2. Changing ecological conditions

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Global food availability heavily depends on the natural resources that make crop production possible. Although precipitation, temperature and soil conditions all create boundary conditions for agriculture, these conditions are not stable, since human interventions in the ecological processes have altered the ecological conditions. The emission of green house gases, the over-exploitation and mismanagement of soil resources, the globalized trade in food products and continuous mono-cropping have all affected the productive potential of ecological systems and rendered them more vulnerable to extreme events.

This chapter considers the claims of changing ecological conditions and their effects on global food availability. First, changing climatic conditions will be discussed, including its drivers and causes, and the potential impact on agricultural production, as well as other side effects. Second, processes of soil degradation will be considered, as these influence both the quantity and quality of agricultural land. The decreasing acreage of suitable land and the productivity decline of available land can have wide-ranging (regional) implications for food production. Lastly, the emerging animal and plant diseases are discussed. Under the influence of globalized trade, climate change and increased mono-cropping, the vulnerability to animal and plant diseases has increased. Three cases serve to illustrate how these diseases affect, and potentially can affect, global food availability: *Avian Influenza*, the cassava mosaic virus, and desert locust plagues.

2.1 Climate change

Climate (the combination of precipitation, sunshine and wind) is the most important growth factor for land-based crop production. Any change in climatic conditions will therefore have a large impact on global food production.

Causes of climate change

The majority of climate scientists agree that climate is changing due to human activity (IPCC, 2001; Oreskes, 2004). Only a small group of scientists reject the claims made by institutes such as the Intergovernmental Panel on Climate Change (IPCC) and the US National Academy of Sciences. These scientists doubt that the causes of climate change lie in increased Green House Gas (GHG) emissions. In this section, the IPCC view will be adhered to (for an overview of climate change critics, read Khandekar et al., 2005).

The IPCC is a group of scientists acting under the umbrella of the World Meteorological Organisation and United Nations Environmental Program (UNEP) that "assesses […] the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation" (IPCC website). The IPCC has concluded that so-called agents cause climate change. Most notable among these agents are increases in the atmospheric concentrations of greenhouse gases and aerosols (microscopic airborne particles or droplets) and variations in solar activity, both of which can alter the earth's radiation budget, and hence the climate (IPCC, 2001).

It is estimated that the temperature of the earth's surface has risen by 0,6 °C since the late 1800s and that Northern Hemisphere mean annual temperatures for three of the past eight years have been warmer than any other year since at least 1400 AD (Mann et al., 1998). The projections of future increases in the earth's temperatures are in the range of 1.5 to 4.5°C for a doubling of CO_2, with a most probable sensitivity of around 3°C (Kerr, 2004). A doubling of CO_2 might be seen by the end of this century. Since 1750, the amount of CO_2 has increased by 31% (IPCC, 2001).

The main emissions of GHG are in the form of carbon dioxides, methane, nitrous oxides and a group of halocarbons. These GHG emissions are produced by industry, agriculture and household activities. Agriculture is responsible for an estimated one-fifth of the GHG emissions (IPCC, 1996). So, when investigating effects of climate change on agriculture, one should take into account the following two processes:

- Agriculture itself contributes to GHG emissions, mainly by emitting GHG such as methane (50% of the world emission), nitrous oxides (70%) and carbon dioxide (20%). Therefore, agriculture will be an important target for mitigation measures that attempt to combat climate change, e.g. as a result of the Kyoto protocol. Mitigation measures can work in two ways: 1) by increasing the sink (e.g. carbon sequestration measures) and 2) by decreasing the source (agricultural emissions). Both will have a huge impact on the structure and type of global land use (McCarl et al., 2001).
- Climate change also has a direct effect on food production, since it alters the conditions for agriculture. This can be in the form of changing precipitation patterns, increased droughts or extreme events. Already, climate change is causing range shifts of natural systems to move to the poles at an average speed of 6.1 km per decade and a mean advancement of spring events by 2.3 days per decade (Parmesan and Yohe, 2003). The effects differ per region.

Changing conditions for food production

Climate change will have a large impact on the conditions for food production. The impact on global food production is diverse and depends on geographical position and crop and soil type (Rosenzweig and Parry, 1994). Possible benefits are:

- Enhanced carbon dioxide assimilation (because the CO_2 content in the atmosphere is higher);
- Increased water-use efficiency of plants (the increased concentrations of atmospheric CO_2 cause plants to partially close their stomates. With their stomates partially closed, plants may lose less water during transpiration);
- Longer growing seasons, especially in the northern hemisphere;
- Increased precipitation.

Possible drawbacks are:

- More frequent and severe droughts, heavy storms and floods.
- More favourable conditions for the proliferation of insect pests, bacteria and fungi pests, and livestock diseases.
- Shorter growth periods due to faster growth, which can lead to shortened life cycles and hampered crop growth.
- Increased flooding and salinization due to a rise in the sea level.

