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Socio-spatial inequalities in flood resilience: Rainfall flooding in the city of Arnhem

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ABSTRACT

This paper critically analyses socio-spatial inequalities associated with the shift towards flood resilience in flood risk management (FRM) and pays particular attention to the notion of 'living with floods' and its implications for citizens. Living with floods and the narrative of 'surviving and thriving' are emphasised within flood resilience literature, but such discussions often ignore the varying socio-spatial vulnerabilities and capacities of citizens. This paper undertakes an exploration of potential socio-spatial inequalities for flood resilience in the Dutch city of Arnhem, which has recently experienced rainfall flooding and is actively encouraging citizen action in FRM. The paper follows a mixed-methods approach that combines secondary data sources, semi-structured interviews, and a document analysis. Three forms of socio-spatial inequalities in flood resilience were identified in Arnhem: existing inequalities exacerbated by the shift, 'hidden' inequalities in vulnerability that are now relevant due to rainfall flood risk, and new inequalities in capacity to fulfil the responsibilities arising from the shift to 'living with floods'. The paper contributes to wider discussions on the shift towards flood resilience in FRM and helps city planners to consider the interactions between vulnerability and capacity in their different neighbourhoods when allocating public resources.

1. Introduction

Cities are increasingly being targeted as sites to build disaster resilience with recent international initiatives including the UN Office of Disaster Risk Reduction's 'Making Cities Resilient' campaign, the Rockefeller Foundation's '100 Resilient Cities network' and 'Asian Cities Climate Change Resilience Network', and the annual 'Resilient Cities' global forum on urban resilience and adaptation[1] (100 Resilient Cities, 2019; ICLEI, 2019; The Rockefeller Foundation, 2014; UNDRR, 2019). A pressing disaster risk for cities is rainfall flooding, which is expected to worsen further due to a combination of climate change, urbanisation and urban growth (EASAC, 2018; IPCC, 2014; Rosenzweig et al., 2018). Planners are increasingly acknowledging the risk of rainfall flooding and are aiming to make cities more flood resilient in preparation for potential flood events (Restemeyer, Woltjer, & van den Brink, 2015; Scott, 2013a).

The shift to resilience in flood risk management (FRM) is accompanied by a change in perspective from 'keeping water out' to 'living with floods' and minimising the consequences of flooding (de Bruijn, 2004; Liao, 2012; Scott, 2013a). Furthermore, flood resilience can be understood as a more strategic and holistic approach to FRM that goes beyond state-dominated FRM and towards governance approaches that include non-state actors in FRM (Forrest, Trell, & Woltjer, 2019; Meijerink & Dicke, 2008). The shift towards governance approaches is important as it means that FRM is no longer controlled solely by public authorities and space is in effect made for non-state actors, such as civil society and citizens, to have an increasingly important role in influencing FRM and by extension flood resilience (Forrest, Trell, & Woltjer, 2020; Nye, Tapsell, & Twigger-Ross, 2011).

The perspective change towards 'living with floods' and to an increasingly important role for non-state actors in FRM is resulting in a 'responsibilisation' of citizens in FRM (Begg, 2018; Butler & Pidgeon, 2011; Nye et al., 2011; O'Hare & White, 2018). This narrative requires citizens to 'survive and thrive' in the face of shocks (ARUP, 2014; Pendall, Foster, & Cowell, 2010), such as flood risk, whilst also taking action to manage the risk that they face. However, this requirement for

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[1] Launched by ICLEI – Local Governments for Sustainability, the World Mayors Council on Climate Change and the City of Bonn, Germany in 2010. Supporting 350 cities in 80 countries.

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citizens to 'survive and thrive' is problematic as it ignores the variation in societal characteristics of urban spaces (i.e. the socio-spatial) in how citizens are able to endure floods and manage their own flood risk. Citizens can have differing vulnerabilities and capacities to cope with flood events and to recover after floods as well as their capacity to take FRM actions that help prepare them for future floods and thus pursue flood resilience (O'Hare & White, 2018). These differing capacities are linked to socio-spatial variation and existing inequalities in attributes such as income, education, age, and access to support and services. Ignoring this socio-spatial variation may not provide adequate support to the diverse range of citizens in cities – in essence entrenching and exacerbating existing socio-spatial inequalities. This variation represents a problem for local government: how can they pursue policies for flood resilient cities that take into account the socio-spatial variation of how citizens endure flooding and manage their own flood risk? The inequalities that already exist in society and the allocation of public resources for FRM raise the problem of how planners involved in FRM can identify potential issues of socio-spatial inequalities related to the socio-spatial variations.

This paper engages with the shift in FRM towards flood resilience and explores potential issues of socio-spatial inequality that arise from two key aspects associated with the flood resilience perspective of 'living with floods' and the implied greater role for citizens in FRM: i) the capacity of citizens to endure floods (i.e. socio-spatial vulnerability to floods, also referred to as exposure), and ii) the capacity of citizens to take action (i.e. to manage their flood risk).

Many countries in the world are facing increasing rainfall flood risks and are aiming to pursue strategies to make their cities more flood resilient. The Dutch city of Arnhem is an example of a city that has recently experienced rainfall flooding (van der Ploeg, 2018) and where the local government is attempting to actively engage citizens in preparing for future rainfall flooding (Bruinsma, 2019; Forrest et al., 2020). Arnhem's rainfall-related FRM actions correspond with the aims of the Dutch 'Delta Plan on Spatial Adaptation' to adapt to predicted climate stresses and be more flood resilient (Bruinsma, 2019). This paper explores the potential for flood resilience approaches to lead to socio-spatial inequalities between different city neighbourhoods. The findings are expected to inform planners in the Netherlands and further afield about the relevance of considering and understanding socio-spatial inequalities before allocating their resources for pursuing flood resilience.

2. Understanding flood resilience

2.1. Resilience in FRM

The shift in FRM towards flood resilience necessitates greater analysis of the nebulous concept of 'resilience'. The pursuit of resilience is becoming globally important with the Hyogo Framework for Action 2005–2015 and its successor, the Sendai Framework 2015–2030, emphasising resilience as part of the goal in dealing with disaster risk (UNISDR, 2015). However, the concept of resilience is dynamic, complex and multi-faceted, which makes it difficult to operationalise and implement in practice (Walker & Salt, 2012; Twigger-Ross et al., 2014; Coaffee & Clarke, 2015). The concept has evolved greatly from its "first serious use" in the engineering sciences (Alexander, 2013:2710) before later being built upon and reaching prominence in the environmental sciences through Holling's (1973) research. It has been widely adopted by academics since then and has various meanings across the disciplines of engineering, psychology, environmental sciences and social sciences (Alexander, 2013; Trell, Restemeyer, Bakema, & van Hoven, 2017). Therefore, this paper first interprets the concept of resilience for flooding before exploring potential socio-spatial inequalities associated with it.

In FRM, flood resilience focuses on reducing flood consequences and also speeding up the recovery from flooding (de Bruijn, 2004; Forrest et al., 2019; Restemeyer et al., 2015). This interpretation introduces an acceptance of flooding within FRM and the idea of living with floods (Liao, 2012; Scott, 2013a). It acknowledges that floods cannot always be prevented and that there needs to be an increase in urban "flood-ability" and the city's ability to accommodate flooding (Liao, 2012:5). Following on from this, flood resilience approaches in practice often emphasise pre-flood measures to increase the capacity of urban areas and citizens to cope with and even accommodate flooding whilst minimising flood impacts. These measures include spatial planning approaches (e.g. 'Room for the River' in the Netherlands), flood-proofing new and existing buildings, and modifying the urban environment to accommodate excess water (Aerts et al., 2014; Liao, 2012; Restemeyer et al., 2015).

The shift to flood resilience opens up new roles and interactions for state actors and citizens in FRM. State actors have traditionally led FRM in the European context, but they cannot act alone to minimise flood consequences as this requires changes to the urban environment on both public and private land that need citizen support and cooperation (Trell & van Geet, 2019). Furthermore, state actors are not able to always be present to support recovery immediately after flood events, with citizens often being the first responders (Forrest et al., 2019). Overall, the flood resilience shift implies a greater role for citizens and subtly places additional responsibilities on the shoulders of citizens in FRM (Begg, 2018; Forrest et al., 2019).

2.2. Critiques of flood resilience

The burgeoning focus on flood resilience is not without critiques and concerns, especially with the underlying 'resilience' concept itself. Two relevant critiques to this paper's argument are concerning the associated narrative shift towards that of survival (Anderson, 2015; Pendall et al., 2010) and the tension between resilience interpretations advocating stability or dynamism (Alexander, 2013; White & O'Hare, 2014).

Firstly, resilience has been described as moving away from a narrative of 'stability and safety' towards one where there is a growing range of threats and the focus is on 'surviving and thriving' in the face of shocks (Anderson, 2015; ARUP, 2014; Liao, 2012; Pendall et al., 2010). This perspective implies a greater role for citizens in enduring flooding and preparing for flood events. Self-reliance of citizens is thus seen as highly important and a description of the disaster-afflicted as 'resilient' can be used by the state to avoid responsibility to take action and provide support. Those affected by disasters are pushing back against being labelled as 'resilient' with a call of "stop calling me resilient" (Kaika, 2017:95). This change in narrative has implications for citizens at the centre of these resilience efforts as they possess different levels of vulnerabilities and capacities, with some having higher levels and a better chance of 'surviving and thriving' than others.

