Climate Research Wageningen UR

Projects, researchers and expertise

WAGENINGEN UR
For quality of life

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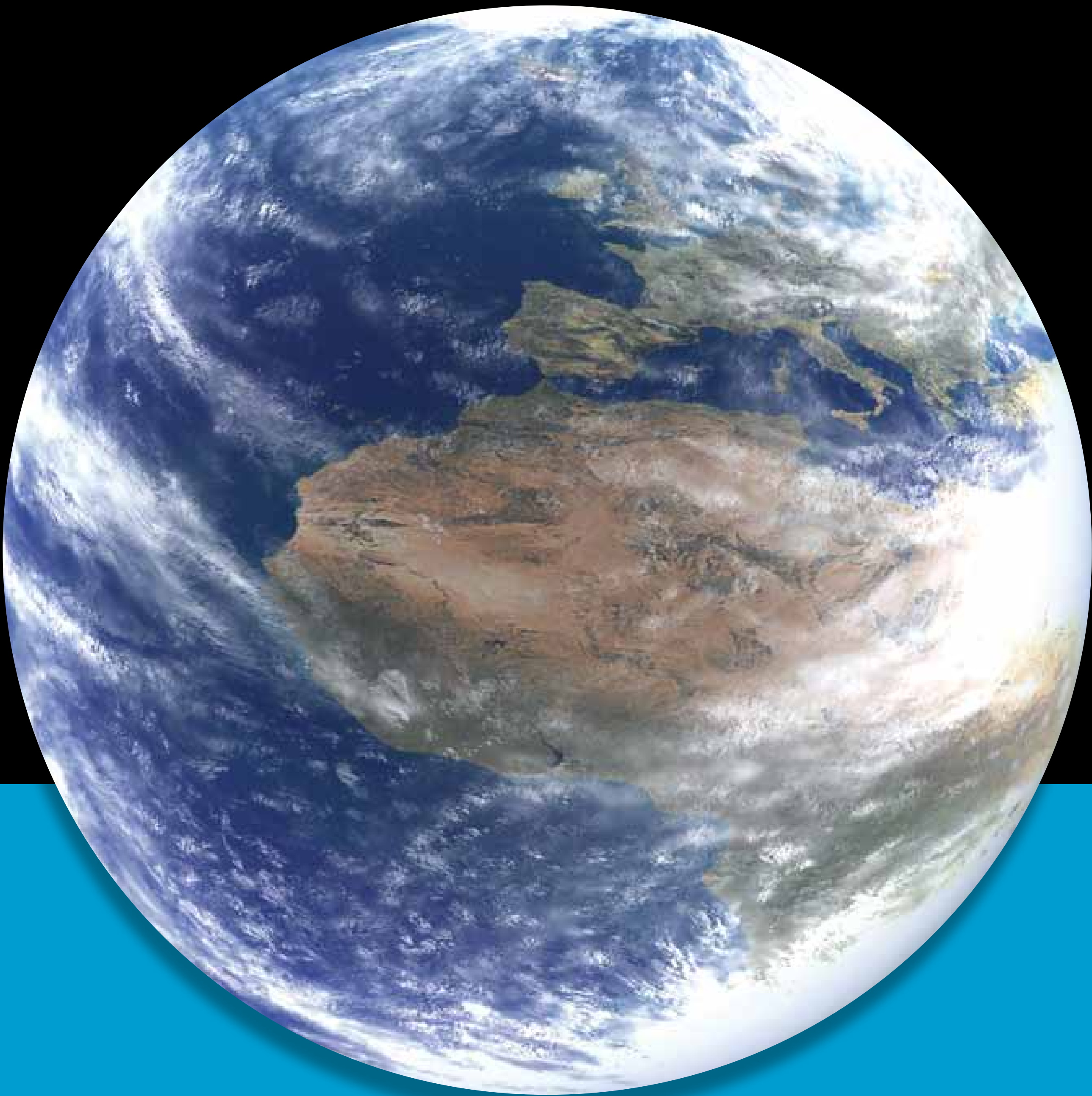
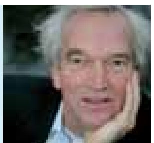


Climate research at Wageningen UR is both in-depth and broad-scoped. ‘Science for impact’ is our guiding principle when working with stakeholders. Wageningen UR focuses not only on the global climate system but also on regional and local climate phenomena, taking both scientific and social aspects into account in an integral way. Wageningen UR wants to play an effective role in the transition to a world that is both climate neutral and climate proof.

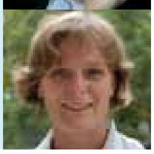
Preface

Climate change is an important and relevant topic for the Netherlands. This is reason enough for Wageningen University and Research Centre (Wageningen UR) and the Dutch Ministry of Agriculture, Nature and Food Quality to devote a great deal of attention to climate change. This brochure and the accompanying film provide a comprehensive overview of the expertise on climate change available at Wageningen UR. The links between the different research activities are very important; we want to bring together the multitude of studies and analyses, from the animal, plant, environmental, spatial, social and economic science perspectives. This will provide new opportunities for innovative business development. Climate change is not only a threat, but also the opportunity to do things better than before. The challenge is to turn the Dutch vulnerability to climate change into a strength. Our strength is using the limited space available in our delta, in a climate-proof manner, thus providing opportunities for among others agriculture, horticulture, aquaculture, recreation and living.
Within Wageningen UR climate change is being explored in a variety of settings. Not only at Wageningen University but also at research institutes such as Alterra, Plant Research International (PRI), LEI, the Agrotechnology and Food Sciences Group (AFSG) and in the institutes for applied research (PPO). Wageningen University and the Van Hall University of Professional Education offer several courses and modules on climate change at the professional, BSc, MSc and PhD levels. Wageningen UR not only answers research questions posed by the Dutch Ministry of Agriculture, Nature and Food Quality but also works for the Ministry of Economic Affairs, the Ministry of Housing, Spatial Planning and the Environment and the Ministry of Transport, Public Works and Water Management. International and local government agencies (the EU and the UN for example) also commission research, so does the private sector. Climate research is also carried out in the context of a number of Dutch and international research programmes.

The first part of this brochure describes the different approaches to climate research and the main research themes at Wageningen UR. This information was gathered in a series of group discussions with researchers from the different Wageningen UR units involved. Professor Herman Eijsackers chaired these discussions.
The second part of this brochure provides an overview of the climate expertise available, listing climate-related projects and contacts. More information about these projects can be found online at www.kennisonline.wur.nl and www.wur.nl (theme climate). The overview of expertise presented here has been created at the request of the Ministry of Agriculture, Nature and Food Quality. The overview will help determine the future focal point of strategic Research Programmes on climate change which is funded by the Dutch Ministry of Agriculture. This programme aims to develop strategic knowledge and expertise for the medium and long term, taking developments in science, policy and society into account. Climate change has many aspects and many effects; on adaptation, mitigation, water supply, landscape, plant health, animal health, food safety, and animal and plant production systems. It is no wonder, therefore, that scientists working at Wageningen UR have a plethora of ideas and opinions regarding the continued development and management of expertise on climate change. It is important that we discuss and agree on the most urgent questions for the future and subsequently define the focal point of future strategic research on climate change.



Pier Vellinga
Theme Leader Strategic Research Programme on Climate Change



Jantsje van Loon
Theme Leader Strategic Research Programme on Climate Change

Content

Introduction

Climate change is covered extensively in the media. Wageningen UR has been carrying out research on climate change for many years already, but recently the sense of urgency among the general public and politicians has increased dramatically. For the strategic research programme on climate change this means that many new questions are raised; regarding adaptation, mitigation and water management for instance. Climate change affects many domains including infrastructure, urbanisation, biodiversity, agriculture and public health. Strategic research aims to find answers to issues that will be relevant five years from now.
It can be difficult sometimes to develop knowledge for future issues in climate change; the topic is so urgent that a great deal of knowledge that is developed today has to be put to use immediately or adapted to the newest insights. This is particularly true of the area of interest to the Ministry of Agriculture, Nature and Food Quality. Many aspects of climate change will affect the domain of the Ministry. At the same time, the business sectors that are part of the Ministry's domain are also contributors to climate change. Land-based agriculture and the dairy industry are examples of this. As a consequence, Wageningen UR will have to work with the agricultural sector and with nature protection agencies to come up with ways to reduce both the causes and the effects of climate change. Changes to animal husbandry systems and to land use will be necessary. Spatial planning can provide many answers to climate change, but Dutch society also needs to adjust to the consequences.
Knowledge on climate change is not only developed in the Netherlands of course, but in many other parts of the world as well. The Netherlands is vulnerable to climate change, as are other deltas. It is in these deltas where the majority of the global population lives. The knowledge and expertise, which we develop in the Netherlands, can therefore be used in many places around the world. As an example we are involved in the international Delta Alliance. Through the Knowledgebase research on climate change, Wageningen UR and the Ministry provide developing countries with the opportunity to prepare themselves for climate change. Thanks to the cooperation between Wageningen University and the Wageningen research institutes, the knowledge that is being developed finds its way directly to the students. As Wageningen University has many international MSc and PhD students, the courses taught here are an efficient instrument for disseminating knowledge on climate change, adaptation and mitigation to the world. At the same time, much can be learned from our international students and partners. Researchers of Wageningen UR are also frequently involved in research that facilitates European climate policies.
Climate change is a very complex issue, which implies that many research projects bring together scientists from a variety of disciplines. This way we are able to develop an effective strategy for mitigation and adaptation. Using a multidisciplinary approach and combining knowledge from both the natural and the social sciences enables us to effectively address technical, economic as well as administrative aspects. The excellent balance between fundamental, policy-oriented and practical research at Wageningen UR also provides us with much added value. Interaction between scientists of different disciplines is important, as many parts of society are still lacking a sense of urgency when it comes to climate change. Experts, however, are convinced that we need to take action as soon as possible. Research at Wageningen UR crosses from the micro-level, through system approaches to the global scale. By connecting spatial dimensions, time dimensions, scientific disciplines and applications in climate research, the knowledge that we develop can be targeted at the different stakeholders, from government agencies to private business.

