Knowledge for Climate

Adapting Dutch agriculture to climate change

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This forecast is one of a series of studies carried out at the request of the Board of Directors of the *Knowledge for Climate Foundation* into the *State of Art* for several important adaptation themes in preparation of the actual commencement of the national research programme *Knowledge for Climate*. These forecasts are concerned with subjects of a scientific and technical nature as well as subjects in the field of social science. The goal was to find out which knowledge is available for the relevant adaptation theme and where the knowledge gaps lie. *The State-of-Art* overviews are intended not only to serve as advice for the Board of Directors and the Programme Board of the *Knowledge for Climate Foundation* with regard to the intrinsic demarcation of the research programme, but also as background information on a number of significant adaptation themes for a wide target group. It is for this reason that the *Knowledge for Climate Foundation* has made the *State-of-Art* foresight studies freely accessible via their website www.knowledgeforclimate.org .Responsibility for the actual content of these studies is borne by the authors themselves who also organised the review of the forecasts by submitting a draft to a group of scientists, experts and stakeholders.

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Introduction

The Intergovernmental Panel on Climate Change (IPCC) concludes in its fourth assessment that global climate is changing and will continue to change in the future despite all mitigation efforts (IPCC, 2007). These mitigation efforts aim to keep changes within acceptable limits through the reduction of greenhouse gas emissions and through carbon sequestration. These mitigation strategies are currently adopted at all levels (Pattberg and Stripple, 2008). For example, at the global level through the UNEP[1]-facilitated Global Network on Energy for Sustainable Development, at the European level through the Adaptation and Mitigation Strategies: Supporting European Climate Policy (ADAM), and at the national level of the Netherlands through the Adaptation Space and Climate program (PCCC, 2007). The actual climatic changes will depend on the extent of mitigation and global development expressed by IPCC in terms of emission scenarios.

Global land use is highly dynamic and changes constantly. Therefore, it is unlikely that the global community will let climate change happen and accept the consequences. More likely is that we will adapt to the changing conditions. With proper adaptation strategies the negative effects of climate change can be minimized and we can optimally profit from positive effects. One can expect that land use will adapt to changing conditions including climate change. There is a big societal and political demand for an assessment of the possibilities of adaptation. This study aims to explore the window of opportunities for the agricultural sector based on a literature review.

Many studies on climate change focus on the emissions and sequestration of greenhouse gases (*e.g.,* Trines *et al.*, 2006). This review takes the expected changes as a given and looks at the options to adapt agriculture and to take full benefit of positive changes and minimize negative effects. Various studies looked specifically at these adaptation strategies (*e.g.*, Veraart *et al.*, 2006; Reidsma, 2007).

It is important to keep the specific character of the agricultural sector in mind. In nature conservation, action is often focused on the specific conservation of species or ecosystems often coordinated by specific organizations (like the Dutch Association for Nature Conservation *Natuurmonumenten* or the National Forest Service *Staatsbosbeheer*). Alternatively, water management focuses on the reduction of the vulnerability of low lying delta's like the Netherlands that can affect the entire society. Central coordinated action is needed to reduce the risks related to water management

[1] United Nations Environmental Program

where (*e.g.,* Wesselink *et al.,* 2005; Deltacommissie, 2008). The agricultural sector is the result of a large population of producers Although coordinated action can also apply to the agricultural sector, the sector can be seen as the result of joint decision making of the large population of producers. Each producer manages an economic production system and can react differently to the changing conditions within their specific farming systems and given their local conditions.

We also see different approaches in the literature. Osinga and Kabat (2006) talk about climate resilient land use as a way to reduce the climate related risks to a societal and economic acceptable level by using a combination of technological and political adaptation measures and low emission land use. Others take a more farmer oriented approach and evaluate how the farms can adopt to the new conditions (*e.g.* De Groot *et al.,* 2006).
This review starts with a brief discussion on agricultural land use in the Netherlands, followed by an overview of the expected climatic changes in the Netherlands and the consequences of land use change on current agricultural practices. Subsequently, adaptation strategies as suggested in the literature are summarized and discussed.

