Integrating social vulnerability to floods in a climate change context

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1 Introduction

Considering the number of flood events during the past 20 years, a significant increase can be observed globally. (Dartmouth Flood Observatory 2007) Within the climate change context, the recently released reports of the Intergovernmental Panel on Climate Change (IPCC) reconfirmed the expectation that flood risks will increase since frequency and intensity of precipitation events are very likely to increase. (Kundzewics and Mata 2007) In addition, human settlements, river modifications and land use changes are responsible for increasing flood risks as well. Floods may cause enormous havoc to society and need to be prevented. In contrast to the other driving forces, the problem of climate change cannot be dealt with locally and climate change mitigation measures are confronted with time lag effects. Therefore, additional to mitigation policy, adaptation policy needs to be implemented, 'aiming to adjust natural or human systems in response to actual or expected effects which moderates harm or exploits beneficial opportunities'. (McCarthy et al. 2001)

The awareness of climate change effects is growing in flood risk management. Hydraulic models are developed to forecast the flood event probability and the surface of flood risk areas within climate change scenarios. (Willems et al. 2007; Booij 2005) In addition, methodologies for ex-ante

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material damage estimation have been developed to assess the flood consequences. (Kok et al. 2004; Vanneuville et al. 2006; Penning-Rowsell et al. 2005) However, decisions on flood alleviation measures that are solely based on potential avoidance of material damage may be expected to be too limited, since social impact prevention is not integrated in the decision-making. Within the recent European objective of developing sustainable flood risk management, the social part of the flood risk story can no longer be neglected. (EU Floods Directive 2007)

Social impacts are experienced by different people in different ways. Therefore, the paper aims to understand the social constellation of the flood risk area, to identify the most vulnerable population groups and to assess ex-ante social impacts by integrating social vulnerability into flood risks maps. First, the conceptual model of the research is explained. Then, the relation between social vulnerability, flood impacts and flood characteristics are analysed. Next, attention is paid to the development of scenarios, useful to project future flood impacts. And last, the methodology is applied to a case study located in Belgium.[2]

2 Social flood impacts, people and floods

Ex-ante flood damage estimations consider properties as the elements at risk of floods. These estimations assess material damage to properties, which are classified into the category of direct tangible flood impacts, like damage to houses, industry, infrastructure, agriculture, etc… Indirect tangible flood impacts are also estimated, which are mainly additional costs of floods like emergency costs, loss of industrial production or recovery costs. (Messner and Green 2006) In addition, there are intangible impacts, which are mainly social impacts, and as argued by Green (2006), we agree that 'the dwelling acts as a lens which either attenuates or magnifies the effects of the flood upon the household'. In other words, we state that the amount of material damage to a family properties influences the severity of social impacts.

Social impacts refer to all changes in the way *people* live, work, related and organise. (Interorganizational Committee on Guidelines and Principles for SIA 1998) More concrete, social impacts concern poverty, loss of life, health effects, loss of community cohesion, loss of time, changing attitudes, impoverished neighbourhood, etc… But social impacts are difficult to quantify in monetary terms and are often not estimated ex-ante. (Mess-

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ner et al. 2006) However, several studies, like the wide impact-survey in Scotland (Werrity et al. 2007) and the survey on flood experience in Belgium (Grinwis and Duyck, 2000), have concluded that flood victims experience intangible impacts as being even more severe than tangible impacts. This confirms the need to estimate ex-ante the social impacts of floods. Contrary to the damage estimations, social impacts estimations focus on people as being the elements in risks.

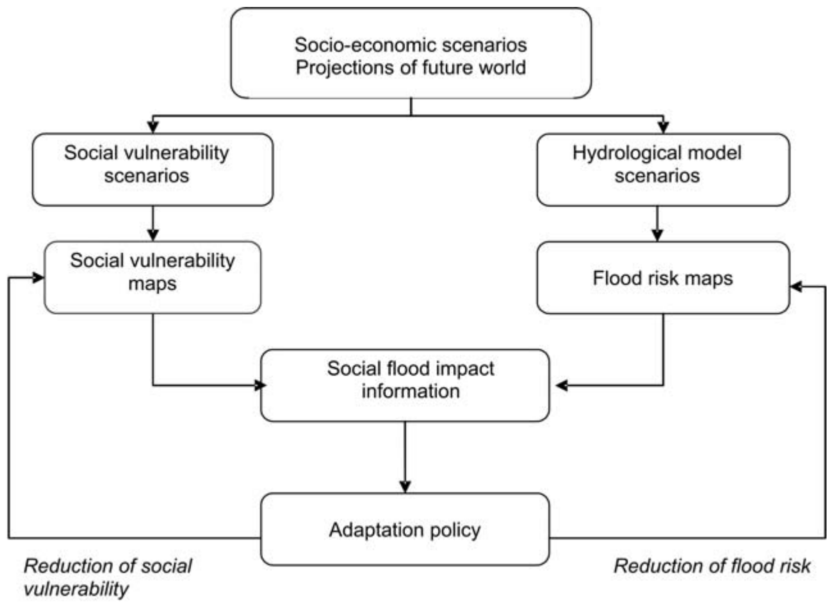
In addition, it is demonstrated that the severity of these social impacts is experienced differently and depends one hand on flood characteristics and on other hand on people's exposure and characteristics, which are respectively named biophysical and social vulnerability in the following sections. (Walker et al. 2006) Therefore, ex-ante social impact estimations need to integrate this variety and focus on social vulnerability, flood characteristics and biophysical vulnerability.

3 Conceptual model

Social flood impact experiences are dependent on three aspects. Two aspects are related to people, being social vulnerability and biophysical vulnerability of people. The third aspect is related to flood events, being flood characteristics. (Messner and Meyer 2005) Therefore, the core element in ex-ante social impact estimation is combining social vulnerability maps and flood risk maps. In order to understand this reasoning, we have to go back to the definition of vulnerability.

