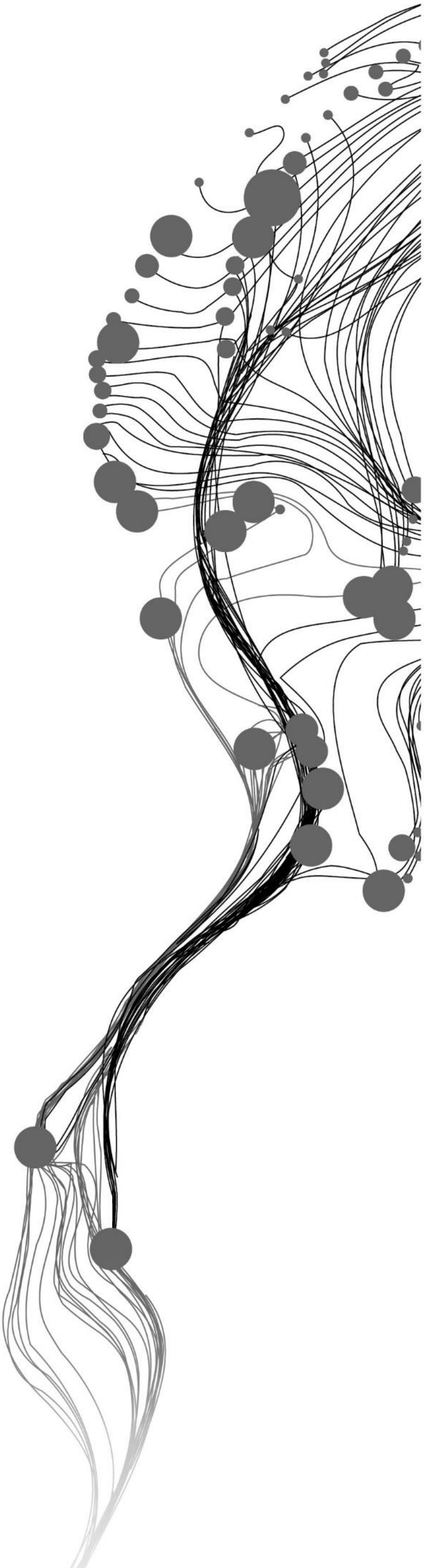
“Nature-based Solution (NbS) for local adaptation of neighborhood to urban flooding: A case study of Enschede, Netherlands”

SADICHCHHA SHRESTHA
August, 2021

SUPERVISORS:
DR. F. (FUNDA) ATUN GIRGIN
PROF. DR. R. (RICHARD) SLIUZAS

ADVISOR:
LIES RUBINGH
(Communication advisor Climate Adaptation, Municipality of Enschede)



“Nature-based Solution (NbS) for local adaptation of neighborhood to urban flooding: A case study of Enschede”

SADICHCHHA SHRESTHA
Enschede, The Netherlands, [August, 2021]

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Urban Planning and Management

SUPERVISORS:
DR. FUNDA ATUN GIRGIN
PROF. DR. RICHARD SLIUZAS

ADVISOR:
Ms. LIES RUBINGH
(Communication advisor Climate Adaptation, Municipality of Enschede)

THESIS ASSESSMENT BOARD:
PROF. DR. KARIN PFEFFER
DR ANGELA COLUCCI (POLITECNICO DI MILANO)

ABSTRACT

The problem of floods in urban areas is increasing worldwide due to the drastic change in land cover of the urban areas by the expansion of hard surfaces. Along with climate change, there is an increase in precipitation which will cause flood more in the future years, and traditional stormwater management is not enough to tackle the problem. So, there is a need to adapt to the flood by enhancing the Nature-based Solutions (NbS). Enschede city in the Netherlands is no exception to this risk of urban flooding during heavy showers. The municipality of Enschede has a goal to limit the damage caused by floods while also maintaining the green in the city. Considering NbS measures to adapt to the flood in Enschede city can be the best way to deal with it.

Hence, this study aims to review the local adaptation of urban floods by integrating NbS in a few of the neighborhoods of Enschede. The local flood adaptation is studied by analyzing the resident's perception of the urban flood problem and areas affected by it and people's preference of NbS by assessing the adaptive capacity of those affected areas. The study also tries to evaluate the effectiveness of local flood adaptation by integrating NbS by exploring the adaptive capacity of the neighborhood and comparing it among the focused neighborhoods. Apart from flood prevention, NbS also has many benefits. Also, the study tries to understand if people's knowledge of the co-benefits of NbS can help make people adaptive to urban floods.

For this, data were collected from the residents in the neighborhood of Lasonder-Zeggelt, Stevenfenne, and Twekkelerveld of Enschede municipality. The data collection was carried out during April 2021, when there was a tough time due to the pandemic of Covid-19 and its restrictions. Though it was tough to carry out fieldwork, it was possible because of the online map-based survey tool "maptionnaire." Almost 150 households: 52 from Lasonder-Zeggelt, 55 from Twekkelerveld, and 54 from Stevenfenne neighborhoods responded. The questionnaire covered the thematic areas of experience of flooding, NbS at household and neighborhood scales, its benefits and disservices, and the institutions and initiatives to coordinate activities for NbS.

The study revealed that the people perceived the cause of urban floods in Enschede municipality to be poor drainage, high groundwater level, and excessive rain, but it differs according to the neighborhood. Similarly, the preference of NbS also varies according to their level of exposure to the flood. Neighborhoods less affected by flood prefer NbS like Façade gardens more for other benefits like visual attractiveness rather than flood prevention. Furthermore, the study also revealed that the adaptive capacity to urban floods depends on various factors like the socio-economic background of the residents. So integrating NbS as the adaptive measure is not enough for the adaptation. Also, one of the remarkable things discovered in the study is that there are still many households without any NbS. Hence, there is much possible to improve flood prevention by scaling up the NbS in households. The municipality needs to focus on the ability and willingness of residents to adopt NbS and develop adaptation strategies according to it for effective adaptation.

Keywords: Nature-based Solutions, urban flood, adaptation, adaptive capacity, benefits, disservices

ACKNOWLEDGEMENTS

First, I would like to thank for the opportunity provided by the Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente to carry out the research. I extend my deepest gratitude towards my supervisors Dr. Funda Atun-Girgin and Prof. Dr. Richard Sliuzas from ITC. I would also like to thank my external advisor, Ms. Lies Rubingh from the Municipality of Enschede, who supported me during my research. They constantly guided me on this project to complete this research.

I would also like to acknowledge Dr. Funda Atun-Girgin, who helped me set up the environment to work online in these difficult circumstances due to pandemics for accessible online communication.

Special thanks to all the experts (name of the experts and also from Autumn Challenge), who helped me understand the context of the study area and provided me information regarding the work carried out regarding the green and blue projects carried out in Enschede.

I am indebted to my friends Prince Asare and Deepak P. Haridas, who were an enormous help to me with the household survey in the study area. I would also like to express my deepest gratitude to the participants who responded to my questionnaire. Their response was invaluable to the research.

Lastly, I would like to thank my friends and family who helped me throughout this research phase. Their constant support and love throughout this thesis are immeasurable and incomparable, which kept me going happily. Lastly, since this thesis was prepared during the pandemic of Covid-19, I would like to thank front liners for their role in ensuring our safety.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This chapter explains the background of the research topic. First, a brief overview of the research is discussed, and a research gap is identified. Further, the research problem is conceptualized with the primary objective, sub-objective, and related research questions. Then methodological outline is briefly discussed to get to the result. The chapter ends with the framework of the thesis structure.

1.1. Background and Justification

Cities are referred to as the engine of economic growth (Colenbrander, 2016). Nonetheless, they are also very vulnerable to the impacts of climate change, such as extreme temperatures, flooding, droughts, and intense storms(White, 2010). Cities globally are prone to many urban disasters due to climate change and anthropogenic factors of rapid urbanization, leading to a drastic change in land cover and land use. An urban disaster like urban flooding is caused by urbanization and aggravated by climate change. The urban flood risks have intensified with the metropolitan areas losing connection with nature, disturbing the biodiversity and ecosystem. The leading causes of an urban flood are increased impervious land due to urbanization and increased rainfall intensity due to climate change. These causes are very dynamic and hard to control to mitigate the disaster. As mitigation refers to the efforts to reduce the impact of a disaster (Coburn et al., 1994), it focuses more on the concept of resistance through controlling the environment. At the same time, adaptation tries to achieve resilience by maintaining a state to respond to changing events. Hence, adapting to the risk is as much crucial as mitigating it to achieve stability to survive, adapt and grow in the crisis.

Adaptation is defined as the process of adjustment while mitigation is defined as a human intervention to reduce the risk." The trouble is generally mitigated through complex engineering, which embeds the risk of raised anthropogenic driven threat of infrastructure. It could therefore have a long-term detrimental effect on the ability of cities to compete in the modern age and subsequently reduce the quality of life of citizens. The lack of adaptation thinking translates into greater vulnerability, given that irrespective of mitigative efforts, continued climate change is inevitable. Where mitigation strategies fail to reduce risk, adaptation can help to lessen the impacts of the risk. In practice trying to adapt may reduce the capability to mitigate. Previously, in climate change plans, the focus was on developing mitigative agenda, but it was realized that effects would arise irrespective of the efficiency of any measure; the adaptation was seen as an equal part of the solution. Adaptation and mitigation should also not be considered as operating independently.

Among many urban risks like extreme weather, urban heat island, pandemics, urban floods are getting more common in most cities globally. From coastal towns to even inland cities like Beijing (Zhang et al., 2016), rainfall events get more frequent due to climate change (IPCC, 2013). Urban flooding or pluvial (surface water) flooding is the flooding in urban areas caused by intense and prolonged rainfall, which overwhelms the drainage system's capacity in modern towns and cities due to increased imperviousness of catchment (Pradhan-Salike & Raj Pokharel, 2017). In recent years, the increase in frequent severe urban flood events has exposed a predominantly narrow technocentric engineered protection approach (White, 2010). Hence, this brings the paradigm shift from industrial engineered defense to the need to work with nature for sustainability.

Realizing the need for a comprehensive approach to promoting sustainable urbanization, "Nature-Based Solution" (NbS) as a novel concept of actions imitating nature (Walters et al., 2016) was coined in the early 21st century.

NbS promotes the renewal of the ecosystem and enhancement of climate change adaptation and mitigation to improve risk management and resilience (Stagakis, 2020). IUCN and European Commission have been promoting this concept of NbS for the synergies between nature, society. The economy and IUCN have defined NbS as "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Walters et al., 2016, p. 2).

Traditional stormwater management or grey infrastructure generally combined sewage systems for stormwater and wastewater drainage is not enough to deal with urban flooding. It is hard to keep up with the rapid urbanization and the expansion of grey infrastructure accordingly. Hence, the introduction of green and blue infrastructure (NbS) and grey infrastructure helps control urban flooding. NbS increases infiltration, reduces surface runoff reduction for the adaptation of flood risk, and maintains an urban ecosystem promoting biodiversity. Hence, recently researchers analyze the effectiveness of adopting Nature-Based Solutions (NbS) to enhance ecosystem services to better adapt to various hazards in the urban system for sustainable urban development and resilience (Lafortezza et al., 2018; Maes & Jacobs, 2017). It helps manage surface water by infiltration, storage, and evapotranspiration throughout the rainfall-runoff process while using plant or soil systems to reduce pluvial flows (Rai, 2013). Of many other approaches of NbS, infrastructure-based practices to reduce urban flooding risk are mainly green infrastructure (e.g., bioswales, rain gardens, permeable pavements, urban wetlands, and green roofs) and blue infrastructure (e.g., ponds, wetlands, floodplains, water treatment facilities). Green and blue measures are cost-effective solutions to societal challenges and help build resilience against climate change (Raymond et al., 2017) with additional economical, ecological, and social benefits (Huang et al., 2020). Thus, addressing urban flooding with an unconventional strategy like NbS has a great prospect. The adaptive measures can be introduced in various scales and approach feasible to the specific context.

NbS for the adaptation to urban flooding needs space in the land owned by different public and private stakeholders (Trell & van Geet, 2019). Most of the lands in urban areas are generally privately owned compared to the publicly owned. Hence, without considering these privately owned lands for NbS, we cannot achieve the desired ground solution of local adaptation of urban flooding. So, citizens and local institutions need to co-operate and interact about their respective roles and responsibilities for integrating the NbS in the community and household level to successfully adapt the urban area to escalating flood risk (Trell & van Geet, 2019). Thus, for the efficient adaptation of risk, the capacity of people in a system to cope with the risk (IPCC, 2014b) should be analyzed. Analysis of the adaptive capacity of the neighborhood will help us understand how NbS on the different scales can help build the ability of the people in a community to adapt to the urban flood risk and what should be considered beyond the sensitivity and exposure of the risk.

1.2. Study Scope and area

Enschede is a municipality in the east of the Netherlands in Overijssel province, as seen in figure 1. The city has ten districts and 70 neighborhoods with 160,000 inhabitants.

Figure 1-1: Location of study area

The city is prone to urban flooding. During heavy rain excessive amount of water suddenly needs to be drained (Gemeente Enschede, 2012), which causes various problems like an overwhelmed sewer system, damage to buildings, and blocked roads. The frequency and magnitude of these problems are expected to increase due to climate change and population growth. The Royal Netherlands Meteorological Institute projected that the rainfall would intensify in the Netherlands in future years (KNMI, 2014). So, there will be increased pressure on the urban drainage system. Accordingly, many municipalities, including Enschede in the Netherlands, need to improve their drainage management to address probable water nuisance due to pluvial flooding.

Hence, the municipality has identified areas sensitive to flooding and initiated Nature-based Solution (NbS) implementation. These NbS include not only large green and blue projects on a city-scale like the Kristalbad wetlands shown in figure 1-2 and the Stadsbeek city stream at the neighborhood level (All Measures | Green-Blue Enschede, n.d.). Also, it includes smaller green measures initiated by residents at a household level like the "Zo groen" campaign that encourages people to green the street together by building the façade gardens (Enschede Becomes So Green Green-Blue Enschede, n.d.). These projects provide additional water retention and reduce the rainwater runoff with the help of infiltration of water in the ground, decreasing the load in the current sewer systems. The municipality owns 30 % of the land, whereas the rest of 70% is private land. The city has come up with creative solutions like encouraging residents to implement green measures in their houses to utilize the best 70% of private land that limits the damage caused by flooding while maintaining biodiversity and human wellbeing.

Figure 1-2 Kristalbad wetland as NbS

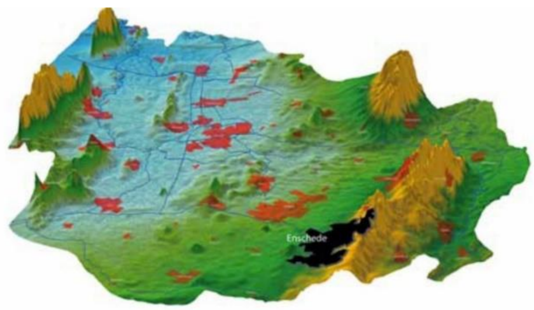


Figure 1-3 Height Differences in Twente and position of Enschede (Source: Regge & dinkel water board)

Hence, the city of Enschede is the right study area to understand how NbS can help in local adaptation of flooding. The elevation maps shown in figure 1 and 2 explains that Enschede is relatively high, and the difference in height within Enschede is approximately 44 meters (Gemeente Enschede, 2012). The elevation map in Figures 1-3 shows that the western areas of Enschede are more susceptible to pluvial flooding as the water flows and accumulates from east to west. In addition, the groundwater level is high due to less water extraction with the decline of the textile industry, which also increases groundwater nuisance in lower parts, as shown in the cross-section of Enschede in figure 1-4 (Gemeente Enschede, 2012). Hence, the lower positions in the west are more susceptible to flood.

Flooding in Enschede is because of the surface water inundation due to an intensive period of precipitation and high groundwater level. In recent years increment in impermeability and high groundwater level due to less extraction of water has raised the waterlogging and flooding

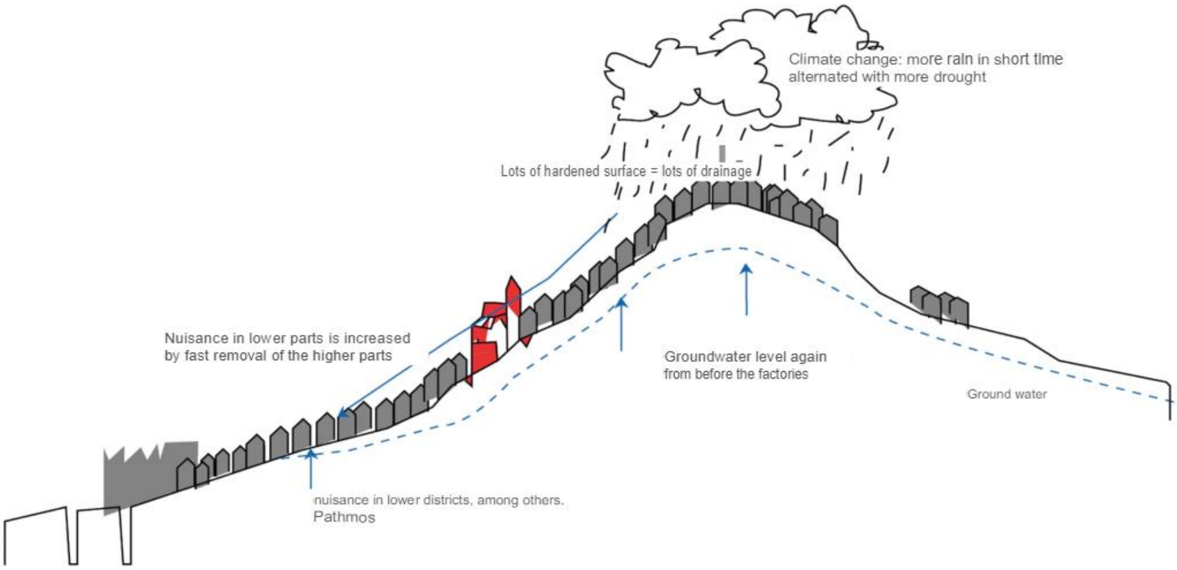


Figure 1-4 Cross- section of the elevation of Enschede explaining how there is problem of flood in Enschede (Gemeente Enschede, 2012)

1.3. Research Problem

Enschede has many projects about Nature-based Solutions (NbS) for various urban risk adaptation. Such projects are implemented by Enschede municiaplity on a large scale to improve mitigation of the risk, but little is explored about the implementation of NbS in local scale for the adaptation of the risk. Also, there is limited study on the people's perception of the urban flood and NbS. There is a lack of scientific or societal research on the local adaptation of urban flood risk by integration of NbS .

Hence, in relation to this study tries to bridge this research gap by first understanding the resident's perception of urban flood situation. Then, analyzes various NbS people have and would like to have that would affect effectiveness of the flood adaptation. The effectiveness is then analyzed by the assessment of adaptive capacity of people in neighborhood. It explores if NbS help people to adapt to the urban flood risk.

Along with adaptation, NbS as adaptive measures has various benefits and disservices that cannot be overlooked. There seems to be a knowledge gap in also the study of the perception of people towards it and how it might affect the adaptive capacity. Hence, the study also tries to analyze if this factor might indirectly help flood adaptation of the focus area. Thus, the purpose of flood adaptation research is vital to understand if any place can adapt to the risk of urban flooding with the help of NbS. The typical application of research is that adaptation efforts related to NbS can be focused on areas with the highest exposures and least adaptive capacity.

1.4. Research objective

The main research objective is to understand the local flood adaptation of the neighborhood by integrating NbS and evaluating its effectiveness by assessing flood adaptive capacity of the neighborhood.

Sub-objectives for the research are further discussed below:

- To understand the residents' perception of the urban flood situation and identify areas affected in the focus area
- To identify NbS preferences of NbS in household and at the neighborhood level in the areas affected in the focus area.
- To explore adaptive capacity of the neighborhood to urban flooding.
- To analyze resident's perceptions of benefits and disservices of NbS and their relation with adaptive capacity.

1.4.1. Research Question

The research problem leads to the following research questions as listed below:

1. To understand the residents' perception of the urban flood situation, and identify areas affected in the focus area
   - According to residents of the case study, which area is affected by the urban flooding in their household and the neighborhood?
   - What is the perception of people towards urban flooding?
   - What factors, according to residents, are causing urban flooding?

2. To identify NbS preferences of NbS in household and at the neighborhood level in the areas affected in the focus area.
   - What are the NbS practiced helping adaptation of urban flooding on a household and neighborhood scale?
   - What are the NbS preferences in the study area on a household and neighborhood scale?
   - Are people willing to apply it for urban flood adaptation at the household level?

3. To explore adaptive capacity of the neighborhood to urban flooding.
   - What are the indicators to determine the adaptive capacity of the neighborhood to the urban flooding considering NbS?
   - What does the difference in adaptive capacity in various neighborhoods clarify?

4. To analyze resident's perception of benefits and disservices of NbS and its relation with adaptive capacity.
   - What is the perception of residents regarding the co-benefits and disservices of NbS?
   - How do the benefits of NbS relate to adaptive capacity?

1.5. Research Outlines

This thesis comprises seven chapters as per the following sequence:

Chapter 1: Introduction
This chapter includes a brief introduction to the project. Its background and justification for the research with objectives and research questions to be answered. It also has a brief explanation of the study area and why the research is significant.

Chapter 2: Literature Review
This chapter includes the theoretical background of urban flooding, adaptation, adaptive capacity, Nature-based Solution, ecosystem services of Nature-based Solutions. From the literature, various factors affecting each of the critical concepts are studied. The determinants, indicators, and factors influencing are identified, discussed, and used in the methodology for the analysis.

Chapter 3: Study area and Method
This chapter presents a brief explanation of the context of the case study area. At the same time, the method section describes the data collection methods and framework for various analyses.

Chapter 4: Analysis and Results
This chapter presents a brief analysis of the data from the maptionnaire to understand more about the context of the study area and multiple factors and determinants affecting the problem in the study area. It also presents the analysis of the adaptive capacity and calculation of the adaptive capacity index of the selected study areas and the cultural ecosystem services of those study areas. Comparison of the established neighborhoods based on the adaptive capacity based on NbS. Analysis of the weakness as well as strengths of each study area.

Chapter5: Discussion of the Results
This chapter looks over the key findings of the research objectives. Furthermore, it tries to examine if the results are valid according to the corresponding literature.

Chapter 6: Conclusion and Recommendations
This chapter summarizes the findings and the methodology followed in the research, discusses the limitations, and recommends a way forward for further study.

2. LITERATURE REVIEW

This chapter includes reviews of existing relevant literature regarding the concepts applied to carry out the research. It comprises the idea of an urban flood, NbS, adaptation, and adaptive capacity. Finally, it concludes with the conceptual framework used as the basis for this research. The conceptual framework explains how all these reviewed concepts are connected and binds the study to give meaning to the results.

2.1. Flood Hazard

Flood is a common hazard worldwide and has been defined as temporary submersion of a land area that is usually not covered by the water (García & Ollero, 2016). However, a rise in the level of water level or exceeding flow volume of the water sources due to intense and extensive precipitation in the water body might not always cause a flood. The cause can be dependent on various aspects. As Hong et al. (2013) explain, it can also occur when the soil's absorptive capacity is exceeded. However, the "flood risk" is however different from the flood. According to Article 2 (European Union, 2007, p.3), flood risk is "*the combination of the probability of a flood event and the potential adverse consequences for human health, the environment, cultural heritage, and economic activity*." Hence, floods are natural phenomena, but the risk due to flood to humans depends on various factors, and some of the human activities can reduce the impact of the flood events.

Flooding is classified mainly into four categories: coastal flood, flash flood, river flood (fluvial flood), and urban flood (pluvial flood). The rise in sea level causes coastal flood, river flood, and flash flood refers to the abnormal increase in the amount of a river or any other water source due to various reasons like the intense rainfall, dam failure, or ice jam (Wright, 2007b). In contrast, urban flooding is more concerned with the flooding caused in urban areas due to poor urban drainage networks and low surface permeability (Wright, 2007b). The urban flood is relative to elevation, localized precipitation patterns, urbanization, and underlying soil (White, 2010).

2.2. Urban flooding

As per the Centre for Research on the Epidemiology of Disasters (CRED, 2011), every year from 2006 to 2015, "urban flooding affected 140 million people and claimed about 10,000 human lives around the world" (Sanderson & Sharma, 2016). Urban flooding or pluvial (surface water) flooding generally refers to the flooding in urban areas caused by intense and prolonged rainfall, which overwhelms the drainage system's capacity due to increased infiltration and imperviousness catchment (Pradhan-Salike & Raj Pokharel, 2017). According to Molavi, Muttil, & Tran (2011), urban pluvial flooding is the consequence of hydrological and climatological factors combined with the magnifying intervention of human factors in the environment. Factors directly affecting the urban flooding are the imperviousness of catchment, storage and conveyance capacity of the catchment, underground and surface land drainage system, and capacity of recharging (Molavi et al., 2011; Molavi, Tran, & Muttil, 2013). Imperviousness can be defined as the "*inability of surface water to be infiltrated in the soil profile into the underground water system*" (Slonecker, Jennings, & Garofalo, 2001). It is a crucial indicator that explains the effect of environmental degradation on the hydrological process that contributes to increased runoff volume (Arnold & Gibbons, 1996; Qin, Li, & Fu, 2013; Yao, Wei, & Chen, 2016). According to Parkinson and Mark, the increase in imperviousness due to land cover change caused by urbanization impacts the hydrological cycle because of the reduction in infiltration (capacity of the soil to absorb moisture), surface storage capacity, and decreased productivity evapotranspiration due to reduction in vegetation wetting and interception by plants. Combined effects of these effects result in increased run-off velocity, volumes, and discharge rates. Simply, pluvial flooding occurs if the volume of water entering a sewer exceeds the design capacity.