Agricultural land use in the Netherlands

The Netherlands is well endowed in terms of agricultural soils with some prime agricultural land and an important agricultural sector that has always been highly dynamic (*e.g.,* Terlouw, 2008). Although agriculture in the Netherlands has lost much of its importance over the last 50 years in terms of the number of people involved and its relative contribution to the economy, its production is still increasing and the area under agriculture has changed relatively little (Koomen et al., 2005).

Farm land still dominates the country covering currently around 57% of the Dutch land surface (LEI, 2008). Agricultural land is dominated by herbivore farms covering 57% and arable farms covering 24%. Land cover is dominated by grassland (53%, including both permanent and temporary grassland), maize (12%), grain crops (12%), and potatoes (8%). Intensive agriculture in the Netherlands produces often close to its potential due to intensive management practices. Important to keep in mind is that land cover is dynamic (Feranec *et al.*, 2007). Currently agriculture is impacted by the continuing urbanization and shows an increase in scale and diversification (Bont *et al.*, 2007; Klijn, 2008).

In addition, there is a wide range of agricultural policies aiming at specific changes. For example, the Dutch Ministry of Agriculture, Nature and Food Quality actively supports the development of organic agriculture and aims at an annual 10% increase of its area currently covering 2.1% (LNV, 2007). At the same time the European Union and the Dutch government will invest in competitiveness and sustainability including *e.g.*, system innovations, sustainable soil management, and encouragement for the development of animal-friendly production systems and energy crops as expressed in the Dutch Outlook regarding the European Agricultural Policy 2020 (Verburg, 2008) and the choice for agriculture: a vision of the future of Dutch agriculture (Ministry of Agriculture, Nature and Food Quality, 2005).

Rounsevell *et al.* (2005) analyze future land use in Europe and take the scenarios defined by the IPCC Special Report on Emissions Scenarios (SRES) (Nakićenović *et al.*, 2000) as a starting point. Following the report, they distinguish between economically and environmentally oriented scenarios and globally versus regionally oriented scenarios. Under the various scenarios, they predict decreases in cropland (between 10 and 45%) and grassland (between 1 and 60%) for the year 2080 for the Netherlands under the various scenarios. Main argument for the decrease in agricultural land is the expected productivity increase given a range of boundary conditions like relatively stable global markets and the implementation of proper research and development and policies.

Environmental changes in the Netherlands

In the Environmental Balance of the Netherlands climate change is mentioned since 1998 (RIVM, 1998, 1999, and 2000). In the same year, Van Gerwen *et al.* (1998) indicate, in a special report for the Dutch government on medium term environmental changes, that greenhouse gas concentrations have risen far above their natural values and that temperature changes may coincide with changes in rainfall patterns, sea water level rises, floods, and changes in vegetation patterns. They conclude that the expected changes are extremely complex and uncertain. Since then climate change became well accepted and after various iterations there is now a general consensus about the climatic changes for the Netherlands that we can expect until 2050. After 2050 we see that the various scenarios diverge and expected changes become unclear. The predictions for the Netherlands are given by numerous authors (Klijn, 2008; Van den Hurk *et al.*, 2006; Van Drunen, 2006; Deltacommissie, 2008):

- *Increasing temperature. After an increase of 1.2 ˚C in the past century, temperatures are expected to continue to increase with another 0.9-2.5˚C by 2050. These changes will take place both in summer as well as in winter.*
- *Increasing rainfall. Average annual rainfall increased in the past century with almost 18%. However, changes in summer rainfall have been minor and the increase in rainfall was mainly due to an increase in winter rainfall. Model predictions for 2050 show varying results for rainfall depending on the temperature increases. Rainfall is expected to continue to increase although predictions show*

almost no increase or even a decline in rainfall in the summer season. In general, studies show an increase of 4 - 14% in winter and -20 - 6% in summer in 2050.

