue to result in huge financial losses and require large eradication programmes and control measures. Among the major occurrences are foot-and-mouth disease in Northern Europe and South America, classical swine fever in Europe, Rift Valley fever in Africa, and the spread of coffee leaf rust throughout the world, soybean rust into the Americas, and citrus tristeza virus in South and Central America and now in the Mediterranean.

6. In addition, unforeseen emergence of "new" diseases and pests has been relatively common. New vectors, selection and recombination of disease genotypes may occur when animal species and breeds and plant species and varieties mix or when insect pests and vectors are introduced without their natural enemies. Change in climate resulting in changes in species composition and interactions will augment the emergence of unexpected events, including the emergence of new diseases and pests.

7. Climate change will especially impact vector-borne animal diseases due to the effects of climate change on the arthropod vectors and macro-parasites of animals due to the climate effects on the free stages of these parasites. Climate change may also result in new transmission modalities and different host species. Although developing countries are already subject to an enormous animal disease burden, both developing and developed countries will be subject to increased incidence or newly emerging diseases that are

[2] Kiritani, K. 2007. The impact of global warming and land-use change on the pest status of rice and fruit bugs (Heteropthera) in Japan. Global Change, 13, 1586-1595.

difficult to predict. Temperate countries will be particularly vulnerable to invasions by exotic arthropod-borne virus diseases and macroparasites.

8. Diseases caused by arthropod-borne viruses (arboviruses) include a large number of arthropod vector-borne (mosquitoes, midges, ticks, fleas, sand flies, etc.) that are often zoonotic, predominantly RNA viruses, that can cause haemorrhagic fevers or encephalitis in humans. They mostly spill over from natural reservoirs such as bats, birds, and rodents or other wild mammals. Emerging arbovirus disease complexes (particularly those in evolutionary flux) are by far the most important (climate change is only one factor altering disease ecologies). This group includes dozens of relevant disease complexes, which may be broken down into at least half a dozen subgroups, of which a number are chiefly animal diseases, others are of mixed animal and public health concern, while a third consists of mainly human diseases with an animal health dimension.

9. Animal disease distribution that will be strongly influenced by climate change includes bluetongue and Rift Valley fever as well as tick-borne diseases. In Europe, bluetongue is now transmitted by autochtonous temperate midge vectors. Rift Valley fever is a mosquito-borne animal and human disease with climate-influenced vectors. The effects of climate change on internal parasites (gastro-intestinal parasites and liver fluke) may include changes in the distribution of the parasites and the intermediate hosts. In areas that become wetter, these will become of greater importance.

10. Thornton (see Annex 4) also noted that the changes wrought by climate change on livestock infectious disease burdens may be extremely complex. Apart from the effects on pathogens, hosts, vectors and epidemiology, there may be other indirect effects on the abundance or distribution of the vectors' competitors, predators and parasites. For example, in the pastoral areas of East Africa, drier conditions may mean fewer water points and thus more intense interactions between livestock and wildlife.

11. While drivers of plant pest change include increases in temperature, variability in rainfall intensity and distribution, change in seasonality, drought, CO_2 concentration in the atmosphere and extreme events (e.g. hurricanes, storms), intrinsic pest characteristics (e.g. diapause, number of generations, minimum, maximum and optimum growth temperature of fungi, interaction with the host) and intrinsic ecosystem characteristics (e.g. monoculture, biodiversity) also affect change. Emerging pests are often plant pests of related species known as "new encounter" pests, which come into contact with new hosts that do not necessarily have an appropriate level of resistance, or are plant pests introduced without their biological control agents (in particular, insect pests, nematodes and weeds).

12. For example, the expansion of maize production driven by climate change will make more areas vulnerable to entry, establishment and spread of the corn root worm (*Diabrotica*). The range of tephritid fruit flies will alter considerably with climate change with corresponding changes in phytosanitary regulations and international trade opportunities. Mountain pine beetle (*Dendroctonus ponderosae*), a pest of North American forests, is expected to decrease in generation time and winter mortality, which will increase the risk of range extension into vulnerable ecosystems. Conversely, some pests will be less damaging because climate suitability will decrease and through interactions with natural enemies and plant defences (see Cannon, Duveiller, Evans, Yukawa, Hendrichs, in Annexes 1, 5, 2, 3, 6).