Kees Slingerland
Domain Leader Land & Water and Director of the Environmental Sciences Group

Climate system

Atmospheric processes in the atmospheric boundary layer

The atmospheric climate is created by the synergy between atmospheric processes that are influenced by solar radiation and interactions with the earth's surface. Solar radiation has been measured at Wageningen UR for over 80 years, because of its importance to agriculture. This means Wageningen UR owns one of the most extensive series of measurements of solar radiation in the world. Several groups in Wageningen have been studying the exchange of heat and water vapour between the earth's surface and the atmosphere intensively for a long time. The Meteorology and Air Quality Group, part of Wageningen University, researches atmospheric processes in the atmospheric boundary layer (the lowermost 2 km of the atmosphere). The Earth System Science and Climate Change Group research the complex interactions between earth and the climate system. Other parts of Wageningen UR also look at the interaction between land use, natural ecosystems and agricultural production processes. Typical for our research into the climate system is the combination of physical knowledge about atmospheric processes and biochemical knowledge of greenhouse gasses, to that we add suggestions for practical measures. Internationally, Wageningen UR makes important contributions to improving climate models and developing methods for innovative observations.

The role of land use in the climate system

In the late Eighties, all large international climate research institutes presumed that the climate system could be explained based on knowledge of the oceans and the atmosphere. Land surface and land use seemed irrelevant. Researchers at Wageningen UR were among the first to start large-scale experiments trying to unravel the mutual influence of land degradation, deforestation and changes in land use on the climate system. Nowadays, the terrestrial system is an integral part of climate models everywhere.

Important perspectives of Wageningen research into the interaction between land use and the climate system are:

- *The influence of land use on weather and climate*
  The distribution of forests, agricultural areas and urban areas has a large influence on (local) weather patterns, even the small-scale distribution patterns. This means changes in land use will lead to changes in the weather and the climate. If for instance the entire Amazon area were to be deforested, new patterns of temperature and precipitation would arise. This is due to the changes in the reflection of solar energy from the earth's surface and the changes to evaporation. The same is true for the Sahel. When the climate becomes drier, vegetation becomes sparser and the interaction with the atmosphere changes, leading to different precipitation patterns. Because of these interactions we devote much research to the consequences of deforestation, desertification and urbanisation on the climate system.
- *The role of land use in the emission and sequestration of greenhouse gasses*
  The global carbon balance is partly dependant on the behaviour of the terrestrial components of 'system earth'. Of the total yearly global CO_2 emission (about eight gigaton), a quarter (two gigaton) is stored in the worldwide forests on a yearly basis. Without these forests, the concentration of greenhouse gasses in the earth's atmosphere would be much higher than it is presently, leading to much greater temperature rises. Also, a large amount of carbon has been sequestered in forest soils. Should this carbon be released, the concentration of greenhouse gasses would rise dramatically, leading to an increase in temperature rises.
- *The role of the hydrological cycle in the climate system*
  The hydrological cycle is an integral part of the climate system and an important resource for agriculture and nature. A number of groups within Wageningen UR are currently focusing on the consequences of climate change to the supply of water in the next 50 years, analysing hydrological processes and calculating scenarios for the future. These scenarios project the impact of climate change on the availability of water in the next 50 years. This research takes place from the global to the local level. Climate change is one of the most

important driving forces behind future water management. Until now most water management was reactive; based on data from the past. With climate change, however, we are dealing with an amount of uncertainty concerning future developments, which requires us to use statistics in a different way. Water management needs to become more pro-active.

Pioneering role and international network

Wageningen Institute for Environment and Climate Research teaches PhD-students in the fields of environmental science and environmental policy. Climate change has been an important subject in these courses for twenty years. This started with research into greenhouse gasses; where do they come from and what are the underlying processes?
One example is PhD-research concerning the production of methane by rice. Rice plants grow in water, without oxygen, which means that all decomposed soil elements leave the system as methane. In the early Nineties it was discovered that the rice plant functions as a 'chimney' for the methane; the gas is quickly emitted into the atmosphere.
Also, CO_2 has been the subject of many research-projects. How much of it is absorbed by forests?
Not only the causes of climate change were investigated, the effects were also researched extensively. What happens when the temperature rises? What are the effects of an increase or decrease in precipitation? The effects on nature and agriculture will be felt globally.
Several Wageningen professors and researchers take part in international programmes. Professor Pavel Kabat for instance, is project leader of the ILEAPS programme. Professor Bert Holtslag directs the Global Energy and Water Cycle Experiment (GEWEX) Atmospheric Boundary Layer Study and professor Rik Leemans is currently chairman of the Earth System Science Partnership. Within this partnership some 10,000 researchers come together to define the research agenda. The strong international network of the forerunners of Wageningen UR provides our students with additional opportunities to work with top researchers of other international institutes.

More information on the projects, researchers and expertise in relation to climate systems please refer to page 26.

Mitigation

The challenge

Climate change is an unwanted by-product of the methods we currently use to generate energy and use our land. These methods result in the emission of greenhouse gasses that influence the climate system and create a rise in global temperatures. Mitigation means fighting climate change by reducing the nett emissions of greenhouse gasses. International agreements, such as Kyoto, have been reached to reduce greenhouse gas emissions. In 2005 the Dutch cabinet decided to take the advice of the Parliamentary Commission on Climate and commit to the so-called 'Two Degrees Climate Target' as proposed by the European Union (EU). This climate target holds that the mean temperature should not rise more than 2˚C. The target calls for sweeping post-Kyoto emission reduction policies: a reduction of 30% of all greenhouse gas emissions by 2020 and a 60% to 80% reduction by 2050. As a consequence, the Netherlands needs to monitor and register these reduced emissions.

Mitigation requires radical adjustments in energy production, water management, nature conservation, spatial planning and land use. Should we use the current knowledge and technology, these adjustments will be very costly. The sectors within the domain of the Ministry of Agriculture, Nature and Food Quality account for about 15% of the total Dutch emission of greenhouse gasses. This percentage varies with the type of calculations used to ascribe energy use to the sectors. The social pressure to move towards climate-neutral agriculture and food production is increasing. Accomplishing this transition would involve such diverse issues as soil management, the choice of crops, energy use, food production, food processing, transport and nature conservation.

Additionally, the Netherlands (and Europe) aim to derive 20% of all their energy needs from biomass by 2020. The Dutch cabinet has made funds available to enable the development of a so-called 'bio-based economy'. Producing energy from biomass can lead to higher world food prices and increase the pressure on global biodiversity. It is important to consider the nett effect of the production and use of biomass for energy, in terms of CO_2-equivalents and sustainability. Wageningen UR carries out a lot of research into the different aspects of mitigation. In the following paragraphs a number of important mitigation research themes are discussed.

Monitoring, feedbacks and early warning

Climate systems research revolving around the interaction of land use and climate not only leads to a better understanding of emission processes, but also plays an important role in discussions about the reports the Netherlands is obliged to deliver based on international agreements. At the moment most reports are based on estimates and assumptions. Over the last few years a system has been developed, together with international partners, which can measure the CO_2-flux on a continuous basis, even at the level of a single field. Monitoring shows that many of the greenhouse gasses in the Dutch atmosphere are actually emitted abroad. It will be important to know where emissions originate from, should more stringent international treaties concerning emission reduction come about in the future.

An insight into the yearly fluctuations of carbon sequestration in, for instance, forests and the emissions by, for example, fen meadows, helps us to understand climate processes and offers a basis for developing measures. Insight into the relevant processes is also material to understanding so-called '*feedbacks*' in the climate system. Little is yet known about these feedbacks; about how strong they are or when they occur. In case the forest cover in certain areas disappears, because of climate change for instance, this could lead to the release of all CO_2 that was sequestered in this forest and consequently enhance climate change. This possibility makes it important to chart all possible feedbacks and to test them for their ability to function as an early-warning system. Methods for influencing these feedbacks should also be looked into. Professor Marten Scheffer investigates warning signals by determining the possibilities of ecosystems to exist under a variety of circumstances and by looking into their vulnerabilities. The goal of his research is to determine the risks to ecosystems at an early stage.

'Source' or 'sink'

Monitoring of emission levels in a variety of land use systems, leads to interesting new possibilities for emission policy. For instance, the development of climate services such as carbon sequestration by the animal husbandry sector.
A typical Dutch dairy farm in an area of fen meadows such as the Groene Hart region is confronted with a very high groundwater table (less than half a meter below ground level). With three cows per ha on average, such a farm raises a nett profit of about € 400 to € 500 per ha per year. About 50% of this profit originates from EU-subsidies. Such an intensive farm, with a high cow-density, produces a significant emission of methane and CO_2; releasing about 10 tonnes of CO_2-equivalents per ha. Should the farming system be adjusted to have less cows per ha and should the water table be deregulated, allowing the land to flood from time to time, this farm will go from being a source of greenhouse gasses to becoming a sink. The new farming system will mean that carbon is actually extracted from the atmosphere. Should the farmland develop into a wetland or swamp forest, the system could absorb about 10 tonnes of CO_2-equivalents per ha (instead of emitting 10 tonnes per ha in the present situation). The option of using the farm as a carbon sink is economically viable, as carbon has become a commodity, worth € 10 to € 50 per ton CO_2-equivalents (depending on market circumstances). Should the farmland indeed become a swamp forest, it will of course lose its agricultural function. The Ministry of Agriculture, Nature and Food Quality could find this type of 'green cultivation' an interesting policy option, worth considering.
Research on this topic starts with understanding the underlying processes; is the area a source or a sink for greenhouse gasses? Subsequently, analyses of the situation will offer the insight needed to evaluate the consequences for policy and practice.

