Effects of Climate Change on the Flemish water system (Belgium)

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Abstract

This state-of-the-art contribution describes recent research in the Flemish region of Belgium (Flanders) on climate induced trends of the different components of the water system. The paper is based on the literature study and evaluation work carried out in the "Climate Proof Areas" project (CPA) and the "Climate change And changes in SPAtial structures in Flanders Research" project (CcASPAR) incorporating all relevant research carried out by a series of Flemish research projects.

One of the main objectives of CcASPAR is to assess the spatial impact of climate change in Flanders for different climate change scenarios. It will geographically differentiate the primary effects (with a focus on the water system) and the secondary effects on different land uses in 2050 and 2100. Subsequently, a spatial adaptation strategy at the macro scale of Flanders will be proposed. Finally, it will safeguard the linkage between spatial planning adaptation vision on one hand and the global Flemish adaptation strategy and risk management on the other hand.

CPA project focuses on gathering, updating and synthesizing all existing information on the expected impact of climate change on the various partner regions (Belgium, Germany, The Netherlands, Sweden and UK) involved in the project and create a North Sea Region (NSR) wide impact analysis. The result will be bundled in recommendations for a NSR climate change strategy and a NSR adaptation toolkit. This will include an overview of the expected impact of climate change on the NSR, main options for adaptations, a methodology to develop a regional adaptation strategy and a contingency overview of viable adaptation measures.

The contribution dwells upon the trends statistically proven by data over the last few decades followed by an analysis of the projections for climate change in the 21st century that are currently used. Consistent with global trends, the average temperature has increased approximately 1 ^{o}C over the last century with minimum temperatures warming faster than the maximum temperature. Based on various studies, the projected increase of precipitation in winter, the groundwater level and flow of watercourses should increase during the winter months. Higher rainfall has been associated with an increase in the number of rain days and heavy rainfall events. Tide gauge data for the Belgian coast indicates a relative sea level rise from 2 mm/year for high water, 1.5 mm/year for mean sea level and 1 mm/year for low water over the past century. The paper analyses the available information and provides suggestion for further research and cooperation on international level.

Keywords: climate change impacts; water system; Flanders; water management; spatial planning

INTRODUCTION

Weather and climate have a huge impact on natural and human systems. As climate has always been changing, humans and nature constantly need to adapt to these changes. Carbon dioxide is emitted into the atmosphere in increasing quantities since the industrial revolution. It considerably raises the average temperature and affects the climate.

In order to try to evaluate the possible consequences of increasing greenhouse effect, the United Nations set up the Intergovernmental Panel on Climate Change (IPCC) in 1988, grouping most of the world's specialists in a rigorous process of expert assessment. The IPCC makes climate change projections based on different socioeconomic scenarios and the outcome of different climate models and other research is analyzed.

Considering the results of all the models and scenarios, the IPCC projects an average global rise in temperature of 1.4 to 5.8°C for the period 1990-2100. The IPCC projections also shows a tendency towards increased precipitation, with considerable seasonal changes. Another effects is rising sea levels followed by the thermal expansion of water bodies and the melting of glaciers of Greenland and the Antarctic.

Climate change could also affect the quantitative and qualitative status of water resources by varying hydrological cycles and systems. The changes in hydrological cycles will affect many variables together with the intensity and frequency of floods and, droughts. Table 1 shows the observed and projected climate change for various variables (EEA, 2007).

Table 1. Observed and projected climate change (EEA,2007)