2.2.1. Significance of urban flooding in Enschede

In recent years, the city of Enschede has encountered local pluvial flooding, as seen in the picture (figure 2-1)(*Approach to Pluvial Flooding in the Municipality of Enschede - Spatial Adaptation*, n.d.).

Figure 2-1 Flooded Princess tunnel near the station of Enschede
Source: Wouter Borre, 2019

The risk analysis for flooding for the Basic Sewerage Plan (BRP) performed in 2015 identified numerous bottlenecks. It explained that the sewerage system becomes overloaded during extensive precipitation and results in water on the street, which ultimately contributes significantly to the surface water nuisance (RIONED & STOWA, 2015). A few of the locations found at 'high risk' of the flood were Goolkatenweg and De Heurne. In Goolkatenweg, during heavy rain, it has been found that water depths of > 30 cm with a return period between once every ten years to once every hundred years which resulted in water in a home, cars, and large flows of sewage through front and back yards (RIONED & STOWA, 2015). The other location found in high risk is the De Heurne, in the center of Enschede.

2.3. Adaptation and Adaptive Capacity

IPCC (2012, p.3) defines adaptation as "*the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities*." The adjustment discussed in the concept of adaptation in a socio-ecological system relates to the adaptive capacity to reduce its vulnerability to external stimuli. Adaptation practices can define adaptive capacity that is innate in a system., Adaptation refers to the process of adapting, while adaptive capacity refers to the ability to adjust.

According to (Boswell et al., 2019, p.174), the climate adaptation process has two-phase vulnerability assessment and strategy development, as seen in figure 2-2. The risk and vulnerability assessment sub-phases include exposure, sensitivity, potential impacts, and adaptive capacity. Assessment of Adaptive capacity is an essential element of long-term adaptation to climate change.

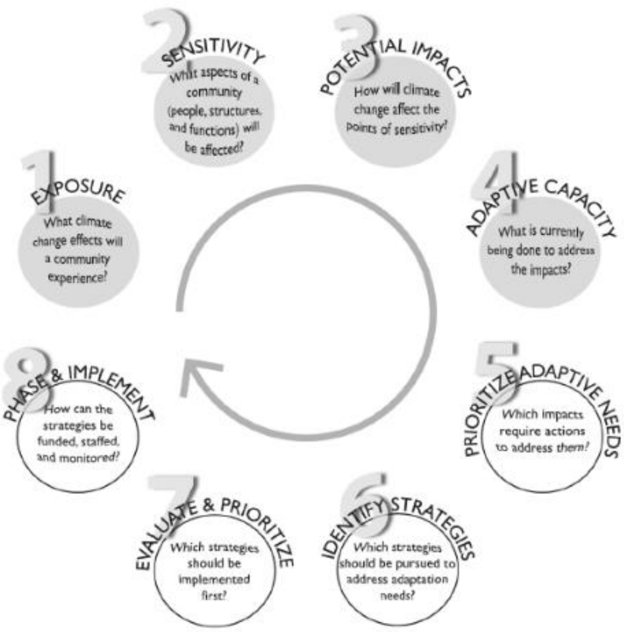


Figure 2-2 Climate change adaptation strategy development process
Source: (Boswell et al., 2019, p.174)

Adaptive capacity has been described as an essential element in the climate change vulnerability AR4 and climate risk AR5 concept (Zebisch et al., 2021), as shown in figure 2-3. Both systems explain the adaptive capacity in the same way as coping capacity, which reduces the vulnerability of people to the impacts of the risk and adapts to it.

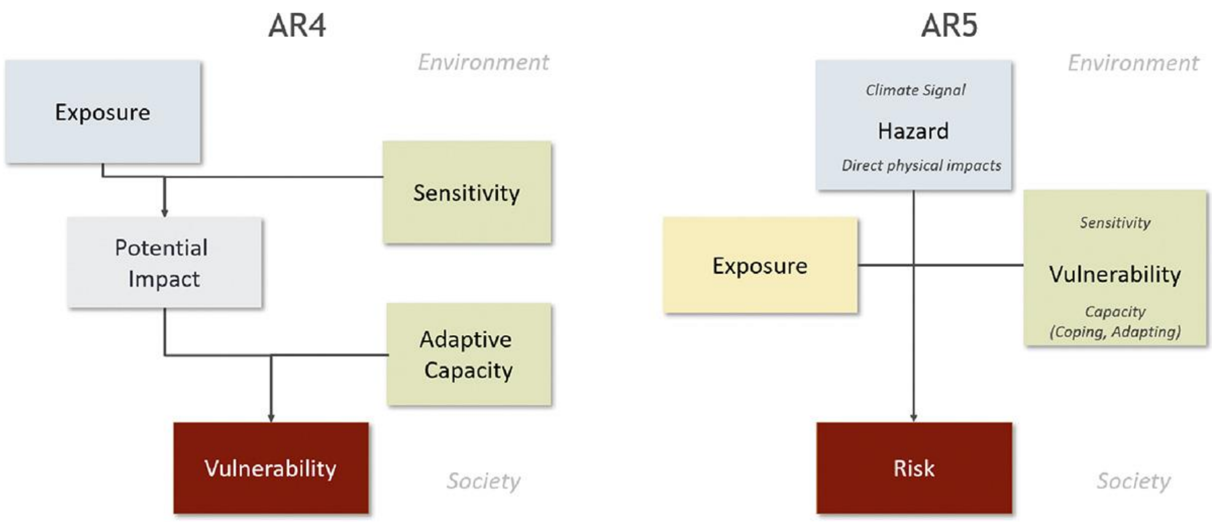


Figure 2-3 Adaptive Capacity linked with other concept in climate change vulnerability (AR4) and Climate risk (AR5) approach
Source: (Zebisch et al., 2017)

Here, we focus on flood adaptation and discuss the vulnerability assessment. In that case, assessing adaptive capacity is one of the essential sub-phases that discusses "What is currently being done to address flood impacts?". For an efficient adaptation of flood on a local scale, the individual and community's capacity to cope with the flood is crucial, along with the adaptive measures fitted to the local conditions (Van De Ven et al., 2011). Here, if NbS as the adaptive measure is taken into consideration, its selection requires knowledge of local context, effectiveness, and cost-benefit ratio of actions. A significant success of the local adaptation lies in stakeholder involvement. If various actors in the regional scale are aware and also involved in influencing the realization of adaptation measures, it can open opportunities for adaptation.

2.4. Assessment of adaptive capacity

Adaptive capacity research is highly interdisciplinary; covers a wide range of areas and scales of analysis. It is highly confused as it uses diverse and sometimes conflicting methods and metrics. Assessment of the current adaptive capacity of a system provides valuable insights into the existing potential of the system to cope with climate disasters. It points out the shortcomings that need to be addressed to improve adaptive capacity.

Many works have been done on the national level assessments of adaptive capacity to climate change (Brooks et al., 2005; Adger & Vincent, 2005). Explorations of the adaptive capacity at the national level are essential to compare across nations; such studies are less relevant at the sub-national and local levels. They do not capture the processes and contextual factors that influence adaptive capacity at the level where adaptation occurs ultimately takes place. Vincent (2007) proves that the indicators of adaptive capacity cannot be generalized across scales. Indicators of adaptive capacity at the national level are misleading at the sub-national or local scale. Thus, exploring the local context is vital to gain insights into local constraints and opportunities.
The earlier studies choose the indicators of adaptive capacity based on subjective assessments; now, it is based on theoretical grounds. Adaptive capacity is multidimensional and is determined by a complex relationship of multiple factors. As noted, many variables of adaptive capacity are not quantifiable. However, indicators and indices help represent a complex reality in simpler terms. Choice of indicators to describe the index for adaptive capacity is constricted because adaptive capacity has no tangible element. The selection of suitable indicators is best based on theories that provide an image of the nature and causes of vulnerability. However, even theory-based deductive

methods are constrained by a lack of sufficient data because subjectivity enters the process of indicator selection. Evaluating and selecting the "determinants" is recognized as a foremost challenge (Yohe & Tol, 2002; Brooks et al., 2005; Haddad, 2005; Adger et al., 2007; Notenbaert et al., 2013). Phi (2011) investigated widely used 18 adaptive capacity determinants in the number of documents as shown in figure 2-4 below.

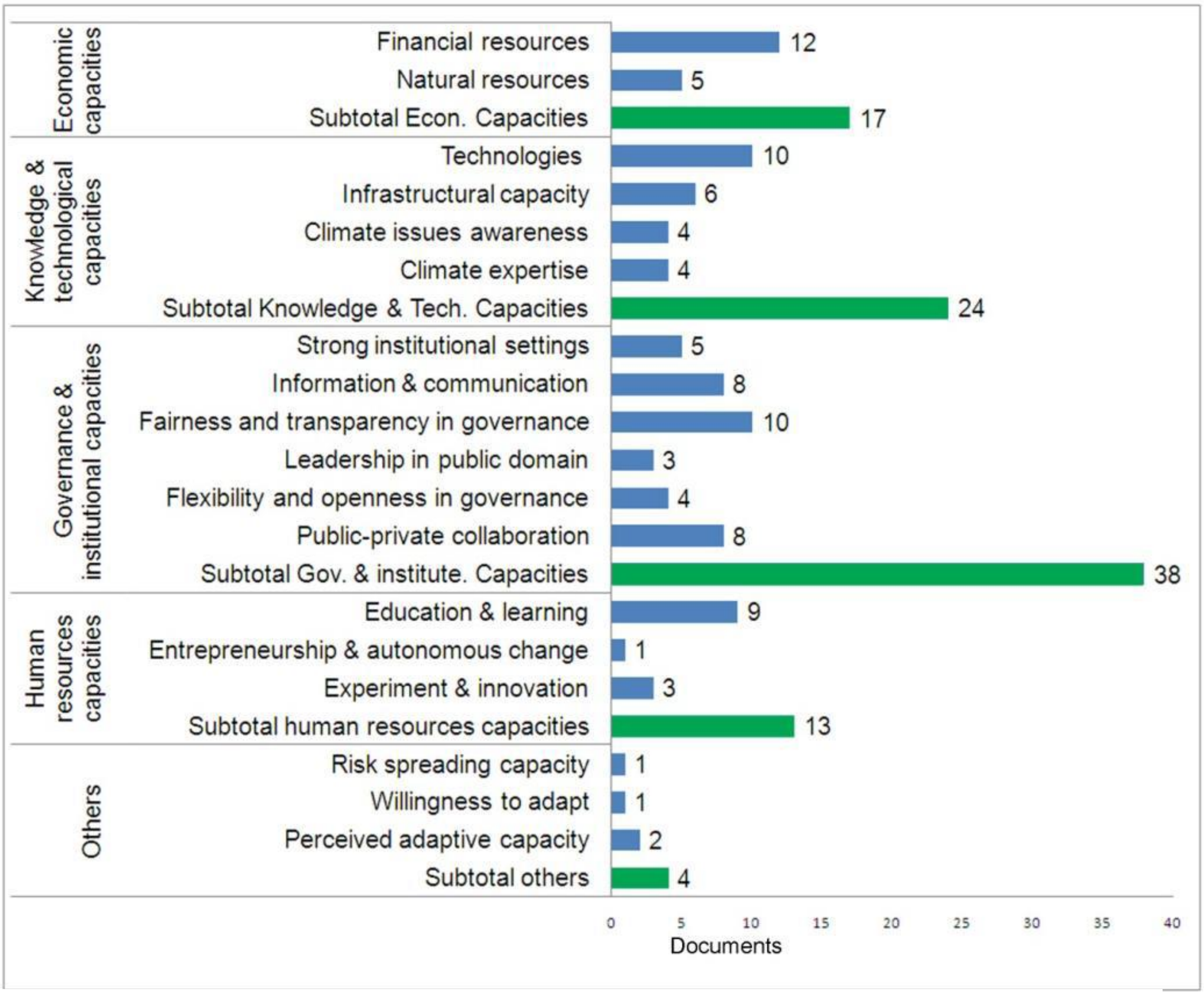


Figure 2-4 Indictors for measuring adaptive capacity and the frequency of its use.
Source: Phi (2011)

The methodology adopted in choosing indicators is crucial since wrong indicators may lead to an invalid index. The best option is to verify the representativeness of the theory based on the identified author's experience, expert judgment, literature review, or subject of interest (e.g., Brooks et al., 2005; Bryan et al., 2015; Notenbaert et al., 2012). Nevertheless, devising an index to measure adaptive capacity is helpful to compare similar systems and provide insights into the underlying processes and determinants of adaptive capacity that are of relevance to policymakers.

2.4.1. A theoretical framework for analysis of adaptive capacity at a local level

Adaptive capacity as a property is none of each specific element mentioned in the definition and only becomes 'visible' when all these elements are integrated under the scope of analysis. Authors have used various theoretical frameworks to analyze adaptive capacity. Some authors used established indices from other fields, such as Sustainable Livelihoods Analysis, sustainability Capitals Framework, or Human Development Index.

Overseas Development Institute (ODI) proposed Local Adaptive Capacity Framework (LAC) aims not only to lookat what a system has that enables it to adapt but also to recognize what a system does to enable it to adapt. Given this, the framework attempts to consider the role of the processes and functions at the local level, which can support adaptive capacity (ODI, 2010). The LAC comprises five fundamental features of local adaptive capacity: asset base, institutions and entitlements, knowledge and information, innovation, flexible forward-looking decision making, and governance. Similarly, Ellis (2000) and DFID (1999) analyze the adaptive capacity of the community. The sustainable livelihoods approach is based on Nobel Laureate Amartya Sen's entitlements approach, where households with a good range of entitlements, capabilities, or assets have more choices of adopting strategies suitable to cope during the periods of adversities or minimize the associated risks (Jakobsen, 2011; Ludi & Slate, 2008). The limited access to livelihood assets increases the defenselessness or incapacity to avoid troubles. It increases the shocks and stresses to which an individual or household is exposed (Shahbaz, 2008). On the other hand, homes with diversified asset portfolios will have more options to substitute among alternative livelihood activities during stress, thereby having more adaptive capacity.

According to a study by Thanvisitthpon et al. (2020), the identified six flood adaptive capacity components: economic resources, social capital, awareness and training, technology, infrastructure, institutions, and policies with 21 flood adaptive capacity indicators were validated by expert's evaluation which is shown in table 2-1.

Table 2-1 Relevancy of adaptive capacity indicators by a panel of experts. Source: Thanvisitthpon et al. (2020)

Adaptive capacity components	ID	Adaptive capacity indicators
Economic resources	E1	Monthly household income
	E2	Monthly household expenditure
	E3	The economic impact in response to flood depth
	E4	Number of the elderly/disabled/unemployed in the household
Social capital	S1	Coordination efficiency between residents and government agencies
	S2	Coordination efficiency between community leaders and government agencies
	S3	Good rapport between community leaders and government agencies
Technology	T1	Advance flood warning
	T2	Reliability of flood forecast from administration
	T3	Accessibility of flood information
Infrastructure	F1	Type of drainage infrastructure (pumping station, canals etc.)
	F2	Efficiency of floodwater retention areas
	F3	Condition of the roads and its impact on flooding
Institution and policies	I1	Institutional (government or non-governmental organizations) assistance in flood prevention and preparedness
	I2	Effectiveness of policies, programs, and projects related to urban flood prevention and preparedness
	I3	Number of policie, programs, and projects related to urban flood prevention and preparedness
Awareness and Training	A1	Levels of education
	A2	Frequency of flood incidents in the area
	A3	Preparedness against future urban floods

2.4.2. Visualization of Adaptive Capacity

The indicators measured for each determinant may be quantitative or qualitative (e.g., number of health centers or healthcare quality). The Adaptive Capacity Wheel (Gupta et al., 2016), identifying 22 indicators for six determinants of the adaptive capacity of institutions, is most commonly cited for visualizing the results of adaptive capacity.

2.4.2.1. Adaptive Capacity Wheel

Adaptive Capacity Wheel was designed in 2007 by Gupta et al. (2016), as seen in figure 2-5, to assess adaptive capacity and express it more clearly. Various rings of the wheel depict different information. The inner circle reveals adaptive capacity; the middle ring reveals the dimensions, and the outer ring shows the indicators.

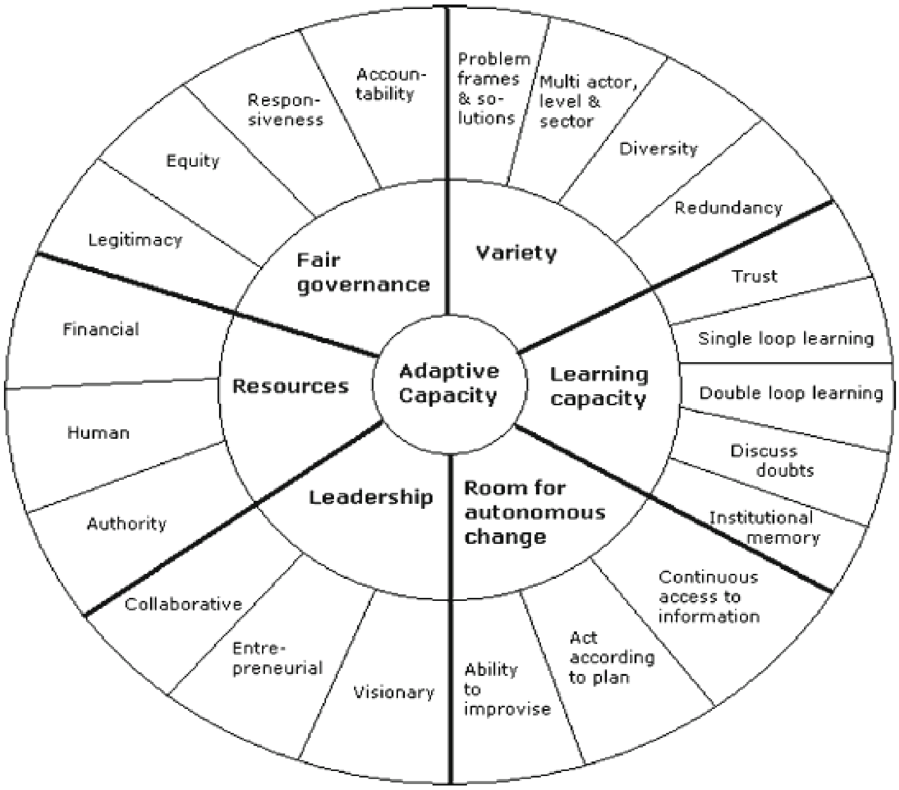


Figure 2-5 Adaptive Capacity Scores visualized in Adaptive Capacity Wheel
Source: Gupta et al. (2016)

The table 2-2 below explains the color and scoring scheme that Gupta et al. (2016) applied to the adaptive capacity wheel. It helps indicate the strong and weak components of adaptive capacity and their factors. The colors help differentiate high (green: quantitative value +2) to low (red: quantitative value 2) adaptive capacity, which can assess and inform the concerned stakeholders or local authority where there may be room for improvement.

Table 2-2 Color and scoring scheme for the adaptive capacity wheel (Gupta et al., 2016)

Effect of an institution on adaptive capacity	Score	Aggregated Scores for dimensions and adaptive capacity as a whole
Positive effect	2	1.01 to 2.00
Slightly positive effect	1	0.01 to 1.00
Neutral or no effect	0	0
Slightly negative effect	-1	-0.01 to -1.00
Negative effect	-2	-1.01 to -2.00

2.5. Nature-based Solution

2.5.1. Emergence and development of Nature-based Solution (NbS) as a concept

Before the term "Nature-based Solution" was coined, the role of nature and ecosystem in human wellbeing is reflected in various indigenous knowledge. Whereas in modern scientific literature, it was the 1970's when the idea of ecosystem service emerged, and by 1990 more systematic approach was promoted. In the late 2000s, the term "Nature-based Solution" was introduced with a paradigm shift as people were seen as beneficiaries of nature and as protectors to solve various challenges (Walters et al., 2016).

2.5.2. Relation of NbS with SDG

NbS aims for sustainable development, which helps to achieve various SDGs as shown in figure 2-6. According to (Warmenbol & Smith, 2018), the IUCN Program (2017–2020) aims to achieve substantial influence to numerous SDGs to confront challenges of food security, climate change, and economic and social development as:

- SDG 1: No Poverty
- SDG 2: Zero Hunger
- SDG 3: Good Health and Well-being
- SDG 11: Sustainable Cities and Communities
- SDG 13: Climate Action

These goals are achieved by promoting NbS related policies and actions in balanced food production, water availability and quality, carbon sequestration, climate change adaptation and mitigation, soil up-gradation, wellbeing, and urban growth to boost healthy societies. Two major SDGs focused on this research are SDG 11, "Sustainable Cities and Communities," and SDG 13, "Climate Action."

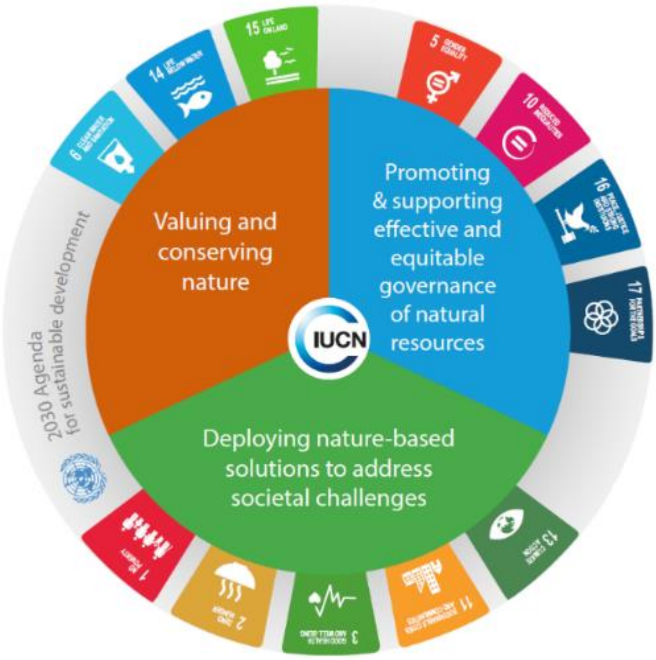


Figure 2-6 Relation of NbS with SDG
Source: (Warmenbol & Smith, 2018)

2.5.3. Nature-Based Solutions (NbS) for adaptation of urban flood

The concept of NbS to solve the issues of the urban flood is similar to ideas of Low Impact Development (LID), Water Sensitive Urban Design (WSUD), the Sustainable Urban Drainage System (SUDS), Sponge City, etc. However, these terms carry the same idea of using green infrastructure to manage runoff volumes and defer peak flows (Shaver, 2009) and blue infrastructures improving water quality and retaining watercourses in the cities using locally adapted systematic interventions(Eckart et al., 2017).

While adopting NbS at the household level might only bring a small benefit, the cumulative effects over an entire catchment could be very considerable for runoff reduction and groundwater recharge. Its primary role to control the urban flood can be listed as below:

- to reduce the quantity of runoff discharge termed as "source control."
- to slow the velocity of runoff discharging from an area termed as "permeable conveyance."
- retaining runoff either over the long term or temporarily, providing a passive level of treatment expressed as "storage and pollution management."

Implementing NbS at the local or national level is not possible without considering the institutional and governance factors. Large-scale implementation is not linear as changing the knowledge and perception of infrastructure would require co-operation with stakeholders, like water and sewerage companies, municipality, and local people. However, the gradual application of NbS as the adaptive measure at the household level for resilience to hazards within a city may address the risk and manage the risk's exposure and vulnerability (White, 2010).

2.5.4. NbS and their suitability to relevant drainage

As per (Fletcher et al., 2015), stormwater management can be classified as infiltration or retention-based technologies to reduce imperviousness in an area. Nevertheless, a combination of retention and infiltration helps maintain the natural hydrological flow (Eckart et al., 2017). There are many NbS measures for stormwater management, but here in the research, we focus on the local flood adaptation and NbS that require no or less land for construction. The application of these NbS requires a good knowledge of its design. Significant factors affecting the selection of NbS are location and rainfall. So, considering the ability and awareness of target group (i.e., residents and municipality), only a few of the NbS measures at the household and neighborhood level are considered for the study. Here, for the study, NbS measures considered at the household level are façade garden, rain barrel, green roof, vegetable garden, and water-passing pavement. Whereas, Urban waterways, trees and plants, wadi, rainwater ponds, and water-passing pavement are NbS considered for neighborhood-level, as shown in fable 2-3 below.