- *An increase in extreme events.* *Besides the average changes in temperature and rainfall, extremes are expected to increase. This increase in climate roughness includes a potential increase in extremely wet periods (both in winter and summer) but also longer periods of drought in summer.*
- *A continuing rise of sea water levels.* *Sea water levels have increased approximately 0.20 m in the past century. Different views on the rise of sea water levels for the future exist. In its fourth assessment IPCC (2007) estimates a rise of 0.25- 0.76 m, whereas KNMI estimates a rise of 0.40-0.85 m (Van den Hurk et al., 2006) and the Deltacommissie (2008) estimates a maximum relative sea water level rise of 0.40 m in 2050 for the Netherlands..*
- *Salt intrusion due to higher sea levels.* *The process of saltation of groundwater started centuries ago with the establishment of polders and continues up to now (Deltacommissie, 2008). An accelerated rise will further coincide with an accelerated salt intrusion. However, we should realize that predictions on the problems are difficult to assess as insight in the exact processes is limited (see for example Maas, 2007).*
- *Changing CO_2 concentrations.* *Significant increases in CO_2-concentrations are expected from the current 384 ppm up to 484-572 ppm in 2050 (IMAGE-team, 2001).*

Although there is general consensus in the literature about the expected climatic changes for 2050, authors agree that there is a possibility that the Atlantic thermohaline circulation may decline. This will result in a temperature decline of approximately 2˚C by 2050 and potentially impact all the above changes.

The predicted changes in environmental conditions are typically calculated for different emission scenarios. However, these scenarios do not result in major differences in the predictions for 2050. In this review we will concentrate on 2050 and therefore not distinguish between the different scenarios. Similarly, this review refers to literature that mostly used the results from the third assessment of the IPCC whereas some of the more recent literature refers to the fourth assessment of the IPCC. It is important to realize that the two assessments show rather consistent results for the Netherlands.

Effects of climate change

What will happen with Dutch agriculture under changing climatic conditions? This question can be answered from different angles. Perhaps one of the most direct ways to look at this question is to study the impact of climatic change on the current production systems.

Direct effects

This Section focuses on the direct effects of climate change on the current production systems. Although the Netherlands is relatively vulnerable for increased precipitation due to its low lying position, climatic changes are relatively small in the Netherlands compared to other parts in Europe (Commission of The European Communities, 2007). For arable farming, several authors (Alcamo *et al*., 2007; Ewert *et al*., 2005; Hermans *et al*., 2008) evaluated the effects of the predicted temperature increase and increased CO_2 concentrations in the atmosphere. They all conclude that the expected climatic changes will have a positive effect on productivity. But, as shown by *e.g.* Reidsma (2007) the effect differs per crop and per farming system. Tol (2002) provides a best guess of the economic impacts of climate change on Europe and conclude with an expected 0.55 % increase of GDP without adaptation. Others (*e.g.,* De Groot *et al*., 2006) do consider other elements of climate change and emphasize the vulnerability of arable farming in the Netherlands. The vulnerability is the result of the expected increase in weather variability including extended dry spells or wet periods and temperature extremes, the problems related to salt water intrusion, and the expected increase in pest and disease pressure.

Where the increase in productivity based on average increases in temperatures and CO_2-concentrations can be quantitatively assessed by crop growth simulation models, the effects of other changes are more difficult to assess and results are often presented qualitatively (see, for example, Veraart *et al*., 2006 and Blom *et al*., 2008). Despite the qualitative character of the results several elements have been quantitatively analyzed and confirmed. For example, an increased pressure of pests and diseases due to warmer temperatures was already observed in the relatively warm period 1989-2004 (Wingelaar *et al*., 2005).

Although these changes occur together with other trends related to an increase in production scale and a decrease in the package of available chemicals, it is likely that the increased pressure will continue to take place under climate change with elevated temperatures and increased rainfall. The exact extent of the problem is, however, still unknown. Another example comes from the Deltacommissie (2008) who shows on the basis of quantitative studies that the intake of water at Bernisse and Gouda has to be stopped 50% of the time due to elevated salt concentrations under the more extreme climate change scenarios. This will have major implications for the horticultural production in the area. The various changes in environmental conditions as listed above are likely to interact. An example is provided by Kruijt *et al.* (2008) who analyze the effect of increased CO_2 concentrations on the transpiration of crops. The study shows that increased CO_2 concentrations may lead to a reduction in transpiration and as a result the effect of extended droughts may be overestimated but the effect of increased wetness may deteriorate.

