Master thesis

Local ecological knowledge and self-reliance: the case of the Grensmaas, Limburg

Do changed landscapes and a new flood risk perception lead to increased vulnerability?

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GRENS

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Summary

This thesis researches the largest river project in the Netherlands, the Grensmaas project. The Grensmaas project is developed based on the principles of a new river management paradigm in which the river has been given more room for natural dynamics. The project has three aims; flood risk reduction, nature restoration and gravel extraction. Through extracting gravel, the project creates more space for the river to flood and for new forms of nature to develop. Taking ecological restoration and increased resilience as a starting point, benefits spill over into social and economic domains, linking social-ecological interactions. Therefore, this project is a practical implementation of a Nature-based Solution. However, there is limited understanding of the social-ecological interactions of Nature-based Solutions and this thesis looks at these social-ecological interactions. The Grensmaas project has drastically altered the landscape and inhabitants used to deal with flooding events by themselves based on local ecological knowledge and responding to changing in river flow. As the project has altered the landscape, it might be that inhabitants cannot read their environment anymore which hampers an effective response in case of potential flooding events. In addition, there are worries that official measures decrease preventative measure taking of communities in the area. Before the project, flooding events were seen as part of daily lives and inhabitants were self-reliant and dependent on their own communities in case of flooding events. Because the project has officially decreased the likelihood of flooding events, it could be that inhabitants have a decreased flood risk perception and therefore take less private preventative measures despite the fact that private preventative measures are important for minimizing damage from flooding events. Therefore, this thesis researches 'to what extent altered forms of local ecological knowledge and a changed risk perception as a result of the Grensmaas project lead to increased vulnerability for inhabitants in the Grensmaas area'. Through an online survey, this research assesses the altered conditions of local ecological knowledge and its influences on vulnerability. In addition, it assesses the current flood risk perception and the attitudes towards taking measures. The results from this thesis show that local ecological knowledge is still largely present and that therefore most inhabitants have not become more vulnerable. In addition, this thesis shows that risk perception is low and that personal measures are also limited. This means that the susceptibility to flooding events has increased and that damage is not minimized although overall vulnerability has decreased because of the project. The recommendations given focus on integrating local ecological knowledge in flood prevention plans and incentivizing private flood prevention measures.

Acknowledgements

Firstly, I would like to thank my supervisor, Andries Richter, for assisting me during the longest and most difficult project in my life so far. He has been of great help, both in terms of content and in terms of the process. In addition to this, I would like to thank those who are part of the larger Grensmaas Research Project of which this research is a part of. The project has allowed me to make use of some funding and provided me with contacts for starting my research. Furthermore, I would like to thank the Grensmaas Consortium for the provided information on the project, for laying first contact with some community groups and for their hospitality in showing me around in the Grensmaas. As a newbie to R, I am very thankful to Aleid Teeuwen and Amanda Schadeberg for helping me to understand the basics of R. Finally, I am thankful for the critical feedback of Carolijn Oudshoorn which helped me in my writing. Closing it off, I am satisfied with my accomplishments and I hope this thesis research provides the reader with interesting insights!

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1. Introduction

The introduction will sketch the background of this thesis research. It will describe the context of river management in the Netherlands with a shifting focus away from a technocratic approach towards one that provides space for natural processes to occur. Out of this shifted focus, news ways of approaching river projects developed. This thesis researches a project which was developed in the spirit of this new approach, the Grensmaas project. After this background, the introduction will move into the problem statement and the importance of researching the Grensmaas project. Finally, the main research question and the sub-questions are discussed, ending with a reading guide of this thesis.

1.1. Water management in The Netherlands

The Netherlands has a long-standing and closely developed relationship with natural water and river management (van Stokkom, Smits, & Leuven, 2005). The country is located in the deltas of the Rhine and the Meuse river, 25% of the country is below sea level and still subsiding, and of the approximately 1500 km of borders, 450 km is formed by the coastline (van Stokkom et al., 2005). There is a long history of exploiting the Dutch water ways for national benefits and adapting to flooding events. Without the current 3500 km of dunes and dikes, approximately, 65% of the most-densely populated areas would be flooded on a daily basis (Rijkswaterstaat VNK Project Office, 2016; van Stokkom et al., 2005). In addition to this, approximately 60% of the Netherlands is susceptible to flooding and two-third of the GDP is produced in 55% of the land which is also flood prone (Rijkswaterstaat VNK Project Office, 2016). Finally, around 100,000 people are living outside official flood defense areas (Rijkswaterstaat VNK Project Office, 2016). Hence, the threat of flooding events, coming from either the rivers and the oceans, has always been imminent. As the Netherlands has always had this close relationship with its water resources, it is a leading authority when it comes to water management (van Stokkom et al., 2005).

River flooding events have always been a threat and have always occurred, but because of technological advancements in the past century, disastrous and deadly flooding events have been relatively scarce. Until approximately the 1980s, there was a large focus on technologies and technical advancements within river management. The reigning river management paradigm at that time was a technocratic approach based on engineering principles (Roth & Warner, 2007). The technocratic approach considers risk defined solely by the probability times the casualties and damages of an event, not taking social values, spatial-differences, adaptability or other forms than engineering principles into consideration (Baan & Klijn, 2004). Technocratic measures have had a large impact on rivers and have drastically altered the hydro systems of Dutch rivers (van Stokkom et al., 2005). In practice, the technocratic approach entailed that the height of the dikes would have to exceed the level of discharge with a certain probability. There were certain frequently taken measures such as river regulation schemes including increasing the heights of levees and embankment of flood plains. As a result, rivers became confined to narrow spaces and became more and more controlled. In addition, in the larger context of societal progress, drainage schemes of agricultural lands and the spreading of urbanized areas with impervious materials also affected hydro systems. These alterations had many consequences. Hydro morphological resilience of the river basins was altered and therefore the river system became more prone to extremes. Water and sediment discharge patterns were immediately reflected by extreme high or low water levels and the subsequent discharge during high water periods (van Stokkom et al., 2005). When rivers are narrow, banked, confined and shortened, more discharge will be running through in less time, therefore increasing water levels. In addition, run-off was increased as it was less easily possible for water to infiltrate in the ground and soil.

The results of the measures described above show that the technocratic approach has certain disadvantages. Firstly, this approach is constant, but not flexible. With increasing water levels, extremes and flooding frequencies, the only possible response of this approach is to always increase the heights of the levees to prevent flooding events (van Stokkom et al., 2005). This does not leave space for natural river dynamics and decreases the quality of landscape values such as scenery and cultural heritage (Vis, Klijn, De Bruijn, & Van Buuren, 2003). Furthermore, the levees created a false sense of security as people perceive that levees will protect them against all future possible flooding events (Baan & Klijn, 2004). In addition to this perception, the economic value which is at risk of flooding still increases since large investments in the area are still being made (Vis et al., 2003). With on the one hand the exposure of ever-expanding populations and growing economy in the lower-laying polders behind the dikes and on the other hand increased peak discharges, levees have to increase again and theoretically, this cycle seems to continue forever. However, flooding events could always happen and will then be more disastrous because of this perception that flooding will not happen anymore and because of increased investments. Finally, the approach is rather static. All land types have the same modelled probability of flooding and it is unknown which areas will flood once the discharge level has exceeded the levees. This makes the approach non-spatial because the same modelled flooding probability is applied to the whole area. This results in evacuations of the whole area, causing unnecessary social and economic disruptions. In sum, always and solely increasing dikes was just not enough and the technocratic paradigm did not provide sufficient safety and a fundamental new approach was needed (van Stokkom et al., 2005).

When in the 1970s and 80s, a new 'Green conscious' emerged, the water management approach changed as well. New values were used, focusing more on landscape and cultural values and moving away from the solely technocratic approach (Roth & Warner, 2007; van Stokkom et al., 2005). The new paradigm looked in a different manner at flood risk and out of this new paradigm a new approach called 'Room for the river' was developed. This philosophy embraced a more natural dynamic which quite literally provides more space for the river to flood while still minimizing social and economic damages leading to more resilience (Vis et al., 2003). This means more space for natural processes and natural river dynamics to occur. The novel approach also took land-use and spatial planning into account, prioritizing high-value areas over lower-valued areas (Vis et al., 2003). Moreover, public awareness and support, early-warning signals and measures, preferably in an international context had to be developed (van Stokkom et al., 2005). This new paradigm gained prominence and momentum especially after the flooding events of the Grensmaas (Border Meuse) river 1993 and 1995 (see chapter 2.5) and the political effects of this flooding event on river management should not be underestimated, leading to a spur of new innovations (van Stokkom et al., 2005). Currently, the 'Room for the river' approach is still very prevalent. With land-use changes as a result of the new approach, it is impossible to see water management as an issue as siege, unrelated to nature conservation and spatial planning (van Stokkom et al., 2005). Therefore, the new paradigm includes the interaction between, on the one hand, the ecological or the natural system, and on the other hand the different human systems. This interaction can be conceptualized by a social-ecological systems (SES) framework. This framework describes systems such as a river system holistically, and looks at the interaction between the coupled social, ecological, political and economic systems. In order to understand the system, it is important to know how these sub-systems influence each other. This framework is further explained in the theoretical background in chapter three.

1.2. The Grensmaas project as a nature-based solution

One of the rivers where a project under the new water management approach was developed was in the Grensmaas river in the province of Limburg, in the south of the Netherlands. Plans were already developed in the 1980s and they were based on the integration of ecological, economic and social objectives, a revolutionary idea for that time (Roth, Vink, Warner, & Winnubst, 2017). The Grensmaas project was initiated upon three different pillars; that of nature development, flood protection and gravel extraction (see figure one). Ecological objectives were related to restoring natural river dynamics in the area. This occurred by providing more space for the river to meander freely, by widening and deepening the flood plains and through widening the channel (Meertens, 2014). These interventions would lead to increased flooding protection as there would be more discharge capacity and they would lead to recreation possibilies (Warner, 2016; Wesselink, Warner, & Kok, 2013). The interventions were realized through the extraction of 54 million tons of gravel from the river bedding, which was needed to make the project profitable. These three pillars are not static, they are interconnected and their importance changes over time. For example, gravel extraction has increased over-time, leading to smaller amounts of nature development (Wesselink et al., 2013). Another example is that flood protection was not a focal point in the beginning of the project, however, after the flooding events of 1993 and 1995 (for more information, see chapter 2.5), this became much more important.

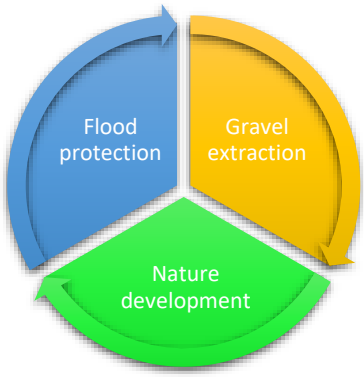

Figure 1: The three pillars of the Grensmaas project

By integrating these seemingly opposite objectives, namely economic activity and the gains of gravel extraction, flood protection and ecological recovery of the river, the project can be considered as part of a nature-based solution (NbS) framework within the context of social-ecological systems (Richter, 2019). Nature-based solutions are currently a trending topic and are defined by the IUCN (n.d.) 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".

In other words, NbS aim to promote ecosystem development while at the same time improving human well-being. It closely acts at the intersection between the human and the natural world. According to the IUCN (n.d.), NbS increase ecosystem resilience based on societal and cultural values. There is a large focus on nature conservation and biological and social diversity in a site-specific context on a landscape scale while also providing social benefits.

The Grensmaas practically implements NbS principles. Taking ecological restoration and increased resilience of the Grensmaas ecosystem as a starting point, the benefits have spill-over effects beyond the environmental domain. Site-specific societal effects are decreased flooding events and recreational activities while the Dutch economy is stimulated by providing gravel extraction opportunities. Hence, combining ecological, social, political and economic principles leads in first instance to combined benefits. NbS and SES as frameworks are related to each other, however, they are not identical. The NbS framework is more solution-oriented and are not per se used to analyze a system while the SES framework is specifically developed to understand relationships among different sub-systems.

Therefore, this research will use SES theory to explain some of the dynamics of the interactions and links between the social and the natural systems of the Grensmaas as a Nature-based Solution.

1.3. Problem statement

Nature-based Solutions are gaining popularity and the term is a buzzword. It is also a very valuable approach by integrating the 'natural' into the social, political and economic and to ensure that there is a balance of these different interests. There is limited understanding on the outcomes of social-ecological processes related to NbS (Nesshöver et al., 2017). These social-ecological interactions are important as blind spots might be overlooked which give way to certain problems arising from implementations of NbS. There are several blind spots which are researched in this project.

There are many reasons why the GM project in its current form can be considered a success. It is beneficial to many stakeholders in different domains. It is ecologically successful because restoration of the river dynamics, the return of flora and fauna and the created nature areas. It is economically successful because of the extraction of gravel which brings revenue and employment. It is socially successful because of nature recreation, flood protection and social acceptance. Finally, it is politically successful because of support for the project, very limited costs for the taxpayer and the successful although limited collaboration with the Belgian counterparts. Nonetheless, as a result of the GM project, social-ecological dynamics have changed, perhaps not only positively.

Before the project started, official flood protection measures were not part of the landscape and flooding events were seen as 'part of everyday life'. Inhabitants of the area were used to flooding events and knew how to deal with them based on collective memory, personal protection measures and reading the river (De Voogt & Munaretto, 2017; Engel, Frerks, Velotti, Warner, & Weijs, 2014). However, this has changed. The landscape has been drastically modified to fit its new function as new nature and in addition to this, the GM river management now falls under national jurisdiction, having to follow national guidelines and regulations with regards to river management. This can have several negative consequences, ultimately, leading to increased vulnerability. Vulnerability here is defined in terms of "*the capacity to anticipate, cope with, resist, and recover from the impact of a natural or man-made disaster"* (see chapter 3.1.2).

This thesis researches the GM project, looking at the issue of increased vulnerability because of the possible loss of local ecological knowledge and increased susceptibility because of possible decreased flood perception. The protection levels in the Netherlands are described by the failure of dikes. The official flood risk for the Grensmaas area was 1/50. This protection level means that once every 50 years, with 'current' modelled estimates of water discharge, the water will reach a level higher than the elevation of the dikes, and hence, will lead to flooding events. The risk of flooding events has decreased as a result of the project, to 1/250 years. However, it might be the case that the GM project could lead to increased vulnerability in relation to flooding events (De Voogt & Munaretto, 2017; Engel et al., 2014).

The possibility of increased vulnerability results from two separate issues as can be seen in figure 2 below: decreased local ecological knowledge (LEK) and decreased flood perception. Firstly, Engel et al., (2014) state that there is a possible increase in vulnerability because the altered landscape after the Grensmaas project disabled the local communities to understand and read the river's behavior as certain signs and marks have been altered and have disappeared because of the changed landscape. In other words, it might be the case that there is a loss of LEK which leads to a decreased understanding of local

environmental conditions. Long before the project, the Grensmaas inhabitants have been relying on environmental knowledge through reading the river and markings in their environment for predicting flooding events. However, this might not be possible anymore due to the new function of the landscape. It possibly inhibits the adaptive capacity of inhabitants, which is in this context the capacity to respond actively and adequately to the changes in the river's behavior in case of the possibility of flooding events. However, this could be balanced to an extent by new markings and the adaptive and dynamic nature of LEK (see 3.2.6). It might be the case that in places where the GM project is finished, new markings exist. Being able to use these markings for reading the river could increase the adaptive capacity again.

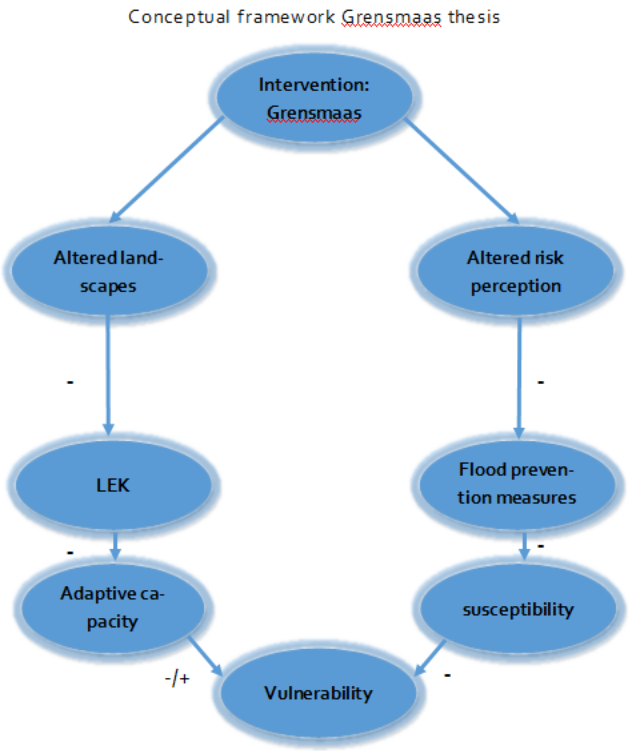

Figure 2: This figure describes the conceptual model on which this research is based. The premises are that as a result of the Grensmaas project, LEK and risk perception has been altered and has possibly led to increased vulnerability

Secondly, there is a changed flood perception because of the large-scale interventions in the area. Because of the interventions, a general feeling that flooding events are part of the past is possibly present. In addition, the 'Levee effect' could also change risk perception. The Levee effect predicts that once protection measures have been taken, people place inappropriate faith in the power of protection works (Baan & Klijn, 2004). Hence, official protection measures has decreased the likelihood of a flooding event taking place and therefore vulnerability. But, in addition, it could lead to an attitude in which, on a household and personal level, there is decreased effort to protect oneself again flooding events. This lower effort increases susceptibility to flooding events and is relevant as personal measures are still very important to decrease flooding damages (Baan & Klijn, 2004; Grothmann & Reusswig, 2006). Thus, this thesis aims to analyze if the loss of LEK and the changed flood perception could lead to increased vulnerability.