Table 2-3 NbS techniques grouped according to suitability (Adapted from Table 5-2. Generalized BMP Suitability for Relevant Drainage Area Characteristics. Chapter 5, Effective Use of BMP in Muthukrishnan, S., 2004. The Use of Best Management Practices (BMPs) in Urban Watersheds)

Stormwater management	Infrastructure Based NbS	Type of NbS	Land use characteristics	Scale of techniques	Effective in impervious areas
Infiltration-based techniques	Green Infrastructure	Vegetated Swales (Wadi)	Ideal for collecting sheet flow runoff from roads and highways	Intermediate	Intercepts runoff from impervious areas but requires land for construction
	Green Infrastructure	Façade gardens	Ideal for collecting rooftop runoff and runoff from yards and sidewalks	Local	Intercepts runoff from impervious areas but requires land for construction
	Green Infrastructure	Permeable pavement	Ideal for highly developed areas: parking lots, driveways, and low-volume roads	Local/ Intermediate	Intended to replace impervious surface
	Green Infrastructure	Vegetable Garden	Ideal for collecting rooftop runoff and runoff from yards and sidewalks	Local	Intercepts runoff from impervious areas but requires land for construction
	Green Infrastructure	Trees and Plants	Ideal for roadsides (residential and highways) and other areas with sheet flow runoff, practical for tiny parking lots only	Intermediate/ Catchment	Intercepts runoff from impervious areas but requires land for construction
Retention-based techniques	Blue Infrastructure	Retention Pond (Rainwater Pond)	Ideal for retaining water from parking lots and residential areas	Catchment	Intercepts runoff from impervious surface surfaces but requires a large piece of land for construction
	Blue Infrastructure	Urban Waterways	Ideal for collecting rooftop runoff and runoff from yards and sidewalks	Intermediate	Intercepts runoff from impervious areas but requires land for construction
	Green Infrastructure	Green roof	Ideal for collecting rooftop runoff	Local	Ideally suited
	Green Infrastructure	Rainwater harvesting/Rain Barrel	Ideal for collecting rooftop runoff	Local	Ideally suited

2.5.5. NbS measures in household level

There are various NbS that could be integrated at the household level. However, some of the widely introduced in Enschede are described below. The effectiveness of the measures to the flooding is referred from the Green-Blue Enschede website.

2.5.5.1. Façade Garden

Façade garden is a small garden created by removing a row of tiles along the façade, as shown in Figure 2-7. The rainwater flowing off the facade can infiltrate the ground, making the streetscape greener and more attractive (*All Measures | Green-Blue Enschede*, n.d.).

Figure 2-7 Image showing construction of Facade Garden Source: (Groene Loper Enschede, n.d.)

2.5.5.2. Rain Barrel (Stormwater harvesting):

Stormwater/ Rainwater harvesting help in improving stormwater retention systems to reduce annual runoff volumes (Fletcher et al., 2015). It is more efficient to minimize surface runoff if it meets daily demands more readily than seasonal demand. It is a significant yet straightforward factor to manage urban hydrology (Fletcher et al., 2015) as it can also help in irrigation. The simple way to harvest rainwater is by connecting the downspout to the rain barrel. The water collected in the barrel of capacity at least 200 liters can be used for watering plants and, if filtered well, can be used for drinking as well (*All Measures | Green-Blue Enschede*, n.d.).

Figure 2-9 Image of Rain Barrel (All Measures | Green-Blue Enschede, n.d.)

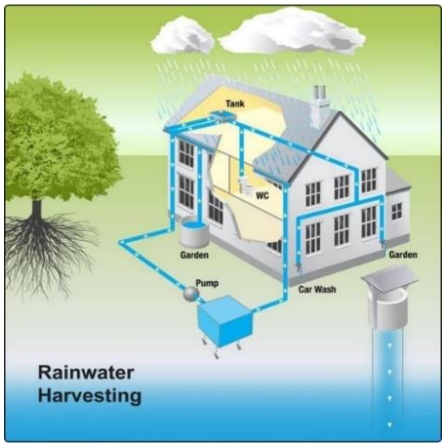


Figure 2-8 Image of rainwater harvesting

2.5.5.3. Green Roof:

Green roofs are rooftops designed as partially or fully covered with vegetation to compensate for its removal while constructing the building (Rowe, 2011; Shafique and Kim, 2015; USEPA, 2000), which mainly reduces the imperviousness and urban stormwater runoff (USEPA, 2000). According to Eckart et al. (2017), for effectiveness, it should be designed considering the extreme rainfall event and can also be added to an existing rooftop without changing structural reinforcement. A simple schematic diagram is shown in figure 4. Similarly, other benefits of a green roof are energy efficiency, an extension of the roof's life, and conservation of land (Eckart et al., 2017). Stormwater harvesting: Stormwater harvesting helps improve stormwater retention systems to reduce annual runoff volumes (Fletcher et al., 2015). It is more efficient to minimize surface runoff if it meets daily demands more readily than seasonal demand.

Figure 2-11 Image of vegetable garden (https://decorloving.com/backyard-vegetable-garden-design-ideas/)

Figure 2-10 Image of Green roof (https://elliotts.uk/products/green-roof)

2.5.5.4. Vegetable Garden

Garden is used for vegetable farming to know what you're eating and help in handling the stormwater. A vegetable garden requires a sunny, light spot and daily attention to take care of plants, shrubs that attract bees that provide pollination and fertilization (*All Measures | Green-Blue Enschede*, n.d.).

2.5.5.5. Permeable pavement:

Permeable pavements help to infiltrate stormwater into the ground compared to more used asphalt and concrete pavements over extreme rainfall events (Brattebo & Booth, 2003). There are varieties of permeable pavements like block pavers, plastic grid systems, porous asphalt, and porous concretes (Dietz, 2007). The figure below shows a typical cross-section of such permeable pavement.

Figure 2-12 Image of various types of permeable pavement (https://www.urbangreenbluegrids.com/measures/porous-paving-materials/)

2.5.6. NbS measures in the neighborhood level

2.5.6.1. Urban Waterways

Open urban waterways can drain and retain rainwater. If there is enough space, various above-ground drainage options, such as open gutters and ditches, can drain into an open urban watercourse. An urban watercourse does not always have to be reconstructed but can also be part of rebuilding an old watercourse (*All Measures | Green-Blue Enschede*, n.d.).

Figure 2-13 Image of Roombek
Source:
(http://landezine.com/index.php/2011/06/roombeek)

2.5.6.2. Trees and Plants

Trees and greenery for roadsides (residential and highways) intercept runoff from impervious areas and other areas with sheet flow runoff.

Figure 2-15 Image showing trees and plants along the pathway
Source: (https://www.vdberk.be/projecten/roombeek-enschede/)

2.5.6.3. Rainwater Pond

Rainwater ponds, also known as wet or retention ponds, are designed to catch rainwater runoff and provide storage of this runoff volume(Field & Taruri, 2005). Above the permanent pond level is the storage volume, replaced in part or entirely by the runoff volume from successive runoff events and regulated release of the mixed inflowing and endless pond water (Field & Sullivan, 2003). Well-designed and maintained rainwater ponds could be highly effective NbS for water quality and quantity control, additionally providing aesthetic value and habitat for a variety of plants and animals (U.S. EPA, 1999a). Along with advantages, there are also many limitations. It requires a larger area and is not suited for a drainage area smaller than 10 acres, and ill design and periodic maintenance can cause stratification (Field & Taruri, 2005).

Figure 2-14 Image of Rainwater pond
(https://www.urbangreenbluegrids.com/measures/rainwater-ponds/)

2.5.6.4. Vegetated Swales (Wadi)

A wadi is a ditch with gravel and sand, which can retain as well as infiltrate water. In a wadi system, the water from roofs and roads does not flow into the sewer system but via above-ground gutters and ditches into the wadi (*All Measures | Green-Blue Enschede*, n.d.). The term "grassed swales" or "vegetated swales" is also used for wadi, as has grassed conveyances, which are channels vegetated with flood-tolerant grasses (Field & Taruri, 2005). Under this layer is a shaft filled with gravel that has much space between them, which helps stormwater to be infiltrated and at the bottom of the case is an infiltration/drain tube (All Measures Green-Blue Enschede, n.d.).

Figure 2-17 Image showing Wadi (https://www.urbangreenbluegrids.com/measures/bioswales/)

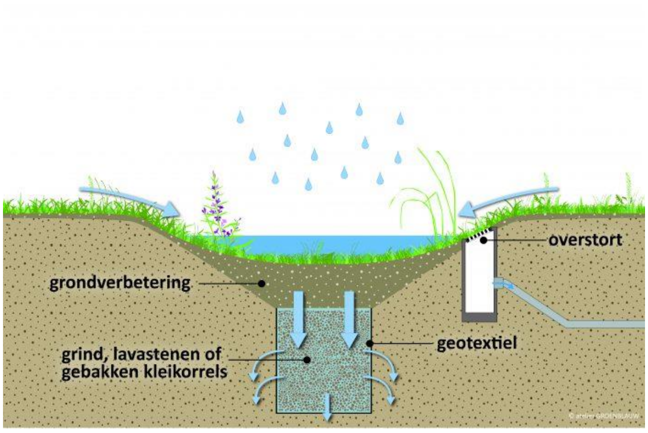


Figure 2-16 Cross section of Wadi

2.6. Conceptual Framework

The conceptual framework for the research is developed to understand the local adaptation to urban pluvial floods by integration of NbS. The framework is based on the concept of defining adaptation to climate change by (Smit et al., 1999), as seen in figure 2-19 and NbS by IUCN, seen in figure 2-18.

According to B. Smit et al., p. 6 (1999), to define adaptation in any scale, some of the factors to be described are:

- the system concerned "who adapts,"
- the climate stimulus "adaptation to what?",
- the processes involved "how does adaptation occur?"

Along with the evaluation "how good is the adaptation?"

Here, in the research, the climate-related stimulus is an urban pluvial flood, the system of interest is a household/ neighborhood where residents are the one who adapts since the spatial scale of research is for the local level. The adaptation occurs with the help of the integration

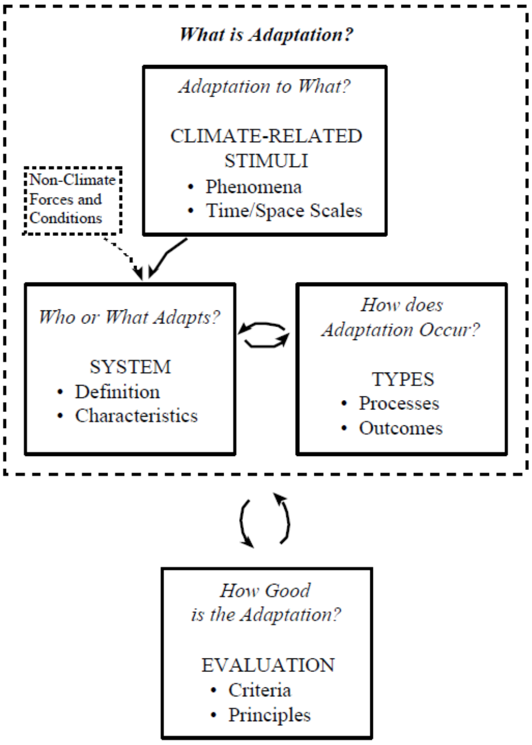


Figure 2-18 Adaptation to climate change and variability Source: Smit et al., p. 6 (1999)

of NbS. The evaluation of adaptation here is considered to be done by assessing the adaptive capacity of the household.

According to IUCN (2020) the adaptation by NbS is defined as the action inspired by nature with various ecosystem restoration, issue-specific, infrastructure, management, and protection-based approaches implemented to address societal problems like climate change, food security, water security, disaster risk, human health, economic and social development to gain human wellbeing and biodiversity benefit.

Here, adjusting the framework developed by B. Smit et al. (1999) and IUCN (2020), a framework for the research as shown in Figure 2-21 is formed. Hence, the overall concept of the research is to show that the application of the ecosystem-based approach (focusing on green and blue infrastructure) of NbS can help solve a societal problem of "urban pluvial flooding" not only physically but also socially with various benefits, which further helps to increase the adaptive capacity of the society. Therefore, the research is developed around these concepts interacting with each other. The framework is further elaborated as in figure 2-21

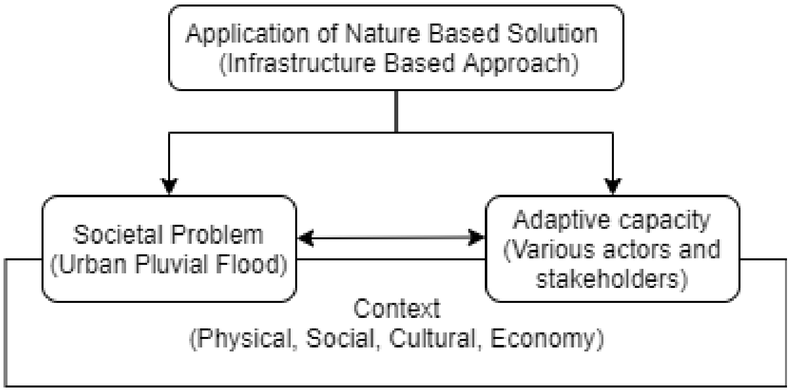


Figure 2-19 Conceptual Framework for research

3. STUDY AREA AND METHOD

The general methodological outline is discussed earlier in chapter one. This chapter details the data collection approach, data collected from various sources, processing of the data, and frameworks. From a simple stakeholder analysis and brainstorming for the research, the main stakeholders were identified. Since the study focuses on the local level, the stakeholders categorized by power and interest in the scope of research were local authorities, i.e., municipality, community group leader (ambassador of the neighborhood), and residents. Hence, the data were collected according to the related stakeholders. The information about the case study area and the works done by the municipality in the study area were collected from documents, websites, and online web-based map tools along with the interview of experts and community leaders, whereas the residents' perceptions in the study areas were collected from the survey.

3.1. Research Methodology

The research uses a case study approach carried out following mixed-method research involving both qualitative and quantitative methods. The unit of analysis of the study is the "NbS for local urban flood adaptation." The integrated process follows an inductive approach focusing on identifying the patterns and relationships regarding the local flood adaptation of the neighborhoods. Since the mixed method is carried out, it follows a simultaneous technique where the quantitative and qualitative analysis method is done side by side. The mixed method is preferred over other methods because of the combined approach to get a concrete result that is reliable with the triangulation of data as a method for validity.

According to the research sequence, the research methodology can be easily explained in three sections: pre-fieldwork, fieldwork, and post-fieldwork. Pre-field work includes literature review, case overview, and questionnaire development; fieldwork includes surveys and interviews with professionals. Post-field work includes analysis, interpretation of the result, and finding and finally deriving conclusions and recommendations.

The first step is to review the literature of previously done research work on the topic related to urban flooding, NbS for urban flooding, and the community's adaptive capacity. Hence, detailed research was done to understand the concept of NbS and the adaptation of urban flooding by integrating it. Along with a literature review of the ideas, the case study area was explored to understand its context and relation with research and research problems. The case study area was selected based on the prevalence of the problem of urban flooding.

After completing the literature review and selecting the study area, the semi-structured interview was carried out. The respondents were representative of the stakeholders (citizens, interest groups, and municipality). The interview was conducted to understand their individual and collective role in the local urban flood adaptation in the institutional and local governance context.

The first step of fieldwork is to survey residents in the neighborhood. The questionnaire is developed, but before conducting the survey, sampling was done. Probability sampling was followed to identify the sampling frame, decide on sample size, and choose the sampling technique. As the target population of the survey are the residents in the study area. The sampling frame will include the people of the particular study area residents and derive a sample size for the research where the confidence level of 95% is considered appropriate with a 5% margin error. A simple random sampling technique was followed as it gives the relevant result and helps in the equal selection of the sample cases.
The result from the survey and interviews are analyzed and interpreted in the form of analyses that is further discussed and validated by examining with several respondents simultaneously (Thiel, 2014). Due to the present

context of the pandemic, it was done by email. It is carried out for sequential triangulation as it helps to validate a process with the ultimate objective to demonstrate result obtained is not a mere product of the method used. Validity is fundamental as the research studies subjectivity which can be very misleading if only one source of data collection is relied on.

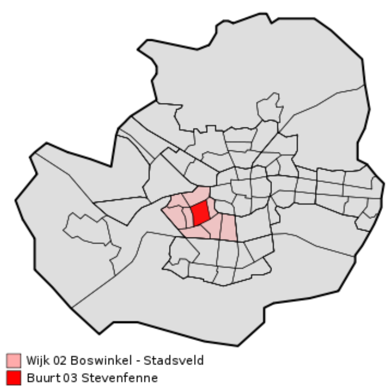
3.2. Case Study

This chapter explains the study area in Enschede City and its significance in the study. From chapter 1, we know that the western area of Enschede is susceptible to urban floods. Recently, in August 2010 and June 2013, many places in Enschede were flooded. Among them, three of the neighborhoods that have complaints of urban flooding were targeted.

3.2.1. Neighborhood selection approach

The municipality, recognizing that the increase in rainfall and urbanization will lead to groundwater nuisance and pluvial flooding, has planned some Nature-based Solutions in those areas. To understand the picture of the local adaptation, three neighborhoods of Enschede were selected from the three most affected districts. Out of a total of 70 communities in Enschede, three were chosen considering the selection of the neighborhood from the three affected districts of Enschede. The criteria to select the three neighborhoods were the low elevated area of Enschede, level of vulnerability to flooding (highly and moderately vulnerable), and the NbS being applied in these neighborhoods on a different scale.

<table>
<tr><th>Lasonder-Zeggelt (Binnensingel District)</th><th>Stevenfenne (Boswinkel Stadsveld District)</th><th>Twekkelerveld (Twekkelerveld THT District)</th></tr>
<tr><td>


</td><td>


</td><td>


</td></tr>
<tr><td colspan="3">Figure 3-1 Selected Neighborhoods of the respective districts</td></tr>
<tr><td>Source: https://nl.wikipedia.org/wiki/Het_Zeggelt</td><td>Source: https://nl.m.wikipedia.org/wiki/Bestand:Map_-_NL_-_Enschede_-_Wijk_02_Boswinkel_-_Stadsveld_-_Buurt_03_Stevenfenne.svg</td><td>Source: https://nl.wikipedia.org/wiki/Bestand:Map_-_NL_-_Enschede_-_Wijk_03_Twekkelerveld_-_T.H.T._-_Buurt_01_Twekkelerveld.svg</td></tr>
</table>

The map below is extracted from the Climate Atlas Twente; the test for extreme showers follows the national standard (from the Delta Plan on Spatial Adaptation) (*Climate Atlas | Twn*, n.d.).

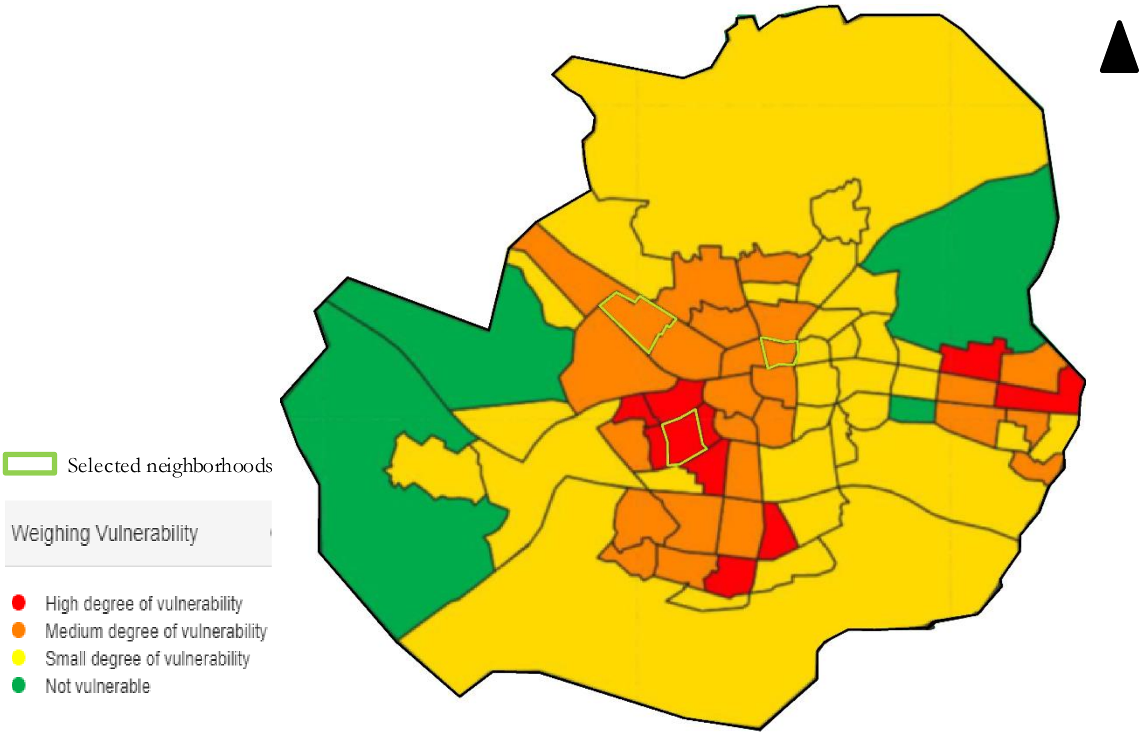


Figure 3-1 Map showing vulnerability of neighborhoods to water logging due to short heavy shower (Climate Atlas | Twn, n.d.)

3.3. General Description of the selected Neighborhoods

Table 3-1 Characteristics of three neighborhoods from Statistics Netherlands (CBS, 2011) and Climate Impact Atlas

	Lasonder-Zeggelt	**Stevenfenne**	**Twekkelerveld**
District	Binnensingel area	Boswinkel Stadsveld	Twekkelerveld THT
Area of neighborhood (Ha)	29	58	85
Number of households	990	2,440	2,350
% of urban green spaces	35.44	27.98	43.38
% of paved space	64.56	72.02	56.62
% of water	0	0	0
Number of inhabitants	1,750	4,505	4,235
Men	910	2310	2170
Women	840	2195	2060
<=15 years	250	675	540
15 - 25 years	320	720	710
25 - 45 years	535	1345	1270
44 - 65 years	400	1160	1025
>=65 years	235	595	685
Population density (per km^2)	6.115	7.809	5.007
Average gross annual income per resident	25,200	17,800	17,800

3.3.1. Lasonder-Zeggelt

3.3.1.1. Urban flood risk areas

According to Climate Atlas Twente some of the areas vulnerable to flood identified were the streets and areas near Lasondersingel, Deurningerstraat, Niermansgang (behind the cemetery), Visserijstraat, Molenstraat, Oldenzalsesstraat, H.B. Blijndensteinlaan, Zeggeltschoolstraat, Dr Benthemstraat, Potgeistraat, Starringstraat. Recently, on May 31 2016, an Elementary School at The Zeggelt at Doctor Benthemstraat 14 observed water over last (*No Ice-Free but Rain-Free: Enschede School Is under Water, No Lesson Today - RTV Oost*, n.d.).

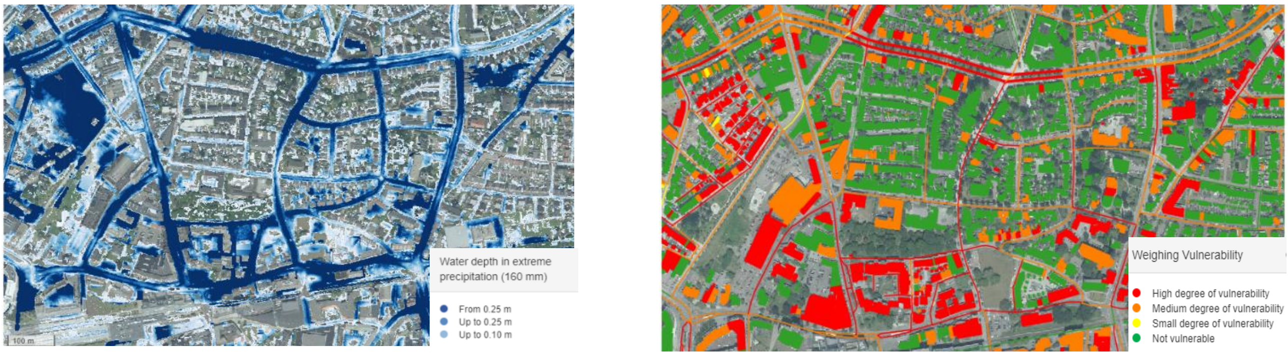


Figure 3-2 Map showing water depth in extreme precipitation (160mm) and vulnerability to heavy shower (right) in Lasonder-Zeggelt and (Source: Climate Atlas Twents waternet, 2021)

Figure 3-3 Images of the street H. B. Blijndensteinlaan that is mostly flooded

3.3.1.2. Refurbishment of Molenstraat in Lasonder – Zeggelt

The Molenstraat that is higher in risk due to the rainwater nuisance is currently being refurbished with various NbS like extra greenery on the sides, 20% less paving, and 58 new trees, twenty wadis with a capacity of 250 cubic meters (Gementee Enschede, 2021). Thus, the risk of flooding will be significantly reduced. Along with the flood control, biodiversity in the street is also maintained and helps get rid of heat stress. This NbS project can bring a tremendous positive influence on the neighborhood.

Figure 3-4 Image of the visualization (left) and in construction (right) of the Molenstraat with cycle street with wadi and green on the side

3.3.1.3. Green Roof in 't Zeggelt

Green roofs are visualized in the newly constructed buildings in 't Zeggelt area. Though there is not much information about climate scan, green roofs might be mandatory water storage in the zoning plan shortly. The Zeggelt area is one of the most flooded areas in the neighborhood; having the green roof based on its type, either extensive or intensive, will help reduce the surface runoff volume and delay the runoff speed and help adapt to the urban flood.