Secondly, there is a critique on the interpretation and operationalisation of resilience and whether this then aims to achieve stability or dynamism (Alexander, 2013; White & O'Hare, 2014). This is important to critically consider as it can lead to i) not challenging underlying causes of disaster risk, and ii) rebuilding and maintaining previous inequalities. Resilience interpretations advocating stability, such as 'engineering' and 'narrow' resilience, aim to 'bounce back', which is "past-oriented" and may not address the underlying causes of disaster risk (Coaffee et al., 2018:407; Kaika, 2017; White & O'Hare, 2014). For example, definitions of resilience in practice may refer to the 'maintenance, preservation and restoration' of essential 'functions and structures' when recovering from a disaster event (e.g. ICLEI, 2019). In 'bouncing back' and 'returning to normal', these 'stability' interpretations of resilience can result in rebuilding and maintaining previous inequalities.

Alternatively, resilience can be interpreted as being more dynamic and seeking to challenge the underlying causes of disaster risk by advocating not simply 'bouncing back' but 'bouncing forwards' (Davoudi, 2012; Scott, 2013b; White & O'Hare, 2014). These interpretations of resilience pay more attention to addressing pre-disaster vulnerabilities and to improving societal conditions through incremental adaptation or more radical transformative shifts (Davoudi, 2012; Forrest et al., 2019; Liao, 2012; Twigger-Ross et al., 2014). Ecological interpretations describe external pressures (e.g. from a flood event) causing a system to move towards a new 'normal' and an 'adaptation' that is then maintained until further pressures. Conversely, evolutionary interpretations reject the existence of equilibria and understand cities as inherently unstable systems that are continuously changing as a result of dynamic pressures (Davoudi, 2012; Vale, 2014). This more active latter interpretation recognises that cities are experiencing both internal and external pressures that lead to changes, which result in an unpredictable and chaotic system (Davoudi, 2012). Evolutionary resilience interpretations also recognise that systems, such as cities, can maintain their function whilst reorganising themselves to better match the current conditions (Spaans & Waterhout, 2017) and demonstrate continuous 'adaptability'. These 'bouncing forwards' interpretations offer opportunities to challenge existing inequalities and, through an evolutionary perspective, suggest reorganisation can occur. This reorganisation and embrace of change can allow inequalities to be addressed.

The paper attempts to engage with these critiques by critically examining the different levels of vulnerabilities and capacities of citizens and neighbourhoods to 'survive' as part of the resilience narrative, in particular when it is implemented through FRM practice. The shift towards flood resilience in FRM raises two important issues that can potentially result in socio-spatial inequalities: i) differences in socio-spatial vulnerability and ii) a mismatch between responsibility and capacity.

3. Socio-spatial inequalities and rainfall flood resilience

3.1. Differences in socio-spatial vulnerability

In the context of living with floods, 'differences in socio-spatial vulnerability' describes the varying social characteristics of urban spaces that can affect citizens' ability to endure floods. Previous research identified socio-spatial variations, based upon differences in citizens' spatial surroundings (i.e. place vulnerability) and individual characteristics (i.e. individual sensitivity), that influence how citizens live with floods (e.g. England & Knox, 2016; O'Hare & White, 2018; Sayers, Penning-Rowsell, & Horritt, 2018; Walker & Burningham, 2011).

The physical flood risk that citizens are facing can be enhanced or reduced by changes to the natural and built environment (England & Knox, 2016) and can be understood as the vulnerability of places. For rainfall flooding, the local topography and land use are important determinants of flood risk exposure with sloped, impermeable pavements acting to guide excess rainwater towards lower-lying neighbourhoods. The amount of green/blue space can also be a neighbourhood characteristic that influences place vulnerability (England & Knox, 2016). The neighbourhood buildings, for example housing characteristics, the presence of mobile or temporary structures, and the amount of green space and paved surfaces can also influence the vulnerability of places to floods (England & Knox, 2016; Klimaateffectatlas, 2019; Sayers et al., 2018).

Even though places may have the same flood risk exposure, the sensitivity of inhabitants and their capacity to resist and survive the effects of rainfall flooding will vary within cities. FRM approaches that focus on addressing flood exposure may "unknowingly compound flood disadvantage" (O'Hare & White, 2018:393). Certain groups of people have been identified as having greater social vulnerability and sensitivity to flooding (England & Knox, 2016; Fielding, 2012; O'Hare & White, 2018). For example, the elderly, very young, and those with long-term illness or in receipt of personal care assistance may have greater sensitivity to flooding than others (Houston et al., 2011; Sayers et al., 2018; Tapsell, Penning-Rowsell, Tunstall, & Wilson, 2002).

3.2. Mismatch between responsibility and capacity

The second issue is that 'living with floods' normalises flood risk and encourages citizens to engage in FRM (O'Hare & White, 2018; Scott, 2013a). Citizens are increasingly taking greater responsibility for managing their own flood risk as they become 'flood risk managers' (Butler & Pidgeon, 2011; Forrest, Trell, & Woltjer, 2017; O'Hare & White, 2018). This increase in responsibilities for citizens, and thus obligations around actions for the benefit of society, can be seen with individuals taking out personal flood insurance, mitigating their own flood risk and making their own properties more flood-resistant, and monitoring watercourses and providing updates to authorities in some countries (Begg, Ueberham, Masson, & Kuhlicke, 2017; Butler & Pidgeon, 2011; Forrest et al., 2017; Johnson & Priest, 2008). In some cases this can be seen as a transfer of responsibility from authorities to individual citizens (Begg, 2018). The capacity of individuals to prepare for flooding can be based on factors such as their financial resources to take actions and whether they own their home and are able to make physical changes to it (Thieken, Kreibichm, & Müller, 2007; Twigger-Ross et al., 2014). Furthermore, characteristics such as education levels can influence an individual's ability to access information to prepare for flooding (Twigger-Ross et al., 2014).

In addition to individual citizens increasingly becoming flood risk managers, there is also a growing role being played by collectives of individual citizens in local FRM. These collectives, known as flood groups and community-based initiatives amongst other names (Forrest et al., 2019; Seebauer, Ortner, Babcicky, & Thaler, 2019), are formed of citizens that engage in local FRM. These groups have attempted to target those who are vulnerable or work in neighbourhoods with higher place vulnerability to floods, helped to prepare citizens by raising flood risk awareness, and worked to mobilise citizens (Seebauer et al., 2019; Forrest et al., 2017). Academics have long argued that citizens should have a right to the city and be able to 'make their voice heard' to influence their city spaces (Harvey, 2008) and the involvement of communities has therefore also been described as "essential to addressing disadvantage" and inequalities in FRM (O'Hare & White, 2018:392). Alternatively, these citizen groups represent a cost-cutting opportunity for the local government as they enable the transfer of responsibilities for FRM to unpaid volunteers (Begg, 2018; Forrest et al., 2019). Individuals may be more likely to take FRM action if they have a strong attachment to their neighbourhood, are comfortable with talking to their neighbours, and are in neighbourhoods with strong social networks as well as active citizens (Cheshire, 2015; Mishra, Mazumdar, & Suar, 2010; Twigger-Ross et al., 2014).

3.3. Inequalities and allocation of public resources

The growing role played by citizen collectives has implications for the allocation of public resources in FRM. In climate adaptation/mitigation-related activities, public resources are often allocated to an organised collective (e.g. local renewable energy cooperatives; urban flood groups etc.) as opposed to individuals, which can result in differences between neighbourhoods that 'take the initiative' and act collectively and those that do not have the capacity to organise themselves. Therefore, the allocation of public funds for local FRM via citizen collectives could perpetuate existing inequalities and privilege those more able to take action as opposed to those who are most at need, which could potentially decrease the overall resilience of a city.

State actors play a relevant role in allocating public resources to pursue FRM. However, resource allocation can potentially reduce the resilience of a city and create issues for equity, as the above illustrates, unless authorities identify and engage with resource allocation issues. Equity differs from equality as it does not simply describe the equal distribution of resources, but also analyses the normative dimension of

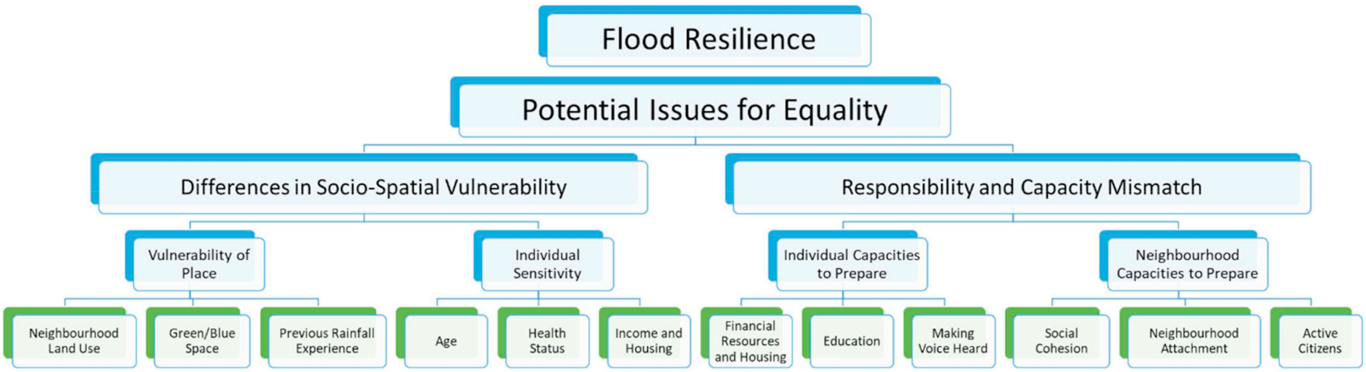

Fig. 1. The potential issues for equality arising from the shift towards flood resilience in FRM (the lowest level shows potential indicators).

this distribution such as "addressing unfair difference" (Wiles & Kobayashi, 2009: 580). This paper understands equality as a descriptive approach to difference, whereas equity is more political and related to policy aims and objectives. It is not always obvious when issues of inequity are present and it is not always the case that inequalities are automatically unjust and inequitable (Davoudi & Brooks, 2012).

