Social Injustice to floods in Flanders (Belgium): a GIS analysis

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Abstract

Flanders (Belgium) applies the Multi-Layered Water Safety concept to cope with Flood Risk Management (FRM). Next to the traditional protective infrastructure this concept addresses spatial planning, crisis management and recovery structures. It implies a shared responsibility between stakeholders from the public, private and civic sector. However, little is known about the populations living in flood prone areas, and if it is just or efficient to ask their cooperation. This paper explores the social characteristics of the exposed population, through a GIS-analysis of the spatial distribution of the different social vulnerability indicators. Two sets of social data are used: statistical sectors for the whole of Flanders and building blocks for the Denderleeuw, Ninove and Geraardsbergen municipalities, which are particularly prone to floods. While a disproportionate exposure of non-Belgians to floods is observed in the non-urban areas of the three municipalities, statistical tests indicate this difference is non-significant. Nevertheless, from the perspective of distributive justice, these inequalities indicate the need for area-specific approaches based on the social characteristics of the population to ensure the efficiency and social justice in FRM. In terms of procedural justice, the social vulnerability indicators entail an underrepresentation in the public participation regarding flood risk policies. These findings advocate the involvement of the citizens at the local scale to define the most appropriate measures in FRM.

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Keywords: Floods, Social justice, Flanders, GIS, Multi-Layered Water Safety, Flood risk Management.

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1. Introduction

Floods in Flanders (Belgium) are historically a recurring problem and are predicted to increase due to climate change and urbanisation trends (Pittock, 2017; Poelmans & Van Rompaey, 2009; Vormoor *et al.*, 2015). In concern to these predictions, the Flemish Government already changed its flood management strategy the early 2000s from a flood control to a Flood Risk Management (FRM) approach (Kellens *et al.*, 2013). But in line with the European Flood Directive 2007/60/EC, recently, the Flemish Region started to apply the concept of “Multi-Layered Water Safety (MLWS)” (VMM, 2014). This MLWS concept recognises that governments can’t guarantee a sufficient flood protection with its traditional engineering instruments. Instead, MLWS focuses on a shared responsibility between water managers, spatial planners, emergency planner, the insurance sector, the building sector and the population. However, public awareness on private flood risk responsibilities remains low (Tempels 2016, Mees et al, 2016). Therewith the MLWS concept has led to a revised debate on flood risk responsibilities in Flanders (Kaufmann et al., 2016). Each layer addresses a specific aspect of floods, increasing the diversity of measures and the number of potentially involved stakeholders, but no one can guarantee yet if this would be efficient or just (Van den Brink *et al.*, 2011).

In this paper, we want to reflect on the social justice issues related with the discourse of MLWS. A common argument is that citizens who have chosen to live in flood-prone areas should share the responsibility to flood risks related to this choice (Mees *et al.*, 2016). A counter-argument could be that these areas might host proportionally more social vulnerable inhabitants, caused by lower housing prices. But today, limited information is available on the socio-economic profiles of the flood exposed populations in Flanders and their vulnerabilities. Therefore, this study explores the social (in)justice to floods in Flanders through an analysis of the social characteristics of the exposed populations. It aims to find an answer to the following research questions:

- Do flood-prone inhabitants in Flanders proportionally dispose of more socially vulnerable characteristics?
- How should policy makers take this into account in their flood risk policies?

The paper starts with a literature study of previous research on the definitions of justice and social distribution of flood risks. Subsequently an overview is presented of social characteristics coinciding with flood vulnerability. These characteristics refer to the gathering of the social data to match with the geographical flood zones in Flanders (ESRI, 2014). The results will give information about the spatial distribution of the different social vulnerabilities of the population and their flood exposures. Finally, the implications of these findings on the efficiency and social (in)justice of MLWS and the subsequent FRM policies in Flanders will be discussed.

2. Social Injustice related to flood risks

The conception of "justice" has been subject of numerous studies, with issues such as fairness, morality, decency and equity often being interchanged in their use (Hay, 1995; Ikeme, 2003). This section focuses on several theoretical reflections and perspectives around the meaning of justice. Based on this overview, we will present a provisional definition that serves as a reference for the exploration of social (in)justice to floods in Flanders. In this respect several studies make usually a distinction between procedural and distributive justice (Adger *et al.,* 2006; Arnold, 1998; Beretta, 2012; Bell & Rowe, 2012). Procedural justice emphasizes equal rights and possibilities during a process that leads to a certain outcome. It focuses on the morality of actions rather than on their outcomes. Distributive justice aims instead for an equal distribution of the benefits and costs resulting from these outcomes (Adger *et al*, 2006; Baden and Coursey, 2002; Ikeme, 2003). However justice in regard to floods involves both process and outcome.

2.1. Distributive justice

Related to distributive justice in FRM, the question arises what an 'equal distribution of benefits and costs' would imply. Does it mean that both citizens in- and outside of flood-prone areas should share the costs of flood risk management (e.g. through general taxes)? Or would it in contrast mean, that the general taxpayer should not carry the financial burden of individuals' choice to live in flood-prone zones? Answering this question is complex, since (increasing) flood risks are the overall result of many processes (climate change, urbanisation trends) that originate from individual behaviours but that are also influenced by decisions made at different governmental levels (Boelens et al., 2017). Flood risks both influences and are influenced by large groups of populations (Ashley, 2005; Hirabayashi *et al.*, 2013; Milly *et al.*, 2002). When applying a *utilitarian approach*, an equal distribution should generate the largest possible benefits for the whole of society (Adger et al., 2006; Johnson et al., 2007; Mees et al., 2017). This would speak against large public investments to the benefit of small numbers of flood-prone inhabitants. The *egalitarian tradition*, on the other hand, advocates that equal opportunities for all citizens should provide in a sufficient distribution of resources. This implies the provision of a guaranteed minimum level of flood protection or preparation for each citizen (Johnson et al., 2007). A *Rawlsian approach* adds to this that inequalities should have the greatest benefit for the least advantaged. In its turn it would require that flood risk managers pay specific attention to vulnerable groups and individuals in their policy planning, e.g. by providing (financial) aid to socially deprived residents (Mees et al., 2017).