Figure 3-5 Images of visualization of green roof in 't Zeggelt area

3.3.2. Stevenfenne

3.3.2.1. Urban flood risk areas

Stevenfenne is also a hard-hit neighborhood by flooding and waterlogging by rainwater and groundwater nuisance, as the Stadsveld districts lie at the end of a dam on the edge of the center of Enschede, and in addition, during heavy showers, surface water flows from other, higher-lying neighborhoods to Stadsveld. The groundwater nuisance is mainly caused due by *"the high groundwater level, limited storage capacity and permeability of the topsoil, seepage from the second aquifer, presence of shallow separating or interfering layers, poor drainage possibilities, for a short time, heavy precipitation causes peaks in the groundwater level that move with the groundwater flow"* (RIONED & STOWA, 2015, p. 31). According to Climate Atlas Twente some of the areas vulnerable to flood identified were the streets and areas near Zweringweg, Acaciaplantsoen, Benjamin Willem Ter Kuilestraat, Elferinksweg, Haaksbergenstraat, S.L.Louwestraat, Warmoesstraat, Remorsstraat, Tuinbouwstraat, Wicher Nijkampstraat, Gerststraat, Doctor van der Zandestraat. It can be clear from the maps that almost all of the streets are moderately vulnerable to flood. Recently, on August 28, 2010 Haaksbergenstraat was flooded (ClimateScan - Project Detail, n.d.-a).

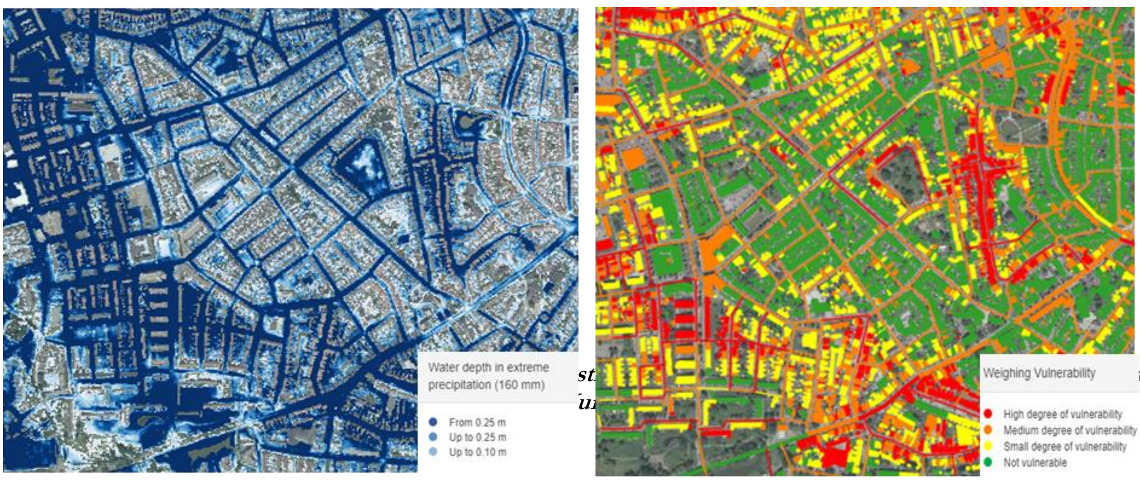


Figure 3-6 Map showing water depth in extreme precipitation (160mm) and vulnerability to heavy shower (right) in Stevenfenne and (Source: Climate Atlas Twents waternet, 2021)

Figure 3-8 Images of some of the streets that are mostly flooded Accaciaplantsoen, Benjamin Willen Ter Kuilestraat

3.3.2.2. Stadsbeek in Elferinksweg

Together with the Vechtstromen Water Board, the municipality has developed NbS like the urban waterway reviving part of the old stream, Stadsbeek. The Stadsbeek is constructed to drain rainwater and drainage water and also the excess groundwater. The drained water is stored in the playground of Pinkeljesplein while the excess water will be supplied to an existing stream located on the outskirts of Enschede (the Usselerstroom). In this way, the groundwater level is sufficiently lowered, and the municipality is taking an essential step in improving the living environment of its inhabitants.

Figure 3-9 Stadsbeek in Elferinksweg

The Stadsbeek as shown in figure 3-8 is designed together with the residents. The construction of the Stadsbeek is in progress, with more trees, plants, and flowers growing along the stream. The residents collaborate by disconnecting the downpipe connected to the wastewater sewer to let the rainwater flow into the stream. Otherwise, rainwater from the roof is flown into the garden, and if the volume of water is overwhelming, it flows into the stream. It will also help to grow all the trees, plants, and flowers in the neighborhood. The characteristic of these streets is that bridges are placed over the stream.

3.3.3. Twekkelerveld

3.3.3.1. Urban flood risk areas

According to Climate Atlas Twente some of the areas highly vulnerable to flood identified were the streets and areas near Bruggenmorsweg, Jupiterstraat, Schietbaanweg, Sterrenstraat, Mercuriusstraat, Perseusstraat, Vennustraat, Planetenstraat, Siriusstraat, Cartostraat, Olieslagweg, Maanstraat, Uranusstraat, Zevensterstraat, Zuiderkruistraat, Regulusatraat, Weegschaalstraat, Van Limborchstraat.

Recently, on June 20, 2013, Jupiterstraat, Mirastraat, Mercuriusstraat, and areas near were flooded (*ClimateScan - Project Detail*, n.d.).

Figure 3-10 Images of flooding areas near Jupiterstraat (ClimateScan - Project Detail, n.d.)

Figure 3-11 Map showing water depth in extreme precipitation (160mm) and vulnerability to heavy shower (right) in Twekkelerveld and (Source: Climate Atlas Twents waternet, 2021)

3.3.3.2. Green Blue Twekkelerveld

Since Twekkelerveld is among ten neighborhoods of Enschede that needs to take action against the flooding municipality is carrying out various water projects in the district of Twekkelerveld. Some of the NbS envisioned in the Twekkelerveld to fight the flooding problems is to introduce greener and less pavement.
Most of the NbS proposed, like the Star Park near the bell church and Healthy Street near the area of G. J Van Heek straat the fragmented and stony outdoor space, removing gray tiles is transformed into a significant, coherent. It will make it look beautiful and maintain a healthy landscape where living, growing up, playing, and caring for each other merge harmoniously.

Figure 3-12 Images showing visualized NbS to be constructed in G.J. Van Heekstraat and Maanstraat

3.3.4. Citizen's participation for implementing NbS by residents in Enschede Municipality

Since 60% of the land in Enschede is privately owned, the municipality to promote NbS by greening and creating space for water in own property need to motivate the residents. The motivation to adopt these measures will depend on the lifestyle of the residents depending on their social status and sentiments. To effectively connect policy and communicate to the residents, Market response with 'Ons Water' mapped six lifestyles.

3.3.4.1. Lifestyle in Enschede

According to the 'Our Water lifestyle finder,' we can find that Enschede is mainly dominated by yellow, blue, and red lifestyles. Yellow and red lifestyle are observed in the selected neighborhoods. Hence, the table below explains the lifestyles in the study area and their factor of motivation to contribute to climate and water-aware actions.

Table 3-2 The major lifestyle in selected neighborhoods (Ons Water & SAMR Martktvinders, 2019)

Lifestyle	Profile	Factor of motivation
The yellow lifestyle (far-from-my-bed show) 	Social, family, and neighborhood oriented. Relatively with low to medium level of education and a young family. ***Twekkelerveld and Stevenfenne*** have maximum residents of this lifestyle.	They can be motivated if they are given information about the social benefits rather than the benefits of NbS for the climate.
The red lifestyle (the committed hedonists) 	Passionate and independent people. Often highly educated and have families with children. ***Lasondr-Zeggelt*** have maximum residents of this lifestyle.	They already have the desired behavior, and no change needs to take place. They are actively involved in the climate and implementation of measures.

3.3.4.2. Project, Policies, and Subsidies to promote NbS by residents

Considering the lifestyles, policies, and subsidies to promote NbS are such that it provides financial help and helps in social and technical assistance. De Groene Loper Enschede, as part of the Groene Loper Overijssel project supports local green (neighborhood) initiatives in Enschede. It helps organize meetings, activities, volunteer support, and advice on subsidies for financing green initiatives.

- **Subsidy: District/ neighborhood budget (Jij Maak de Buurt)**

A resident or residents' organization or group can contact the Groene Loper to get the neighborhood budget to start a local initiative to make the neighborhood greener. Some examples of the innovative green campaigns Bloemenlint provides free flower seeds, constructing facade gardens like in De Laares, Lasonder-Zeggelt neighborhood, creating a nature playground, or preparing urban agriculture (Subsidy and Policy | Green-Blue Enschede, n.d.).

- **Subsidy: Green your school square**

The ambition of the Province of Overijssel is to get all of 600 schoolyards greener before 2025 as green plays an essential role in the physical, mental and social development of children by connecting them with nature. Additionally, it will also contribute to biodiversity and water storage.

3.4. Data Collection

Primary as well as secondary data was collected to achieve the objectives and answer the research questions.

3.4.1. Primary Data

Primary data was collected through fieldwork data collection with the help of maptionnaire and interviews with the use of the online platform of MS- teams. After the sample size and sampling technique have been defined, the survey questionnaire was developed, focusing on the sample cases and following guidelines.

3.4.1.1. Household Survey

Maptionnaire allows downloading the questionnaire data in Excel, so the non-spatial dataset was prepared in Excel, whereas the spatial datasets were prepared in the ArcMap. The dataset contains almost 150 households: 52 from Lasonder-Zeggelt, 55 from Twekkelerveld, and 54 from Stevenfenne neighborhoods in Enschede. The data are representative at the neighborhood (household) level. The questionnaire covers the thematic areas of exposure to flooding, NbS at household scale and neighborhood scale, its benefits and disservices, and the institutions and initiatives to coordinate activities for NbS and preparedness of flood.

3.4.1.2. Interview

The semi-structured interview was conducted to understand the context of the Enschede and understand the stakeholder's role. Their individual and collective role in local urban flood adaptation in the local institutional and governance context.

Table 3-3 Tale showing the experts interviewed for the study

Interviewee Name	Designation	Specialization
Lies Rubingh (External Advisor) Rubingh, L. (ENS-ADV-CSS-COM)	Communication advisor Climate Adaptation at the Municipality of Enschede	Working in communication for Climate Adaptation
Koen Wagelaar Wagelaar, K.H. (ENS-ROB-SO)	Designer Water at the Municipality of Enschede	Working on the design of various NBS in various projects like the "CATCH" Project
Alice Kuil Kuil, A. (ENS-ROB-GP)	Project Manager of Green-Blue Twekkelerveld	Looking after the "Green Blue Twekkelerveld Project"
Nicolette Hogeveen Hoogeveen, N. (ENS-SBF)	Policy advisor biodiversity at the Municipality of Enschede	Working in "Zo Groen" Campaign in Groen Loper Enschede
Lammie Pruntel	Team Manager Space at Municipality of Rijssen-Holten	Started a neighborhood initiative for facade gardens in the Lasonder 't Zeggelt Boddenkamp district

3.4.1.3. Secondary data

The secondary data is collected from the census, documents from the municipality, interactive web-based map tools, websites regarding the urban flood, NbS in the city, and citizens of Enschede.

3.4.2. The questionnaire construction

Based on the literature and the conceptual framework of the research, questions were developed. Questions were designed to understand their experience in living in the neighborhood, Flooding in the area, NbS taken by the residents and the Municipality, mostly visited NbS in the area, participation in projects and initiatives that promotes and looks after the green and blue infrastructure of the neighborhood in the local scale and respondents basic information. The questionnaire was constructed mainly for the residents of the selected areas and was intended to be filled in 20-25 minutes. Since the survey was carried out in the Netherlands, not all the residents were comfortable with English. So, the questionnaire was designed to select their preferred language to fill up the form, i.e., either in English or the local (Dutch) language. The questionnaire, in the beginning, had detailed information regarding the intention of the research and the instruction to fill-up the form. It also included information regarding data privacy, ethical considerations, and their consent.

Similarly, testing of the questionnaire is essential, so a pilot study was done among a few respondents for the revision of questions and reliability and validity (Thiel, 2014). Though the pilot study was done, I changed a few settings in the questionnaire, which later created problems and confused the respondents. There happened to be a decrease in the responses and various issues, which is further discussed in limitations.

3.4.3. The dissemination of the questionnaire

The online questionnaire was constructed using "maptionnaire" platform, as it helps to build the questions in a suitable, exciting, and interactive format. Since it is a map-based questionnaire, it helps to gain the answers from the respondents. It helps to locate various features in the map to help community mapping or participatory GIS get detailed information. It also provided easy and secure means to disseminate as it is entirely GDPR compliant. Its privacy policy terms and conditions are elaborately explained in the respective links: https://maptionnaire.com/customer-privacy and https://maptionnaire.com/customer-terms. Similarly, the questionnaire also included an informed consent which on the very beginning of the questionnaire asked the respondent if they were willing to volunteer as a participant in the study. They were also informed that they could refuse to answer the question and withdraw from the study at any time without having to give any reason.

The questionnaires were disseminated by distributing the leaflets (included in appendix 1) to the houses in the neighborhoods. In total, approximately 2000 leaflets were distributed. The flyers were designed more like an advertisement to make them more appealing for the respondents. The leaflet included the basic information of the research like the topic, the date till which it could be filled up, the link, and the QR-code to fill up the questionnaire. To increase the response rate, it also included the information that if they took the survey, they could win a 25-euro gift voucher from "Dille en Kamille" by participating in the raffle. For more clarity and any help needed to fill up the form, the leaflet also included my mail address and contact, which was helpful as many respondents contacted me when they had confusion.

While distributing the flyers, much care was taken as the fieldwork was carried out during pandemic. It was made sure that none of the Covid -19 restrictions were violated. Proper safety gears like masks and hand sanitizers were used to ensure safety and maintained at least 1.5-meter social distance all the time. Another main thing to consider was not to bother people who do not want to get such flyers. In the Netherlands, people keep JA/ NEE stickers in their residential mailboxes to let the deliverer know if they are willing to get addressed mails (mail intended for a resident in specific address) or unaddressed mails (mail meant for advertising for any neighborhood, which could be a flyer or any other form of promotion). So, it was made sure that leaflets were only dropped in the mailboxes that had JA-JA stickers which meant the resident wishes to receive addressed or unaddressed mails. Whereas mailboxes with NEE -JA and NEE-NEE stickers show they didn't wish to get any unaddressed mails, hence they were omitted.

The survey was carried out from 18th till 30th of April. After completing the study, as an appreciation for the help and with the consent for the participation in the raffle of gift vouchers, the raffle was done on the 1st of June to get ten lucky winners among the interested participants. The selection of the raffle winners among the respondents was made with the help of online raffle software called "Name Picker." The online system was used to have a transparent lucky draw to get random 10 participants from the surveyed neighborhoods to keep it fair and unbiased. The winners were then declared, and all the winners were informed about it through e-mail along with the online gift cards and information regarding how the raffle was done and also, the links were provided to them if they would like to check it. Here, below, the links are provided, which show the selected winners of various neighborhoods.

Link to the winner selection:

- Lasonder: https://commentpicker.com/random-name-picker.php?id=rnp_60b60b89181bd441
- Stevenfenne: https://commentpicker.com/random-name-picker.php?id=rnp_60b60eeb3cc42476
- Twekkelerveld, Tubantia - Toekomst : https://commentpicker.com/random-name-picker.php?id=rnp_60b611d97f3f5251

3.4.4. Research Method

The research is done to achieve four objectives and answer their related questions. A mixed method of both quantitative and qualitative are used to implement the research throughout four stages, corresponding to the four objectives, as illustrated in the figure below. The first objective is to understand the problem of urban floods from people's perspective in the study area is achieved by a detailed literature review, detailed case overview, and analysis. Then, the second objective is to understand the practiced and preferred NbS measures on the sites in relation to objective 1. Then, for the third objective, the adaptive capacity is analyzed in regard to objectives 1 and 2. Finally, objective four is to understand if the co-benefits (like human well-being or biodiversity) of NbS have any relation to adaptive capacity. Hence, the overall objective is to understand the local flood adaptation of neighborhoods with the integration of NbS and its effectiveness.

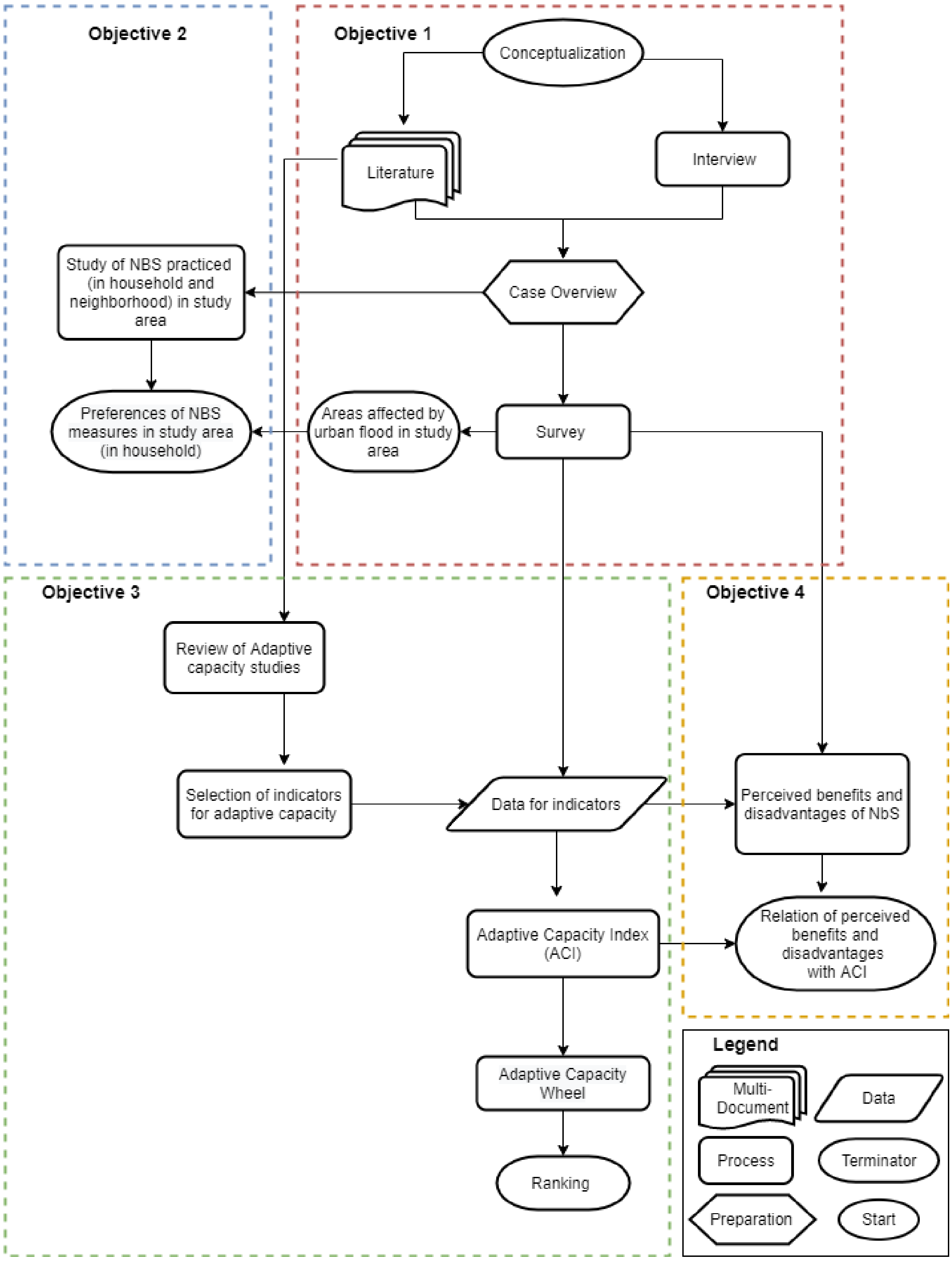


Figure 3-13 Overall flowchart of the overall method

3.4.5. Objective 1: To understand the residents' perception of the urban flood situation and identify areas affected in the focus area.

From the literature review, 160 survey and 4 interviews were carried out in the study area; analysis is performed to identify the places that were primarily flooded. It involves locating the areas that the respondents have pointed out to be mostly flooded. The crosstabulation analysis was carried out to make the observation that was verified the correlation of various relevant variables. Hence, it helps to understand the adaptation's climate-related stimuli (i.e. urban flood) and the concept of **"adaptation to what."**

3.4.6. Objective 2: To identify NbS preferences of NbS in household and at the neighborhood level in the areas affected in the focus area.

Similar to objective 1, the analysis is performed by cross-tabulation along with the verification by correlation matrix to understand the practiced and preferred NbS measures on the sites. Hence, it helps to understand the concept of **"how does the adaptation occur"** by NbS.

3.4.7. Objective 3: To explore adaptive capacity of the neighborhood to urban flooding.

The evaluation of adaptation to urban pluvial flood by NbS is done by assessing the Adaptive Capacity of the neighborhoods. Identification of the adaptive capacity is crucial for the implementation of adaptation strategies (Kruse et al., 2013). This Adaptive Capacity Index (ACI) is calculated for each study area and later compared among all the study areas to better evaluate **"how good is the adaptation."** Here, we discuss how the ACI is calculated. Specifying adaptive capacity indicators

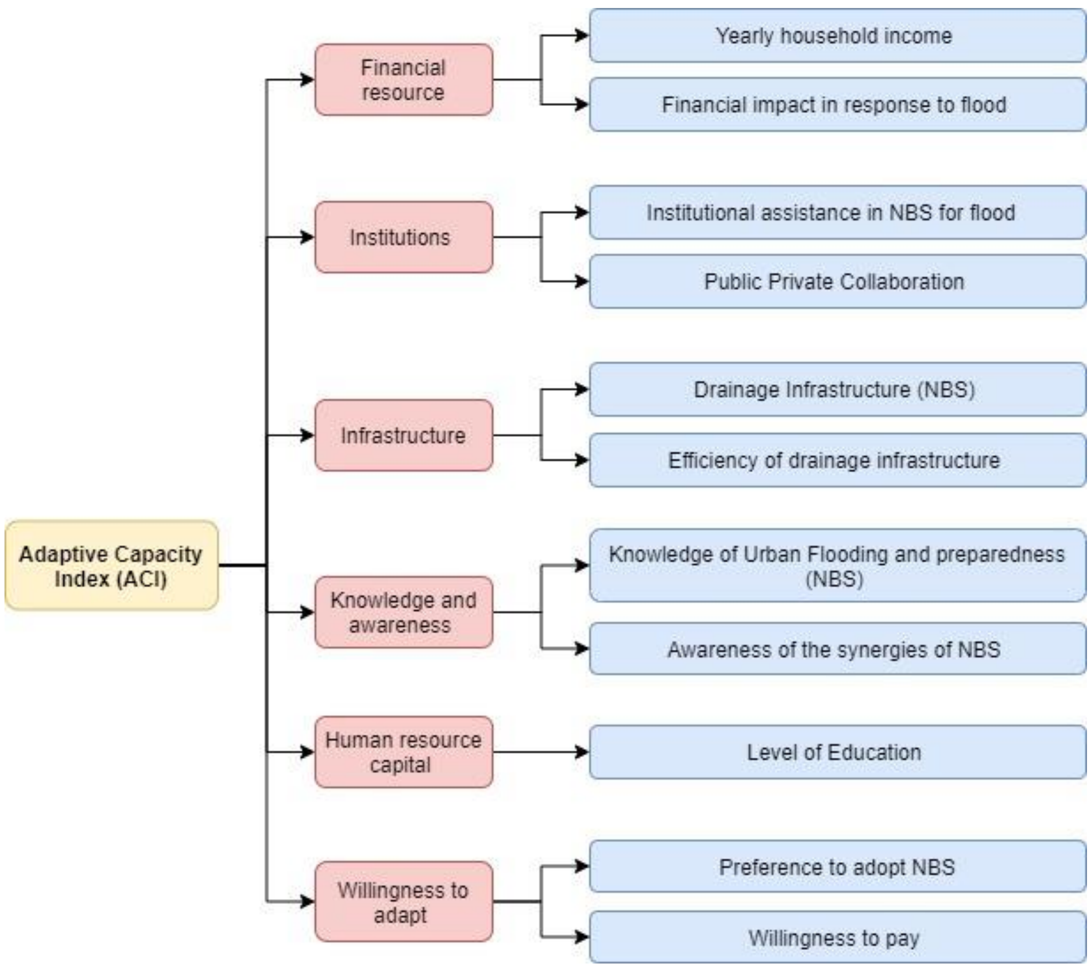


Figure 3-14 Indicators for calculating Adaptive Capacity Index (ACI)

3.4.7.1. Selection of indicators

As explained in the theoretical framework, the adaptive capacity of a household is taken to be an emergent property of the five types of livelihood assets viz. physical, human, natural, financial, and social. Further, following Thanvisitthpon et al. (2020) six components of flood adaptive capacity: economic (financial resources), social capital (institutions, awareness, and training), human resource capital, physical (infrastructure), and willingness to adapt are taken into consideration.