3.4. Conceptual framework

Socio-spatial inequalities can potentially be present in the shift to flood resilience in FRM and towards the requirement to 'live with floods'. This shift raises two important issues that can potentially result in socio-spatial inequalities: differences in socio-spatial vulnerability and a mismatch between responsibility and capacity. Indicator categories were generated from the above discussions and are summarised in the conceptual framework (Fig. 1) in order to guide the data collection and analysis for this paper.

4. Research approach

4.1. Arnhem, the Netherlands

The Netherlands is an appropriate country to explore potential socio-spatial inequalities associated with the shift towards flood resilience in FRM. The Netherlands has undertaken a shift towards flood resilience in FRM through their focus on 'spatial adaptation' (e.g. the National Delta Plan on Spatial Adaptation) and on modifying the urban environment to accommodate future high-intensity rainfall events, which can also be seen as step towards increasing the urban area's 'floodability'. Dutch FRM professionals are also now recognising the increasingly urgent threat posed by rainfall flooding (e.g. van Luijtelaar, 2014; Langeveld, Stuurman, Schilling, & Dassen, 2013; H2O, 2016).

Arnhem is selected for this research as the north of the medium-sized Dutch city is at risk of rainfall flooding (Fig. 2) and has experienced intense rainfall events that led to flooding in 2014, 2016 and 2017 (Bouwman, 2017; Gemeente Arnhem, 2015; van Alfen, 2018). Furthermore, the local government is considered to be a 'leading municipality' for undertaking rainfall FRM measures (van der Ploeg, 2018). The city is recognising the new threat posed by rainfall flooding and planners have been taking action to adapt the urban environment areas and 'live with floods'. The city's approach to rainfall FRM was highlighted as a good example of the work done as a result of the national Delta Plan on Spatial Adaptation (Bruinsma, 2019). At the same time, Arnhem has relatively active citizens (Bruinsma, 2019) and there is evidence of citizens taking action to manage their own rainfall flood risk (Arnhem Climate Platform, 2019; Forrest et al., 2020).

4.2. Methodology

This paper followed a mixed-methods approach that utilised both quantitative indicators and qualitative semi-structured interviews in order to identify and explore potential socio-spatial inequalities associated with the shift towards flood resilience in FRM within Arnhem. Quantitative data provides comparable attributes between neighbourhoods, whilst qualitative data allows a 'thick description' and a more in-depth understanding 'on the ground' to be obtained.

The paper identified 16 indicators based on the literature review presented in Section 3 (Table 1) across the main categories of vulnerability of place, individual sensitivity, and the individual and neighbourhood capacities to prepare for flooding (identified in Fig. 1). These indicators were a mixture of census (e.g. percentage of individuals under 4 years old and over 75 years old) and survey data (e.g. involvement in civil society activities) obtained from the Municipality of Arnhem Data Portal and municipality policy documents.

The data for the quantitative indicators were collected at the neighbourhood scale in order to allow comparisons between different parts of the city of Arnhem and were also based upon data availability. Furthermore, the quantitative data were converted through a min-max normalisation to give each neighbourhood a relative score between 0 and 1. This score provides a "relative value in which multiple places can be compared" (Cutter, Ash, & Emrich, 2014:68) and is most appropriate for reaching the paper's aim.

Qualitative data, in the form of 8 semi-structured interviews (Table 2), were collected and analysed to gain a richer picture of the main categories. Interview data was recorded, transcribed verbatim and then coded in ATLAS.ti based upon the four categories identified in the literature (see Fig. 1). Additional themes that appeared in the interview transcripts were also emergently coded. The interviews were conducted with employees responsible for FRM in the Municipality of Arnhem and citizens involved in umbrella organisations for community activities and citizen initiatives, such as Arnhem Climate Platform (Arnhem Klimaatbestendig), Green Arnhem (Groen Arnhem), and Climate Active Neighbourhoods (AAN). These organisations identify and support community activities and citizen initiatives relating to climate change impacts, such as rainfall flooding, in Arnhem. Interviewees were asked about flood risk and the previous rainfall flood experiences of 2014; the current rainfall flood vulnerabilities in neighbourhoods and the use of green/blue space to reduce them (place vulnerability); neighbourhoods at greater risk and the reasons why (individual sensitivity); and the capacity of individuals and neighbourhoods to organise themselves and to take action for FRM (individual and neighbourhood capacities to prepare for flooding).

Furthermore, policy reports and media articles were both identified through web-based searches and provided to the researchers by interviewees throughout the data collection period. Where relevant, analysis of these reports and articles are referenced in the following sections to

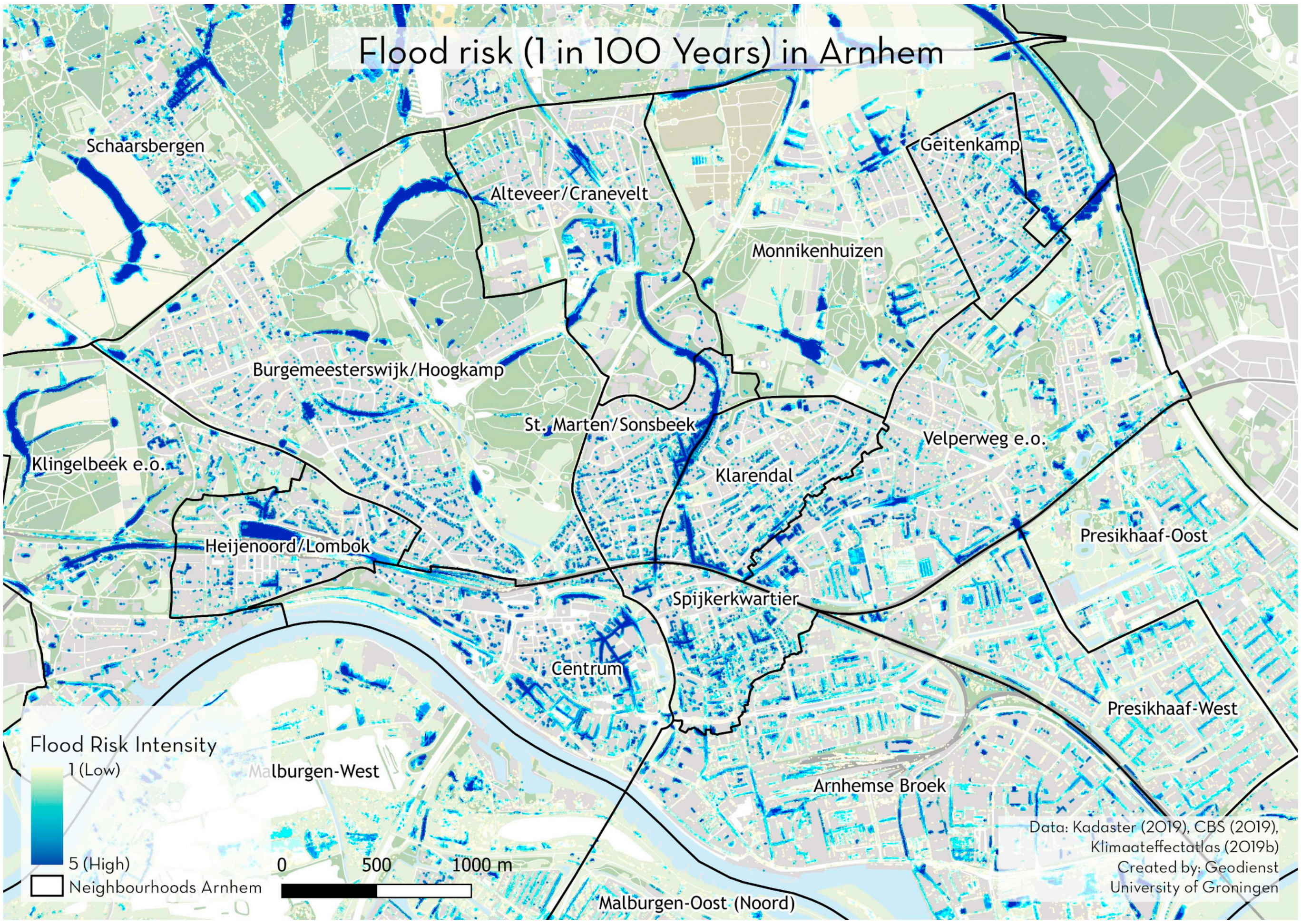

Fig. 2. 1 in 100 rainfall flood risk in Arnhem (Centraal Bureau voor de Statistiek, 2019a; Centraal Bureau voor de Statistiek, 2019b; Kadaster, 2019; Klimaateffectatlas, 2019).

help illustrate and contextualise the current FRM situation in Arnhem.

5. Socio-spatial inequalities in flood resilience

5.1. Place vulnerability

'Place vulnerability' focused on exploring and comparing different factors influencing the vulnerability of neighbourhoods in Arnhem to flooding. The severest rainfall flooding event was in 2014 and led to neighbourhoods in Arnhem North being inundated with rainfall flooding, which caused transport disruption as well as affecting properties (Bruinsma, 2019; Gemeente Arnhem, 2015; van der Ploeg, 2018). Housing characteristics in Arnhem contributed to place vulnerability to flooding. Interviewees reported that those with "koekoek windows" (windows below ground level) or basement areas were at greater risk of rainfall flooding and also flooded in 2014 (Interviewee Municipality Planner). Windows in the basements acted as an entry point for rainwater flows (Interviewee Municipality FRM Policymaker).

The Centrum, Spijkerkwartier, Klarendal, and Schaarsbergen neighbourhoods were most affected by rainfall floods in 2014 (see Appendix 1) with rainwater flowing into homes from paved surfaces and parking areas, sports fields, overflowing sewers, and from higher parts of Arnhem (Gemeente Arnhem, 2014; Fig. 3). Rainwater drains along the natural gradient of Arnhem North from higher-lying neighbourhoods southwards towards the lower-lying neighbourhoods (Fig. 3; e.g. Spijkerkwartier, Velperweg and Klarendal) with roads acting to speed up rainwater flows (Interviewee Climate Active Neighbourhoods).