In all cases, applying a single perspective to an equal flood risk distribution can easily be challenged, due to the complexity of flood risks and their causes. Climate change, urbanisation and the implementation of protective measures significantly impact the shape of flood zones, which makes flood risk distribution dynamic in time. Next to this environmental physical dimension, flood risk distribution has a social dimension too. Flood vulnerabilities can differ significantly depending on the social characteristics of flood-prone inhabitants (Coninx & Bachus, 2008; Few, 2003; Sayers *et al.*, 2017; Steinführer *et al.*, 2009; Walker & Burningham, 2011).

Following this, it is not surprising to notice that studies relate floods either to social justice or environmental justice; however mostly without a clear denomination (Fielding & Burningham, 2005; Maantay & Maroko, 2009; Sayers, 2017; Walker & Burningham, 2011). Maantay & Maroko (2009) state that certain groups in society (e.g. low socio-economic status, language, colour, geographically or socially isolated) are often disproportionately more confronted with the environmental burdens whilst they have little knowledge of or influence on relevant decision-making. In their turn Coninx & Bachus (2008) and Sayers *et al.* (2017) focus more on the social vulnerability with regard to the community's capacity to support individuals and the citizen's individual susceptibility to have a loss of well-being, their preparedness, their response capacity and the recovery potential. In this paper we will include both perspectives in our working definition regarding the social (in)justice of FRM in Flanders.

2.2. Procedural justice

In addition the social-environmental vulnerabilities discussed above, do not only impact distributive justice, but relate to procedural justice as well. In order to be just, inhabitants from in- and outside flood-prone areas should have opportunities to influence the decision-making that leads to flood risk measures, financing schemes, etc. (Maantay & Maroko, 2009; Mees et al., 2017). Bell & Rowe (2012) compare the power of influence in equality and proportionality in the decision-making process. In order to achieve procedural justice, they advocate decision-making processes which distribute the power in proportion to the stakes of each communities. This implies that communities more affected should get more influence in making that decision.

However, even if these principles for providing rights to participation are guaranteed, citizens do not have the same capacity to do so (Bulkeley & Fuller, 2012). Opportunities to influence decision-making depend not only on formal procedures, but also individuals' and communities' social capital. This social capital is, amongst other things, influenced by individuals' socio-economic status (SES) (Walker & Burningham, 2011). According to Hawkins & Maurer (2009), people with lower economic resources tend to have fewer capabilities to interact with governmental actors. In participation trajectories across the globe, an overrepresentation of highly educated citizens with a higher economic status is found (Irvin & Stansbury, 2004; Fung, 2006; Thijssen & Van Dooren, 2016). Reaching individuals with a lower SES to participate in decision-making appears to be less evident.

2.3. Defining social (in)justice

In this paper and due to the specific circumstances with regard to the environmental features[4], urbanisation history[5] and abilities of the inhabitants to affect policy measures in our case (i.e. the Dender basin) we will include all three elements in our working definition regarding social (in)justice. Based on the preceding reflections on procedural and distributive aspects, and on social and physical dimensions, we have therefore defined the following working definition for this paper:

Social injustice to floods is the situation where certain population groups are disproportionately exposed to flood risks both due to historical, physical and social characteristics (distributive injustice) and have little or no influence on the societal mechanisms that reduce the population's vulnerability (procedural injustice).

Therewith in this paper we will make a connection between the flood exposure of a population and the vulnerability of that population, socio-economic characteristics, and their possibility to have more or little influence on policy and legislation. With regard to the latter two, these can be represented by the following social data.

- ***Age*** as a particularly relevant vulnerability indicator with the very young and the elder being the most vulnerable (Walker & Bunningham, 2011). People aged 75 are generally less resistant and have more difficulty to recover from flood events (Coninx & Bachus, 2008). Sayers *et al.* (2017) mentions also the association made between flooding and increased mental health and behavioural problems in children of young age.
- ***Health***, which can be analysed from both a mental and physical perspective. In case of physical health problems, citizens have a reduced mobility making them less capable in preparing, protecting and evacuating. Citizens with mental health issues are also less capable in prepare, react or recover to floods and can also have more difficulties to cope with the stress of flooding (Coninx & Bachus, 2008; Sayers *et al.,* 2017).
- ***Income,*** which is, with health and age, the most mentioned indicator from studies. Poorer households are potentially more vulnerable because of the lower financial resources to prepare, respond and recover from flood events (Walker & Burningham, 2011). Coninx & Bachus (2008)

[4] The Dender river rises in Wallonia, whereas its main floods occurs in Flanders.
[5] In the urbanisation history of Flanders some have just build in floodprone areas, extended their poperities illegally or surfaced their gardens with floor tiles.

mention the possible vicious deprivation circle in which poorer households can be stuck after a flood event. Low income families often cannot afford insurances that can help in the recovery, lowering the means for adaptive measures and consequently increasing the recovery costs after the next flood.

- ***Education***; Sayers *et al.* (2017) indicated that people with low education level could be more vulnerable due to illiteracy or lack of language proficiency but no clear correlation has been proved yet. Instead, local knowledge and awareness are more important indicators. But local knowledge is generally also linked with nationality and social capital (Sayers *et al.*, 2017).
- ***Social capital***, which plays an important role in enhancing the community resilience, the response and recovery capacity (Walker & Bunningham, 2011). Social capital increases the preparedness of a community to floods. Sayers *et al.* (2017) indicate that single parents, lone pensioners and new arrivals are more likely to have a lower social capital, and thus greater vulnerability.
- ***Nationality***, which can play an indirect role in the vulnerability of individuals to floods. Especially recently arrived foreigners with language difficulties have a lower anticipation, resistance and recover capacities due to a lack of information dissemination (Coninx & Bachus, 2008; Walker & Bunningham, 2011).
- In terms of family status, **single parents' households** are the most vulnerable. Since they have to bear all the financial costs, they have a lower capacity to anticipate and recover from floods (Coninx & Bachus, 2008). Furthermore, they often lack emotional support because they have to cope with all the stress and worries alone.
- The specificities of ***property tenure***, which can have an influence on the vulnerability of its inhabitants. Social housing tenants may experience difficulties in the preparation of measures to cope with floods due to their living arrangements and they are more likely to have lower income. Tenants may not be allowed to make structural alterations of to the properties and leaseholders may not feel worthwhile to do so (Sayers *et al.*, 2017).
- ***House characteristics***, like poor quality houses and mobile homes, which have limited protection against floods compared to buildings that are structurally competent (Sayers et al. 2017). Single floor properties, mobile homes and bungalows do not allow to move belongings upstairs (Coninx & Bachus, 2008).