Model studies of the sensitivity of world agriculture to potential climate change suggest that the overall effect of *moderate* climate change on world food production may be small, as losses in some areas are balanced by gains in others. The same studies find, however, that vulnerability to climate change is systematically greater in developing countries – which in most cases are located in lower, warmer latitudes (Rosenzweig and Parry, 1994). Most industrialized countries in the northern hemisphere will gain. The area of productive land will expand in a northerly direction.

Especially Europe, Northern Asia, the USA and Canada will benefit (see Box 1 for regional scenarios). However, some scientists speculate that non-linear behaviour in climate dynamics will cause abrupt changes. For example, the Northern thermohaline seawater flow may cause sudden cooling in Northern Europe if a certain threshold is exceeded (Box 2).

Box 1: Regional scenarios

Africa	Over the next century, East Africa could receive more rain while southern Africa will probably become a great deal drier. Food and water shortages are likely to increase throughout most of Africa, as will floods and storms. Desertification will remain a major threat in arid and semi-arid regions.
Asia	While northern and mid-latitude Asia will enjoy dramatic advances in crop production in a warmer world, South and Southeast Asia will see food production drop due to intolerably high temperatures and declines in rainfall and water supply. In arid and semi-arid Asia, higher temperatures and increased evaporation will reduce rice yields dramatically.
Europe	A changing climate will dry out the south and boost agricultural production in central and northern areas. The arctic landscape will change permanently as ice and permafrost melt, the tundra dries and forests migrate north.
Latin America	The Amazonian rainforests will dry out. If, as seems likely, El Niño events become more frequent in a warmer world, the climate will dry in northern Amazonia, northeastern Brazil and the Peruvian-Bolivian Altiplano. Andean glaciers could retreat further, while Mexico's droughts could become more frequent.
North America	Floods, droughts, storms and landslides are expected to increase in frequency, severity and duration. The Great Plains in the US and the Canadian prairies may face increased drought, but North American food production will rise overall in a warmer world.

(UNEP, 2003)

Mitigation measures: carbon sequestration

Carbon sequestration measures have been proposed to mitigate global warming. Scientists estimate that about 80 percent of terrestrial global carbon stocks are stored in soils or forests and that a considerable amount of the carbon originally contained in soils and forests has been released as a result of agricultural activities and

deforestation (FAO, 2002). Land use can play a major role in the retention of carbon dioxides by preserving and creating forests, through improved grazing, less-intensive tillage, soil regeneration, agroforestry practices and growing energy crops on spare lands (Lal, 2004).

The Kyoto protocol also deals with these types of measures. Carbon emission abatement costs are substantially lower in developing countries than in industrialized ones (McCarl et al, 2001). Via the Clean Development Mechanism (CDM), industrialized countries can invest in carbon sequestration projects in developing countries. Therefore, it seems likely that the economic value of certain types of land use (especially forestry) will rise, which influences the potential area for food production. The value of carbon sequestration in the EU has been between €15 en €30 per ton CO_2 since the introduction of the Emission Trading System on January 1, 2005.[1]

Though carbon sequestration measures seem promising as a tool for mitigating global climate change, critics argue that alternative measures for decreasing GHG emission at source are far more efficient and less costly.

Conclusion

Climate change will have an important impact on agriculture and food production. The areas suitable for food production will change and mitigation measures may compete with food production for land. On a global scale, the gradual climate change may not cause major disruptions in the availability of food, but on a regional scale these impacts could be enormous. Additionally, the increase in extreme weather events makes food production more insecure and the frequency of harvest failures may increase.

Box 2: Abrupt change in the Northern thermohaline flow

The thermohaline circulation is a global ocean circulation. It is driven by geographic differences in the density of seawater, which are controlled by temperature (thermal) and salinity (haline). In the North Atlantic this circulation transports warm and salty water from the tropics to the north. There, during the winter, the water cools and releases heat to the atmosphere, warming the North Atlantic region. Once the water loses heat, it becomes cooler and denser, sinking into the deep ocean. This newly-formed deep water then flows slowly (~0.1 m/s) south, and rises to mid-depths around Antarctica, where it joins the Antarctic circumpolar current. The deep water around Antarctica flows northward into the Indian and Pacific Oceans, returns to the surface, and eventually flows back into the Atlantic. (NCDC, 2004)

The Younger Dryas is seen as an event that predicts possible changes that can happen as a result of the melting of large quantities of ice. The Younger Dryas occurred during the transition from the last glacial period into the present interglacial one (13000-11000 B.P.). During this time, the continental ice sheets were rapidly melting. A pulse of this meltwater flowing into the North Atlantic reduced the salinity and density of the surface ocean, causing a reduction in the rate of deepwater formation. As deepwater formation slowed, less warm water flowed north from the tropics and the North Atlantic became colder. Eventually, the meltwater flux slowed and other changes occurred, causing deepwater formation to increase. (NCDC, 2004)

The result of such an abrupt change in the Northern thermohaline flow is that average temperatures in Northern Europe will drop by 5 to 10°C, within decades.