The physical flood risk was increased in Arnhem North through previous changes to transport infrastructure and the urban environment (Fig. 3). Tunnels were identified as problematic locations where rainwater accumulated and became like 'rivers' (Interviewee Municipality Urban Design; Interviewee Green Arnhem). Furthermore, the presence of the elevated railway tracks directed the rainwater flow through the tunnel into the Spijkerkwartier neighbourhood (Interviewee Municipality Planner). The elevated railway tracks acted as a dike that trapped the water in the Velperweg neighbourhood, but protected the neighbourhood on the other side (Interviewee Municipality FRM Policymaker; Interviewee Municipality Planner). Additionally, culverting of the water drainage channel underneath the railway led to rainwater accumulation in the southern part of the Burgemeesterswijk/Hoogkamp neighbourhood (Interviewee Municipality Planner; Interviewee Climate Active Neighbourhoods).

Neighbourhood typology impacted on place vulnerability to flooding in Arnhem. The narrow streets, cobbled paving, and lack of space for design interventions and greening as a FRM action made the older inner city neighbourhoods (e.g. the Centrum) more vulnerable to the rainfall flooding (Interviewee Climate Active Neighbourhoods; Interviewee Municipality FRM Policymaker; Interviewee Municipality Urban Design). Furthermore, the older areas had mixed sewage systems with pipe capacity shared between sewage water and clean rainwater, which leads to dirty water overflowing when capacity is overwhelmed (Interviewee Municipality FRM Policymaker).

Interviewees reported that the natural greenery of Arnhem was part

Table 1
Indicators used for exploring inequalities in Arnhem (author's own).

Category	Indicator	Data source[a]
Place vulnerability		
Neighbourhood typology[b] and rainfall flooding	Vulnerability of neighbourhood characteristics to rainfall flooding	Semi-structured interviews
Previous experiences	Rainfall flooding experiences of neighbourhoods	Semi-structured interviews; Gemeente Arnhem (2014)
Individual sensitivity		
Age (young and elderly)	% of individuals under 4 years old and above 75 years old	Gemeente Arnhem (2018a)
Health status	% of individuals registered as disabled (those receiving WAO benefits)[c]	Centraal Bureau voor de Statistiek (2018)
Income	% of individuals unemployed (those receiving WW employment benefits)[d]	Centraal Bureau voor de Statistiek (2018)
	% of individuals on low income (in the lowest 20% income bracket)	Centraal Bureau voor de Statistiek (2016)
Housing	% of individuals in renting houses with low value[e]	Gemeente Arnhem (2019)
Individual capacities to prepare for flooding		
Financial resources	% on high income (compared to Arnhem average)	Centraal Bureau voor de Statistiek (2016)
Home ownership	% of individuals owning own home	Gemeente Arnhem (2019)
Educational attainment	% of individuals with medium or high levels of education[f]	Centraal Bureau voor de Statistiek (2017)
Making voice heard	Turnout in political elections[g]	Gemeente Arnhem (2018b)
Neighbourhood capacities to prepare for flooding		
Social cohesion	% Can go to neighbours for help	Semi-structured Interviews; Gemeente Arnhem (2017)
	% individuals will give help to their neighbours	
Neighbourhood Attachment	% individuals believing that they are partly responsible for the neighbourhood	
Active citizens	% individuals active as volunteers	
	Involvement in improving neighbourhood	

[a] The most recent data has been used for each indicator.
[b] Comprising 'Neighbourhood Land Use' and 'Green/Blue Space'.
[c] The number of people who receive an occupational disability (WAO) benefit under the Occupational Disability Insurance Act on January 1.
[d] The number of people receiving WW benefits under the Unemployment Act on January 1.
[e] WOZ-value of less than €150,000 (WOZ refers to the Real Estate Valuation Act).
[f] Medium: l MBO 2, 3 or 4, HAVO, VWO, HBO-propedeuse; High: HBO, WO, postgraduate and PhD.
[g] 2018 City Council elections.

Table 2
Interviewee table.

Interviewee affiliation	Interviewee
Municipality of Arnhem	Interviewee Municipality Planner
Municipality of Arnhem	Interviewee Municipality Flood Risk Management Policy (interviewed twice)
Municipality of Arnhem	Interviewee Municipality Urban Design
Green Arnhem	Interviewee Green Arnhem
Climate Active Neighbourhoods	Interviewee Climate Active Neighbourhoods (interviewed twice)
Arnhem Climate Proof	Interviewee Arnhem Climate Proof

of their FRM strategy to reduce physical flood risk by diverting rainwater flows towards green areas (Interviewee Municipality Planner; Interviewee Green Arnhem; Interviewee Municipality FRM Policymaker). For example, speed bumps were restyled and angled to direct rainwater flows towards green areas in response to the 2014 flood experiences where speed bumps allowed rainwater to accumulate and increased localised flood risk (Interviewee Climate Active Neighbourhoods; Interviewee Municipality FRM Policymaker):

> "*Arnhem is the city of parks…We have to use them as a backup system for these heavy rainfalls*" (Interviewee Municipality FRM Policymaker).

Overall, the data illustrates that the natural environment can increase place vulnerability through its natural topography as well as reduce place vulnerability through the presence of green areas for rainwater storage. The urban environment can increase place vulnerability by restricting possible design solutions in narrower and older inner city neighbourhoods. Furthermore, changes to the urban environment have increased place vulnerability to floods in Arnhem, for example, changes to transport infrastructure (e.g. elevated railway tracks, tunnels, and speed bumps) have enhanced rainfall flood risk.

5.2. Individual sensitivity

'Individual sensitivity' focused on exploring and comparing the factors that influence the extent to which citizens in Arnhem's neighbourhoods are able to live with floods. The quantitative indicators (Table 1) show that the neighbourhoods in Arnhem have different levels of individual sensitivity (Fig. 4; Appendix 2).

Geitenkamp was identified as the neighbourhood with the highest individual sensitivity to rainfall flooding and was identified as being a neighbourhood with high unemployment, low levels of education, and poorer diets (Interviewee Municipality FRM Policymaker). Arnhemse Broek, Presikhaaf West and Klarendal are three of the four neighbourhoods in Arnhem that were identified in the list of 40 problem neighbourhoods ('De 40 wijken van Vogelaar') by the Dutch Government in 2007 and associated with social problems and high unemployment (Interviewee Municipality FRM Policymaker). Interviewees also revealed that there were attempts to improve the Klarendal neighbourhood through urban development to remove 'undesirable' businesses and to promote the neighbourhood as a fashion centre (Interviewee Municipality FRM Policymaker; Interviewee Climate Active Neighbourhoods).

On the other hand, Burgemeesterswijk/Hoogkamp had the lowest score for individual sensitivity to flooding. This neighbourhood is a relatively prosperous neighbourhood with low levels of unemployment, and a low proportion of citizens receiving disability support, being on a low income or renting housing in low housing value brackets. The neighbourhoods with the lowest scores for individual sensitivity to flooding also had the lowest proportions of unemployment, low proportions of citizens in the lowest 20% of income bracket and for citizens renting housing in the lowest two housing value brackets.

Overall, the data illustrate variations in individual sensitivity to flooding across the neighbourhoods in Arnhem.