3. Methodology

Next we have tried to 'translate' these theoretical reflections towards an operational framework for our case in Flanders, the Dender basin, which is one of the most susceptible basins to flood risk of Flanders (Mees *et al.*, 2016). Therewith we came up with the following possibilities and challenges.

3.1. Flood exposure data

The demarcation of possible flood prone areas is freely available on the geographical database of the Flemish Region (AGIV, 2018). The Flanders Environmental Agency (VMM) is in charge of processing those maps showing the location of the potential flood zones. Two zones are defined: the effective flood zones and the potential flood zones. The effective flood zones have the highest risk of flooding and are defined through hydrological models, delineating zones with a 100 year return period, in combination with local observations of recent floods. Potential flood zones are natural flood zones where flood sediments were collected, but were never recorded to have flooded (VMM, 2015). The maps are regularly updated with maps of 2006, 2011, 2014 and 2017. For this research we have used the flood zone maps from the year 2011, since these coincide the best with the year of the last census and the production year of the land cover map. No information is given, unfortunately, about the possible intensity of the flood zones such as their duration, height or even velocity of occurrence.

3.2. Social vulnerability data

A high variety of social data in Flanders can be gathered at various public and private sources. The social data can be open source or requires official agreements with the institutions owning the data. In this study, the most recent open source census data (a) and social data (b), both from the year 2011, were used for this research.

(a) The census data are registered in Belgium by Statbel, the Belgian official statistical research institution, and are freely available on the office website. These census data are renewed every ten years, hence those from the year 2011 being the most recent (Statbel, 2017). Moreover, these data are aggregated by statistical sectors of which the population count varies from 1 to 6082 inhabitants. Thus, the level of aggregation and subsequently the difference in representativeness between statistical sectors can be very high. Moreover, the types of data available are limited and could not fulfil all the vulnerability indicators (see table 1). These indicators comprise: younger than 15 years old, older than 65 years old, median income, unemployment, citizens with no diploma, citizens with only a primary diploma, non-EU nationality, non-Belgian nationality, single fathers and mothers and rented properties.

(b) Therefore and next to census data per statistical sector, we added social data, which are registered per building block. The social data per building blocks are more precise in terms of representativeness of the population with populations ranging from 0 to 731 inhabitants. Consequently, the amount of vulnerability indicators at building block level is lower than at the statistical sector level due to privacy norms. The available data per building block were: younger than 10 years old, older than 65, unemployed and non-Belgian nationality. Using the whole dataset of the Flanders' territory would not have been computable because of the amount of building blocks it represents. We consequently focused on three municipalities of our case study: Denderleeuw, Geraardsbergen and Ninove. This represents a total of 1236 building blocks.

Vulnerability indicators	Social vulnerability data in Flanders	
	Per statistical sector	Per building block
Age	< 15 (inh. and %) ≥ 65 (inh. and %)	< 10 (inh. and %) ≥ 65 (inh. and %)
Health	/	/
Income	Median income (euros/year) Unemployed (inh. and %)	Unemployed (inh. and %)
Education/Local knowledge	No diploma (inh. and %) Primary school (inh. and %)	/
Social capital	/	/
Nationality	Non-EU nationality (inh. and %) Non-Belgian nationality (inh. and %)	Non-Belgian nationality (inh. and %)
Family Status	Single father (inh. and %) Single mother (inh. and %)	Single father (inh. and %) Single mother (inh. and %)
Property tenure	Rented housings (%)	/
House characteristics	/	/

Table 1: Overview of the social vulnerability data aggregated per statistical sectors (from Statbel) and per building block (from the Health and Wellbeing Office of the Province East-Flanders) used in this study as vulnerability indicators.

3.2 Societal and political mechanisms

Societal mechanisms, such as reimbursement of property damage due to floods or emergency services, are dependent of various processes and factors. Moreover, it can have unexpected side effects. Consequently, it demands an analysis of their effectiveness and their influence on different population groups and other societal mechanisms. For instance, the insurance systems can be beneficial in reducing the costs from flood damage but can also encourage further urbanisation in floodplains (Tempels, 2016). Next to this, the contribution of the emergency services to social justice is determined by the amount of training and preparedness of the crew and the local volunteers, its availability, accessibility and their equipment (Lindell, Prate & Perry, 2006). The broadcasting of information about floods and the possible countermeasures are freely available on the websites of the VMM and CIW. Yet, these mechanisms, their side-effects and effectiveness are also dependent on local infrastructural factors, cultural characteristics and the level of dissemination of information.

Several authors have linked the efficiency of societal mechanisms to community resilience, being the capacity of a community to anticipate, adapt and quickly recover from hazards (Lo *et al.*, 2015; Norris *et al.*, 2008; Twigger-Ross *et al.*, 2011). These authors stress the importance of the citizens' social capital in the development of community resilience, which increases informal and logistic support between the individuals and the potential of mobilising resources and knowledge. Furthermore, it can enhance the interactions with governmental bodies enabling the share of information between state and societal actors (Mees *et al*., 2017). Other studies have noticed that social capital is dependent on socio-economic status (SES) with citizens having lower SES tending to have lower social capital (Hawkins & Maurer, 2009; Walker & Burningham, 2011). This relationship is however not straightforward with citizens with lower SES having sometimes more time to increase their social capital (Jakobson, 2012). Lower social capital not only decreases the efficiency of local societal mechanisms but also reduces the participation of citizens in the local decision-making process.