Vulnerability refers to 'the degree to which a person/place is susceptible to or unable to cope with adverse effects of climate change'. (McCarthy et al. 2001) Biophysical vulnerability of people is determined by their exposure to floods by living in a flood risk area. People living inside the area will experience more severe impacts than people living outside the area. But social impact experiences vary also within the flood victims. This can be explained by social vulnerability which is related to individuals that are living in the exposed places. The social vulnerability concept refers to the inability of people to cope with the flood impacts due to some personal characteristics. (Messner and Meyer 2005) In addition, the experience of social impacts is dependent on flood characteristics like inundation depth, velocity and water rise speed. For instance, the higher the water depth, the larger the damage, the more severe the social impacts are. Data on social vulnerability characteristics will be displayed by social vulnerability maps, while data on the exposure and flood characteristics are provided by flood modelling and flood risk maps.

Impact estimation of climate change-induced floods in the future includes the use of scenarios. Social vulnerability scenarios enable the construction of social vulnerability maps within different future worlds, while flood risk maps are based on climate change and hydrological model scenarios. These scenarios are based on socio-economic scenarios that project how the world may look like in the future.



Source: Coninx (2007) HIVA-KUL

Fig. 1. Conceptual model of integrating social vulnerability

The results of the study are:

1. The identification of areas within the flood risk area where people have more difficulties to cope with flood impacts than other regions (regional comparison)
2. The projection on the evolution of social vulnerability in and outside the flood risk area within climate change scenarios
3. The projection of climate change-induced floods and information on the flood characteristics like flood area and inundation depth within different hydrological model scenarios
4. The estimation of potential social impacts caused by climate change-induced floods.

In combination with ex-ante damage estimation methods and ex-ante ecological impact estimations, this methodology can contribute to the consideration of sustainable adaptation measures. It is possible to distinguish between technical and non-technical adaptation measures. Technical measures aim to prevent people from being flooded (reducing flood risks) for instance by preserving storage capacity of flood plains, enhancing the retention capacity of soils by prevention of paving, or by reducing peak flows by dams or protecting from flooding by building dikes. Non-technical measures aim to reduce social vulnerability of people in the flood risk area by increasing the coping capacity of the most vulnerable people by appropriate flood preparedness, flood warning, emergency and recovery management.

3.1 Exploring flood characteristics and flood impacts

This section explores the relation between several flood characteristics and flood impacts based on a literature review which is summarised in a table. (Appendix 1)

Inundation depth and velocity

It is demonstrated that the higher the inundation depth and velocity, the larger the risk to properties damage, what may causes large social impacts as well, like disruption of time spending and household organisation, temporary or permanently relocation, resulting in large costs. The lack of insurances affects the household's financial situation. People get destabilized when being flooded by 1 m^2/s. (Helsinki University of Technology 2000) Thus the higher the depth or the velocity, the larger the risk to injuries and death. In addition, the higher the flood depth, the more anxious people are. People are less anxious when being flooded by water depth of less than 0.1m, while they are most anxious by water levels higher than 1 m. (Lekuthai and Vangvisessomjai 2002)

Speed of the water rise

A study, carried out by the British Defra/Environment Agency (2004) argues that the faster the speed of the water rise, the more traumatic the event is and the greater the health effects. The surprising effect of a flood also influences people's risk perception.

Duration and frequency of the flood

The longer properties are flooded, the larger the damage, as well as the household disruption and the levels of stress they experience. (DEFRA/EA 2004) Flood duration also affects anxiety. A study has concluded that people experience large anxiety up to 15 days after the flood having faced flooding for more than 2 weeks. (Lekuthai and Vangvisessomjai 2002) Another study states that being flooded twice results in more worrying and a larger loss in house value, but being flooded three times or more results in less worrying, probably due to more fatalistic reactions. (Werrity 2007) No correlation was found between frequency of being flooded and health effects. Nor is the duration of the flood expected to affect physical health. (DEFRA/EA 2004)

Water pollution and debris

Contaminated water affects health more than clean water. After the flood, people keep on having the feeling to live in a polluted environment. (DEFRA/EA 2004) The presence of debris, like branches or cars, adds to the risk of injuries. (Ramsbottom et al. 2003)

Time of the flooding

The time of being flooded may affect the amount of damage. In particular, sudden floods at night or during day when people are at work may be more damaging due to lack of time to protect properties. The cold water of winter flooding increases the risk to suffering from hypothermia. (Ramsbottom et al. 2003) Winter flooding aggravates the recovery process, since drying the house is more difficult having cold temperatures outside. (DEFRA/EA 2004)

3.2 Unravelling social flood vulnerability and social flood impacts

According to the Flood Hazard Research Centre (UK), personal characteristics determining social flood vulnerability are age, health status, income and family composition. (Tapsell et al. 2002) We argue to include nationality and property type as well. A summarizing table is added in the appendix. (Appendix 2)

Age

People aged 75 or more are vulnerable to flood impacts because of limited mobility and reduced hearing and visual capacities. (Tapsell et al. 2002) In addition, many older people have lost their partners and are living on their own or in a rest home. And often, they have limited social networks and few resources, making recovery difficult. (Thrush et al. 2005)

Elderly are in particular susceptible to physical health impacts, because of poor physical condition or due to heart attacks. In addition, older people often perceive their own losses are larger than the others in the neighbourhood, indicating coping difficulties. They are also more affected by the loss of personal items. The inability or unwillingness to leave the residence before, during and after the flood may result in poor living environment and an impoverished neighbourhood. Those who do leave may experience health problems. Recovery often takes a long time, because elderly are dependent on others to clean the dirt and to negotiate with insurers and builders. (Walker et al. 2006)

Income

Financially deprived people are often stuck in a vicious deprivation circle when affected by floods. To start, they often do not have the money to protect themselves by means of insurances or by means of flood protection materials. In addition, their properties are often of less valuable quality. As a consequence, they are confronted with more damage then those who are able to prepare and to protect their properties. After the flood, they are hit the hardest because they have to bear all the costs on their own. But due to limited financial resources, recovery is a long term process.