Agricultural research and climate issues

Traditionally, agricultural research has been aimed at increasing the yield of solar influx and using water and nutrients in an efficient way. These aims are also very relevant to climate issues. For instance: To find out whether certain soils can be used to sequester carbon and thus help mitigation, knowledge about the efficient use of natural resources can be very relevant. This knowledge is also used in research projects looking into the possibilities of creating a farming system with completely closed carbon and nitrogen cycles.
Dairy farms contribute significantly to the Dutch emission of methane. Fermentation processes in the cow's rumen play an important role in methane production. Researching the effects of different types of feed on both milk production and methane emission gives dairy farmers more information on the effects of emission-reducing measures on milk production. This research also supplies information that can be used to record emissions per farm. At the moment emission registration in the Netherlands still uses average statistics (gathered by Statistics Netherlands).
In order to find successful strategies, the entire agricultural chain needs to be taken into consideration. As it turns out, primary production accounts for about 40% of all emissions in the chain. Reaching agreements on reduction involves many stakeholders; from entrepreneurs to consumers to policy-makers.
Mitigation measures in agriculture are using up a lot of fossil fuel at the moment. To make our agriculture less dependant on energy, a lot of new and mostly highly technological knowledge is required. Farms offer several opportunities to help mitigation as they have a lot of space available to install windmills, solar panels and bio-fuel installations.

Climate change gives agricultural research a new perspective. An example of this is the current research into energy-producing greenhouses.

In addition to sunlight, water and nutrients, biodiversity is an important natural resource. An interesting question is how to use biodiversity in a smart way, supporting responsible land use and mitigating the effects of climate change.

Trade-offs

Research at Wageningen UR is also aimed at trade-offs of climate measures. Acting on one problem can create another. To optimise climate measures, it is important to gain insight into all relevant trade-offs. This not only includes climate-related trade-offs, but also trade-offs concerning animal welfare for instance. Climate change is connected to many other sustainability issues, as well as to social issues. Note that a recent study by Leon Braat (Alterra) has shown that not taking any climate measures also induces trade-offs.
In a current EU-project Alterra is mapping how other policy fields are connected to climate change policy. Researchers use scenarios to calculate the effects of climate measures on the environmental goals of the European Union. This knowledge is also applied to determine the effect of mitigation measures on a regional level. In the Netherlands, but also in China for instance,
This type of instrument, that projects the outcomes of certain measures, is very useful in international negotiations. It can help to determine whether the goals that have been set are realistic.
Insight into the climate trade-offs of making agriculture more intensive or more extensive, and of regular, organic and high-tech systems is important when choosing the direction of agricultural developments. For example: A more extensive use of grasslands might improve the nitrogen-efficiency on dairy farms, but if the quality of the feed decreases at the same time, it could also lead to a higher methane production per cow.
The forestry sector is also interested in trade-offs of climate measures. Forests can be used to store carbon (in wood) but also provide raw materials for bio-energy. These two do not mix, however. This makes it important to look at both, and include the effects of certain measures on the economy and biodiversity in the research. One way to do this is by analysing the sustainability of the entire wood production chain. Such an analysis could also give insight into the climate effects of Natura2000, for example. If the Netherlands and Europe protect larger forest areas, this will result in more wood being imported from other countries. This will affect biodiversity and sustainability in other parts of the world.
Food production is largely connected to the natural resources in our soils. Loss of soil fertility is very hard to counteract. This means trade-offs related to soils are very important in the discussions on bio-energy.

Forests and climate

Many areas in the world will suffer further desertification as a result of climate change. Spain, which has about 20 million ha of forest (the Netherlands has 300.000 ha), will become much drier and forests will disappear. The loss of millions of hectares of Mediterranean forests will cause massive decomposition of organic material. At the same time the buffer function of these forests is lost, which will result in erosion, large effects on biodiversity and a huge impact on the local population. Alterra is currently looking at the effects of climate change on forests on a European scale. What amounts of carbon can be sequestered and how much wood and biomass can be taken from these forests in case of increases or decreases in the forest dimensions? To find out, projections are available for all European forests, enabling comparisons between countries.

Bio-based economy

The concept of a bio-based economy is attractive because it can help mitigate climate change and reduce the use of fossil materials. In a bio-based economy renewable resources, in this case biomass, replace fossil fuels. It is important in this concept to use this biomass in the most efficient manner possible. This not only means using biomass as a source of energy, but also as a resource for other products and materials, combined with bio-energy. In addition, the production chain needs to be organised as efficiently as possible. Shipping biomass across the globe to be processed and subsequently re-distributing the product worldwide – as now happens in oil production - is undesirable. Wageningen UR has a leading role in Europe when it comes to refining biomass and coordinates several large projects. Research is mainly aimed at technological process-development, but also involves calculating effects. Bio-diesel is not the only subject of research; we also look into the use of bacteria and fungi for new products such as bio-plastics, natural softening agents and 'green' polystyrene foam.

Much attention is devoted to the subject of sustainable production methods. AFSG is looking into second-generation bio-fuels, for instance. This research has shown that literally all environmental effects have to be taken into account when comparing first and second generation bio-fuels. Policy-demands can be a good method to pave the way for second-generation bio-fuels and sustainable new technology. Note that parts of the bio-based economy are very low-tech; it also includes people using wood or cow dung for cooking.

Life cycle analysis

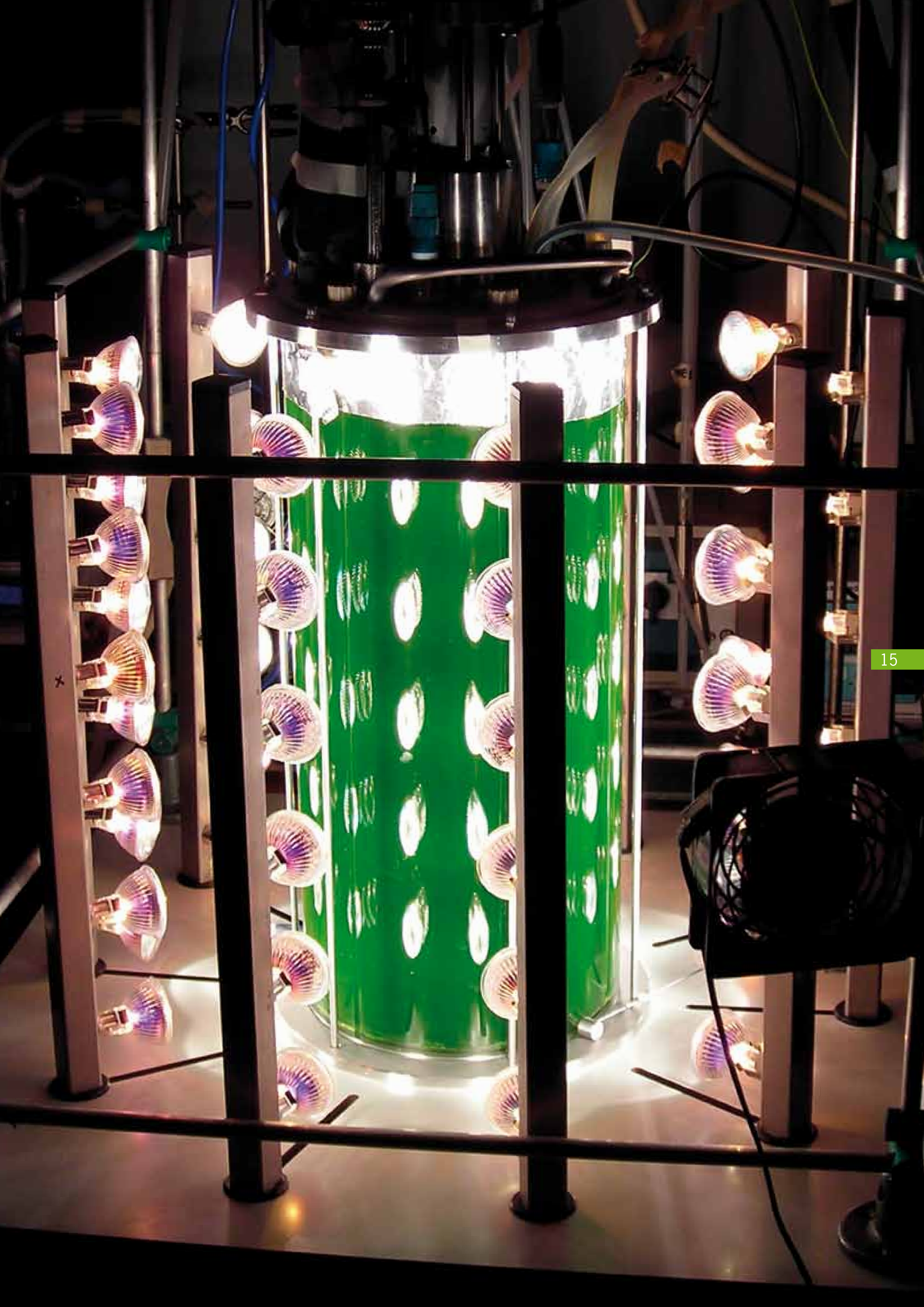
The development of a climate-footprint can enable consumers to get a grip on the climate effect of products such as food. It can help them take climate into consideration when buying. These kinds of labels already exist for household appliances, cars and houses. Producing food in a climate-neutral way is a big challenge. Because we operate in an open global economy, consumer wishes across the globe are as important as the desires of Dutch clients.

Working with other international institutes, Wageningen UR is developing a methodology for a climatological life cycle analysis. The parameters that should be included in this analysis are looked into and index numbers are being determined.