Currently, there is some evidence that the water in the North Atlantic is growing less salty due to global warming and that the conveyor belt may be slowing. But scientists believe that even if part of the ocean conveyor were to fail, this would not be for several decades, and any cooling effects would be overshadowed by the continued general warming over the same period (Worldwatch, 2004).

2.2 Soil degradation

Global food production depends on a diversity of variables, including the amount and quality of crop- and rangeland. Often, e.g. in modelling exercises, the amount of suitable agricultural land is seen as fixed. In the case of the quality or suitability of soils, the perception is that these can be (linearly) improved by market mechanisms. However, the biophysical behaviour of soil degradation and improvement does not necessarily follow a linear path, and irreversible or multi-equilibria situations in soil productivity are common. This chapter discusses these processes and the future effects that soil degradation may have both on the amount of land and on the general productivity of soils.

[1] www.emissierechten.nl/marktanalyse.htm

What is soil degradation?

Soil degradation is a process that lowers the current and/or future production capacity of the soil. When looked at from the human perspective, this implies that especially the capacity of the soil to supply desired products and/or services, e.g. food, is decreased. (Poels and van Mensvoort, 1998)

Basically, soil degradation can be grouped in three types (Poels and van Mensvoort, 1998):

- Physical degradation: This includes all forms of erosion (water and wind) as well as forms of compaction, sealing and crusting of the topsoil;
- Chemical soil degradation: This mainly refers to processes of soil nutrient depletion, acidification and salinization.
- Biological soil degradation: This implies the disturbance and reduction of (micro) biological activity in the soil.

The impact of these various forms of soil degradation differs per soil type, climate and farm management. Soil degradation can be considered irreversible once a certain threshold has been exceeded. An example is the desertification process that is triggered by overgrazing and nutrient mining. In this case, non-linear soil processes cause a regime shift when the land has been degraded beyond a certain threshold, so that it becomes almost impossible to restore it (Breman, 1997; Koppel et al, 1997; Scheffer and Carpenter, 2003).

Something similar accounts for the salinization process. Low-quality irrigation can cause salt levels in soils to rise. Once a (crop-dependent) threshold has been exceeded, crops can no longer be grown. Only large quantities of good-quality water can flush the accumulated salts. In most cases,however, these quantities are not available. Large tracts of land in Australia also suffer from salinization, but here the process is different: the new agricultural cropping system uses less water than the original natural ecosystem. The groundwater level rises, thereby bringing the salts in the soil to the surface.

The degradational processes are mostly induced by human behaviour. The main driving forces for soil degradation are deforestation, overgrazing, agricultural mismanagement and overexploitation (Oldeman et al, 1990). Underlying causes of a more socio-economic-political character are: poverty, population growth, lack of knowledge and extension, and failing macro-economic policy (IFPRI, 2000; Eswaran et al, 1999; Scherr, 1999; Koning and Smaling, 2005).

The present extent of soil degradation

Although criticised, the main study on the global assessment of soil degradation remains ISRIC/UNEP's GLASOD study (Oldeman et al, 1990). This study was carried out in 1990 on a 1:10.000.000 scale and assessed the impact and degree of the different types of soil degradation. The study was undertaken with the aim of raising awareness on the issue at the United Nations Conference on Environment and Development (which was followed by the 'Earth Summit') in Rio de Janeiro. The map was based on expert views from all over the world and covered the type, degree and speed of soil degradation since 1945. GLASOD remains the only study that has tried to describe the nature, extent and causes of worldwide soil degradation.

The degrees 'strongly and extremely degraded' refer to irreversible soil degradation, or, as the authors state for strongly degraded soils: "These soils are not anymore reclaimable at farm level and are virtually lost. Major engineering work or international assistance is required to restore these terrains" (Oldeman et al, 1990: 28).

The total land surface of the earth is some 13,000 million hectares. Of this, only 4500 million hectares (23%) are used as or potentially suitable for crop- and rangeland (IFPRI, 2000). In its estimations, GLASOD uses the *inhabited* land area, leaving out the uninhabited polar regions, deserts and rainforests. The total GLASOD land area therefore comprises 8200 million hectares. GLASOD assesses that around 1250 million hectares of this area (38% of agricultural land and 21% of the permanent pastures) is suffering from some degree of human-induced soil degradation. Of this, 300 million hectares is strongly or extremely degraded, which means that 3,7% percent of all inhabited land has been irreversibly degraded. Irreversible soil degradation has been most common in Africa (124 million hectares) and Central America (25 million hectares) (Oldeman 1993).

