Food and Agriculture Organization
of the United Nations

Climate change, sanitary and phytosanitary measures and agricultural trade

Background paper for
The State of Agricultural Commodity Markets (SOCO) 2018

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Contents

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Acronyms

ASF	African swine fever
BGCI	Botanic Gardens Conservation International
BT	Bluetongue disease
CABI	Centre for Agriculture and Biosciences International
Codex	Codex Alimentarius Commission
DSU	Dispute Settlement Understanding
FAO	Food and Agriculture Organization of the United Nations
GATT	General Agreement on Tariffs and Trade
GEF	Global Environment Facility
IICA	Inter-American Institute for Cooperation on Agriculture
IPCC	Intergovernmental Panel on Climate Change
IPPC	International Plant Protection Organization
ISPM	International Standard for Phytosanitary Measures
OECD	Organisation for Economic Cooperation and Development
OIE	World Organisation for Animal Health (Office international des épizooties)
RCP	Representative Concentration Pathway
RPPO	Regional Plant Protection Organization
SPS	sanitary or phytosanitary
SPS Agreement	The WTO Agreement on the Application of Sanitary and Phytosanitary Measures
STC	Specific Trade Concern
STDF	Standards and Trade Development Facility
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WBG	World Bank Group
WCO	World Customs Organization
WHO	World Health Organization
WTO	World Trade Organization

Abstract

The warming of the climate system as a result of human activity is unequivocal and presents a huge threat to global food security. Many developing countries will be particularly affected by climate change impacts and will suffer reductions in agricultural yields. International agricultural trade presents an opportunity to leverage these challenges, providing the possibility to counteract regional food shortages caused by climate change impacts. However, both climate change and international trade are expected to affect the dispersion of pests and diseases, as well as food-borne pathogens and contaminants. To realize the potential of international agricultural trade and to prevent it from increasing pathways for the geographical distribution of pests, diseases or food-borne pathogens, it is imperative for countries to establish efficient Sanitary and Phytosanitary measures. Ensuring the establishment of such measures, is particularly challenging due to the unpredictable nature of the impact of climate change on pests and diseases. It is necessary to upgrade existing knowledge about climate change effects on pests, diseases and food-borne pathogens and, where possible, for research to be undertaken collaboratively at, for example, regional level.

Executive Summary

The warming of the climate system is a scientifically proven fact and is unequivocal! Human influence has been the dominant cause of the observed warming since the mid-20th century and will also be the determining factor for the scale of future warming until the end of the 21st century.

Global trade in food and agricultural products has tripled in value terms since the turn of the millennium and it is expected that this trend will continue. Global trade in food products will continue to expand rapidly, but the structure and pattern of trade will differ significantly by commodity and by region. Greater participation in global trade is an inevitable part of most countries' national trade strategies.

Trade, and especially international trade of agricultural commodities, may function as a pathway for the movement and spread of pests, diseases and food safety risks to new areas where they were previously unknown. Countries usually want to protect themselves against such risks by establishing sanitary and phytosanitary (SPS) measures to regulate the import of agricultural commodities. The World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) ensures that SPS measures are solely used to protect against SPS risks, are based on scientific evidence, and not used for protectionist purposes.

Trade presents a high potential to leverage challenges, such as regional food shortages due to climate change impacts. International agricultural trade also generates returns for many countries in the world. Several of the Sustainable Development Goals (SDGs) of the UN can only be realized through a robust international trading system, especially an agricultural trading system. Climate change impacts on pests and diseases of plants and animals, as well as food-borne pathogens, threaten this international trading system. Pests and diseases as well as food-borne pathogens and contaminants benefit from international trade as a pathway for geographical dispersion.

To realize the potential of international agricultural trade and to prevent it from increasing pathways for the geographical distribution of pests, diseases or food-borne pathogens, it is imperative for countries to establish efficient SPS systems. Since pests, diseases and food-borne pathogens particularly are affected by anthropogenic climate change and the epidemiology of these organisms may change considerably, robust surveillance and monitoring systems are vital at national, regional and international level. Strengthening SPS relevant infrastructures at national level also includes improving SPS relevant border point infrastructures as well as investing in diagnostic capabilities.

Knowledge about pests, diseases and food-borne pathogens and their life-cycles, epidemiology and pathogenicity is essential to undertake risk assessments to determine steps and actions to combat these threats effectively and economically. Risk assessments

are also indispensable as they provide strong justification for trade limiting SPS measures. Any risk assessment, however, is dependent on the underlying scientific data available. In order to increase risk assessment activities at national, regional and international levels, it is necessary to upgrade existing knowledge about climate change effects on pests, diseases and food-borne pathogens. It is of paramount importance that research in these areas is increased and, where possible, be undertaken collaboratively at, for example, regional level in order to enhance focus, maximise resource value and reduce disputes between countries.

Many developing countries will be particularly affected by climate change impacts because they are located in areas where climate change scenarios predict the most severe consequences. Countries in Africa, Asia and Latin America will especially suffer from climate change induced disadvantages. This is particularly exasperating as most countries on these continents already face daily struggles in getting their economy and agricultural production to a satisfying level. It is essential that the international community help those countries to overcome the impediments caused by climate change, through provision of SPS technical assistance and capacity building. International organizations, such as the Food and Agriculture Organization of the United Nations (FAO) and the World Bank Group (WBG), standard setting bodies (Codex Alimentarius, the International Plant Protection Convention (IPPC) and the World Organisation for Animal Health (OIE) as well as global partnerships such as the Standards and Trade Development Facility (STDF), should be involved in these efforts, in order for developing countries to benefit from their expertise and ensure international harmonization.

When following the international climate change discussion it becomes very clear that issues, such as pests and diseases are usually only mentioned at the fringe of the adaptation debate. Physical climate change events such as melting icecaps or extreme weather events receive much more attention. However, the international spread of pests, diseases and food-borne pathogens may have much stronger impacts on biodiversity and living conditions on earth. It is essential that these developments are included to their fullest in the international policy consideration for climate change. Political attention and additional funding for SPS needs related to climate change at national, regional and international levels will only become available when the spread of pests, diseases and food-borne pathogens is recognized as a critical component of the climate change debate.

1. Introduction

Global trade in food and agricultural products has tripled in value terms since the turn of the millennium and this trend is expected to continue. In 2015, the Food and Agriculture Organization of the United Nations (FAO) reported that the global trade in food products will continue to expand rapidly, but that the structure and pattern of trade will differ significantly by commodity and by region. FAO also predicted that a broader participation in global trade is an inevitable component of most countries' national trade strategies, but that the process of opening to trade, and its consequences, will need to be appropriately managed if trade is to work in favour of improved food security outcomes (FAO, 2015).

The increase in trade has been largely stimulated by the international trade liberalization, which was initiated by the General Agreement on Tariffs and Trade (GATT) and its successor "Marrakesh Agreement", which was signed in 1994 and led to the establishment of the World Trade Organization (WTO) on 1st January 1995. While early efforts to liberalize agricultural trade mainly focussed on tariff reductions, WTO also addressed non-tariff measures. In particular, unjustified sanitary and phytosanitary (SPS) measures were brought under stricter disciplines, with a view to prevent the use of protectionist trade policy instruments (Crivelli and Gröschl, 2012).

Trade, and especially international trade of agricultural commodities, may function as a pathway for the movement and spread of pests, diseases and food safety risks to areas where they were previously unknown. Countries usually want to protect themselves against such risks by establishing SPS measures to regulate the import of agricultural commodities. Countries may, however, introduce unjustified SPS measures in order to protect their own producers and food industry from competition. The "*WTO Agreement on the Application of Sanitary and Phytosanitary Measures*" (SPS Agreement) sets a number of rules which attempt to prevent the establishment of SPS measures that are discriminatory and unjustified and can act as a protectionist device. The SPS Agreement requires that SPS measures are based on scientific principles and encourages in particular the development of SPS measures based on international standards ("harmonization").

Pests and diseases as well as food safety risks of agricultural commodities are a technical subject. The WTO does not possess the necessary technical expertise to set the relevant international standards, guidelines and recommendations that are required for international trade. Instead, the SPS Agreement explicitly recognizes the scientific and technical competence of three international standard-setting organizations to do so:

- the World Organization for Animal Health (OIE) for animal health,
- the International Plant Protection Convention (IPPC) for plant health, and
- the Codex Alimentarius Commission (Codex) for food safety issues.
-

These three organizations and programmes cooperate with the WTO on SPS issues.

In 2014, the contribution of Working Group II of the Intergovernmental Panel on Climate Change (IPCC) to the Fifth Assessment Report stated that "*human interference with the climate system is occurring, and climate change poses risks for human and natural systems*."[1] Risks are extremely likely to occur in rural agricultural systems, in particular. They are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development (IPCC, 2014b). There is a high confidence by the IPCC that major future rural impacts are expected in the near term and beyond. These impacts will particularly affect water availability and supply, food security, and agricultural incomes, including shifts in production areas of food and non-food crops across the world (IPCC 2014a). In addition, the IPCC predicts that the continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems (IPCC, 2014b).

The impact of climate change on agricultural production is generally considered to be negative, with countries in lower latitudes suffering the most from changes in climate (IPCC 2014a). The IPCC estimated that for major staple crops such as wheat, rice and maize in tropical and temperate regions, climate change without adaptation is projected to negatively impact aggregate production (IPCC, 2014a). This is estimated for local temperature increases of 2°C or more above late-20th-century levels. However, some individual areas may benefit from climate change in terms of agricultural production. These increases, however, are not believed to be sufficient to compensate for the yield losses anticipated on a world-wide scale.