Climate variable	Observed change	Projected change (without mitigation)	References
Temperature	Global: increase 0.76 °C in last 100 years 1990s warmest decade for 150 years; 1998 and 2005 warmer than any individual year since 1850	Global: best estimated increase 1.8–4.0 °C during this century (range 1.1–6.4 °C)	IPCCa,b, 2007;
	Europe: increase 1.1 °C, winters increase more than summer, largest increase over Iberian Peninsula, south-east Europe and Baltic States	Europe: mean increase 2.1–4.4 °C by 2080 (range 2.0–6.2 °C) with larger increases in eastern and southern Europe.	EEA, 2006; Schröter, 2005.
Precipitation	Global: trends highly variable in space and time have been observed during the last century Northern Europe: 10–40 % more precipitation South and east Europe: 20 % less precipitation	Northern Europe: annual precipitation increase 1–2 % per decade. Decrease in summer precipitation Southern Europe: Overall decrease in annual precipitation. 5 % decrease in summers.	IPCCa,b, 2007; JRC, 2005; Klein Tank *et al.*, 2002.
Extremes	Temperature extremes are more intense and more frequent than some decades ago	Heat waves are expected to increase in frequency and severity in a warmer world	Klein Tank, 2004; Meehl and Tebaldi; 2004, Moberg and Jones, 2005; Stott *et al.*, 2004.
	Globally, more intense and longer dry periods Significantly more wet days in mid and northern Europe, fewer wet days in southern Europe More heavy rain events in most parts of Europe, strongly linked to the North Atlantic Oscillation Increasing trend in consecutive dry days	More frequent extreme precipitation events in entire Europe. Northern Europe: more frequent summer droughts, despite more intense precipitation events during these periods. Southern Europe: more droughts in all seasons.	Alexander *et al.*, 2006; Frei *et al.*, 2006; Haylock and Goodess, 2004.
Sea level	Sea levels rose by 0.17 m during 20th century 1.8 mm $year^{-1}$ 1961–2003 3.3 mm $year^{-1}$ 1993–2003	0.2–0.6 m by 2100. Increased Greenland-Antartic melt may add 0.1–0.2 m to this Larger values can not be excluded (due to factors not yet sufficiently understood)	IPCCa,b, 2007.

With climate change already happening, societies worldwide face the challenge of having to adapt to its impacts as a certain degree of climate change is inevitable throughout this century. In European commission's green Paper, the Commission provided a broad outline of Community action to be taken for the EU's adaptation to climate change. EU policy aims at mitigating the impact of climate change by limiting the global average temperature increase to 2°C compared with pre-industrial levels. Four pillars of action are being considered on a Community scale: early action in the EU provided sufficient knowledge has been acquired, integrating adaptation into EU external relations, improving knowledge where there are gaps and involving all stakeholders in the preparation of adaptation strategies (EU Green paper, 2007).

No general adaptation strategy is available for the Flemish region of Belgium but there is a promising bottom-up approach by various departments. An inter-departmental climate change working group exist at federal level. Next year Flanders would start making an interdepartmental adaptation action plan to be finished by 2010. There are several ongoing mainly scientific projects on impacts of climate change and adaptation strategies:

- **CLIMAR** studies the impacts of climate change and adaptation measures of Belgian North Sea and the Flemish coastal region (http://www.arcadisbelgium.be/climar/).
- **ADAPT** focuses on developing an integrated decision tool for adaptation measures for climate change induced floods (http://dev.ulb.ac.be/ceese/ADAPT/home.php) .
- **CCI-HYDR** analyses the climate change impact on hydrological extremes along rivers and urban drainage systems (http://www.kuleuven.be/hydr/CCI-HYDR.htm).
- The Institute for Nature and Forest (**INBO**) conducted a research project on climate change impact on ecology and climate change scenarios, that is not published yet.
- The European research and training network **SeaMocs** deals with the application of stochastic models for coastal currents, climate and safe transportation (www.maths.1th.se/seamocs).
- **CcASPAR** deals with the qualitative exploration of possible planning concepts for a more adaptive approach of changes in spatial structures and implementation of spatial adaptation strategies in relation to climate change.
- **CPA** deals with the acceleration of the climate change adaptation process in the North Sea Region (NSR) by means of the joint development and testing of innovative adaptation measures in pilot locations for a variety of areas representative for the NSR, including comparison of climate change effects and adaptation strategies.

IMPACTS OF CLIMATE CHANGE

Primary impacts

The primary impacts of climate change mainly concerns temperature, sea level, storminess and ocean circulation patterns. Climate change will also have an indirect impact on the flooding due to sea level rise as well as to storm surges, and to coastal erosion.