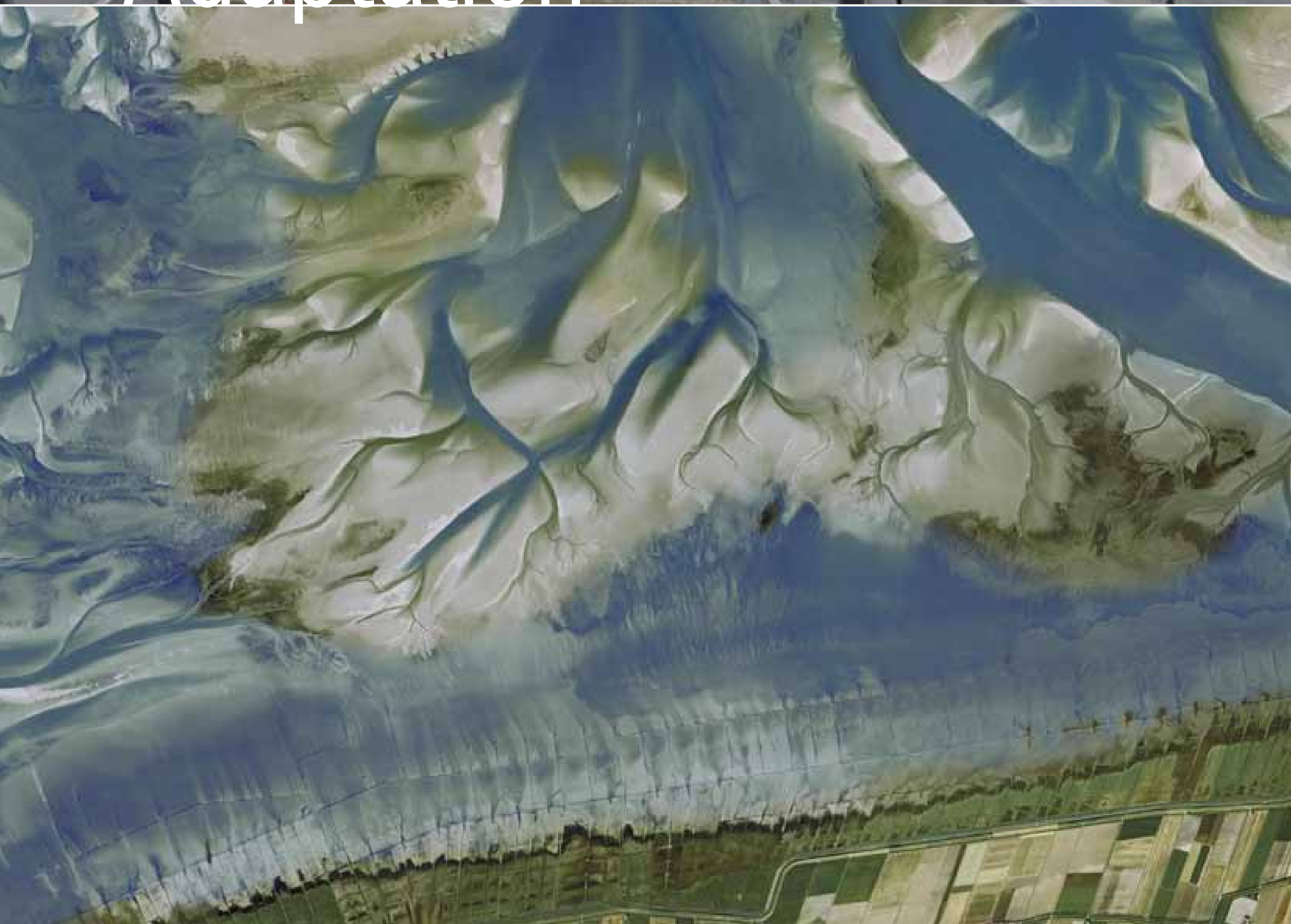
AFSG currently looks at the possibilities offered by a range of agrarian residual products. Some can be used in animal feed or the production of bio-energy. It is important that technical availability should not be the only consideration. The emission of greenhouse gasses should also be taken into account. Therefore, AFSG has developed a calculation tool for CO_2, which indicates the amount of CO_2 that is released at different stages of the energy production chain. This type of calculation is very relevant, as energy producers need to show how much CO_2 is released.

PPO is currently working with the city of Almere to find out how much emission reduction can be achieved by stimulating local food production. This includes production, processing and distribution of food on a local scale. Cars are the main method of transport for Dutch consumers when grocery shopping, however. This means that the transport from the store to the consumer's home actually has a much larger effect on greenhouse gas emissions than the (global) transport of the food product.

More information on the projects, researchers and expertise in relation to mitigation please refer to page 27.



Adaptation



Adjusting to climate change

Even though international agreements have been reached to reduce the emissions of greenhouse gasses, the time lag in climate effects means climate change is inevitable. We need to reckon with temperature rises, associated rises in sea level and extreme weather conditions such as intense rainfall, heat waves and drought. We will also see slow changes leading to alterations in ecosystem dynamics, which cause loss of biodiversity and the introduction of new pests, for example.

The 'low countries' are vulnerable to climate change and The Netherlands will have to make a large effort to adjust in time. It is crucial to make conscious decisions about the measures needed. The government should facilitate these measures. To work on useful adaptation strategies, a national policy on Adaptation, Spatial Planning and Climate has been initiated by the Ministry of Agriculture, Nature and Food Quality; the Ministry of Economic Affairs; the Ministry of Housing, Spatial Planning and the Environment; the Ministry of Transport, Public Works and Water Management; the provincial governments; the Association of Netherlands Municipalities and the Dutch Association of Regional Water Authorities.

Adaptation is not new to the Netherlands. Our country has been redesigned a few times already. New are the many uncertainties that exist regarding the nature, speed and measure of change we can expect and regarding the reaction of ecosystems and agriculture to the occurring changes. Adaptation to climate change means dealing with uncertainties and variability.

An important question to consider is: Should we adjust by changing the way we do things or by doing different things? Agricultural changes are usually directed by national and international policies on landscape, biodiversity and agriculture. Climate change could have a prominent role in future policies.

The challenge for agriculture will be to optimise its systems for changed climate patterns, for instance by choosing crops that are less sensitive to salinity and drought. This might include changing the water supply. We also need to adjust our safety measures for higher sea level and the changed flow in our rivers. Electricity producers should be prepared for the changes in availability of cooling water and industry needs to find ways to produce at higher temperatures or altered precipitation patterns (that could lead to flooding). More storms and more powerful winds could damage houses, office buildings and installations. This means urban areas also have to be adapted. Not only to changing wind patterns, but also to periods of heat or intense rainfall. Inner cities in particular run the risk of accumulating heat because of the dense build-up (that holds warmth) and the large amount of people and activities (such as transport) in city centres. This is called the 'heat island' effect. Also, the health care sector needs to be prepared. When heat stress is imminent, it is essential to have enough cooling facilities. A changed climate could also mean new pests and diseases.

Research has an important role to play when it comes to evaluating costs and benefits of adaptation measures. Knowing these, efficient policies and strategies can be devised. Wageningen UR is involved in research concerning adaptation. Below, we will present a few of the themes our research currently focuses on.

Multidisciplinary approach

Adaptation is a complicated process involving many stakeholders and uncertainties. Wageningen UR's wide scope and expertise in quantifying effects and uncertainties coupled with the ability to translate these into consequences for spatial planning is valued internationally. A multidisciplinary approach helps to find synergy. A good example is the idea to expand the 'Ecological Main Structure' (a network of ecological corridors) to suburban areas, in order for our cities to profit from the cooling effect of green areas. Thanks to the cooperation between administrative and physical scientists in Wageningen, our administrative scientists are at the forefront when it comes to introducing the topic of climate change into the international arena of the administrative and political sciences. Connecting scientific knowledge from the social and physical fields also provides us with opportunities to consider the issue of climate adaptation on a variety of scales. Adaptation measures are often conceived on a regional or national scale, but these areas might not coincide with a ecologically coherent area.

Knowledge from the social sciences can also be important to the implementation of adaptation measures as some of these might encounter a lot of resistance. In those cases communication about measures is more important than quantifying parameters or effects. There is still a gap between the information provided by climate researchers and the information needed by society.

Adaptation in nature conservation

In April 2009, the EU published the so-called 'White Paper' on climate change. This document states that realising spatial coherence is one of the important adaption strategies for nature. This includes connecting ecosystems, allowing species whose habitats are shifting to move with their habitats. European nature conservation policies have led to the designation of Natura2000 areas. Unfortunately, these areas do not yet function as a coherent network.
An important research question is whether multifunctional landscapes can be used to interconnect Natura2000 areas. Facilitating this by restructuring agricultural subsidies is an important aspect of this research. An example could be the afore-mentioned climate services. When creating such policies, scale effects are important. The goal is to realise international spatial coherence, but this coherence is to be implemented on the regional level. This means knowledge and tools are needed to balance the larger picture and individual stakes in regional processes.
European nature conservation needs an international overview or map of the locations, which offer the best opportunities for each type of natural ecosystem. The Netherlands, being a delta, clearly has an international responsibility when it comes to protecting swamp nature and wet nature. This needs to be taken into account on a national and regional level. Research needs to provide answers on this should be done.

Diseases and pests

Knowledge of the effects of climate change on pests and diseases is currently limited. Do pests and diseases occur more frequently because of climate change? Does the intensity change or are new pests and diseases appearing? To facilitate a timely response, more knowledge is needed on these issues.
The Central Veterinary Institute of Wageningen UR is trying to predict the spread of infectious diseases based on microbiological, immunological and epidemiological knowledge. Combining this knowledge with climate models offers an important challenge. A recent outbreak of bluetongue disease provides a good illustration. Future outbreaks of bluetongue will be dependent on the amount of resilience built-up in the cattle on the one hand, and the prevention of midges on the other. Because of the relationship between the occurrence of midges and temperature, we need to combine research into midges with climate models. The opportunities for risk analyses and predictions will be expanded by this combination.
Infectious diseases are often dealt with in a responsive way. As risk analyses improve, we will be able to better anticipate future developments. An example of this type of pro-active behaviour dates from two decades ago, when climate issues were not as urgent as today. African swine fever does not occur in the Netherlands normally, it is an exotic virus that only occasionally pops up in Northern countries. The occurrence and spread of this disease has a distinct climate component. About 20 years ago, researchers prepared for introduction of the African Swine Fever virus and developed diagnostics. When the virus appeared in the Netherlands a few years later, we were well prepared and measures could be taken quickly, a good example of pro-active behaviour. We will always be confronted with surprises when dealing with infectious diseases, however.