There has been abundant literature on the impacts of different climate scenarios on agriculture and yield expectations (IPCC, 2014a). However, many studies are focussing on abiotic factors such as temperature increases and water availability on plant and animal physiology. Studies on biotic factors, such as climate change impacts on pests and diseases and their effects on agricultural production, are much less analysed

[1] Citation from: IPCC 2014; p 3.

(Breukers, 2010). Pests and diseases of animals and plants as well as food-borne diseases, for example, may be considerably affected by climate change and, in combination with ecosystem changes, may have substantial impacts on agricultural productivity. In addition, biotic factors, such as pests and diseases and their changed interactions with ecosystems, as well as the SPS measures taken by countries to protect themselves against changing risks, may have considerable effects on trade patterns.. Considering that international trade has been identified as a major mitigating element to counter negative impacts of climate change on food security (Schiavone 2010), it is essential to analyse in detail the potential difficulties climate change and SPS measures present to international trade, especially of agricultural commodities.

2. The SPS Agreement and its Impact on the International Trade of Agricultural Commodities

The globalization of agricultural trade has been increasing considerably over recent decades. The trade of agricultural commodities provides countries with possibilities to complement their food supplies, and to increase their revenues through access to new export markets. Trade may, however, not only have positive repercussions. Globalized trade may also be the cause for the international distribution of pests and diseases of humans, animals and plants, resulting in substantial health and economic damages. To prevent this international dissemination of pests and diseases, countries often establish SPS relevant legislation.

Box 1: WTO Definition of SPS Measures

"A SPS measure is any measure applied

- *to protect animal or plant life or health within the territory of the Member from risks arising from the entry, establishment or spread of pests, diseases, disease-carrying organisms or disease-causing organisms;*
- *to protect human or animal life or health within the territory of the Member from risks arising from additives, contaminants, toxins or disease-causing organisms in foods, beverages or feedstuffs;*
- *to protect human life or health within the territory of the Member from risks arising from diseases carried by animals, plants or products thereof, or from the entry, establishment or spread of pests; or*
- *to prevent or limit other damage within the territory of the Member from the entry, establishment or spread of pests."*

(SPS Agreement Annex A; WTO 1995)

Such SPS legislation usually describes the exact technical requirements a commodity must fulfil before it is allowed to enter the country. Appropriate SPS legislation not only protects a country from the introduction of pests, diseases, and food-borne hazards it also strengthens consumer confidence.

SPS legislation may at times exceed its original purpose, to prevent the introduction of pests, diseases and food-borne hazards into a country, and may be used to prevent the introduction of the commodity itself with the purpose of protecting the competitiveness of domestic producers. In such cases, the use of SPS legislation is unjustified and constitutes a disguised restriction on international trade. .

To prevent this, in 1995 the SPS Agreement was established, implementing a multilateral framework of rules and disciplines to guide the development, adoption and enforcement of sanitary and phytosanitary measures in order to minimize their negative effects on trade (WTO, 1995).

The multilateral framework described in the SPS Agreement is based on a number of principles, of which the most relevant for climate change related considerations are:

- International Harmonization
- Equivalence
- Risk Assessment (scientific base)
- Adaptation to Regional Conditions

2.1. International Harmonization

One of the major aims of the SPS Agreement is that countries use harmonized SPS measures when trading. Article 3 of the SPS Agreement provides that countries shall base their SPS measures as much as possible on international standards, guidelines or recommendations developed by the relevant international standard setting organizations i.e. Codex, OIE and IPPC, (WTO, 1995). The purpose of promoting international harmonization is that the application of internationally agreed standards, guidelines or recommendations will automatically constrain arbitrary or unjustified discrimination between trading partners. In order to achieve the aim of international harmonization it is important that the body of international standards, guidelines or recommendations developed by the OIE, IPPC and Codex is sufficiently large and covers a wide palette of products and traded commodities.

The development of international standards, guidelines or recommendations relies very much on the detailed scientific knowledge of the pests, diseases and food-borne hazards they aim to address. As climate change affects the biology, epidemiology and pathogenicity of many organisms in an unpredictable way, this makes the adoption of international standards, guidelines or recommendations more difficult.

2.2. Equivalence

The SPS Agreement allows for an alternative way to mitigate SPS risks that also facilitates trade. Importing countries may agree to accept that various measures can be used to fulfil a particular regulatory goal, as long as such measures meet the importing countries' appropriate level of protection (Box 2). The acceptance of alternative measures allows exporting countries to maintain measures that are technically and economically feasible for them, whereby, increasing their capacity to trade internationally. This principle is enshrined within the SPS Agreement as "Equivalence" (WTO, 2018).

Box 2: SPS Agreement definition of "Appropriate Level of Protection" a.k.a. "Acceptable Level of Risk"

"The level of protection deemed appropriate by the Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory.

NOTE: Many Members otherwise refer to this concept as the "acceptable level of risk".

(SPS Agreement Annex A; WTO 1995)

The acceptance of an equivalent measure is in many cases determined through bilateral negotiations between the importing and the exporting country. The exporting country usually provides appropriate science-based and technical information to demonstrate that its measure achieves the appropriate level of protection identified by the importing country (WTO, 2004). In the case of pests, diseases and food-borne organisms, this information will often be based on an organism's distribution and epidemiology. These are, however, closely affected by climatic conditions. Variations in the distribution and epidemiology of organisms caused by climate change may occur rapidly and may alter established mitigation measures, such as pest free areas for fruit flies, or make them obsolete.

2.3 Risk Assessment

The requirement that countries establish SPS measures on the basis of an appropriate risk assessment is one of the cornerstones of the SPS Agreement. If countries establish measures, which do not conform to international standards, guidelines or recommendations, they must scientifically justify their measures if requested. This justification must be carried out through an appropriate risk assessment.

Box 3: SPS Agreement definition of "Risk Assessment"

For food safety:

"*The evaluation of the potential for adverse effects on human or animal health arising from the presence of additives, contaminants, toxins or disease-causing organisms in food, beverages or feedstuffs*"

For pests and diseases:

"*The evaluation of the likelihood of entry, establishment or spread of a pest or disease within the territory of an importing Member according to the sanitary or phytosanitary measures which might be applied, and of the associated potential biological and economic consequences*"

Since risk assessment is a complicated scientific process, the standard setting organizations OIE, IPPC and Codex have developed a suite of risk assessment standards to facilitate the risk assessment activities of national authorities:

- IPPC
  - ISPM 02 Framework for pest risk analysis (IPPC, 2016a)
  - ISPM 11 Pest risk analysis for quarantine pests (IPPC, 2017a)
  - ISPM 21 Pest risk analysis for regulated non quarantine pests (IPPC, 2016b)
- OIE
  - Terrestrial Animal Health Code - Chapter 2 - Risk Analysis (OIE, 2017a)
  - Aquatic Animal Health Code - Chapter 2 - Risk Analysis (OIE, 2017b)
- Codex
  - Working Principles for Risk Analysis for Food Safety for Application by Governments (Codex Alimentarius) (FAO/WHO, 2007)

These standards include detailed advice on how, for example, the introduction potential for an organism should be assessed. Such assessments include the analysis of climatic factors, the availability of potential host range and the occurrence or absence of predators to demonstrate if an introduced pest or disease can establish permanently.

Since food safety, animal and plant health are largely dealing with biological threats and the scientific knowledge about biology of many organisms is still insufficient, the scientific evidence required to conduct a full-fledged risk assessment may sometimes be missing. This insufficient biological knowledge may be further amplified by climatic variability and extreme weather events. This may lead to risk assessments being more dependent on expert judgement and less based on facts, resulting in the establishment of more provisional SPS measures.

2.4 Adaptation to Regional Conditions

Pests and diseases of animals and plants are not uniformly distributed around the world. In addition, the prevalence of pests and disease is very much dependent on the area of its evolutionary development and how favourable ecosystem conditions are to the organism in question: the prevalence of hosts, absence of major predators and the appropriate climatic and environmental conditions to develop. Consequently, in many cases the distribution of pests and diseases is very diverse.

Box 4: SPS Agreement definitions of "Pest- or disease-free area" and "Area of low pest or disease prevalence"

Pest- or disease-free area:

"*An area, whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific pest or disease does not occur.*
NOTE: A pest- or disease-free area may surround, be surrounded by, or be adjacent to an area - whether within part of a country or in a geographic region which includes parts of or all of several countries - in which a specific pest or disease is known to occur but is subject to regional control measures such as the establishment of protection, surveillance and buffer zones which will confine or eradicate the pest or disease in question."

Area of low pest or disease prevalence:

"*An area, whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific pest or disease occurs at low levels and which is subject to effective surveillance, control or eradication measures.*"

As pests and disease are not distributed uniformly around the world – many areas are free from certain pests and diseases –the least trade restrictive and most secure way of trading products is often to import certain commodities from geographic areas that are free from a specific pest or disease. The SPS Agreement specifically promotes this concept in its Article 6[2], which states that countries shall recognize the concept of pest- or disease-free areas and areas of low pest or disease prevalence (WTO, 1995; WTO 2008).