Moderately degraded soils account for more than 900 million hectares, or 11% of all agricultural land, permanent pasture, and forest and woodland. These soils have a greatly reduced productivity and major improvements are required if this productivity is to be restored. Depending on the speed of the degradation process, it is the further degradation of these soils that poses a threat to the future global food availability. The most important processes that cause moderate soil degradation are: water erosion (73%), wind erosion (9%), nutrient depletion (7%) and salinization (7%).

Criticism of the study has been summarized by (Stoorvogel, 2004):

- The study is subjective and not reproducible. The expert views are in some way biased and too negative;
- All the potential agricultural land is taken into account. Also degradation on non-agricultural land is used;
- Every shift in soil use from a natural to an agricultural system leads to degradation;
- It is hard to assess which part of the degradation is human-induced. For example, there are also relationships with climate change.

Studies about the future speed of soil degradation are scarce. Only Scherr and Yadav (2002) have tried to quantify the increase in global irreversible soil degradation in the past decades and made projections for the coming decades. They base their study on GLASOD too, although GLASOD researchers feel that GLASOD was never intended for making projections of future soil degradation (Kaufman et al. 2004). Scherr and Yadav indicate that "estimates of land loss due to degradation vary widely, from 5 to 12 million hectares every year. Assuming that land loss continues at current rates, an additional 150 to 360 million hectares would go out of production by 2020" This would mean, ceteris paribus, that 1.4 to 2.8% of total cropland, pasture and

forestland will have been lost by 2020 (Scherr and Yadav, 2002). The greatest threats are in Africa, Asia and Central America.

The vast majority of the 38% of agricultural soils are affected by water and wind erosion, which account for more than 80% of total soil degradation. Quantifying the extent of productivity loss is difficult, but indications show that between 1945 and 1990 soil degradation conributed to a 17 percent cumulative productivity loss worldwide (Crosson, 1994). Lal (1995) predicts that if accelerated erosion continues unabated, yield reductions by the year 2020 may amount to 16,5 percent for the African continent (in: Scherr and Yadav, 2002).

Nutrient depletion, multi-equilibrium states and agricultural investment

So, *productivity* loss appears to be a far greater risk to global food availability than *land* loss. Loss of nutrients and/or topsoil causes farmers to convert land to lower-value uses. Regime shifts in farmers' cropping system, because of soil degradation, seem to have the greatest impact on agricultural yields. From example farmers may plant cassava, sorghum or millet, which demand fewer nutrients, instead of maize, or convert cropland to grazing land. These changes tend to behave in a non-linear way and reflect multi-equilibrium states in food production (Koppel et al, 1997; Scheffer and Carpenter, 2003; Stoorvogel, 2004).

This finding leads to questions on certain assumptions of present bio-economic models like IFPRI's IMPACT[2] model. This model assumes linear relations between the application of fertiliser and soil productivity and between fertility investment and prices, both in upward and downward directions. Farmers would always invest in fertilizers when prices of agricultural products are high, and this would have an immediate effect on productivity. However, the multi-equilibria nature of the soil-crop system results in soil fertility investment possibly not proving to be profitable once soils have passed a certain threshold (and consequently moved to a new soil-crop equilibrium). Once a soil has been seriously degraded, the farmer has to apply such quantities of fertilizer and organic material to return to the higher equilibrium state that this would not be profitable for him.

Conclusion

As most authors indicate, irreversible soil degradation poses a serious threat to food security in some parts of the world (especially Central America and Africa). However, it does not pose a major threat to the *global* availability of food (IFPRI, 2000; Eswaran et al, 1999; Scherr and Yadav, 2002). It is estimated that in 2020, between 1,4 and 2,8% of agricultural land will be lost due to irreversible soil degradation. The impact of this can be compensated for by productivity increases in other areas. On the whole, irreversible degradation appears likely to pose only a modest threat to aggregate global food supply or trade by 2020, because of the global capacity for supply substitution and the dominance of temperate regions – where soils are less easily degradable – in world food production.

However, gradual soil degradation and non-linear productivity decline do cause great yield losses in less developed countries. Improvement of these lands seems difficult, due to the fact that investment in fertility measures need not pay off in the short term. This may lead to increased food availability problems in parts of Asia, Africa and Central America in the upcoming decades.

2.3 Emerging animal and plant diseases

Emerging animal diseases have a potentially huge impact on both the structure and quantity of globalised livestock production. In addition, plant diseases and pests are traditionally also seen as threats to world food production. An increasingly interconnected world with changing climatic conditions can have an unforeseen impact on the spread and scale of disease outbreaks.