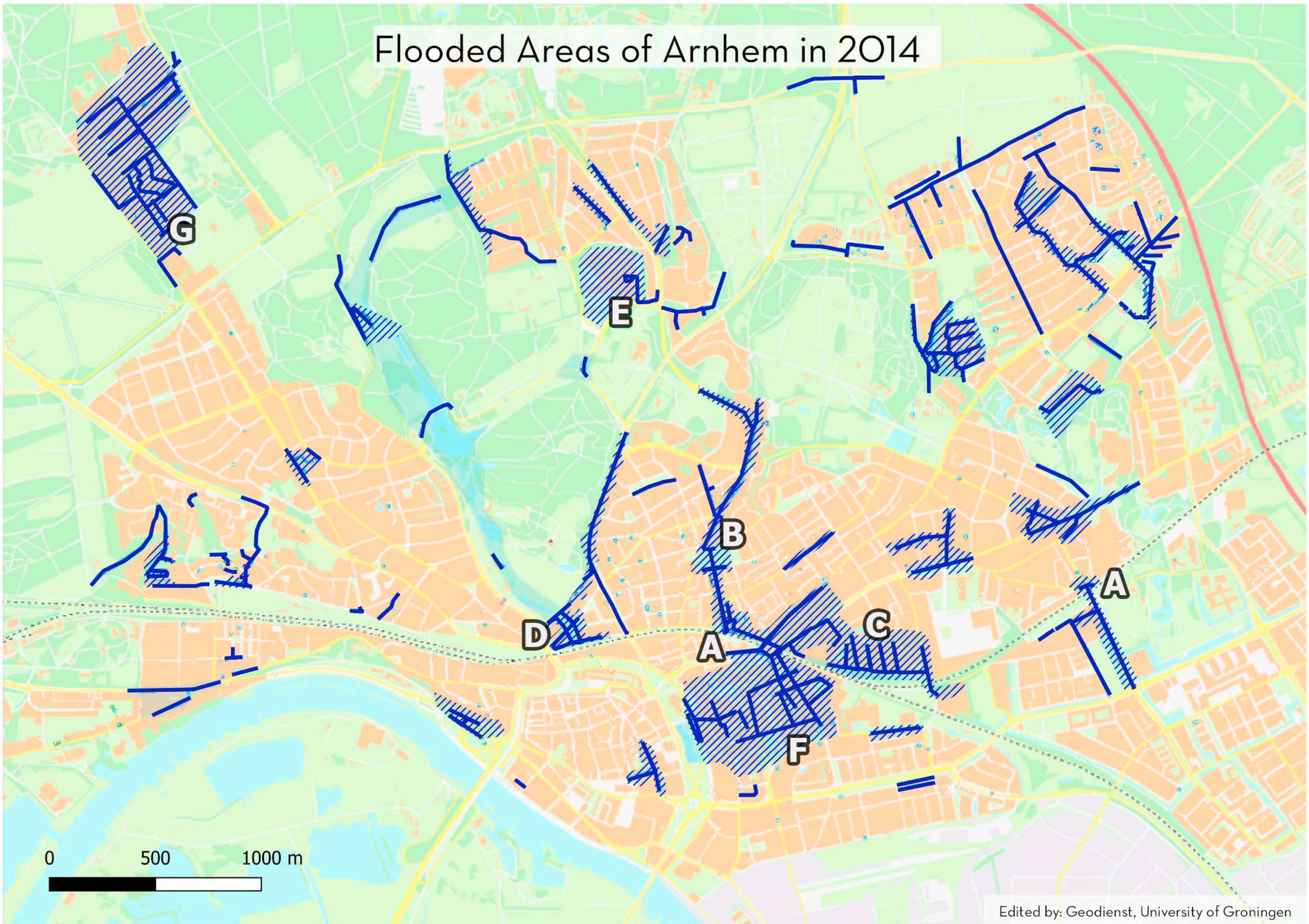

Fig. 3. Map showing flooded areas (dark blue) of Arnhem in 2014 (original source: Gemeente Arnhem, 2014) A: flooded tunnels; B: north-south rainwater flow; C: elevated railway track; D: culverted water drainage channel; E: flooded hospital; F: Spijkerkwartier flooded extensively; G: Schaarsbergen flooded extensively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

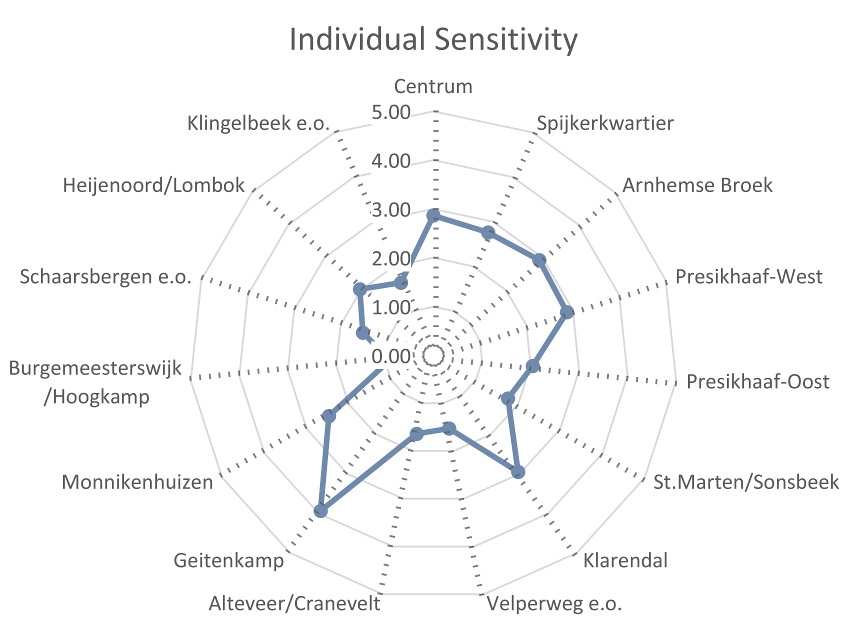

Fig. 4. Radar Graph showing the cumulative score (out of 5) for the indicators of 'individual sensitivity' of Arnhem North's neighbourhood.

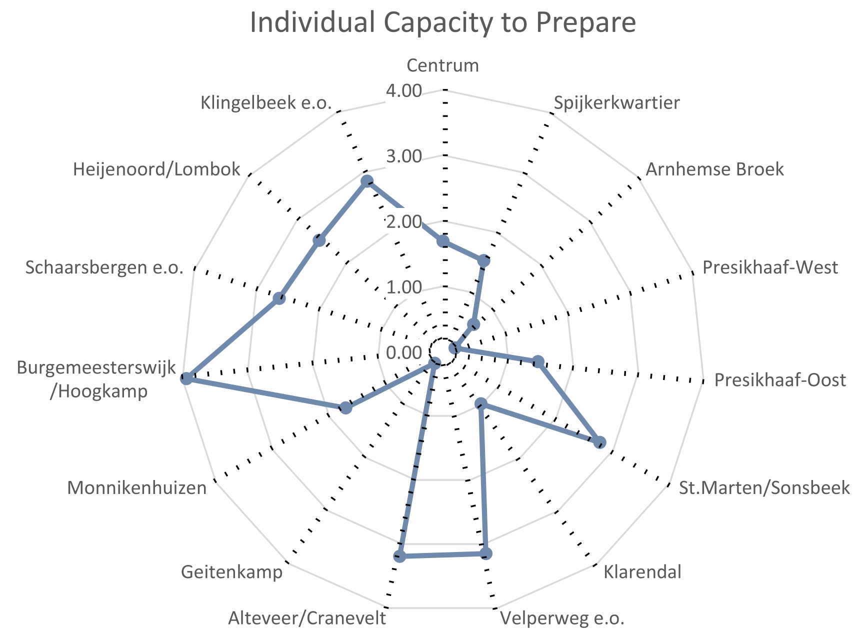

Fig. 5. Radar Graph showing the cumulative score (out of 4) for the indicators of 'individual capacity to prepare' for Arnhem North's neighbourhood.

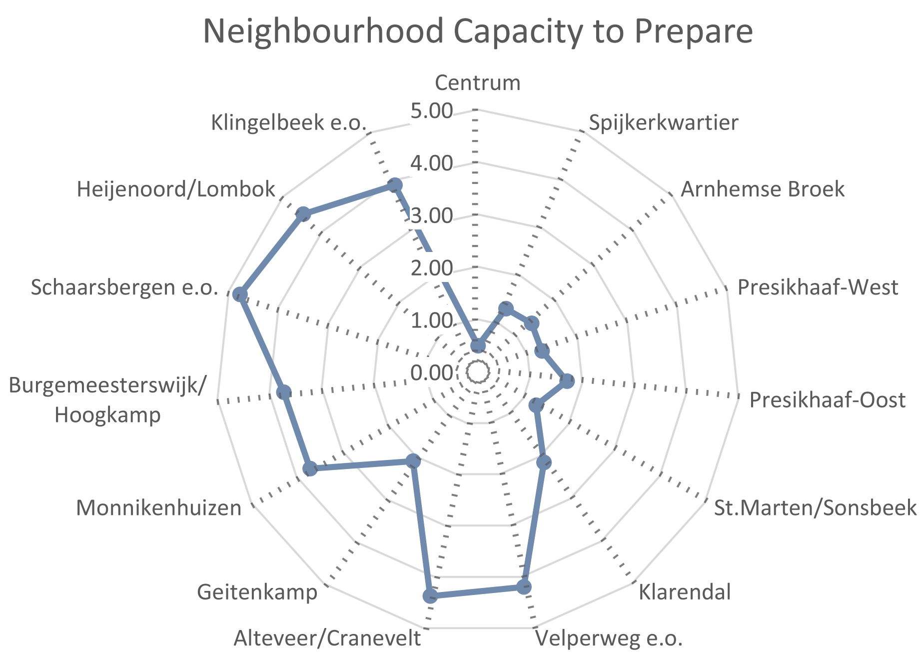

Fig. 6. Radar Graph showing the cumulative score (out of 5) for the indicators of 'neighbourhood capacity to prepare' for Arnhem North's neighbourhood.

5.3. Individual capacity to prepare for flooding

'Individual capacity to prepare for flooding' focused on exploring and comparing the factors that influence the extent to which citizens in Arnhem's neighbourhoods are able to individually prepare for rainfall floods. The quantitative indicators (Table 1) show that the neighbourhoods in Arnhem have different levels of individual capacity to prepare for flooding (Fig. 5; Appendix 3).

The Burgermeesterswijk/Hoogkamp neighbourhood scored highly in terms of individual capacity to prepare for flooding with high proportions of citizens owning their own home, having high educational attainment, being in the top 40% income bracket, and having a high turnout in the City Council elections. On the other hand, Presikhaaf-West and Geitenkamp neighbourhoods had comparably low individual capacities to prepare for flooding.

Educational attainment relates to the knowledge that individuals have, which does not necessarily have to be FRM-related knowledge, in order for them to take FRM-related actions. Interviewees often related education levels of citizens to their capacity to take action (Interviewee Green Arnhem). The high and moderate scoring neighbourhoods generally had high educational attainment, although Schaarsbergen had relatively lower levels compared to these neighbourhoods.

The Spijkerkwartier and Centrum had high levels of educational attainment, but low levels of home ownership (perhaps due to their location near the city centre) and a low proportion of citizens in the top 40% income bracket. Higher home ownership shows the capacity to have financial resources to afford a house and capacity to modify the property in preparation for rainfall floods. Interviewees reported that citizens not owning their own home were reluctant and even unwilling to take FRM actions, such as installing green roofs and rain barrels

(Interviewee Municipality FRM Policy; Interviewee Climate Active Neighbourhoods). This is because they were unsure about whether they were allowed to do this and, in some cases, afraid of whether the landlords (or housing companies) will charge them money to 'repair' and return the home to normal when they leave. Whilst it was not found in this research, low home ownership could also be beneficial for this indicator as a high proportion of social housing could be better 'for taking action' as individual property measures can be coordinated and undertaken together at the same time.