[2] Article 6 of the SPS Agreement provides that countries "*shall ensure that their sanitary or phytosanitary measures are adapted to the sanitary or phytosanitary characteristics of the area - whether all of a country, part of a country, or all or parts of several countries - from which the product originated and to which the product is destined*" (SPS Agreement Article 6.1. WTO, 1995.).

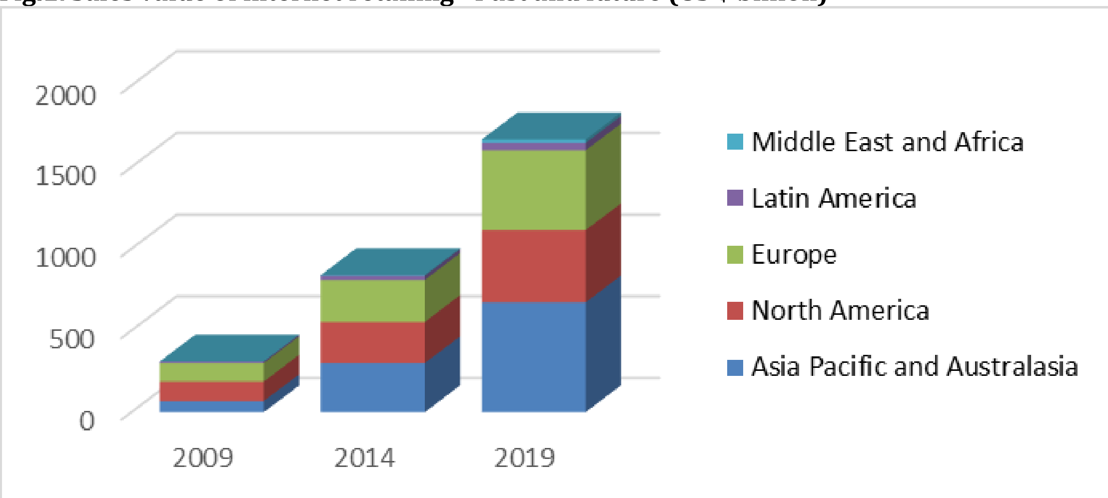
The provisions of the SPS Agreement concerning adaptation to regional conditions may be strongly affected by climate change. Regional climatic conditions may change substantially, causing the introduction and spread of new organisms or leading to the occurrence of new hosts for specific pests, diseases or food-borne organisms. A changing climate may thus lead to the abolition of carefully and expensively established and maintained pest- or disease-free areas.

2.5 Trends

The trade of agricultural commodities is likely to continue to increase in the near future. This will be as a result of the development of new trade routes, increased market access activities and also, increasing volumes of existing trade patterns. There are, however, a few visible trends, which may have considerable impact on SPS related activities by countries and international organizations.

One of the major developments over recent years, and a trend which is most likely to increase in the future is E-commerce. There is increasing popularity for consumers to buy products, such as, flower seeds, online. Overall, internet sales more than tripled since 2009 and are predicted to increase even more (see fig.1). E-commerce with regard to seeds and plants has increased and, in many cases, online traders of plants and plant products do not take a customer's location, and its pest and disease status, into account before agreeing to a sale and shipping their purchases to them (IPPC, 2017b).

Fig.1: Sales value of internet retailing - Past and future (US $ billion)



Source: from Medina 2017 (original source Euromonitor International)

Analyses by international organizations, such as World Customs Organization (WCU) (Medina, 2017) and the IPPC (IPPC, 2017b) show that although E-commerce does present opportunities for the international trading system. However, it also incorporates considerable challenges in relation to SPS considerations, both as a result of the fragmentation of trade patterns and the dissemination of plant species to new areas and countries. Climate change may contribute to this increased E-commerce as warmer temperatures, particularly in the northern hemisphere, may lead to increased purchases of subtropical species via the internet.

Another trend to be observed in relation to trade and SPS measures is the complexity of processing steps and their geographical location. In the past, many products were produced and further processed in one country. Today this picture is changing, especially with relation to plants, for example, seed production may be divided between different countries. Parental lines may be produced in one country, then shipped to another country with better climatic conditions to produce basic seed and then shipped to a third country to produce hybrid seed. In between there may be further shipping involved in order to conduct cleaning and packaging of the seed batches, before the final batch is sent to the destination market which may be in yet another country. Such a complicated step by step processing system makes it difficult to comply with all SPS measures in the countries involved, because at the time of seed production, the destination countries and their phytosanitary import requirements may not be known, especially if a number of years pass between production and export to the final destinations (IPPC, 2017c).

It is expected that such a diversification with regard to primary production and secondary processing will continue in the future and that climatic conditions in particular play an important role in shaping these trade patterns. As in the case of the seed trade, one could expect that this development will have profound consequences on how SPS measures are established for products produced under such conditions. It may trigger an international development, in which the SPS certification of establishments involved in the production chain are more relevant than country based import requirements.

3. Climate Change and its predicted impacts on agriculture and trade flows

In 2013, the IPCC stated that the:

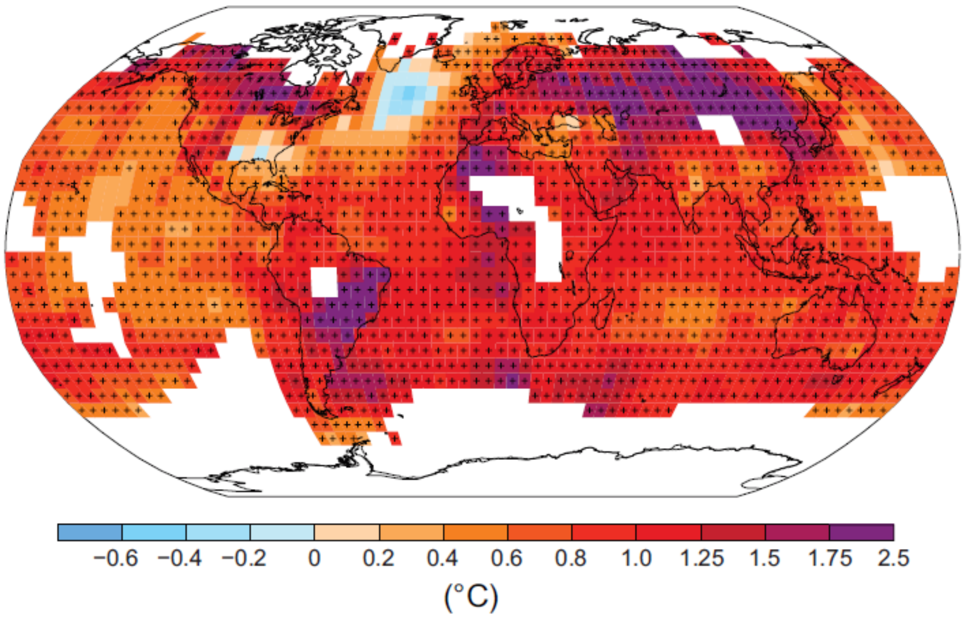
> *[w]arming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.*[3]

The IPCC also declared that each of the last three decades has been successively warmer at the earth's surface than any preceding decade since 1850 and that the northern hemisphere between 1983–2012 was likely the warmest 30-year period of the last 1400

[3] Citation from IPCC, 2013, p. 4.

years. From 1901 to 2012, the period when calculation of regional climatic trends is sufficiently complete, almost the entire globe has experienced surface warming (see Fig.2), (IPCC, 2013).

Fig.2: Map of the observed surface temperature change from 1901 to 2012



Source: IPCC, 2013

The production of anthropogenic (i.e. originating in human activity) greenhouse gas emissions caused a mean surface warming to be in the range of 0.5°C to 1.3°C over the period 1951 to 2010 (IPCC, 2013). This is, however, just the beginning. Scenarios for future global temperature developments are predicting even steeper increases in temperatures. This will depend very much on future emissions of greenhouse gases, as future emissions will continue to cause further warming and changes in all components of the climate system (IPCC, 2013). Although it is not possible to predict future climate changes exactly, like the weekly weather forecast on a weather channel, assessments show that depending on the future extent of anthropogenic greenhouse gas emissions, a number of scenarios are possible (see fig. 3).

These scenarios focus very much on different categories of greenhouse gas emissions. According to the IPCC (IPCC, 2013), global surface temperature change for the end of the 21st century is likely to exceed 1.5°C (relative to 1850 to 1900) for all greenhouse gas emission scenarios except the scenario in which greenhouse gas emissions peak between 2010-2020, with emissions declining substantially thereafter (RCP2.6 scenario - Representative Concentration Pathways 2.6). All other greenhouse gas emission scenarios, in which the greenhouse gas emissions peak later, or are not declining at all will lead to substantially higher temperatures by the end of the 21st century, (IPCC, 2013). Consequently, the international community decided with the adoption of the "Paris Agreement" under the United Nations Framework Convention on Climate Change (UNFCCC) to:

> *[hold] the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.*[4]

In order to achieve this goal, the Paris Agreement set the aim to reach global peaking of greenhouse gas emissions as soon as possible, (UNFCCC, 2015). Already now, however, there are indications that the agreed greenhouse gas emission reductions of the Paris Agreement are not sufficient to keep global warming below the 2 °C above pre-industrial levels and it seems to be likely that we will face a temperature increase to 3 °C above pre-industrial levels by 2100 (UNEP, 2016).