Table 3-4 List of determinants and indicators of Adaptive capacity with its justification

Adaptive Capacity Determinants	Adaptive Capacity Indicators	Justification	Direction of Relation
Economic Capacity (Financial Resource)	Yearly household income	Household incomes play a role in individuals' adaptive capacity in flood prevention and rehabilitation efforts (Thanvisitthpon et al., 2020).	+
	Financial impact in response to flood	The impact of the flood is more pronounced if financial obligations are significant and long-term (Thanvisitthpon et al., 2020).	-
Institutions	Institutional assistance for flood preservation and preparedness (by integrating NbS)	The existence of an institutional environment allows fair access and entitlement to resources (Jones et al., 2019).	+
	Public-Private Collaboration	The system can incorporate and respond to changes concerning its governance structures (ODI, 2010).	+
Infrastructure	Drainage Infrastructure (NbS)	Availability of infrastructure allows the system to respond to the expected stimuli.	+
	The efficiency of drainage infrastructure	Efficient urban floodwater management helps to respond to the flood.	+
Knowledge and awareness	Knowledge of Urban Flooding	The knowledge of flooding and information supports adaption activities for preparedness.	+
	Preparedness against flooding		
Human resource capital	Level of Education (C1)	Education and learning help system to incorporate and respond to changes.	+
Willingness to adapt	Preference to adopt NbS	Willingness to adopt adaptive measures in the household helps respond to changes.	+
	Willingness to pay	Interest for payment for the adaptive measures helps to adopt adaptive measures.	+

3.4.7.2. Calculation of Adaptive Capacity Index (ACI)

Having chosen the theory-driven indicators, it is validated with the appropriate theories, which is explained in its justification in the table 3-5.

Determinants and indicators measuring adaptive capacity per region were retrieved using different types of survey questions (closed/open questions, single/multiple-choice questions, and three or five Likert scales). Now all these indicators are normalized to values within the range of 0 (lowest level) to 1(highest level), so they are directly comparable and can be aggregated. In the study, each indicator's score is calculated as a weighted average indicator (WAI) referred from Thanvisitthpon et al. (2020), as shown in the table 3-7. The weights are assigned according to the importance of the responses from the respondents. To calculate WAI, many assumptions are made, which are clarified in the table.

Once WAI is calculated, aggregation was achieved by equal weighting of the different indicators within each determinant. Similarly, the scores of the six determinants were also aggregated with equal weighting to get a final overall index of Adaptive Capacity based on the literature with equal weighting (Vincent, 2007).

3.4.7.3. Visualization of ACI by Adaptive capacity Wheel (ACW)

While calculating ACI, multiple indicators are aggregated to one value, and again these values are aggregated to six dimensions and finally into one score on a specifying neighborhood's adaptive capacity. However, with increasing aggregation, detail is lost. Thus, Adaptive Capacity Wheels (ACW) helps to clarify the details of such assembly.

The color scheme (traffic light system) refers to Gupta et al. (2010), where green symbolizes a high score and red a low score. The scoring method is maintained from 0-1, where 1 symbolizes positive effect whereas 0 symbolizes negative impact on the adaptive capacity as shown in table 3-6.

Table 3-5 Table showing color and score scheme for the adaptive capacity wheel

Effect on adaptive capacity	Aggregated Scores for dimensions and adaptive capacity as a whole
Negative effect	0 - 0.2
Slightly negative effect	0.21 - 0.4
Neutral or no effect	0.41 - 0.6
Slightly positive effect	0.61 - 0.8
Positive effect	0.81 - 1

Calculation of adaptive capacity score (Weighted Average Indicator)

Table 3-6 Table showing the calculation of Weighted average indicator score

Adaptive Capacity Components	**Adaptive Capacity indicators**	**Calculation of Adaptive Capacity scores (ACS)**
Financial Resources	Yearly household income	WAI = [n1(0.20) + n2(0.40) + n3(0.60) + n4(0.80) + n5(1.00)]/N, where n1, n2, n3, n4, and n5 are the number of respondents is below model, same as modal, about 1.5 times modal, About two times modal, and more than two times modal (Modal: gross €22,000 to 24,000 per year) income groups, respectively. N is the total number of respondents in the neighborhood who responded to the question to this indicator.
	Financial impact in response to flood	WAI = [n1(0.20) + n2(0.40) + n3(0.60) + n4(0.80) + n5(1.00)]/N, where n1, n2, n3, n4, and n5 are the number of respondents with financial impact more than € 400, € 200 - € 400, € 100 - € 200, less than € 100 and € 0, respectively; and N is the total number of respondents in the neighborhood who responded this question.
Infrastructure	Drainage Infrastructure (NbS)	(In Household) WAI =[n1(0) + n2(0.20) + n3(0.40) + n4(0.60) + n5(0.80) + n6(1.00)]/N, where n1, n2, n3, n4, n5 and n6 are the number of respondents with No measures,1, 2, 3, 4 and all 5 (Façade Garden, Rain Barrel, Green roof, Vegetable Garden, Water Passing Pavement) respectively, and N is the total number of respondents in the neighborhood who responded this question.
		(In Neighborhood) WAI =[n1(0) + n2(0.20) + n3(0.40) + n4(0.60) + n5(0.80) + n6(1.00)]/N, where n1, n2, n3, n4, n5 and n6 are the number of respondents with No measures,1, 2, 3, 4 and all 5 (Urban Waterways, Trees and Plants, Wadis, Rainwater Pond, Water passing pavement) respectively; and N is the total number of respondents in the neighborhood.
	The efficiency of drainage infrastructure (NbS)	(In Household) WAI = [n1(0) + n2(0.5) + n3(1)]/N, where n1, n2, and n3 are the number of respondents with No measures, measure with 💧low and 💧💧moderate effectiveness respectively; and N is the total number of respondents in the neighborhood.
		(In Neighborhood) WAI = [n1(0) + n2(0.33) + n3(0.67) + n4 (1)]/N, where n1, n2, n3, and n4 are the number of respondents with No measures, measure with 💧low, 💧💧moderate and 💧💧💧 high effectiveness respectively. N is the total number of respondents in the neighborhood.
Institutions	Institutional assistance in NbS for flood	WAI= Respondents answer to questions related to assistance related to NbS, where yes will be scored one and no 0 then quantified in average score 0 to 1
	Public-Private Collaboration	WAI= Respondents answer to questions related to the participation in NbS projects, where yes will be scored one and no 0 then quantified in average score 0 to 1

Adaptive Capacity Components	**Adaptive Capacity indicators**	**Calculation of Adaptive Capacity scores (ACS)**
Knowledge and Awareness	Knowledge and Experience of Urban Flooding	WAI= Respondents answer to few questions related to experience in flooding, area flooded, cause of the flood, where yes will be scored one and no 0 then quantified in average score 0 to 1
	Preparedness against flooding	WAI = Respondents answer few questions related to the action for prevention of flooding, in household level, if they can answer it will be scored one and if they don't know it will be cut 0 then quantified in average score 0 to 1
Human resource capital	Level of Education	WAI = [n1(0.20) + n2(0.40) + n3(0.60) + n4(0.80) + n5(1.00)]/N, where n1, n2, n3, n4, and n5 are the number of respondents with No completed education, Elementary School, High School, Middle - level applied education (MBO in Dutch), Higher Professional Education (HBO in Dutch), University (WO in Dutch) education level, respectively. N is the total number of respondents in the neighborhood.
Willingness to adapt	Preference to adopt NbS (HH) & (N)	WAI = [n1(0.20) + n2(0.40) + n3(0.60) + n4(0.80) + n5(1.00)]/N, where n1, n2, n3, n4, and n5 are the number of respondents who willingness to adapt no measures, 1, 2, 3, 4 and 5 measures, respectively in household and neighborhood; and N is the total number of respondents in the neighborhood.
	Willingness to pay	WAI = [n1(0.20) + n2(0.40) + n3(0.60) + n4(0.80) + n5(1.00)]/N, where n1, n2, n3, n4, and n5 are the number of respondents with € 0 and don't know, less than € 5, , € 5 - € 15, € 15 - € 25 more than €25 willingness to pay, respectively; and N is the total number of respondents in the neighborhood.

Here,
N is the total number of respondents who answered questions related to those indicators.

3.4.8. Objective 4: Analyze various benefits and disservices of NbS and its relation with adaptive capacity.

For further evaluation of **"how good is the adaptation,"** the relation of adaptive capacity is analyzed with the perceived benefits and disservices of NbS. For this, data regarding respondent's perception of the benefits and disservices of the mentioned NbS at the household and neighborhood level were analyzed by cross-tabulation. Then, to better evaluate, the ACI and its relation to the sum of perceived benefits and disservices are compared among neighborhoods to get a clear picture.

3.5. Ethical Consideration

The research mainly depends on the personal data obtained from the participation of human subjects from surveys and interviews. These personal data are treated as very confidential. It is ensured that the information provided by any respondents is not misused through this research and to make the data subject (respondents and stakeholders) assure of it the introduction in the survey form explains about the data confidentiality and how the data will be used.

The survey forms were only distributed after the ITC Ethics Committee approved it by successfully filling up the MSc Research Ethics questionnaire. In this the explanation of ethical approach regarding sensitive data like the name, identification number, and location was given. According to the description given to ITC Ethics committee, the personal data are kept confidential and even if the data subjects have a problem with it, they have the right to be forgotten and the right to erasure. With the agreement of ITC Ethics committee suggestions, Informed consent were provided to the respondents. If the data subjects permit the information, it will be recorded by an explicit statement in the informed consent form.

Further, data were collected respecting the dignity and background of people involved in the research avoiding offensive and discriminatory language. Considering the situation of pandemic, safety was kept in priority of the respondents. While researching, various other researchers' works are also referred to, which is acknowledged with proper citation and references, avoiding plagiarism issues.

4. RESULT AND ANALYSIS

This chapter elaborates the findings of the conducted survey with the residents of the selected neighborhoods. Appendix 2 shows the constructed questionnaire. The questionnaire were completed by residents living in Lasonder- Zeggelt, Stevenfenne, and Twekkelerveld and the area of Enschede.

4.1. Objective 1: To understand the residents' perception of the urban flood situation, and identify areas affected in the focus area

This section discusses the status of urban floods and the risk areas from the comparative presentation of residents' perception of three study areas. It reviews urban flooding, areas where it occurs more often, its cause, related problems, and actions taken against it obtained from the survey.

4.1.1. Experience of urban flood

In Lasonder-Zeggelt, only a few 20% of respondents have experienced flood in their street, garden, and basement. In Stevenfenne, almost 30% have experienced flood, mostly in their garden and street. A few of the resident's parking lots and basements (also mentioned crawl space under the house, alley, and shed) get flooded. At the same time, a maximum number of respondents in Twekkelerveld, i.e., more than 65% of respondents have experienced a flood, mostly in their streets. Some also mentioned that their shed and garage were flooded.

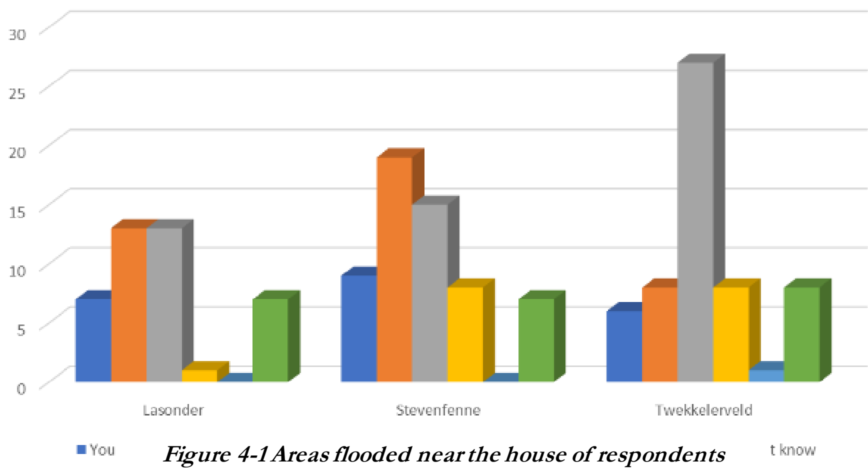


Figure 4-1 Areas flooded near the house of respondents

Further, the correlation matrix helps us to clarify the experience of floods in the neighborhoods. From the matrix, it is clear that in Lasonder-Zeggelt, the people living here between 5-10 years have a positive correlation with the experience of the flood, which means they have experienced more flood. In contrast, in Stevenfenne and Twekkelerveld, people living there for more than ten years seem to have experienced more floods as it is moderately positively correlated.

Table 4-1 Correlation matrix of years of people living in the neighborhood with the experience of flood.

Experienced flooding	Lasonder	Stevenfenne	Twekkelerveld
Less than 5 years	-0.20	-0.35	-0.51
5 - 10 years	**0.44**	-0.05	-0.09
More than 10 years	-0.36	**0.42**	**0.52**

4.1.2. Flooded areas

Based on the results of the correlation matrix, another correlation was done with only the relevant group of people, i.e., between people who have experienced flooding and most flooded area. In Lasonder-Zeggelt, home or basement and garden are seen positively correlated with the experience of flooding. In contrast, in Stevenfenne, the basement, street, and parking lot are more positively correlated. Similarly, Twekkelerveld has a moderately positive correlation with the streets as mostly flooded. The results derived from the cross-tabulation are the same as the correlation matrix. This means people living in Lasonder – Zeggelt believe they experience more flood in basement and garden, in Stevenfenne streets and parking lot are more flooded whereas in Twekkelerveld streets are more flooded.

Table 4-2 Correlation matrix of perceived flooded areas around the house with years of people living in the neighborhood and the experience of flood

Neighborhood	Mostly Flooded	Home or basement	Garden	Street	Parking lot
Lasonder-Zeggelt	Experienced flooding (Yes)	**0.67**	0.06	0.17	-0.07
	5 - 10 years	-0.14	**0.35**	0.07	-0.05
Stevenfenne	Experienced flooding (Yes)	0.18	0.08	**0.38**	**0.34**
	More than 10 years	**0.21**	-0.03	**0.29**	0.16
Twekkelerveld	Experienced flooding (Yes)	0.01	0.19	**0.56**	0.30
	More than 10 years	-0.04	0.16	**0.50**	0.26

4.1.3. Flooded areas in relation with the perceived cause of urban flooding

The respondents could quickly locate the affected areas on the map by relating the survey responses of the respondents' perception of flooded areas in maptionnaire. According to the survey and area found and mentioned in the maptionnaire, the flooded area in study areas identified is shown in the heat maps. Here, the perceived causes are observed in relation to flooded areas.

In Lasonder-Zeggelt, some people also experience groundwater nuisance due to high groundwater levels. Almost 23% of them believe the leading cause for the flood here is poor drainage structure. While some also believe that the green spaces are not just inadequate but also not enough. A respondent who has been living in the study area for more than 20 years said that *"The cause of the water problem is well known, the presence of an impermeable layer that is in some parts (and mostly just outside the area of your survey) is present at little depth. An example is an area along the Museumlaan and its surroundings."*

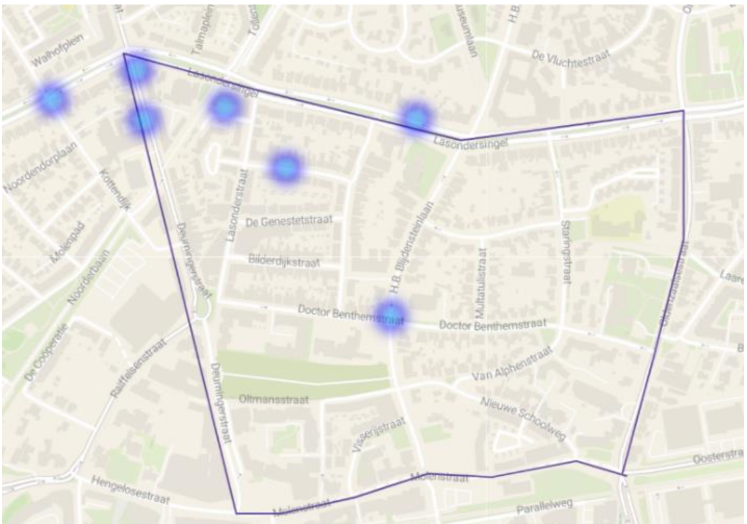


Figure 4-2 Heat Map showing the responses for located areas flooded in Lasonder-Zeggelt

In Stevenfenne, 23% of respondents believe the leading cause of the flood is poor drainage structure, and around 20% consider it due to excessive rain. Only 14% and 11% of the respondents think that the green spaces are inadequate, and the impermeability is the cause for flooding, which seems to be one of the major causes. Of 12% of respondents, one who believes the flooding is because of high groundwater level explained the reason being *"One of the lowest places in Enschede; when the textile industry left they didn't use water anymore which caused the water level to rise."* Also, a respondent living in the study area for more than ten years believes that the flooding is mainly caused by the poor drainage *"In renovations, do not consider drainage in gardens, so that water does not run off."*

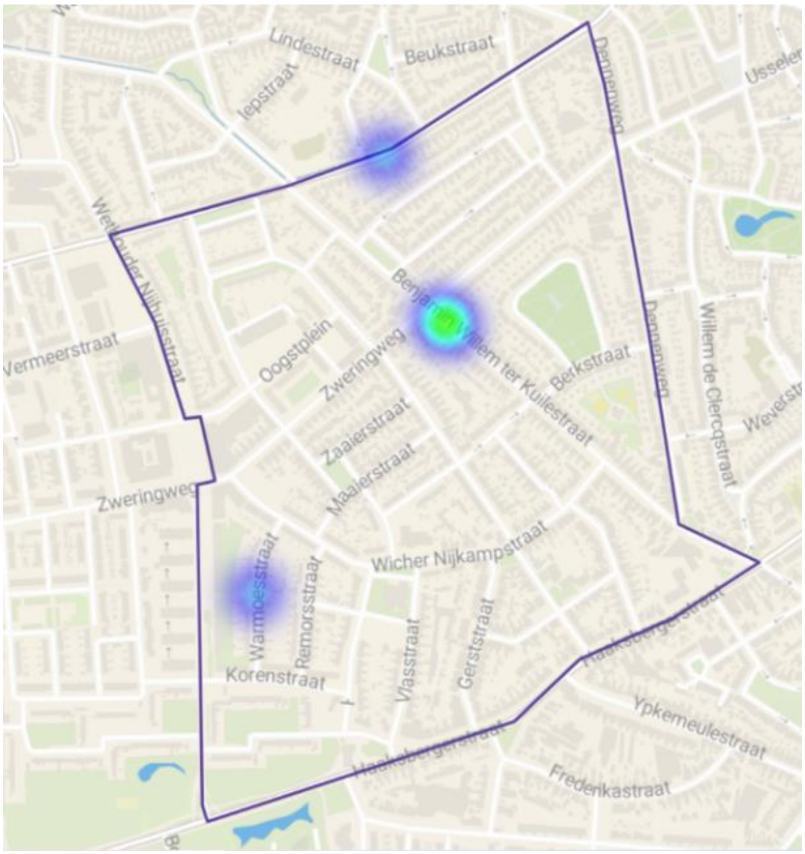


Figure 4-3 Heat Map showing the responses for located areas flooded in Stevenfenne

In Twekkelerveld, more than 40% of respondents believe the leading cause of the flood is poor drainage compared to other reasons like excessive rain, inadequate green spaces, and impermeability. Very few respondents, only around 10%, believe that flooding is caused due to high groundwater levels. As per responses, one of the respondents living in the study area for more than ten years clearly explained that the flooding is because *"All of Enschede's water runs through twekkelerveld, sewers can't cope, and twekkelerveld is low."* Similarly, two of the respondents living here more than ten years also mentioned its because of lack of maintenance of drains as they said the causes to be *"Failure to clean the manholes on the street and the thresholds on the street where water remains between them," "And people should keep the state gullies leaf and debris free or call the municipality when they are full. This can also prevent nuisance."* Description of the flooded areas given by the respondents explains how flooding is one of the severe issues of the Twekkelrveld like; one of the respondents who have been living in the area for more than ten years explained: *"GJ van Heekstraat and surroundings. The water then flowed through the GJ van Heekstraat from the city towards Hengelo. Sometimes even small boats sailed through. With us, it never came into the house, fortunately".*

From the correlation matrix 4-3, it is clear that people affected by flood in Lasonder-Zeggelt tend to perceive the cause of flood to be more because of poor drainage and high groundwater level. Similarly, in Stevenfene poor drainage and high groundwater level and Twekkelerveld excessive rain and poor drainage.

Table 4-3 Correlation matrix of perceived cause of flood with people who have experienced flood

Causes of flood		Excessive rain	Inadequate green spaces	Poor drainage structure	Impermeability	High ground-water level
Lasonder-Zeggelt	Experienced flooding (Yes)	0.14	0.03	**0.36**	0.14	**0.50**
Stevenfenne	Experienced flooding (Yes)	0.14	0.02	**0.26**	0.11	**0.18**
Twekkelerveld	Experienced flooding (Yes)	**0.19**	0.04	**0.33**	0.01	-0.13

4.1.4. Problems due to flooding and actions taken to overcome

In Lasonder-Zeggelt, not many people have experienced flooding and more than 50% of those affected by flooding act to it. Some residents also make sure they regularly clear debris from drains and ditches, point down pipe away from the house, and few of them have also installed foundation vents, sump pumps, or dehumidifiers for the problem of wet basements.

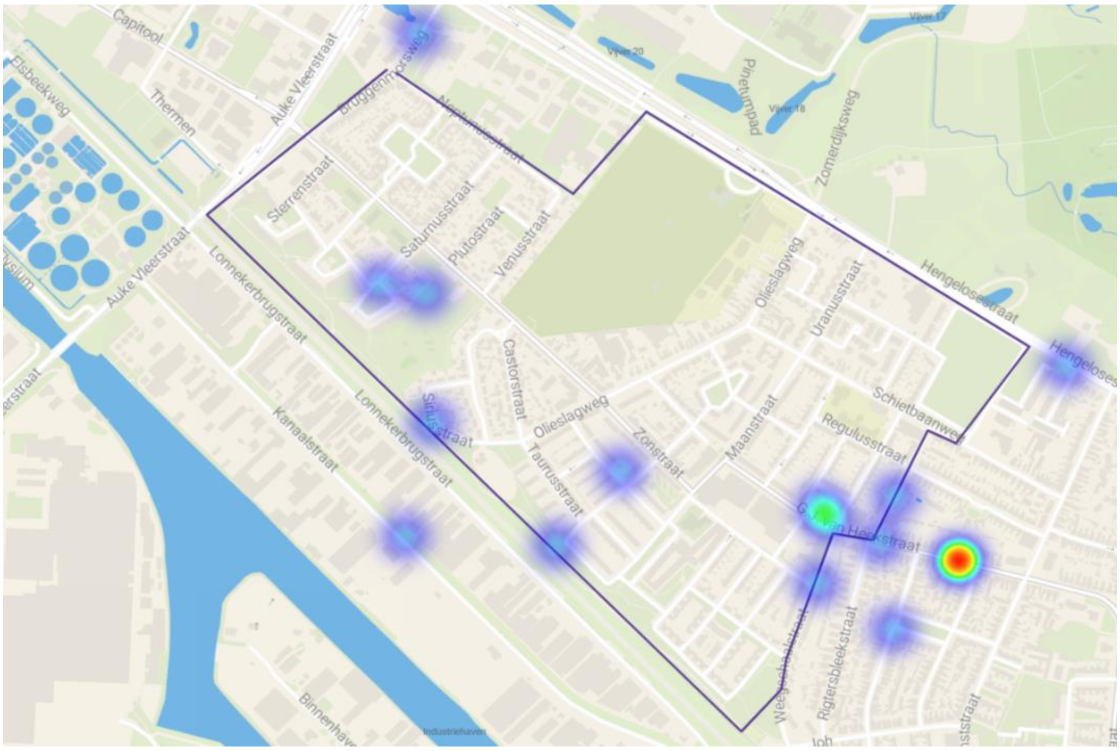


Figure 4-4 Heat Map showing the responses for located areas flooded in Twekkelerveld

An elderly respondent living in Dacostastraat whined, *"Basement wet even without rainfall and streets were full of severe rainfall. Now I use a dehumidifier. Every three days we need to empty it. A few years ago, it was not necessary."*

In Stevenfenne, most of the residents are not much aware of the causes and ways of dealing with the flooding at the resident level. So, when asked if they take action to tackle the flooding, almost 48% said they do not take any action, while 45% said they act. Among people who say they take action when asked about what they do, there are almost 25% who do not know what to do. However, nearly 45% install green and blue measures, as some of the residents surveyed explain they replaced stones in the garden with plants. Some residents of almost 19% make sure they regularly clear debris from drains and ditches. A respondent explained that he sweeps water too well with the broom. 11% of respondents point downpipes away from the house, and one of them said, *"Have had the tiles in the aisle laid as a gutter towards the street so that the water is directed to the street."*

In Twekkelerveld, the response was 50-50 who do and do not take any action personally to prevent flooding in their residence. Among people who take action, 45% install green and blue measures, and it is also clear from the direct observation that most houses have gardens with plants and gravel. One of the respondents explained that having *"Fewer stones, more green grass in the garden."* Also, 33% make sure they regularly clear debris from drains and ditches. A respondent explained, *"I keep the street gully in front of our house clean."* Around 8% of respondents point downspout away from the house. Only in Twekkelerveld, 4% have installed water sensors or flood detection systems.