In sum, because the Grensmaas project is such a far-reaching project, it can have a large influence on the social and natural surroundings of the inhabitants. This thesis will uncover these influences, focusing on LEK and risk perception. It will research the interaction between the larger social-ecological systems and the individual agency of inhabitants by analyzing the broader context and individual perceptions within the system.

1.4. Relevance

This research is useful because it sheds light on possible negative outcomes of NbS projects that were not foreseen, in this case increased vulnerability because of decreased risk perception and altered forms of LEK. In environmental circles, restoration of degraded habitats and environmental conservation is normally seen as positive. In times of environmental crises and decreased space for nature to claim its place, projects increasing natural areas need to be developed. However, it must be critically assessed

how these conservation interventions play out for those affected by it and how these effects can be mediated. This thesis does so by looking at the effects of this NbS project.

Also, when institutions are creating large-scale landscape modifications which impact inhabitants living there, it is important that those institutions are aware that in tacit ways, they can impact their surroundings. Inhabitants, those who are affected, need to be aware that the way they relate to the world is changing (Engel et al., 2014). Because of this impact on them, it is also important that they are able to partake in decision-making processes. This is especially relevant in the case of risk perception in disaster management, where there is generally a large discrepancy between 'experts' and 'official' perceptions of risk versus peoples' perceptions (Baan & Klijn, 2004). This thesis points out the subtle issues that inhabitants might have and thereby providing a higher legitimacy for them to actually participate.

Moreover, when a flooding event occurs, damages are larger because of the bath-tub effects (Engel et al., 2014). After the 1993 and 1995 flooding events, levees were constructed and heightened in the Grensmaas area. This lowers the likelihood of flooding events, however, it increases the damage once a flooding event occurs. When water surpasses the levees or when the levees break, the area will fill up quickly while it is more difficult for the water to leave because the water cannot escape. This makes it even more important to read signals of the river to be able to minimize damage

Finally, research on LEK in the Western context is limited and even non-existent in the context of the Benelux (Hernández-Morcillo et al., 2014). This research can shed some light on LEK and its uses in a western context. Several aspects of LEK are interesting in this case, such as the change and potential loss of LEK, which has not frequently been studied in a European context either (Hernández-Morcillo et al., 2014). In the Western world, the scientific paradigm is very strong and although LEK and scientific knowledge cannot be distinguished on a conceptual level (see section 2.2.2), there are definitely forms of LEK in the Western context. In the context of the flooding, LEK provides fine-grained knowledge on the behavior of the water during flooding events next to predictive qualities. Utilizing these 'other' forms of knowledge can be of great value, and sometimes even greater value, than purely scientific knowledge which might not be detailed enough. In addition to the practical and adaptational value in preventing or minimizing losses and damages from flooding events, having LEK also gives feelings of self-worth (Baan & Klijn, 2004; Lindsey McEwen & Jones, 2012; Vogt et al., 2016). Finally, LEK as a means of understanding ecological systems, is a basis for dealing and responding to ecological dynamics (F. Berkes, 2012). It is not possible to respond to flooding events when there is no knowledge and expertise to understand and interpret the natural conditions. Hence, understanding the link between the changing landscapes and the loss of LEK is important because of its changed link to self-reliance which is the norm in the Grensmaas area (Engel et al., 2014).

1.5. Research question

To what extent do altered forms of local ecological knowledge and a changed risk perception as a result of the Grensmaas project lead to increased vulnerability for inhabitants in the Grensmaas area?

1.6. Sub-questions

1) Is local ecological knowledge used for predicting high water events of the Grensmaas river?
2) How do altered conditions of local ecological knowledge influence vulnerability of the inhabitants?
3) Has the Grensmaas project changed flood perception of the inhabitants?

4) How has a changed risk perception influenced susceptibility through private flood prevention measures?

These sub-questions are closely related to the conceptual model mentioned in figure 2. They follow directly from the links of the concepts in the conceptual model and they form the bridge between different concepts. Sub-question one links altered landscapes to LEK. It establishes the baseline as to what extent inhabitants use LEK in the context of the Grensmaas and what the characteristics of the current condition of LEK are. Sub-question two relates different conditions of LEK to different levels of adaptive capacity and vulnerability (see the left side of the conceptual model). After sub-question one establishes how LEK has changed before and after the Grensmaas project, sub-question two establishes a link between altered conditions of LEK and vulnerability. It is needed to understand how altered conditions of LEK influence the capacity to predict flooding events and thereby how it influences the adaptive capacity of inhabitants. This adaptive capacity is directly linked to vulnerability (as described in 3.2.1.) and therefore, the impact on vulnerability can be analyzed. The second component of vulnerability is related to risk perception. Risk perception dynamics are analyzed in sub-questions three and four. Sub-question three discusses the current state of different dynamics of risk perception for inhabitants of the Grensmaas. Once this current state is known, the effects on personal flood prevention measures are analyzed in sub-question four as it links altered risk perception to flood prevention measures and to a changed susceptibility (see the right side of the conceptual model).

1.7. Structure of the thesis

In *chapter two*, this thesis will elaborate on the context of the Grensmaas river. It will firstly describe the Grensmaas river, its historical context and its special characteristics, which are at the basis of choosing the river for this NbS project. After this, a background sketch of the environmental, political, social and economic developments of the project will highlight the interesting and sometimes disruptive developments of the projects and how all the above-mentioned dynamics are interlinked. *Chapter three* will then delve into the theoretical background and the concepts used in this thesis. The larger framework of the research is a SES framework. This holistic approach is very useful because of the interlinked social and natural systems. Several different concepts within SES which are useful for this thesis, namely resilience and vulnerability are described. These terms are highly interlinked and used interchangeably, hence it is important to clarify them. Narrowing down, the concept of vulnerability will be elaborated upon in terms of adaptive capacity and susceptibility. The operationalization of these concepts is used to answer the research question. The first three chapters of this research, the literature chapters, consist mainly of governmental reports and scientific literature, but also of some grey literature consisting of newspapers and websites. *Chapter four*, materials and methods, will first elaborate upon the research design, which is a survey. Furthermore, the areas in which the research has been done is described as well as the manner in which the survey has been executed. Most importantly, the data analysis section will describe the operationalization between on the one hand, the research questions the theory and concepts and on the other hand the survey. By doing so, the links between the theory, concepts and research questions becomes clear and this provides a clear guide for analyzing and interpreting the results. *Chapter five* will describe the different results consisting of the descriptive results, correlations and a regressions. *Chapter six* contains the analysis of the results and what this means for the project. It connects the research questions, the theory and the concepts with the results and describes interesting outcomes. It also places these outcomes in the broader context and therefore it shows the value of this research. The final chapter, *chapter seven,* is the conclusion. It consists of the most important outcomes of the study, the limitations of this research, possible follow-up research ending with recommendations for policy makers in the Grensmaas area.

2. Context of the Grensmaas river and the Grensmaas project

Firstly, this chapter will introduce the Grensmaas river and the historically changed natural and environmental characteristics are described. These are important as explains the existence of the Grensmaas project. Thereafter, the section will delve deeper into the historic developments of the Grensmaas as a project. It will examine the political struggle of the creation of the Grensmaas project based on a wide range of social, economic and political dynamics. Thereafter, it will describe the characteristics of the project and the current project developments.

2.1. The Grensmaas River and its characteristics

The Grensmaas river is a part of the Maas (Meuse) river in Limburg, running for approximately 40 km from Maastricht to Roosteren, separating the Netherlands and Belgium (see figure 3) (Swam, 2010). It is an area with a relatively small population of about 12.000 inhabitants scattered in the villages and parishes of the area (Warner, 2016). The Maas sees its origins near Nancy in France after which it has cut out a steep valley, entering Belgium, where it becomes a narrower valley as it meanders through the Ardennes (Wesselink et al., 2013). Arriving in the Netherlands, the Maas sees a drop of 45cm/km, which is steep for Dutch standards (Warner, 2016). This results in a fast-flowing meandering river which is prone to erosion, leading to a dynamic river area (Looy & Peters, 2000). The Maas is a rain-fed river and because it is rain-fed it sees highly variable discharges, ranging from 25 m3/s to 3,100 m3/s. Discharges are especially variable after heavy rains in the Ardennes which can reach the Netherlands within two days (Engel et al., 2014; Warner, 2013). The GM has several unique characteristics. Firstly, it is the border between the Netherlands, on the east of the river in figure 3, and Belgium on the west of the Maas. Secondly, it is the only part of the Maas river in the Netherlands where the river still follows a 'natural' course; where the Maas is not canalized, and where ships and boats are prohibited. Finally, the Grensmaas is a river with a gravel bedding which is also unique in the Netherlands as there is no other river with the same bedding (Rijkswaterstaat, 1994). Gravel is mainly found in the southern areas of the Maas, between Maastricht and Beesel (Consortium Grensmaas, n.d.). Especially the unique gravel bedding and the fact that the GM is not canalized provides special opportunities for restoring the natural course and for nature to development.

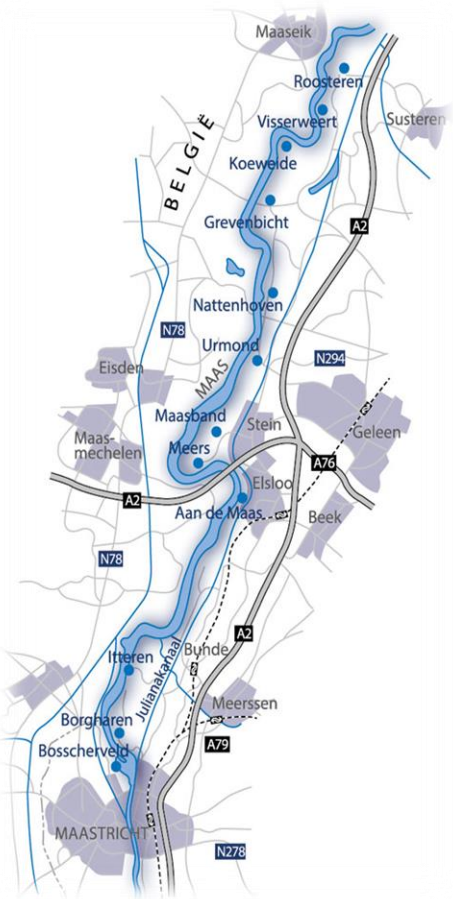

Figure 3: The Grensmaas river and area

2.2. The Grensmaas River until the 1980s: A dull river

The Maas river used to form a strong part of the identity of the province of Limburg; the river was an eye-catcher and it connected the different regions in the province (Helmer, Overmars, & Litjens, 1991). In addition to this, the Maas used to have wide river banks and to meander freely with space to carve out its own course. However, over the course of time, many of these characteristics have disappeared. The Grensmaas specifically suffered the same fate. It has lost much of its natural character since the beginning of the 19th century when levees were built in order to increase its navigability (Meertens, 2014;

Rijkswaterstaat, 1994). From then on, the Grensmaas flowed through a 60m. narrow channel, surrounded by steep banks and economically not very valuable agricultural fields (Meertens, 2014). However, the river was never suitable for large-scale shipping activities, partly because of lacking cooperation between Belgium and the Netherlands and partly because of the steep gradient of the river (Meertens, 2014). Although there was no demonstrated economic use for the summer levees, they were not removed because of its use for fixing the border between both countries and because of its protection against small flooding events (Meertens, 2014). However, the levees were since the 1980s not anymore seen as a long-term solution for river management in the Netherlands and was replaced by the 'Room for the river' approach (see chapter 1.3).

2.3. Nature development and restoration of the river dynamics

The new approach would change the fate of the GM area. In the new approach, the Maasdal (Meuse valley), and with that, the GM river, were marked by the Dutch government as important areas for nature development (Helmer et al., 1991). To formalize this, the area has become part of the 'Ecologische Hoofdstructuur'. Within this framework, the Dutch government had identified key natural areas and key development areas with the goal of reversing, or at least halting, the loss of biodiversity (Helmer et al., 1991). The GM river fitted well with this approach because it consists of unique potential for nature development as it is a gravel river and as the river is prohibited to be used for shipping and boating (Helmer et al., 1991; Rijkswaterstaat, 1994). Next to the added natural area, the novel nature was envisioned to also develop environmental consciousness in combination with tourist activities (Helmer et al., 1991; Meertens, 2014). In addition to the potential for nature development, there were also economic considerations which made the GM interesting. As the river consists of a gravel bedding, the gravel could satisfy the national gravel demand (Helmer et al., 1991). This fitted well with the goal of nature development as extracting gravel is a way to achieve nature development (see chapter 2.6 below). Another reason the GM river fitted well was that gravel extraction was already common throughout Limburg. For example, north of the Grensmaas, near Roermond, thousands of gravel pits form the Roermondse plassen. Next to the positive economic effects of gravel extraction, it was also a source of tension (Warner, 2016). The Roermondse plassen consist of unsightly gravel holes and its development generated much noise, dust and transport pollution. This had led to protests of nature organizations and affected citizens (Warner, 2016). The protests against gravel in the Roermondse plassen led to promises of establishing novel links between the environment and economic activities in which gravel extraction would become greener, for example by extracting gravel superficially and in which gravel extraction would be phased out. Gravel as a fuel for conflict has also played a major role in the case of the Grensmaas as subsequent sections will show.

2.4. The Grensmaas project and its aims

Based on ecological and environmental principles, the GM River was to change from a static, narrow channel to a dynamic and natural river once again. After the extraction of gravel, natural river processes, without much interference, would lead to an environment with renewed flora and fauna. Small islands, river dunes, gravel- and sand banks, dynamic local erosion and sedimentation processes, variable currents and new channels would develop over time (Helmer et al., 1991; Meertens, 2014; Rijkswaterstaat, 1994). Letting horses and cattle roam freely in the area would create a diverse nature with pioneer grass species alternated with grassy flowery fields, woody shrubs and different types of woodlands by curbing forms of succession (Meertens, 2014). These types of flora would attract different forms of wildlife and fauna such as the beaver and the fish eagle which are species with a high cultural value (Meertens, 2014; Rijkswaterstaat, 1994).

The proposal to restore the Grensmaas was developed already in the 1980s (Roth et al., 2017). In the initial proposal agreement in 1990, the province of Limburg made an agreement with the former Ministry of Transport and Water Management to extract 35 million tons of gravel from the GM for national needs (Helmer et al., 1991). The way gravel extraction that would take place in this project was radically different from before. In anteceding projects such as projects in Roermond, gravel extraction had always been in forms of deep extraction, creating large pits (Warner, 2013). In the GM project, extraction would be mainly superficial, but there would also be some deeper extraction. With the deeper extraction, as can be seen in the right part of figure 4, first the topsoil ('deklaag') would be removed after which the gravel will be won and transported to the process location straight away. In the superficial extraction of gravel and sand, the top soil would also be removed and used to fill up the deeper pits. This topsoil, which mainly consist of clay, would decrease water seepage from the river into the surrounding area as it is less permeable than the gravel and therefore it would be part of the protection of the surrounding area (Rijkswaterstaat, 1994). When the top soil from the superficial area had been removed, a layer of gravel and sand would be extracted after which deeper layers of gravel would come to the surface.

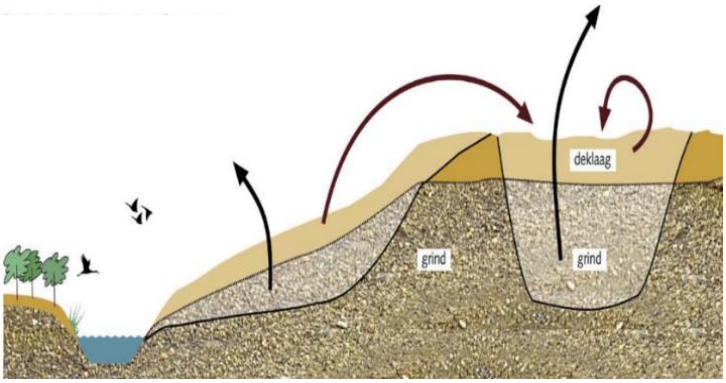

Figure 4: The process of gravel extraction in the Grensmaas project (Swam, 2010). Although the figure is in Dutch, it gives a good overview of the process. The Dutch words are explained means the following: 'Grind' means gravel and 'deklaag' means topsoil

The two main goals of that time were gravel extraction and nature development, while flood protection was not seen as a priority. These goals were synthesized in 1992, when the provincial government of Limburg, the Ministry of V&W and the Ministry of Agriculture, Nature management and Fisheries initiated the Grensmaas project (Rijkswaterstaat, 1994). The gravel extraction and the corresponding comeback of nature was to occur in 12 locations, surrounding over 15 parishes and villages. The project would be tendered to the private sector which would be the Grensmaas Consortium (GC) and with the monetary gains from the project, the nature restoration would be funded (Wesselink et al., 2013). The land, acquired by the consortium for the gravel extraction would be transferred to a Dutch environmental NGO, Natuurmonumenten. As the project was going to have a large impact on the surrounding landscape, the project planned to include inhabitants and other stakeholders in dialogues and other forms of input (Rijkswaterstaat, 1994).