3.1 General Impacts

Plants are the life form on earth on which all other species live on. Regardless of what is on our plates every day, there is one constant - the food we eat is directly or indirectly derived from plants. With their ability to metabolize minerals and to catch light energy, transform it through photosynthesis and store it in the form of carbohydrate molecules, plants provide all other life on earth with the nutritional necessities and oxygen to survive and further develop. There are over 350 000 known species of plants on this planet (BGCI, 2013), and every year on average 2000 new species are scientifically described (Willis, 2017).

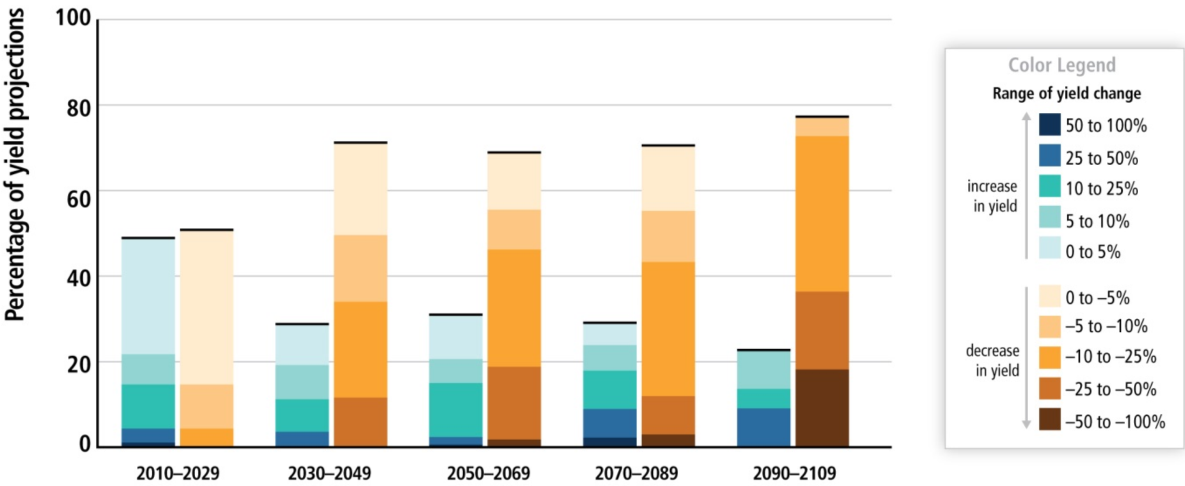
The ability to conduct photosynthesis is also the main reason why plants, and consequently agricultural production, will be extremely sensitive to climate variations and be severely influenced by climate change. In order to transform light energy into carbohydrate molecules the plant needs light energy, carbon dioxide and water. The chemical process also requires the appropriate temperatures, high or low ambient temperature extremes, in particular, can inhibit photosynthesis. Consequently, the increase of surface temperatures in many regions of the world will lead to impacts on food and agriculture supply. Shifts in production areas of food and non-food crops around the world will occur, (IPCC, 2014a). Heat and drought stress will severely affect plant production in some areas of the world and will also be a cause for food security issues which may ultimately lead to migration and conflict, (IPCC, 2014a).

It is predicted that climate change will reduce the production of the major staple crops around the world (see fig.3). For the major crops, wheat, maize and rice, it is predicted that climate change without adaptation will negatively impact production for local temperature increases of 2°C or more. Benefits in crop production may occur for some areas of the world, however, projected impacts vary across crops and regions and

[4] Citation from UNFCCC, 2015, Article 2 (1a).

adaptation scenarios, with about 10% of projections for the period 2030–2049 showing yield gains of more than 10% and about 10% of projections showing yield losses of more than 25%, especially in lower latitude locations (IPCC 2014a).

Fig.:3: Summary of projected changes in crop yields, due to climate change over the 21st century



Source: IPCC, 2014a; p.18

While there has been extensive work undertaken with regard to crop production and potential climate change impacts on yields, less work has been done on animal production. Animal production is also affected by climate change. Potential impacts on animal production are primarily caused by climate change impacts on the amount and quality of feed crops and forage, water availability, animal reproduction, growth and milk production impacts caused by heat stress, as well as disease susceptibility and occurrence, biodiversity loss and changes in agro ecological zones (Rojas-Downing *et al.*, 2017). Climate change effects on animal production will be especially pronounced in arid and semi-arid locations of the world and are also expected to negatively affect the nutritional content of livestock products, primarily because of pathogens and diseases in feed and the animals (Rojas-Downing *et al.*, 2017). These effects are considered to be specifically caused by higher temperatures and the connected heat stress of animals as well as the reduced availability of water (Rojas-Downing *et al.*, 2017).

As described in previous paragraphs the impacts of climate change on agriculture and livestock production will very much depend on the regional circumstances. While it is predicted that high-latitude locations may benefit in the medium future, low-latitude locations are predicted to suffer most from climate change related impacts on agriculture (IPCC, 2014a). Also, intra-regional differences in climate change impacts may occur. International trade will offer a possibility to adapt to these challenges by providing a means to bridge differences in demand and supply of agricultural products (WTO/UNEP, 2009). This may lead to new trade flows from locations which can provide agricultural products to countries which suffer most from the shortage of them. In addition, in cases where crop production for specific species shifts according to climatically changed conditions, trade routes for these species will also change. Consequently, the IPCC predicts that climate change will increase international agricultural trade volumes in both physical and value terms (IPCC, 2014a).

3.2. Specific SPS Related Impacts of Climate Change

Many of the projections relevant to climate change and crop or animal production and productivity are focussed on the main parameters influencing plant or animal physiology, such as temperature, carbon dioxide and water availability. Indirect factors, such as increased susceptibility to pests and disease as well as the geographical shift of pest and disease distribution patterns and their secondary impact on plant and animal production, have featured much less in modelling crop yields. It is, however, important to connect the range of climate change-related variables (extreme events and changes in precipitation, temperature, and CO_2) with indirect factors such as the establishment and spread of pests, vectors, and pathogens, because they will negatively impact production systems (IPCC, 2014a). Climate change impacts on pests and diseases and food borne risks can be extremely complex and diverse as the following chapters demonstrate.

3.2.1. Impacts of climate change on plant health

Plant health is not an exactly defined discipline or concept, but may have a multitude of meanings and connotations. It has, however, been used very much as a technical term for issues related to plant hygiene and international plant trade (Döring *et al*., 2012). In 2016, the International Plant Protection Convention (IPPC) states that:

> *plant health …is usually considered the discipline that uses a range of measures to control and prevent pests, weeds and disease causing organisms to spread into new areas, especially through human interaction such as international trade.*[5]

It should be clarified that the international plant health community does not specifically talk about "pests and diseases" but generally about "pests". In this context, the term "pest" has been defined by the IPPC to mean "*any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products*[6]". Under this definition, pests may include insects, bacteria, fungi, nematodes, viruses and any other organism that can directly or indirectly be injurious to plants, such as weeds.
The capacity of agricultural crops to react to the challenges of climate change will also depend very much on their ability to respond to threats posed by biotic factors such as plant pests. Plant pests are usually a part of the ecosystem in which they occur and have developed together with their hosts over millennia. Evidence for this coevolution has

[5] Citation from IPPC 2016c, p.131.
[6] Citation from IPPC 2017d, p.15.

been especially recognized for plants and their pests (Woolhouse *et al*., 2002) and has lead in many ecosystems and over time to a stable balance between hosts and pests. Problems arise when ecosystems are disturbed by factors such as high temperatures, strong storms with physical plant damages, the lack or excess of water or other exceptional conditions (forest fires). In such cases, the host plant is weakened and disease expression or infestation can be much more severe than under stable conditions.

Another scenario, which is more serious, is the introduction of new pests into an ecosystem. In such cases, the introduced pests have not evolved with the new host species, consequently, the host species may not have acquired a defence mechanism against the pest. In addition, natural enemies of the pest may be lacking and the outcome is quite often extremely serious. In many cases the pest kills its host and damages to the ecosystem or agricultural production are significant. There are many examples in which pests that were not considered serious in their original location, caused absolute destruction in a new ecosystem (see Box 5 for case study).

Box 5: Case Study: Introduction of Pine Wood Nematode into Japan

An example of how the pathogenicity of a pest can change once introduced into a new environment, was the introduction of the pine wood nematode, *Bursaphelenchus xylophilus* (Steiner & Buhrer) into Japan in the early 1900s. The pine wood nematode is not considered to be a serious pest in its native North America (Wingfield *et al*., 1984), however, in Japan, it spread throughout the country causing devastating damage to pine trees in the form of pine wilt disease. In 1979, annual losses of pine wood caused by the nematode were counted to be 2.4 million m^3 (Mamiya, 1988). In the last three decades, the disease has spread from the southwest and central parts of Japan to the northeast and to pine forests distributed at higher elevations (Mamiya & Shoji 2008). This may be an indication of climate change effects.

The environment influences plants and their pests both directly and indirectly. Consequently, changes in the climatic conditions will have significant effects on these plants and their associated pests. Changes in temperatures, water availability, precipitation, carbon dioxide concentration, extreme weather events and ozone levels do affect plants and pests and may lead to biological interactions, which would not happen under stable circumstances. There are a number of ways how climate change can influence pests and this may happen through different factors and their interactions: through changes caused either by the host plants, or through direct changes to the pests and environmental changes in the ecosystem. However, there is a further factor that influences the pest/host relationship in times of climate change - man and its management of pests in crop production and green spaces. (Breukers, 2010).