5.4. Neighbourhood capacity to prepare for flooding

'Neighbourhood capacity to prepare for flooding' focused on exploring and comparing the collective neighbourhood capacities that can support FRM actions (Fig. 6; Appendix 4).

The Schaarsbergen neighbourhood scored highly for neighbourhood capacity to prepare for flooding with a high proportion of citizens active as volunteers, active for neighbourhood development, believing that they are partly responsible for the neighbourhood, and that say they can go to neighbours for help or will give help to their neighbour. On the other hand, the Centrum neighbourhood had the lowest score for neighbourhood capacity to prepare for flooding with low proportions active as volunteers or in neighbourhood development, believing that they are partly responsible for the neighbourhood, and that say they can go to neighbours for help or will give help to their neighbour.

Certain neighbourhoods (e.g. Schaarsbergen) had citizen initiatives active in greening their local area, thus indirectly contributing to pluvial FRM. There were also citizen initiatives focusing specifically on rainfall FRM. These included initiatives such as installing rain barrels in Velperweg and St Martins/Sonnbeek neighbourhoods, a green roof initiative in the Velperweg neighbourhood, greening of parking areas in the Heijenoord/Lombok neighbourhood, the climate cafes and climate carousels in the Klingelbeek neighbourhood, and gathering residents' views in preparation for interacting with local government in Velperweg and Spijkerkwartier neighbourhoods. These initiatives were based on neighbours working together to take FRM-related actions and can be related to attachment of neighbourhood (Interviewee Climate Active Neighbourhoods):

> "*I think it's because they feel involved with their own environment and their own neighbourhood – I think that's the most important reason they do it*" (Interviewee Green Arnhem).

The capacity of a neighbourhood to take action can be strengthened through the presence of local leaders who can take a leadership role and provide direction to the community (Forrest et al., 2017; Seebauer et al., 2019) with Olsson et al. (2006:1) labelling leadership and shadow networks (i.e. citizen initiatives in this case) as 'critical' for preparing "a system for change". The presence of leaders was reported as being important in the citizen initiatives identified (Interviewee Arnhem Climate Proof). The leaders possessed FRM and related topic expertise in urban planning and landscape architecture (Interviewee Climate Active Neighbourhoods). The participants, especially in the rain barrel scheme, green roof initiative, climate cafes, and climate carousels had an awareness of the issues at hand (i.e. rainfall flooding and climate change adaptation), the time to engage in the topic, and the financial resources to participate. However, the reliance on a few individuals for leadership and expertise can threaten the longevity of these citizen initiatives:

> "*A lot of times, there are a few people who are doing all the work and if one falls out or there is some fallout, then your initiative is very vulnerable so I think that's the problem*" (Interviewee Green Arnhem).

Overall, the data shows variations in neighbourhood abilities to prepare with attachment to neighbourhood and presence of citizen initiatives identified in quantitative and qualitative data. Furthermore, the presence of leadership and skills in neighbourhoods emerged from the semi-structured interviews.

5.5. Overlapping vulnerabilities and capacities

The four categories allowed comparisons between the unequal distribution of socio-spatial vulnerabilities and mismatch between responsibility and capacity for citizens in 'living with floods' in different neighbourhoods in Arnhem. Trends can be identified in terms of the relative position of where neighbourhoods were consistently scoring (Appendices 2, 3, and 4) and this becomes a problem when neighbourhoods have low scores in multiple categories that can then overlap.

The data reveals that certain neighbourhoods (e.g. Spijkerkwartier) had both high place vulnerability and high individual sensitivity suggesting that they will be strongly affected by rainfall flooding. On the other hand, the data also shows other neighbourhoods (e.g. Velperweg) had high place vulnerability, but also low individual sensitivity to floods suggesting that citizens here would be better able to 'survive' and live with floods. High individual sensitivity to flooding is not necessarily disadvantageous if the neighbourhood also has low place vulnerability to rainfall floods (e.g. Presikhaaf-Oost).

There is potentially a mismatch between the greater responsibility given to citizens and the capacity of citizens individually and collectively to live with floods in their neighbourhoods. The data reveals that certain neighbourhoods (e.g. Burgemeesterswijk/Hoogkamp) had both high individual and neighbourhood capacity to prepare for rainfall floods. Citizens in these neighbourhoods may therefore be able to accept the additional responsibilities given to them in the shift to flood resilience in terms of managing their own flood risk and 'living with floods'. On the other hand, other neighbourhoods (e.g. the Centrum and Arnhemse Broek) had both low individual and neighbourhood capacity to prepare for rainfall floods. These neighbourhoods may find it more difficult to 'survive' and prepare themselves and work with their fellow citizens to live with floods.

6. Navigating the inequalities in Arnhem

6.1. Forms of socio-spatial inequalities in flood resilience in Arnhem

The research findings show that the potential socio-spatial inequalities in Arnhem can be understood as i) existing socio-spatial inequalities that could be exacerbated by the shift, ii) 'hidden' socio-spatial inequalities in vulnerability that have become relevant due to the rainfall flood risk, and iii) new socio-spatial inequalities in capacity to fulfil the responsibilities arising from the shift to living with floods.

Firstly, the research identified existing inequalities that were exacerbated by the shift towards living with floods relating to the differences in socio-spatial vulnerability and capacities between neighbourhoods. In Arnhem, neighbourhoods with a lower socio-economic status (i.e. low income, low home ownership, and high unemployment) were also less able to individually and collectively prepare for floods. In this way, increasing flood risk can also reinforce existing inequalities and represent a "double risk burden" (Fielding, 2012:492).

Secondly, 'hidden' inequalities that previously existed (but did not have any impact) were shown to become relevant due to the increasing rainfall flood risk. Rainfall flood experiences and the production of rainfall flood risk maps can bring to light risk inequalities that were previously not regarded as such. For example, the data shows that properties that are at the top of the hill and on sandy soils would logically have a lower risk of rainfall flooding than those at the bottom of the hill. These inequalities in topography have always existed, but only through the recent rainfall flood risk have they become relevant. Furthermore, changes to transport infrastructure over time (e.g. railways track elevation, tunnel creation, and speed bump installation) have also created 'hidden' inequalities in place vulnerability that have been exposed through recent rainfall floods in Arnhem.

Thirdly, new socio-spatial inequalities are arising in the capacity of citizens to shoulder the new responsibilities associated with this shift to flood resilience. It is not only the varying capacities of citizens to survive flooding and to prepare for flooding in Arnhem, but also the capacity of citizens to fulfil these new responsibilities. Potential mismatches between socio-spatial vulnerability and the capacities to take action can mean that neighbourhoods have high socio-spatial vulnerability, but low capacity to take action. In these neighbourhoods, it may be harder for citizens to fulfil their responsibilities to 'live with floods'. This can lead to inequalities between those who can fulfil the responsibilities to 'live with floods' and those who have trouble to 'survive and thrive' in this shift towards flood resilience.

6.2. Planners and potential resource allocation issues in Arnhem

City planners have a role in allocating public resources to living with floods and FRM in the form of funding as well as their knowledge and expertise. Potential issues of resource allocation are not only limited to the actions of city planners with the data suggesting that the actions of citizen collectives need to be considered in resource allocation. These issues of resource allocation are now explored based on the three forms of socio-spatial inequalities identified for flood resilience in Arnhem.

Firstly, the research identified existing socio-spatial inequalities that were exacerbated by the shift. There were attempts by city planners to address existing inequalities, for example the urban renewal of Klarendal as a fashion area. City planners also recognised the existing socio-spatial inequalities in Geitenkamp and explored opportunities to improve people's lives in addition to undertaking FRM actions. A partnership was formed between the municipality, housing associations, a local education centre and a health insurance company in order to support the neighbourhood. There was also an emphasis on employing local businesses in implementing FRM measures in order to keep public funding in the local area:

> "*There is a landscape bureau over there. So, they can do the drawings. And they can also design the streets, the green parts of it. And maybe there is also a small gardener over there who can deal with the planting. So it's not a big enterprise that does it, but a small one, and they get paid for it. So the money stays in the area*" – Interviewee Municipality FRM Policymaker.

Existing inequalities need addressing in flood resilience, as Vale (2014:192) argues, "resilience can only remain useful as a concept and as progressive practice if it is explicitly associated with the need to improve the life prospects of disadvantaged groups". Therefore, planners engaged in FRM should also focus on capacity building to reduce existing inequalities alongside traditional FRM measures. This will require FRM planners to break through silos and collaborate with new partners, but also for other planners to recognise the connections between their policies and FRM in order to identify potential opportunities (e.g. through urban regeneration) that can both increase capacities and reduce place vulnerability.

The data showed that certain neighbourhoods in Arnhem had high place vulnerability and relatively high numbers of citizen initiatives that were able to mobilise themselves and attempt to influence their local milieu. However, other neighbourhoods with high place vulnerability were not showing signs of citizen initiatives. Citizen initiatives are able to mobilise local capacities as well as organise themselves to influence FRM decision-making and how FRM resources are allocated. It could therefore be that the uneven presence of citizen initiatives in neighbourhoods is exacerbating existing inequalities: enabling neighbourhoods with relatively higher capacities to take action and influence local FRM, whilst neighbourhoods with relatively lower capacities are less able to take action and influence local FRM. Therefore, FRM planners need to assess the potential impacts of citizen initiatives on existing capacities and vulnerabilities when allocating resources.

Secondly, the research identified 'hidden' socio-spatial inequalities in vulnerability that have become relevant due to the rainfall flood risk. There were attempts by city planners to reduce the problems caused by topography and changes to transport infrastructure. For example, city planners are angling and restyling speed bumps to limit rainwater accumulation. The 'hidden' inequalities arising from topography and changes to transport infrastructure, both of which increase place vulnerability to rainfall floods, appeared to have activated citizen collectives to manage their own flood risk. These collectives responded to these previously hidden inequalities with activities that included trying to reduce place vulnerability through installing rain barrels and green roofs as well as advocating for changes to the urban environment. In this sense, both city planners and citizen initiatives have a role in actively identifying, challenging and attempting to address 'hidden' socio-spatial inequalities.