2.5. The flooding events of 1993 and 1995

In December 1993, the Maas saw its water levels rising to levels not seen since the 1926 flooding, the last large river flooding in the Netherlands. There was a discharge of 3120 m/s^3 and a water level of 45.90 m, 6 meters higher than usual (D.-G. Rijkswaterstaat, 1994). During the flooding, approximately 10% of Limburg was flooded, around 8,000 people were evacuated and damages were approximately €122 million (Wesselink et al., 2013). There were several areas within the GM which saw severe flooding; Borgharen, Itteren, Geulen and Meers. As this was the first large flooding event since 1926, flooding events were not present anymore in the collective memory (Wesselink et al., 2013). However, after this flood, flood protection became a priority for the province of Limburg and for the rest of the Netherland, accelerating the novel 'room for the river' approach to river management (van Stokkom et al., 2005; Wesselink et al., 2013). It was in this light that the Grensmaas project was revitalized as the gravel extraction could achieve the right protection levels of 1/250 years by increasing the capacity of the basin.

This level of 1/250 is lower than it is in more urbanized, more densely populated and more economically valuable areas (Wesselink et al., 2013). With these initial plans slowly developing, a year later, the Maas again flooded. It reached similar, but somewhat lower, water levels. However, in total, 250,000 people in areas prone to flood risk were evacuated, also outside of Limburg (Wesselink et al., 2013). The Limburgers wanted immediate action and the government saw this as a window of opportunity to push through the original plan, therefore flood prevention became a national issue (Wesselink et al., 2013).

2.6. The foundations of the current Grensmaas project

When flood protection became a major pillar for the Grensmaas river, the project as it is today, was developed. The stakeholders executing the project, is called the Grensmaas Consortium (GC). The GC consists of 14 private partners, of which three contractors (Van den Biggelaar, Boskalis & van Oord), 11 gravel extraction companies (L'Ortye Stein BV among others) and Natuurmonumenten, an NGO which manages nature areas in the Netherlands. The total costs of the project are approximately 550 million euros and around 10,000 permits had to be obtained (ING, n.d.; Nieuwenhuizen, 2018). Currently, the project is scheduled to be finished in 2027. The project contract is a self-realization contract which was revolutionary at the time it was implemented. It is based on the premises that a land-owner can and is willing to execute the government designed destination-plan of an area. This means that there is no contractor-client relationship between in this case the government and the GC, but that the GC bears all the risks and profits of the project (Swam, 2010). This also means that the GC has to acquire the land from the landowners themselves and has to transfer the land to the involved nature conservation organisations once the project is finished. The role of the government agencies is to oversee the project and ensure that the terms of the contract are met.

In total, it was agreed that 55 million tons of gravel and 10 million tons of sand would be extracted (see table one). As can be noted, by far most of the gravel would be extracted from Koeweide with over 26 million tons, making up 40% of the total amount. Koeweide is also the location where all the gravel of the northern-most locations is processed and shipped away from because its connected to the Juliana kanaal (Juliana Channel). After Koeweide, Itteren follows with around 11 million tons of extraction. Itteren, where the project has ended, is the place where the gravel and sand from the southern locations was processed and shipped away from via the channel. Borgharen and (Guelle) aan de Maas see approximately 7.5 and 6.2 million tons of gravel extraction. The locations where the least amounts of gravel has been and will be won are Urmond with 160,000 tons, Grevenbicht with 1,2 million tons, Nattenhoven (1,6 mil tons) and Maasband (1,7 mil tons).

Areas of extraction	**Amount extracted in tons**
Bosscherveld	2.957.552
Borgharen	7.557.265
Pond (Borgharen)	750.000
Itteren	12.132.333
Aan de Maas	6.213.739
Meers	2.617.959
Maasband	1.739.735
Urmond	159.864
Nattenhoven	1.630.352
Grevenbicht	1.221.808
Koeweide	26.254.363
Vissersweert	2.276.797
Total amount extracted	**65.511.767**

Table 1: Final extraction numbers of the GM project. The total consists of 55 mil. tons of gravel and 10 mil. tons of sand. Retrieved from personal correspondence with Ben Vis

Gravel in the Netherlands is used for a multitude of purposes such as in tarmac, roads, office buildings and overpasses (Consortium Grensmaas, n.d.). Information about monetary value of gravel are scarce,

because there is no specific indexing for gravel. Prices from 1999-2004 were between 8-10 euro's per ton (Rijkswaterstaat, 2005). The importance of gravel is shown in table two. Gravel, of all the Dutch extractive surface minerals, makes up 7-8% of the total in volume (Hoen, 2017). Generally, more than 4 million tons of gravel is won in the Netherlands on a yearly basis (see table two). Around 85% of the Dutch gravel extraction is won in Limburg. Of that 75% comes from the GM project (Hoen, 2017). Therefore, in total, 60% of all the Dutch gravel is extracted by the consortium. This highlights the dependency on the gravel from the project and it highlights the stakes involved. The gravel extraction industry in Limburg employs directly and indirectly around 500 people (Consortium Grensmaas, n.d.) which is 0,1% of the total number of jobs in the province (Arbeidsmarktinzicht.nl, 2019).

	2009	2010	2011	2012	2013	2014	2015	2016
Provinces								
Overijssel	33	36	31	32	24	39	51	47
Gelderland	243	289	409	488	403	478	594	583
N-Brabant	151	319	317	340	213	110		
Limburg	2.820	3.615	4.168	3.625	3.960	4.568	3.675	3.941
Total provinces	3.247	4.259	4.925	4.445	4.600	5.195	4.320	4.571

Table 2: The amount of gravel won per province between 2009-2016 (amount in). Adapted and retrieved from Hoen (2016)

Location	Total amount in ha	Total amount of novel nature outside of the winterbeds (ha)	Start	Ending
Bosscherveld	35	37	2009	2017
Borgharen	125	84	2010	2014
Itteren	205	130	2008	2017
Aan de Maas	105	72	2012	2015
Meers	135	64	2008	2024
Maasband	60	42	2014	2017
Urmond	35	29	2016	2018
Nattenhoven	60	58	2019	2021
Grevenbicht	75	47	2017	2021
Koeweide	260	170	2015	2024
Vissersweert	60	34	2016	2019
Total	1155	768		

Table 3: Amount of novel nature. Retrieved from personal correspondence with Ben Vis

In addition to the gravel extraction, 1208 hectares (ha) of novel nature areas will be added of which currently 1124 ha have been realized (Meertens, 2014; Rebel, 2018). A total of 768 ha of novel nature will be created and provided to Natuurmonumenten. This amount includes only the outside of the river beds and is thus also created for recreation. The remaining ha is added within the boundaries of the river beds. This means that sometimes the river will claim the space depending on the water-level fluctuations while at other times, the areas will be dry. In total, 3,500 hectares of nature will be added in the Netherlands and Belgium in the Grensmaas area (Meertens, 2014). As table three shows, most novel nature would come at Koeweide (260 ha) followed by Itteren (205 ha) and Meers (135 ha). The least amount of added nature is at Bosscherveld (35 ha) and Urmond (35 ha). These novel nature areas are part of the RivierPark Maasvallei, a trans-border nature area centered around the Grensmaas (Consortium Grensmaas, n.d.). The area has seen recreational development such as hiking and biking paths, for now mainly focused around Guelle aan de Maas, Meers and Grevenbicht.

3. Theoretical background

Chapter three will examine the different theoretical frameworks on which this thesis research is based. Chapter 3.1 will look into the literature on social-ecological systems and resilience and will explain the reasons for taking a social-ecological system and resilience approach in the case of the Grensmaas. Following this, vulnerability, as part of the resilience framework will be discussed. The chapter ends by highlighting two variables that play a role in the concept of vulnerability, namely adaptive capacity and susceptibility. These two concepts are operationalized through local ecological knowledge and flood risk perception. Chapter 3.2 will look into the concept of local ecological knowledge and that of local flood knowledge. Chapter 3.3 focuses on flood risk perception and the influence of preparedness and awareness on susceptibility to flooding.

3.1. Resilience, vulnerability and adaptive capacity

This section will elaborate on resilience, vulnerability and adaptive capacity. It will look into the concepts and definitions, specifically linking the terms to flood management and flood risk. This is also where it gets messy as resilience, vulnerability and adaptive capacity are highly interrelated (Smit & Wandel, 2006) and are interpreted differently by different scholars whose characterizations of one of these concepts can fit under another concept for another scholar.

3.1.1. Social-ecological systems and resilience

Flood events are the most frequently occurring natural disaster and the damages of flooding events have been increasing over the years (Batica & Gourbesville, 2016; Birkholz, Muro, Jeffrey, & Smith, 2014). Living in floodplain areas represents an interaction between the hydrological, ecological and geophysical and the human system comprised of economic, social and geographical relationships with high levels of uncertainty (Birkholz et al., 2014) Therefore, it is important to look at the dimensions which influences the extent of the damages resulting from flooding. One way of looking at this, and the framework that this thesis is using, is through the lens of resilience in social-ecological systems (SES). Natural systems and social systems are seen as complex systems in themselves (Fikret Berkes, Colding, & Folke, 2008). As environmental problems are emerging from linked social and ecological dynamics, they are also regarded as complex systems (Fikret Berkes et al., 2008). Solving these types of problems is difficult for disciplinary approaches separately because of the connections and interactions within and between the systems. For example, understanding the hydrology of the Grensmaas river is important for river management, however, understanding discharge and flow of the river and basing management solely on this, ignores social dynamics such as those in Itteren. Inhabitants from Itteren view flooding events as part of daily life and the national government as relatively intruding (Engel et al., 2014). This is important to understand as measures have to take these social attitudes into account and are partly based on social and political attitudes themselves, which also need to be understood. Therefore, understanding environmental issues from a SES perspective is a novel way of analyzing these issues. In the framework of SES, resilience is very important as it is a perspective to analyze interactions and dynamics within SES (Folke, 2006). It is a way to look at the way societies deal with 'external' change and disturbances (Fikret Berkes et al., 2008). Resilience is a term originating in ecology (Holling, 1973) and is identified in general terms as

the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker, Holling, Carpenter, & Kinzig, 2004, p. 2).

Resilience consists of four main aspects; resistance, latitude, panarchy and precariousness (Walker et al., 2004). Resistance relates to the ease of changing the system, latitude to the maximum amount that a system can be changed before it crosses a threshold, panarchy to the influence of dynamics and states at other scales and precariousness finally relates to the vicinity of a threshold. One of these 'external' disturbances could be flooding events. There is a general consensus that flooding events will only become more prominent and more extreme, also in the case of the Netherlands and the GM (Rijkswaterstaat, n.d.). Therefore, looking at resilience dynamics in the case of flood and flood risk management in the Netherlands, is important. Resilience in terms of resistance, latitude, panarchy and precariousness could be thought of in case of the Grensmaas. Resistance for example would discuss the proneness of altering social or hydrological conditions which creates more difficulties for flooding and therefore might increase the resilience of the system. Looking more specifically into resilience in the context of flood management is framed differently and is more focused on the impact of the flooding. According to the definition of De Bruijn & Klijn (2001) resilience is

Strategies for flood risk management in which resilience is used focus on reducing the impact of floods by "living with floods" instead of "fighting floods"

This form of resilience is focused on creating space for flooding events to occur with the goal of minimizing the impacts of the flooding events and to accelerate the recovery. It is focused around continuous and flexible adaptation to changing circumstances, but it does not look at the four main aspects as described by Holling (2004) and Berkes et al (2008). This approach looks at the landscape- and spatial level, taking the area as a whole including all its social, spatial and natural dynamics into account. It differentiates between higher- and lower valuable areas as higher-value areas are protected over lower-value areas, looking from an economic perspective (Vis et al., 2003). In order to 'live with' flooding events, space has to be created to accommodate flooding within certain boundaries. The two main principles for this are flood-bed detention and 'green rivers'. Flood-bed detention increases temporary water storage at a local scale which decreases down-stream discharge by detaining water more upstream. In the Grensmaas project, this occurs by lowering and widening the floodplains. Green rivers measures refer to additional channels which are (re)created to enable extra discharge and peak attenuation. As these principles need physical space to develop, land which was owned by different groups of people, these novel measures have social- and psychological impacts and change perceptions of people. However, resilience is still a broad term, too broad to sufficiently capture the dynamics researched in this thesis. Delving into more detail is needed as this research will look more specifically at the loss of local ecological knowledge and at altered risk perception. These are dynamics influencing resilience, but are not captured by it completely, therefore. In natural hazard and flood research, vulnerability is tightly linked with resilience (Birkholz et al., 2014) and this concept will be developed in more detail in the next section.

3.1.2. Vulnerability, susceptibility and adaptive capacity

Vulnerability is a term which has not seen a consensus amongst the scientific community (Few, 2003). It is especially messy as the concepts of vulnerability and adaptive capacity are overlapping and as there is no consensus on which characteristics and which indicators belong to which concept (Smit & Wandel, 2006). Within vulnerability science, there are many (related) definitions and concepts existing and this master thesis will highlight a few, after which it will provide a rationale of the reasons for choosing a certain definition. In relatively broad terms, the IPCC defines vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007). As can be noted, this definition is already more specific than the

definition of resilience as it specifically highlights climate variability and extremes, which is relevant in the case of flooding. It differs furthermore from resilience in the sense that vulnerability is more focused on the dynamics preceding the event itself, explicitly relating to a certain amount of risk and the factors deciding on its damages. It focusses less on the capacity to overcome and learn from disasters. Also, it implies a long-term focus, while flooding requires a short-term focus as well. In risk disaster management, vulnerability has been prevalent for over 40 years and the concept is developed and utilized much more than the concept of resilience is (Fekete, Hufschmidt, & Kruse, 2014). Messner & Meyer (2006) define vulnerability as the potential of socio-economic and ecological systems to be harmed by a hazardous event. This focus on the potential, or the susceptibility, of a system is important as stated before, because vulnerability specifically focuses on the dynamics which define the extent of the potential impact of the flooding event. Finally, Schneiderbauer & Ehrlich (2004) define vulnerability as

The characteristics of a person or a group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural or man-made disaster — noting that vulnerability is made up of many political–institutional, economic and socio-cultural factors' (p12)

As this master thesis focuses on the capacity on a personal, household and community level and less so on the whole system, this definition fits well. It shows also, as Birkholz et al. (2014) suggest, that vulnerability explores the role of the social context in shaping risk. In addition, the definition highlights the capacity of a person or groups. This capacity is important as it provides agency to people and communities to actively, and not only passively, deal with disasters contrary to the definition of the IPCC. People are not only victims, but they also shape their conditions and interact with the systems they are living in.

Vulnerability is described as having three components, namely exposure to a hazard, susceptibility to harm and adaptive capacity. When a system or a community sees a high exposure, a high susceptibility and has a low adaptive capacity, the damages are likely to be higher. Important for this thesis are the concepts of susceptibility and of adaptive capacity. Susceptibility in this case, is more socially-oriented and it related to the likeliness to be influenced by the disaster (Messner & Meyer, 2006). Indicators of susceptibility include awareness and preparedness, but also socio-economic factors which are correlated to the impact of flooding events (Messner & Meyer, 2006). Awareness and preparedness are of prime interest for this thesis and the thesis argues that susceptibility could increases as awareness and preparedness decrease because of altered risk perceptions (see section 3.3).

Adaptive capacity refers to the potential of a system, in this case households, to make adjustments and prepare more effectively for the effects and impacts of hazards (Lopez-Marrero, 2010). This is very similar to the concept of vulnerability, but it focuses more on a specific part of vulnerability, namely the local capacity of providing a condition to respond to flooding events. In the case of the GM project, having LEK enables inhabitants to respond proactively to flooding events because inhabitants can see them coming. This gives them an advantage in preparing and anticipating the flooding and therefore to minimize damages. Adaptations are often characterized as processes or actions that are either responsive or anticipatory and they are necessarily contextual and scale-specific (Eakin, Lerner, & Murtinho, 2010). One of the local factors of adaptive capacity is access to knowledge (Eakin et al., 2010). In the case of this research and the GM project, this access to knowledge is possibly decreased as the landscape has changed to the extent that there is less direct knowledge available (see chapter 3.2 for more in-dept information). This decrease of knowledge might inhibit an effective an proactive response.