The research section of the Flemish Government (SVR) has conducted a broad demographic study which included an analysis of the level of public participation of different population groups in Flanders. The study noticed that population with a lower education level, older people, non-Belgians and single parents tend to have a lower public participation and lower social capital. On the other hand, higher percentages of public participation were observed amongst the population with higher income and higher education level (SVR, 2017). These indicators concord with the social vulnerability data gathered for the study. The percentages of lower education levels, older than 65 years old, non-Belgians and single parents were subsequently used as indicators of a potentially lower social capital and public participation in the decision-making process.

3.3 Geographical differences

Next to that and as mentioned above, several studies have indicated in the past differences in socio-economic characteristics between different areas of the Flemish Region (SVR, 2017; Loris & Pisman, 2017). Consequently, the distribution of the population's vulnerability to floods will depend on the type of demarcation and thus, also, on the scale of observation. Walker & Burningham (2011) for instance observed a substantial difference in the patterns of flood exposure across the different vulnerability groups in the UK between the coastal and the river flood areas. No difference in exposure was noticeable in the river flood areas, while the most vulnerable groups were more likely to be exposed in coastal flood areas. When looking at the scale of the Flemish Region, the populations of urbanised areas have higher chances of being more vulnerable to floods due to the higher concentrations and densities of population. Moreover, urban areas in Flanders tend to have higher percentages of non-Belgians and unemployed and lower percentages of older than 65 years old (SVR, 2017). Subsequently, the study explores the differences in vulnerability between the populations exposed and non-exposed to floods within this these geographical demarcations, urban and non-urban areas. This delineation was defined by deriving the population density per statistical sector. The limit of 150 inhabitants per km² presented by the Organisation for Economic Co-operation and Development (OECD) is internationally recognized to delineate urban from non-urban areas. However, the level of urbanisation of the Flemish Region would lead to consider the whole territory as urban using these criteria. Consequently, the limit of 600 inhabitants per km² was used as proposed by the study of Lenders *et al.* (2006) as a result of his survey amongst local experts. The statistical sectors were categorized in urban and non-urban area depending on their population density.

3.4 Matching flood exposure and social vulnerability data

As water is an integral and natural element, the boundaries of the flood zones do not concur with the boundaries of the social data collection. Moreover, population data are usually aggregated per census zone, which assumes that the data are evenly distributed throughout the zone. In reality, population distribution is generally highly heterogeneous (Wu *et al.*, 2005). In order to deal with this, Fielding (2007) used a surface population model called Surface Builder that imputes the distribution of larger area statistics into 200m grid squares, based on the population centroids for each census area. Maantay & Maroko (2009) in their turn compared the impacted population determined by three mapping methods: the centroid-containment method similar to Fielding (2007), the filtered areal-weighting interpolation (FAWI) and the cadastral-based expert dasymmetric system (CEDS). The level of disaggregation increased from the first to the third method, meaning that CEDS was the best method to feature the heterogeneity in the census zones. The lowest level of aggregation of data available for this study was, however, at the level of building block, and not that of cadastres.

Therefore and in order to get a clearer indication of the population distribution within a statistical sector, a raster land cover map from the Flemish Agency for Geographical Information was used (AGIV, 2018). This map has a 1m resolution and covers the whole Flemish Region. The buildings were retrieved using the extraction by the attributes tool of ArcGIS to arrive to a map solely depicting buildings in the Flemish Region. The overlay function was then performed with the flood zones resulting in a map categorizing (1) buildings in effective flood zones, (2) buildings in potential flood zones and (3) buildings not located in flood zones. The area in square meters for each building category per statistical sector was computed using the Zonal toolset of ArcGIS. Consequently, the proportion in percentage of buildings located in these different flood zones was calculated per statistical sector (Figure 1).

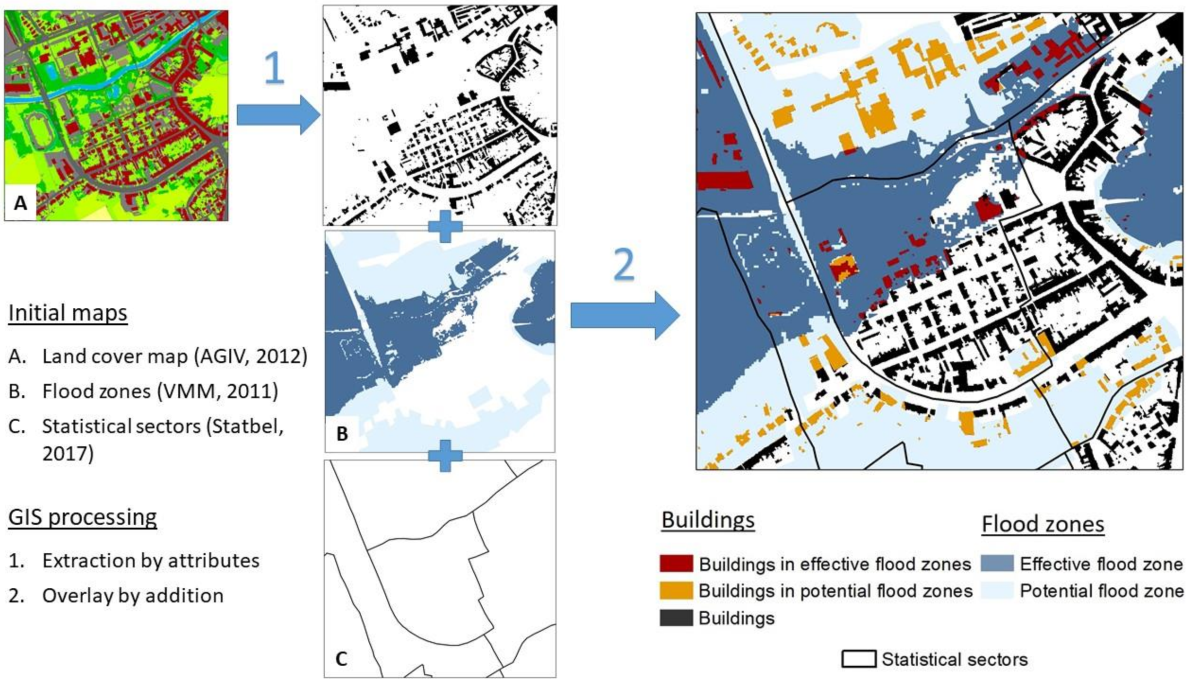

Figure 1: Scheme showing the input maps (A, B and C) and GIS functions (1 and 2) to process the final maps.