Temperature: The last two decades in Belgium were marked by very high yearly average temperatures and the warming trend is well established. This trend is clearly reflected in the figure 1 which indicates the evolution of the average temperature in Uccle since instrumental record (KMI, 2009).
The evolution of the annual number of heat waves since 1901 in Uccle shows a large variability during the 20th century and heat waves were observed almost every two years. The trend analysis shows a significant increase in annual number of heat waves around the mid 1990s (KMI, 2009).

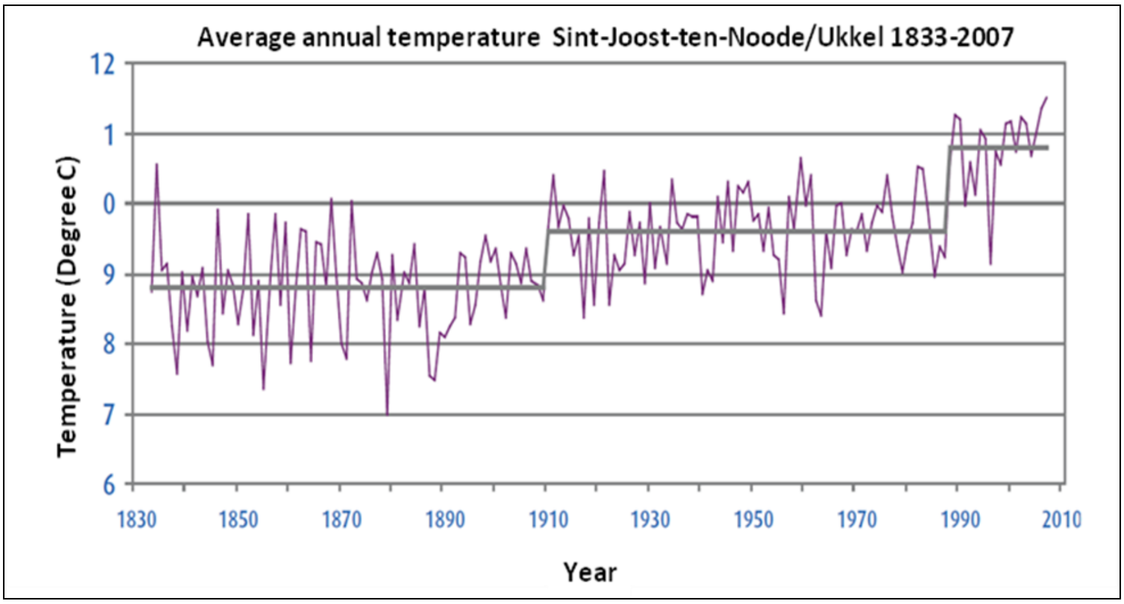

Figure 1: Evolution of the mean annual temperature in Uccle over the period 1833-2007 (source: KMI, 2009)

Precipitation: In Belgium, expected future evolution of precipitation vary drastically between winter and summer time. It can be concluded that the projections for the evolution of winter precipitation during the 21st century show a moderate increase. Recent studies mention an increase in winter precipitation by 3-13% in 2050 (FLOODSITE, 2006) and decrease in summer precipitation by maximum 3% or remain constant (d'Leteren et al., 2004). Such a possible decrease in summer precipitation combined to an increase in temperature would lead to losses of availability of water. (ADAPT, 2008). Discharge in rivers would decrease in summer in between 20 % and 70 % (CCI-HYDR, 2008).
The summer storm events would however be more intense (maximal 30 %) en more frequent (CCI-HYDR, 2008), inevitably leading to problems with sewer overflows in urban areas.