Direct impacts on pests

Conceivably, the direct effects of climate change on pests should be at the forefront of any investigation. Pests, be it insects, fungi, bacteria, viruses, weeds or any other organism will be influenced by changes in climatic conditions. Insect pests have short life-cycles and are therefore, very sensitive to temperature variances, even a small change in climate has the potential to influence their distribution and abundance (Kinnunen *et al*., 2013). Here temperature plays a major role in the occurrence and severity of pests. For example, warming temperature in temperate locations may allow pests to increase their survival potential and their population sizes. An important aspect of insect development is their ability to conclude a certain number of generations per year, which varies both between species and geographically within one species. For example, in colder regions the number of generations that can be completed is limited by the length of the growing season (Lange et al., 2006). A study in Norway showed that the European spruce bark beetle (*Ips typographus*) developed not just one but two generations per year due to warming and that this shift may have profound effects on the spruce forest ecosystem and on forestry in Norway. It worsens the situation that Norway spruce is probably more susceptible to beetle attacks later in the summer than during the current flight period in mid-May (Lange *et al*., 2006).

The warming of temperate areas may lead to the situation that pests extend their distribution into previously unhospitable areas. An example of this is the Old World bollworm (*Helicoverpa armigera)*, which considerably increased its distribution in the United Kingdom from 1969-2004 and at the northern edge of its range in Europe (FAO, 2008a). Another example is the oak processionary moth (*Thaumetopoea processionea),* which has extended northward from central and southern Europe into Belgium, Netherlands and Denmark (FAO, 2008a).

Modelling studies have also confirmed the possibility of further changes in pest distribution as a result of climate change. For example, the range and distribution of two important lepidopteran forest defoliators, the Nun moth (*Lymantria monacha*) and the Gypsy moth (*Lymantria. dispar*) were simulated with CLIMEX-modelling software, with and without climate change scenarios (Vanhanen, 2008). It was found that, under the climate warming scenario, both species demonstrated a northward shift in distribution range of approximately 500–700 km. The southern edge of the ranges, however, also retracted northwards by 100–900 km (Vanhanen, 2008). This change in the distribution of pests may have considerable effects on international trade and SPS measures.

Climate change impacts on plants and their interaction with pests

Climate change does not only impact pests directly, but also has impacts on their hosts which will in turn contribute to pest development. Changes in temperature and humidity could affect the susceptibility of certain plants to pests (Breukers, 2010) and may consequently lead to an increase in pest occurrence. Extreme weather conditions, in particular, such as extreme heat, drought and extreme storm damage may lead to infections or pest infestation at epidemic levels. Changes in the physiology of plants, due to climate change may also increase the population of some species not currently recognized as pests. Most importantly, climate change is very likely to enhance the suitability of certain areas to non-native pests and pathogens, many of which may be introduced unknowingly on infected propagation material (Tubby & Webber, 2010). In addition, the distribution of plants is very likely to shift due to climate change. The shift in cropping regions of the world will also affect the international trade of plants, changing global trade patterns, (IPCC, 2014a). Since global trade in plants and plant products is a recognized pathway for the accidental introduction of pests it seems probable that pest distributions may change even faster due to the shifted trade patterns of plants and plant products.

Climate change impacts on ecosystems and their interaction with pests and hosts

The impacts of climate change on ecosystems and their consequential interactions and impacts on pests is perhaps the least understood component in the interactions between pests, hosts, environments and man. Modelling for climate change impacts on pests, such as the CLIMEX model (Southerst & Maywald, 1985), does not usually incorporate certain limiting abiotic and biotic factors, such as soil type, salinity, competing pests, pest interactions and weed impacts and so on. Consequently, the prediction of whether a pest can establish itself in a certain area depends largely on climatic parameters. However, it is reported that a greater variability in temperature and precipitation might change the effectiveness of natural enemies, and consequently biological control agents, in disease or pest suppression (Breukers, 2010). In addition, climate change can affect the synchronicity between growth, development and reproduction between pests and predators, which may lead to a shift in the balance between pests and predators (Breukers, 2010).

Humans and their climate change induced interactions with pests, hosts and the environment

The last, and perhaps the most determining factor in the interactions between climate change and plant health are the actions of humans and their consequences. Humans undertake crop and pest management activities which have direct results on plant health. It is humans that select crops and crop rotation and apply plant protection products or fertilizers. Climate change will affect the uptake, effectiveness and duration of plant protection products, such as chemicals or biological control agents (Breukers, 2010). Finally, humans may also be the determining factor in facilitating the distribution of pests into new locations though trade and tourism related activities. For example, a study of forestry pests found that there are 109 exotic phytophagous species reported to have successfully invaded and established themselves on Europe's woody plants, from both North America and Asia, and more will invade as international trade continues and its volume increases (Vanhanen, 2008).

All in all, it must be said that the diversity of plant pests is so huge – there being thousands of recognized plant pests – that the prediction of which species could possibly have a boost of its pathogenicity, distribution or epidemiology is very difficult if not impossible to calculate or forecast. In addition, many pests will also suffer from climate change because their ecosystems will be damaged if, for example, their host plants cannot survive. The vast diversity of plant pests and their numerous interactions with hosts, ecosystems or their interfaces with humans and their pest management activities make the plant health sector possibly more affected by climate change than animal health or food safety.

3.2.2. Impacts of climate change on animal health

As with plant health, the impacts on animal health caused by climate change are predicted to be considerable. The negative affects on plant production are likely to directly affect animal production systems; impairing animal growth, meat, milk and egg yield and quality, as well as reproductive performance, metabolic and health status, and immune response (Nardone *et al.*, 2010). In addition, expected changes in pathogen and disease behaviour in terms of spread pattern, diffusion range, amplification and persistence in novel habitats (de La Roque *et al.*, 2008) could pose further problems for animal production systems and, in the case of zoonotic infectious diseases[7], could be potentially devastating, (de La Roque *et al.*, 2008). The influence on human health caused by zoonotic diseases may be overwhelming. Climate change may cause vector-borne diseases to shift in distribution because the vectors' ecology and the pathogen development rate within them strongly depend on environmental conditions (Guis *et al.*, 2011). This may lead to shifts to previously unexposed populations of humans and animals, which could have severe or even devastating consequences (Guis *et al.*, 2011). In addition, pathogens may turn more aggressive in settings where the hosts have become more abundant and/or immune-compromised or perform a host species jump, possibly in response to increased contact between different host species (Lubroth, 2012).

In a general study on biological consequences of climate change (Hughes, 2000) four categories were identified:

- Effects in physiology
- Effects on distributions
- Effects on phenology
- Adaptation

Although the categorization was undertaken in general for species and communities it can nevertheless, also be applied for animal health purposes, because they equally apply to both the animal pathogens and their vectors (de La Roque *et al.*, 2008).

[7] zoonosis = an infection or disease that is transmissible between animals to humans under natural conditions

Box 6: Case Study: Bluetongue extension and climate change

Bluetongue (BT) is a viral disease of ruminants transmitted by biting midges (*Culicoides* spp.). The disease can replicate in all ruminants, but severe clinical signs are usually restricted to certain breeds of sheep and some species of deer. BT has been responsible for large-scale sheep mortality and was previously classified as a category "A" disease and, therefore, notifiable to the OIE.

BT is considered by many to represent one of the most plausible examples of climate change driving the emergence of a vector-borne disease, because it has circulated on Europe's fringes for decades – in sub-Saharan Africa, Turkey and the Middle East - without making major incursions into Europe despite favourable wind conditions and a prevalent livestock trade. Some isolated outbreaks of BT were confined to southern Iberia, Cyprus and some Greek islands and occurred wholly within the range of the major African-Asian vector *Culicoides imicola*.

In 1998 a dramatic change occurred when an unprecedented series of outbreaks began, causing the deaths of millions of ruminants, and major economic consequences for the region. This emergence of BT has been attributed, in part, to the northwards spread of *C. imicola*, across the Mediterranean basin. The pattern of *C. imicola*'s range extension during this time mirrors the pattern of warming. Originally absent from northern Europe, BT occurred for the first time in North-West (NW) Europe in 2006, transmitted by indigenous species of *Culicoides*.

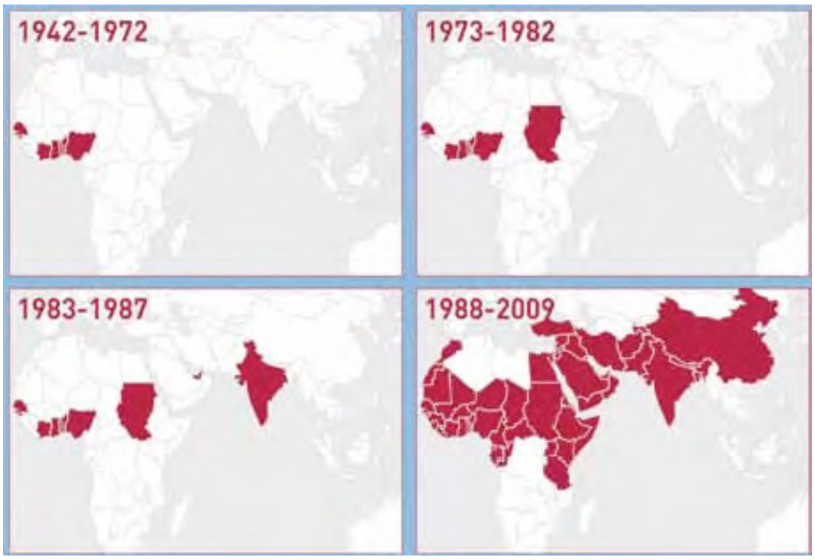
Studies undertaken to investigate the relationship between BT and climate change parameters showed that the occurrence of the disease in North-Western Europe correlated well with warming temperatures. BT incidence in the south of Europe has increased most markedly in areas where temperature has increased by at least 1°C since the 1980s. Bluetongue incidence in northern Europe increased in areas that have warmed by almost 1.5°C, making these areas as warm as infected areas of Italy, Spain and Greece much further south.