From the correlation matrix, it is clear that people affected by flood in Lasonder-Zeggelt, Stevenfenne and Twekkelerveld tend to clear the debris regularly.

Table 4-4 Correlation matrix of actions taken to prevent flood with years of people living in the neighborhood and the experience of flood

Action taken to prevent flood		**Point downpipes away from the house**	**Install green and blue measures**	**Install water sensors or flood detection systems**	**Regularly clear debris from drains and ditches**
Lasonder-Zeggelt	Experienced flooding (Yes)	**0.29**	-0.10	0.01	**0.41**
	5 - 10 years	-0.05	-0.07	**0.17**	**0.35**
Stevenfenne	Experienced flooding (Yes)	0.04	-0.02		**0.39**
	More than 10 years	**0.11**	-0.12		**0.10**
Twekkelerveld	Experienced flooding (Yes)	0.14	0.08	-0.19	**0.19**
	More than 10 years	-0.02	0.16	-0.15	**0.36**

4.2. Objective 2: To identify NbS preferences of NbS in households and at the neighborhood level in the areas affected in the focus area.

This section explains the status of NbS practiced and preferred in three neighborhoods. While the results of the perception of residents over NbS practiced, preferred, willingness to accept it, and participation in the implementation of NbS for urban flood adaptation are obtained from the survey. All these are compared among the three neighborhoods.

4.2.1. NbS practiced at the household level

If we see, Lasonder-Zeggelt has the highest percentage (95%) of people adopting NbS. In contrast, Twekkelerveld (17%) and Stevenfennne (13%) have more dwellings not taking any measures to control stormwater. The green roof is already practiced in the residences in Lasonder (16%), whereas in Twekkelerveld, none of the residents have it, and in Stevenfenne (1.2%), few percent of houses have it. Almost all three neighborhoods have a remarkable percent of permeable pavement. Rain barrel also being the cheap measure all the neighborhoods have many percent. Most of the household in Lasonder-Zeggelt (31%) are practicing façade garden while most of the households of Stevenfenne (30%) and Twekkerlerveld (23%) are practicing permeable pavement.

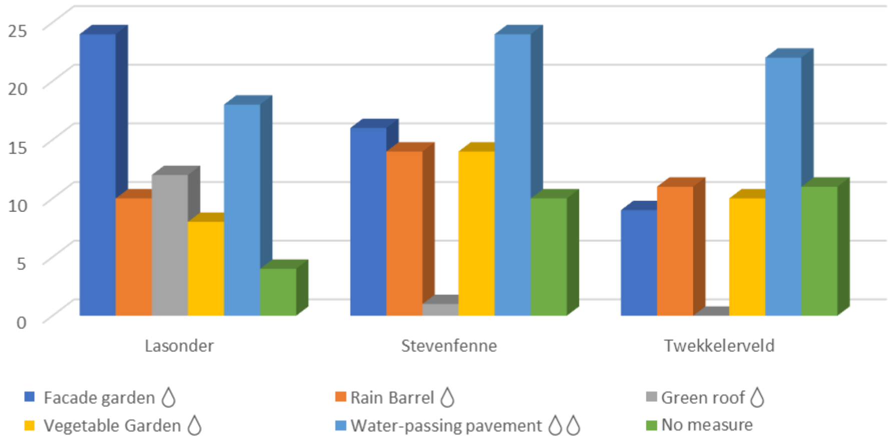


Figure 4-5 Graph showing NbS practiced in household level

4.2.1.1. NbS preferences in household level

Some residents (3.6%) in Stevenfenne do not know any adopt measures. Rain barrels and passing water pavement being cheap and easy people prefer it more in all the neighborhoods. Similarly, people in Lasonder would like to have more green roofs because of their lifestyle. Likewise, the other two areas also want green roofs but lesser than Lasonder.

4.2.1.2. NbS preferences in household level in relation with mostly flooded places around the house

From the correlation matrix, it is clear that in Lasonder-Zeggelt, those who believe their basement is flooded prefer Façade garden more, whose gardens are flooded prefer all the NbS except vegetable garden, whose streets are flooded prefer Vegetable garden, whose Parking lot is flooded prefer Green roof.

Table 4-5 Correlation matrix of preference of NbS with the flooded area in Lasonder-Zeggelt

Preferences of NbS in Lasonder-Zeggelt	Mostly Flooded - home or basement	Mostly Flooded Garden	Mostly Flooded Street	Mostly Flooded -Parking lot
Facade garden	0.09	0.07	-0.21	-0.10
Rain Barrel	0.00	0.22	0.13	-0.12
Green roof	0.00	0.13	0.04	0.16
Vegetable Garden	-0.05	-0.05	0.23	0.19
Water-passing pavement	0.00	0.22	0.13	0.16

Similarly, in Stevenfenne, those who believe their basement is flooded prefer vegetable garden, water- passing pavement, whose gardens are flooded prefer rain barrel and green roof, whose streets are flooded prefer facade garden, whose Parking lot is flooded prefer rain barrel.

Table 4-6 Correlation matrix of preference of NbS with the flooded area in Stevenfenne

Preferences of NbS in Stevenfenne	Mostly Flooded home or basement	Mostly Flooded Garden	Mostly Flooded Street	Mostly Flooded-Parking lot
Facade garden	0.21	-0.16	0.32	0.12
Rain Barrel	0.05	0.20	0.04	0.21
Green roof	0.03	0.24	0.01	-0.21
Vegetable Garden	0.18	-0.01	0.19	-0.14
Water-passing pavement	0.22	-0.10	0.01	-0.07

Similarly, in Twekkelerveld, those who believe their basement is flooded prefer the Green roof, whose gardens are flooded prefer all NbS except the green roof, whose streets are flooded prefer all NbS.

Table 4-7 Correlation matrix of preference of NbS with the flooded area in Twekkelerveld

Preferences of NbS in Twekkelerveld	Mostly Flooded home or basement	Mostly Flooded Garden	Mostly Flooded Street	Mostly Flooded-Parking lot	Mostly Flooded-Playground
Facade garden	-0.08	0.21	0.13	0.09	-0.08
Rain Barrel	-0.08	0.09	0.13	-0.02	-0.08
Green roof	0.22	-0.11	0.14	0.01	-0.08
Vegetable Garden	-0.15	0.10	0.16	-0.04	-0.06
Water-passing pavement	0.00	0.26	0.17	-0.07	-0.09

4.2.2. NbS practiced at the neighborhood level by the municipality

The NbS here discussed here are in different phases of their construction and implementation, which helps to understand the involvement of citizens in the planning, construction, and implementation process. Here the driver of the change and leading actor is the municipality.

4.2.3. NbS preferences in the neighborhood level

In all three study areas, people prefer trees and plants as these are perceived to be visually attractive and effective in flood prevention. People in Twekkelerveld feel that they should have more rainwater ponds (19%) and urban waterways (18%). In Stevenfenne, people (27%) think there is lack of measures and want to have water passing pavement more.

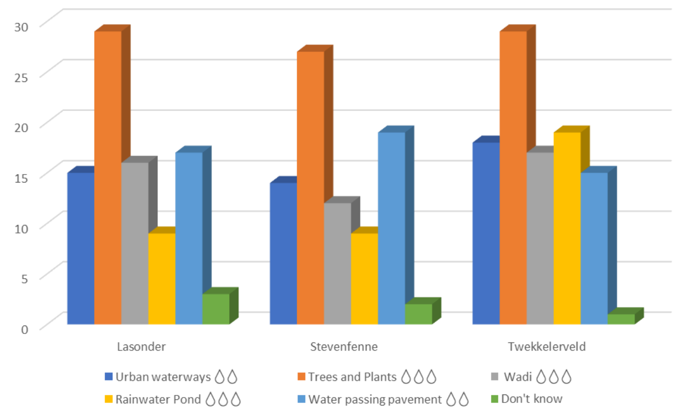


Figure 4-6 Graphs showing NbS preferences in neighborhood leve

4.2.3.1. NbS preferences in neighborhood level in relation to willingness to pay

From the cross table below, it is clear that the NbS preference corresponds to the willingness to pay. In Lasonder-Zeggelt, most respondents are willing to pay more than € 30 for trees and plants (maximum)and €10-20 for urban waterways. In Stevenfenne, they are willing to pay 10-20 for trees and plants (top) and less than € 10 for urban waterway and water passing pavement. In Twekkelerveld, most people pay € 10-20 for trees and plants (maximum) and water-passing pavement.

Table 4-8 Cross-tabulation of Preference of NbS in neighborhood and willingness to pay

Row Labels	Urban waterways	Trees and Plants	Wadi	Rainwater Pond	Water passing pavement	Don't know
Lasonder	**15**	**29**	**16**	**9**	**17**	**3**
€ 0	1	3	1	0	2	0
< € 10	2	5	2	0	2	1
€ 10 - € 20	5	6	2	3	3	0

€ 20 - € 30	0	2	3	1	3	0
> €30	5	8	5	4	4	0
Don't know	0	2	1	1	1	2
(blank)	2	3	2	0	2	0
Stevenfenne	**14**	**27**	**12**	**9**	**19**	**2**
€ 0	3	3	3	2	4	1
< € 10	4	6	4	3	2	0
€ 10 - € 20	2	7	1	2	4	0
€ 20 - € 30	2	4	1	1	3	0
> €30	1	1	0	0	0	0
Don't know	2	4	3	1	3	1
(blank)	0	2	0	0	3	0
Twekkelerveld	**18**	**29**	**17**	**19**	**15**	**1**
€ 0	2	3	1	2	1	0
< € 10	1	4	2	2	2	0
€ 10 - € 20	4	8	4	5	6	1
€ 20 - € 30	4	5	4	4	1	0
> €30	2	3	2	2	3	0
Don't know	5	6	4	4	2	0
(blank)						
Grand Total	**47**	**85**	**45**	**37**	**51**	**6**

4.2.4. Citizen's Participation in NbS in the neighborhood level

All the study areas have NbS being constructed, and some are planned to be constructed shortly. Most of the respondents of all three study areas are well informed about the work and progress with the newsletter, leaflets, etc. Most of the respondents in Lasonder were observed participating actively in suggesting possible solutions. However, they were not much consulted, whereas in Stevenfene and Twekkelerveld, they were consulted more, but they give fewer suggestions.

4.2.5. Factors of motivation to participate in adopting NbS

In all three study areas, people do not know what motivates them to adopt NbS but believe that minor time-consuming procedures can encourage them. People in Lasonder prefer accessible communication (20%) rather than assurance of financial and technical assistance (8%), while in Stevenfenne (23%) and Twekkelerveld (18%), people prefer financial and technical assistance.

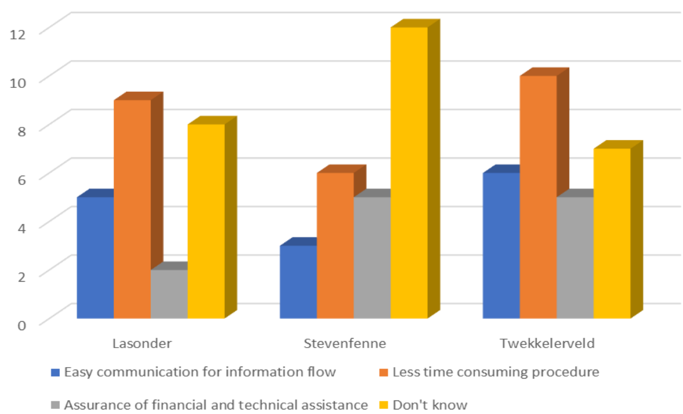


Figure 4-7 Graph showing the perceived factor of motivation for the study areas

4.3. Objective 3: To explore adaptive capacity of the neighborhood to urban flooding.

This section explains the assessment of adaptive capacity with the help of the Adaptive Capacity Index (ACI) calculated for each neighborhood as described in the method in chapter-4. The result of scores of various determinants, indicators, and overall ACI is expressed with the help of the analytical tool of the "Adaptive Capacity Wheel" (ACW) as there are not many exclusive tools to assess the various determinants of the AC. The case studies are explained in terms of ACW reviewing the capacity performance to adapt to urban pluvial flood in the neighborhood of Lasonder-Zeggelt, Stevenfenne, and Twekkelkerveld concerning NbS. It also helps to communicate the strength and weaknesses of a specific area in its various components.

4.4. Adaptive Capacity Wheel

4.4.1. Lasonder- Zeggelt (ACI = 0.65)

According to the adaptive capacity wheel in figure 4-8 overall ACI expresses that the neighborhood has a slightly positive result of being adaptive to the flood integrating NbS, and it scores highest among the three areas. Also, there are no determinants or indicators that have a negative impact on adaptive capacity. Among all the determinants, having "Human resource capacity" has a highly positive effect on the adaptive capacity since the maximum number of the respondents here are at the university level, and almost all are well educated. Other determinants having slightly positive effect are "Knowledge and Awareness" as most of the people are very much aware of the flood risks and with "Financial resource" most of the respondents have more than two times the modal. In contrast, there are comparatively fewer people having income below modal and less financially impacted due to flood.

Nevertheless, the determinants that are related to NbS do not have any effect on adaptive capacity. Though NbS as drainage infrastructure is slightly practiced, the efficiency of those infrastructures to prevent flooding is not so good. "Institutional Capacity" also does not affect the adaptive capacity as it scores less in both public-private collaboration and even institutional assistance in NbS. Even people are unwilling to adapt as they have moderate no. of preference to adjust and less willingness to pay.

Table 4-9 Summary of the scores of determinants, indicators, and Adaptive capacity index of Lasonder - Zeggelt

Determinants	Adaptive Component Score (ASC)	Indicators	Indicator Score
Financial Resource	0.75	Yearly household income	0.68
		Financial impact in response to flood	0.83
Infrastructural Capacity	0.49	Drainage Infrastructure (NbS)	0.43
		Efficiency of Drainage Infrastructure	0.55
Institutional Capacity	0.55	Institutional Assistance in NBS	0.59
		Public-Private Collaboration in NBS	0.52
Knowledge and Awareness	0.73	Knowledge of flood	0.85
		Preparedness	0.61
Human Resource Capacity	0.86	Education and learning	0.86
Willingness to adapt	0.59	Preference to adopt NbS	0.51
		Willingness to pay for NbS	0.57
Overall Adaptive Capacity Index (ACI)			0.65

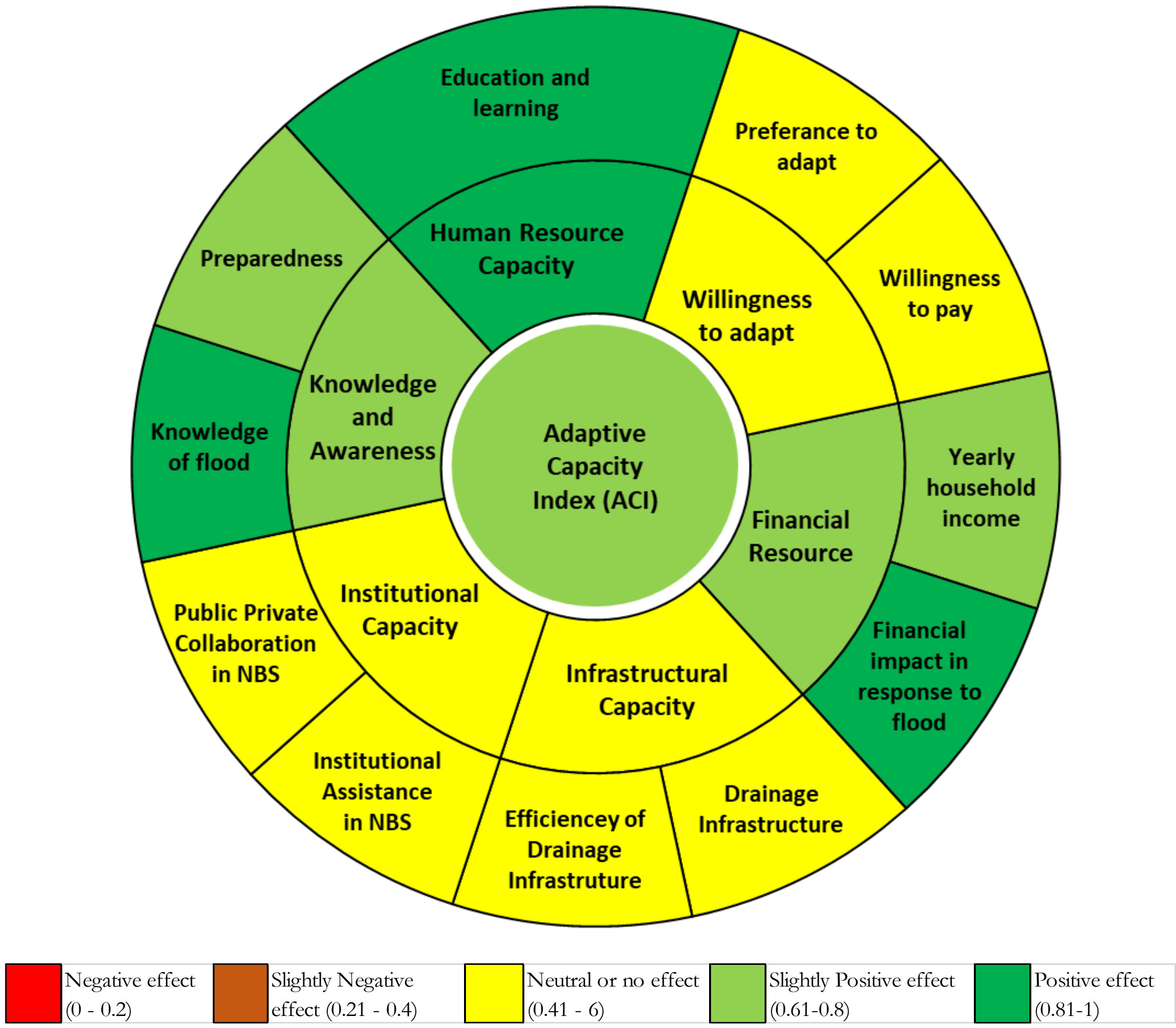


Figure 4-8 Adaptive capacity wheel of Lasonder-Zeggelt

4.4.2. Stevenfenne (ACI = 0.55)

From the calculation of ACI, it was found out that it scored the least with 0.55 among all three neighborhoods. From the wheel in figure 4-9, it is observed that the determinant "willingness to adapt" has a slightly negative effect on the AC with the minor scoring indicator "willingness to pay" as people here were not willing to pay to adopt NbS in their house or neighborhood. Similarly, the determinant of "infrastructural capacity" does not affect AC. Its indicator of NbS as drainage infrastructure was observed to negatively impact as most of the residents here barely have NbS measures in their houses. However, the efficiency of the little NbS practiced is good, so it has a positive effect on AC. Similarly, the determinant of "institutional capacity" has no impact in AC as less score can be observed in indicator of "public-private collaboration in NbS" and "institutional assistance in NbS" as people seem to be less aware and interested in such collaboration and initiatives for adopting NbS. In contrast, it is seen that people are aware of the flood and have good knowledge but however are not well prepared for it, which shows that the determinant of "knowledge and awareness" has a slight positive effect on adaptive capacity. Also, "human resource capacity" is observed to have a positive effect as the people are well educated. The determinant of "financial resource" shows no effect on adaptive capacity as the average household income scores low; however, the financial impact by the flood is low.

Table 4-10 Summary of the scores of determinants, indicators and Adaptive capacity index of Stevenfenne

Determinants	Adaptive Component Score (ASC)	Indicators	Indicator Score
Financial Resource	0.54	Yearly household income	0.42
		Financial impact in response to flood	0.67
Infrastructural Capacity	0.50	Drainage Infrastructure	0.35
		Efficiency of Drainage Infrastructure	0.66
Institutional Capacity	0.47	Institutional Assistance in NBS	0.55
		Public-Private Collaboration in NBS	0.38
Knowledge and Awareness	0.67	Knowledge of flood	0.87
		Preparedness	0.47
Human Resource Capacity	0.69	Education and learning	0.69
Willingness to adapt	0.40	Preference to adapt	0.42
		Willingness to pay	0.39
Overall Adaptive Capacity Index (ACI)			0.55

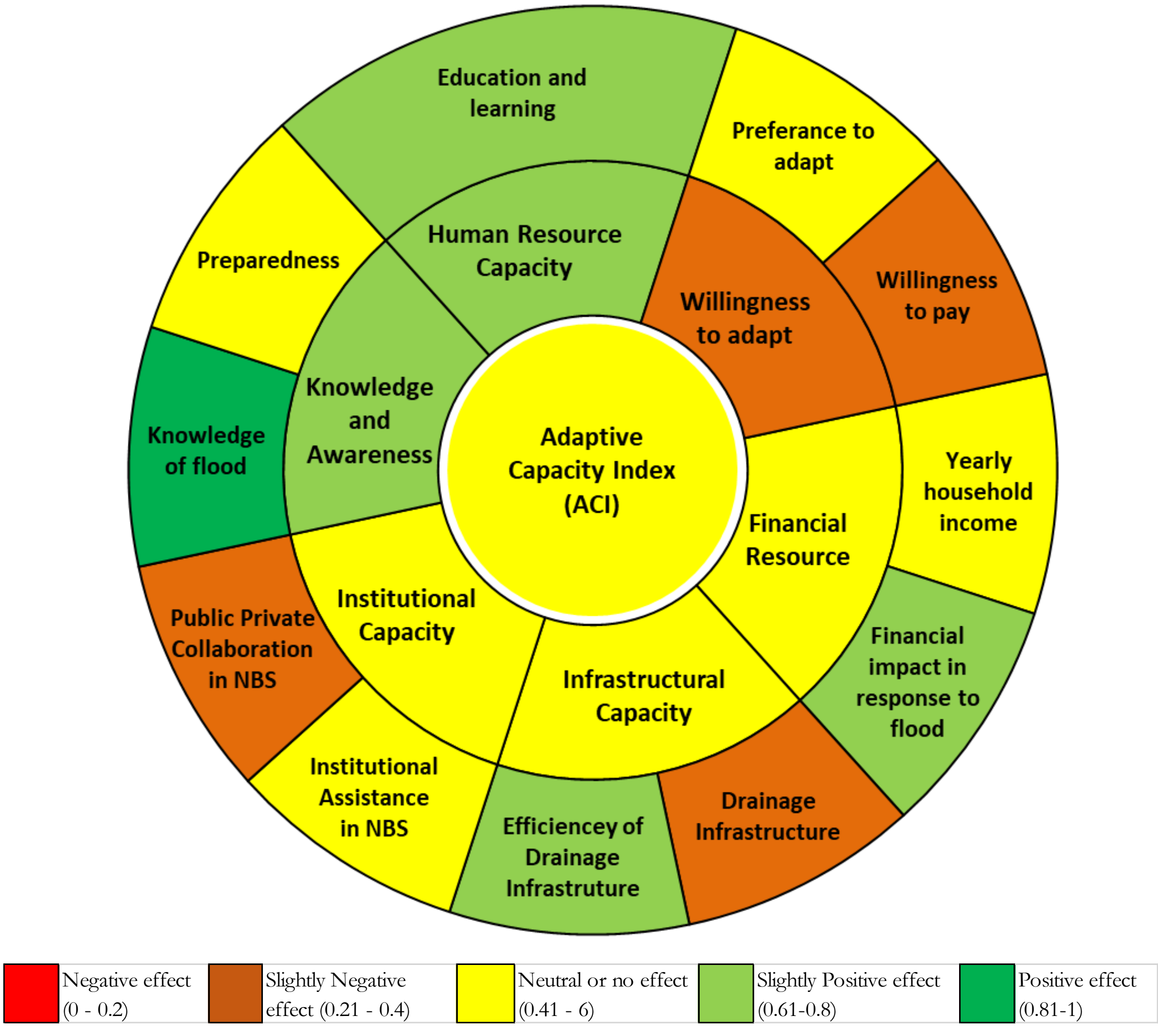


Figure 4-9 Adaptive capcity wheel of Stevenfenne

4.4.3. Twekkelerveld (ACI = 0.61)

The overall ACI expresses that the neighborhood is slightly favorable to being adaptive to the flood integrating NbS. The wheel in figure 4-10 shows that the determinants have slightly positive or no effect on the AC. The determinant of "financial resource," "knowledge & awareness," and "human resource capacity" are seen to have slightly positive as people have a less financial impact due to flood but also have low yearly income as most of the people had a household income of about 1.5 times the modal and very few had income less than modal. Almost all the residents are educated, and most have attained HBO Professional. People are highly aware of the flood as they are more exposed to it but are not as prepared for it as they are knowledgeable. From the wheel, it is clear that the determinants related to NbS "infrastructural capacity" do not affect AC as there is less drainage infrastructure by NbS in house and neighborhood, so it has a slightly negative effect. However, the efficiency of the prevalent NbS is good, so it has a somewhat positive impact on AC.

Similarly, "institutional capacity" that promotes NbS seems not to affect AC, as people are not much interested and involved in the participation of NbS on a household or neighborhood scale. Comparably, the assistance provided to adopt NbS has a slightly positive effect on AC. Likewise, the "willingness to adapt" does not affect AC as people here do not prefer much NbS in their house & neighborhood, and also, they are not willing to pay for NbS.