This thesis will use the framework as seen in figure 5. This figure shows the embeddedness of the different concepts in order to create clarity of the different levels of the concepts. The GM as a social-ecological system is the overarching approach, reflecting all the social and natural dynamics and interactions involved. Central within SES is the concept of resilience. Because of the interconnections between the systems, human pressures influence natural dynamics which in its turn influence human systems (Folke, 2006). The capacity to withstand and deal with disturbances and pressures is related to resilience. Resilience in itself is still a broad concept. Most relevant of resilience in this research is vulnerability. Vulnerability is important because the large-scale interventions of the project can lead to disturbances, increasing vulnerability. However, in order to operationalize this, a further narrowing is needed. This occurs through the concepts of adaptive capacity and susceptibility. These concepts highlight the individual choice and agency of people who interact with the larger system.

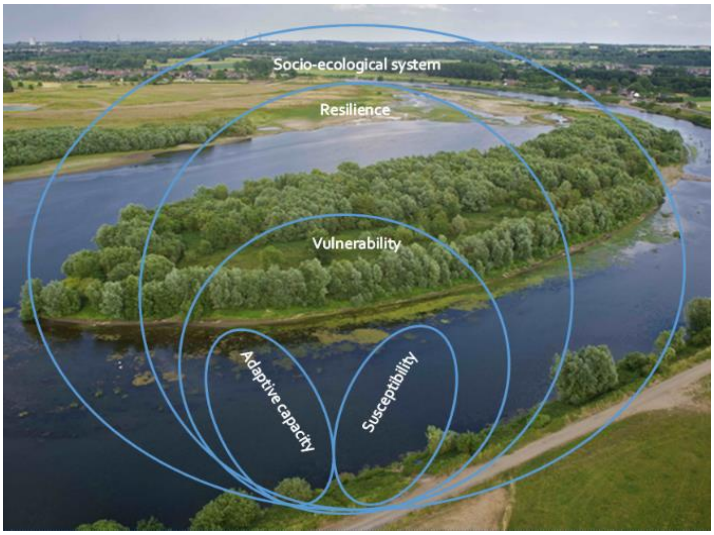

Figure 5: The conceptual scheme of the different nested Grensmaas scales

Having described the concepts of SES, resilience and vulnerability, the general framework of this thesis has been laid-out. Diving deeper into the specifics, as this thesis focuses on social-ecological dynamics, the dissection between the social and the ecological can be further conceptualized in two ways, both related to vulnerability and the concepts of susceptibility and adaptive capacity. Firstly, with regards to the changed environment and altered perception of it, the socio-ecological interaction is manifested through LEK (see chapter 2.2). The erosion of LEK impacts vulnerability, as described by Schneiderbauer and Ehrlich (2004), as it might decrease the adaptive capacity of people and groups to resist and anticipate flooding events. In addition to this, LEK may increase adaptive capaity as it has a richer knowledge system which can be used to cope with novel problems and stresses (Joshi, Arévalo, Luque, Alegre, & Sinclair). Secondly, the GM project might alter measures taken by inhabitants. It is conceptualized through flood risk perception (Birkholz et al., 2014), specifically of preparedness to flooding events. The susceptibility to flooding events is likely to increase as preparedness is impacted. This is described in section 3.3.

3.2. Local ecological knowledge

The first section will delve deeper into local ecological knowledge and its definitions, dynamics and relevance, specifically in relation to resilience and flooding events.

3.2.1. Definitions of local ecological knowledge and related concepts

In the literature on LEK, there are three different concepts which are closely related and which need to be understood. These three concepts are LEK, traditional ecological knowledge (TEK) and indigenous ecological knowledge (IEG). There are no universal definitions of the three concepts and their definitions partly overlap, however, they still target somewhat different aspects of ecological knowledge. One of the most accepted definitions of TEK is a definitions by Berkes (2012):

"Cumulative body of knowledge, practice and belief evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings and with one another and with their environment" (p8).

This definition highlights the continuous alignment and adaptation of societies with their ecological surroundings, focusing mainly on less industrial- and technological societies. Berkes et al. (2012), also observe that TEK contains components of local observations, a component of practice and a component of beliefs underlying those practices (Fikret Berkes, Colding, & Folke, 2000). However, there are certain problems with this definition as it depicts societies as traditional and out of touch with the rest of the world, existing essentially within a vacuum. In addition to this, the term handed down reflects a rather static form of knowledge transmission, however, knowledge is in its essence hybrid and ever-changing. Most importantly, the word traditional can have negative connotations of simple and savage, especially in a western context (Warren, 1995), which is the context of this research. IEK is often defined as similar to TEK, but with a focus on the indigenous as it is more representative of the fluid and dynamic nature of the knowledge. In addition to this, it distances itself from the negative connotation of traditional (McCarter, Gavin, Baereleo, & Love, 2014; Vinyeta & Lynn, 2013). LEK, the term used in this paper, can be defined as

"Knowledge, practices, and beliefs regarding ecological relationships that are gained through extensive personal observation of and interaction with local ecosystems, and shared among local resource users" (Charnley, Fischer, & Jones, 2007).

LEK focuses more on the site-specific character of knowledge, highlighting the fluid and dynamic character of knowledge and less on the cultural and historical meaning. This research is more interested in a site-specific and local approach to the different forms of knowledge that people have and how it has changed recently. The inhabitants of the Grensmaas do not depend on their environment for their livelihood, neither are they indigenous per se. Hence, this paper will explore the topic of the GM in more detail based on the definition of LEK. However, LEK and TEK are quite similar, they are sometimes hard to distinguish and because the inhabitants of the Grensmaas also have recent historic relations to the Grensmaas with many inhabitants having family ties to the area as well as specific cultural ties to the land as is highlighted in TEK, LEK and TEK will be used interchangeably.

LEK is at the intersection of social and ecological systems, which is characterized in figure 6. Local ecosystems are in interaction with people in a continuous feedback with management practices in place. These management practices are also interacting with institutions built around these practices, which also have an influence on local ecosystems. For example, in the GM, the actions taken at specific high water levels (an outcome of the local ecosystem), are a form of management practices influenced by the social and political formal and informal institutions, such as certain official flood prevention measures, but also informal measures such as solidarity and neighborhood warning signals.

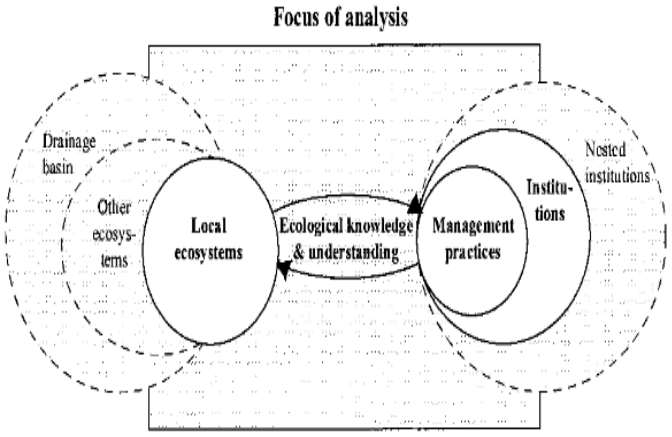

Figure 6: A characterization of LEK. Retrieved from (Olsson & Folke, 2001)

It is important to note that LEK is more than solely the practical knowledge that exists within a locality. This can be conceptualized by the knowledge-practice-belief framework (F. Berkes, 2012). Only when local ecological processes are understood, a response can occur. In order to respond to the knowledge on a collective level, there must be a management system in place, with its tools, techniques and practices. Thirdly, these management systems depend on social institutions, coordination, cooperation and rules for their functioning. In section 3.2.3, it will be discussed how the inhabitants of the Grensmaas relate to this framework.

3.2.2. Local ecological knowledge and scientific knowledge

Due to the growing importance and relevance of LEK, it has become a scientific area of study. One of the essential questions is whether and to what extent traditional, local or indigenous knowledge is different from 'Western' or Scientific knowledge and whether it is possible to see the value of it when it turns out that there is not much overlap. Some, such as Levi-Strauss (1966), point out that there is a distinct and parallel division between indigenous and Western knowledge. The physical world is, according to Western knowledge, approached as abstract and distant while indigenous people are approaching it concrete and based on personal experience. However, following from the fact that all peoples have a universal cognitive structure of the brain, Berkes (2012) notes that Western and indigenous knowledge are the result of cognitive processes to create order out of disorder and hence have similarities between them. Agrawal (1995) provides a deeper analysis and concludes that it is not possible to come up with distinct differences between indigenous and Western knowledge, most importantly because philosophers of science have let go of the possibility of distinguishing science from non-science. He concludes with stating that it would be more sensible to accept the differences and find similarities across the two modes of acquiring knowledge. As it is important to be aware of these nuances, LEK can be described as taking different forms and be less static than 'scientific knowledge' because of its fluid and adaptive nature. The impossibility to create a distinction between scientific knowledge and in this case LEK is important as this thesis does not see LEK so much as opposing scientific knowledge, but more that both can be complementary to each other, showing that there are other forms of knowledge which can be used next to scientific knowledge. As LEK and scientific knowledge are inseparable, this places LEK on an equal level to scientific knowledge and also highlights its inherent relevance providing strong arguments to use LEK also for creating policy. Knowing this, it is important to elaborate on the characteristics of LEK in order to understand what it is and how it can be applied to the case of the Grensmaas.

3.2.3. Renewed interest in local ecological knowledge

The past three to four decades have seen a global renewed interest in LEK. As it was previously seen as unimportant, the 1980s marked the start of a change in the perception on LEK (Agrawal, 1995). However, as the general disappearance of traditional knowledge was so perceived to be so widespread, the question whether or not LEK would survive the 20th century was raised (Gómez-Baggethun, Corbera, & Reyes-García, 2013).

The interest in LEK has been revived for several different reasons. First of all, LEK proves to be very valuable in understanding complex social-ecological relationships (Gómez-Baggethun et al., 2013). Throughout history, societies that maintained close relations to ecosystems and their processes have consequently developed knowledge, practices and institutions related to these ecosystems as LEK shapes local conceptualities, their livelihoods and their ecological surroundings while responding to and interacting with disturbances and changes in ecosystem dynamics. The knowledge that people have is very useful for a manifold of reasons and it acknowledges peoples' experiences and priorities (Davis &

Wagner, 2003). Therefore, it is also important to identify those who have LEK. Oftentimes LEK develops over generations and therefore, it is commonly associated with elderly and those who have had many chances of experiencing LEK (Davis & Wagner, 2003; Souto & Ticktin, 2012). This evidence has been largely coming from a non-Western context, but because LEK is rarely studied in a (Western) European context, it is unknown if the same predictors hold in the case of the Grensmaas. However, if the same predictions hold, it is assumed that inhabitants who have been living in the area longer and elderly, have more LEK. This also counts for inhabitants who feel connected to the area, as they might engage more deeply with the environment they live in.

Also, instead of perceiving LEK as having no intrinsic value and based solely of folkloric interest, a paradigm shift occurred which focused on the value of adaptive capacity of LEK and its contribution to social and environmental resilience (Gómez-Baggethun et al., 2013). This focus on its adaptability in modern times shifted from being static and essentialized to being hybrid and dynamic with capabilities to adjust to shifting social and environmental conditions. This acknowledgement of LEK is not only happening within the academia, but also in politics (F. Berkes, 2012; Gómez-Baggethun et al., 2013). It highlights that LEK is a useful form of knowledge to tackle environmental problems and that it is a source for peoples to adapt to changed environmental conditions which is vital in times like these.

This is relevant in the case of the Grensmaas as the inhabitants were able to read the river's 'behavior' and were able to act accordingly (Engel et al., 2014). From looking at the knowledge-practice-belief framework provided by Berkes (2012), inhabitants of the Grensmaas used to have local knowledge related to the functioning of the river system, as they were able to interpret river signs. This knowledge interacts with the management system in place, which is mainly a self-reliant form of management. For example, Borgharen is divided in blocks where one person is leading the evacuation in case of high water events (Engel et al., 2014). On the other hand, there are also municipality-level measures in place. These management systems are embedded in and interact with the cultural context of solidarity and self-sufficiency. Hence, having the ability to read the river brings with it certain practices which in its term interact with the knowledge. However, according to Engel et al., (2014), LEK is decreasing. This undermines these management and social systems underlying the LEK of the Grensmaas residents and increases its vulnerability.

3.2.4. Local Flood Knowledge

There is a limited number of studies conducted that share some light on the dynamics of local flood knowledge (LFK) (Lindsey McEwen & Jones, 2012; LJ McEwen, Krause, Jones, & Hansen, 2012). As seen within LEK, the value of LFK is also increasingly becoming acknowledged and integrated for improved flooding management (Lindsey McEwen & Jones, 2012). People who have LFK are oftentimes inhabitants of a region or people working for local authorities. This knowledge is experience-based and therefore it is very connected to memories of past flooding events and on emotional responses (LJ McEwen et al., 2012).

LFK is important because it is characterized by a very fine-grained and precise scale of how water moves in times of flooding events (Lindsey McEwen & Jones, 2012). For example, during flooding events, LFK can elaborate on the precise way water will move through a street and where points of clogging might occur, which is not always recognized by 'expert' forms of knowledge. In addition to the scale and detail of LFK, it is also characterized by the possibility to verify the course of flooding events by repetitive and successive observations, by positioning processes in time and space, by its sense-of-place and other historical evidence (Lindsey McEwen & Jones, 2012). LFK can be expressed through narratives, histories

and folk memories and they can be orally expressed, written-down, institutionalized in museums, by photographs and in public spaces, where flood markings can be shown (Lindsey McEwen & Jones, 2012; LJ McEwen et al., 2012). In the case of the Grensmaas, these forms of knowledge also seem to exist. High water events such as 1993 and 1995 are in peoples' memories and have left remembrance marks in the area. In addition to this, the flooding events could have been very important when it comes to having that fine-scale knowledge of the movement of flooding events.

3.2.5. The loss of local ecological knowledge and local flood knowledge

Section 3.2.3 has shown the importance of LEK with respect to the adaptive capacity and resilience of communities to climate disturbances and flooding events. However, the loss of LEK creates difficulties for these communities. The loss of LEK and the problems associated with it will be described in the following section.

In a global literature review by Aswani et al., (2018), the loss of LEK has been researched on a meta-level. On a global scale, about 77% of the papers, writing about the dynamics of LEK, has seen an actual loss. In another paper by Tang and Gavin (2016), globally 89% of cases has seen a decrease in LEK. The loss is not equally distributed among different forms of LEK, mainly impacting ethnobotanical and medical forms of LEK (Aswani et al., 2018). There are several drivers which are generally provided as causing the loss, such as globalization, formal education systems, tourism, shift from primary to secondary sectors, modern agricultural practices, market integration and acculturation (Aswani et al., 2018; Fernández-Llamazares et al., 2015; Gómez-Baggethun et al., 2013; Gomez-Baggethun, Mingorria, Reyes-Garcia, Calvet, & Montes, 2010; Gómez-Baggethun & Reyes-García, 2013). There are also correlations between the loss of biodiversity and erosion of LEK, in that where biodiversity decreases, LEK seems to decrease (Maffi, 2005). Finally, conservation was also mentioned as a cause of the erosion of LEK (Gomez-Baggethun et al., 2010).

As stated before, there is a bias of researching TEK and LEK outside of Europe, with limited studies done within Europe. This also accounts for the papers related to the erosion of LEK. There are, however, papers, which have researched the loss of LEK and also in Europe there seems to be a trend towards decreased LEK. Out of the 37 studies that Hernández-Morcillo (2014) examined, 21 examined local trends of which 14 mentioned losses. The erosion of LEK in Europe can mainly be attributed to inclusion into the market economy (Calvo-Iglesias, Crecente-Maseda, & Fra-Paleo, 2006; Gomez-Baggethun et al., 2010). In addition to this, demographic changes, inflexible policies and decreased interest of the younger population (Hernández-Morcillo et al., 2014). Finally, one case of increased conservation has led to the erosion of LEK (Gomez-Baggethun et al., 2010).

McEwen and Jones (2012) also mention several ways through which LFK can be lost. Flood markings can disappear through planning and development of spaces, through the breakdown of knowledge networks as communities change and through clashes of local and expert knowledge when LFK is not integrated.

Especially the disappearance of flood markings is important in the case of the GM. Interestingly, the relation between conservation and erosion of LEK, which does not seem to be a prime cause leading to the erosion of LEK, also plays a role in the GM. The landscape which has changed tremendously because of conservation and regeneration efforts, could have led to difficulties for inhabitants to read the landscape. This could lead to a general loss of LEK as the landscape has changed tremendously. This is potentially dangerous as Engel et al., (2014) have noted because of the capacity to respond.