Furthermore, modelling predicts that under future-climate conditions, the potential distribution of BTV may broaden further, especially in central Africa, United States, and western Russia.

Effects on distribution are perhaps the most apparent effects observed in animal pathogens and their vectors. The sudden extension of the distribution of bluetongue disease (BT) of ruminants has been widely accepted as an example of climate change induced effects on distribution (Purse *et al*., 2008). In the early 2000's BT extended its range from the fringes of Europe to North-Western Europe (see Box 6). This was seen as a consequence of warming and subsequent development of vector competence of biting midges (*Culicoides* spp.) previously not known to vector the pathogen and pathogen development.

Animal diseases can be separated into vector-borne and non vector-borne diseases. It has been widely assumed that the major risks in relation to climate change and animal diseases are to be linked with vector-borne diseases. Non vector-borne diseases of animals, however, can also be influenced indirectly by climate change factors, for example, infections such as avian influenza may be influenced by changes to migratory routes of wild waterfowl (Dufour *et al*., 2008). Another example may be the changing prevalence of host animals which determine the increased occurrence of certain diseases. Changes in livestock production systems, such as a shift from cattle farming to small ruminants and camel production in increasingly arid and semi-arid locations may be the reason for the spread of "peste des petits ruminants" (see Fig.:4), also known as sheep and goat plague and a major disease of goats and sheep (Lancelot, 2015*)*.

Fig.:4: Known emergence of Peste des Petits Ruminants 1942-2009



Source: Lancelot, 2015

It must be concluded that animal diseases and their vectors are as highly affected by climate change factors as plants and plant pests. Animal pathogens and their vector can be easily distributed by international trade. Changing trade patterns and animal production configurations may influence the international dissemination of dangerous organisms which, in the worst case, may become more aggressive and undertake a host species jump - to humans.

3.2.3. Impacts of climate change on food safety

Climate change will also affect food safety. As in the cases of plant and animal health the climatic impacts on micro-organisms affecting food safety are thought to be substantial. Threats to food safety posed by climate change can be predominantly categorized into three categories:

- Direct effects on food-borne pathogens
- Direct effects on organisms producing myco- or biotoxins
- Indirect effects caused by contaminants, such as chemicals

Food-borne pathogens

In 2014, the IPCC (IPCC 2014a) reported that warmer climate in combination with inappropriate food handling may contribute to increased incidences of food-borne diseases. In particular, the prevalence of carriers of food-borne pathogens and major hygienic pests in the domestic environment, such as flies, cockroaches, and rodents could change in response to climatic changes (IPCC 2014a). In many countries the main food-borne diseases to be concerned about are *Salmonella, Campylobacter* and *E. coli.* In temperate countries, strong seasonal patterns to the incidence of food-borne diseases has been observed and links between ambient temperature and the occurrence of *Salmonella, Campylobacter* and *E. coli* O157 infections, above and beyond any seasonal trend have been demonstrated (Séguin, 2008).

Another food-borne disease is cholera, which is caused by the organism *Vibrio cholera*. The disease is predominantly water-borne, however, food washed or irrigated with contaminated water may serve as the source for food poisoning by cholera (FAO, 2008b). A study undertaken in which a mathematical model interfaced with empirical case data on cholera was applied to the bacterium *Vibrio cholerae* and its disease dynamics in Bangladesh. The results showed that climate plays a pivotal role in modulating the size of outbreaks, with local, regional, and global indices of climate variability showing a link with pathogen transmissibility, (Koelle 2009).

Mycotoxin or biotoxin producing organisms

Mycotoxins are toxins which are produced by certain fungi, mainly species from the genera of *Alternaria*, *Aspergillus*, *Fusarium* and *Penicillium.* Probably the most commonly known mycotoxin is aflatoxin which is produced by *Aspergillus flavus* (A+fla = Afla) and which is highly carcinogenic. Fungi that are producing mycotoxin are highly dependent on appropriate temperatures and water availability. Favourable temperature and water activity are also essential for mycotoxin production (Patterson & Lima, 2010). Mycotoxin production is not only possible during the growing period (pre-harvest) of the plants which have been infested by the relevant fungi, but is also continuing after the plants or seeds have been harvested (post-harvest) and are put into storage. Climate change may actually lead to a shift in the occurrence of certain mycotoxin producing fungi. Cool and temperate climates may see an increase in aflatoxin incidence due to increased *Aspergillus* occurrence while tropical countries may experience a decline because temperatures are getting too hot for *Aspergillus* (Patterson & Lima, 2010). The major problem with the climate change interactions on the fungal growth and mycotoxin production is the fact that mycotoxins may contaminate staple cereals such as wheat or corn (Medina *et al*., 2017) which have an enormous importance for food security.

Biotoxins (also called phycotoxins) are mainly a marine related problem and are produced by certain phytoplankton species. They can accumulate in various marine species such as fish, crabs or filter feeding shellfish such as mussels, oysters, scallops and clams. They usually do not cause adverse effects on the shellfish itself, but when sufficient amounts of contaminated shellfish are consumed by humans this may cause severe intoxication. There have been reports that the frequency of toxic algae blooms has been increasing in recent years and that there seem to be new marine toxins appearing in areas that are heavy producers of seafood (Botana, 2016). This increase and appearance of new toxins may be linked to climate change factors. The problems of biotoxins is not limited to marine environments also the quality of lakes used for water supply could be impaired by the presence of algae producing toxins (IPCC, 2014a).

Contaminants and residues

Climate change will also affect the contamination of food sources with chemicals, such as plant protection product residues. Through climate change induced altered agricultural practices and possible increased pest pressures as a result of rising temperatures and extreme weather events the use of plant protection products may be intensified. In cases of inappropriate application or storage of such plant protection products or veterinary drugs this may lead to excessive residues and acute food safety risks.

4. Flexibility of the International Regulatory Framework in Dealing with Climate Change Related SPS Matters

The current international regulatory framework with regard to SPS matters is basically composed of the main international agreements and organizations:

- SPS Agreement
- IPPC
- OIE
- Codex

Each of these organizations and programmes has a role to fulfil to help national authorities to protect their territories against animal and plant pests and diseases and food safety risks, while ensuring that trade is not unduly and unjustifiably hindered. Beside these main international agreements there are also regional organizations, such as the Regional Plant Protection Organizations or the OIE Regional Commissions that aim to support the functions of the IPPC and the OIE at regional level.

National regulatory authorities dealing with SPS matters may face considerable problems in tackling climate change related issues. These challenges are the benchmark against which to measure the suitability of the international regulatory framework in dealing with emerging climate change issues. The major topics identified to assess the flexibility of the international regulatory framework are:

- International Harmonization
- Equivalence
- Risk Assessment (scientific base)
- Adaptation to Regional Conditions
- Dispute settlement & SPS Committee

In addition to these major topics in the international SPS related framework it should be important to address if countries have the tools to counter threats posed by climate change and to implement the SPS framework appropriately. The themes that need to be discussed in this context would be:

- Surveillance and monitoring
- Contingency and emergency measures
- Capacity building

4.1. International Harmonization

As described in chapter 2.1.1 it is important that the body of international standards, guidelines or recommendations developed by Codex, IPPC and OIE is sufficiently large and covers general principles and frameworks on consumer safety, human, animal and plant health, as well as a wide range of products and traded commodities. These standards should also take climate change related specifications into account. Codex and OIE have, until now, developed a large number of international standards. The IPPC, which started standard setting in 1993, has adopted only a limited amount of standards: as of May 2018, 41 International Standards for Phytosanitary Measures (ISPMs) have been adopted. In addition to these ISPMs the IPPC adopted 24 diagnostic protocols and 31 phytosanitary treatments as annexes to two ISPMs.

It is generally considered that the international harmonization process is relatively flexible to accommodate changes and emerging issues. Standard setting procedures by Codex, IPPC and OIE are based on consensus and foster transparency and a high degree of consultation with all stakeholders concerned. They also provide flexibility and short-cuts allowing standards to be adopted in shorter time frames in case of emerging issues. However, since the consensus-based standard setting processes in the three organizations is dependent on the agreement of all or most of the member states in these organizations, particularly difficult and trade sensitive standards may not be adopted in a timely manner.

4.2. Equivalence

Equivalence had already been identified in chapter 2.1.2 as one of the principles which may be of relevance to climate change considerations. When determining equivalence of measures of systems countries usually conduct bilateral negotiations. These were often challenging in the past, therefore, the SPS Committee decided on guidelines for the determination of equivalence, (WTO, 2004). At this time, the OIE and the IPPC were invited to elaborate guidelines on equivalence of sanitary and phytosanitary measures and equivalence agreements in the animal health and plant protection areas (WTO, 2004). The OIE has adopted such guidelines and added them to their relevant codes (OIE, 2017a; OIE 2017b). The IPPC has also adopted a standard on equivalence (IPPC, 2017e).