Sea level rise: Changes in water temperature and melting of ice caps and glaciers are the two mechanisms which provokes sea level rise (den Ouden et al., 2004). Extreme high water levels will be observed with higher frequencies as a result of sea level rise and these frequencies might show rising trends due during extreme events. Sea level rise increases the likelihood of erosion and inundations along the coast line. As sea level rise influences tidal rivers, the increase in high water levels in the river Scheldt caused by sea level rise is several times larger than sea level rise itself (IRGT-KINT,2004; MIRA, 2005). The annual mean sea level (MSL) trends were analysed as a part of the CLIMAR project from 1929 through 2001 at Oostende. The MSL varies in between 2.172 m (in 1929) and 2.357 m (in 2001). Even though the variability from year to year is high, it is very clear that the average sea level has increased significantly during this period. Extrapolation of current trends leads to increase of sea level in between 20 and 200 cm, depending on the extrapolation function (CLIMAR, 2009).

Flooding: From the probable increase of precipitation in winter, the groundwater level and flow of watercourses should increase during the winter months. Studies carried out on different hydrographic basins conclude that there will be a rise in the risk of flooding until 2100 for all basins studied (ADAPT, 2006).

In Belgium, changes in mean river discharges are found to be either positive or negative, according to diverse climate change scenarios. The result depends on the balance between increased precipitation and higher evapo-transpiration. This annual drainage change may be in between 5% increase and 30% decrease (National Climate Commission, 2002). The CCI-HYDR project is investigating possible climate changes on the occurrence of floods and low-flows in Belgium. Latest results of this project indicate that peak discharges could increase with a maximum of 35 %, hence overall flooding effects could still be manageable and only lead to an area and water depth increase at certain inundation zones (CCI-HYDR, 2008). More thorough investigation for flooding risk of navigable rivers is in the pipeline.

Drought: A long period without precipitation, or with almost no rainfall, can affect different sectors. The concept of drought is not simple and easy to define. The rainfall deficit plays a crucial role in characterizing the severity of the drought, but other parameters like wind, temperature, amount of water present in the soil also play an important role and could be helpful with the scale and impact assessment. KMI studied the evolution of maximum number of consecutive annual dry days at Uccle from 1901 through 2007. The trend analysis showed no significant evolution of this parameter during the 20th century (KMI, 2009).

Secondary impacts

Secondary impacts are defined as the effects that socio-economic activities have to undergo due to a combination of primary impacts. Figure 2 shows secondary impacts divided into three broad categories (economical, ecological and social effects). It is important to consider the clear link between these three types of effects.