Animal diseases

Animal diseases can be grouped into the following seven groups:

1. Fast-mutating zoonosis. This group consists of diseases that can spread to humans and can mutate very fast, hampering timely provision of medication. Examples are avian influenza ('Bird Flue'), SARS, NIPA and HIV/AIDS.
2. Ordinary contagion. These animals can infect human beings because they are able to live inside human beings, e.g. all kinds of worms and snails.
3. Insect-borne diseases. Insects can spread diseases to animals. Examples of insect-borne diseases in livestock are rinderpest, bluetongue disease, teak-borne disease and West Nile virus. These diseases are a function of climate, vegetation and management. With good and adaptive management the diseases can be prevented.
4. Metabolic, food-induced diseases. Examples are cupper intoxication or 'cow diabetes'.
5. Diseases that lead to 'food scares'. Lately, contamination of animal feed has led to some food scandals, the most well-known being MPA, dioxin and salmonella.
6. Endemic diseases. These are mostly bacterial diseases like brucellosis, tuberculosis and 'cow variola'.

[2] IMPACT: International Model for Policy Analysis of Agricultural Commodities and Trade

7. Miscellaneous diseases. These cannot be grouped, because they have various or isolated causes. The most important are foot and mouth disease, Newcastle disease and bovine spongiform encephalopathy (BSE).

Plant pests

Plant pests constrain agricultural production. These pests include animals, pathogens, weeds and insects and their distribution is a function of ecological, agroclimatic and socio-economic conditions. Changes in patterns of crop production also influence the size and frequency of the appearance of pest populations (Yudelman et al, 1998). The number of plant pests and subsequent crop losses have increased since the 19th century when trade in plant seeds spread globally. One of the most notorious examples was the Irish potato blight between 1845 and 1849. In this case the exogenous (South American) potato was introduced to the agroecosystem of Ireland, where natural enemies to the upcoming *Phytophtora infestans* were absent. The results were mass hunger, 1 million deaths and the emigration of one million people (Garelik, 2002).

Little research has been undertaken to quantify the effects of plant pests on global crop production. Oerke et al (1995) tried to do this for eight important crops (wheat, corn, rice, barley, soybean, cotton, potatoes and coffee). The study concluded that "despite the cultural, manual, biological, and chemical methods being used to protect these eight crops, about 42 percent of attainable annual production is a loss as the result of pests." The percentage lost is higher in Africa (49%) than in Europe (28%). On a global average, the largest losses of potential output were caused by insects (15 percent), followed by pathogens (13 percent) and weeds (13 percent). With post-harvest losses due to pests adding a further 10 percent to the pre-harvest annual losses, pest-induced losses of these important crops were estimated to be more than half of attainable output (Yudelman et al, 1998). Earlier studies (by Cramer, 1967; FAO, 1975 and Pimentel, 1992) also indicate that between 35-40 percent of the attainable production is being lost as a consequence of plant diseases. Some field experts, however, state that these figures are at the high end, which also depends on the definition used of 'attainable production'.

Overestimated or not, it appears that (despite the green revolution techniques) the pre-harvest losses have remained steady over the past decades. The main causes of this and continued plant pests can be summarized by:

- Climate change seems to be a new factor influencing the spread of diseases to new agroecosystems. The ranges of several important crop insects, weeds and plant diseases have already expanded northward[3] (Anderson et al, 2004).
- Global trade in seeds, crops and food products, and its subsequent spread of diseases;
- Increased monoculture, reduced crop diversity and rotation, and use of herbicides have all boosted yields, but have increased vulnerability to pests as well. Pests tend to develop resistance to pesticides, requiring higher use to sustain production. (Pinstrup-Andersen, 2001)

New pest control strategies focus on integrated pest management (IPM) methods. Definitions of IPM range from "pesticide-free ecological agriculture" to "a range of efforts to use chemical pesticides more judiciously and usually as a last resort, in combination with other pest management approaches, with more careful scouting for pests and improved targeting of pesticides when they are used" (Pinstrup-Andersen, 2001).

Experts state that IPM strategies will probably have the greatest potential for reducing crop losses. However, they also state that a certain crop loss as a result of globalisation and climate change will cancel out these benefits.

Case studies

Three case studies serve to illustrate the wide range in animal and plant diseases. Currently the most threatening of the animal diseases is *Avian Influenza* (AI). For plant diseases, the cassava mosaic virus and the plagues of locusts are chosen as the most destructive outbreaks.

Avian Influenza (AI)

This is a poultry disease caused by a group of viruses that have a low and high pathogenic variant. The highly pathogenic variant (HPAI) is also pathogenic for human beings (EC, 2003). The virus can be divided into 15 subtypes based on haemagglutinin (H) antigens (H1-H15). In addition to the H antigen, influenza viruses possess one of nine neuraminidase (N) antigens. Virtually all H and N combinations have been isolated from birds (Capua and Alexander, 2004).