Figure 4-10 Adaptive capacity wheel of Twekkelerveld

Table 4-11 Summary of the scores of determinants, indicators, and Adaptive capacity index of Twekkelerveld

Determinants	Adaptive Component Score (ASC)	Indicators	Indicator Score
Financial Resource	0.68	Yearly household income	0.6
		Financial impact in response to flood	0.77
Infrastructural Capacity	0.47	Drainage Infrastructure	0.30
		Efficiency of Drainage Infrastructure	0.65
Institutional Capacity	0.55	Institutional Assistance in NBS	0.63
		Public Private Collaboration in NBS	0.48
Knowledge and Awareness	0.69	Knowledge of flood	0.90
		Preparedness	0.48
Human Resource Capacity	0.76	Education and learning	0.76
Willingness to adapt	0.49	Preference to adapt	0.51
		Willingness to pay	0.47
Overall Adaptive Capacity Index (ACI)			0.61

4.5. Objective 4: Analyse various benefits and disservices of NbS and its relation with adaptive capacity.

From the survey, it is clear that the households in all neighborhoods are well aware of the benefits and disservices of NbS at the household and neighborhood level apart from flood prevention. This section discusses the perceived advantages and disadvantages of NbS and its relationship with adaptive capacity.

4.5.1. Perception of Benefits and Disservices of NbS by residents in household level

The cross table below shows the maximum benefits mentioned for the NbS in the household. However, none of the said measures were seen having any benefits of traffic noise reduction.

Table 4-12 Table showing the most mentioned benefits of NbS in household

NbS in the household (Benefits)			
NbS	**Lasonder**	**Stevenfenne**	**Twekkelerveld**
Façade Garden	Visually attractive	Visually attractive, Air purification	Visually attractive
Rain Barrel	Biodiversity	Biodiversity, Temperature regulation (cooling)	temperature regulation, air purification
Green roof	Temperature regulation	Temperature regulation, air purification	
Vegetable garden	Biodiversity	Biodiversity	Biodiversity
Water passing pavement	Temperature regulation	Temperature regulation, Biodiversity	temperature regulation
NbS in the household (Disservices)			
Façade Garden	No disadvantage	No disadvantage, Hard to maintain	Hard to maintain, no disadvantage
Rain Barrel	No disadvantage		
Green roof	No disadvantage	Hard to maintain, Expensive maintenance	Hard to argue, expensive maintenance
Vegetable garden	No disadvantage, hard to maintain (time-consuming)	Hard to maintain	Hard to maintain, no disadvantage
Water passing pavement	No disadvantage	No disadvantage	No disadvantage

4.5.2. Perception of Benefits and Disservices of NbS by the municipality at the neighborhood level

The cross table below shows the maximum benefits mentioned for the NbS in neighborhoods. However, people believe that there are not many disadvantages of NbS at the neighborhood level except that people in Lasonder-Zeggelt and Stevenfenne find that there might be safety issues with urban waterways.

Table 4-13 Table showing the most mentioned benefits of NbS in neighborhood

NbS in the neighborhood (Benefits)			
NbS	**Lasonder**	**Stevenfenne**	**Twekkelerveld**
Urban waterways	Visually attractive, temperature regulation	Visually attractive	Visually attractive
Trees and Plants	Air purification	Air purification	Air purification
Wadis	Temperature regulation	Visually attractive, Biodiversity	Visually attractive
Rainwater pond	Temperature regulation	Temperature regulation	Temperature regulation
Water passing pavement	Temperature regulation	Biodiversity	visually attractive, temperature regulation
NbS in the neighborhood (Disservices)			
Urban waterways	Safety issues	Safety issues	No disadvantage
Trees and Plants, Wadis, Rainwater pond, Water passing pavement	No disadvantage	No disadvantage	No disadvantage

4.5.3. Knowledge of benefits and disservices and their relation with adaptive capacity

Here, people in Lasonder-Zeggelt and Twekklerveld believe there are more benefits of the NbS and fewer disservices than Stevenfenne. Relating the knowledge of benefits of NbS with the adaptive capacity index as seen in figure 4-11, it is observed that there is positive relation of knowledge of benefits and disservices with adaptive capacity index. This shows that people who have more knowledge of the benefits of NbS are more adaptive to the urban flood.

Table 4-14 Percentage of the sum of perceived benefits and disservices of NbS with the ACI of the neighborhoods

	Lasonder-Zeggelt	Twekkelerveld	Stevenfenne
ACI in 100	65.00	61.00	55.00
% sum of perceived benefit	67.13	68.32	66.29
% sum of perceived disservices	32.87	31.68	33.71

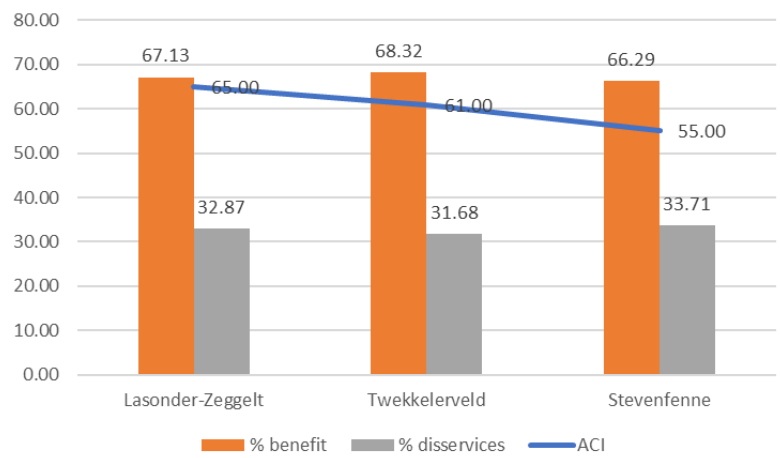


Figure 4-11 Graph showing sum of perceived benefits and disservices of NbS with the ACI

5. DISCUSSION

This chapter includes a discussion of the results explained in the previous chapters. The results are discussed based on each objective, compared among the study areas, and related to the literature. The discussion is made in four sections regarding the state of urban flood and their attitude towards it in the study areas. Based on the results derived from the documents, household survey, and the comparative analysis of the study areas, the extent of the problem of the study areas for people living there is tried to derive.

5.1. Relation of urban flood occurrences in the neighborhood and NbS

The results from the map responses and the vulnerability and flood depth map in extreme precipitation from "Climate Atlas Twente" have a good match which explains that people are well aware of the problem and know exact locations which are more problematic during heavy rain. The urban flood occurrences are seen as dependent on various factors like the location and existing conditions. At the same time, the actions to prevent floods, like NbS, are influenced by the severity of the flood and the people's lifestyle.

Lasonder-Zeggelt has a low green percentage in the neighborhood to infiltrate the surface water and a more significant pavement percentage, increasing the impermeability. From the survey, it was clear that groundwater nuisance was not evident in the past. However, a substantial problem of groundwater nuisance was observed in streets like Dacostastraat. Also, Climate Impact Atlas states that there is a high probability of groundwater nuisance in 2050 of some areas in the neighborhood. From direct observation and survey, it is observed that the regions at the east are elevated compared to west. Some of the areas elevated in adjacent neighborhood Roombek has the highest percentage of pavement that lets more surface water flow from that neighborhood to the lower elevated areas of neighborhood Lasonder-Zeggelt. Most of the residents here are climate-active citizens (the committed hedonists), according to a lifestyle study by Ons Water & SAMR Martktvinders (2019). So, most of the residents are aware of the green and blue measures and have been involved in the community initiative of "so green," where they have installed green façade in their houses. People are aware of the problem. Here, people have a greater average income level than other neighborhoods, which gives better ability to act on it and are willing to adopt NbS in their residences. Hence, people here are willing to pay even the highest mentioned tax per year for NbS at the neighborhood level as many find the green spaces inadequate. However, Lasonder-Zeggelt is less affected by flood than other neighborhoods, so they prefer all kinds of NbS except vegetable gardens considering visual attractiveness instead of flood prevention.

In Stevenfenne, the green spaces are inadequate and insufficient as the percentage of green is only 27.98%, whereas the pavement percentage is 72.02 %. Hence, impermeability is likely to be a significant cause of flooding. Many people face groundwater nuisance and also according to Climate Impact Atlas the whole area of Stevenfenne has a moderate probability of having groundwater nuisance in the future 2050. Many believe that flooding is caused due to high groundwater levels and being in the lowest elevated area of Enschede. The surface water flows from other neighborhoods towards it. RIONED & STOWA (2015) have also pointed out that people believe poor drainage of shallow depth cannot take the excessive volume of surface water. So, there are some existing N bS like the Stadsbeek (urban waterway), which helps drain stormwater and maintain groundwater levels. In this NbS, residents actively participate by disconnecting the down water pipe to sewer and directing it to Stadsbeek on its excellent utilization. However, from the direct observation, few residents were not pleased with this idea because their pathways are flooded during heavy rain. According to the Ons Water & SAMR Martktvinders (2019), the residents of Stevenfenne are "far from my bed lifestyle," which often consists of women with a low to medium level of education and a young family decreases their level of awareness and ability to act on the problem. Hence, people here are willing to pay the least mentioned tax per year for NbS at the neighborhood level since Stevenfenne is more vulnerable to flood, so their preferences of NbS are relatively for flood prevention and cheap easy to maintain, like a rain barrel.

Of the three study areas, Twekkelerveld has the highest green percentage (43.38%) and the least pavement percentage (56.62%), which means less impermeability and more infiltration. However, as it is the lowest point in Enschede, it still observes flooding due to the large volume of surface runoff flows. From the survey, the leading cause of the flooding is poor drainage structure and lack of maintenance of drains. According to Climate Impact Atlas, the whole area of Twekkelerveld has less probability of having groundwater nuisance in the future due to low groundwater level, so there is a minimum chance of having flood because of groundwater level. The residents of Twekkelerveld also have a "far from my bed lifestyle." meaning that they have less awareness, ability, and interest in the action against flooding at the resident level. Therefore, people here are willing to pay the average amount of tax mentioned for NbS at the neighborhood level. Since Twekkelerveld is more vulnerable to flood, residents are motivated to participate in some NbS planned in the neighborhood level for the future. However, due to their lifestyle, they are highly supportive. Hence, the factor of motivation to participate in such planning should be easy and efficient. Since most of the people here have experienced a flood, the preferences of NbS in residence are mainly for flood prevention. So, they are willing to adopt all kinds of measures, especially those that are relatively cheap and easy to maintain, like rain barrels and vegetable gardens.

5.2. Influence of NbS in Adaptive Capacity of urban flood

The urban flood in Enschede is mainly affected by precipitation, high imperviousness, and less water infiltration. The external factors like precipitation cannot be controlled, but the aspect of imperviousness and drainage capacity can be improved. For this, NbS is the best way for sustainable stormwater management. As mentioned in the previous section, the integration of NbS varies with the context of each neighborhood.

The adaptive capacity of the neighborhood is explored, considering various determinants related to NbS and other socio-economic factors that affect the adaptation of urban floods measured by ACI. According to ACI, Lasonder-Zeggelt scores highest, and Stevenfenne scores lowest to be the neighborhood most and least adaptive to the urban flood considering NbS as the drainage infrastructure.

The application of NbS for adaptation and to influence the adaptive capacity for urban flood depends on various factors also discussed in the earlier section, like the severity of the flood and the lifestyle of the residents of the neighborhood. From the research, it is clear that it depends on the purpose and scale of its application, drivers of the application of NbS, and interactions between these drivers. The influence of NbS on adaptive capacity is explored by comparing the ACI component scores and indicator scores related to NbS among the least and high adaptive neighborhoods, i.e., Stevenfenn and Lasonder-Zeggelt.

5.2.1. Influence of NbS in Adaptive Capacity of urban flood in Lasonder-Zeggelt

In Lasonder-Zeggelt, the scale of application of NbS in household and neighborhood levels is impressive compared to other study areas. According to the survey, many people have integrated NbS in their houses and neighborhood. One example would be currently being refurbished Molenstraat that will have many NbS like greener, wadi, water passing pavement, etc. Hence, it scores highest for the indicator of drainage infrastructure by NbS among the neighborhoods but still does not affect adaptive capacity. As mentioned in the earlier section, the purpose of NbS application is more for attractiveness, so scores the lowest for the indicator of efficiency for flood prevention which affects the overall score of the component of "infrastructural capacity," which does not affect the adaptive capacity.

Climate, active citizens with good socioeconomic status, prefer to adopt more NbS and are willing to pay the highest amount of tax; hence scores the highest for the "willingness to adapt" component. However, it does not affect adaptive capacity.

NbS projects with public and private collaboration like community initiatives like "constructing façade gardens" in Lasonder led by resident Lammie Pruntel with the help of institutions like Groene loper Enschede, part of municipality helps to boost NbS more in the neighborhood. Here, people have received assistance as well. Hence also scores highest for "institutional capacity" among the neighborhoods, but it still does not affect the adaptive capacity.

5.2.2. Influence of NbS in Adaptive Capacity of urban flood in Stevenfenne

Among three study areas, Stevenfenne has low NbS in household and neighborhood, so scores less showing a slightly negative effect on adaptive capacity. In contrast, the purpose of the application of NbS here is concerned more with flood prevention. Hence, the indicator of the efficiency of drainage infrastructure scores highest among the study areas and has a slight positive effect on adaptive capacity. Overall, the component of infrastructural capacity scores good but does not affect the adaptive capacity.

Residents here have the slightest preference to adopt NbS and willingness to pay, so the component of "willing to adapt" shows a slightly negative effect on adaptive capacity.

The "institutional Capacity" component also scores least and slightly negatively affects adaptive capacity as people have not received enough institutional assistance to adopt NbS. Also, there is not much public-private collaboration for NbS.

Hence, in the adaptive capacity wheel of all neighborhoods, all the components related to the integration of NbS have no effect on adaptive capacity except in Stevenfenne, where the element of "willingness to adapt" is seen to have a slight negative impact on adaptive capacity. Similarly, few of the indicators in Stevenfene have a negative effect on adaptive capacity. Lasonder-Zeggelt scores better among other neighborhoods for more NbS and the potential to adopt more for flood adaptation, but it still does not affect AC. So, according to the research for the significant influence in the adaptive capacity, there should be a remarkable increase in the number of effective NbS integration, willingness to adapt, and good institutional interaction to promote NbS. Therefore, the NbS can build the adaptive capacity of neighborhoods for flood, but the integration of NbS should be significant as other factors affect the adaptive ability. But, saying that having more NbS can also have some disservices, reducing adaptive capacity like safety issues, social segregation, etc.

5.2.3. Relation of Adaptive Capacity and benefits of NbS

When people are aware of synergies of NbS, people will prefer more NbS as the adaptive measure, and it seems to be true. Stevenfenne ranks least in ACI; people perceive fewer benefits of NbS compared to other neighborhoods. This kind of direct relation of higher the perceived benefits higher the adaptive capacity must be because when people know about the benefits of NbS, they are more willing to adopt it more in their household, which helps further develop the adaptive capacity. Also, people like solutions that have multi-functions, so if they know about more benefits of a particular NbS, people will prefer it more and be willing to adopt it more.

6. CONCLUSION

The primary purpose of this study is to recognize the local adaptation of urban flood of neighborhoods. So, it revolves around the climate stimuli: urban flood, its adaptation by NbS, and the adaptation evaluation by assessing the selected neighborhoods' adaptive capacity. The key findings of the research were concluded in the context of the sub-research objectives.

In analyzing the residents' perception regarding urban flood the responses of all the neighborhoods were compared. The study reveals that the urban flood and its concern directly corresponds to the level of exposure to the flood. All neighborhoods have experienced flood at different level, people of Lasonder-Zeggelt and Stevenfenne believe the cause to be high ground water level and people of Twekkelerveld believe the cause to be poor drainage structure. Causes vary not just because of the physical conditions like location and existing conditions but also because of the social context of the study areas. Most people exposed to flood and less prepared for flooding are vulnerable, like those in the neighborhood of Stevenfenne. Whereas, Twekkelerveld has the highest percentage of green but due to its location and poor maintenance faces flooding.

NbS is generally not opted for flood prevention. More people are concerned with maintaining the drain and other physical interventions. The neighborhood less impacted by flood see NbS for attractiveness, but areas that have experience more flood see its potential for flood prevention and prefer efficient flood prevention. People are willing to pay more for the NbS that they lack in their neighborhood.

From the evaluation of adaptation, it was realized that for NbS helps to build adaptive capacity but along with integration of NbS S in household and neighborhood scale there should also be good public and private collaboration among institutions to promote it in different scale. Further, the research also reveals that people, when are more aware of all the other benefits of NbS, are more adaptive to the flood.

6.1. Recommendations and way forward

The research studies the relation of NbS and its role in building the adaptive capacity of the neighborhood in the context of Enschede Municipality. The study shows that the neighborhood most vulnerable to flood is less adaptive to flood. Also, one of the remarkable things discovered in the study is that there are still many households without any NbS. Hence, there is much possibility to improve flood prevention by scaling up the NbS in households. The municipality needs to focus on the ability and willingness of residents to adopt NbS and develop adaptation strategies according to it for effective adaptation.

With the research findings, further studies can be done on the possible NbS measures applied to the study areas and how it might help mitigate urban floods. NbS, as a blue-green infrastructure, provides many ecosystem services, which can also be quantified to understand if the ecosystem service supply by NbS meets ecosystem service demand and its relation with the adaptive capacity of the neighborhoods.

This analysis substantively does not address the policy and decision-making processes that deal with the conditions that can alter adaptive capacity. It is assumed that the output of indications of the relative adaptive capacity will apply in policy and decision-making by identifying the neighborhood with the most significant vulnerability or least adaptive capacity.

6.2. Limitations

There are some limitations in the chosen methodology for the calculation of adaptive capacity index (ACI). The research would have been better if a focus group discussion or an interview with the experts could be conducted to rank the indicators and determine the weights to make the adaptive capacity study. However, selecting indicators to measure indicators is not standardized and there is no outcome measure against which researchers can validate their results. Similarly, there is the uncertainty of whether an upgrade in the indicator outcomes has positive or negative effects on adaptive capacity. Meanwhile, the weights are not assigned to any of the indicators or components. Here, the study assumes the elements have equal importance in building adaptive capacity which might not give an accurate picture by under or over-representing some indicators.

Furthermore, limitations faced during data collection were technical issues which made the respondent leave in the middle of the survey. However, from the respondent's feedback, that issue was dealt with soon. Also, there was a language barrier to conduct the study. Since I am not a native Dutch translation was needed and this has meant some delays and possible mis-communication about concepts and some ongoing local projects.

LIST OF REFERENCES

Adger, W. Neil, & Vincent, K. (2005). Uncertainty in adaptive capacity. *Comptes Rendus - Geoscience*, *337*(4), 399–410. https://doi.org/10.1016/j.crte.2004.11.004

Adger, W.N., Agrawala, S., & Mirza, M. M. Q. (2007). Assessment of Adaptation Practices, Options, Constraints And Capacity. Climate Change 2007: Impacts, Adaptation and Vulnerability. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, *January*, 717–743.

All measures | Green-blue Enschede. (n.d.). Retrieved May 30, 2021, from https://groenblauwenschede.nl/professionals/maatregelen/?id=909

Approach to pluvial flooding in the municipality of Enschede - Spatial adaptation. (n.d.). Retrieved October 6, 2021, from https://klimaatadaptatienederland.nl/en/?ActLbl=sand-engine-lasts&ActItmIdt=164050

Boswell, M. R., Greve, A. I., & Seale, T. L. (2019). *Local climate action planning* (Revised). Island Press.

Brattebo, B. O., & Booth, D. B. (2003). Long-term stormwater quantity and quality performance of permeable pavement systems. *Water Research*, *37*(18), 4369–4376. https://doi.org/10.1016/S0043-1354(03)00410-X

Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change*, *15*(2), 151–163. https://doi.org/10.1016/j.gloenvcha.2004.12.006

CBS. (2011). *Gemeente op Maat*. http://www.cbs.nl/NR/rdonlyres/91D89C26-7B71-4373-A216-72169F48A214/0/Vlaardingen.pdf

Climate Atlas | Twn. (n.d.). https://twn.klimaatatlas.net/

ClimateScan - Project detail. (n.d.). https://climatescan.nl/projects/6013/detail

Coburn, A., Spence, R., & Pomonis, A. (1994). *Disaster Management Training Programme Disaster Mitigation 2nd Edition. February 2016*.

Colenbrander, S. (2016). Cities as engines of economic growth: The case for providing basic infrastructure and services in urban areas. *International Institute for Environment and Development*, *October*. www.iied.org@iiedwww.facebook.com/theIIEDhttp://pubs.iied.org/xxxxxIIEDwww.iied.org3

Dietz, M. E. (2007). Low impact development practices: A review of current research and recommendations for future directions. *Water, Air, and Soil Pollution*, *186*(1–4), 351–363. https://doi.org/10.1007/s11270-007-9484-z

Eckart, K., McPhee, Z., & Bolisetti, T. (2017). Performance and implementation of low impact development – A review. *Science of the Total Environment*, *607–608*, 413–432. https://doi.org/10.1016/j.scitotenv.2017.06.254

Enschede becomes So Green | Green-blue Enschede. (n.d.). Retrieved May 30, 2021, from https://groenblauwenschede.nl/bewoners/zo-groen/

Eriksen, S. H., & Kelly, P. M. (2007). Developing credible vulnerability indicators for climate adaptation policy assessment. *Mitigation and Adaptation Strategies for Global Change*, *12*(4), 495–524. https://doi.org/10.1007/s11027-006-3460-6

European Union. (2007). Directive 2007/60/EC of the European Counil and European Parliment of 23 October 2007 on the assessment and management of flood risks. *Official Journal of the European Union*, *2455*, 27–34. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007L0060&from=EN

Field, R. ;, & Sullivan, D. (2003). *Wet-Weather Flow in the Urban Watershed: Technology and Management*. CRC Press LLC.

Field, R., & Taruri, A. N. (2005). *The Use of Best Management Practices (BMPs) in Urban Watersheds*. *September*, 268.

Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J. L., Mikkelsen, P. S., Rivard, G., Uhl, M., Dagenais, D., & Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal*, *12*(7), 525–542. https://doi.org/10.1080/1573062X.2014.916314

García, J. H., & Ollero, A. (2016). *An Introduction to Flood Risk and Management* (Issue December 2016).

Gemeente Enschede. (2012). *Water in Enschede feiten, cijfers en trends*. 13. https://www.ruimtelijkeplannen.enschede.nl/NL.IMRO.0153.SV00005-0003/db_NL.IMRO.0153.SV00005-0003_1.pdf

Gupta, J., Bergsma, E., Termeer, C. J. A. M., Biesbroek, G. R., van den Brink, M., Jong, P., Klostermann, J. E. M., Meijerink, S., & Nooteboom, S. (2016). The adaptive capacity of institutions in the spatial planning, water, agriculture and nature sectors in the Netherlands. *Mitigation and Adaptation Strategies for Global Change*, *21*(6), 883–903. https://doi.org/10.1007/s11027-014-9630-z

Haddad, B. M. (2005). Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit. *Global Environmental Change*, *15*(2), 165–176. https://doi.org/10.1016/j.gloenvcha.2004.10.002
Hong, Y., Adhikari, P., & Gourley, J. J. (2013). Flood hazard and disaster. In *Encyclopedia of Earth Sciences Series*. https://doi.org/10.1007/978-1-4020-4399-4_138
Huang, Y., Tian, Z., Ke, Q., Liu, J., Irannezhad, M., Fan, D., Hou, M., & Sun, L. (2020). Nature-based solutions for urban pluvial flood risk management. *WIREs Water*, *7*(3), 1–17. https://doi.org/10.1002/wat2.1421
IPCC. (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. https://doi.org/10.1017/cbo9781139177245
IPCC. (2013). IPCC CLIMATE CHANGE 2013 Climate Change 2013. In *Researchgate.Net*. https://doi.org/10.1017/CBO9781107415324.Summary
Jones, L., Ludi, E., Jeans, H., & Barihaihi, M. (2019). Revisiting the Local Adaptive Capacity framework: learning from the implementation of a research and programming framework in Africa. *Climate and Development*, *11*(1), 3–13. https://doi.org/10.1080/17565529.2017.1374237
KNMI. (2014). Climate change scenarios 2014 for The Netherlands. In *TemaNord*. https://doi.org/10.6027/9789289330954-5-en
Kruse, S., Stiffler, M., Baumgartner, D., & Pütz, M. (2013). Vulnerability and Adaptation to Climate Change in the Alpine Space: A Case Study on the Adaptive Capacity of the Tourism Sector. *European Climate Vulnerabilities and Adaptation: A Spatial Planning Perspective*, 273–287. https://doi.org/10.1002/9781118474822.ch15
Lafortezza, R., Chen, J., van den Bosch, C. K., & Randrup, T. B. (2018). Nature-based solutions for resilient landscapes and cities. *Environmental Research*, *165*(December 2017), 431–441. https://doi.org/10.1016/j.envres.2017.11.038
Maes, J., & Jacobs, S. (2017). Nature-Based Solutions for Europe's Sustainable Development. *Conservation Letters*, *10*(1), 121–124. https://doi.org/10.1111/conl.12216
No ice-free but rain-free: Enschede school is under water, no lesson today - RTV Oost. (n.d.). https://www.rtvoost.nl/nieuws/245623/Geen-ijsvrij-maar-regenvrij-Enschedese-school-staat-onder-water-geen-les-vandaag
Notenbaert, A., Karanja, S. N., Herrero, M., Felisberto, M., & Moyo, S. (2013). Derivation of a household-level vulnerability index for empirically testing measures of adaptive capacity and vulnerability. *Regional Environmental Change*, *13*(2), 459–470. https://doi.org/10.1007/s10113-012-0368-4
Phi, L. H. (2011). *Adaptive capacity Framing the concept and building a framework for assessment of adaptive capacity to climate change in the water sector* (Issue August).
Pradhan-Salike, I., & Raj Pokharel, J. (2017). Impact of Urbanization and Climate Change on Urban Flooding: A case of the Kathmandu Valley. *Journal of Natural Resources and Development*, 56–66. https://doi.org/10.5027/jnrd.v7i0.07
Rai, A. (2013). *DESIGNING GREEN STORMWATER INFRASTRUCTURE FOR HYDROLOGIC AND HUMAN BENEFITS: AN IMAGE BASED MACHINE LEARNING APPROACH*.
Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., Geneletti, D., & Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environmental Science and Policy*, *77*(July), 15–24. https://doi.org/10.1016/j.envsci.2017.07.008
RIONED, & STOWA. (2015). *Enschede Testing Ground: risk-based (waste) water management*.
Shaver, E. (2009). *Low Impact Design Versus Conventional Development: Literature Review of Developer-related Costs and Profit Margins* (Vol. 0504, Issue 045). http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Low+Impact+Design+Versus+Conventional+Development+Literature+Review+of+Developer-related+Costs+and+Profit+Margins#0
Smit, B., Burton, I., Klein, R. J. T., & Street, R. (1999). *THE SCIENCE OF ADAPTATION: A FRAMEWORK FOR ASSESSMENT*.
Stagakis, S. (2020). *Nature-Based Solutions Handbook*. *730338*.
Thanvisitthpon, N., Shrestha, S., Pal, I., Ninsawat, S., & Chaowiwat, W. (2020). Assessment of flood adaptive capacity of urban areas in Thailand. *Environmental Impact Assessment Review*, *81*(January), 106363. https://doi.org/10.1016/j.eiar.2019.106363
Trell, E. M., & van Geet, M. T. (2019). The Governance of Local Urban Climate Adaptation: Towards Participation, Collaboration and Shared Responsibilities. *Planning Theory and Practice*, *20*(3), 376–394. https://doi.org/10.1080/14649357.2019.1629573

Van De Ven, F., Van Nieuwkerk, E., Stone, K., Veerbeek, W., Rijke, J., Van Herk, S., & Zevenbergen, C. (2011). *Building the Netherlands Climate Proof: Urban Areas*.