13. Migratory plant pests, in particular locusts, are totally dependent on rain, temperature and vegetation and their habitats change rapidly. The desert locust (*Schistocerca gregaria*), like other locusts, can change its behaviour and physiology from solitary grasshoppers to gregarious stages that form swarms. Solitary desert locusts occur at low density in the recession area, which covers North Africa, the Sahel, the Red Sea countries and parts of India, Pakistan, Iran and Afghanistan. The outbreak area reaches from Mauritania to India and from southern Europe to Cameroon and Tanzania. Outbreaks and plagues originate in the recession areas when there are several cycles of good breeding conditions. Although the effects of climate change on this system are difficult to judge, climate scenarios with more winter rain in the Sahel may provide better breeding conditions.

14. Aquatic animals are very vulnerable as water is their life-support medium and their ecosystems are fragile. Hine (see Annex 7) found a number of fish diseases that may be susceptible to climate change. Temperature and rainfall are critical ecological factors for epizootic ulcerative syndrome (EUS), a fungal disease of cultured and wild fish in fresh and brackish water that affects more than 60 host species, which recently expanded its distribution to southern Africa. Perkinsus olseni, a major mollusk pathogen, affects more than 100 host species and is also temperature dependant. Red tides (harmful algal blooms), influenced by climate change, are being spread into new locations by ships' ballast water.

Contributors to transboundary pests and diseases

Factors that affect the entry, establishment and spread of animal and plant pests and diseases and invasive alien aquatic species include:

- globalization,
- human population growth,
- ecosystem diversity, function and resilience,
- industrial and agricultural chemical pollution,
- land use, water storage and irrigation,
- atmospheric composition, CO_2 and oceanic acidification by carbonic acid,
- species interactions with hosts, predators and competitors, and
- trade and human movements.

These factors are not independent of each other and climate change interacts with each of them.

15. In terms of vulnerability and risk analysis, Sutherst (see Annex 8) found that production of crops, livestock and aquatic animals will vary according to their exposure to climatic hazards, such as droughts, floods, extreme temperatures, oceanic acidification and sea level rise. The *sensitivity* of each production system to those hazards will depend on the crop varieties, pest and disease species involved and their geographical locations. Response options will be determined by the local biodiversity which can act as a regulator of the pest population by varying degrees.

16. There is a need for a better impact assessment of climate change on animal and plant pests and diseases and invasive alien aquatic species. In the Fourth Assessment Report of the IPCC[3] these risks are insufficiently addressed.

17. Methods exist for risk analysis. However, the application of methods within the context of climate change to assess risks of entry, establishment and spread of threats is resource intensive and requires a large extensive and reliable data. These risk analyses will have to be re-evaluated and updated as climate continues to change. Considerations of cost effectiveness and limits to resources demand that approaches to risk analysis exploit minimum data sets and generic modeling tools to answer questions related to numerous pest species on a global scale.

18. Cost effectiveness and availability of resources will determine the depth of the analysis, through a hierarchy of expert opinion, rule-based assessments, analogous climates, species-specific climate envelopes, process-based simulation models, and crop-pest models linked to macro-economic analyses of the vulnerability of industries or regions. In view of the large number of animal and plant diseases and pests and the large number of potential invasive aquatic species, it is clear that, in most cases, detailed risk assessment is unlikely to occur, especially since invasive species ecology is in its infancy. Nevertheless, in principle, it is possible to estimate the area that is climatically receptive to a species, with the usual caveats on genetic homogeneity, biotic interactions at both the source and destinations, and human-modified microhabitats, such as irrigated crops.

19. To understand the contribution of climate change to outbreaks, there is a need to: i) establish benchmarks of current biosecurity status and impacts and costs of biosecurity; and ii) monitor indicators of change in biosecurity in relation to rates of invasions by foreign species, rates of crop, livestock, forest and fish losses, and changes in costs of biosecurity. However, the costs associated with such may be prohibitive.

III. Impact on food security

20. Food security is defined as “When all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life” (World Food Summit, 1996). Components of food security are food availability, food access, food utilization and food stability.