In relation to social impacts, financially deprived people have difficulties to cope with the material damage in the first place, which may even cause poverty. The impact of the loss of personal items seems to be higher than for other income groups. They are more susceptible to health impacts than higher incomes. (Werrity et al. 2007) First because they live in low quality houses that are not resistant to floods. And secondly, because they are forced to keep on living in the impoverished neighbourhood. Mental health impact is larger for low-income families because the financial scarcity is an extra concern besides the other flood impacts. Higher levels of anxiety are experienced in this population group because of the stress of the flood and the need to leave home. This may also influence the family relations, often resulting in more conflicts. Temporary relocation is often no option for those people. (Walker et al. 2006)

Health status

People who are restricted in daily activities by handicap or chronic illness are more vulnerable because they are hampered in protecting properties, evacuation and recovery. People suffering from psychological problems have more difficulties to cope with the stress of flooding. (Ramsbottom et al. 2003)

People with poor pre-flood health conditions are more susceptible to health impacts, death and problems related to preparedness, protection and evacuation. (Defra/EA 2004) The presence of disabled family member puts a pressure on the household organisation and the recovery of properties may take longer. (Thrush et al. 2005)

Family structure

Most vulnerable are lone parents, since they have to bear all the financial costs by means of one income. Furthermore, they have to cope with all the stress and worries alone and they often have a lack of emotional support. Single parents are more vulnerable to health impacts than others. They are more hampered in meeting basic needs, like food, housing and emotional support to their children. (Tapsell et al. 2002)

Nationality

Several studies have demonstrated that some nationalities are more vulnerable to floods than others. The explaining factors are language, cultural background and economic difficulties. Language difficulties hamper the accessing of appropriate information on flood warnings, evacuation plans and recovery mechanisms. Therefore, it is possible that these people are surprised by the flood, do not know how to prepare, or to evacuate and have no idea about the existence of disaster insurances or funds. In addition, the cultural differences may hamper support from emergency management due to misunderstandings. Some cultures do not know the Western system of protection and recovery. And lastly, some nationalities lack financial resources to enable recovery. Many do not have flood insurances. (Thrush et al. 2005; Walker et al. 2006) In addition, these newcomers often do not know the flood history of the area. And it seems that religious factors may affect coping behaviour when the flood is considered as an act of good which has to be accepted. (Thrush et al. 2005)

The identification of vulnerable nationalities is based on the ethno-stratification of Verhoeven (2000) that distinguishes different strata in a society, corresponding to the labour market. The categorisation argues that Belgian nationalities, people from neighbouring countries and people from developed countries like USA and Australia are in the top strata, South-European nationalities are in the second strata and East-European and other non-European nationalities are in the third strata. In this context, we consider the third strata as being most vulnerable to flood impacts.

Property type

Residents of mobile homes are very vulnerable to flood impacts because their house seldom resists floods and because they do not have extra space to save properties. They can lose everything. The same is true for bungalows and one-level residences.

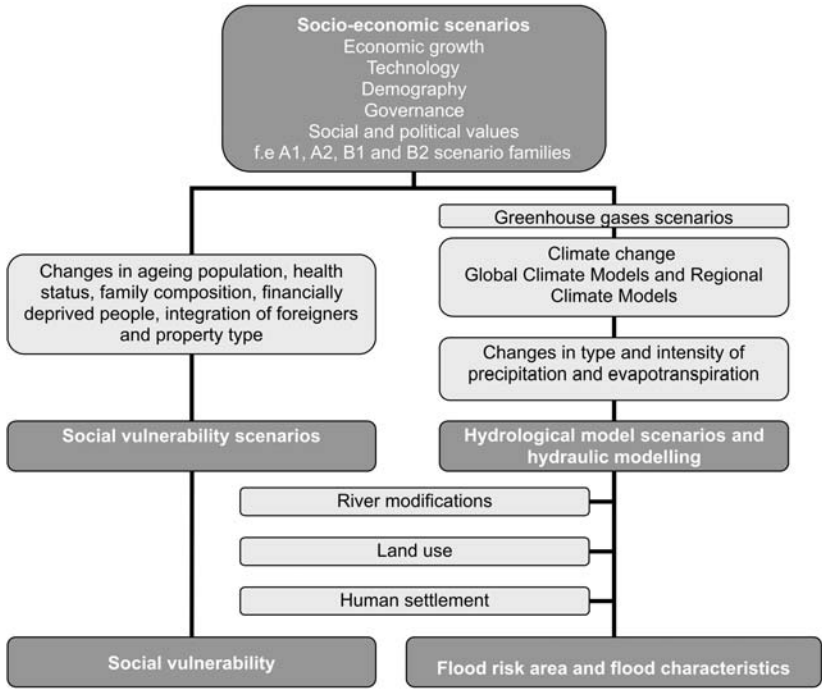
Studies have clarified that those living in single storey properties suffer more household ‘disruption, longer periods of evacuation and a greater loss of sentimental items’. (Tapsell et al. 1999)

3.3 Projection of flood impacts in the future climate change context by scenarios

Estimating social impacts of floods in the future is complex due to uncertainty on how the world will change in the future. Therefore, scenarios are used, since they sketch out several plausible trajectories of societal change. (Hall et al. 2005) Three types of scenarios are needed:

1. socio-economic scenarios that illustrate how the world may look like in the future
2. hydrological model scenarios, which are based on greenhouse gasses scenarios and climate change scenarios and which are used to develop hydraulic modelling
3. social vulnerability scenarios that project changes in social vulnerability.

The figure below illustrates the interconnection between the scenarios.