Marine environment

The water temperature of the North Sea has seen a significant increase recently (over 1.5˚C near Texel island). This increase influences the variety and distribution of fish species.

The shift in species has consequences for fishing. Red mullet, for example, is a species that is relatively new to the North Sea. It now features on many menus, but no quotum for this species has been set. Climate change could lead to such a transformation in the marine system that jellyfish could take the place of fish.
Additionally, the future will bring other large changes to the sea environment. For instance, the construction of large-scale windmill parks in the sea (a mitigation measure) has considerable consequences for spatial planning at sea. From an economic perspective, location choices for windmill parks are made based on distance to the shore, sea depth and associated ecological effects. Windmill parks could be used for marine production, for instance breeding shellfish or producing raw materials for bio-fuels.
Nature protection areas, species protection areas and Natura2000 areas are also found at sea. One of the species that needs protection is the ocean quahog (*Arctica islandica*), a mollusc that can live to 120 years in the North Sea and literally hundreds of years old near Iceland. This species is almost at the top of the priority list and environmental protection agencies are arguing for the designation of a specific ocean quahog protection area near Doggersbank. The ocean quahog is at the limit of its temperature tolerance near the Netherlands, however. Should the temperature rise any further, it will disappear from our waters. This knowledge is important to future protection policies.

Sea level rises

The Delta Commission 2008 - a special committee appointed by the Dutch government to advise on protecting the country from climate change - has used knowledge generated by Wageningen UR when preparing her advice on water safety in the Netherlands. This knowledge was developed while researching the possibilities of adjusting freshwater management and water safety. Because of rises in sea level, coastal areas will be confronted with more salinity problems. Water management and water use in these areas need to be adjusted.
As space is limited in the Netherlands, Wageningen UR is currently looking at the possibilities for multifunctional dams that combine the safety function with other functions, such as nature development, habitation, infrastructure, aquaculture and saline agriculture. Another safety measure we are researching is the addition of sand. The effect of sand supplementations to the natural values of the littoral zone and the shifting behaviour of the supplemented sands are subjects of our research. The supplemented sands shift from the beach to the dunes, thus enabling the dunes to keep up with sea level rises. This research combines physical aspects with vegetation science, as vegetation plays an important role in the formation of dunes.
The long-term research into land subsidence caused by the extraction of natural gas near Ameland Island, is also interesting. In this research the subsidence of the soil plays the same role as sea level rises; providing insight in the future effects of rises in sea level, a more dynamic coast and a rising intensity of coastal processes.

Adjusting agriculture

Because of climate change, agriculture will be confronted with a rise in temperature, changes in precipitation patterns and extreme weather conditions. The expected decrease in rainfall during the summer will have a particularly significant impact on agriculture. At the same time, rising sea levels will cause higher salinity in coastal areas. The rising amount of CO_2 (one of the main greenhouse gasses) in the atmosphere also has an effect on crop growth.
Alterra and PRI have looked at the impacts of climate change on future agriculture within the EU. In Southern Europe in particular, it could become too dry for certain crops, which means their cultivation will move further north. For the Netherlands, however, the effects of climate change on agricultural production are thought to be positive.
It is imperative that agricultural systems are optimised in time to confront changing climatic circumstances. An example is the introduction of crops that are less vulnerable to drought or salinity. Perhaps we have to adjust our water supply by storing freshwater in the IJsselmeer and divert this water to the more saline coastal areas in the south western delta.

At ASG researchers are finding out whether farm animals can adjust to higher salinity levels. Wageningen UR is also researching the cultivation of salt-tolerant crops. Willem Brandenburg at PRI is looking into the opportunities for cultivating innovative saline crops in the Dutch coastal zone.

Plant breeding is another way to adjust crops to the changing circumstances. Rice is one of the most important food crops in the world. Most rice is grown in Asia, where the availability of freshwater for rice cultivation is diminishing rapidly. By changing the rice genome to increase the plant's water efficiency, rice fields could possibly be turned into aerobic systems; making regular irrigation no longer necessary.

A research project in the Directorate General Development Cooperation (DGIS) / Wageningen UR partnership is currently focusing on safeguarding plant genetic resources against climate change. This project is carried out at farm level in Ethiopia.

Institutional arrangements

Adaptation not only means changing the way we do things, it is also involves adapting our institutions (the set of rules, organisations and policies designed to govern public affairs). Research shows that it is important to clearly define the tasks of the public and private sectors in adaptation. In the Netherlands this definition of roles is currently unclear. This calls for new institutional arrangements, which provide an insight into the responsibilities of the administration and clarify who has to take the initiative. For agriculture, for example, it is important to know to what extent the government will take measures to secure the water supply and to what extent the sector has to provide its own solutions. If this is not clear from the start, suboptimal solutions are the best we can hope for.

When dealing with a topic as current as adaptation, top-down solutions such as new laws are usually the first to come to mind. However, connecting to other policy areas might be much more effective. Characteristic to the issue of adaptation is the fact that many measures are still unclear. That is why the 'adaptation-wheel' is used to find out if institutions are flexible enough. The 'adaptation-wheel' is an instrument designed to measure whether rules and regulations are adaptive or not and to see if and where improvements could be made. The instrument is geared towards governmental agencies at all levels: European, national and regional. All levels of government create regulations, laws, by-laws and licences that could have learning elements built-in.

More information on the projects, researchers and expertise in relation to adaptation please refer to page 30.

Internationalisation

Global Problem

Climate change is a global problem. The effects of climate change occur everywhere and it is high on the international agenda. A large number of Wageningen professors and researchers play an important role in the international climate research community. They work together in the Intergovernmental Panel on Climate Change (IPCC), in global climate programmes, in the International Human Dimension Programmes (IHDP) and in the Food and Agriculture Organisation of the UN (FAO).

Agriculture, fisheries, food systems and nature conservation are directed internationally by policies and regulations on the level of the EU (CAP, Natura2000) and the UN (WTO). Because of this, climate research at Wageningen UR is internationally oriented.

A lot can be learned from other countries and there is a large global demand for knowledge on the effects of climate change and options for adaptation. Wageningen UR is working with a number of other knowledge institutes, at home and abroad, on creating the International Delta Alliance. In this alliance all low-lying countries of the world will come together to find solutions to the problems of sea level rises, soil subsidence, warmer cities, salinisation and the associated reduction in water availability faced by our delta cities.

Wageningen UR is an important player internationally. Not only because we have a lot of expertise available on climate change, but also because we have a very international scientific and educational community. Many students and staff hail from other countries and there are a great number of courses that are taught in English. By now, about 60% of our PhD-students are foreigners, most of whom return to their countries of origin after their promotion and end up in strategic positions. Through Nuffic (Netherlands Organisation for international Cooperation in Higher Education) and other programmes we support universities and research centres, throughout the worlde helping fundamental capacity building.

A large part of our research effort is directed towards finding solutions, not driven by mere curiosity or fundamental science. Finding solutions is exactly what is needed internationally. Measures regarding adaptation to the effects of a changing climate often require changes to the use of space. This often means taking adaptation measures in all sectors, from water management to agriculture to urban development. Changes should be taken everywhere, involving all inhabitants. This calls for social and participatory policy development.

Wageningen UR has a long tradition in working in an interactive way, especially in the tropics. We are used to translating local problems together with counterpart organisations (both political and scientific) to come up with research questions.

Another strong point is our ability to connect the various scales. An example is the Wageningen research on agricultural economics. One minute our researchers are making calculations on the world trade balance for FAO or the Council of Ministers, looking into global movements of raw materials; the next minute they are researching adaptations for an agricultural system on farm level or helping large international corporations to include environmental sustainability in their annual reports.

Plant seeds and propagation material provide the basis for agriculture. We collect the basic material for breeding – the species and the propagation material - from all over the world. This also means Wageningen UR, Dutch private industry and the Northwest-European community as a whole have a large international responsibility to enable sustainable development. A number of research themes, in which internationalisation is important, is described below.

International nature conservation policies

Nature protection areas everywhere are designated to protect certain species or habitats. Climate change causes a shift in environmental circumstances. Some plant and animal species will easily move with their habitat or adjust to the changes, but others will find it difficult. For example this is because land use between habitats prevents them from moving. It is important to find out how to deal with this problem. In Europe rules and regulations are in place, but developing nations are also confronted with these issues. Sometimes it proves

easier to designate trans-national nature parks in the tropics than here. But developing countries also have many areas undergoing strong urbanisation.
Wageningen UR is involved in a number of integrated research projects concerning large herbivores. What will happen for example when a herd of elephants move out of a national park because of drought? The area available to elephants has been drastically reduced by climate change. This is true even for the large herds of East Africa.