3.2.6. Perseverance and novel forms of LEK

Although there is a general tendency towards the erosion of LEK, adaptation, which is at the basis of LEK and TEK, also highlights the perseverance of LEK. LEK, in essence, has the tendency to adapt and proliferate through hybridization and fusion with different types and modes of knowledge. The conservation and persistence of LEK occurs through the persistence of belief- and cultural systems (Aswani et al., 2018). Also, as LEK is dynamic (Godoy et al., 2009; Gómez-Baggethun & Reyes-García, 2013; Mathez-Stiefel, Brandt, Lachmuth, & Rist, 2012), novel and hybrid forms of knowledge are being formed which not necessarily need to lead to a loss of LEK (Aswani et al., 2018). In the case of the GM, this hybridization of knowledge also seems possible. Although the river landscape in its current form might be very different from the landscape before the project and although it might be harder to read it now, new forms of LEK might develop. They could be obtained through novel observations and experiences. However, as Engel et al., (2014) note, knowledge might only come back after a flooding event has struck again. In addition to this, public signs commemorating flooding events, museums, stories by people who have experienced these events and the media and governmental institutions also play a role in maintaining and developing new (Lindsey McEwen & Jones, 2012; LJ McEwen et al., 2012).

3.3. Flood risk perception and private measure taking

Flooding events can be devastating in material terms as well as in personal and emotional terms (Jonkman, 2005; Linnerooth-Bayer & Amendola, 2003). Therefore, it is important that it is understood how flooding impacts can be minimized. One way of doing so is by highlighting the importance of taking preventative measures (Terpstra, 2011). It has been widely acknowledged that risk perception plays an important role in the response of communities and individuals towards risks judgment (Birkholz et al., 2014). Messner and Meyer (2006) identify risk perception as referring to the intuitive risk judgements of individuals and social groups in the context of limited and uncertain information. It is a complex process which involves cognitive and affective responses and as currently widely acknowledged, it is socially produced (Messner & Meyer, 2006). Studies show that human perception of flooding events is closely correlated with previous experiences and with the immediacy of flooding events (Lara, Saurí, Ribas, & Pavón, 2010). When there is less previous experiences and there is no immediacy, flood perception is low. In the case of the Grensmaas, the current project might take away from the immediacy as it has decreased the flooding likelihood.

However, it is important that individuals, households and communities keep on taking precautionary principles because these measures are seen as being highly effective in decreasing monetary and emotional damages (Grothmann & Reusswig, 2006) and can decrease flooding damage by 50% (Baan & Klijn, 2004). Susceptibility to flooding events depends on the preparedness and awareness as part of risk perception (Messner & Meyer, 2006). This preparedness and awareness has been researched in a paper by Grothmann and Reusswig (2006) in which they argue that there are four different components which lead to different levels of precautionary measures, namely threat appraisal, coping appraisal, threat experience appraisal and administrative measures appraisal. Threat appraisal relates to risk perception factors. What is the damage potential and what is the probability of an event. Coping appraisal occurs when a certain level of threat perception is reached and is related to the performance and ability of taking protective measures and doing what is perceived to be needed. Threat appraisal is likely to lead to some forms of protective coping response, however, this is more motivational while it does not automatically lead to protective behavior. Coping appraisal on the other hand, leads to actual behavior. The third element, threat experience, relates to past experiences and should motivate for action. Finally, administrative measures relate to official measures by public agencies and it is hypothesized that taking personal measures is negatively related to this. Hence, when for example administrative measures are

appraised highly, i.e. when there is confidence in the measures of authorities, then less individual and households take precautionary measures. Risk preparedness and awareness are highly relevant in the case of the Grensmaas as in the Grensmaas, authorities and the GC prioritize flood risk reduction through the measures taken in the project. This then might assume that because of a lower threat appraisal and trust in administrative measures, inhabitants are less likely to take measures.

In conclusion, there are two components of vulnerability relevant for this thesis, that of adaptive capacity through altered states of LEK and flooding preparedness through altered risk perception. These two components will be operationalized through a survey.

4. Materials and methods

This section describes the different aspects of the methodology and materials of this master thesis. It starts with the research design in which the main research method, the survey, is described. Where after the research area is elaborated upon. The data collection section will elaborate on the sampling methods and on the strategies to obtain a sufficient number of survey respondents. The data analysis section describes in detail how the theory and the concepts are linked with the research question through the survey; which survey questions are used as indicators for which concepts and which survey questions are used for the sub questions of this research.

4.1. Research design

The research design of this thesis is based on quantitative field research ny means of an online survey. A survey is defined by Check and Schutt (2011) as "*the collection of information from a sample of individuals through their responses to questions*" (p160). This research is mainly quantitative because the online survey consisted mainly of numerically rated items and closed questions. However, there are some qualitative aspects to the survey. It is a cross-sectional survey because the survey is collected at one point in time. As the survey forms the main part of the research, most effort with regards to the organization of the research has been put in the development and promotion of the survey.

4.1.1. The online survey

The survey questions are all related to perception, behaviors and attitudes of and towards local ecological knowledge and risk perception. A survey design is used because surveys are common and useful for obtaining social characteristics of participants, such as attitudes, beliefs and reasons for behaviors, especially within the field of natural hazards (Bird, 2009). The survey questions were developed by the author and based on some of the literature of Engel et al. (2014), Lindsey McEwen & Jones (2012) and Messner & Meyer (2006). Firstly, a pilot survey was composed. This has been checked by several people from the five Klankbordgroepen (community cooperatives) in the Grensmaas area. It was chosen to check the pilot by people from the different Klankbordgroepen because they are all experts on the developments in the Grensmaas project. They are the representatives of the villages and parishes and they take part in discussions with the CS about the developments in the area they live in. These experts have a lot of knowledge about the area and about the project developments. Above all, they are very engaged citizens. For the pilot survey, they were asked to provide comments and recommendations on clarity of language, length and content. The final survey was distributed online through the paid version of Qualtrics, for which the WUR has a license. Qualtrics was used as the survey program because of its professional and useful functions for good implementation and data analysis of the surveys. The survey was sampled based on convenience- and snowball sampling. First a Word version of the survey was composed where after the Qualtrics version was developed. In order to obtain more respondents, there were three prices which the respondents could win. The prices were 100, 50 and 25 euros worth of VVV (the Dutch national tourist information center) coupons to spend on a dinner or an activity affiliated with the organization.

The survey consisted of approximately 50 questions divided into four sections and can be found in appendix one as well as on tinyurl.com/grensmaasproject and was put online on the third of December 2019 until the 7th of February 2020. The first sections contain questions on experiences with high water events before and after the Grensmaas project. The second section questions awareness and preparedness of the residents before and after the implementation of the project. The third section compares the local ecological knowledge before and after the project and the final section asks about

demographics. The questions consist mainly of closed questions because of the statistical component of the analysis. Most questions are ordinal or nominal, but there are also some interval questions. The ordinal questions always have three or five categories and they are always categorized from negative or low etc. categories, to positive or high etc. categories. The ordinal questions are sometimes categorized on a numerical scale, always ranging from 1-5. When the distinctions between the most negative and most positive categories were not straight-forward or when using numbers was not logical, nominal questions were worded.

4.2. Research areas

The following section will describe the areas in which the survey would be conducted. The areas include the surroundings of and the parishes where the Grensmaas project has been active. They differ in characteristics such as demographics, socio-economic backgrounds and extent of GM activities, the last one which can be seen in the figures in chapter 2.6. The location of the different villages and parishes can be seen in figure 7 and the main areas which are developed in the Grensmaas project are described below from south to north. The areas described include the main villages and parishes directly near project locations of the Grensmaas project as has been taken from the website of the Grensmaas. However, there are also respondents from other villages and parishes within the Grensmaas area as can be seen in the results section.

Figure 7: The villages and parishes in the Grensmaas area

1. **Bosscherveld** is a small neighborhood in the north of Maastricht with a population of only 50 inhabitants (ThuisinMaastricht, n.d.). Bosscherveld is the southern-most location of the GM project and it is the only location on the Western banks of the Grensmaas and therefore not connected to the other GM areas (Consortium, 2017). In addition to this, the function of the landscape has completely changed from an agricultural to a nature area of approximately 42 hectares. It is a relatively small nature area with different small channels, islands and hiking and hiking opportunities. As the area is part of Maastricht, it is functioned to become an important recreational area (Consortium, 2017). Because of the economic crisis, the project was stagnated in 2010, but has been finished in 2019.

2. **Borgharen** has approximately 1,838 residents, most of which have been living in the area their whole life (De Voogt & Munaretto, 2017). The main occupation of the inhabitants is in the secondary and tertiary sector (De Voogt & Munaretto, 2017). The project execution in Borgharen has been quite extensive, with an extension of 125 ha of nature and a considerable amount of gravel extraction of 4,8 million tons. The project ran from 2010-2014 and is finished now for over five years.

3. **Itteren** has 1012 inhabitants, most of which are farmers and most of which have been living in Itteren their whole life (De Voogt & Munaretto, 2017). During the floods of 1993 and 1995, Itteren

saw heavy floodings and also in 2011, a smaller flooding event has hit Itteren. The project in Itteren ran from 2008-2018 and around Itteren the largest amount of nature area has been created out of agricultural lands (205 ha). Itteren is also where the most gravel has been extracted of the northern locations and in addition to this, it used to be the distribution area for the gravel in the southern part of the Grensmaas.

4. The parish of **Guelle aan de Maas** is a small parish with approximately 80 houses and 200 inhabitants (Plaatsengids.nl, n.d.-a). In 1993 and 1995, the parish was flooded after which levees were constructed (Guelle.com, n.d.). These levees averted other flooding events in 2002 and 2003 (Guelle.com, n.d.). This GM project was in process from 2012-2015 and took place mainly in the north of Guelle aan de Maas. A relatively small amount of gravel was won near Guelle (1,5 million tonnes), while approximately 105 ha of nature was added. After the original plans to create a storage for the gravel were altered and Itteren became the new location for shipping, the inhabitants were sceptic because of the movement of hundreds of trucks per day. However, because of a reached agreement with the Consortium which had taken extra measures such as sound walls, a deepened working road and sprinkle installations, the nuisance was limited (Guelle.com, n.d.).

5. **Meers** is a parish with around 1200 inhabitants (MaasKentji, n.d.). In 1993 and 1995, the parish escaped extensive flooding events (MaasKentji, n.d.). In 1998, Meers was the guinea pig project of the Grensmaas and the GM consortium worked around Meers from 2001-2008 (Ark.eu, n.d.). The construction included some minor work on levees, but largely a widening of the river channel (north)west of Meers. In 2017, the development of 135 ha of novel developed nature was finished. Natural river dynamics already seem to be back as in the winter of 2018, the river created a novel channel while washing away part of the forest (NatureToday, 2018). The total amount of gravel extracted is 5,5 million tons and will be finished in 2023.

6. **Maasband** is a very small parish north of Meers, with approximately 140 inhabitants and around 60 houses (Plaatsengids.nl, n.d.-c). The GM project, which will run from 2021-2023, will not include channel widening as there is too little space on the riverside of Maasband. Therefore, a secondary channel, east of Maasband will be constructed to increase protection against flooding events (Plaatsengids.nl, n.d.-c). In addition to this, the levees on the west of Maasband are fortified and new levees are constructed on the east. In case of high water events, Maasband will become an isolated island. Therefore, a bridge will be constructed to keep Maasband out of isolation. Because of the limited amount of space, only 60 hectares of nature will be added while 3,5 million tonnes of gravel will be won.

7. **Urmond** has approximately 5,000 inhabitants and it consists of two centers, one on each side of the Julianakanaal (Plaatsengids.nl, n.d.-e). Because the part of the village which is on the eastern side of the Julianakanaal is outside of the Grensmaas region, this research only focuses on the part of Urmond located between the Julianakanaal and the Grensmaas river. Urmond used to be a port until the channel was constructed in 1930. The operational phase of the GM project takes place from 2016-2021. During that time, 35 hectares of nature will be added in the south-western part of Urmond through limited channel widening and winterbed lowering. Only 1,5 million tons of gravel will be won. This means that Urmond is a site with relatively little construction. In addition to the gravel extraction, the existing levees will be widened and will be increased (Waterschap-Limburg, n.d.).

8. **Nattenhoven** is a small parish in the municipality of Stein and has approximately 170 inhabitants (Plaatsengids.nl, n.d.-d). Although Nattenhoven is a small parish, the Consortium is winning 4,1 million tonnes of gravel between 2018-2020 in the area west of Nattenhoven. The area will be converted into nature, adding 60 hectares of nature. The areas close to the river will function for river widening, while the areas somewhat further east of the river are used for floodplain development. Furthermore, several levees will be fortified, mainly north of the parish .(Consortium Grensmaas, n.d.)
9. **Grevenbricht** is a village with approximately 2,400 inhabitants (Plaatsengids.nl, n.d.-b). It is one of the larger villages within the Grensmaas area and the work of the Consortium includes mainly widening the channel of the river. Grevenbicht sees relatively little work as only 1,5 million tons of gravel will be won and 75 hectares of nature will be added from 2019-2021. **Koeweide/Trierveld** is the area north of Grevenbicht, right before the sharp right turn of the Maas. It is relatively undisturbed by parishes or villages and therefore the gravel is processed and distributed there. The project here started in 2016 and will end in 2025, when all the gravel in the northern part of the Grensmaas has been extracted. In Koeweide, the Grensmaas will see a large widening of the channel as well as increases in the heights of levees. The largest amount of gravel will be won here, 14,2 million tons. In addition to this, the area will also see the largest increase in nature added, namely 260 hectares (Consortium Grensmaas, n.d.).

10. **Vissersweert** is a small parish of around 50 inhabitants (Plaatsengids.nl, n.d.-b). It is the northernmost location of the GM project where the project ran between 2016-2018. The GM consortium has extracted 2,3 million tons of gravel at Vissersweert and has added 60 ha of nature. This occurred mainly north of Illikhoven and northwest of Vissersweert. As there was no space to widen the river channel west of Vissersweert, a novel channel has been dug east of Vissersweert. Because of this, Vissersweert will be enclosed by the Maas in case of high water events. In order to keep Visserseert out of isolation, a bridge has between Illikhoven and Vissersweert has been constructed. In addition to this, levees surrounding the village have been fortified and new levees have been constructed south of Vissersweert.

4.3. Data collection

In order to obtain a sufficient sample size, two methods of sampling were utilized: the non-probability sampling methods of convenience sampling and snowball sampling, with a focus on convenience sampling. The rationale for these methods is simple. These were the most cost- and time efficient ways to obtain a sufficient level of respondents. There was no budget nor time for extensive and expensive random sampling methods. In addition to this, because of the communal and trust-based atmosphere in the villages, word of mouth was very effective to obtain a large number of respondents. However, there are limitations to the methods used, all leading to a decreased representativeness of the respondents in the area. There were two strategies deployed for collecting the data; contacting people online and asking to fill in and spread the survey as well as advertisement through a flyer.

The first strategy started with email contact with a project coordinator within the GM project in order to developed initial contacts with key groups in the area. The GM coordinator has been very involved in dealing with inhabitants and groups and provided details of the consortium contacts within the five Klankbordgroepen (community groups) Guelle aan de Maas, Borgharen, Itteren, Bosscherveld and Trierhoven. They were contacted to assist with the pilot survey and for promotion of the survey. They were reached out to via email and phone with the goal of establishing first contacts within the parishes and villages. The people were asked to help distribute the survey in the areas they lived in and also to

distribute it with their contacts in the Grensmaas area in general. The emails were accompanied with a flyer (see appendix 2) in which they could find more information on the project and with a link to the survey. Based on these contacts, more email addresses of people within other community groups and of inhabitants were obtained, which in their turn received emailed about the project. In addition to this, several local newspapers, such as Beeg.nl and Born Online were reached out to and agreed to promote the survey on their websites and in their newspapers. In the end, a large group of people was reached and the survey appeared twice in the monthly newsletter of the GC, on Beeg.nl and on Born-Online. In addition, the survey appeared in several Facebook groups from the villages of Borgharen, Itteren and the Obbricht. Moreover, it was distributed within several dorpsraden (village assemblies), such as those of Itteren, Borgharen, Grevenbicht, Illikhoven, Vissersweert, Guelle aan de Maas and Meers. Finally, the contacts have also distributed the survey within their personal surroundings.

The second strategy deployed for obtaining responses to the survey was by promoting the survey through flyering. Around 1,800 flyers were distributed and the flyer can be found in appendix two. The flyers were distributed in the area from 11-13 December 2019. The following villages and parishes were visited: Roosteren, a part of Grevenbicht, Guelle aan de Maas, Voulwames, Schipperskerk, Illikhoven, Vissersweert, Maasband, Itteren en Borgharen.

4.4. Data analysis

This section elaborates on the way that the data has been analyzed. For the analysis, R-studio, an open-source programming language for statistical computing, was used. After the data collection ended on the 7th of February of 2020, there were a total of 364 valid respondents. Of the 364, there were 34 respondents who did not completely filled in the survey. Because they finished the survey for over 50%, they were still selected. This section will first describe the way the survey connects the research questions with the theory and the concepts, where after the guide to understanding the results will provide clearance on the analyses done.

4.4.1. Linking the theory, the concepts and the survey

In order to operationalize the research questions and in order to link the theory and the concepts to the current case of the Grensmaas, specific questions in the survey have been developed as indicators. These are not all the questions in the survey, but the most important questions, specifically in relation to the correlation- and regression analyses. In the survey in appendix 1, the following questions can be found in brackets.