Vincent, K. (2007). Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change*, *17*(1), 12–24. https://doi.org/10.1016/j.gloenvcha.2006.11.009

Walters, G., Cohen-Shacham, E., Maginnis, S., & Lamarque, P. (2016). What are Nature-based Solutions? In *Nature-based solutions to address global societal challenges*. https://doi.org/10.2305/IUCN.CH.2016.13.en

Warmenbol, C., & Smith, M. (2018). International union for conservation of nature (IUCN). In *The Wetland Book: I: Structure and Function, Management, and Methods*. https://doi.org/10.1007/978-90-481-9659-3_110

White, I. (2010). *Water and the City Risk, Resilience and Planning for a Sustainable Future*. Routledge. https://doi.org/10.4324/9780203848319

Yohe, G., & Tol, R. S. J. (2002). Indicators for social and economic coping capacity - Moving toward a working definition of adaptive capacity. *Global Environmental Change*, *12*(1), 25–40. https://doi.org/10.1016/S0959-3780(01)00026-7

Zebisch, M., Schneiderbauer, S., Fritzsche, K., Bubeck, P., Kienberger, S., Kahlenborn, W., Schwan, S., & Below, T. (2021). The vulnerability sourcebook and climate impact chains – a standardised framework for a climate vulnerability and risk assessment. *International Journal of Climate Change Strategies and Management*, *13*(1), 35–59. https://doi.org/10.1108/IJCCSM-07-2019-0042

Zebisch, M., Schneiderbauer, S., Renner, K., Below, T., Brossmann, M., Ederer, W., & Schwan, S. (2017). *Risk Supplement to the Vulnerability Sourcebook*. http://www.adaptationcommunity.net/wp-content/uploads/2017/10/GIZ-2017_Risk-Supplement-to-the-Vulnerability-Sourcebook.pdf

Zhang, X., Guo, X., & Hu, M. (2016). Hydrological effect of typical low impact development approaches in a residential district. *Natural Hazards*, *80*(1), 389–400. https://doi.org/10.1007/s11069-015-1974-5

APPENDICES

Appendix 1: Flyer for an invitation to participate in the survey in English

Appendix 2: Flyer for an invitation to participate in the survey in Dutch

Appendix 3: Maptionnaire Survey form

Adaptive capacity of Household to Flood (Lasonder-Zeggelt)

This questionnaire is performed by an MSc student (Sadichchha Shrestha) of the Urban Planning and Management program at the Faculty of Geo-information and Earth Observation (ITC), University of Twente to complete her thesis to graduate. This research data is for academic purposes only under the supervision of Dr. F. A. Girgin (f.atungirgin@utwente.nl), Prof. dr. R. V. Sliuzas (r.sliuzas@utwente.nl) and Lies Rubingh (Communication advisor Climate Adaptation, Municipality of Enschede). The data collected will be anonymous and will be treated as very confidential. The participant has the right to withdraw his / her data at any time if so deemed and here attached is the informed consent, where you can deny filling it up at the very beginning if you do not feel comfortable.

For a little motivation, few 10 lucky residents to respond can win € 25 worth of gift vouchers which will be raffled on 1st of May and will be informed through mail address or the postal address if mentioned.

The questionnaire is about green (vegetation) and blue (water) space in your household and neighborhood. It will take approximately 10-15 minutes. * Please note that you can choose your preferred language (English or Dutch) below.

Thank you in advance for your help and feel free to contact Sadichchha Shrestha if you have any comments or questions in (s.shrestha-3@student.utwente.nl) or +31633016587.

Nederlands English

Informed consent

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.

○ Yes
◉ No

I have accurately read the information sheet, I freely consent to proceed with the survey.

○ Yes
◉ No

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Geo-Information Science and Earth Observation: ec-itc@utwente.nl

Lasonder Zeggelt

1.1 How long have you been living in Lasonder-Zeggelt?

○ Less than 5 years
○ 5 - 10 years
◉ More than 10 years

1.2 Have you ever experienced flooding in Lasonder-Zeggelt?

○ Yes
○ No
◉ Don't know

(Image: https://www.rtvoost.nl/nieuws/227509/Enschede-en-waterschap-besparen)

Flooding

2.1 If yes, Where? Can you name the street or area flooded, or can you show it in the map?

Flooded area (You can mark more than one location by clicking on this box)

2.2 When it rains heavily which place gets flooded most in and around the house?

☐ Your home or basement
☐ Your garden
☐ Your street
☐ Parking lot
☐ Playground
☑ Don't know

If other, Please specify

2.3 Did the flooding have significant financial impact like expenditure due to repairing?

○ more than € 400
○ € 200 - € 400
○ € 100 - € 200
○ less than € 100
○ € 0
◉ Don't know

2.4 What do you think can be the cause of flood in Lasonder-Zeggelt? (Selection of more than one response is possible)

☐ Excessive rain
☐ Inadequate green spaces
☐ Poor drainage structure
☐ Impermeability (hardening of soil surface)
☐ High ground water level
☑ Don't know

If other, Please specify.

2.5 Do you personally take any action to reduce the effect of flooding in your living area or house?

○ Yes
○ No
◉ Don't know

2.6 If yes, What do you do?

○ Point downspouts away from house
○ Install foundation vents or sump pumps
○ Install green and blue measures (like rain barrel, green roof, vegetable garden, etc)
○ Install water sensors or flood detection systems
○ Regularly clear debris from drains and ditches
◉ Don't know

If other, please specify.

Green and Blue Measures by Residents

Green (vegetation) and Blue (water) measures like ponds, parks, wadis, wetlands, green roof also helps a lot in storm water management like the drainage system. The following questions are to understand your views regarding it. You may be tenant but you can answer what the owner of the house could do in the house you are living in.

Effectiveness of Flood Prevention by mentioned measures below
(💧 low, 💧💧moderate, 💧💧💧high)

3.1 Do you have any of these features in your house ?(Selection of more than one response is possible)

☑ 1. Facade garden 💧 (Image: Groene Loper Enschede, n.d.)

☐ 2. Rain Barrel 💧 (Image: https://www.eco-business.com/news/rainwater-harvesting-could-save-australia-billions/

☐ 3. Green roof 💧 (Image: https://elliotts.uk/products/green-roof)

☐ 4. Vegetable Garden 💧 (Image: https://decorloving.com/backyard-vegetable-garden-design-ideas/)

☐ 5. Water-passing pavement 💧💧 (Image: https://www.urbangreenbluegrids.com/measures/porous-paving-materials/)

☐ 6. No measure (Image: https://www.bigstockphoto.com/image-203816920)

3.2 What benefits do you think the photographed green and blue measures in house provide apart from flood prevention?	Air purification	Traffic noise reduction	Temperature regulation (cooling)	Visually attractive	Biodive
1. Facade Garden	☐	☐	☐	☐	☐
2. Rain Barrel	☐	☐	☐	☐	☐
3. Green Roof	☐	☐	☐	☐	☐
4. Vegetable Garden	☐	☐	☐	☐	☐
5. Water Passing Pavement	☐	☐	☐	☐	☐

3.3 What disadvantages do you think the photographed green and blue measures would have if adapted in house?	Safety issues	Hard to maintain (time consuming)	Expensive maintenance	No disadvantage
1. Facade Garden	○	○	○	○
2. Rain Barrel	○	○	○	○
3. Green Roof	○	○	○	○
4. Vegetable Garden	○	○	○	○
5. Water Passing Pavement	○	○	○	○

3.4 Would you prefer to adopt any of the above mentioned measures in your house to prevent flooding ?

◉ Yes
○ No
○ Don't know

3.5 If yes, which one would you prefer to adopt? (Selection of more than one response is possible)

☑ 1. Facade garden 💧
☐ 2. Rain Barrel 💧
☐ 3. Green roof 💧
☐ 4. Vegetable Garden 💧
☐ 5. Water-passing pavement 💧💧

3.6 If no, what would motivate you to adopt these measures ? (Selection of more than one response is possible)

◉ Subsidies and financial assistance
○ Technical assistance
○ Community initiative

If other, Please specify.

Green and Blue Measures by Municipality

When it rains heavily, a number of streets in Lasonder-Zeggelt are flooded, particularly around Zeggelt. The municipality is working on refurbishing Molenstraat with more green which will help to prevent flooding with other benefits.

Image: https://centrumkwadraat.nl/molenstraat-enschede/

4.1 Were you aware of the Green/Blue measures planned by Municipality to prevent flooding like "Refurbishment of Molenstraat" or "Green Blue Enschede" website ?

○ Yes
○ No
◉ Don't know

4.2 Do you think measures like more green in Molenstraat will help to prevent flooding in your neighborhood?

○ Yes
○ No
◉ Don't know

Effectiveness of Flood Mitigation by mentioned measures below
(💧 low, 💧💧 moderate, 💧💧💧 high)

4.3 Some of the widely introduced green and blue measures in neighborhood scale are mentioned below. Which do you see in your neighborhood?(Selection of more than one response is possible)

☐ 1. Urban waterways 💧💧 (Image: http://landezine.com/index.php/2011/06/roombeek)

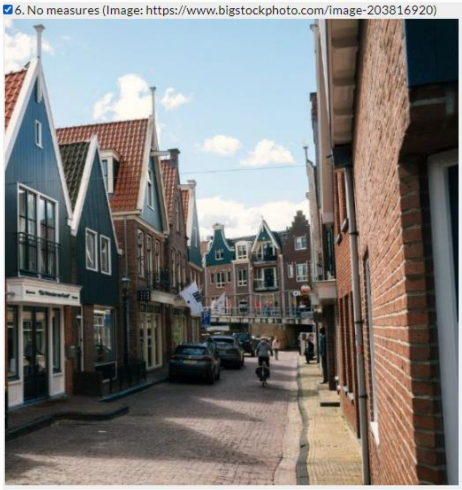
☐ 2. Trees and Plants 💧💧💧 (https://www.vdberk.be/projecten/roombeek-enschede/)

☐ 3. Wadi 💧💧💧 (Images: https://www.urbangreenbluegrids.com/measures/bioswales/)

☐ 4. Rainwater Pond 💧💧💧 (https://www.urbangreenbluegrids.com/measures/rainwater-ponds/)

☐ 5. Water passing pavement 💧💧 (Image: https://www.urbangreenbluegrids.com/measures/porous-paving-materials/)

☑ 6. No measures (Image: https://www.bigstockphoto.com/image-203816920)



If other, Please specify

4.4 What benefits do you think the photographed green and blue measures in neighborhood provide apart from flood prevention?	Air purification	Traffic noise reduction	Temperature regulation (cooling)	Visually attractive	Bio
1. Urban waterways	☐	☐	☐	☐	☐
2. Trees and Plants	☐	☐	☐	☐	☐
3. Wadis	☐	☐	☐	☐	☐
4. Rainwater Pond	☐	☐	☐	☐	☐
5. Water passing pavement	☐	☐	☐	☐	☐

4.5 What disadvantages do you think the photographed green and blue measures would have if adapted in house?	Safety issues	Hard to maintain	Rise in property price	No disadvantage
1. Urban waterways	☐	☐	☐	☐
2. Trees and Plants	☐	☐	☐	☐
3. Wadi	☐	☐	☐	☐
4. Rainwater Pond	☐	☐	☐	☐
5. Water passing pavement	☐	☐	☐	☐

4.6 Which measures do you want to see more in the neighborhood? (Selection of more than one response is possible)

☐ 1. Urban waterways
☐ 2. Trees and Plants
☐ 3. Wadi
☐ 4. Rainwater Pond
☐ 5. Water passing pavement
☑ 6. Don't know

4.7 What is your main reason to choose preferred measure in the previous question?

○ Currently lacking in my neighborhood
○ Visually attractive
○ Effective in flood prevention/mitigation
◉ Don't know

Mostly visited Green/Blue Spaces in Lasonder-Zeggelt

5.1 Can you write the name of the green/blue space in the neighborhood you visit the most OR show it in the map?

Green / Blue Spaces you visit the most (You can mark more than one location by clicking on this box)

Institutions

6.1 Have you ever participated or involved in these kind of green and blue measures plans of municipality?

○ Yes
○ No
◉ Don't know

Image: (Waterhuishouding & Waterbouw, 2015)

6.2 If yes, how were you involved?

☐ informed (by eg. information meeting, leaflets and newsletters on plan draft)
☐ consulted (by the municipality through surveys, written statements/consultation)
☐ suggested/ discussed issues/ objectives from an early stage on (eg. round tables, planning charrettes)

If other, Please specify

6.3 If no, why couldn't you participate or involve?

☐ not informed
☐ lack of time for participation
☐ lack of motivation
☐ too many programs with same objective
☐ not interested

6.4 "Zo Groen" campaign helps citizens to green their house and street with financial as well as technical assistance from the City Council. Will you be willing to coordinate with your neighbors to start the campaign ?

○ Yes
◉ No

6.5 If no, what can be the motivation to start the initiative?

○ Easy communication for information flow
○ Less time consuming procedure
○ Assurance of financial and technical assistance
◉ Don't know

If other, Please specify.

How effective do you think it is to have participation of the local residents in such green and blue projects ?

not effective — very effective

Willingness to adapt

7.1 To realize green and blue space in Enschede, money is needed. How much would you be willing to pay for new green and blue space via municipal taxes? The amount is the additional tax per household per year, so it comes on top of current municipal taxes.

○ € 0 : no investments and no new measures for green and blue space
○ less than € 10 : only investments for small measures such as vegetated strips at street level
○ € 10 - € 20 : reasonable investments for measures at street and neighborhood level
○ € 20 - € 30 : reasonable investments for measures at street and neighborhood level
○ more than €30 : large investments for measures at all levels, street, neighborhood
◉ Don't know

7.2 If answer is € 0: What is the main reason that you are not willing to pay?

○ It is not worth my money
○ I do not think it is important enough/ it has no priority for municipal investments

If other, please specify:

Basic Information

In this section the personal information about the respondent is collected. This information will be confidential according to the privacy regulations of GDPR. The response will be anonymized if necessary.

8.1 Address (Post code) (Eg: 7514 AD)

8.2 Age	16 - 25	26 - 45	46 - 65	66 or older
(Choose your age group)	○	○	○	○

8.3 Gender

- ○ Male
- ○ Female
- ○ Other

8.4 Ownership of the place of living

- ○ Owner
- ○ Tenant
- ○ Housing Company

8.5 What is your household income? Modal: gross €22,000 to 24,000 per year

- ◉ Below modal
- ○ Same as modal
- ○ About 1.5 times modal
- ○ About 2 times modal
- ○ More than 2 times modal

8.6 What is your highest completed education level?

- ○ No completed education
- ○ Elementary School
- ○ High School
- ○ Middle - level applied education (MBO in Dutch)
- ○ Higher Professional education (HBO in Dutch)
- ◉ University (WO in Dutch)

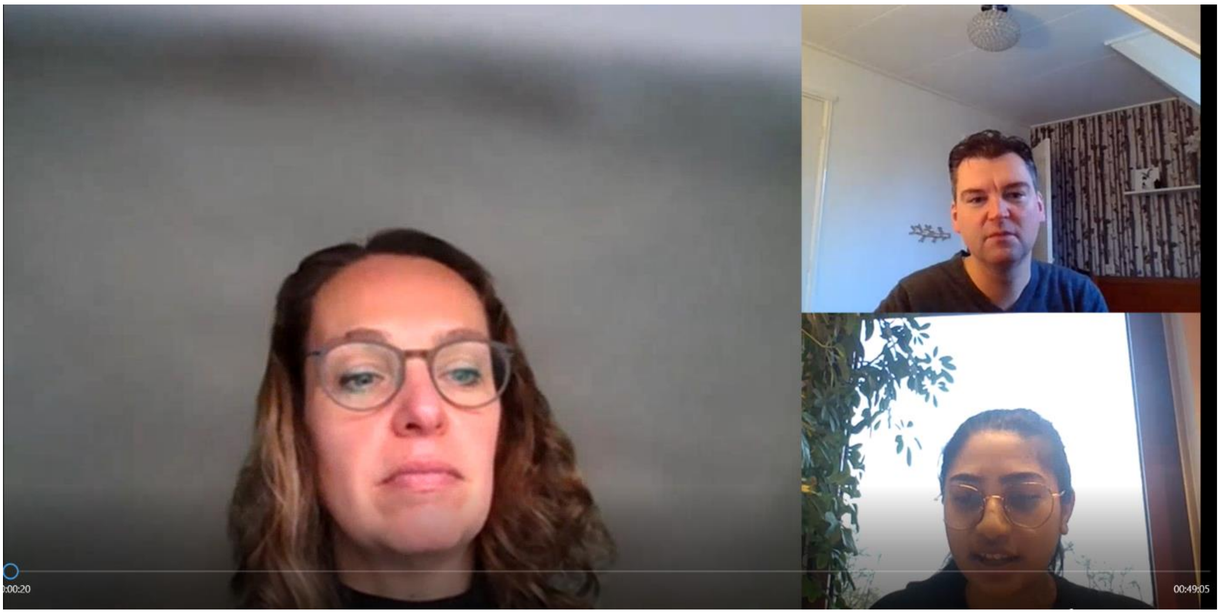
Email address (not mandatory, only if you are interested for the participation in raffle of gift voucher)

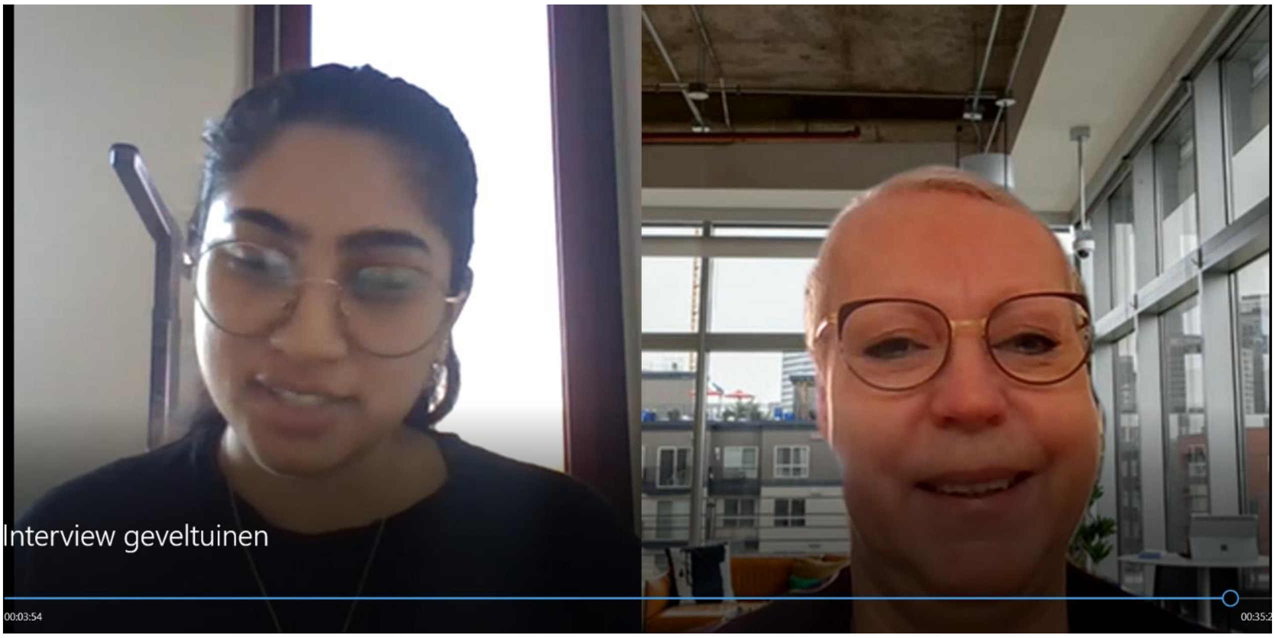
Postal address (not mandatory, only if you are interested for the participation in raffle of gift voucher)

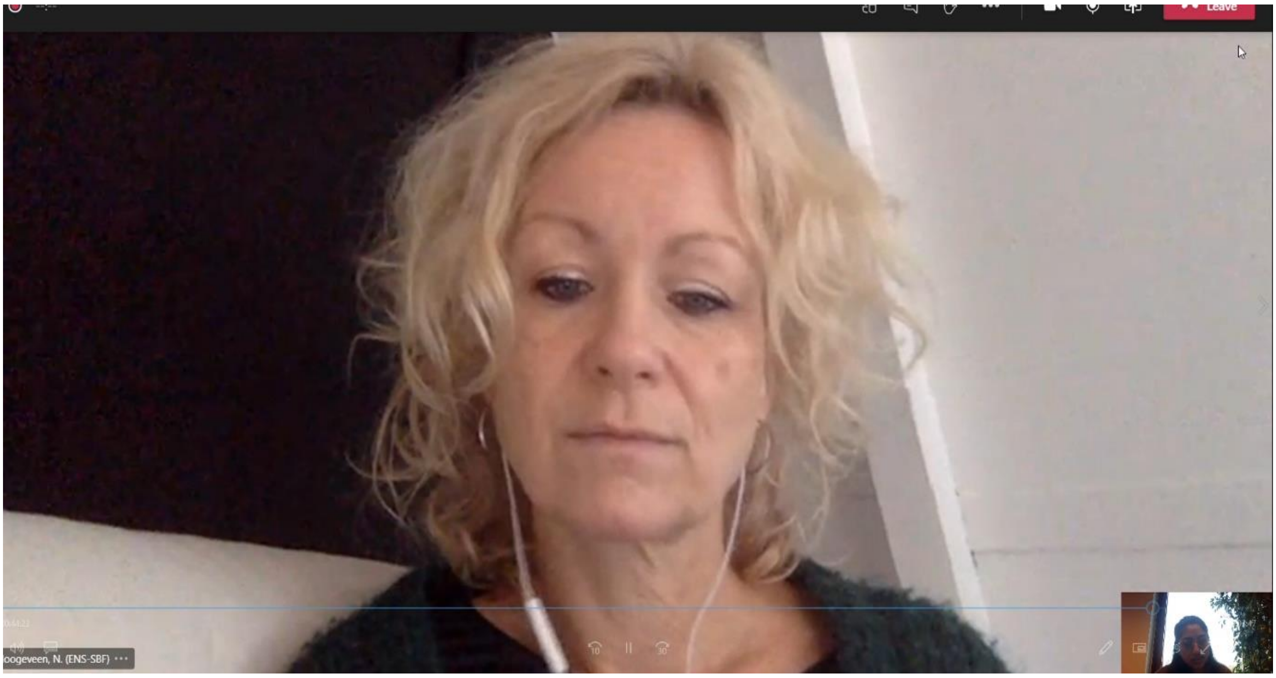
< Done

Appendix 4: Image taken during field work

Appendix 5: Images taken during the interview




Interview geveltuinen
00:03:54


Leave