21. *Availability of food.* Animal and plant pests and diseases and alien invasive aquatic species reduce the availability of quantities of food of appropriate quality, whether supplied through domestic production or imports. Overall quantifications of losses and potential losses due to animal and plant pests and diseases and alien invasive aquatic species are limited. Entry and establishment, emergence and outbreaks of animal and plant pests and diseases have historically resulted in major food problems either directly through yield reductions of food crops and losses in animal production, or indirectly through yield reduction of cash crops (e.g. rinderpest, potato blight, locusts). Climate change will result in a higher volatility and, therefore, is likely to cause

[3] IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E.Hanson, Eds., Cambridge University Press, Cambridge, UK, 976 pp.

additional crises in local agricultural production, in particular for small farmers and those involved in subsistence agriculture and aquaculture with different consequences for socio-economic groups and genders.

22. *Access to food*. Plant and animal pest and disease regulations are designed to facilitate trade while reducing the risk of international movement of restricted organisms whose introduction could require expensive eradication or control operations. Animal and plant pests and diseases and alien invasive aquatic species reduce food access through reduction of income from animal production, reduction of yields of food and cash crops, reduction in forest productivity, changes in aquatic populations as well as increased costs of control. Indirect effects are reduced access to international markets due to the occurrence of quarantine for animal diseases or plant pests.

23. *Utilization of food*. Food utilization in relation to animal and plant diseases and pests, chiefly concerns food safety. Climate change may result in food-borne zoonoses and increased use of veterinary drugs, while redistribution of plant pests and changes in pest incidence and intensity may result in additional and inappropriate pesticide use. New aquaculture diseases also could result in increased pesticide use. Consequently, there may be higher and even unacceptable levels of pesticide and veterinary drugs in food. Mycotoxins in food are a growing problem. Changes in rainfall, temperature and relative humidity may favour the growth of fungi that produce mycotoxins and thus may make food such as groundnuts, wheat, maize, rice and coffee unsuitable for human and animal consumption.

24. *Stability of food***.** To be food secure, populations, households or individuals must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks such as economic or climatic crises or cyclical events such as seasonal food insecurity. The concept of stability refers to both the availability and access dimensions of food security. Introduction or emergence of new animal and plant pests and diseases, and plagues of migratory pests may have substantial effects on the stability of food supply through direct losses as well as through the reduction of income and will also influence the stability of the production system.

IV. Possible technical and policies responses

25. Climate change will result in a higher probability of entry, establishment and spread of vector-borne diseases of animals, parasites of animals with free-living life stages, and pests of plants, diseases of fish and invasive alien aquatic species for the following reasons:

Climate change will create winners and losers. For some animal and plant pests and diseases and invasive alien aquatic species, the climate will become more conducive and for others the meteorological conditions will become less favourable. This will result in unstable situations with a high probability of entry and establishment in areas that are presently protected by unsuitable conditions.

- Meteorological and related environmental circumstances may change the geographical distribution of host species, putting them in contact with animal and plant pests and diseases of related hosts to which they do not possess resistance.
- New animal and plant pests and diseases may emerge due to evolving selection and adaptation to new situations.

26. *Data for projecting risk*. Projections of future distribution, severity and incidence can be made for animal and plant pests and diseases that are presently of quarantine significance, using various risk analysis methods and tools. However, the combination of climate change, new environments and new ecological conditions and limited data that pertain to these situations make the assessments of future situations less reliable. Emergence of animal and plant pests and diseases and invasive alien aquatic species rarely can be foreseen, and lack of reliable data will make projections of the potential spread of such animal and plant pests and diseases and invasive alien aquatic species highly unreliable. Changes in rainfall, very complex to foresee, will have a major impact on outbreak and plague patterns of migratory plant pest species, in particular on locust species which are totally dependent on moisture and temperature.

27. *Early warning and prevention strategies*. The strategy to address transboundary animal and plant pests and diseases and alien invasive aquatic species is prevention, early warning including forecast, early detection, early control and research. Investments in early control and detection mechanisms will be critical, to avoid higher costs of eradication and control. Prevention and early warning requires a reduction of the possibilities of entry and establishment and can be accomplished through better border control and rapid diagnostic tools for better surveillance of animal and plant pests and diseases and invasive alien aquatic species. To be successful, surveillance systems require monitoring and input from farmers as well as government services.Prevention and early warning also requires cooperation of countries within the same geographic/eco-climatic region to ensure better monitoring of animal and plant health in the region. FAO's Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES) provides support to governments in all of these areas.