Section 1

In order to answer sub-question one:

'Is local ecological knowledge used for predicting high water events of the Grensmaas river?,

the following questions were devised:

1. Did you use marking in the landscape to predict the behavior of the river in times of high water with risk of flooding before the project?
2. What were markings in your surroundings which you used for perceiving high water with a risk of flooding before the project?
3. To what extent were you able to use the markings to predict high water with the possibility of flooding before the project?
4. Are the markings you used still visible after the project has been finished?

5. Which markings are not visible or present anymore?
6. Has your knowledge to predict high water and flooding events changed as a result of the project?
7. To what extent is it now more difficult to predict high water with a chance of flooding?

These questions relate to the different conditions of LEK before the project and after the project and the types of markings which were used as a basis for LEK. Questions 1-3 establish a baseline of the condition and uses of LEK before the project. Question 1 indicates the frequency of use of LEK and question three highlights the ability of respondents to use LEK. Questions 4-5 relate to LEK, specifically to the markings, after the project. These two questions are used to measure a change in the perception of markings and to establish if they are still used. Questions 6 is again more general and measure the current condition of LEK compared to before the project. This question is used to measure a changed condition of LEK towards increased or decreased LEK. Question 7 indicates a change in adaptive capacity by the indication of a survival of LEK. Whether or not respondents find it harder to read the river and predict high water, indicates a change in their capacity to predict high water and therefore in their response to a potential flooding event. When this response is inhibited because it is more difficult to predict high water, their adaptive capacity has decreased.

Section 2
In order to answer sub-question two:

'How do altered conditions of local ecological knowledge influence vulnerability of the inhabitants?',

which refers to adaptive capacity and vulnerability, the following questions were devised:

8. To what extent to you feel more or less vulnerable through the disappearance of the markings?
9. Are there new markings in the landscape which you use to predict high water and flooding events?
10. Have you developed new LEK after the project to make judgements about high water and possible flooding events?

Question 8 is used as the indicator for the perception of vulnerability as a result of a decreased LEK. Question 9-10 indicate the adaptive capacity and looks if new forms of LEK have developed after the project. If there are new markings and if new knowledge has developed than this indicates some forms of adaptive capacity through newly developed knowledge. Hence, this indicator of adaptive capacity is different from the indictor of adaptive capacity in question 7, (section 1). In some analyses, several survey questions used to answer sub-questions one- and two of this research are combined.

Section 3
In order to answer sub-question three:

'Has the Grensmaas project changed flood perception of the inhabitants?',

which refers to risk perception, the following questions were devised:

11. Do you have confidence that the measures taken within the Grensmaas project lead to less flooding events?
12. To what extend do you perceive high water, after the completion of the Grensmaas project as a threat?
13. Do you think the likelihood of flooding events has changed as a result of the project?

14. Do you think the possible damage of flooding events has increased or decreased as a result of the project?
15. How often do you expect large flooding events such as 1993 and 1995 to take place?
16. Do you expect that the likelihood of flooding events to take place changes in the future (2050) for example because of climate change?
17. To what extend did you perceive to have personal damage as a result of flooding events before the project (all forms of damage, so emotional, social, economic and financial)
18. To what extend did you perceive high water to be a threat before the project?
19. The likelihood that a flooding event would occur was … (smaller to larger) than the likelihood that a flooding event after the completion of the project would take place?

Questions 11-15 highlight different aspects of risk perception as a result of the project. Question 11 refers to the concept of administrative measures appraisal. With a higher administrative appraisal, there is more trust in official measures. Questions 12-15 refer to different components of the concept of threat appraisal. When threat appraisal is higher, a respondent feels a higher threat. Question 16 refers to the expectation of future flooding events and question 17 is a proxy for threat experience. When threat experience is larger, one has experienced more personal damage. Question 18-99 indicate past threat appraisal.

Section 4
In order to answer sub-question four:

'How has a changed risk perception influenced susceptibility through private flood prevention measures?',

which refers to different aspects of flood prevention measures, the following questions were devised:

20. Do you take personal measures to decrease damage from flooding events?
21. Which measures do you take to protect yourself against water damage?
22. Do you take other measures next to preventative ?
23. Do you find it important to take personal measures to prevent flooding events?
24. Do you feel sufficiently prepared for dealing with flooding events
25. Do you see, in comparison with before the project, a larger or smaller necessity to take personal measures?
26. Before the project, did you find it important to take personal measures?
27. Are you planning to alter taken measures because you see a changed necessity for these measures or have you done so already?
28. Do neighbors/friends/acquaintances who live in the area take preventative measures?
29. Do you take in relation to them more or less measures?

All these questions are related to preparedness and awareness. Question 20 is key in understanding whether people take measure and is related to the susceptibility. question 21 highlights which measures are common and which are less so, both proxies for preparedness. Question 22 compares one's own behavior to the behavior of others and thereby can highlight another proxy for the general perception of measures taken. Questions 23-25 are indicators of perceived relevance of awareness to take measures. Question 26 indicates awareness before the project while question 27 establishes if there is possible change in preparedness. Questions 28-29 relate to the communal context and provide a proxy of knowledge of preventative measures of others and also highlights if there is communication about prevention measures.

Section 5

Finally, many sub-questions are analyzed also with regards to some general characteristics of sampled population. Several of these questions which relate to these characteristics are stated here:

30. Sex of the respondent
31. Year of birth
32. Living area
33. Since when are you living in the Grensmaas area?
34. Is at least one of your parents born in the Grensmaas area?
35. Do you feel connected to the Grensmaas area?

Question 30 has been changed in order to analyze to age groups of the respondents. These age groups are chosen arbitrarily as 15-45 years (n=59), 46-65 years (n=140) and 66+ years (n=129), creating age groups more or less similar in size, while still reflecting the existing variation. Question 31 has more categories than described above in section on research areas because of the small parishes which are not directly near project locations of the Grensmaas project. In the results, question 32 is not used because numbers were small for most areas of living. Question 33 has also been grouped. These groups are 0-11 years (n=35), 12-24 years (n=53), 25-40 years (n=92) and 41+ years (n=149). These groups have cutting points based on the large flooding events of 1993 and 1995 and of the high water event of 2009.

In all sections, the number of valid responses is given by the n values. Especially in the regression section, the n value is lower because all the respondents with a least one 'blank' or 'not applicable' response have been taken out. A final note is that many ordinal questions in the survey were, when possible, simplified in the result section through combining the number of categories which the respondent could choose from. This is an arbitrary process and it was done in order to create clearer and easier understandable results. This simplification always occurred based on the middle category, which is defined and indicated as average as it is the middle response, not indicating a clear preference. The categories indicating the left of the middle category were considered lower or less than the average and the categories on the right of the middle category were considered higher or more than average. Also, to some questions, an 'I do not know' category was added in order to give respondents the choice to not choose. In the analysis of the results, these categories were not taken into account.

4.4.2. Statistical models and econometric estimation

The first step in analyzing and creating a structure for the results is by getting a grip of the data. This resulted in the descriptive analysis of the results. This section of the results is structured on the basis of the four sections in the survey: characteristics of the respondents, flooding perception, personal preventative measures and local ecological knowledge and vulnerability. These statistics are useful in obtaining population-wide trends regarding risk perception, measure taking and LEK. Some results are mentioned with a question in between brackets. These are the questions described above in section 4.4.1. These are results which are also used in the correlation and regression analyses and are therefore more important than results which are not mentioned in relation to a question

Correlations

The graphs in the correlations section show combined information of two survey questions and groups the responses of one question based on the categories of another question. The questions mentioned in brackets in the correlation analyses chapter are the questions as they are in section 4.4.1 and are there for the ease of relating the results to the questions. The correlation tests show the linkages between the survey questions and therefore between concepts. In addition, it shows more detailed information about

subgroups of the Grensmaas population. The correlations are Spearman correlations and Spearman is chosen because of the non-parametric nature of the variables. For comparing the means of different population groups Chi^2 tests were executed.

The correlation tests are executed in order to highlight how the new function of the Grensmaas landscape is related to LEK and how LEK in its turn is related to adaptive capacity. Linking the altered landscapes to changed levels of LEK, firstly, it needs to be established if LEK exists. Therefore, it is hypothesized that those who used LEK frequently before the project (question 1), also had a higher ability to read the river before the project (question 3). In addition, it is hypothesized that those who have been living in the area longer, also had more LEK (questions 1 and 33). In order to measure changes of LEK as a result of the project, it is predicted that those who used LEK more frequently before the project (question 1), have also lost more LEK (question 6) and that those who used LEK more frequently (question 1) also see less markings present after the project (question 4). In addition, those who state that markings are less visible are hypothesized to have less knowledge after the project (questions 4 and 6). Moreover, those who had a higher ability before the project (question 3), are hypothesized to use less LEK after the project (question 6).

Furthermore, for highlighting the links between LEK and adaptive capacity, question 7 is important. Those who have more difficulty to predict high water after the project (question 7) are hypothesized to have used LEK more frequent before the project (question 1), to have a higher ability of LEK before the project (question 3) and to state that less markings are currently present (question 4). Inhabitants who are older and those who have been living in the area for longer, are also hypothesized to have a decreased ability to read the river after the project (questions 31, 33 and 7). The theory with regards to the adaptive capacity of LEK also states that LEK is adaptive and that new knowledge accumulates over time. Thus, adaptive capacity should also exist for those who have knowledge after the project. Therefore, it is hypothesized that respondents who have more knowledge after the project, also state that there are more markings present (questions 6 and 9). In addition, those who used LEK frequently before the project and those who had a higher ability, are also hypothesized to state that there are more new markings present after the project as they will adapt more quickly because of their new knowledge (questions 1, 3 and 9). In addition those who have a higher ability after the project (question 7), those who have been living in the area longer (question 33) and those who are older (question 31) are also projected to have more newly developed LEK (question 10).

Finally, adaptive capacity is linked to vulnerability and those who have less adaptive capacity are thought to be more vulnerable. It is hypothesized that a higher adaptive capacity (question 7) is correlated with lower forms of vulnerability (question 8) and that those who have more LEK after the project (question 10) also feel less vulnerable (question 8). Also, the groups who have more LEK, that is the elders (question 31) and those who have been living in the area longer (question 33), are hypothesized to feel less vulnerable (question 8).

In addition to connecting LEK with adaptive capacity and vulnerability, the correlations also link risk perception with measure taking. It is hypothesized that those who have a higher administrative appraisal (question 11), take relatively more often no measures compared to those with a low administrative appraisal (question 20). In addition, those whose threat- appraisal (question 12) and experience (question 17) is higher, are more likely to have taken preventative measures (question 20) than for those which fall in the lower levels of threat- appraisal and experience. Finally, those who have been living in the area longer (question 33) and those who are older (question 31) are hypothesized to be more likely to take preventative measures. In addition, those who have a higher administrative appraisal (question 11) and

threat appraisal (question 12) are more likely to place importance on taking measures (question 23). Respondents whose threat appraisal (question 12) is higher, are also hypothesized to be more likely to feel prepared (question 24). Moreover, those whose threat experience is higher (question 12), are hypothesized to have been living in the area longer (question 33).

Relating the narrative of the flood free future to risk perception and measure taking, it is hypothesized that a higher administrative appraisal (question 11), a lower threat appraisal (question 12) and a lower likelihood to flooding events (question 13) is related to a lower likelihood that flooding events like 1993 and 1995 will still occur (question 15). Finally, it is also hypothesized that there is a higher likelihood that flooding events like 1993 and 1995 will occur for those who take preventative measures (question 20) and for those who place a higher importance on taking preventative measures (question 23).

There are more results described than there are graphs shown. When this is the case, one of two comments is provided. The first one is ' result is not shown ' or 'see appendix'. The correlation analyses are structured based on the research questions. In the correlation analyses, the survey question related to administrative appraisal (question 11) is 'trust in measures taken'. However, as this question only had 18 responses stating a lower trust, this question could not be used in the correlation analyses as the n value was too small. Similarly, a survey question related to threat appraisal (question 13), namely the altered likelihood of flooding damage as a result of the project, only has 11 responses stating an increased likelihood and was also not used in the correlation analysis. Importantly, it has not been possible to do post hoc tests for the chi^2 tests. The 'fifer' package which is used for this, is no longer supported and it was not possible to install the right sub-package of the 'Devtools' package. Therefore, when looking at chi^2 analyses, figures in which both variables are shown are leading in the conclusions and the conclusions are very carefully phrased. Finally, table 4 below, shows all the different correlations that have been carried out in this thesis in order to answer the sub-questions and the main research question. It provides a guide of the links between the theory and the results through the survey questions.

Questions	Indicators	Correlation
LEK		
1 – 3	Baseline of LEK	.42
1 – 4	Change in the condition of LEK	Not significant
1 – 6	Change in the condition of LEK	Not significant
1 – 31	Accumulation of LEK in age groups	Not significant
1 – 33	Accumulation of LEK by years living in the area	.18
4 – 6	Change in the condition of LEK	-.25
3 – 6	Change in the condition of LEK	Not significant
Adaptive capacity		
7 – 1	Change in adaptive capacity	-.17
7 – 3	Change in adaptive capacity	Not significant
7 – 4	Change in adaptive capacity	-.25
7 – 31	Ability after per age group	.13
7 – 33	Ability after by years living	.16
9 – 6	Development of new markings	.25
9 – 1	Development of new markings	.19
9 – 3	Development of new markings	Not significant
7 – 10	Development of new LEK	Not significant
10 – 31	Development of new LEK per age group	.17

10 – 33	Development of new LEK by years living	.15
Vulnerability		
7 – 8	Adaptive capacity and vulnerability	-.18
8 – 10	Adaptive capacity and vulnerability	-.13
8 – 31	Vulnerability per age group	.2
8 – 33	Vulnerability by years living	.15
Risk perception		
20 – 23	Measure taking and measure taking perception	.48
20 – 12	Measure taking and threat appraisal	Not significant
20 – 17	Measure taking and threat experience	.27
20 – 31	Measure taking and age	Not significant
20 – 33	Measure taking and years living	.16
23 – 12	Threat appraisal and perceptions about measures	.23
24 – 12	Threat appraisal and perceptions about measures	-.16
31 – 17	Threat experience and demographics	.21
Flood free narrative		
15 – 12	Threat appraisal and flood free narrative	Not significant
15 – 20	Flood free narrative and measure taking	Not significant
15 – 23	Flood free narrative and perceptions about measures	Not significant

Table 4: The correlations and their significance

Regressions

The final section of the results discusses the three regression analyses of this thesis. Regression analyses are used in this research in order to analyze which predictors are important for taking measures, for predicting vulnerability and for predicting of having LEK. Once this is known, underlying dynamics can be related back to the theory. Moreover, certain predictors can be targeted in order to raise risk perception or to uncover which dimensions are important for decreasing vulnerability. In none of the regressions, Dummy variables were specifically used because the packages in R automatically compare the subsequent levels with the baseline level. In all regressions, the variable 'years living in the area' (question 33, see section 4.4.1) was used while age (question 31) was not. The reason for choosing one is that both could not be combined because of the issue of multicollinearity. 'Years living in the area' was chosen over age because it says more about the relationship with LEK than age does.

Regression 1

The first regression analysis is a binary logistic regression (BLR) in which the binary variable 'taking measures' is the dependent variable. There are seven predictors used in the analysis. The following equation based on Schuppert (2009) is the model used for the regression analysis:

$$P(Y) = \frac{e^{a_j + b_{1j}x_1 + b_{2j}x_2 + b_{3j}x_3 + b_{4j}x_4 + b_{5j}x_5 + b_{6j}x_6 + b_{7j}x_7}}{1 + e^{a_j + b_{1j}x_1 + b_{2j}x_2 + b_{3j}x_3 + b_{4j}x_4 + b_{5j}x_5 + b_{6j}x_6 + b_{7j}x_7}}$$

In which

P = the probability of Y occurring

Y = taking personal measures (question 20)

e = natural logarithm base

a_j = the intercept at the y-axis

b_1 = line gradient (this counts for b_1 to b_7)

x_1 = threat perception (question 12)

x_2 = perception of trust in the project (question 11)

x_3= perception of personal damage (question 17)
x_4 = importance to take measures (question 23)
x_5 = at least one parent born in the area (question 34)
x_6 = connection to the area (question 35)
x_7 = years living in the area (question 32)

For all these predictors, the theorem of Grothmann and Reusswig (2006) is used (see section 3.3). It is hypothesized that respondents with a higher threat perception, i.e. a higher threat appraisal, are more likely to take measures, compared to those with a lower threat appraisal. In addition, it is hypothesized that respondents who have a higher trust, take less measures, as their administrative appraisal is large. Similarly, respondents with a higher perception of personal damage, i.e. a higher threat experience, are also more likely to take measures. Respondents who perceive importance to be higher, are also hypothesized to be more likely to take measures. The same counts for those who have at least one parent born in the area as those parents have experienced a flooding event. Those with a higher connection to the area have more knowledge of the area and are therefore more likely to take more measures. Finally, those who have been living longer in the area, have experienced a flooding event and are therefore more likely to take more measures.