Climate and decision-making

The environmental effects of policy measures are not taken into full account yet. This is true both in developing nations and in Europe. In the decision-making process little consideration is generally given to possible negative effects on climate change or other domains.
For this reason Wageningen UR is interested in mechanisms or institutions that can incorporate environmental concerns in the decision-making process. This could be done in a positive way, using subsidies. An example could be the development of agricultural policies that pay for reductions in the environmental burden. At LEI, researchers are considering the introduction of ecological services and the associated conditions and prices.
Many mechanisms have been developed to translate policy decisions on the highest levels to the stakeholders. The freedom of action of individual farmers is now contained by decisions by the Food and Agriculture Organization (FAO) or the Organisation of Economic Cooperation and Development (OECD).
Opposite mechanisms, supplying feedback on the experiences and considerations of the stakeholders to the policy-makers are still weak. Wageningen UR investigates the possibilities of participatory approaches on various scales from a social-economic perspective. The goal of this research is to facilitate feedbacks from the grass-root level to policy makers. This knowledge is very relevant to the development of international climate policies.

Development issues, competing claims and climate change

In many countries development issues are still high on the agenda. Climate change should be integrated with development issues. Wageningen UR has a long tradition in researching rural development and food security. Climate change is a new aspect of this research.
It is important to know, for instance, whether intensifying food production in a certain area is even possible under changed climate conditions. How can you make agricultural systems more robust and are these systems in line with the wishes of the local people?
Another important subject refers to rival claims. An important part of the Dutch bio-based economy, for example, will have to get their raw materials from abroad. Unfortunately, this could cause deforestation or affect food production and natural values. It is therefore important to gain an insight into the global effects of changes in land use resulting from the introduction of a bio-based economy. These include effects on the environment, soil, water quality, water supply, biodiversity and landscape. It is also important to take social-economic aspects into account. Research into the possibilities provided by the oil palm specifically considers so-called ‘smallholders’. A group of over one million small farmers owns about half of the entire oil palm acreage. This has consequences for the production level that can be obtained, as small farmers are not always looking to increase production because of labour or cost restraints.

More information on the projects, researchers and expertise in relation to internationalisation please refer to page 34.

Wageningen UR Climate Expertise: more information at www.kennisonline.wur.nl

Focus	Expertise (through projects)*	Number of projects	Number of researchers	Size of research budget**	Research budget in 2009**	Statutory Research tasks (LNV)	Knowledgebase Research (LNV)	Policy-supporting research (LNV)	University funding	EU programmes	Public and private sector	N.W.O.***	Programmes (FES, BSIK)	Contact	E-mail
CLIMATE SYSTEM															
Climate system on a global, regional and local scale															
Global	Improving climate models	2	1	M						x				Ronald Hutjes	ronald.hutjes@wur.nl
	Feedbacks	1	5	G						x				Fulco Ludwig	fulco.ludwig@wur.nl
	Boundary layer clouds	1	2	M	K							x	x	Bert Holtslag	bert.holtslag@wur.nl
	Carbon cycle	1	1	G	K							x	x	Wouter Peters	wouter.peters@wur.nl
Regional	Describing and predicting the climate system	4	10	G	M					x		x	x	Sjoerd van der Zee	sjoerd.vanderzee@wur.nl
	Modeling greenhouse gas budgets	1	5	G									x	Ronald Hutjes	ronald.hutjes@wur.nl
	Critical weather conditions	1	2	M	K								x	Bert Holtslag	bert.holtslag@wur.nl
	Carbon 14 signature	1	2	M	K							x		Maarten Krol	maarten.krol@wur.nl
	Particulate pollution budget	1	2	M	K						x			Maarten Krol	maarten.krol@wur.nl
	Nutrient emission and monitoring	1	2	M	K						x			Ype van der Velde	ype.vandervelde@wur.nl
	Climate extremes	1								x				Eddy Moors	eddy.moors@wur.nl
Local	Development of monitoring tools	5	8	G	M					x		x	x	Remko Uijlenhoet	remko.uijlenhoet@wur.nl
	Urban areas	3			M								x	Bert van Hove	bert.vanhove@wur.nl
	Tree rings, anatomy of wood	1	6									x		Ute Sass-Klaassen	ute.sassklaassen@wur.nl
	Describing and predicting the climate system	1	3	M	K								x	Ton Hoitink	ton.hoitink@wur.nl
	Modeling greenhouse gas budgets	1	3	M									x	Bart Kruyt	bart.kruyt@wur.nl
	Field of measurement	1	2		K				x					Bert Holtslag	bert.holtslag@wur.nl
	Surface fluxes	1	3	M	K							x		Bert Holtslag	bert.holtslag@wur.nl
	Critical weather conditions	1	2	G	K								x	Bert Holtslag	bert.holtslag@wur.nl
	Turbulent structure parameters	1	2	K	K							x		Oscar Hartogensis	oscar.hartogensis@wur.nl
	Fog	1	2	K	K								x	Bert Holtslag	bert.holtslag@wur.nl
Climate-ecosystem interaction															
Global	Relationship between vegetation and thawing of permafrost	1	4	M	K				x				x	Frank Berendse	frank.berendse@wur.nl
	Feedbacks	10	10	G					x	x		x		Marten Scheffer	marten.scheffer@wur.nl
	Forest-savannah interactions	1	1	G							x			Elmar Veenendaal	elmar.veenendaal@wur.nl
Local	Effect of climate change on growth season	1	3						x		x		x	Arnold van Vliet	arnold.vanvliet@wur.nl

* Within various themes Projects & expertise can reoccur.

** K = budget < K€ 200 M = K€ 200 ≤ budget projects ≥ K€ 500 G = budget > K€ 500
Wageningen UR Climate Expertise (indication based on project information spring 2009)

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MITIGATION															
Transition to climate neutral land use, nature conservation and food production															
Agriculture	Sustainable agriculture	1	3	G							x			Ina Pinxterhuis	ina.pinxterhuis@wur.nl
	Energy use and greenhouse gas emissions in organic agriculture	2	2	M				x						Wijnand Sukkel	wijnand.sukkel@wur.nl
	Deminishing emission of nitrous oxide by harvesting from fixed paths	1	3	K				x						Bert Vermeulen	bert.vermeulen@wur.nl
	Soil tillage and the emission of greenhouse gasses	1	5	G			x	x						Wijnand Sukkel	wijnand.sukkel@wur.nl
Animal husbandry	Mitigation options and grazing	1	1	K	K		x							Hein ten Berge	hein.tenberge@wur.nl
	Ecological impact of organic egg production	1	2											Peter Groot Koerkamp	peter.grootkoerkamp@wur.nl
	Impact dairy and pigsectors	1	2											Mark Dolman	mark.dolman@wur.nl
	Carbon Footprint pig sector	1	5	K				x			x			Eveline Stilma	eveline.stilma@wur.nl
	Sustainable animal husbandry systems	1	1		K		x							Bram Bos	bram.bos@wur.nl
Dairy sector	Feed and methane emissions	2	4	G						x	x			Andre Bannink	andre.bannink@wur.nl
	Connecting process models for dairy cattle and greenhouse gas	1	2											Theun Vellinga	theun.vellinga@wur.nl
	Reduction of ammonia emission from stables	1	1	K							x			Hendrik-Jan van Dooren	hendrikjan.vandooren@wur.nl
	Breeding and reduction of methane emission	1	1	K						x			x	Roel Veerkamp	roel.veerkamp@wur.nl
	Effect of grassland renewal on greenhouse gas emissions	1	1								x			Theun Vellinga	theun.vellinga@wur.nl
	Ecological footprint dairy industry	1	2	K					x					Leon Sebek	leon.sebek@wur.nl
	Sustainable dairy production systems	1	4	M				x						Peter Groot Koerkamp	peter.grootkoerkamp@wur.nl
Food production chain	Energy use and greenhouse gas emissions in regional food production	1	3	K				x			x			Jan Eelco Jansma	janeelco.jansma@wur.nl
	Conversion of proteins in animal production chains	1	1	K							x			Leon Sebek	leon.sebek@wur.nl
	GRI guideline for sustainability reports in foodprocessing industry	1	2	K										Koen Boone	koen.boone@wur.nl
Greenhouse cultivation	Energy-supplying greenhouse	4	4	G							x			Silke Hemming	silke.hemming@wur.nl
	Energy reduction in greenhouses	2	3	G	G								x	Jouke Campen	jouke.campen@wur.nl
Plant breeding	Increasing efficiency of photosynthesis	1	1	G										Luisa Trindade	luisa.trindade@wur.nl

* Within various themes Projects & expertise can reoccur.

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Wageningen UR Climate Expertise (indication based on project information spring 2009)

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	Improving cell walls of maize for use in bio-fuel	1	1	G										Luisa Trindade	luisa.trindade@wur.nl
Forestry	Forest development of secondary forests	1	3						x		x	x		Frans Bongers	frans.bongers@wur.nl
	Long-term forest development	1	3	M	K				x		x	x		Lourens Poorter	lourens.poorter@wur.nl
	Carbon sequestration	2	3	M	K				x		x			Frits Mohren	frits.mohren@wur.nl
Peatlands	Carbon-Climate-Human interactions in tropical peatlands	2	2	K			x	x						Henk Wosten	henk.wosten@wur.nl
Increasing climate efficiency of the use of biofuels and materials															
Energy	Analysis of the biomass production chain	3	10	G			x	x			x		x	Johan Sanders	johan.sanders@wur.nl
	Developing production systems for biomass	1	1	G										Jan Kamp	jan.kamp@wur.nl
	Availability of biomass from landscape, nature and forests	1	4	K				x						Joop Spijker	joop.spijker@wur.nl
	Sustainable refining process for bio-butanol	1	6	G			x						x	Rob Bakker	robert.bakker@wur.nl
	Analysis of direct and indirect effects of biofuel from Brasil	1	4	K				x						Wolter Elbersen	wolter.elbersen@wur.nl
	Processing residues for bio-energy or animal feed	2	3	G							x			Johan Sanders	johan.sanders@wur.nl
	Ethanol and bio-gasses	2	4	K				x			x			Koen Meesters	koen.meesters@wur.nl
	Pellet production chain	1	2	K				x						Koen Meesters	koen.meesters@wur.nl
	Crops for bio-energy and agricultural water use	1	6	K						x				Berien Elbersen	berien.elbersen@wur.nl
	Locating opportunities for bio-based chains	1	1	K	K		x							Berien Elbersen	berien.elbersen@wur.nl
	'Green gas' from composting of manure	2	4	K			x	x						Koen Meesters	koen.meesters@wur.nl
	Energy production from sugar beets and beet leaf	1	2	K							x			Wim Corré	wim.corre@wur.nl
	Bio-fuels and functional agrobiodiversity	1	2	M	K					x				Wim van der Putten	wim.vanderputten@wur.nl
	Improving production of Jatropha	1		M							x			Raymond Jongschaap	raymond.jongschaap@wur.nl
	Treatment of surface water and biomass production	1	1	G						x	x		x	Adrie van der Werf	adrie.vanderwerf@wur.nl
	Sustainable energy concepts	1	1	G										Andrea Terbijhe	andrea.terbijhe@wur.nl
	Assessment tool biomass production systems	1	2				x							Sjaak Conijn	sjaak.conijn@wur.nl
Packaging	Packagin materials and bioplastics	1	1	G						x				Wim Mulder	wim.mulder@wur.nl