Less authors pay attention to the livestock production as the impacts of climate change are less clear (Blom *et al*., 2008). Overall, productivity of temperate European grassland is expected to increase (Alcamo *et al*., 2007; Byrne and Jones, 2002; Kammann *et al*., 2005). Nevertheless, warming alone is likely to have negative effects on productivity and species mixtures (Gielen *et al*., 2005; de Boeck *et al*., 2006). Hopkins and Del Prado (2007) evaluate the effect of climate change on pastoral areas and talk about increased herbage growth increased use of legumes in diet, reduced opportunities for grazing and harvesting on wetter soils, higher concentrations of H_2O soluble carbohydrates and lower nitrogen concentrations at a given dry matter. In addition, the distribution of dry matter production will change throughout the year with the more humid winters an dryer summers and increased climate roughness. As a result of the latter there will be a greater reliance of farmers on conserved feed.

Besides the more general effects on Dutch agriculture presented above and despite the fact that the Netherlands is relatively small, we have to keep in mind that the effects are strongly regionalized due to topographic differences, differences in soil types and differences in cropping systems. Blom *et al.* (2008) illustrate the regional effects with the specific conditions for the low lying areas along the coast with the specific risks for salt intrusion and flooding. On the other hand the higher, more sandy parts in the east of the country are specifically vulnerable for drought stress originating by the expected more prolonged dry spells in the summer.

An expert panel evaluated the impacts of climate change on the main crops in the Netherlands. Surprisingly there is limited attention for the positive effects of climate change. We should also recognize that there are a lot of discrepancies in the Netherlands. Where the expert panel in Blom *et al.* (2008) claim the negative effects of salt water intrusion on grassland production, Antheunisse *et al*. (2007) mention that the effects of salinity on grassland are of minor importance. How agrarian systems respond to extremes is less well understood, but recent examples of damage related to flooding, drought, hail and storms reveal that impacts of extreme events are large (Gupta *et al.*, 2007).

Indirect effects

There are also several indirect effects of climate change on Dutch agriculture. These include the indirect effects of mitigation efforts, water management, and the effects of climate change on other areas within Europe.

There is a general consensus in society that mitigation efforts need to take place to keep climate change within acceptable limits. Mitigation efforts will impose specific land use changes to minimize emissions. Examples include the cultivation of bio-energy crops, carbon sequestration through *e.g.* minimum tillage, and changes in livestock management to reduce greenhouse gas emissions. In terms of mitigation efforts, the literature talks about the cultivation of bio-energy crops and the sequestration of carbon. Increasing crop yield (Ewert *et al.* (2005) predict combined yield increases of wheat by 2050 ranging from 37% to 101% under the different scenarios) and decreasing or stabilizing food and fibre demand could lead to a decrease in total agricultural land area in Europe (Rounsevell *et al.*, 2005). This large-scale reduction in land demanded for cropland in Europe (Rounsevell *et al.*, 2006) creates opportunities to increase the cultivation of bioenergy crops (Schröter *et al.*, 2005). In addition, there is a rapid development in carbon markets creating opportunities. Through carbon contracts farmers may adopt alternative crops and crop management (*e.g.,* minimum tillage). Finally, changes in livestock management can be supported through policies to reduce greenhouse gas emissions.

Water management receives significant attention in the 2008 report of the Delta Commission to deal with the expected climatic changes and increases in sea water levels. Examples include the use of low lying polders as overflow areas in cases of extreme discharges of the rivers in the Dutch delta, but also increasing the groundwater tables of other areas to deal with the intrusion of salt water. The latter may result in wetter growing conditions on Dutch farms.

Effects at different scale levels

Climate change is not only impacting land use in the Netherlands. It is also impacting land use at the European and global level and mitigation efforts take place on these other levels. We have to see Dutch agricultural in a European and global perspective. Climate change (including all mitigation efforts) will impact agriculture globally and as a result prices of agricultural inputs and commodities will change that may induce Dutch farmers to opt for alternative practices (see *e.g.*, Veraart *et al.,* 2006). We have to look at the impacts on other sectors. Decisions with respect to water management but also global energy prices or specific policies to mitigate climate change to stimulate, for example, bio-energy. Jürgens 2002 (cited by FAO 2007) shows the impact of climate change on commodity prices. The future of markets remains uncertain as illustrated by Abildtrup *et al*. (2006).