For this binary regression, the *general logistic model* (glm) function from the 'aod' package was used with the following command in R:

"Call:
glm(formula = Taking.measures ~ threat + damageflooding + Importance + parents + connection + yearsliving, family = "binomial", data = BinaryRegress)"

This odds ratio is also what is given in the output table in the corresponding results section. The output table features the predictor categories, the odds ratio, which is described in the effect column and whether or not the effect was significant with a p-value of 0.05. The odds ratio shows the effect of the predictor on taking measures, holding all other variables equal. So, taking measures as opposed to not taking measures becomes x times as likely or x times less likely for an predictor value compared to the baseline of that same predictor value. As an example, respondents who perceive the threat of the river to be neutral compared to respondents who feel the threat of the river to be low, are 0.99 times as likely to take measures compared to not taking measures, holding all other predictor values constant.

Regression 2
The second regression analysis is an ordinal regression. The outcome variable, which is the perception of vulnerability, has five statements; ranging from 'way less vulnerable' indicated by a 1 to 'way more vulnerable' indicated by a 5. As stated in the final paragraph of 4.4.1, several variables were reduced to three categories. The outcome variable is reduced to three categories; less vulnerable, neutrally vulnerably and more vulnerable. In addition, predictor one and two also have three categories (see the result section 5.3.2). This regression about the perception of vulnerability is based on the adaptive capacity of LEK. The following equation is the model used for the regression analysis adapted from Liu & Koirala (2012):

$$logit\left(P(Y > j \mid x1, x2, \ldots x_p)\right) = a_j(b_{1j}x_1 + b_{2j}x_2 + b_{3j}x_3 + b_{4j}x_4 + b_{5j}x_5$$

In which

P = the probably of Y being above category j, given a set of predictors with j-1 categories

Y = the level of neutrally and more vulnerable compared to less vulnerable (question 8)

j =1, 2, …, j−1

a_j = the intercept at the y-axis

b_{1j} = coefficients (this counts for b_1 to b_5)

x_1 = perception predictive ability after the project (question 7)

x_2 = perception newly developed LEK after the project (question 10)

x_3 = at least one parent born in the area (question 34)

x_4 = connection to the area (question 35)

x_5 = years living in the area (question 32)

It is hypothesized that respondents who have a larger predictive ability, are less vulnerable because of their LEK. The same counts for those who have newly developed LEK. Respondents who have at least one parent born in the area, are also hypothesized to feel less vulnerable because of accumulated LEK of the parent(s). Those with a higher connection to the area have stronger ties to the land and might have more LEK. Therefore, they are more likely to feel less vulnerable. Finally, those who have been living longer in the area, are hypothesized to have accumulated more LEK and therefore feel less vulnerable.

In R, the *proportional odds logistic regression'* (polr) function from the 'Mass package' was used, with the following command in R:

"Call:
polr(formula = Vulnerability ~ predicting + newknwoledge + parentsinthearea + connection + yearsliving, data = DataRegres2, Hess = T)"

The output table features the predictor value, the odds ratio which is described by the effect column and whether or not the effect was significant with a p-value of 0.05. The odds ratio explains the effect that the predictor has on the perception of vulnerability, keeping all the other values the same. In the regression analysis, neutrally and more vulnerable is compared to less vulnerable. So, feeling neutrally and more vulnerable as compared to feeling less vulnerable becomes x times as likely or x less likely for an predictor value compared to the baseline of that same predictor value. As an example, respondents who perceive that they have increased predictive abilities compared to respondents who have decreased predictive abilities, are .45 times as likely to feel neutrally or more vulnerable compared to less vulnerable, holding all other predictor values constant.

Regression 3

The final regression is also an ordinal regression. The outcome variable is 'did you use markings in the landscape to predict the behavior of the Grensmaas river during high water with chances of flooding?'. This question indicates having LEK and therefore this regression analysis explains which predictors contribute to having LEK. This outcome variable also has five categories, ranging from 'never' to 'always'. For this analysis, the categories have been made numerical and have also been reduced to three, ranging from 'not or not really using LEK', 'occasionally using LEK' and 'often or always using LEK'. Moreover, predictor one and five have also been reduced to three categories. The following equation is the model used for the regression analysis adapted from Liu & Koirala (2012):

$$logit\left(P\left(Y > j \mid x1, x2, \ldots x_p\right)\right) = a_j(b_{1j}x_1 + b_{2j}x_2 + b_{3j}x_3 + b_{4j}x_4 + b_{5j}x_5$$

In which

P = the probably of Y being above category j, given a set of predictors with j-1 categories

Y = occasionally or oftentimes using markings compared to never (question 1)

j =1, 2, …, j−1

a_j = the intercept at the y-axis

b_{1j} = coefficient(this counts for b_1 to b_5)

x_1 = ability before the project (question 3)

x_2 = years living in the area (question 33)

x_3 = sex (question 30)

x_4 = at least one parent born in the area (question 34)

x_5 = connection to the area (question 35)

It is hypothesized that respondents who have a larger predictive ability, use LEK more frequently. Respondents who have been living longer in the area, are hypothesized to have accumulated more LEK because of the interaction with their environment. Respondents who have at least one parent born in the area are also hypothesized to have more LEK because of the accumulated LEK of the parent(s). Finally, those with a higher connection to the area have more interaction with their environment and therefore have more LEK.

In R, the *proportional odds logistic regression'* (polr) function from the 'Mass package' was used, with the following command in R:

"Call:
polr(formula = Vulnerability ~ predicting + newknwoledge + parentsinthearea + connection + yearsliving, data = DataRegres2, Hess = T)"

The same conditions with regards to the interpretation of this analysis exist as with regression analysis 2 and therefore, the explanation of the second regression analysis is used. A final note, although not always mentioned in the results section of the analysis, because of readability predictors are always compared to their respective baselines.

5. Results

This chapter describes the main findings that follow from this research. Firstly, in the descriptive section, the general findings of the survey are described. In the second section, the main correlational links between the different sub-questions of the research are discussed. The final section, 'Regression analyses' delves deeper into the three regressions that form the explanatory core of this research.

5.1. Descriptive analysis

The descriptive section describes the outcomes of the questions in the survey on a question-to-question basis. It will first highlight the summary statistics, after which it will look into the results of the three different themes of the survey, 'risk perception, ' personal measures' and 'local ecological knowledge'.

5.1.1. Summary statistics

Table 5 shows the main characteristics of the respondents. 63% of the participants are male while 37% are female. The mean age is relatively high (58 years) with a standard deviation of 14.8 years. This aligns with the fact that the inhabitants generally have been living for many years in the area (mean = 37.5 years). However, with a standard deviation of 20 years, there is a larger variation than there is with age. 45% of the inhabitants have at least one parent living in the area. Of all respondents, 16% works in the area. Also, inhabitants are very satisfied with living in the area (mean = 6.3 on a scale from 1-7). These results indicate that many inhabitants traditionally have strong ties to the Grensmaas area. Most respondents are well aware that they are living in a flood-prone area (87%), indicating that there is a wide-spread awareness. Finally, most inhabitants that answered are from Grevenbicht (n=68), followed by Itteren (n=50), Roosteren (n=43), Borgharen (n=39), Obbicht (n=37), Guelle aan de Maas (n=21), Meers (n=13) and Papenhoven (n=11). In the other 12 areas, there are 10 or less responses.

Summary statistics of the respondents	
Age (n=328)	
min	15
max	96
Median	62
mean (sd)	58 (14.79)
Sex (n=338)	
Male	212 (63%)
Female	126 (37%)
Years living in the area (n=330)	
min	1
median	37
max	87
mean (sd)	37.5 (20.3)
Working in the Grensmaas area (n=339)	
Yes	53 (16%)
No	286 (84%)
At least one parent living in the area (n=337)	
Yes	150 (45%)
Attachment to the area (N = 360)	
mean (sd)	6.3 (0.97)
Awareness living in a flood prone area	
Completely unaware	9 (2%)
Not really aware	7 (2%)
Somewhat aware	34 (9%)
Well aware	126 (35%)
Very well aware	188 (52%)

Table 5: Summary statistics

5.1.2. Flood risk perception

As can be seen in table four above in 5.1.1., inhabitants are generally well aware that they are living in a flood prone area (87%), and only 4% stated to be not at all aware or not really aware. Figure 8 on the right shows the threat perception of high water before and after the Grensmaas project on a scale from 1-5 of which 3 is average (n=364). It shows that high water is perceived to be less of a threat after the project compared to before the project. After the project, 27% perceives the threat of high water to be of level 4 or 5 while this was 40% before the project. After the project, 45% perceives the threat to be of level 1 or 2, while this was 21% before the project. The survey question asking about the likelihood of flooding events as result of the Grensmaas project yielded similar results (question 13, results not shown, n=364). A majority of 83% believes that the likelihood of flooding has decreased while only 3% believes it has increased. These results highlight that risk perception is relatively low.

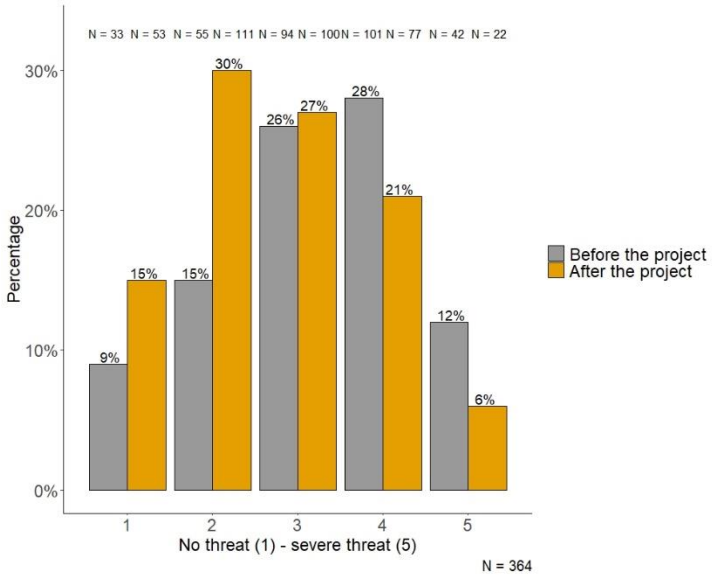

Figure 8: The perception of threat before and after the project

On the other hand, responses are more varied when asked about the perception of flooding events in the future (2050) as a result of for example climate change (question 19, see figure 9, n=364). 51% of the inhabitants mention that chances of flooding events will increase in the future while 38% does not see an increase. Related to this is the question about the occurrence of actual flooding events such as those in 1993 and 1995 (question 15, not shown in results, n=359). Interestingly, most respondents (68%) do not believe the official new 1:250 flooding likelihood and think flooding events will occur more often, indicating some form of resistance against the official messages of a flood free narrative. 21% states that the likelihood has not changed while 11% states flooding events will never happen. Also, before the start of the Grensmaas project, inhabitants did generally not perceive the river as a source of personal damage (question 17, see figure 24 in appendix 4, n=326). 30% stated that the river did not lead to any personal damage at all, while 15% saw some form of damage while 35% saw a lot of damage. Finally, respondents indicated that potential forms of personal damage as a result of flooding events has

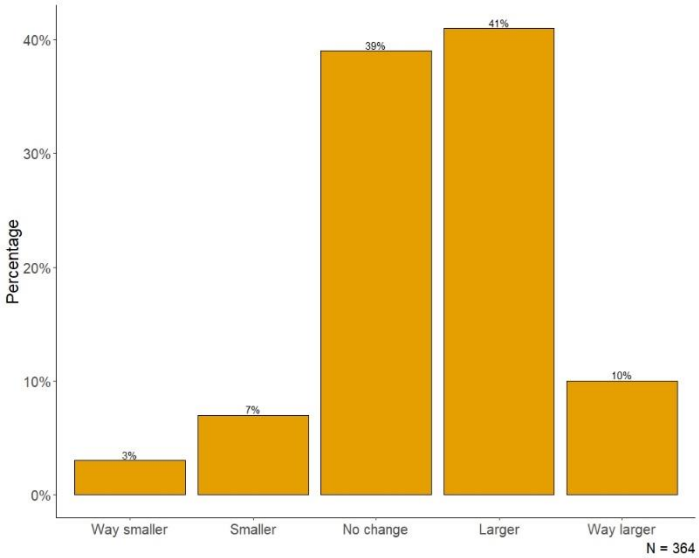

Figure 9: The perception of flooding events in 2050

decreased. 63% states that the potential is lower, 24% that there is no change while 13% predicts an increase. Again, these results indicate lower forms of risk perception (not shown in results).

5.1.3. Perception of personal measures

An important survey question with regards to the perception of measures, asked if respondents have taken personal measures against damage from flooding events (question 20, results not shown, n=364). Almost two-third of the respondents, 64%, state that they do not take personal measures to prevent flooding events while 36% has taken personal measures. Of the respondents who take measures, there is a wide array of different measures chosen (question 21). From the given options in the survey, the most chosen were tiled floors (n=83), a water pump (n=78), possibility to elevate furniture (n=66) and emergency lighting (n=53) (not shown in results). However, several options were also mentioned in the 'other' category, the most frequent being elevated floors on the ground floor as well as houses rebuild on higher ground or separate aggregates for the basement (results not shown). The results of grouping the taken measures by number of years working in the area, is shown in figure 10. There is a difference between inhabitants who have been living in the area for only several years and people who have been living in the area for a longer period of time. Respondents who have been living in the area for a long time, seem to have taken more measures. People in the age category of 41+ and 25-40 have taken 1.55 and 1.51 measures per person respectively while the year groups of 0-11 and 12-24 have taken .54 and .68 measures per person respectively. Aside from measures in house, respondents do not tend to take other measures (question 22). There are 251 responses stating to not take other measures, 42 responses stating to make agreements with the neighbours and 65 responses stating to use communal warning systems. In addition to this, respondents are limitedly aware of personal measures that others take, (question 28, results not shown, n=363). 39% of the inhabitants were not aware of measures that other people took with respect to river protection. In addition to this, 51% of the respondents state that others take little or no measures to mitigate flooding events and only 10% thinks that they take many measures. Respondents think that they take the same amount of measures as others do (question 29, results not shown, n=364). 45% thinks they do not take more or less measures while 32% does not know. 18% takes less measures while only 5% thinks they take more measures.

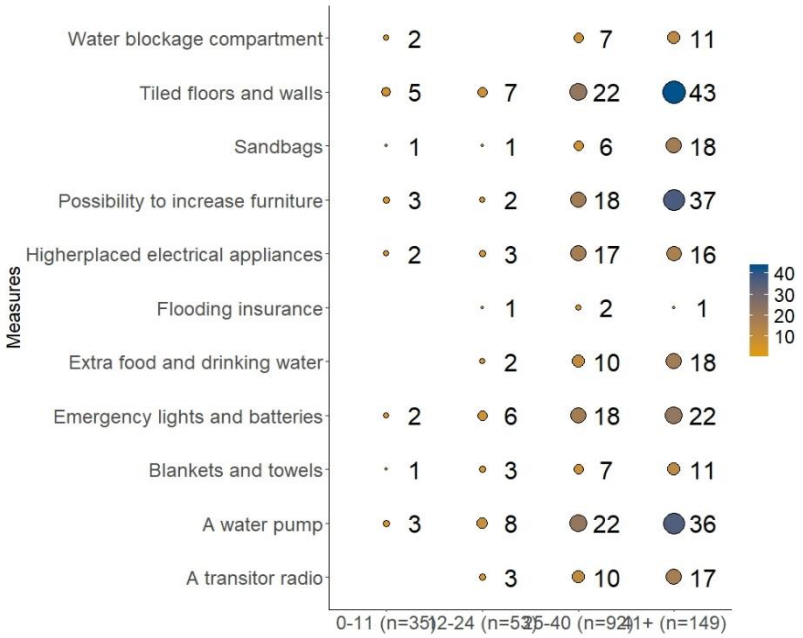

Figure 10: The different measures taken grouped by the number of years people have been living in the area

Two important survey questions ask about the perception of importance to take measures before and after the project (see figure 11, n=364). The figure show that there are three distinct groups of respondents. After the project (question 23), 33% place no particular importance on taking protection measures. 33% deems measures as unimportant while 34% placed a higher than average importance on measures. Before the project (question 23), 54% placed a higher than average importance on measures while the group who perceives it to be of less importance has stayed more or less the same. Hence, there seems to be a shift towards neutral importance of flooding events. Related to this question is the perception of urgency to take measures now compared to before the project (question 25, results not shown, n=363). 63% sees less urgency now compared to before the project while 33% does not see a changed urgency to take measures.