The virus is easily spread and hosted by a number of aquatic birds (e.g. water fowl). These birds can carry the virus largely without suffering any adverse effects. Domestic poultry, however, are highly susceptible to AI. It was hypothesized that droppings of wild birds caused the AI outbreak in the Netherlands in 2003. These wild birds were infected by a low pathogenic AI variant (LPAI), which then mutated on a poultry farm in Renswoude to an HPAI variant (EC, 2003). This underscores the assumption that AI is a fast-mutating disease. The greatest threat of AI lies in the fact that it can be passed on to human beings. So far, all known cases of human infection have been able to be traced directly back to contact with live chickens. Infected birds shed the virus in their faeces; humans then breathe in the faecal dust. The virus is not passed on in the meat or eggs (Arnst, 2004).

As early as 1918, an influenza (type A) virus had caused a pandemic in the entire world. The so-called Spanish Flue (H1N1) was first spread by birds and then mutated into a form that could also spread human-to-human. It resulted in 20 to 40 million deaths worldwide (Hammel and Chiang, 2005). Since the Hong Kong

[3] E.g.: "Range expansion of the grey leaf blight of corn, caused by the fungus *Cercospora zeae-maydis*, was first noticed during the 1970s, and, in the past two decades, has become the major cause of corn yield loss in the USA."

pandemic of 1968, the human strains of influenza A have been fairly stable. However, in the late 1990s, new avian strains began to infect humans in relatively small numbers. From 1996 onwards different strains of Avian Influenza spread to: UK (1995), Hong Kong (1997, 1999, 2003), Italy (1999, 2000), the Netherlands (2003), Canada, Egypt, Vietnam, Thailand, Malaysia, China, South Korea, Indonesia and Cambodia (2004). These outbreaks resulted in the 'destruction' of around 200 million chickens and caused the death of around 40 humans. The main virus strains were of the type H7N7, H7N3 and H5N1.

The current large-scale outbreak of AI in Asia highlights the increased vulnerability of livestock systems to emerging animal diseases. The main causes for this increased vulnerability are the rate of movement of humans, livestock and livestock products. In general, the process of globalisation has caused a large increase in the occurrence and scale of animal diseases. Any new or emerging disease has the ability, given the right circumstances, to spread across the world to entirely new populations of humans or animals with different susceptibilities and immunities (Jeggo and Eaton, 2003). In addition, the increasing urbanisation in developing countries where hygienic conditions are hazardous has increased the opportunities for transmission of zoonotic diseases (Thys et al, 2005). Big, dirty cities in Southeast Asia, with their live ('wet') markets, could be the perfect breeding ground for the development of such diseases.

At the moment, FAO experts (News-Medical, 2004) state about AI in Asia that "it's probably unreasonable to expect that the disease can be totally excluded from the region in the near future. The presence of highly pathogenic strains of the virus in wild birds makes the control of the disease particularly complex and difficult." The most important threat in AI virus infections of humans is that, while infections to date have been extremely limited in their human-to-human spread, it is quite feasible that AI and human influenza viruses could infect the same individual. This could result in reassortment between the two viruses with the consequence that a virus could emerge with the internal genes from the human virus, allowing easy transmission among humans, but with the H antigen from the AI virus. Such an antigenic shift would cause a global pandemic because humans would have no immunity to the new strain. (Capua and Alexander, 2004; Hammel and Chiang, 2005)

Sources within the WHO believe that we are as close to the next pandemic as we have been at any time in the past 36 years, with all the necessary ingredients being mixed in Asia. Epidemiological modelling suggests that a future influenza pandemic would cause 2 - 7.4 million deaths worldwide. The severe acute respiratory syndrome (SARS) outbreak of 2003 merely hinted at the likely economic consequences of pandemic influenza. (The Lancet, 2004) A possible outbreak of an influenza pandemic would not only lead to the deaths of human beings on a large scale, but also trigger societal and political instability. In an increasingly complex and interlinked world this can have a serious impact on international trade relations.

- Key elements of a successful control strategy are (Jeggo and Eaton, 2003):
- Surveillance operative in all production systems;
- Strengthened bio-security of commercial enterprises;
- Immediate response to outbreaks including stamping out in affected areas, disinfection, restriction of movement of animals and goods;
- Targeted and strictly monitored vaccination remains a complementary option.

The control strategies outlined above hint at a further 'industrialisation' process in poultry keeping. A similar tendency is observed in other animal husbandry sectors that suffer from global disease outbreaks (food and mouth disease in cattle, swine fever in pigs). The aim is to improve chain management and to minimise intra-chain transportation. This tendency might lead to closed 'agro-production parks' in which all conditions can be controlled and food safety can be secured at all stages of the production process (E.g. Smeets, 2003). At the moment, civil society groups and politicians that strive for animal welfare and 'natural' conditions in intensive livestock keeping are still succeeding in preventing this structural change from happening in western European countries. In the US, however, this process has already been taking place for some time, whereas in developing countries such trends are largely absent. Livestock disease and related human health problems tend to increase. This is partly related to the inadequacy and deterioration of the public health and veterinary infrastructure, and the subsequent lack of control (Thys et al, 2005).