Considering that the SPS Committee has adopted a regular agenda item for equivalence considerations and the standards adopted by OIE and the IPPC it appears that the international framework seems to be sufficiently flexible.

4.3. Risk Assessment

The provisions of the SPS Agreement with regard to risk assessment stand at the heart of the international regulatory framework and the need to adopt technically justified SPS measures. The provision has also been at the centre of every major SPS dispute dealt with through a panel and appellate body under the WTO Dispute Settlement procedure. There has been considerable guidance provided through the legal interpretation resulting from dispute settlement. In addition, the international standard setting organizations have adopted standards and guidance with regard to risk analysis and risk assessment.

The very detailed provisions of the SPS Agreement on risk assessment are central to the problems caused by climate change for SPS related issues. The alteration of biological processes caused by climate change will have impacts on anybody carrying out risk assessment work for SPS measures. The underlying reasons for many biological processes under different climate change scenarios are simply not known. Scientific research concerning pests and diseases and their behaviour under climate change is in its infancy. Many organisms which could become plant pests under climate change, such as fungi, bacteria or viruses may not even be scientifically described, yet. Climate change will alter pest and disease distributions and agricultural trade flows in ways which cannot be fathomed (IPPC, 2008).

Without underlying dependable scientific data, a risk assessment becomes speculative or judgemental and the aim to establish scientifically justified, consistent and least trade restrictive SPS measures may turn out to be ineffectual. The SPS Agreement allows for uncertainties in Article 5.7, and provides that countries shall seek to obtain the additional information necessary to complete the risk assessment within a reasonable period of time. This is however, very difficult to achieve when dealing with hypothetical assumptions, which may or may not realize in the way they have been anticipated. In the IPPC, it had been proposed that new and better pest risk assessment procedures that incorporate climate change models would be needed in order to address threats posed by climate change (IPPC, 2008). Some countries were, however, very sceptical if climate change modelling and the knowledge about pest reactions under different climate change scenarios are sufficiently robust to base phytosanitary requirements on them (IPPC, 2008). This uncertainty demonstrates a dilemma for risk assessors. The choice between being "*approximately right or precisely wrong*" (Sutherst, 2008) may lead to precautionary approaches that are overly trade restrictive and SPS measures which may be scientifically justifiable but insufficient and ineffective. There is the danger that the less knowledge is available on climate change in risk assessment the more provisional measures may be taken under Article 5.7 of the SPS Agreement, which would mean that trade restrictions increase (STDF/WB, 2011).

It is clear that risk assessment will stand at the forefront of activities in relation to SPS measures and climate change. Current risk assessment methodologies may not be best equipped to take climate change threats sufficiently into account.

4.4. Adaptation to Regional Conditions

Regional conditions will experience substantial changes caused by climate change. Areas which may not have been suitable for the production of specific crops or infestation by certain pests may become so. When designing pest- or disease-free areas or areas of low pest or disease prevalence for animal and plant pests and diseases, countries would have to take into account threats of introductions, which may be exacerbated by climate change. The important factor in any establishment and maintenance of pest- or disease-free areas or areas of low pest or disease prevalence is appropriate surveillance and monitoring. Consequently, pest and disease surveillance and monitoring should be the most appropriate tools to address climate change issues with regard to regional conditions.

4.5. Dispute Settlement & SPS Committee

The WTO dispute settlement system has been utilized for several SPS related disputes over the last 22 years. Many disputes, such as the *EU - Hormones*[8] case or the *Australia - Salmon*[9] case, have set the jurisprudence for the interpretation of the provisions of the SPS Agreement. The main provisions on dispute settlement of WTO are contained in the "*Understanding on Rules and Procedures Governing the Settlement of Disputes*" which is also called the "*Dispute Settlement Understanding*" or DSU for short (WTO, 1995b). The DSU is a general procedure for the settlement of disputes under WTO and is not specifically designed for SPS purposes. The rulings on a specific dispute obtained under the DSU are obligatory to implement. That makes the DSU a powerful tool and cornerstone in the international trade order.

Since the DSU is a juridical approach to settling SPS related disputes, technical sanitary and phytosanitary issues may not be dealt with at an appropriate technical level. To facilitate the resolution of disputes on a technical level, both OIE and the IPPC have established their own dispute mediation (OIE, 2017a & 2017b) and dispute settlement (IPPC, 1999) procedures. Both are based on technical aspects and rely on voluntary participation of the disputing parties. This makes them ideal to resolve technical misunderstandings and differences in judgement. In cases where the disputes deal with trade policy issues, such as the strength of measures applied, the OIE and IPPC resolution procedures are less efficient since parties will defend their requirements with all means.

[8] For more details see: https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds26_e.htm.
[9] For more details see: https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds18_e.htm.

For example, there has been a case raised under the IPPC Dispute Settlement procedure related to citrus blackspot, which has been ongoing since 2010. In this case the strength of phytosanitary measures continues to be disputed without a resolve in sight[10].

In addition to the WTO DSU, the SPS Committee, which usually conducts three regular meetings per annum, provides the opportunity of countries to raise specific trade concerns (STC) which they believe deserve the attention of the SPS Committee. Altogether, 416 STCs have been raised in the 22 years between 1995 and the end of 2016. Of these 416 STCs 148 were resolved and 32 were partially resolved. This leaves 236 STCs open for which no resolution was reported (WTO, 2017b).

In conclusion, the dispute resolution possibilities for countries are appropriately covered under the WTO, IPPC and OIE. In addition, trade issues can be solved without formal DSU involvement. These resolution options are also applicable to disagreements on measures in relation to climate change and SPS.

4.6. Surveillance and Monitoring

Surveillance and monitoring for pests and diseases is one of the underlying fundamental activities of veterinary and phytosanitary services. Only sufficient surveillance activities can detect newly introduced pests and diseases early enough to allow immediate control and eradication actions, which then may have a chance of success. Surveillance and monitoring is also an important tool in the declaration of pest- or disease-free areas or areas of low pest or disease prevalence, an instrument which usually permits frictionless trade. One of the major components for a strategy to address the dangers of introduction of animal and plant pests and diseases must be surveillance (FAO, 2008a).

In the wake of the highly pathogenic avian influenza outbreaks in Europe and Asia, OIE recommended strengthening animal disease surveillance world-wide and stated that it is important to ensure extensive and optimal surveillance in wildlife and domestic animals and that additional resources are needed for the active search for pathogens in wildlife (OIE, 2014). The IPPC has also focussed much of its work on surveillance. In 2016, a manual on surveillance was produced (IPPC, 2016) under an STDF grant[11] (STDF Project 350). In addition, the IPPC urged its members and Regional Plant Protection Organizations (RPPO) to commit to increased emphasis on plant pest surveillance and to contribute resources for surveillance (IPPC, 2015).

Surveillance and monitoring data can inform risk assessments and reduce their uncertainty. Surveillance is, therefore, one of the major activities to be undertaken and

[10] For more details see: https://www.ippc.int/en/core-activities/dispute-settlement-phytosanitary-disputes//south-africa-and-eu-citrus-blackspot-ds10zaf01/.

[11] See also: https://www.ippc.int/en/publications/86051/.

strengthened to adequately manage risks posed by climate change. Surveillance may not only be an activity undertaken by individual countries only, but there may be the need to undertake surveillance for specific pests and diseases jointly by several countries on a regional or sub-regional level. Surveillance may also be done jointly for animal diseases and food-borne pathogens at the same time (de Balogh *et al*., 2013). In addition, the possibility of utilizing "citizen science" (vigilance) more systematically for the detection of emerging biosecurity threats should be investigated further, (Welvaert *et al*., 2017).

4.7. Contingency and emergency measures

History shows that there have always been outbreaks of animal and plant pests and diseases and food-borne pathogens in new areas. The last 100 years, which saw a dramatic increase in trade and the movement of people have shown a multitude of pest and disease outbreaks. Climate change may accelerate and diversify new outbreaks of animal and plant pests and diseases and food-borne pathogens. It may also cause outbreaks of previously unknown pests or diseases. The only way to deal with these new situations adequately is to detect them early and apply immediate measures to eradicate the threat. Predefined contingency plans and readily available eradication methods assist in the eradication of new threats. In fact, strengthening of rapid response capability will be one necessary measure to fight the effects of climate change, (Sutherst, 2008).

OIE has provided considerable information[12] about animal disease preparedness and the FAO has published guidance on the preparation of contingency plans for a number of animal diseases[13]. The IPPC, however, has not yet addressed the issue of contingency planning in a prominent way. Developing guidance on how new plant pest outbreaks could be eradicated in a timely manner should be a priority task for IPPC in order to strengthen capacity among member countries.

4.8. Capacity Building

We live in a global community. A pest or disease outbreak will not only be of consequence for the country where the outbreak occurs. If not addressed properly it will ultimately affect neighbouring countries or trade partners. The old proverb that "a chain is only as strong as its weakest link" has a particular relevance to the spread of animal diseases, plant pests and food-borne pathogens. This basic understanding of the collaborative need to adapt to climate change related threats requires focusing on strengthening sanitary and phytosanitary know-how and infrastructures through capacity building efforts.