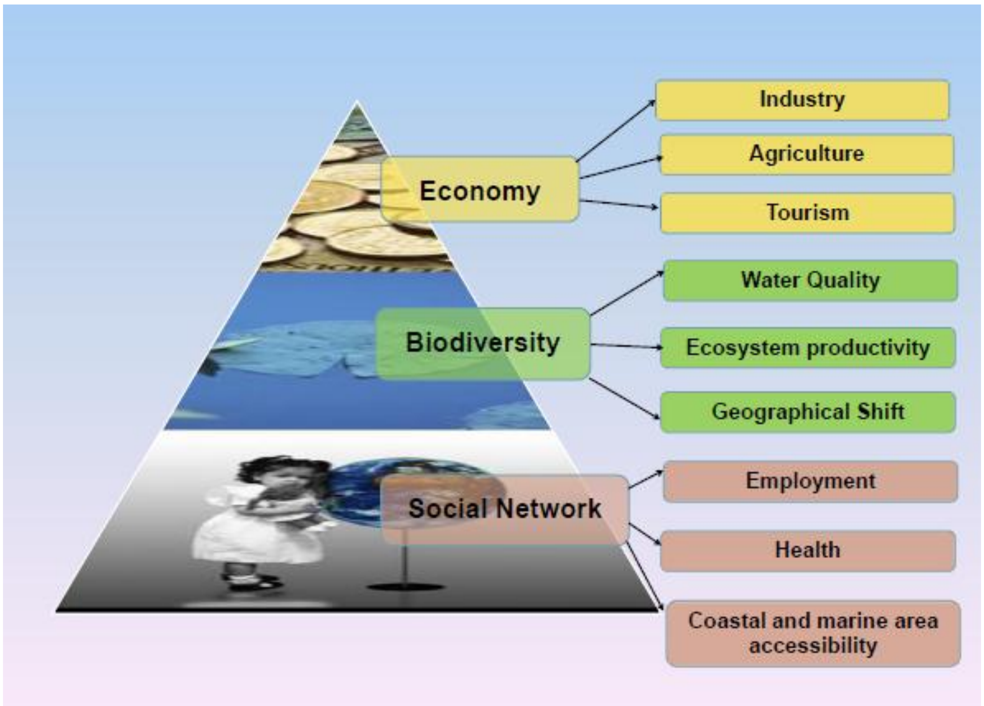

Figure 2. Secondary impacts of climate change

Economy: Climate change could affect economy in several ways. One of the main impacts is on industry as the demands for water and energy which will greatly increase during heat waves. The cost of the "rise in demand" will obviously increase too. Adverse weather conditions may bring about a failure in the supply of raw materials. In the same way, the transport of commuters to their place of work will also be hit by the weather. EU Ruralis (www.eururalis.eu) is a project looking at the adaptation potential of the Flemish agricultural mapping. There is not much known yet in Flanders, except on the economical damage by flooding. Only some limited work on agriculture (www.eururalis.eu) and tourism (CLIMAR, ongoing) has been carried out Up till now, there is no sign of an bottom-up adaptation policy by any socio-economic activity.

Ecology: Climate change is expected to have a range of effects on ecological systems. Some effects may be related to changing water temperatures, circulation or habitat, while others occur through altered pathways within biogeochemical cycles and food webs. There are several ongoing scientific projects related to ecology (e.g. the INBO project (ongoing), Adapt (impact of flooding on ecology), …)

Social network: Like the economic and the ecological system, society is able to deal with extreme climate conditions but only to a certain degree. The direct and indirect impacts of climate change are projected to jeopardize basic needs like food, water, housing, basic furnishing, employment and safety (Douglas et al., 1998). Too extreme events may turn society into a disaster area (Smit and Pilifosova, 2003). In Belgium, more floods, heavy rainfalls and droughts may occur. (ADAPT, 2006). The social aspects are traditionally given less importance but there are indications of emerging attention (e.g. social impacts of flooding (ADAPT), influence of climate change on coastal tourism (CLIMAR), policy instruments for risk communication of flooding (www. overstromingsvoorspeller.be), ….

FUTURE WORK

Climate Change and changes in SPAtial structures in Flanders – Research Project (CcASPAR)

A literature study on possible climate change effects in Flanders will be carried out, geographically differentiated and for all land uses. While evidence and quantitative information on primary effects can be distilled out of current ongoing projects in Flanders, the geographical differences and spatial translation will need to be elaborated, based on hydrological balance modelling. The set up of a land use scenario model is a core component and the most important assessment tool within this project. The land use model is forced by the climate and socio-economic scenario's and simulates what the land use pattern in 2050 and 2100 might look like when no adaptation measures in Flanders are being taken. Next, the model allows to simulate the effects of spatial planning adaptation measures which result in a landscape pattern that is more climate proof.

Climate Proof Areas (CPA)

Between 2008 and 2011, 14 project partners from five countries (The Netherlands, the United Kingdom, Germany, Belgium and Sweden) cooperate in CPA.
The project focuses on gathering, updating and synthesising all existing information on the expected impact of climate change. It also deals with the comparison of climate change impacts and existing adaptation framework for the partner countries involved.

CONCLUSIONS

Based on the work carried out in the ongoing projects CPA and Ccaspar, the following conclusions can already be drawn.
The expected future evolutions of precipitation vary drastically between winter and summer time. Decrease in summer rainfall and increase in evaporation could be accompanied by summer drought as well as deterioration in surface water quality. Lots of ongoing research is going on inland and coastal flooding and the impacts seems manageable. There are very limited studies available on the consequences of increasing frequency of drought, leaving this to become a major socio-economic issue in Flanders. Some measures are being taken for rivers and canals already facing problems (e.g. Albert canal, Meuse). Also the issue of climate change induced groundwater changes and increasing salinity intrusion in the coastal area seems an open area of research.
No general adaptation strategy is available for the Flemish region but there is a promising bottom-up approach e.g. by the water management authorities.

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