Potential adaptation strategies for Dutch agriculture

Adaptation in a broader context

IPCC defines adaptation as the adjustment in natural or human systems to a new or changing environment. FAO (2007) and the IPCC make a useful separation between autonomous and planned adaptation. Autonomous adaptation is the reaction of a farmer to climatic changes in that he changes crop allocation and management. Planned adaptation measures are conscious policy options or response strategies aimed at altering the adaptive capacity of the agricultural system or facilitating specific adaptations. Although it is useful for conceptual purposes to separate the two forms of adaptation, in practice it may be difficult to separate them. Climate change is not happening as an independent process but many concurrent developments are taking place (Abildtrup *et al*., 2006).

The distinction between resiliency and adaptation is useful in examining the ability of agriculture to deal with climate change in this paper. Short-term adjustments to climate change by farmers, the economy and institutions are efforts to keep the agricultural system in a status quo and, thus, resilient. They are autonomous in the sense that no policy changes or new research are needed in their development or implementation. Short-term adjustments are, in essence, the first line of defense against climate change. Long-term adaptation of agriculture refers to major changes in infrastructure, production technologies, market mechanisms and government policies in response to some environmental or economic stimulus. Such changes effect fundamental and long-term changes in the resource base and social preferences as reflected in government policies (Easterling 1996). The farmers' capacity to deal with these changes is referred to as the adaptive capacity.

The importance of adaptation is indicated by numerous studies. Key is that adaptation can result in a reduction of the negative effects and in a strengthening of positive effects. As such, climate change also creates opportunities (Kabat *et al.,* 2005; Maracchi *et al*., 2005).

Adaptation on the policy and research calendar

It is indisputable that the reform of EU agricultural policies will be an important vehicle for encouraging European agriculture to adapt to climate change (Olesen and Bindi, 2002) and for reducing the vulnerability of the agricultural sector (Metzger *et al*., 2004). Interesting enough policy documents of the European Union do not talk about the adaptation to climate change and focus mostly on mitigation. Nevertheless, many studies discuss the need for adaptation. Appleton (2003) notes that at the national level the Dutch government operates in line with international conventions dealing with mitigation but the government did not formulate a national adaptation strategy. More recently the Delta committee did formulate recommendations to adapt but mainly in the context of water management purposes. However, PCCC (2008) reports that a lot has been done in 2007 with the national program on "Adaptation Space and Climate" (ARK) as a joint initiative on adaptation by various ministries and organizations. At the same time it argues that to much attention to adaptation could take away the attention from mitigation which had first priority.

Despite the fact that adaptation came late on the policy agenda in the Netherlands, it is becoming more important. In this context, the Dutch government asked for a quickscan to evaluate the potential changes of adaptation on the Water Framework Directive (Veraart and Westein, 2005; Veraart *et al.*, 2006). The motion by Lemstra in the Dutch Senate (March 21, 2005) argues that long term developments like climate change and sea water rise receive inadequate attention in the regional policy documents (cited by Veraart *et al.*, 2006). Despite the initial emphasis on mitigation, there is an increasing awareness that adaptation is necessary and that we cannot rely on autonomous adaptation. Adaptation is increasingly seen as an opportunity for innovation and new technologies, with a growing potential for exporting technological solutions developed in the EU (Commission of The European Communities, 2007). The importance of adaptation is illustrated by Tol (2002). They assess an increase of the economic impacts of climate change in Europe from 0.55% increase of GDP without adaptation to a 2.09% increase with adaptation with adaptation.

Adaptation strategies

Smit and Skinner (2002) grouped agricultural adaptation options according to four main categories that are not mutually exclusive: (1) technological developments, (2) government programs and insurance, (3) farm production practices, and (4) farm financial management. The typology is based on the scale at which adaptations are undertaken and at which stakeholders are directed. The first two categories are dealing with planned adaptation and are the responsibility of public agencies and agri-business. Categories 3 and 4 mainly involve farm-level decision-making by producers and as such refer more to autonomous adaptation.. For practical purposes, the subdivision between the various categories is often difficult to implement. Crop management can be adapted by farmers through autonomous adaptation but it may also require research and development followed by extension to support farmers in the development and implementation.