4. Results

4.1 Statistical analysis

This processing resulted in a set of data with variables per statistical sector showing population, proportion of buildings in effective flood zones, median annual income in euros, percentages of unemployed, non-Belgian nationalities, aged under 15, aged above 65, population with a primary diploma or none (no diploma's and primary diploma's), single parents and rented properties. Only the effective flood zones were included in the analysis because these zones were recently flooded or were defined as the highest chances of flooding following hydrological models (CIW, 2016).

As a first step of descriptive statistics, the statistical sectors were categorized in function of the proportion of building areas in effective flood zones. The following categories were defined (see table 2): not exposed (0-1%), slightly exposed (1-5%), moderately exposed (5-20%), highly exposed (20-50%) and very highly exposed (>50%). In total and over the whole Flemish Region, 43 statistical sectors have more than 50% of their building in effective flood zones and 132 with an effective flood exposure ranging from 20 to 50%. These two categories represent a total population of 22,179 and 58,433, and a total of living properties of 9,225 and 24,067 respectively. In both urban and non-urban areas, the percentages of single parents are slightly higher in the very highly flood exposed sectors compared to their other respective exposure categories. Finally, the biggest difference can be seen in the percentage of non-Belgians and rented housings in very highly exposed statistical sectors of the non-urban areas, which is substantially higher than in any other category. However the statistical significance of the differences between the very highly exposed non-urban sectors with the other categories were evaluated using the Kruskall-Wallis test[6] and were found non-significant. As shown by Walker & Burningham (2011), the delineation of categories have notwithstanding an influence on descriptive statistics. Spearman's ρ correlation coefficient tests[7] were thus also run comprising the complete dataset of Flemish Region. The significance of the relationships between the proportion of buildings in effective flood zones per statistical sector with the social vulnerability indicators was thereby calculated. The tests indicate a significant but marginal correlation between the proportion of buildings in effective flood zones and median income (ρ=0,046), unemployment (ρ=-0,044), non-Belgians (ρ=-0,072), single parents (ρ=-0,029) and rented housings (ρ=-0,118). Running a same test by

[6] The Kruskall-Wallis test is a statistical method to see whether different samples, e.g. the exposure categories, originate from the same distribution.
[7] The Spearman's ρ correlation coefficient is a statistical test to investigate the degree of relationship between two continuous variable, e.g. the percentage of exposed buildings and the different vulnerability indicators.

groupings of the statistical sectors in the urban and non-urban areas we found similar correlation (see annex). Therewith we conclude that the high degree of statistical significance is due to the very large dataset (N=9.182). The Kruskall-Wallis test solely indicates that there is no evidence that the difference in vulnerability indicators between the very highly vulnerable non-urban statistical sectors and the other categories is not the result of a random selection. In addition, the marginal Spearman's correlations indicate that there are no distinct relations between the flood exposure and the different social vulnerabilities of the statistical sectors at the scale of Flanders.

Overall, the statistical tests need therefore to be taken with a certain reserve. Firstly, the descriptive statistics have indicated the higher percentages of non-Belgians, lower education level, single parents and rented housings in very highly exposed statistical sectors of non-urban areas. However, this category represents a total of 20 statistical sectors and any significance test would be irrelevant due to the low amount of statistical units. This explains the non-significance of the Kruskall-Wallis test. However it does not rule out the fact that these differences are present in real life. Secondly, as mentioned before, the distribution of the population within the statistical sectors is also unknown. The data gathered and the results of the descriptive statistics only provide information about the statistical sectors. While the percentage of buildings in effective flood zones can be an indication of the sectors' flood exposure, it cannot be used as an indication of the amount of inhabitants living in these effective flood zones.

Categories of flood exposure	N° of statistical sectors	Population		Living properties	
		in urban areas	in non-urban areas	in urban areas	in non-urban areas
Not exposed (0-1%)	7,232	4,365,346	775,547	1,844,198	297,070
Slightly (1-5%)	1,126	563,367	228,677	231,763	87,192
Moderately exposed (5-20%)	649	290,082	82,516	119,033	31,763
Highly exposed (20-50%)	132	47,039	11,394	19,611	4,456
Very highly exposed (>50%)	43	21,140	1,039	8,723	502
Total	9,182	5,286,974	1,099,173	2,223,328	420,983

Categories of flood exposure	Urban areas							
	Median Income (€/year)	Unemployment	Non-Belgians	Under 15	Above 65	Primary or no diploma	Single parents	Rented housings
Not exposed (0-1%)	23,931	2.45%	8.11%	16.16%	18.46%	16.05%	9.80%	32.55%
Slightly (1-5%)	23,910	2.11%	5.93%	16.37%	18.25%	15.83%	9.55%	26.96%
Moderately exposed (5-20%)	24,129	2.14%	5.37%	16.64%	17.85%	16.57%	9.68%	26.99%
Highly exposed (20-50%)	24,394	2.41%	7.23%	15.44%	19.28%	15.48%	10.50%	28.24%
Very highly exposed (>50%)	26,013	2.27%	7.92%	15.76%	19.73%	15.82%	12.12%	27.74%