[12] See also: http://www.oie.int/en/animal-health-in-the-world/the-world-animal-health-information-system/national-disease-contingency-plans/.
[13] See also: http://www.fao.org/docrep/004/X2720E/X2720E00.HTM.

Within the SPS related disciplines, the international regulatory framework arranges for some ways to provide capacity building assistance. The Standards and Trade Development Facility (STDF) is a global partnership established by FAO, WTO, the World Health Organization (WHO), OIE and the World Bank Group (WBG) that supports developing countries in building their SPS capacity. It works as a coordination mechanism and knowledge platform and identifies good practice in cross-cutting issues related to food safety, animal and plant health and trade. The STDF has issued publications and briefing notes on - *inter alia*- climate change and SPS risks. The STDF also provides seed funding for the development and implementation of projects that help developing countries meeting the international standards and gain or maintain access to markets.[14] The STDF has, over its 15 years of existence, developed and implemented over 180 SPS projects, often co-funded by partners, bilateral donors and the private sector. The FAO has also implemented numerous food safety, animal and plant health projects and the IPPC has recently increased focus on implementation issues.

Besides the regulatory bodies indicated above, capacity building in SPS disciplines is undertaken by a number of other international and regional organizations. For example, the Centre for Agriculture and Biosciences International[15] (CABI) and the Inter-American Institute for Cooperation on Agriculture[16] (IICA), are particularly active in SPS relevant capacity building. Furthermore, the WBG is committed to helping countries around the world meet the climate challenge as it provides on average close to USD 11 billion a year for projects that increase resilience to climate impacts and reduce emissions.[17] The Global Environment Facility (GEF) also actively supports capacity development with regard to biodiversity conservation and climate change mitigation and adaptation.[18]

The international SPS related regulatory framework provides enough possibilities to assist in capacity building for SPS and climate change related issues. The IPCC in its Fifth Assessment Report (IPCC, 2014a) stated that countries in the lower latitudes will bear the brunt of the climate change disadvantages. This makes the countries in Africa, Asia and Latin America over-proportionately at risk and in need of capacity to mitigate and adapt to climate change related SPS risks. Developing countries need capacity in almost all SPS relevant areas, however, there are a few specific subjects where capacity assistance should focus:

[14] See for more information: http://www.standardsfacility.org/.[15] See for more information: https://www.cabi.org/.
[15] See for more information: https://www.cabi.org/.
[16] See for more information: http://www.iica.int/en.
[17] See for more information: http://www.worldbank.org/en/topic/climatefinance#1.
[18] See for more information: http://www.thegef.org/.[19] Citation from Annex C 1(a) of SPS Agreement (WTO, 1995).

Diagnostic capacity

Diagnostics are a fundamental underlying discipline for SPS related activities, being it testing samples from surveillance or border points. Many developing countries lack the technical capacity to set up and maintain state-of-the-art diagnostic or toxicological laboratories. Pest and disease diagnostics as well as toxicological laboratories are essential to the early identification of pests and diseases as well as food-borne hazards. Reliable testing and diagnostics also facilitate trade flows and avoid trade losses due to misidentifications.

SPS relevant border points

Annex C of the SPS Agreement specifies that SPS control or inspection procedures "*are undertaken and completed without undue delay and in no less favourable manner for imported products than for like domestic products".*[19] SPS border infrastructure is an important component of any well-functioning SPS system. The border inspection is the first line of defence against the unintentional introduction of pests and diseases through trade. The SPS border inspection points also determine the speed and ease at which trade flows can pass. Good SPS border posts with sufficient infrastructure reduce waiting times and the associated costs for operators, to the absolute minimum. In many developing countries, border points need investments in order to face the challenges of climate change and increased trade. This is particularly the case for continental countries with extensive land borders.

[19] Citation from Annex C 1(a) of SPS Agreement (WTO, 1995).

5. Recommendations

The previous chapters outlined the SPS relevant threats posed by climate change to humans, agricultural production, the environment and international agricultural trade. Pests and diseases of animals and plants, as well as food safety hazards, especially food-borne diseases and toxic contaminants, are highly affected by climate change and will spread and intensify if not dealt with by appropriate SPS measures. Since international agricultural trade will be an indispensable tool to counteract food shortages created by climate change in various parts of the world, it is important that SPS measures are sufficiently efficient to maintain a functioning and safe international trading system. We also have to realize that climate change has changed the way in which the SPS relevant authorities at national, regional and international level have to view decision-making processes and competences as we can no longer rely on historical precedents to design for the future actions, (Sutherst, 2008). In order to address these challenges it will be necessary to undertake a number of activities over the next years to counterpoise the SPS threats posed by climate change.

Intensification of Risk Assessment Activities

Risk assessment provides the scientific justification of all SPS measures, also those established by the international standards setting organizations. Risk assessment activities need to be intensified at national, regional and international levels and climate change aspects need to be included into the assessment of SPS risks. In order to be resource efficient, the creation of regional or sub-regional risk assessment networks as fora for collaboration should be considered.

Strengthening Research Activities and Collaboration

Knowledge about the behaviour of pests and diseases under different climatic conditions and in different ecosystems is very limited. In order to be able to include more data into risk assessment activities and to design appropriate SPS measures, more research is urgently needed. Mitigation of and adaptation to SPS relevant climate change threats depends on research. In order to be resource efficient and focussed, collaboration on a regional or international level of SPS and climate change research should be considered.

Intensification of Surveillance and Monitoring

National, regional and international surveillance and monitoring activities of SPS threats should be intensified. Multilateral surveillance programmes should be established especially in developing countries to offset SPS threats.

Undertaking Contingency and Emergency Planning for Plant Pests on International Level

Especially for plant pests, international activities, such as standard and guidance setting for contingency plans and emergency measures must be undertaken. International solidarity to fight serious plant pest outbreaks needs to be established or strengthened.

Raising Efforts for Capacity Building

Because of considerable SPS threats, developing countries will be the most affected by climate change impacts. The generally weak SPS infrastructure in developing countries should be improved, in particular through institutional capacity building and training. Capacity building should focus very much on risk assessment, surveillance, monitoring, diagnostics and border infrastructure. Novel approaches, such as the establishment of regional laboratories or centres of excellence should be explored to save resources and facilitate cooperation.

Mainstreaming SPS Issues into Climate Change Policies

SPS issues in relation to climate change must receive a higher standing in the general policy consideration for climate change. Reinforcing a similar recommendation from 2011 (STDF/WB, 2011), it is essential that SPS policies and strategies are adequately reflected in the Sixth Assessment Report of the IPCC. Political weight and subsequent funding for SPS needs at national, regional and international level will only be available when SPS issues are recognized as an important component of the climate change debate.

6. Conclusions

Trade presents a high potential to leverage challenges, such as regional food shortages due to climate change impacts. International agricultural trade also generates returns for many countries in the world. Several of the UN Sustainable Development Goals (SDGs) can only be achieved through a robust international agricultural trading system, however, climate change may threaten this due to its impacts on plant pests, animal diseases and food-borne pathogens.

To realize the potential of international agricultural trade and to prevent that the benefits of this trade are offset by SPS hazards, it is imperative to strengthen SPS activities with a particular emphasis on climate change. Strengthening SPS relevant infrastructures at national level includes the improvement of SPS relevant border point infrastructures as well as the investment in diagnostic capabilities. Since pests, diseases and food-borne pathogens are especially affected by anthropogenic climate change and the epidemiology of these organisms may change considerably, robust surveillance and monitoring systems are vital at national, regional and international levels.

Knowledge about pests, diseases and food-borne pathogens and their changes in life-cycles, epidemiology and pathogenicity is essential to undertake risk assessments to determine steps and actions to manage these threats effectively and economically. Risk assessments are also needed as credible justifications for trade limiting SPS measures. Any risk assessment, however, is dependent on the underlying scientific data available. In order to increase risk assessment activities at the national, regional and international level, it is also necessary to intensify the knowledge about climate change effects on pests, diseases and food-borne pathogens. More research on climate change effects on pests, diseases and food-borne pathogens is urgently needed and if possible should be undertaken collaboratively to enhance focus and to ensure an optimal use of resources.

Many developing countries will be especially hit by climate change impacts because they are located in areas for which climate change scenarios predict the most severe consequences. Countries in Africa, Asia and Latin America will especially suffer from climate change induced disadvantages. It is particularly exasperating that most countries on these continents face daily struggles in getting their economy and agricultural production to an appropriate level. It is essential that the international community help those countries to overcome the impediments caused by climate change, including by increasing the provision of SPS technical assistance and capacity building. International organizations, such as the FAO and the WBG, standard setting bodies (Codex, IPPC and OIE) as well as global partnerships such as the STDF, should be involved in these efforts, in order for developing countries to benefit from their expertise and ensure international harmonization.

When following the international climate change discussion it becomes very clear that issues, such as pests and diseases are usually only mentioned at the fringe of the adaptation debate. Physical climate change events such as melting icecaps or extreme weather events receive much more attention. However, the international spread of pests, diseases and food-borne pathogens may have much stronger impacts on biodiversity and living conditions on earth. It is essential that these developments are included to their fullest in the international policy consideration for climate change. Political attention and additional funding for SPS needs related to climate change at national, regional and international levels will only become available when the spread of pests, diseases and food-borne pathogens is recognized as a critical component of the climate change debate.

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