Thirdly, the research identified new socio-spatial inequalities in the capacity of citizens to fulfil the responsibilities arising from the shift to living with floods. There was evidence that city planners were prioritising neighbourhood areas for FRM actions based on their flood experiences in 2014 and the condition of their sewerage systems. The research did not find evidence that the capacities of citizens to live with floods were considered in prioritising neighbourhoods. This lack of consideration could lead to citizens being unable to fulfil their new responsibilities to live with floods, but this may only be realised during the next flood event. Therefore, there is a need for city planners to also assess citizen capacities when prioritising neighbourhoods for FRM actions.

Overall, the shift towards a resilience narrative of 'surviving and thriving' places greater attention on the role of city planners and the allocation of public resources. Planners need to consider which neighbourhoods are most affected by rainfall flooding (i.e. socio-spatial vulnerability) and least able to take action (i.e. individual and neighbourhood capacity) in order to identify those that most need their support. A recommendation from this paper is that city planners should prioritise and allocate public resources (e.g. time and energy of their employees) to capacity building and vulnerability reduction in these neighbourhoods. A second recommendation is that city planners focusing on FRM have to collaborate with other planners, break down silos with other authority departments, and collaborate with citizen initiatives as part of attempts to address the potential socio-spatial inequalities that can arise from the shift towards living with floods. The four categories that this paper proposes, with some adaptations and tailoring to each specific city context, could be valuable for city planners navigating these inequalities by helping to identify and prioritise neighbourhoods that most need support.

6.3. Interpretations of flood resilience

The interpretation of flood resilience and whether it aims to achieve stability or dynamism (Alexander, 2013; White & O'Hare, 2014) can have implications for these socio-spatial inequalities. If planners choose an 'engineering' or 'narrow' interpretation of flood resilience that advocates stability and 'bouncing back' then they are choosing a past-oriented, business as usual approach. This could mean rebuilding flood damage and maintaining the status quo, which would ignore and potentially exacerbate existing and hidden socio-spatial inequalities. The Municipality of Arnhem's response to the 2014 floods was an acknowledgement of the need to 'live with floods', but very little (if any) new money was allocated to FRM and therefore it became mainly a 'make-do' attitude:

> "*We will try to solve the biggest issues but for sure there is always a risk and you have to live with it*" (Interviewee Municipality FRM Policymaker).

In Arnhem, there was also evidence of ecological interpretations of flood resilience that include dynamic responses that can lead to stability (a new equilibrium) until the next shock necessitates another dynamic response. This interpretation can be understood as 'adaptation' and saw the municipality attempting to pursue an aim of 'bouncing forwards' in rainfall FRM in response to the 2014 rainfall floods. For example, restyling speed bumps to divert rainwater towards green areas. These approaches can try to address previously 'hidden' socio-spatial inequalities relating to topography and changes in transport infrastructure.

There was some evidence of evolutionary interpretations of flood resilience, which recognise the continuously changing nature of the city and attempts to move towards 'adaptability' (as opposed to 'adaptation'). This 'adaptability' can be seen by the emergence of citizen initiatives in Arnhem that relate directly or indirectly to rainfall FRM. These initiatives emerged in response to local needs and their actions, in either supplementing local government actions or undertaking new actions that local government could not do, as new FRM actors. In this sense, these initiatives are part of a reorganising of the local FRM landscape whereby citizens are gaining responsibilities and becoming more able to manage their own flood risk and 'live with floods'. In doing so, citizens are receiving additional responsibilities, but those who are able to take action are building their own capacity to be flexible and adaptable.

6.4. From inequalities to inequities in pursuing flood resilience

The presence of inequalities does not necessarily result in inequities, which have a greater focus on the normative dimension of distribution (Davoudi & Brooks, 2012; Wiles & Kobayashi, 2009). The indicator-based model shows that the interactions between vulnerabilities and capacities can lead to potentially inequitable outcomes.

Hidden inequalities were found to be strongly related to interest and use of space. For example, the elevated railway track increased place vulnerability for one neighbourhood, but acted as a dike and protected the neighbourhood on the other side of the track, which had a relatively higher sensitivity to rainfall flooding. This means that whilst the elevated railway track was a form of hidden inequality, it may not have been a case of inequity when considering the benefits to the more sensitive neighbourhood that was protected. Furthermore, the elevated railway track benefitted commuters as the train network was unaffected by the flooding and continued to operate as normal. Therefore, there is a need to balance different societal interests and neighbourhood differences in making a decision on how to respond to these hidden inequalities within a city context. There is also a spatial connection between flood risk-enhancers in higher-lying neighbourhoods with tiled and impermeable surfaces and lower-lying neighbourhoods that are affected by additional rainwater and experience floods.

In Arnhem, there was a mismatch between citizens' responsibility to live with floods and their capacity to take action. This could be an issue of equity as not all citizens have the same conditions to 'survive and thrive' despite this being asked of them. The issue of equity is further complicated by the unequal presence of citizen initiatives that can help certain citizens and neighbourhoods to better live with floods, but are absent in other neighbourhoods that may have relatively high vulnerabilities or low capacities. In order to pursue more equitable flood resilience, city planners need to assess and account for neighbourhoods' socio-spatial vulnerability and capacity to meet the additional responsibilities for living with floods. However, there may be difficulties in ensuring that this is achieved in current planning practice, where there is no obligation to consider socio-spatial vulnerability and capacity as part of FRM plans and policies. Therefore, an obligation for authorities to identify, report and consider socio-spatial vulnerability and capacity should be made into a formal requirement for city FRM plans and policies. This policy recommendation would not only result in authorities being more transparent about their considerations of socio-spatial variation, but also make them more accountable for decisions that ignore those unable to live with floods. The increased transparency and accountability could also encourage policymakers and city planners to take pre-emptive action to identify and support citizens with high socio-spatial vulnerability and low capacity to live with floods. However, this is not the 'silver bullet' that can solve socio-spatial inequalities and, if used within a context of state retreat, could lead to authorities shifting FRM responsibilities to civil society actors.

7. Conclusions

Rainfall flooding is a pressing disaster risk and a clear urban policy concern that is becoming increasingly urgent. FRM policy is increasingly turning towards flood resilience-based perspectives of 'living with floods' and an implied greater role for citizens in FRM. This paper focused on two critiques of flood resilience concerning the narrative shift towards survival (Anderson, 2015; Pendall et al., 2010) and the tension between advocating stability or dynamism (Alexander, 2013; White & O'Hare, 2014). The narrative of 'survive and thrive' associated with resilience (Anderson, 2015; ARUP, 2014; Pendall et al., 2010) means that there needs to be greater scrutiny and consideration of the different vulnerabilities and capacities that citizens have (individually and as a result of their neighbourhood) to 'survive and thrive'. Previous research has found a need to consider that not all citizens are affected by flooding in the same way nor do they have the same capacity to be flood resilient (O'Hare & White, 2018). This paper contributed to these discussions on resilience and inequalities by exploring potential issues of socio-spatial inequality that arise from the shift towards flood resilience and the implied greater role for citizens in the Dutch city of Arnhem. Three forms of socio-spatial inequalities were identified: existing inequalities that can be exacerbated, 'hidden' inequalities that can become relevant, and new inequalities that can be created in the shift towards 'living with floods'.

This paper has takeaways for policy and practice at both the city and international levels. At the city level, the research findings emphasise that city planners need to critically reflect on their pursuit of flood resilience and 'living with floods' by taking issues of socio-spatial inequality into account in their planning process. The first recommendation is that there should be a formal requirement for city planners to analyse and report inequalities around vulnerabilities and capacities, and for planners to have to consider these in their FRM policies and plans. Neighbourhoods with high vulnerability and low capacity should then be prioritised with public resources allocated to reduce vulnerabilities and to build the capacities of individuals and neighbourhoods. The greater emphasis on FRM planners to focus more on vulnerability reduction and capacity building can contribute to making citizens more adaptable in the face of increasing flood risk. Furthermore, a second recommendation is that FRM planners also need to identify and attempt to address existing and hidden inequalities by working with other planners, authority departments, and citizen initiatives. This means breaking through silos and collaborating with housing associations, educational centres and health organisations (and other actors) on FRM as done in Arnhem. As part of this, there is also a need for planners and policymakers in other fields, and with different responsibilities, to also recognise and understand that their policy choices can also impact citizens' abilities to live with floods and can contribute to the socio-spatial inequalities identified in this paper.

Furthermore, the greater citizen role in flood resilience draws attention to the issue of varying vulnerabilities and capacities associated with 'living with floods' and the need to account for them when allocating resources in flood resilience policies. The involvement of communities has been described as "essential to addressing disadvantage" in FRM (O'Hare & White, 2018:392), but supporting citizen collectives with public resources can advantage the already advantaged if there is no assessment of whether these collectives are formed by those that are already more able to live with floods. Therefore, identifying and providing resources to existing citizen collectives in neighbourhoods that have high vulnerability and low capacity to act could be a good way to allocate public resources and enable public policy to support those who are most at risk from flooding. A third policy recommendation is for cities making flood resilience strategies and allocating public resources: it is important to recognise and consider citizen initiatives when taking a strategic city-based perspective and balancing the socio-spatial vulnerabilities within and between neighbourhoods and with different city users (e.g. commuters). In doing so, city resilience strategies can seek to challenge socio-spatial inequalities and not entrench them.