Source: Coninx (2007) HIVA-KUL

Fig. 2. Scenarios development

Socio-economic scenarios

The foundation of social vulnerability scenarios and hydrological model scenarios can be found in socio-economic scenarios, which illustrates how the world will look like in the future. They contain the driving forces of socio-economic change. (Cabinet Office UK 1999; Dahlström and Salmons 2005):

1. economic growth
2. demography
3. technological change
4. governance
5. social and political values

The socio-economic scenarios used in this study are based on the IPCC scenarios families (A1, A2, B1 and B2) and the UKCIP Socio-economic scenarios, but to avoid confusion, they are named differently. (McCarthy et al. 2001; UKCIP 2001)

1. *Global economy scenario (A1 scenarios family):* in the future world, the economy grows rapidly and trade barriers are reduced, efficient technologies are produced, population increases and there is a lot of international people mobility and economic cooperation. Dominant values are individualistic, personal independence and material wealth. Migration is large to Western Europe but no programs enable integration.
2. *Self-contained nation scenario (A2 scenarios family):* future world is characterised by limited international cooperation. The world is differentiated and preserves local identities. Economy is an important theme. Migrants are not allowed to enter the country. National population declines. And technological change is fragmented.
3. *Sustainable developed world scenario (B1 scenarios family)*: the world is convergent and characterised by international cooperation. Clean technologies are produced and the emphasis is on global sustainable solutions. World population peaks in the middle of the century and migration is limited because of programs to reduce migration motivations.
4. *Local responsibility scenario (B2 scenario family):* emphasis is laid on local sustainable solutions and local self-reliance. The economy grows slowly and investments in R&D are lower in comparison to today. Local inequity is limited due to community-support networks.

Socio-economic scenarios are used on the one hand to characterise the vulnerability of social systems in relation to climate change and on the other hand to characterize the underlying anthropogenic greenhouse gas emissions that cause climate change, as illustrated by figure 2. (McCarthy et al. 2001) From these socio-economic scenarios, two sorts of scenarios are extracted: hydrological model scenarios and social vulnerability scenarios.

Hydrological model scenarios

Socio-economic scenarios can be related to greenhouse gas emissions scenarios. The ‘global economy’ scenario is related to high emissions, the ‘sustainable developed’ world to low emissions, the ‘self-contained nation’ scenario to medium-high emissions and the ‘local responsibility’ scenario to medium-low emissions. (IPCC 2000) Global climate models (GCMs) and regional climate models (RCMs) are derived from these emissions scenarios. These models are used to develop hydrological model scenarios. The used hydrological model scenarios are provided by the CCI-HYDR project carried out by the Hydraulics Laboratory of the Catholic University of Leuven and the Royal Meteorological Institute of Belgium (http://www.kuleuven.be/hydr/CCI-HYDR.htm). (Willems et al., 2007). Key elements in the hydrological model scenarios are precipitation and potential evapotranspiration (combination of evaporation and transpiration processes for reference grass vegetation). The results of these models are used in hydraulic projections on the area that will be flooded, as well as inundation depth, flow velocity along the floodplain and rising water velocity. The hydrological model scenarios are developed based on the data extracted from 24 different regional climate model (RCM) scenarios of the PRUDENCE project (prediction of regional scenarios and uncertainties for defining European climate change risks and effects) (http://prudence.dmi.dk). Those RCM scenarios are for their part developed based on general climate models (GCM) and emission scenarios (SRES). The RCM models of the PRUDENCE project are all situated in the A2 and B2 scenario families. The CCI-HYDR project has the ambition to extend their hydrological model scenarios with A1 and B1 scenario families. Projections were made for 2100. (Baguis et al. 2007)

The CCI-HYDR project has developed three different scenarios: Low scenario, mean scenario and high scenario. (Boukhris et al., 2007)

Table 1. Hydrological model scenarios

	Low scenario	Mean scenario	High scenario
Winter rainfall	0% increase	8% increase	16% increase
Summer rainfall	20 % decrease	13% decrease	6% decrease
Winter potential evapotranspiration	27% increase	17% increase	6% increase
Summer potential evapotranspiration	25% increase	15% increase	4% increase

Source: Willems et al. (2007) Klimaatverandering beïnvloedt rivierafvoeren, http://www.kuleuven.be/hydr/cci/reports/WL-CCI%20Algemene%20samenvatting.pdf

Social vulnerability scenarios

The driving forces of socio-economic scenarios affect social vulnerability. More concrete, the ageing population is induced by birth rate decline and life expectancy expansion, which are driven by economic growth, households welfare, individualistic values and technological change (anti-conception/abortion). (Morgan and Taylor 2006; NIS 2001) Whether the status of public health improves, is less clear and depends on technological change that may either harm or improve health or on welfare increase, releasing people from unhealthy housing. The proportion of lone parents is influenced by economic growth and welfare increase as well, but also by secularisation and individualisation of society. (Dupont 2005; Baker 1999) The increase or decrease of financial deprived people depends on the inequality in economic growth and the ruling social values on smoothing down income inequalities. The proportion of vulnerable nationalities depends on migration and integration policy.

The quantification of the social vulnerability scenarios in Belgium is based on the BESEECH socio-economic scenarios (Dahlström and Salmons 2005) and is illustrated in the table below.

Table 2. Social vulnerability projections in 4 scenarios (2050) applied to Belgium

		Baseline (2001)	Global economy	Sustainable developed world	Self-contained nation	Local responsibility
Age	% aged 75 and more	7.3%	19.7%	15.3%	16%	15.4%
Health	% daily restrictions	17%	19%	16%	18%	17%
	% psychological distress	26%	28%	24%	26%	22%
Family structure	% lone parents	11.4%	16%	12%	13%	11%
Financial situation	% financially deprived people	13%	20%	7%	17%	4%
Nationality	% non-Belgian residents	8%	12%	8%	7%	8%

Source: based on Dahlström and Salmons (2005)

4 Case study

Recent study on trends in precipitation and weather extremes in Belgium has found significant evidence of increasing winter precipitation intensity since the 1980s by up to 20%. This trend may be explained by climate change and/or natural variability. However, summer precipitation trend is not demonstrated to be significant. (Ntegeka et al. 2007)

Estimations of future precipitations project that winter rainfall in Belgium may increase by 3-30%, which, in combination with other factors, may result in river floods. Summer precipitation projections range from status quo to a decrease of up to 50%. However, one estimates that the intensity of summer rainfall will increase, which may cause flash floods. (National Climate Commission 2006) Belgium has experienced several floods during the last decade (1995, 1998, 2002, 2003 and 2005). Acknowledging the high population density, valuable human settlements near rivers and the high pressure on land use, proactive policy is needed to limit the effects of increasing flood risks.