Categories of flood exposure	Non-urban areas							
	Median Income (€/year)	Unemployment	Non-Belgians	Under 15	Above 65	Primary or no diploma	Single parents	Rented housings
Not exposed (0-1%)	23,997	1.53%	4.43%	16.34%	17.14%	15.20%	7.01%	16.43%
Slightly (1-5%)	24,680	1.51%	3.30%	16.17%	17.17%	15.39%	6.86%	13.72%
Moderately exposed (5-20%)	24,322	1.68%	5.03%	15.78%	17.56%	14.97%	7.37%	15.52%
Highly exposed (20-50%)	24,303	1.89%	3.76%	15.46%	17.92%	14.89%	7.10%	15.06%
Very highly exposed (>50%)	22,190.5	1.92%	10.78%	17.13%	16.27%	17.20%	9.62%	23.31%

Table 2: In the upper table: the number of statistical sectors and populations in urban and non-urban areas per category of flood exposure. In the middle and lower table: the median income and percentages of other social vulnerability indicators per category of flood exposure in urban areas and non-urban areas.ngle parents per category of flood exposure in non-urban areas.

4.2 Cartographic analysis

4.2.1 Statistical sectors

The absence of a distinct relationship of statistical sectors with a high social vulnerability and their level of flood exposure can be analysed more clearly looking at Figure 2. In this example, we have presented the percentage of non-Belgian nationalities, because the statistical results showed a notably higher percentage in the very highly exposed non-urban areas. These statistical sectors are marked with blue boundaries. As shown on the map, high percentages of non-Belgians can be found at border areas (due to cross border commuting effects) or within the biggest inner cities (due to their attractiveness or the character of housing stock for migrants). By zooming in at the level of municipalities itself, the more exposed statistical sectors of non-Belgians with a high vulnerability to floods can be identified at several spots. When comparing the municipalities of Geraardsbergen, Ninove and Denderleeuw, two very highly exposed non-urban areas can be found in Ninove and one in Denderleeuw, all located at the edge of urban statistical sectors. Two of those three sectors have a percentage of non-Belgians higher than 10%.

This scale of observation allows a view on the social distribution of the vulnerable parts of the municipalities' population, and the differences between them. The unequal variability of the population's types of vulnerabilities are unique for each municipality and it features a kind of authenticity that entails peculiar challenges.

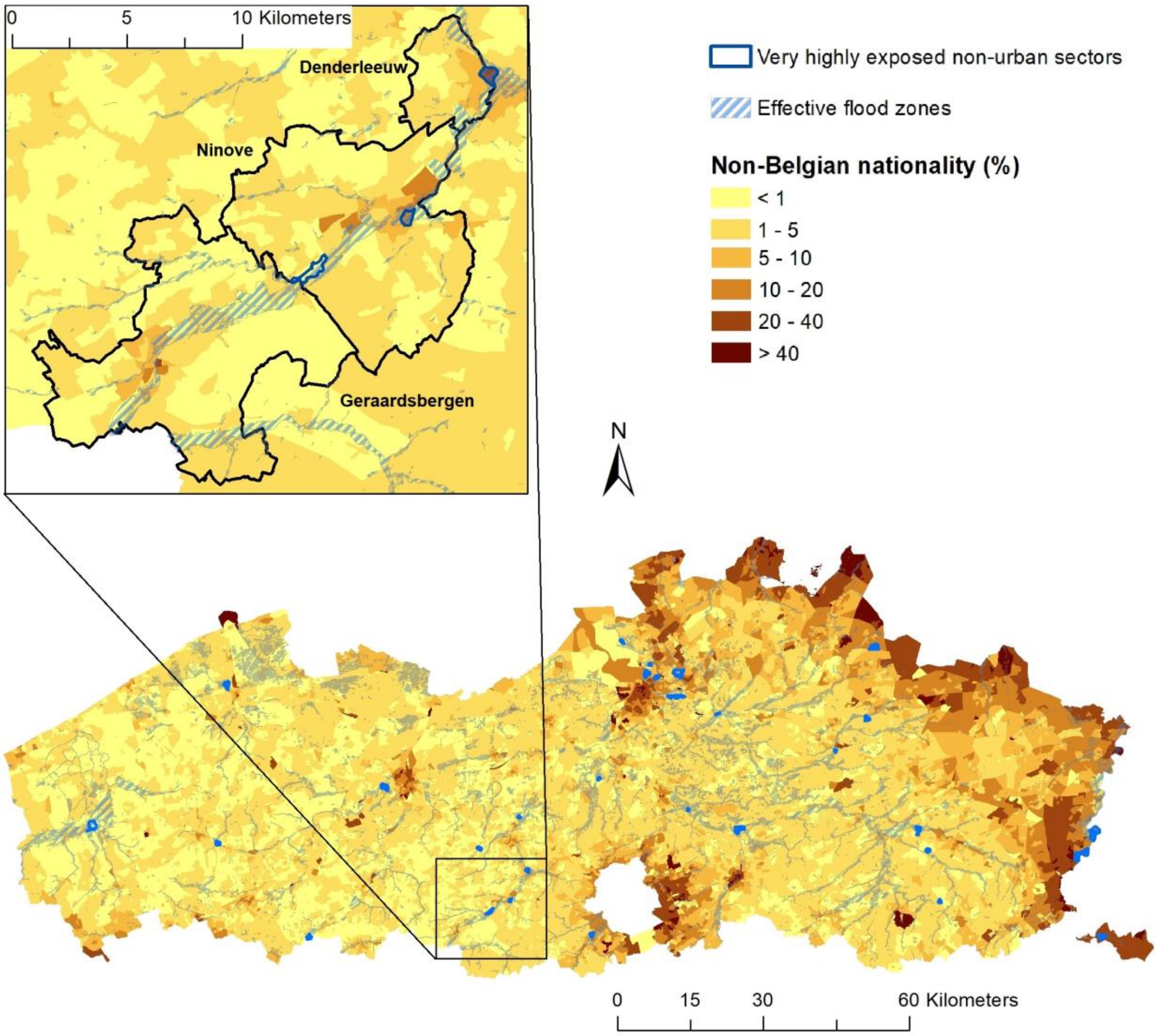

Figure 2: The map of Flanders with the percentage of non-Belgian nationalities per statistical sectors compared to the effective flood zones (below) and a zoom in on the Geraardsbergen, Ninove and Denderleeuw municipalities (above), both with the very highly exposed non-urban sectors in blue.