A whole array of potential adaptations is listed in the literature (Smith and Almaraz, 2004; Salinger *et al*., 2005; Reilly and Schimmelpfennig, 1999; Wolfe *et al*., 2008; Bleumink, 2006; Van Ierland *et al.,* 2006) including:

- Crop choice
  - Alternative crop rotations or crop allocation using existing crop varieties better suited to new climatic conditions.
  - Introduction of new crops. A good example is the development of salty agriculture in areas affected by salt intrusion where highly sensitive crops like seed potatoes are cultivated. This could involve more salt tolerant crops like sugar beets, spelt, and barley (Vinckers, 2006) but also the cultivation of domesticated halophytic crops (Rozema and Flowers, 2008)
  - Genetic development of new crop varieties that are better capable to deal with indirect effects like increased pest and disease pressure.

- Crop management
  - Changes in cropping calendar (including *e.g.,* changes in planting dates).
  - Changes in input use. This could include changes in fertilizer use to adopt fertilizer applications to meet changing potentials but also changes in pesticide use to deal with an increase pest and disease pressure.
  - Alternative tillage systems (including minimum tillage).
  - Irrigation and drainage to deal with more extreme droughts as well as with wetter conditions.

- Agricultural policy
  - Policy changes: current policies promote the production of established crops. We will need new and more flexible policies that allow the introduction of new crops and cropping patterns, that are better adapted to a climate-changed world!
  - Capacity building to create awareness and get the sector prepared for changes.

Although the literature predominantly focuses on changes in the production system, we can also study some of the changes in a landscape perspective. A good example is to interpret the actual changes as a production shift among regions (*e.g.,* Reilly and Schimmelpfennig, 1999).

Adaptive capacity

Given the uncertainty of future impacts, technical solutions are difficult to plan. Perhaps one of the most effective ways to stimulate and support farmers in the adaptation process is to stimulate the innovation “ambiance” as indicated by The Scientific Council for Government Policy (WRR, 2008). This should increase the adaptive capacity of the farmers through which effective autonomous adaptation can be supported. Van Galen and Verstegen (2008) analyse the innovation process in Dutch agriculture. They show that currently 11% of the farms collaborate in innovation projects. The adaptive power of the agricultural sector is well illustrated by Verburg *et al*. (2004).

The starting point is that land use has always been dynamic and is constantly changing. Changes in past and recent land use patterns revealed a number of key drivers as determinants of change. Recent land-use conversions, studied for the period 1989-96, are no longer related to the biophysical properties of a location. Accessibility, spatial policies, and neighborhood interactions are more important determinants of current land-use changes. These factors are, to some extent, related to the historic developments in land-use patterns.

Moreover, Schröter *et al*. (2005) and Berry *et al*. (2006) found that different types of agricultural adaptation (intensification, extensification and abandonment) may be appropriate under different scenarios and at different locations. They link, however, the potential with the introduction of new crop species and varieties but warn for the increased need for plant protection (Olesen and Bindi, 2002). Is the current rate of innovation enough to keep up with climate change (Borgstein *et al*., 2007)? The Scientific Council for Government Policy (WRR, 2008) stresses the importance of innovation and to provide a business climate in the Netherlands that allows for innovation. Adaptation is seen as the first solution track to climate change by the WRR (2007)!

Analytical methods

The wide array of results on predicted climate change, its impact on agriculture, and the effect of alternative management strategies to adapt to climate change is based on a wide array of analytical methods. The methods range from global circulation models to expert panels. Validation of the tools is extremely difficult making the studies best educated guesses. Through the intensive coordinating efforts of the IPCC many global circulation models have been used to evaluate a number of standardized emission scenarios. The results have been published on the web and do nicely illustrate the increasing uncertainty with time. Although the results of the various models do vary by 2100, the simulated results are surprisingly consistent until 2050. The results also do not show major differences between the different emission scenarios in the coming 50 years after which the results start to differentiate.

The impact on the agro-ecological environment is already more challenging. Partly due to the fact that the temporal resolution starts to play an important role. Whereas the results of the global circulation models typically are presented on a yearly or monthly time scale, crop growth is often governed by processes at a daily or weekly time step. Although several of the global circulation models do operate at high temporal resolutions (up to 3 hour time steps), the uncertainty is rather high. Analyzing the effect of climate change on the agro-environment using average monthly or yearly averages assumes that the variability remains the same. There is, however, as mentioned before a general tendency that weather conditions will be more variable and extreme. In addition, we see that different approaches are followed. Where some calculate the impacts of changing temperature and precipitation, others consider the changing CO_2-concentrations in the atmosphere. Others include other effects related to *e.g.,* a changing pressure of pests and diseases. De Nijs *et al.* (2004) show the complexity to make land use predictions for the future.