4.1 Case study delineation

The case study area is limited to the neighbouring cities of Geraardsbergen and Ninove, located in the Dender basin in the Flemish region of Belgium. The river Dender is the main water course and runs through two different governmental regions. The river source is located in the Walloon region, while the estuary into the Scheldt river is located in the Flemish region. In other words, two different governments are responsible for policy in the natural catchment of the Dender. It is obvious that the policy in one region can affect flood risks in the other region. The case study area is situated near the place where the Dender surges into the Flemish region. Before streaming to Ninove, the Dender crosses the centre of Geraardsbergen. (CIW 2006)

This area is selected first because of its flooding history (1995, 1999, 2001 and 2002-2003). The areas affected by the floods became more extensive with each flood. Secondly, various land uses occupy the river banks and the flood plains like residence, industry, nature reserves and agriculture. The river itself is used for recreational navigation and fishing, production of goods, transport, water treatment and waste water discharge. Third, social and political debate is going on about potential adaptation measures to prevent and to protect against floods. And lastly, a flood model including climate change projections is available for the river identifying the areas at risk of floods for different return periods.

4.2 Method design and data collection

To identify social vulnerable groups, social vulnerability needs to be measured by an index. The measurement of social vulnerability is based on the methodology of the Social Flood Vulnerability Index of the Flood Hazard Research Centre (UK). Many years of experience in social flood research have brought them to the identification of social vulnerability variables with regard to floods. The variables are financially deprived people, long-term sick, single parents and elderly. (Tapsell et al. 2002)

When data was not available for the proposed variables, similar variables were used. Besides, to FHRC-index we have added two variables, namely nationality and property type. Including nationality is based on the fact that coping floods is difficult to some nationalities. Property type is used in a limited way, since only residents of mobile homes are included. It would be better to include one-floor residences, but due to lack of data, we are restricted to the proportion of people living in mobile homes.

Thus, the KUL-index is composed by 6 variables (financial deprivation, long-term sick, lone parents, elderly, foreigners and mobile homes). Some of these variables are measured by more than one item, like financial deprivation and long-term sick.

Table 3. Comparison between FHRC-index and index used in case study

FHRC-index	KUL-index
Financial deprivation:	**Financial deprivation:**
unemployment: unemployed residents aged 16 and over as a percentage of all economically active residents aged over 16	*unemployment:* unemployment rate, defined as unemployed job seekers as a percentage of all economically active residents between 18 and 65 years.
overcrowding: households with more than one person per room as percentage of all households	*No basis comfort:* weight sum of houses without toilet or bathroom or central heating
non-car ownership: households without a car as a percentage of all households	*Non-car ownership*: proportion of houses without a car
non-home ownerships: households not owning their own home as a percentage of all households	*Non-house ownership*: proportion of houses that are rented.
Long-term sick:	**Long-term sick:**
residents suffering from limiting long-term illness	*Mobility problems:* proportion of people suffering from restrictions in daily activities due to long term illness, handicap or chronic diseases. *Psychological distress:* proportion of

	people suffering from psychological distress
Lone parents: lone parents as a proportion of all residents	**Lone parents:** single parent families as a proportion of all families
Elderly: residents aged 75 and over as a percentage of all residents	**Elderly:** residents aged 75 and over as a percentage of all residents
	Foreigners: strata 3 nationalities as a proportion of all residents
	Mobile homes: residents of mobile homes as a proportion of all residents

Source: based on Tapsell et al. 2002

Data on social vulnerability is collected from the most recent population census in Belgium, dating from 2001 (NIS 2001). This data is available at the level of districts, which is the smallest level of population data availability. This level is chosen because the smaller the area, the more accurate the problem areas can be identified. Number of people living in a district ranges from 0 to 1628, with average number of 405 residents in this case study. Unfortunately, data is not available for all variables at this district level. More specifically, data on unemployment is gathered by regional employment offices, VDAB and Forem only at the level of municipalities. However, in the future, more detailed data is expected to be available. Furthermore, data on health status has been collected by health surveys in 1997, 2001 and 2004, but can only be used adequately at the provincial level. Including these aggregated data would wrongfully influence the index. Therefore, they are currently removed from the index, with the idea of including them as soon as the data is available.

Since all data are expressed in percentages, they can be summed up easily having equal weights. The results are indices that are related to each district. To enable geographical comparison, the indices are illustrated in maps by GIS-software. Indices are scaled along fixed values:

1. 0-0.05 values are considered to be resilient in terms of social vulnerability towards flood risks impacts
2. 0.05 – 0.1 are values considered to be at risk of social vulnerability towards flood risks impacts
3. 0.1-0.15 are values considered to be socially vulnerable
4. 0.15-0.2 are values considered to be highly socially vulnerable
5. More than 0.2 are values considered to be extremely socially vulnerable

Social vulnerability indices within the scenarios are estimated by translating national changes equally to the district level. These new indices are demonstrated in social vulnerability maps according to the same scaling.

4.3 Results and analysis

Two conclusions can be made from the social vulnerability maps. (see appendix 3) First, social flood vulnerability varies with time. And second, social flood vulnerability varies between the regions.