28. *Eradication, containment, impact reduction*. Once animal and plant pests and diseases and invasive alien aquatic species establish, an immediate decision is required on follow-up action. Where possible and economically feasible, eradication and containment should start as early as possible. Countries need appropriate emergency capacity to take action as well as regional infrastructures that can support and coordinate action among countries. Joint action of countries in the same region is an absolute necessity. Where eradication and containment is judged not feasible, actions should be undertaken that will reduce the impact of the introduced animal or plant pest or disease, or the invasive alien aquatic species. These actions can include changes in agronomy and animal management, introduction of new varieties, species or breeds, carefully considered introduction of biological control agents and Integrated Pest Management, all of which are within the framework of overall autonomous and planned adaptation as identified in the Fourth Assessment Report of the IPCC.[4]

29. In forestry, adaptation responses include: reforestation choices that take a long-term ecological view, increased monitoring and data sharing, enforcement of wood packaging standards, funding for emergency control operations and control of spread after introduction, and capacity building for better compliance by trading partners.

30. The trade in ornamental fish and other ornamental aquatic species is a major pathway for the introduction of fish diseases and invasive alien aquatic species. Legislation and national systems to prevent the entry and establishment of alien aquatic species and fish diseases only exist in a limited number of countries. There is great

[4] IPCC, 2007: Climate Change 2007 (op.cit.)

concern about the largely unregulated movement of ornamental fish species and aquatic organisms that spread diseases or become pests that impact aquatic systems. Governments should legislate and seek to establish capacity to implement systems that prevent the entry and establishment of alien aquatic species and fish diseases.

31. *Information options*. The effects of climate change on migratory pests will most likely require that new areas have to be surveyed in different time periods with control capacity available at different periods of the year and more locations than at present. Addressing changing locust situations will require better surveillance and monitoring, and earlier control.

32. Additional information is required on distribution of animal and plant pests and diseases and invasive alien aquatic species, and on their epidemiology. In particular, there is need for better surveillance methodologies; fast and cheap identification methods; epidemiological knowledge; and information on biological control organisms and mechanisms and resistant crops and animal breeds and species. Coordinated research, including the Consultative Group on International Agricultural Research (CGIAR) programmes related to climate change and food security, will be needed to improve the range of options available to countries. Better accessibility and analysis of existing historical data and more detailed data for all regions in relation to different climate change scenarios will improve the baselines needed to assess adaptation.

33. *Food trade industry*. The introduction of diseases and pests will result in higher costs to national food industry in relation to inspection, treatment and compliance with obligations of the importing trading partners. Trade disputes in the WTO systems could become more frequent. Information exchange mechanisms exist at global and regional levels. At national level, there are many national databases as well as those maintained by non-governmental organizations (NGOs) and universities. However, data are of varying quality and are often incomplete or out of date. As provision of data on distribution of animal and plant pests and diseases and invasive alien aquatic species can be perceived as harmful to trade interests, provision of such data needs cooperation and commitment of all parties. To enable risk assessment, prevention, monitoring, early detection and warning, and control, there is a need for an overall global data exchange mechanism covering the distribution of diseases, pests, invasive alien aquatic species and correlated ecological conditions including climate. In order to improve information exchange, it will be necessary to increase cooperation among national, regional and global organizations, specifying the data required and the safeguards that should be applied to protect national interests. Government agencies and relevant stakeholders should come together and discuss specifications and sustainable systems for practical use.

34. *Government constraints*. The national animal and plant protection infrastructure, in particular in developing countries, is often unable to execute the range of activities required for prevention, early warning and early control of transboundary animal and plant pests and diseases. National systems are often fragmented among agencies and ministries. The high level of uncertainty and the concomitant requirements for better legislation, increased risk analysis, better border control and the increase in requirements for eradication, containment and adaptation are beyond the possibilities of most plant and animal health services, in particular those of developing countries. Learning and sharing lessons from failures as well as from successes is especially important at national level. Governments also need to be aware of the importance of maintaining capacity for dealing

with new animal and plant pests and diseases. Those that reduce funding when there is no crisis often suffer later from failure to maintain capacity.

35. At present most countries have insufficient enabling legislation and resources allocated to:

- surveillance and monitoring
- border control and inspections
- expertise in risk assessment
- diagnostic tools for early detections
- expertise in diagnosis (taxonomy)
- data collection and access to information
- tools for rapid response to entry, establishment and spread
- control measures at the source of the produce.