Land/soil/animal/vegetation emission and absorption of greenhouse gasses, process analysis and improving monitoring techniques

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Monitoring, tools and scenarios	Greenhouse gas information system	1	1	K	K		x						x	Ronald Hutjes	ronald.hutjes@wur.nl
	Variation of emissions in space and time	1	8	G	K		x						x	Eddy Moors	eddy.moors@wur.nl
	How to integrate agricultural emissions in IPCC scenarios	1	1					x						Peter Kuikman	peter.kuikman@wur.nl
	National report on carbon in soils	1	1	K				x						Peter Kuikman	peter.kuikman@wur.nl
	National report on carbon in forest soils	2	3	K	K			x						Mart-Jan Schelhaas	martjan.schelhaas@wur.nl
	Biomass delivery chain	1	1	K	K		x						x	Bert Annevelink	bert.annevelink@wur.nl
	Modeling emission of dairy farms	3	4	K	K	x	x		x					Andre Bannink	andre.bannink@wur.nl
	Mitigation and adaptation strategies for climate change	1	2	G	K		x			x				Saskia werner	saskia.werner@wur.nl
	Cost-benefit analysis of ecosystem services	1	4	K			x							Roel Jongeneel	roel.jongeneel@wur.nl
Analysis emission land use	Analysis greenhouse gas balance in soil: source or sink?	1	4	G	K		x					x		Jan-Willem van Groenigen	janwillem.vangroenigen@wur.nl
	Interaction between climate change and soil quality	1	1	M						x	x			Peter Kuikman	peter.kuikman@wur.nl
	Monitoring emissions at different soil management systems	2	2	K			x	x						Kees van wijk	kees.vanwijk@wur.nl
	Developing measurements of soil resilience	1	2	K			x							Marjan de Boer	marjan.deboer@wur.nl
	Carbon footprint organic matter and nutrients	1	3	K				x						Peter Dekker	peter.dekker@wur.nl
	Effect of supplying nitrogen on greenhouse gas emissions	1	1	K	K		x							Wim de Vries	wim.devries@wur.nl
	Integrated framework for land use based emission reduction	1	1	K	K		x						x	Mart-Jan Schelhaas	martjan.schelhaas@wur.nl
	Emissions from grass and crop land	1	2	G			x			x				Eddy Moors	eddy.moors@wur.nl
	Measurements and analysis fen meadows	2	4	G	K				x		x		x	Frank Berendse	frank.berendse@wur.nl
	Emission of nitrous oxide from manure and manure processing	1	1	M							x			Gerard Velthof	gerard.velthof@wur.nl
	Regional and national projections of future emissions	1	7	M						x	x			Gerard Velthof	gerard.velthof@wur.nl
Landscape services	Landscape elements and carbon sequestration	1	2	K				x						Joop Spijker	joop.spijker@wur.nl

Focus	Expertise (through projects)*	Number of projects	Number of researchers	Size of research budget**	Research budget in 2009**	Statutory Research tasks (LNV)	Knowledgebase Research (LNV)	Policy-supporting research (LNV)	University funding	EU programmes	Public and private sector	N.W.O.***	Programmes (FES, BSIK)	Contact	E-mail
ADAPTATION															
Adjusting agriculture, horticulture and fisheries to climate change (including salinization)															
Adjusting agriculture and horticulture	Systems modelling, farming systems analysis	2	10	G	M								x	Martin van Ittersum	martin.vanittersum@wur.nl
	Multi-scale, integrated assessment of adaptation strategies in the North of the Netherlands	1	4	M			x							Martin van Ittersum	martin.vanittersum@wur.nl
	Climate change impacts on agriculture	1	1	K			x							Tia Hermans	tia.hermans@wur.nl
	Adaptation agriculture	1	2	K				x						Tia Hermans	tia.hermans@wur.nl
	Spatials adaptation strategies in agriculture	1	1					x						Greet Blom-Zijlstra	greet.blom@wur.nl
	Tailoring climate scenarios – case study on crop yield	1	1	K	K		x							Allard de Wit	allard.dewit@wur.nl
	Effect of urban agriculture and climate neutral suburb	1	1	G										Andries Visser	andries.visser@wur.nl
	Transition SW Delta	1	1	K	K									Krijn Poppe	krijn.poppe@wur.nl
	Income and property losses due to salinization	1	3	K										Piet Rijk	piet.rijk@wur.nl
	Adjusting crops through breeding	1	7						x		x		x	Ep Heuvelink	ep.heuvelink@wur.nl
	Development of production systems with intrinsic diversity	1	1				x							Rob van den Broek	rob.vandenbroek@wur.nl
	Genetic diversity, spatial model	1	2	M										Rene Smulders	rene.smulders@wur.nl
	Effect of climate change on the food chain	1	3	G						x				Pieternel Luning	pieternel.luning@wur.nl
Animal husbandry	Robust husbandry systems	1	1	K			x				x			Jan ten Napel	jan.tennapel@wur.nl
Dairy sector	Effect heat stress on dairy cattle	1	2				x							Theun Vellinga	theun.vellinga@wur.nl
	Effect salinization on diary farming	1	3	K	K		x						x	Theun Vellinga	theun.vellinga@wur.nl
Water management	Effects of climate change on groundwater quality & flows	2	4	G	K					x	x		x	Sjoerd van der Zee	sjoerd.vanderzee@wur.nl
	Water management and soil subsidence in fen meadows	1	1								x			Idse hoving	idse.hoving@wur.nl
Salinization	Modeling freshwater lenses	1	4	M	K				x					Sjoerd van der Zee	sjoerd.vanderzee@wur.nl
	Soil salinity and sodicity, irrigation, stochastic modelling	1	2								x			Sjoerd van der Zee	sjoerd.vanderzee@wur.nl
	Salinization of surface waters	1	1	K	K		x							Natasha Marinova	natasha.marinova@wur.nl
	Integrated mixed saline farm	3	5	G			x				x		x	Willem Brandenburg	willem.brandenburg@wur.nl

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Wageningen UR Climate Expertise (indication based on project information spring 2009)

*** Nederlands Organization for Scientific Research (NWO)

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	Salt-tolerant crops, genetics, breeding	2	5	M	K		x		x			x		Gerard van der Linden	gerard.vanderlinden@wur.nl
Fisheries	Role of stakeholders in sustainable marine management	1	1	K	K		x							Birgit de Vos	birgit.devos@wur.nl
	Relationship climate change and changes in demersal ecosystem	1	1	K			x							Ralf van Hal	ralf.vanhal@wur.nl
Adjustments to nature management															
Nature - General	Effects of climate change on nature and possible adaptation measures	2	3	M			x	x					x	Frank Berendse Claire Vos	frank.berendse@wur.nl claire.vos@wur.nl
	Model infrastructure for feedbacks	1	1	M	K		x							Mart-Jan Schelhaas	martjan.schelhaas@wur.nl
	Communicating current and visible effects on nature	1	3								x			Arnold van Vliet	arnold.vanvliet@wur.nl
Nature goals	Adaptation National Ecological Network (EHS)	5	17	G	M	x	x	x	x				x	Frank Berendse Claire Vos	frank.berendse@wur.nl claire.vos@wur.nl
	Agriculture and Natura2000	1	6	K										Hans Leneman	hans.leneman@wur.nl
	Nature goals and climate change	1	1	M				x						Anna Besse-Lotskaya	anna.besse@wur.nl
	Robust connections	1	12	G				x						Willemien Geertsema	willemien.geertsema@wur.nl
Multifunctional areas	Climate adaptation areas & National Ecological Network (EHS)	1	3	K	K		x							Marcel Pleijte	marcel.pleijte@wur.nl
	Reconaissance of multifunctional climate areas in Brabant and Drenthe provinces	1	4	K	K						x			Herman Agricola	herman.agricola@wur.nl
Bio-invasions	Consequences of climate-directed area enlargements for bio-invasions	1	2	G	K							x		Wim van der Putten	wim.vanderputten@wur.nl
Forest ecosystems	Role of forests in adaptation strategies	1	1	K				x						Hans Peter Koelewijn	hanspeter.koelewijn@wur.nl
	Evaluation of forest management strategies	1	1	K	K		x							Mart-Jan Schelhaas	martjan.schelhaas@wur.nl
	Behaviour of biochar in soils	1	2	G	K				x					Thom Kuyper	thom.kuyper@wur.nl
	Forest Ecosystem Services	3	5	G			x				x			Wim de Vries	wim.devries@wur.nl
	Terrestrial biodiversity and ecosystem functioning	1	1	K	K		x							Hans Peter Koelewijn	hanspeter.koelewijn@wur.nl
	Effects of climate change on forest ecosys-tems	1	1	K	K		x							Mart-Jan Schelhaas	martjan.schelhaas@wur.nl
	Analysing tree rings in relation to climate change	1	2						x					Jan den Ouden	jan.denouden@wur.nl
	Tree ecophysiology, management	1	5	G					x		x	x		Frans Bongers	frans.bongers@wur.nl