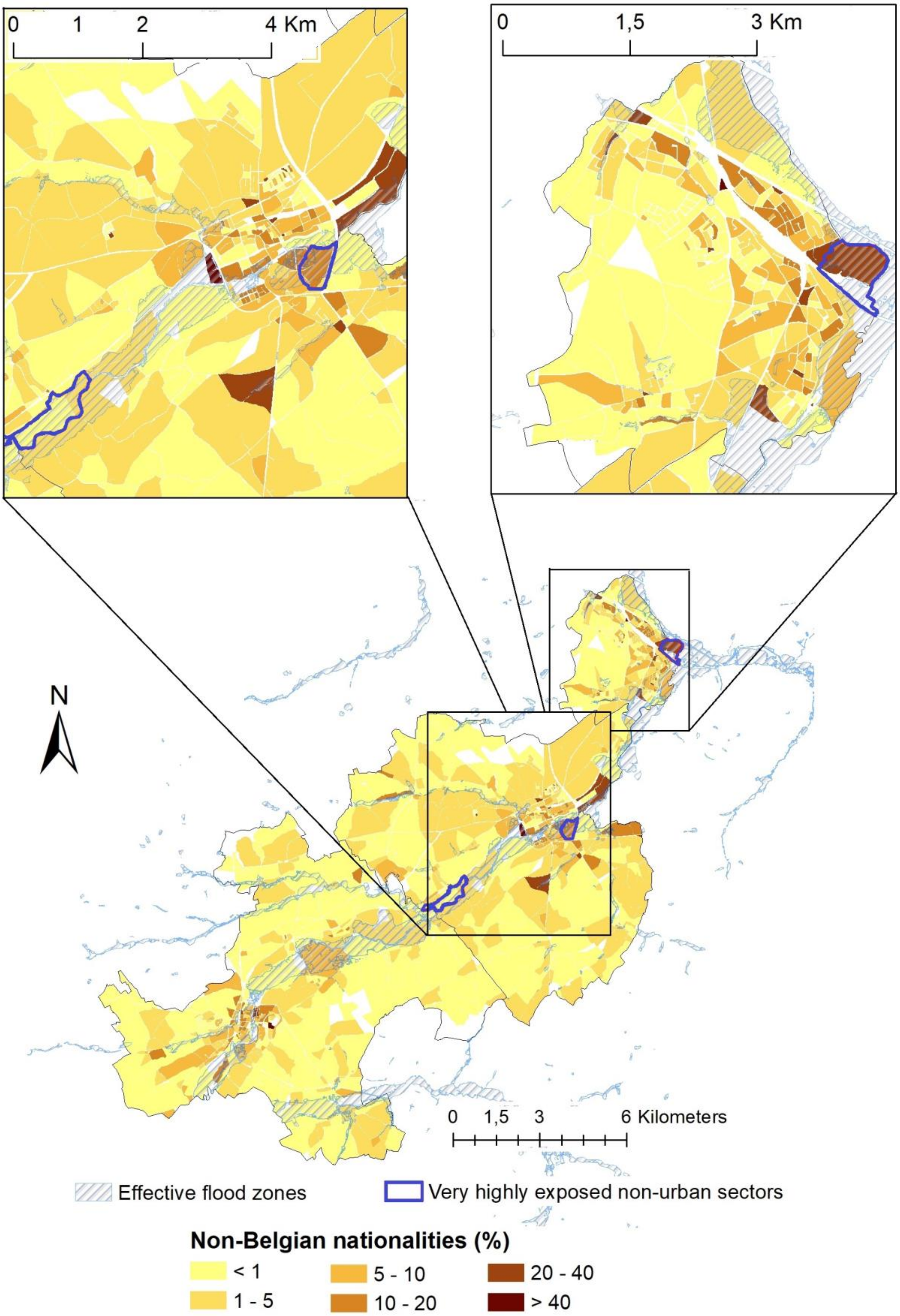

Figure 3: The percentage of non-Belgian nationalities per building block for the municipalities of Geraardsbergen, Ninove and Denderleeuw (lower map)shows more precise distribution of the social vulnerability indicator. Two zooms (superior maps) give a more detailed view of Ninove (upper left) and Denderleeuw (upper right).

4.2.2. Building blocks

Contrary to the statistical sectors data, no significant correlation was found between the flood exposure of the building blocks and their social vulnerability indicators. However and interestingly, the results for each vulnerability indicator per exposure category, with distinction of urban versus non-urban areas, are similar than the results of the statistical sectors with minor differences. For instance, the percentages of non-Belgians per building block in the three municipalities vary in urban areas from 3.26% to 5.50%. In particular, the difference between exposure categories in non-urban areas is noteworthy. While the percentage of non-Belgians in very highly exposed non-urban areas is 10.45% (very close to the 10.78% at the scale of Flanders), the other percentages are substantially lower with 4.71% in the highly exposed and around 1% in the other categories. Applying the Kruskall-Wallis test like at the Flemish scale with the statistical sectors, there is no evidence whether these differences are the result of a trend. Nonetheless, the results of the tests exclusively imply data aggregated per statistical sector for the Flemish Region and per building blocks for the Geraardsbergen, Ninove and Denderleeuw municipalities, with the limitations it entails (e.g. the lack of information about the spatial variability within the boundaries of the aggregated areas). The higher percentage of non-Belgians living in very highly exposed non-urban building blocks for the three municipalities and statistical sectors for the Flemish region (both above 10%) indicate a substantial disproportionate exposure of a specific group of the population on this level. The overall results from the statistical sector analysis and the difference between the three municipalities in the population patterns and their social characteristics indicate that this disproportionality is dependent of the area itself and the scale of observation. Each municipality is confronted with a unique distribution of populations' characteristics with specific inequalities.