36. *Government priorities*. A top priority for dealing with animal and plant pests and diseases is strengthening national veterinary and plant health services and animal and plant health systems through capacity building. This includes improvement of infrastructure, border control, better legislation and enforcement, and better surveillance. Other priorities include improving the ability to respond to movements of animal and plant pests and diseases through increasing preparedness, ensuring maintenance of expertise and adopting rapid diagnostic tools and forecasting models. Investment in capacity building will contribute to reduction of emerging animal and plant pests and diseases at source. Basic sciences such as climate change science, taxonomy, modeling, population ecology and epidemiology should be given highest priority by governments.

37. Resources to address animal health, plant health and invasive alien aquatic species are often distributed among national ministries and agencies. In a number of countries, there is a move to establish “biosecurity” agencies that bring several of these functions together. In view of the additional strains climate change puts on these systems, governments may wish to design and implement national strategies that capture synergies across the agencies and entities responsible for managing animal plant pests and diseases and invasive alien aquatic organisms, and consider moving towards biosecurity approaches.

38. *Ecosystem processes*. Climate affects both local and regional ecosystem processes and production. Many threats are transboundary and countries will not be able to address these issues individually. Regional cooperation is a high priority for risk analysis, regional standard setting, exchange of information and coordinated action. Countries should examine and, where appropriate, strengthen their regional organizations and cooperation in animal and plant health and on alien invasive aquatic species. Regional and sub-regional organizations and cooperation exist but coverage, functions and efficiency vary among regions. In such cooperative frameworks, issues such as standard setting, joint risk assessment, joint action and access to information should be carefully considered and, where required, organizations should be strengthened.

39. *Global frameworks*. Global regulatory frameworks are provided by the World Trade Organization (WTO), the World Organisation for Animal Health (OIE), the FAO International Plant Protection Convention (IPPC) and the Convention on Biological Diversity. OIE and IPPC also provide standard setting mechanisms for animal and plant health. IPPC and OIE have the structures to serve adequately under climate change

scenarios, but their resources are limited. Concerning invasive alien aquatic species, the International Maritime Organization (IMO) International Convention on the Control of Harmful Anti-fouling Systems on Ships entered into force in 2008 while the International Convention for the Control and Management of Ships' Ballast Water and Sediments, was adopted in 2004 but is not in force yet. However, an overall global framework to adequately address invasive alien aquatic species and be prepared for the additional effects of climate change does not exist.

40. Relevant global organizations should seek further cooperation in appropriate fields through information exchange and capacity building. The Standard and Trade Development Facility, a WTO-hosted joint programme of FAO, OIE and World Health Organization, is a good example.

V. Main findings and recommendations

41. The spread of plant pests, animal diseases and invasive alien aquatic organisms across physical and political boundaries threatens food security and represents a global public “bad” that links all countries and all regions.

42. There is clear evidence that climate change is altering the distribution and potential distribution, incidence and intensity of animal and plant pests and diseases.

43. Climate change creates new ecological niches allowing for the potential for establishment and spread of animal and plant pests and diseases and invasive alien aquatic species to new geographical areas and from one region to another. It will also result in the emergence of new animal and plant diseases and pests. Change in climate resulting in changes in species composition will augment the emergence of unexpected events, including the emergence of new diseases and pests. The additional opportunities for entry, establishment and spread will result in higher uncertainty.

44. The impact of climate change on migratory plant pests is difficult to foresee. However, climate scenarios predict more winter rain in some Sahelian areas which may provide better breeding conditions for the desert locust (*Schistocerca gregaria*).

45. Transboundary plant pests, animal diseases and invasive alien aquatic species are a constraint to food security due to their impacts on food availability, food access, food safety and food stability.

46. Impact assessment and cost-benefit analyses of adaptation measures at national and regional levels and methods that take a wide range of factors into account should be developed and used in strategic planning.

47. The introduction of diseases and pests will result in higher costs to the national industry in relation to inspection, treatment and compliance with obligations of the importing trading partners. Trade disputes in the WTO systems could become more frequent. Investments in early control and detection mechanisms will undoubtedly be valuable, to avoid higher costs of eradication and control.

48. Adaptation to the increased potential of spread of transboundary plant pests, animal plant pests and diseases and invasive alien aquatic species under different climate scenarios requires higher levels of forecasting, prevention, early warning and early

reaction. Early detection and identification, including through genotypic characterization, preparedness for and rapid response to new and emerging pests are critical elements.

49. Prevention needs cooperation of countries in the same geographic region to ensure better monitoring of animal and plant health in the region.