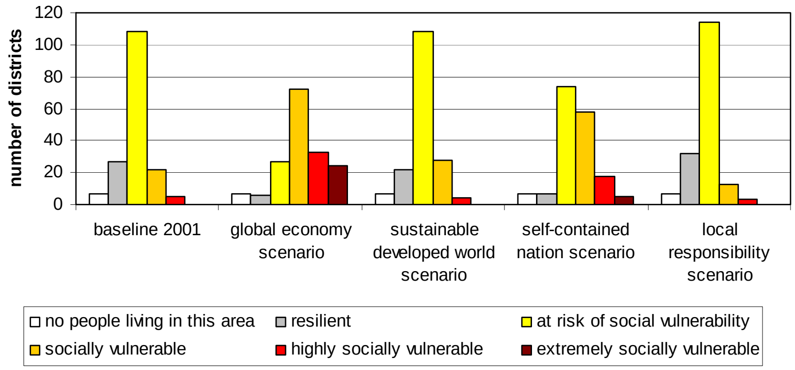


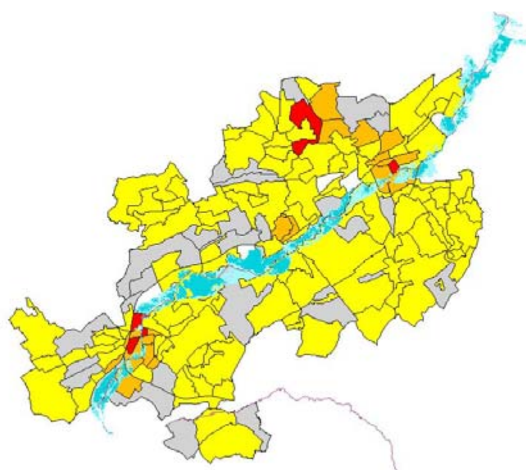
Fig. 3. Number of districts located in social vulnerability categories

Figure 3 demonstrates the social flood vulnerability of the districts in Geraardsbergen and Ninove in 2001 and the scenario projections for the year 2050. In 2001, the majority of the districts (135 districts out of 169) were situated in the categories 'resilient' or 'at risk'. Only a small minority was considered to be socially vulnerable (22 districts) or highly socially vulnerable (5 districts). When comparing with scenarios in 2050, it is clear that social vulnerability will grow strongly in the scenarios 'global economy' (477%) and 'self-sustained nation' (300%), with the 'global economy' scenario reflecting the highest number of socially vulnerable districts (129). This is explained by the increasing proportion of financially deprived people, the high percentage of single parents and the ageing population. The scenario 'sustainable developed world' demonstrates a slight increase in the number of districts in the category socially vulnerable (32 districts). And in the scenario 'local responsibility', people are even less socially vulnerable in comparison with the baseline (decrease of 59%), which is mainly caused by the reduced proportion of financially deprived people.

When considering the regional variety of social flood vulnerability within the case study area, one can conclude that vulnerability varies significantly between districts ranging from resilient to highly socially vulnerable. (see figure 4) In the baseline, the most socially vulnerable areas are located near the city centres and thus near the Dender with the exception of three districts located outside the flood risk area.

From the flood maps, one can conclude that the flooded area expands with longer return periods, ranging from about 363 ha in the case of 2 year return period-floods up to 1087 ha in the case of 1000 year return period-floods. Higher peaks of inundation depth are expected with longer return periods. (64 cm in the case of 2 year return period and 4.2 m in 1000 year return period). However, mean inundation depth in the case study area does not correlate with longer return periods.

Combining social vulnerability maps and flood maps enables the identification of districts at risk of flooding in the baseline and in future scenarios. Flood modelling has resulted in flood maps for several return periods (2, 10, 25, 50, 100, 500 and 1000 year return period). Out of these, we select to compare current and future flood maps taking into account a 50 year return period. We make this choice for two reasons: first, because the inundated area of the 50 year return period is comparable to larger return periods and secondly because the probability to be confronted with a 50 year return period flood during a human life is fairly high.



Source: FPS Economy, DG Statistics, own adaptation

Fig. 4. Results of baseline scenario of 50 year return period flood

In the baseline situation (2001), about 17,676 people are at risk of flooding, living in 40 districts. Figure 5 demonstrates that the majority of these people (10,330) are living in districts that are categorized to be at risk of social vulnerability. 4,655 are living in socially vulnerable areas and 1,675 are living in highly socially vulnerable areas. None of the people are living in extremely socially vulnerable areas.

More detailed analysis reveals that the areas are socially vulnerable because of the large proportion of single parents and financially deprived people.

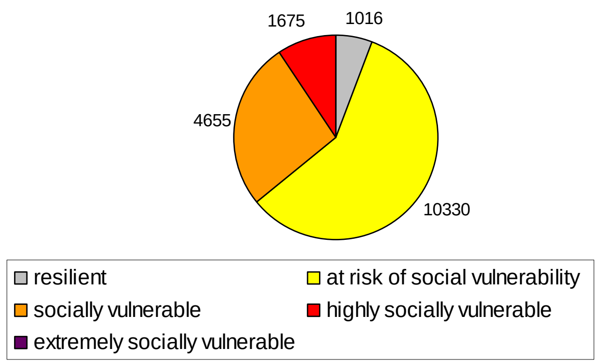


Fig. 5. Number of people living in flood risk area according to social vulnerability category (50 year return period).

Social impact estimations are based on the combination of social vulnerability and flood characteristics. Figure 6 illustrates the relation between social vulnerability and inundated area and demonstrates that in the baseline, the mean and the high self-contained scenario the category of ‘at risk to social vulnerability’ is the largest in terms of surface. It is difficult to estimate whether this corresponds to the largest number of people due to uncertainty about demographic movements. The high-self contained nation scenario affects the largest socially vulnerable regions in terms of surface, namely 268 ha, while in the low-self contained nation scenario and the mean-self contained nation scenario socially vulnerable areas are respectively 67 ha and 114 ha. The vulnerability is due to the large proportions of single parents and financially deprived people.