These diverging trends may lead to a regional differentiation of high- and low-tech animal husbandry systems. The low-tech systems (in developing countries) will be based on genetic diversity and limited human, animal, and animal product movement. The high-tech systems will increasingly try to close the chains within a limited geographical area, controlling all possible inputs of food, air and water.

It remains unclear how successful the disease control strategies will be and what the impact on global food availability might be. So far, for trade in and production of animals and meat, the trends will probably be: increased insecurity of poultry supply (especially in Asia); restricted intercontinental trade; and slightly increased cost of food production, due to increased food safety standards.

It also remains unclear what a new large-scale outbreak of a livestock disease, and the consequent destruction of livestock, will have on public opinion. Continual, large-scale, televised destruction of poultry and pigs may cause eating preferences to shift towards a vegetarian diet. However, history shows that such shifts are normally only short-term. On the other hand, the outlined solutions to prevent animal diseases (e.g. pig flats) may cause a longer-term change in diet. The wealthy, animal welfare-conscious, Western citizen might change his inclination for meat, once livestock is seen to be really kept like machines in factories.

The cassava mosaic virus

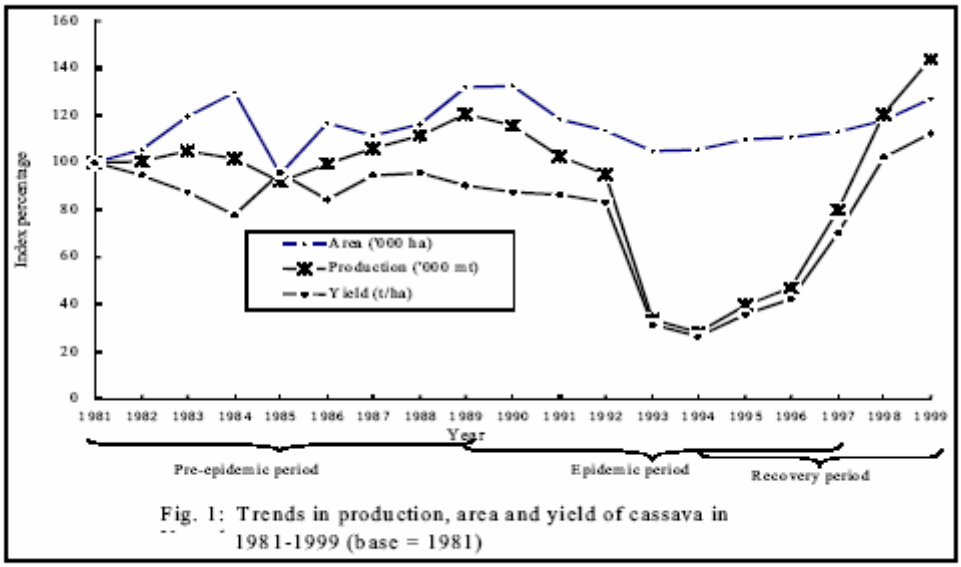
Cassava mosaic disease (CMD) is the most important biotic constraint of cassava production. This disease started spreading from its source in Tanzania in 1894, occurring Africa-wide by 1987. The disease is caused by whitefly-transmitted begomoviruses, including African cassava mosaic virus (ACMV) west of the Rift Valley, and East African cassava mosaic virus (EACMV) east of the Rift Valley. In 1988, an epidemic of a highly virulent variant of EACMV began in Uganda and spread throughout East and Central Africa, causing crop losses on a scale that required international intervention to prevent widespread famine (Anderson et al, 2004).

The cause of this pandemic outbreak of CMD, which caused the destruction of 80% of the cassava production between 1989 and 1997 in Uganda (Anonymous, 2003), was found in the recombination of the two

strains of the African cassava mosaic virus, EACMV and ACMV. This recombination can only take place in a cassava plant doubly infected with the two parental viruses. Double infections are rare events, but once they have taken place, the resulting crossing is well-adapted to be transmitted by local strains of the whitefly. This caused the disease to be so widespread (SCRI, 2004).

The variation in the virus appears to be linked to geographic separation and host plant genetic divergence, as well as to continental drift. Begomoviruses have existed for at least tens of millions of years. A wide variety of virus genotypes exist, probably as well-adapted and essentially symptomless infections in endemic species or weeds. Any change in transmission characteristics of the vector will result in the appearance of the virus in crop plants almost instantly (Rybicki and Pietersen, 2000). Decreased diversity in the types of host plants and increased trade in farm products (and in their wake the white fly that carries the viruses) can cause increased recombinations of the mosaic virus. In areas that depend for a large part on one staple crop (like cassava in Uganda), an outbreak of a mosaic virus can cause widespread food scarcity.