Several studies indicate that as soon as we talk about the long term effects of climate change on a particular sector we have to broaden our scope. We may have to use more integrated modeling approaches (*e.g.,* Krol and Bronstert, 2007). At the same time we need to look at other forms of land use like nature, recreation, urban areas, and water (Veraart *et al.,* 2006). The uncertainty in the global circulation models, the complexity of the agro-ecosystems, and the linkages with other issues results in various studies to fall back on expert judgment as quantitative models to evaluate the impacts and adaptation are simply lacking (*e.g.*, Klijn *et al.,* 2005). Others, like Krol and Bronstert (2007) provide integrated modeling approaches to assess the impacts of climate change. Key is that it is generally recognized that tools are required to analyze the agricultural systems in a more holistic way (Hopkins and Del Prado, 2007; Howden *et al.*, 2007).

Besides the more obvious analysis of climate change impacts on agriculture and the adaptation of agriculture to the new conditions, there are numerous indirect effects. Climate change will impact the hydrological conditions of the Netherlands and as a result will result in the salinization of some aquifers. Only few attempts have been made to actually model the hydrological changes and estimate actual salinization (*e.g.,* Maas, 2007).

Discussion

Although it is clear that climate change will have a major global impact on agriculture, the effects on Dutch agriculture are not yet clear. The direct effects of climate change on the current agricultural systems are often considered to be minor and many studies emphasize the positive impacts of the increased temperatures and CO_2 concentrations. The Dutch Central Planning Agency concludes in a reaction to EU communication COM 354 that Dutch agriculture will be confronted with a temperature rise of several degrees. They conclude that “the growing season will have to be shifted and lengthened slightly but given the large, mostly autonomous, changes over the past century, temperature changes do not seem to be a major problem”. Other studies emphasize the deterioration of the production conditions in the Netherlands. An example is provided by Veraart *et al.* (2006) who emphasize the expected negative changes on the agricultural sector in the Northern part of the Netherlands.

Many studies, however, show a more balanced view that incorporates both the positive and negative elements of climate change including, for example, changes in pest and disease pressure, the salinization of aquifers, and changing market conditions. The main problem to effectively develop adaptation strategies for climate change is the uncertainty in the predictions. As long as we do not know what is going to happen, it is extremely difficult to define effective strategies to deal with the changes. We are not only dealing with uncertainty in the actual climatic changes but also with mitigation strategies that may be implemented and potential market developments that may induce farmers to switch practices. A good example is the large scale cultivation of bio-fuels that is discussed in the literature and will directly impact the agricultural sector. Similarly, despite clear recommendations from the Delta Commission, the actual implementation in terms of overflow areas, management of groundwater tables, and other measures are still unclear but will have an impact on Dutch agriculture.

Does this mean that we have to wait with the development of proper adaptation strategies? Certainly not! It means that we have to tackle the changes in a different way. In a general context, Kabat *et al.* (2005) talk about the need for climate proofing to reduce the risks of climate change to an acceptable and quantified level through technological, institutional and societal innovations. The Scientific Council for Government policy stresses the importance to create an atmosphere that facilitates innovation to deal with climate change (WRR, 2007). Similarly, the IPCC report talks about the adaptive capacity at a slightly different scale level. Given the fact that things will be changing, we will have to strengthen this adaptive capacity or innovation of the agricultural sector to enhance autonomous adaptation. A good example is the enhancement of risk management will be increasingly important in agriculture. With proper risk management the adaptive capacity of the agricultural sector will increase (Baltussen *et al.*, 2008).