These unique inequalities in function of the location are more accurately depicted when observing the maps in Figure 3. Zooming in we can for instance depict major differences between Ninove and Denderleeuw. By comparing the two maps, the overall colour domination in Figure 2 tends at first sight to indicate higher percentages than in Figure 3. However, by looking more closely, building blocks with particular higher percentages can be identified. Those building blocks have a major impact on the percentage of the respective statistical sectors. This observation demonstrates how the social vulnerability to floods at the level of statistical sectors can lead to misinterpretations. The spatial variability of vulnerable population groups and their flood exposure can be examined with a higher accuracy when using building blocks. Next to the marked very highly exposed non-urban statistical sectors, other very highly exposed building blocks with a higher social vulnerability can also be distinguished in urban areas. Thus data aggregated per building blocks has a clear advantage compared to the statistical sectors for the identification of specific vulnerable areas. However this data is not openly available for overall Flanders and needs to be requested at the local public authorities (municipality or province). Moreover, the amount of building blocks in Flanders would require a high computing performance. Specific areas need to be defined beforehand to carry out the analysis. Similarly to statistical sectors, certain variability is also present within the building blocks and a more pronounced analyses of the local situation can only be attained through additional input of local information.

Furthermore, the social characteristics do not represent the same level of vulnerability over the whole Flemish territory. Societal mechanisms such as emergency services have the aim to reduce the population's vulnerability to adversity by increasing the response capacity of a community. However, the efficiency of each local emergency service is dependent on local factors (availability, accessibility, equipment, training of the crew,…). Other societal mechanisms exist at municipality scale that tend to enhance the community's resilience. But, these mechanisms can vary greatly from one municipality to another. This makes the local community resilience dependent on its socio-economic history, social capital and the level of communication from the structures responsible of these mechanisms (Norris *et al.*, 2008). The high plurality in social vulnerability and societal mechanisms leads to an overall absence of distributive injustices to floods but entails specific inequalities at the local level that require locally adapted approaches. On this behalf, a cartographic analysis of the spatial distribution of the social characteristics using the building block data would allow the identification of specific socially vulnerable areas, in order to consequently develop a more engaged local strategy.

5. Conclusions

5.1 Distributive justice

In this analysis, we researched whether populations in flood-prone areas in Flanders show proportionally more social vulnerability characteristics than others. Spatial variability analysis at Flemish and municipal scale found either marginal or statistically non-significant relationships. Interestingly, a higher percentage of non-Belgians was found in the non-urban statistical sectors (population density lower than 600 inhabitants per km^2) with more than 50% of the buildings being exposed to floods. This becomes mainly apparent in the municipalities of Geraardsbergen, Ninove and Denderleeuw, using data at the level of building blocks. Statistically, however, it is non-significant, and could be the result of a random phenomenon.

Despite this statistical non-significance, they still present a major share of the population as well. Moreover, inequalities change from one municipality to the other, as shown by comparing Geraardsbergen and Ninove and Denderleeuw. In the case of non-Belgians, the language difficulties diminish the accessibility to information and their social capital. Non-Belgians are not the only population group confronted with the language issue. An increasing amount of French-speaking citizens with migrant roots moving from the Brussels to the Dender valley was observed from 2005 to 2013 (De Maesschalck *et al.*, 2015). These population tend to have a lower SES and emigrated from Brussels due to economic insecurity and the increasing cost of housing (De Laet, 2018). Dealing with the language difficulties and the lower social capital is thus necessary to increase the community resilience. Single parents do not necessarily face the same difficulties as non-Belgians and thus require a different approach.

Therefore, we argue that policy makers should still pay attention to these populations groups when drafting flood risk policies based on a shared responsibilities discourse. In order to increase both FRM's effectiveness, efficiency and equality, it would be advisable not to apply MLWS as such, but to draft a more area-specific approach based on the social characteristics of the involved inhabitants. This is in fact in line with a Rawlsian approach to social justice. But in order to propose more area-based measures, a cartographic analysis per building block could be an interesting tool in revealing to which social (in)justice challenges these measures should be targeted, and what its proposed adaptive MLWS strategies might be.

5.2 Procedural justice

The call for a Rawlsian approach does not only apply to an equal distribution of a flood risk policy's impact, but also to its decision-making process. Research has shown that socially vulnerable population groups are significantly underrepresented in public participation processes and consequently, influence (local) flood risk policies to a lesser extent (Irvin & Stansbury, 2004; Fung, 2006; Thijssen & Van Dooren, 2016). When drafting flood risk policies, policy makers should be aware of this inequality and aiming at an equal participation of the different population groups. Such issue can be challenging (Jakobson, 2012; Hawkins & Maurer, 2009; Irvin & Stansbury, 2004; Lo *et al.*, 2015; Norris *et al.*, 2008). Putting more effort on citizen's participation, depending on the method used, can be costly and ineffective (Irvin & Stansbury, 2004). Jakobson (2012) noticed that the citizen's knowledge, skills, tools and time availability are important resources to enhance the participation's effectiveness and consequently, advocates for enhanced governmental efforts to provide these resources to citizens. Each type of social vulnerability can be linked with a shortcoming of one of these resources. For instance, non-Belgians are potentially lacking knowledge of the existing institutional structures and societal mechanisms due to language difficulties. Single parents on the hand generally have reduced time to focus on participation (SVR, 2017).

Concluding, every flood zone has its own inherent inequalities featuring an authenticity and entails very specific challenges in terms of distributive and procedural justice. The process of establishing an efficient and just FRM thus needs to include the local types of social vulnerability, the available infrastructure, existing societal mechanisms and the behavioural response of the population in its strategies. The MLWS concept implies a shared responsibility between different actors from the public, private and civic sector. The level it answers distributive and procedurally justice is dependent on the local efficiency of each flood risk measures and of the method of participation. From this perspective, an appropriate method that ensures the involvement of citizens at the local scale is required to define the most appropriate measures. Flood risk management at regional scale, in addition, requires a field of action broad enough to answer the plurality of local characteristics.

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