Figure 1 Cassava production, area and yield in Uganda (Anonymous, 2003)



The solution in Uganda was found through the introduction of a resistant cassava variety, developed by the International Institute for Tropical Agriculture (IITA). Tropical Manioc Selection (TMS) varieties were crossbred with local varieties. Within five years, cassava production was back to pre-epidemic levels (figure 1). Experts point to the importance of IPM measures for limiting outbreaks of EACMV and ACMV. Research is being undertaken to know more about the natural enemies of these viruses. In addition, new pesticides are being developed to combat the viruses in the future.

Desert locust plagues

Outbreaks of desert locust plagues have been known from ancient times in the Middle East and Africa. Swarms of devastating desert locusts destroying the harvest of African small-scale farmers were widely broadcast during the last big outbreaks in the 1986-1989, and 2004-2005 periods.

Outbreaks of desert locusts depend on many variables. Locusts normally live solitarily and migrate across the Sahara from winter to summer and vice versa. It is only if small green areas are available, after precipitation, that the population can grow and a mutation of the locusts into the gregarious state takes place. Once this occurs, desert locusts start living in groups that can assume an enormous size and spread over large areas. Swarms normally contain 50 million locusts per square kilometre and can bridge a distance of up to 5000 km. One locust needs two grams of fresh vegetation a day, which means that 100 tons of fresh vegetation can be eaten during one day of a locust invasion. A locust plague does not evolve overnight, however. The concentration, multiplication and gregarization of desert locusts, and the subsequent steps from outbreak and upsurge to plague can take years. Small hopper bands and swarms are continuously present in the Sahara, and if favourable conditions occur they can evolve into larger outbreaks, upsurges and finally plagues (van Huis, 1995).

The impact of a desert locust outbreak on crop yields has been scarcely studied. In an FAO report, Steen indicated that "a main finding of the study is that the circumstances under which the Desert Locust poses a severe risk to livelihoods and food security are unusual" (Steen, 1997: 3). Van Huis adds to this that normally only a small percentage of the farmers are affected during a plague outbreak. These farmers, however, do suffer great losses and it is not rare for them to lose their entire harvest. A total harvest loss for five percent of the farmers has a more serious impact than a loss of five percent for each farmer. The political impact, therefore, is bigger, which also explains the interest of the international donor community in the topic.

Three different strategies of control can be distinguished: preventive control, upsurge suppression and plague elimination. Preventive control is very demanding when it comes to the monitoring and surveillance of

locust upsurges. The potential inhabitation area of the desert locust covers 25 countries and approximately 16 million square kilometres (van Huis, 1995). In addition, access is sometimes difficult due to logistical or security reasons. For this reason, it is often hard to organize adequate control in the early stages of an outbreak.

Upsurge suppression and plague elimination were long executed with the help of the insecticide *dieldrin*. The use of dieldrin, however, has been restricted lately due to its negative environmental impact, leading to contact insecticides having to be used instead. As a consequence, single-band treatment has become increasingly difficult. In addition, the rapid multiplication rate of the Desert Locust poses obstacles to its containment. During upsurges, the generation-to-generation multiplication can rise to 16. Van Huis (1995) calculates that already a multiplication rate of higher than five requires a pest control of more than 80%. An 80% control implies that all the hopper bands are sprayed as well as the scattered hoppers during the early upsurge breedings. It has been argued that such coverage is practically impossible. Although new insecticides are being developed to control the locust upsurges and outbreaks, these have not yet proved to be an effective replacement for dieldrin. According to Steen (1997), control can reduce the risk substantially but control operations are currently an uneconomic proposition in most circumstances.

According to Van Huis, only Integrated Pest Management and Integrated Crop Management can create sustainable solutions for semi-arid agricultural production. The assistance to Sub-Saharan Africa farmers, through Farmers Field Schools, might have more effect than massive projects on locust monitoring, surveying and control. More success could be achieved in preventing outbreaks and plagues by helping the natural enemies of the desert locust.

Conclusion

Animal and plant diseases have been a phenomenon for centuries. The desert locust plague illustrates this. However, new developments such as climate change, increased trade in animal and plant products, and the increased mono-cropping and industrial livestock keeping now add to the forces that encourage the emergence and spread of diseases. Losses through animal and plant pests of varying nature (virus, bacteria or insect) cause substantial productivity losses. Present control strategies show an ambiguous trend. On the one hand, high-tech, end-of-pipe solutions remain popular, aiming at an increased industrialised farming system. On the other hand, more integrated source-oriented strategies are being undertaken, like IPM and ICM. The former can lead to greater vulnerability of the agricultural system, whilst the latter might not allow sufficient increases in production to feed a growing and more demanding world population.