In the discussion about the adaptation of agriculture to minimize the negative effects and optimally benefit the positive effects we have to look at the agricultural sector and climate change in a broad context. We cannot discuss the adaptation to climate change without looking the mitigation and water management interventions (De Groot *et al.*, 2006). What will happen if farm land is used as spill over (increased nature/recreational value!), if energy crops are to be grown as mitigation strategies, or if soil organic matter contents are raised to sequester carbon (Rosezweig and Tubiello, 2007). Rounsevell *et al*. (1999) show the potential indirect effects of climate change on soil processes. These synergies and tradeoffs are important to keep in mind but also hinder the discussions around the effects of climate change on agriculture and the required adaption strategies.

At the policy level there is an increasing consensus about a changing climate and that the agricultural sector will be affected. Climate change will impact production levels and through adaptation will the agricultural sector benefit even more. It is important to keep an integrated vision that includes all the mitigation efforts in the Netherlands (see VROM, 2005). At the farm level, the decision makers may find limited utility in long-term projections of climate, given the high uncertainties at the finer spatial and temporal scales at which their decisions are made (Giorgi, 2005; Howden *et al*., 2007). Farmer organizations recognize the important role of the agricultural sector in the mitigation of climate change but also the need for proper water management to avoid salinization of water resources. Key is that farm management will take place on the basis of economic principles to fulfil their primary task to produce food and ornamentals (LTO Nederland, 2008). In this context, Westhoek *et al.* (2006) question whether climate change should be included in every study. Studies on the future of agricultural land use in the Netherlands (*e.g.,* Koomen *et al.,* 2005) need to incorporate the effect of climate change. Although detailed studies on climate change effects on individual crops (*e.g.,* Blom *et al.,* 2008) are useful they should be placed in a broader context.

Jansen and Hetsen (1991) already argued for the need for agricultural planning at the European level. With the Common Agricultural Policy in Europe new policy tools have become available. A regional shift of agriculture further north may have local consequences in terms of the introduction of alternative crops and the abandonment of others. However, at a European level this may be very well acceptable.

Consequences of climate change can have other indirect effects. In the context of the Soil framework Directive, farmers are bound to sustainable soil management to avoid, among others, salinization of the soil. Although this is meant for proper soil management, an increase in sea water levels may lead to salt water intrusion and salinization in the Netherlands (Römkens and Knotters, 2007).

Question that remains is whether we need to develop adaptation strategies or that we need to focus on those factors that determine the resilience of the system and influence the adaptive capacity of the system (examples of these factors are provided by Swanson *et al*. (2007). As stated by the WRR (2007): strive for robust solutions rather than optimal solutions given the uncertainties! This is in line with Van Dorland *et al.* (2008) who conclude that it is difficult to determine *a priori* the effectiveness of adaptation measures. The uncertainty already starts with the initial estimates on emissions (Van Amstel *et al.,* 1999) but continues throughout the analysis. Given the uncertainty, it is important to get knowledge by ‘learning by doing’ with input of scientific research. In the Climate for Space research program a project was started where under different market and climate scenarios the effect on dairy production, grain, and potato farming was evaluated at three different scale levels (EU, Netherlands, Northern Netherlands).

The study emphasized the importance of market development as one of the key drivers behind changes. Innovations will be necessary to deal with salinization and weather extremes. Discussion with farmers indicated that farmers are not dealing with the developments or are not well informed.

Conclusions

- Different studies include different factors while studying the effect of climate change on agriculture with very different results. Although it is useful to study specific elements of the system, one has to be very careful in the interpretation of the results and consider that autonomous adaptation may take place.
- Although the analysis of the impact of climate change on individual activities may help us to provide insight in the system, there is a general consensus that more integrated approaches are required.
- Although technical solutions may support the adaptation to climate change, it may be similarly effective to focus on the adaptive capacity of the agricultural sector.
- Few studies include stakeholders in the set up of the analysis and in the interpretation of the results. However, they may play an important role in both autonomous as well as in planned adaptation.

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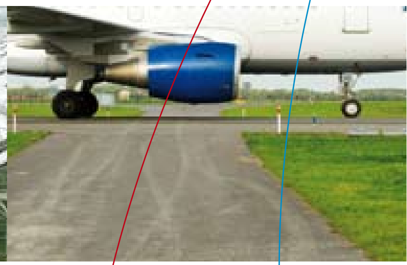

To develop the scientific and applied knowledge required for climate-proofing the Netherlands and to create a sustainable knowledge infrastructure for managing climate change

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