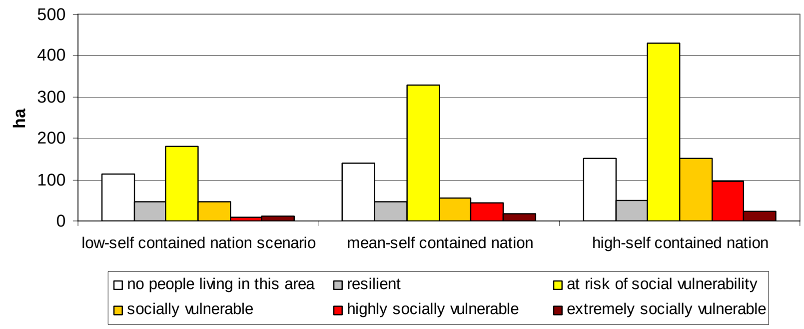


Fig. 6. Inundated area vs. social vulnerability within 50 year return period flood mid-century in the self-contained nation scenario.

In the 'local responsibility' - scenario, only a small proportion of the surface is located in the socially vulnerable areas. However, this proportion is increasing to up to 94 ha in the high-local responsibility scenario. The main reasons explaining the social vulnerability are the large proportion of old people and the relatively large proportion of single parents. (Fig. 7)

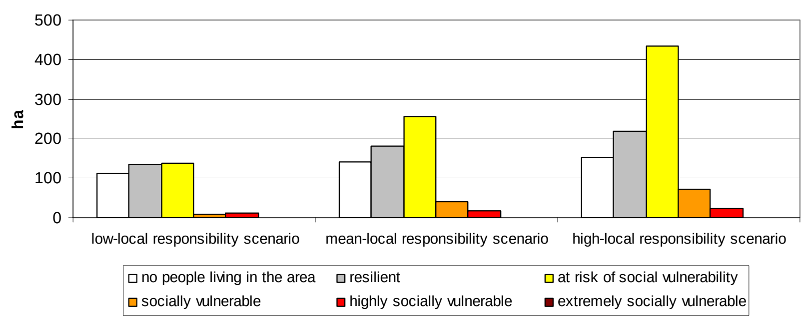


Fig. 7. Inundated area vs. social vulnerability within 50 year return period flood mid-century in the local responsibility scenario.

The tables below demonstrate the maximum inundation depth that may be expected within the different social vulnerability areas. Maximum inundation depth seems to be highest in the 'high-self contained nation scenario. (max 53 cm) The highest inundation depth will be experienced by areas within the category of 'at risk of social vulnerability'. But socially vulnerable areas are expected to face maximum inundation depths between 25 and 36 cm in future scenarios.

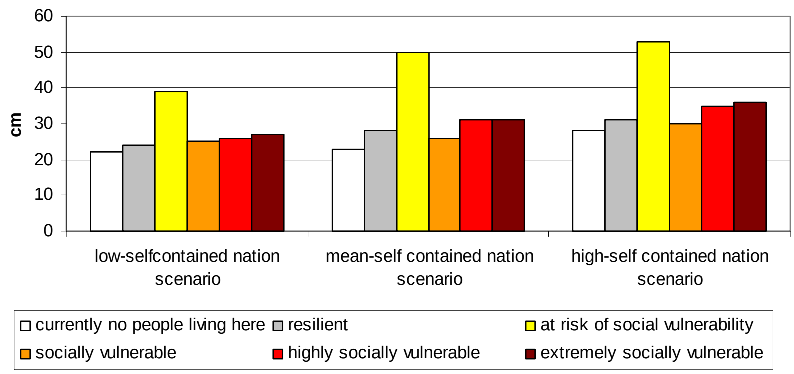


Fig. 8. Maximum inundation depth vs. social vulnerability within 50 year return period flood mid-century in the self contained nation scenario.

Taking into account the maximum expected inundation depth within the local responsibility scenario, it is clear that the largest inundation depth is expected in the least vulnerable areas. However, the projected inundation depth in the vulnerable categories is increasing within the mean and the high scenarios (31 cm and 36 cm).

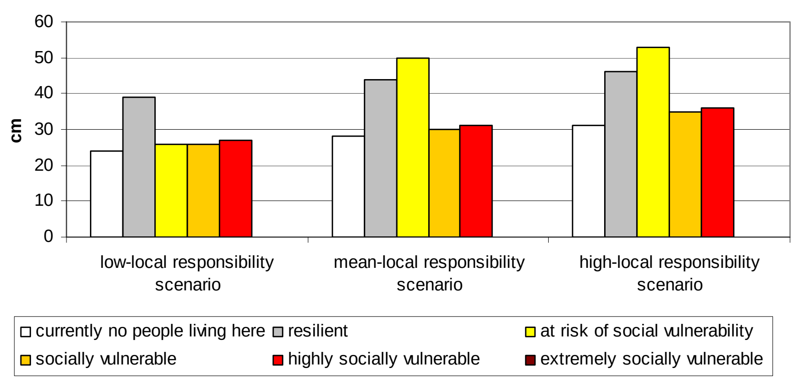


Fig. 9. Inundation depth vs. social vulnerability within 50 year return period flood mid-century in the local responsibility scenario

Based on this information, social impact can be estimated. People living in the inundated area will be confronted with more severe social impacts than those living outside the area. Inundation depth is between 25 and 50 cm in future scenarios, which may cause a lot of damage to properties, in particular to people in the ‘resilient’ and the ‘at risk’ categories. In addition, the inundation depth may harm personal items and may cause stress to people before and after the flood. Even at levels of 50 cm, some people may be forced to leave the house during recovery, which may disrupt their financial situation. In the future, other flood characteristics will be derived from this model like velocity and water rise speed, to specify projections even more.

Since the area is characterised by a large proportion of financially deprived people in the case of the self contained nation scenarios, we may expect that many people will have difficulties coping with the damage to properties, difficulties in meeting basic needs, disruption of financial situation and mental health. Often, the environment these people live in will become impoverished without governmental help. Another large population group are the lone parents, who may suffer from stress and mental health problems, disruption of financial situation and difficulties in meeting basic needs and housing recovery due to limited time and resources. In the future, the proportion of elderly is expected to grow dramatically. These elderly cannot cope easily with evacuation, temporary relocation, recovery and the loss of personal items.