50. To meet the likely increase in entry, establishment and spread of animal plant pests and diseases and invasive alien aquatic species, countries need appropriate emergency capacity to take action and, where appropriate, regional infrastructures should support and coordinate action among countries. Joint action of countries in the same region is an absolute necessity.

51. To enable risk assessment, prevention, monitoring and control, there is a need for global data exchange mechanisms covering the distribution of diseases, pests, invasive alien aquatic species and correlated ecological conditions including climate. In this respect, it will be necessary to increase cooperation among national, regional and global organizations and specify better the data required and the safeguards that should be applied to protect national interests. Government agencies and relevant stakeholders should come together and discuss specifications and sustainable systems for practical use.

52. Where eradication and containment is judged not to be feasible, actions need to be undertaken that will reduce the impact of the introduced animal or plant pest or disease, or the invasive alien aquatic species: Changes in agronomy and in the management of animals, new varieties, new species, new breeds, carefully considered introduction of biological control agents and Integrated Pest Management. The general autonomous and planned adaptation measures listed in the in Fourth Assessment Report of the IPCC[5] should be considered when formulating local, national and regional strategies for adaptation to plant pests, animal diseases and aquatic organisms under climate change scenarios.

53. Adaptation responses in forestry include: reforestation choices that take a long-term ecological view, increased monitoring and data sharing, enforcement of wood packaging standards, funding for emergency control operations, control of spread after introduction, and capacity building for better compliance by trading partners.

54. The impact of climate change on migratory pests will require that, possibly, new areas have to be surveyed in different time periods and control capacity be available at different periods of the year and different locations than at present. Locust situation will require better surveillance and monitoring, and early control to be able to properly address a changing situation.

55. The national animal and plant protection infrastructures, in particular in developing countries, are often unable to execute the range of activities required for prevention, early warning, early control, eradication, containment and adaptation of transboundary animal diseases and plant pests, and will be further strained due to the impacts of climate change.

56. The top priority for animal and plant pests and diseases is strengthening of national veterinary and plant health services and animal and plant health systems through capacity building including infrastructure, border control, better legislation and

[5] IPCC, 2007: Climate Change 2007 (op.cit.)

enforcement and better surveillance. Another priority should be to respond to movements of animal and plant pests and diseases through preparedness, maintenance of expertise, rapid diagnostic tools and forecasting models. Investment in capacity building will contribute to reduction of emerging animal and plant pests and diseases at source. Basic sciences (i.e. climate change science, taxonomy, modeling, population ecology and epidemiology) should obtain highest priority by governments.

57. Resources to address animal health, plant health and invasive alien aquatic species are often distributed among national ministries and agencies. In view of the additional strains on these systems by climate change, governments may wish to design and implement national strategies that capture synergies across the agencies and entities responsible for managing animal plant pests and diseases and invasive alien aquatic organisms, and consider moving towards biosecurity approaches.

58. There is great concern about the largely unregulated movement of ornamental fish species and aquatic organisms that spread diseases or become pests that impact aquatic systems. Governments should legislate and seek to establish capacity to implement systems to prevent the entry and establishment of alien aquatic species and fish diseases.

59. Climate affects ecosystem processes and production at local and regional scale. Many threats are transboundary and countries will not be able to address these issues individually. Regional cooperation is a high priority for risk analysis, standard setting, exchange of information and coordinated action. Countries should examine and, where appropriate, strengthen their regional organizations and cooperation in animal and plant health, and alien invasive aquatic species.

60. Global regulatory frameworks and standard setting mechanisms for animal and plant health are provided respectively by the OIE and the IPPC. These organizations have the structures to serve adequately under climate change scenarios, but their resources are limited.

61. An overall global framework to adequately address invasive alien aquatic species and be prepared for the additional effects of climate change remains unavailable.

62. Additional information and research is required on distribution of animal and plant pests and diseases and invasive alien aquatic species, and on their epidemiology. In particular there is a need for better surveillance methodologies; fast and cheap identification methods, epidemiological knowledge; and information on biological control organisms and mechanisms; resistant crops and resistant animal breeds and species. Coordinated research, including the CGIAR programmes related to climate change and food security, will be needed to improve the range of options available to countries. Better accessibility and analysis of existing historical data and more detailed data for all regions in relation to different climate change scenarios will improve the baseline studies needed to assess adaptation.