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	Drought effects on trees	1	5						x			x		Lourens Poorter	lourens.poorter@wur.nl
	Climate effects on tree performance	2	3						x		x		x	Frank Sterck	frank.sterck@wur.nl
	Climate response and population dynamics	1	6						x		x			Frans Bongers	frans.bongers@wur.nl
Aquatic ecosystems	Climate change and aquatic biodiversity	1	2	M				x						Anna Besse-Lotskaya	anna.besse@wur.nl
	Climate change and aquatic ecosystems	4		G	K			x		x				Piet Verdonschot	piet.verdonschot@wur.nl
	Effect of climate change on toxic cyanobacteria	10	10	G					x		x		x	Miguel Lurling	miquel.lurling@wur.nl
Marine environment	Effects of climate change on fish populations	1	2	G	K		x			x				Adriaan Rijnsdorp	adriaan.rijnsdorp@wur.nl
	Consequences of climate change to spatial planning at sea	1	1				x						x	Rob Witbaard	rob.witbaard@wur.nl
	Use of space on the North Sea	1	1	K	K		x							Han Lindeboom	han.lindeboom@wur.nl
	Long-term changes to the marine ecosystem	2	2	G	M		x						x	Han Lindeboom	han.lindeboom@wur.nl
Peatlands	Adaptation in tropical peatlands	1	1	K			x							Henk Wösten	henk.wosten@wur.nl
Semi-arid areas	Internal feedbacks in semi-arid systems	1	1	K			x							Eddy Moors	eddy.moors@wur.nl
Climate-proof spatial planning in rural areas															
Landscape and climate change	Multifunctional landscapes as an adaptation strategy	1	1	K				x						Jan Verhagen	jan.verhagen@wur.nl
	Effects climate change on water balance and measures	1	11	G					x		x			Sjoerd van der Zee	sjoerd.vanderzee@wur.nl
	Modeling future land use	1	6											Peter Verburg	peter.verburg@wur.nl
	Assessment tools land degradation	1	3											Manuel Seeger	manuel.seeger@wur.nl
	Sustainable land management	1	3						x					Jan de Graaff	jan.degraaff@wur.nl
	Combining adaptation and mitigation measures	1	2	K			x							Mart-Jan Schelhaas	martjan.schelhaas@wur.nl
Water management	Water-model for developing spatial scenarios	1	1	K			x							Ronald Hutjes	ronald.hutjes@wur.nl
	Integral water management in a changing climate	1	1	K	K		x			x				Fons Jaspers	fons.jaspers@wur.nl
	Drought in European catchment areas	1	1				x			x				Eddy Moors	eddy.moors@wur.nl
	Drought (global, regional and catchment levels)	1	4	M	K					x				Henny van Lanen	henny.vanlanen@wur.nl
	Supplementing groundwater aquifers in semi-arid areas	4	5	G				x			x		x	Sjoerd van der Zee	sjoerd.vanderzee@wur.nl
	Availability of freshwater in a changing climate	1	1	K	K		x							Jeroen Veraart	jeroen.veraart@wur.nl
	Effects of climate change on groundwater systems	2	2	K	K		x	x						Piet Groenendijk	piet.groenendijk@wur.nl

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	Introducing climate in cost-efficiency instruments	1	3	K										Hans Leneman	hans.leneman@wur.nl
Water safety	Knowledge development for National Water Plan and Delta Program	1	1					x						Saskia Werners	saskia.werners@wur.nl
	Adaptation strategies Rhine catchment	1	1	K	K		x							Eddy Moors	eddy.moors@wur.nl
	Climate-proof, multifunctional dams	1	1	K	K		x							Jantsje van Loon	jantsje.vanloon@wur.nl
Spatial planning	Multifunctional land use as an adaptation strategy	1	7	K										Arianne de Blaeij	arianne.deblaeij@wur.nl
	Integrated adaptation strategies for spatial problems	1	2	K				x						Willemien Geertsema	willemien.geertsema@wur.nl
Urban areas	Urban ecology, design and planning	1	4							x				Vincent Kuypers	vincent.kuypers@wur.nl
Governance	Adaptation transition	1	1	K	K		x							Judith Klostermann	judith.klostermann@wur.nl
	Governance processes in planning in rural areas	1	1		K		x							Trond Selnes	trond.selnes@wur.nl
Dealing with new, climate-change-induced risks of diseases and pests for plants, animals and people (where cause is related to plants or animals)															
Invasions	Multitrophic interactions	1	2	G	K							x		Wim van der Putten	wim.vanderputten@wur.nl
	Invasions, diseases and pests	1	1	K				x						Leen Moraal	leen.moraal@wur.nl
Diseases and pests	Effect climate change on viruses (Chikungunya, Dengue en West Nile virus)	3	4								x			Gorben Pijlman	gorben.pijlman@wur.nl
	Lyme disease risk model	1	5											Willem Takken	willem.takken@wur.nl
	Effect of climate change on malaria	1	3											Willem Takken	willem.takken@wur.nl
	Possible effects of climate change on plant health	1	1	K			x							Annemarie Breukers	annemarie.breukers@wur.nl
	Effects of climate change on agricultural pests and diseases	1	1	K	K		x							Eefje den Belder	eefje.denbelder@wur.nl
	Rift Valley Fever Virus	1	2	M			x	x		x	x			Rob Moormann	rob.moormann@wur.nl
	Bluetongue virus	1	1	M			x	x		x	x			Piet van rijn	piet.vanrijn@wur.nl
	Tools surveillance emerging diseases in wildlife	1	1		K					x				Kitty Maassen	kitty.maassen@wur.nl
	Climate change and resistence of insects	1	3		K		x	x						Ben Vosman	ben.vosman@wur.nl
	Effects climate change on plant viruses	1	1				x							Maarten de Kock	maarten.decock@wur.nl

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INTERNATIONAAL															
Influence of climate change and climate policies on international market of bio-materials (and connection to food security)															
Food security	Climate Change and Adaptation in Africa	1	5	G							x			Ken Giller	ken.giller@wur.nl
Biofuels	Forest biomass management and energy policy	1	2								x		x	Arthur Mol	arthur.mol@wur.nl
	Biogas production and consumption behavior	1	2								x		x	Arthur Mol	arthur.mol@wur.nl
	Social and environmental aspects of biofuel production	1	3	K	K						x			Arthur Mol	arthur.mol@wur.nl
	(Inter)national initiatives for sustainable biofuels certification	1	3											Sarah Stattman	sarah.stattman@wur.nl
Climate-related international regulations that are important to national policies on agriculture and nature															
Competing claims	Integrated dynamic scenarios at multiple scales	1	8	G								x		Bart Kruijt	bart.kruijt@wur.nl
	Integrated, multi-scale, participatory water scenarios	1	4	G						x				Fulco Ludwig	fulco.ludwig@wur.nl
	Competing claims on natural resourses	1	3	G										Ken Giller	ken.giller@wur.nl
	Adaptation and mitigation to climate change in developing countries	1	5	K				x						Catharien Terwisscha van Scheltinga	catherien.terwisscha@wur.nl
	Climate change, land use and sustainable development in developing countries	1	1	K				x						Rene Verburg	rene.verburg@wur.nl
	Adaptation strategies for Shoreline Development in San Francisco Bay	1	1	K							x			Eddy Moors	eddy.moors@wur.nl
Stakeholder processes	Developing multi-stakeholder processes for climate policy	1	3		M		x							Arend-Jan van Bodegom	arendjan.vanbodegom@wur.nl
Climate-related policy	Impact assessment tools, Land use modelling	1	5	G	G		x			x				Floor Brouwer	floor.brouwer@wur.nl
	International dimensions of Dutch climate adaption policy	1	1	G	K		x							Rob Swart	rob.swart@wur.nl
	Climate governance; EU climate policy	1	3	K							x			Kristine Kern	kristine.kern@wur.nl
	Climate policy, CDM, institutional theory, ecological modernization	1	2	K						x	x			Arthur mol	arthur.mol@wur.nl
	Impact van de nieuwe EU richtlijn CO_2 emissiehandel	1	1	K				x						Frank Bunte	frank.bunte@wur.nl
	Costing adaptation through local institutions	1	2	K										Vincent Linderhof	vincent.linderhof@wur.nl
	Assessing the adaptive capacity of agriculture	1	6	G										Martin van Ittersum	martin.vanittersum@wur.nl
Land degradation	Scientific knowledge base needed for successful land conservation	1	3											Saskia Visser	saskia.visser@wur.nl

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Capacity building	Strenghtening the interaction between research and policy	1	5	K	K						x		x	Jouwert van Geene	jouwert.vangeene@wur.nl
Nature	Natura2000 and CAP agricultural subsidies	1	2	K										Claire Vos	claire.vos@wur.nl
	Spatial planning for solving nature issues	1	4							x				Claire Vos	claire.vos@wur.nl
Agriculture and animal husbandry	Emissions in non-Annex 1 countries	1	2	K				x						René Schils	rene.schils@wur.nl
Water	Ecological integrity in Mediterranean temporary streams	1	1	K			x							Jochen Froebrich	jochen.froebrich@wur.nl
	Techniques related to moistening traits of soils	1	2				x							Erik van den Elsen	erik.vandenelsen@wur.nl
	Adaptation to changing water availability	1	1	G	G					x				Eddy Moors	eddy.moors@wur.nl
International treaties and disaster policies															
Drought	Climate change and drought	1	2	M	K					x				Henny van Lanen	henny.vanlanen@wur.nl
Transnational climate governance	Climate change, transnational relations, global governance	1	17								x			Kristine Kern	kristine.kern@wur.nl

Colophon

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