5 Conclusion

Social impacts are often experienced as being severe in flood events. Moreover, they are experienced differently by different people. The social impact experience is determined by people's characteristics like social vulnerability and exposure, and by flood characteristics. Therefore, it is necessary to understand the social constellation of the flood risk area. In our case study, we have identified the location of the most vulnerable people, evaluated the evolution of social vulnerability inside and outside the flood area over time, we have evaluated the projections of flood characteristics like inundated area and inundation depth. And in the end, we have made a preliminary estimation on the social impacts that may be expected in these areas. This is carried out by combining social vulnerability maps and flood maps and by developing scenarios for future projections.

The main conclusions are that social vulnerability varies between districts and in time, that correlations exist between inundation area and social vulnerability and between inundation depth and social vulnerability. In addition, the social vulnerability causes can be retrieved from the model. The social vulnerability maps can be a useful tool for decision makers to decide on which areas to focus when designing technical measures from the social perspective (reducing flood risks). In addition, when it is not resource-efficient to protect these vulnerable areas from flooding, the maps can be used for appropriate information dissemination and emergency management (reducing social vulnerability).

This study is a preliminary step in social flood impacts research in a climate change context. Further research would like to focus on extending the understanding of the relations between social impacts, flood characteristics and social vulnerability. This knowledge may contribute to the specification of a more adapted social vulnerability index. Besides, to enable equal treatment of social impacts in comparison to economic and ecological impacts in flood risk management, social impacts need to be quantified.

Acknowledgement

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Appendix

Appendix 1

Table : relation flood characteristics and social impacts (work in progress)

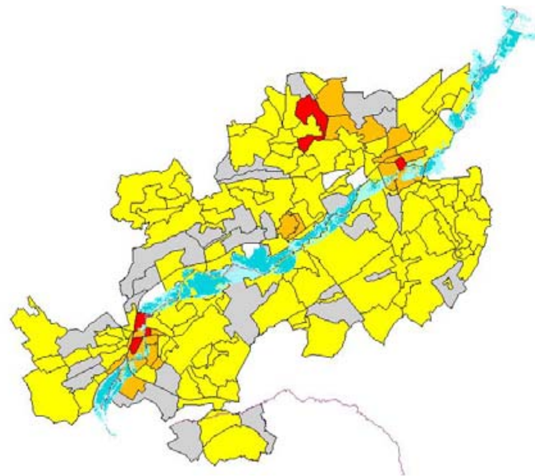
	Water depth	Water rise	Velocity	Duration	Pollution	Frequency	Time
Damage to properties	X		X	X		X	X
Loss of items with personal value	X			X			X
Disruption of physical health	X	X	X	-	X	-	X
Disruption of mental health	X			X			
Disruption of time spending	X						
Disruption of financial situation	X						
Change in persons' attitude and risk perception		X			X		
Temporary relocation	X						
Difficulties in meeting basic needs							
Difficulties in recovering the house	X						X
Changing relations between household members							
Changing relations at work and with friends							
Impoverishment of neighbourhood							
Migration							

Appendix 2

Table : relation social vulnerability and flood impacts (work in progress)

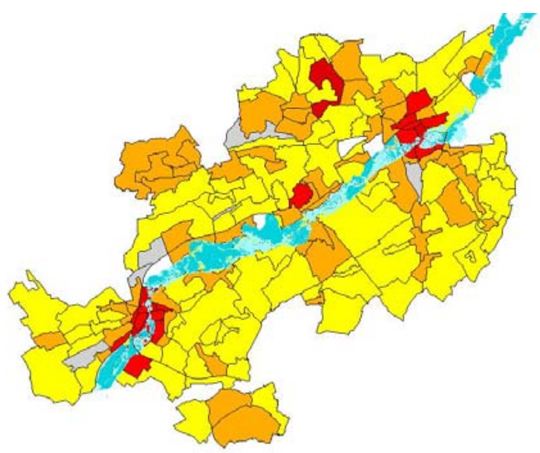
	Elderly	Financially deprived	Poor health status	Lone parents	Foreigners	Mobile home-residents
Damage to properties	X	X				X
Loss of items with personal value	X	X				X
Disruption of physical health	X	X	X			
Disruption of mental health		X	X	X		
Disruption of time spending		X		X		
Disruption of financial situation		X		X	X	
Change in persons' attitude and risk perception						
Temporary relocation	X				X	
Difficulties in meeting basic needs		X		X		
Difficulties in recovering the house	X	X	X	X	X	X
Changing relations between household members		X	X			X
Changing relations at work and with friends						
Impoverishment of neighbourhood	X	X				
Migration						

Appendix 3



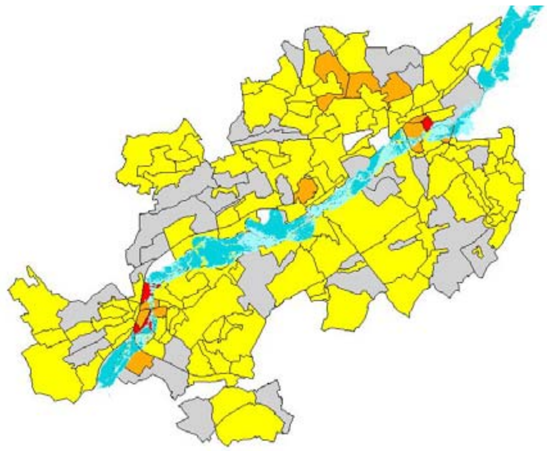
Source: FPS Economy, DG Statistics, own adaptation

Fig. Combination of social vulnerability map in baseline situation (2001) and 50 year return period flood map.



Source: FPS Economy, DG Statistics, own adaptation

Fig. Combination of social vulnerability map in self-contained nation scenario (2050) and 50 year return period flood map within high scenario.



Source: FPS Economy, DG Statistics, own adaptation

Fig. Combination of social vulnerability map in local responsibility scenario (2050) and 50 year return period flood map within high scenario.