Furthermore, the categories identified in this paper are a helpful starting point for helping cities across the world to identify and raise awareness about socio-spatial inequalities ‘hidden’ in flood resilience strategies, but they should be further modified to account for place-specific characteristics such as informal settlements, urban natural areas and greenery, and cultural identities. For example, cities with informal settlements should include specific indicators for these in their categories as they may have implications for vulnerabilities (e.g. housing and health) and capacities (e.g. social capital and networks).

The paper also has takeaways for policy and practice at the international level. Cities across the world are facing increasing rainfall flood risks and are being encouraged by international initiatives to pursue strategies to increase their resilience to disasters (e.g. flood resilience). These international initiatives encouraging the pursuit of disaster resilience need to understand, identify and engage with the potential socio-spatial inequalities identified in this paper in order to help challenge the underlying contributors to flood damages and lead to more dynamic flood resilience interpretations that also improve societal conditions.

Overall, this paper provides a basis for the further exploration of socio-spatial inequalities of flood resilience and living with floods. The interactions of socio-spatial vulnerability and the mismatch of responsibility and capacity provides new insights into the difficulties associated with ‘flood resilience’ and the need to be critical of potential city flood resilience narratives in practice that emphasise ‘surviving and thriving’ whilst ignoring the variation in socio-spatial characteristics of neighbourhoods within their cities.

Declaration of competing interest

None

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Credit author statement

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Appendix 1. Extent of 2014 rainfall flooding in Arnhem

	Rainfall flood category					
Neighbourhood	**I**	**II**	**III**	**IV**	**V**	**VI**
Spijkerkwartier	*	*	*	*		
Centrum	*	*	*		*	
Klarendal	*	*		*	*	
Schaarsbergen e.o.	*	*				
Velperweg e.o.		*	*	*	*	*
Burgemeesterswijk/Hoogkamp		*	*	*	*	*
Arnhemse Broek		*		*	*	*
Geitenkamp		*		*	*	
Monnikenhuizen		*		*	*	
Heijenoord/Lombok		*		*	*	
Klingelbeek e.o.		*		*		
Presikhaaf-West			*			
St.Marten/Sonsbeek			*			
Alteveer/Cranevelt			*			
Presikhaaf-Oost						

Rainfall flooding in 2014 was categorised into four types by the Municipality of Arnhem: **I.** Rainwater that flows into the houses from the sewer; **II.** Rainwater that flows into the private area from the public road (and sometimes flows into homes); **III.** Rainwater that remains on main access roads for a long time; **IV**. Rainwater that remains on district access roads for a long time; **V.** Rainwater that remains on other roads for a long time; **VI.** Inundation from surface water. (Source: Gemeente Arnhem, 2014).

Appendix 2. Quantitative data for individual sensitivity

	Individual sensitivity (1 most sensitive)										
Neighbourhood	**Ranking for individual sensitivity**	Age (2019) (% under 4, over 75)	Age *	Disability (WAO) (2018) (%)	Disability (WAO)*	Unemployment (2018 WW applicants as % of population)	Unemployment (WW)*	Low income (2016) (%)	Low income *	Rental housing in low WOZ homes (2019) (%)	Rental housing in low WOZ homes*
Burgemeesterswijk/ Hoogkamp	**1**	10.86	0.42	2.21	0.00	1.69	0.25	15.00	0.09	7.76	0.13
Velperweg e.o.	**2**	14.73	0.66	3.33	0.09	1.72	0.28	18.00	0.18	16.14	0.28
Schaarsbergen e.o.	**3**	9.52	0.33	14.77	1.00	1.38	0.00	18.00	0.18	1.33	0.00
Alteveer/Cranevelt	**4**	18.33	0.89	2.62	0.03	1.75	0.30	18.00	0.18	12.28	0.21
Klingelbeek e.o.	**5**	20.06	1.00	9.82	0.61	1.40	0.02	12.00	0.00	1.10	0.00
St.Marten/Sonsbeek	**6**	6.36	0.14	3.77	0.12	2.40	0.85	25.00	0.39	12.81	0.22
Heijenoord/Lombok	**7**	8.67	0.28	4.00	0.14	2.50	0.93	22.00	0.30	17.26	0.30
Presikhaaf-Oost	**8**	13.45	0.58	4.86	0.21	1.53	0.12	26.00	0.42	37.63	0.69
Monnikenhuizen	**9**	16.61	0.78	4.93	0.22	2.35	0.81	24.00	0.36	21.05	0.38
Spijkerkwartier	**10**	4.22	0.00	5.46	0.26	2.28	0.75	43.00	0.94	43.32	0.80
Arnhemse Broek	**11**	6.49	0.14	8.28	0.48	2.03	0.54	43.00	0.94	38.55	0.71
Klarendal	**12**	6.66	0.15	8.07	0.47	2.29	0.75	41.00	0.88	35.14	0.64
Centrum	**13**	5.08	0.05	6.75	0.36	2.25	0.72	42.00	0.91	46.90	0.86
Presikhaaf-West	**14**	12.27	0.51	6.45	0.34	1.98	0.50	38.00	0.79	44.55	0.82
Geitenkamp	**15**	9.43	0.33	9.81	0.61	2.58	1.00	45.00	1.00	54.13	1.00

Quantitative data for neighbourhoods with the lowest (green) and highest (blue) individual sensitivity to rainfall flooding *min-max normalised values.

Appendix 3. Quantitative data for individual capacity

	Individual capacity (1 most capable)								
Neighbourhood	**Ranking for individual capacity**	Owning home (2019) (%)	Owning home*	Educational attainment (2017) (%)	Educational attainment*	High Income (top 40%) (2016) (%)	High income (top 40%)*	Turnout city elections (2018) (%)	Turnout city elections *
Burgemeesterswijk/ Hoogkamp	**1**	72.24	1.00	87.00	0.94	54.00	1.00	73.50	1.00
Alteveer/Cranevelt	**2**	52.05	0.67	84.00	0.86	45.00	0.74	70.60	0.92
Velperweg e.o.	**3**	59.41	0.79	82.00	0.81	49.00	0.86	62.30	0.69
Klingelbeek e.o.	**4**	52.75	0.68	78.00	0.69	54.00	1.00	54.50	0.48
St.Marten/Sonsbeek	**5**	51.25	0.66	89.00	1.00	38.00	0.54	57.70	0.57
Schaarsbergen e.o.	**6**	66.67	0.91	72.00	0.53	49.00	0.86	49.30	0.34
Heijenoord/Lombok	**7**	56.85	0.75	84.00	0.86	39.00	0.57	50.40	0.37
Monnikenhuizen	**8**	37.28	0.43	70.00	0.47	36.00	0.49	49.10	0.33
Centrum	**9**	20.22	0.15	85.00	0.89	24.00	0.14	55.50	0.51
Spijkerkwartier	**10**	27.60	0.27	82.00	0.81	24.00	0.14	48.10	0.30
Presikhaaf-Oost	**11**	42.37	0.51	68.00	0.42	30.00	0.31	44.80	0.21
Klarendal	**12**	29.73	0.31	67.00	0.39	24.00	0.14	42.40	0.15
Arnhemse Broek	**13**	26.18	0.25	61.00	0.22	23.00	0.11	38.70	0.04
Geitenkamp	**14**	11.01	0.00	53.00	0.00	19.00	0.00	45.00	0.22
Presikhaaf-West	**15**	19.31	0.14	53.00	0.00	21.00	0.06	37.10	0.00

Quantitative data for neighbourhoods with the highest (green) and lowest (blue) individual capacity *min-max normalised values.

Appendix 4. Quantitative data for neighbourhood capacity

	Neighbourhood capacity (1 most capable)										
Neighbourhood	**Ranking for neighbourhood capacity**	Active as volunteers (2017) (%)	Active as volunteers*	Active for neighbourhood improvement (2017) (%)	Active for neighbourhood improvement*	Believe they are partly responsible for the neighbourhood (2017) (%)	Believe they are partly responsible for the neighbourhood*	Can go to neighbours for help (2017) (%)	Can go to neighbours for help*	Will give help to neighbour (2017) (%)	Will give help to neighbour*
Schaarsbergen e.o.	**1**	42	1.00	35	1.00	91	1.00	66	0.95	50	0.83
Heijenoord/Lombok	**2**	41	0.95	32	0.87	89	0.94	62	0.86	51	0.87
Alteveer/Cranevelt	**3**	42	1.00	33	0.91	85	0.81	68	1.00	46	0.65
Velperweg e.o.	**4**	42	1.00	34	0.96	84	0.78	56	0.72	48	0.74
Klingelbeek e.o.	**5**	35	0.67	32	0.87	84	0.78	63	0.88	47	0.70
Burgemeesterswijk/ Hoogkamp	**6**	39	0.86	27	0.65	78	0.59	63	0.88	48	0.74
Monnikenhuizen	**7**	34	0.62	26	0.61	80	0.66	60	0.81	54	1.00
Klarendal	**8**	30	0.43	19	0.30	77	0.56	39	0.33	43	0.52
Geitenkamp	**9**	32	0.52	19	0.30	67	0.25	47	0.51	43	0.52
Presikhaaf-Oost	**10**	32	0.52	17	0.22	59	0.00	46	0.49	42	0.48
Arnhemse Broek	**11**	30	0.43	15	0.13	68	0.28	37	0.28	37	0.26
Spijkerkwartier	**12**	33	0.57	21	0.39	69	0.31	25	0.00	32	0.04
Presikhaaf-West	**13**	31	0.48	19	0.30	60	0.03	36	0.26	36	0.22
St.Marten/Sonsbeek	**14**	21	0.00	14	0.09	79	0.63	42	0.40	35	0.17
Centrum	**15**	26	0.24	12	0.00	65	0.19	28	0.07	31	0.00

Quantitative data for neighbourhoods with the highest (green) and lowest (blue) neighbourhood capacity *min-max normalised values.

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