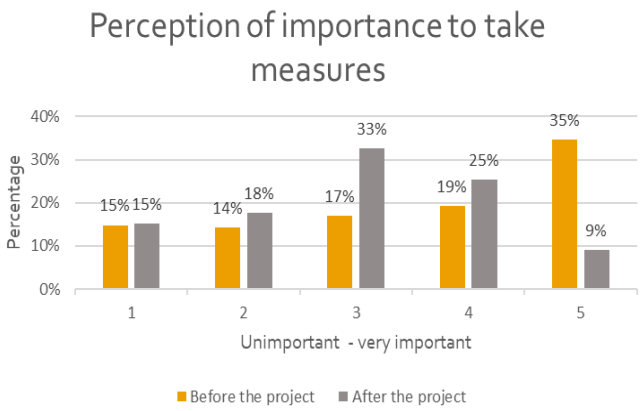

Figure 11: Perception of importance to take measures before and after the project

Although more than half do not deem protection measures particularly important, most respondents feel sufficiently prepared (question 24). The survey question highlighting this, asked about the preparedness of inhabitants (see figure 25 in appendix 4, n=363). Over 70% of the respondents feel that they are sufficiently prepared for flooding events, while 27% feels underprepared. Finally, asked if inhabitants want to change current personal measures because of a changed urgency, only 20% of the people actually want to decrease the measures taken while 80% does not see the need to change measures taken (question 27, not shown in results, n=364).

5.1.4. Local ecological knowledge and vulnerability

Looking at the LEK of the respondents, the results shown in figure 12 indicate the use of LEK before the project (question 1, n=316). 44% of the people often or always used markings in the landscape to read the river during high water events. 22% used markings in the landscape occasionally while 33% almost never or never used markings. There were several markings used oftentimes before the project (results not shown). The markings most used are river borders (n=236), gauges (n=168), possible flooding areas (n=164) and flooded agricultural fields. Related to this question is the question about which markings are not present anymore as a result of the altered landscapes (results not shown). The alteration of the landscape has changed the markings which inhabitants used for predicting high water events. The largest decreases were found for river borders (mentioned 147 times), gauges (mentioned 102 times), possible flooding areas (mentioned 90 times) and agricultural fields (mentioned 89 times). In the perception of inhabitants,

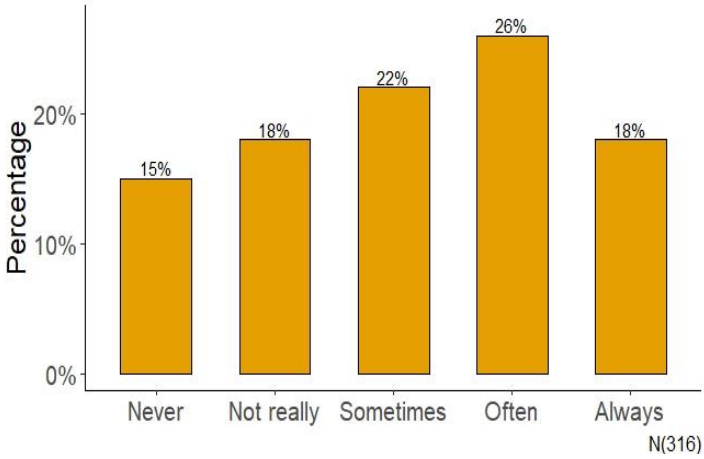

Figure 12: Percentage of respondents using local ecological knowledge to read the river before the project

the landscape markings were very useful (question 3, not shown in the results, n=316). 70% of people stated that they could predict the 'behaviour of the river' with relative ease based on the markings, while 19% thought it was neither easy nor difficult and 11% stated that it was difficult. Generally, LEK seems to be a mode of knowledge used throughout the GM area.

The perception of LEK after the project, seems to hint to the fact that LEK is mostly still present. Figure 13 shows the perception of the presence of markings after the project compared to before the project (question 4, n=347). The majority of the respondents (37%) states that markings used to read the river have not disappeared after the development of the GM project. 32% states that they have partly disappeared while 13% argues that the markings have been gone. The results are comparable to the results of the question whether people feel their knowledge to predict high water has changed (question 6, results not shown, n=347). 54% of the respondents state that their level of knowledge has not changed, for only 20% of the respondents their knowledge has decreased while 26% states that their knowledge has increased. Again, results from a question asking whether it is harder to predict high water points in the same direction (question 7, results not shown, n=344). 51% of the respondents do not think it is harder to perceive river dynamics. However, still over a quarter of the people (30%) find it harder to read the river while 19% finds it easier. Two question with regards to the adaptive capacity of respondents highlight that new LEK has not yet been developed. The majority of respondents (59%) state that they cannot yet identify new markings in the landscape while 41% can (question 9, results not shown, n=345). In addition to this, most respondents state that they do not have new knowledge (38%), 29% has some new knowledge while 19% of the respondents state that they have new knowledge (question 10, results in appendix 4 figure 26, n=337).

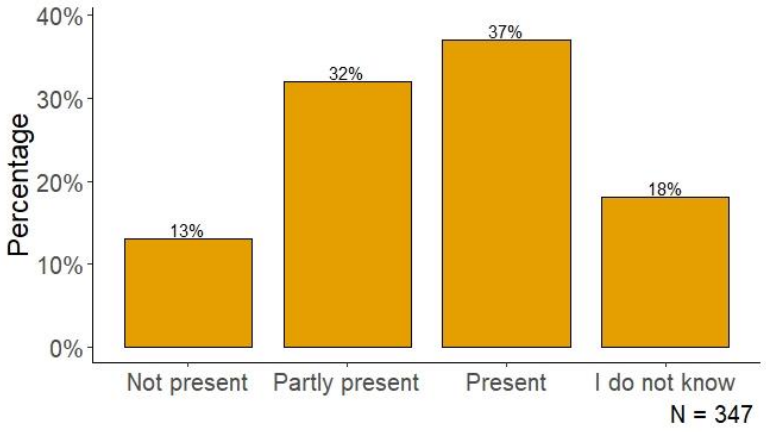

Figure 13: Perception of the presence of markings after the project compared to before the project

Generally, figure 14 (question 8, n=399) shows that people do not feel more or less vulnerable because of the disappearance of the markings (63%). 25% of the respondents feel less vulnerable while 12% feels more vulnerable. Different results are found in the perception of independence (not shown in results, n=348). Although inhabitants feel to be less vulnerable, they do generally feel somewhat more dependent on authorities after the project. The majority feels rather more dependent than less dependent (28% over 17%). 55% of the respondents do not see a difference in dependence. This increased dependence does not make inhabitants feel very uncomfortable (not shown in results,

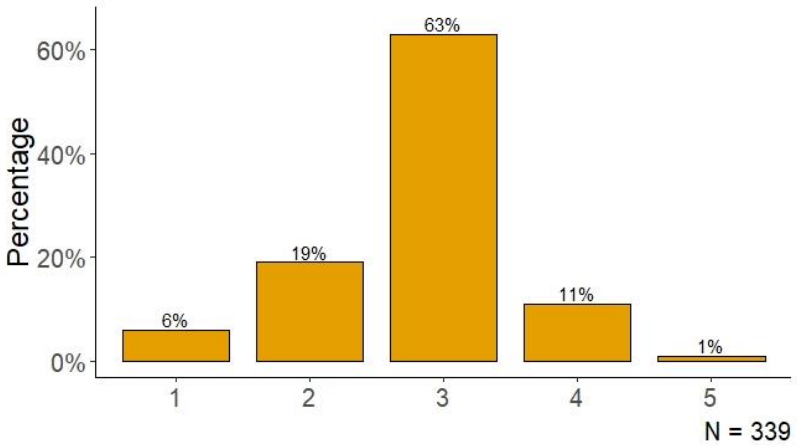

Figure 14: The perception of vulnerability

n=346). Not a scale from not uncomfortable (1) to very uncomfortable (5), with 3 being average, 39% feels less than average uncomfortable while 16% feels more uncomfortable. Combining these questions, people who feel more dependent feel generally more uncomfortable than comfortable while people who feel more independent feel also less uncomfortable. For most people whose dependence has not changed, they also feel not uncomfortable (results not shown).

5.2. Correlation analyses

This section analyses the sub-questions and their links to the concepts through correlations. This is built on the conceptual framework found in the problem statement (chapter 1.3). This section is organized based on the research questions as are described in more detail in chapters 1.6 and 4.4.1.

5.2.1. Altered landscapes and changed conditions of LEK

Generally, it can be observed that respondents who possess forms of LEK, are more capable in their ability to use it. Figure 15 establishes the link between the different frequencies of using LEK and the ability of respondents to predict the river before the start of the project (questions 1 and 3, n=316). The frequency of use is grouped by the ability to read the river. The majority states that they can read the river quite well (n=222) while only 33 respondents stated that they were not really able to read the river. The figure highlights that inhabitants who feel that they have less than average skills to read to river, did not really use the markings (75%). On the other hand, of the people who feel that they have more than average ability, 57% used the markings often or always in times of high water. This observation is highlighted by the significant intermediate correlation between the two variables (Spearman= .42, p<.05). This means that the more inhabits use their LEK, the easier it becomes to read to river. Hence, there is a positive relationship with the frequency of usage and the knowledge that inhabitants have. The same holds for the relationship between the number of years people have been living in the area. The longer people have been living in the area, the more they seem to perceive themselves to use LEK (questions 1 and 33, figure 27 in appendix 4, Cramer's V=.18, p=<.05).

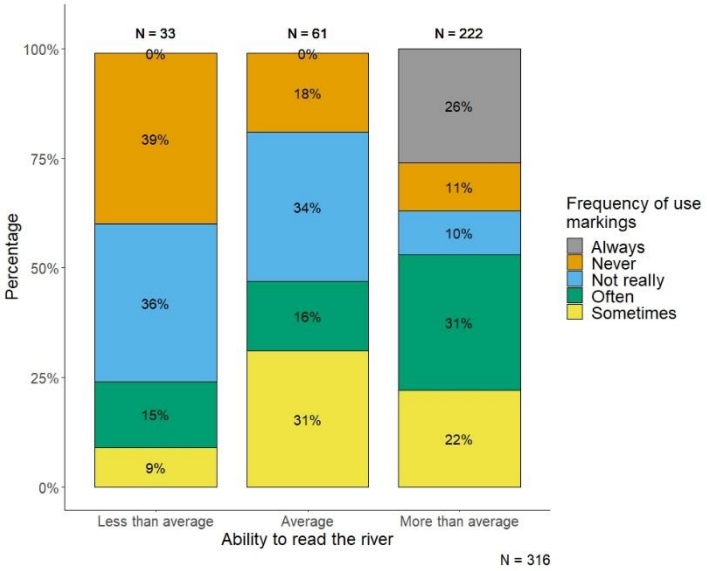

Figure 15: The frequency of use and ability to use LEK

The results are indicating that the disappearance of LEK is small. There is an indication of the disappearance of LEK in groups who argue that the markings have disappeared from the landscape as can be seen in figure 16. Figure 16 shows the condition of LEK after the project grouped by the presence of markings after the project (questions 6 and 4). Of those who state that markings are not present anymore, 46% argues that they have less knowledge. There is a significant intermittent negative correlation between presence of markings and a change in LEK. For inhabitants who think markings are not present anymore, it is harder to see high water coming, when leaving out the 'I do not know' group (Spearman= -.25, p<.05). On the other hand, there are indicators that point out that the loss of LEK is not severe. There is no correlation between the indicators of frequency of using LEK before the project and the presence of markings after the project (questions 1 and 4, results not shown). Hence, those who frequently use LEK, do not significantly more often think that markings are not present anymore. Also, there is no significant correlation found between the ability to read the river before the project and the condition of LEK after the project (questions 3 and 6, results in figure 28 in appendix 4). Hence, respondents whose ability was high, do not always indicate their knowledge has been lost. This is also the case for respondents who use LEK frequently (questions 1 and 6). They also do not always indicate that their knowledge has been decreased. This shows that there are only very limited indications that LEK is lost.

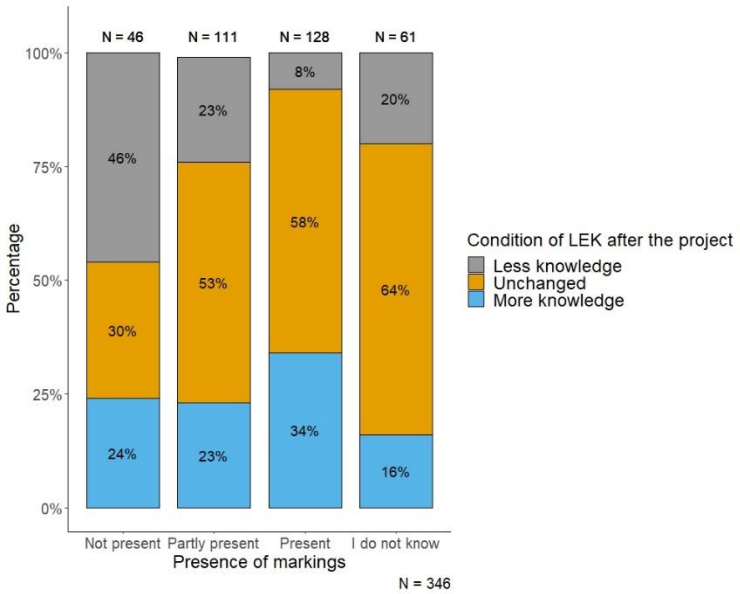

Figure 16: Altered levels of LEK

5.2.2. LEK and adaptive capacity

The results highlight that the adaptive capacity of the inhabitants has somewhat decreased as a result of the project. This is shown by correlating the questions of the frequency of LEK use and the ability of predicting high water based on own experience. There is a significant negative correlation, showing that for those who used LEK more often before the project, they find more difficulty to use LEK after the project, leaving out the 'I do not know' group (questions 1 and 7, results in figure 30 in appendix 4, Spearman= -.17, p<.05). Hence, those who used LEK frequently, indicate that their ability after the project has decreased. In addition to this, those whose ability has decreased, also state significantly more often that markings are partly or not present anymore after the project when leaving out the unknowns (questions 4 and 7, see figure 17, Spearman= -.25, p<.05). Figure 17 shows the existence of LEK after the project. It does so by highlighting the link between

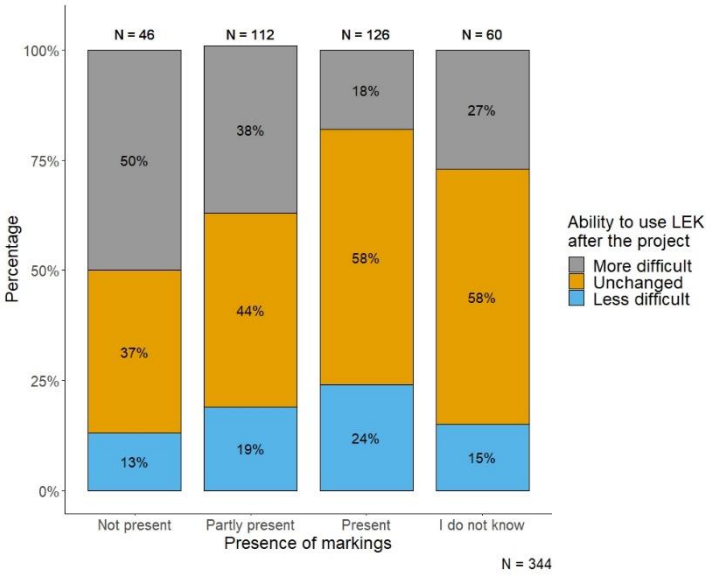

Figure 17: Existence of LEK after the project

a change in the ability to use LEK and the perception of the presence of markings after the project. It is expected that there is a relationship between the presence of the markings and the difficulty of reading. Most respondents perceive the markings to be still there (n=126). However, 112 respondents argue that the markings are only partly present while 46 state that they are not visible anymore. Out of the respondents who agree that the markings are still present, more inhabitants find it easier to read the river after the project while out of the inhabitants who state the markings are partly present or not present anymore, respectively 38% and 50% finds it harder to read the river. Hence, there is a negative relationship stating that for people who perceive that markings have (partly) disappeared, it has become harder to read the river. This indicates also that LEK is disappearing because the markings form the basis for predicting the river. On the other hand, there is no correlation between the ability to use LEK before the project and after the project, indicating no change in adaptive capacity (questions 3 and 7, results not shown). In addition to this, older age groups seem to have more adaptive capacity as their ability has increased after the project while respondents who have been living in the area longer seem to have less adaptive capacity (questions 7, 31 and 33, see figure 29 and 31 in appendix 4, Cramer's V= .13 and .16 with p<.05 respectively).

In addition to lost adaptive capacity, the results also highlight that there is new LEK being developed in certain groups and therefore that their adaptive capacity is increasing. Figure 18 depicts the condition of LEK after the project and the perception of inhabitants to use new markings. There is a significant correlation between the presence of new markings and the perception of new knowledge (questions 9 and 6, Cramer's V= .25, p<.05). The group which has more knowledge after the project, also seem to state that there are new markings. This means that although the landscape was changed beyond recognition, there is an adaptive capacity of LEK in finding new markings. In addition to this, there is also a significant correlation between the frequency of use of LEK before the project and the presence of new markings (questions 1 and 9). The groups who used LEK more frequently also state that they have new LEK, when leaving out the 'I do not know' group (results not shown, Spearman =.19, p<.05). Hence, those who generally made frequent use of LEK, are also adaptive and have created new forms of knowledge. On the other hand, there is no significant correlation between the ability to use LEK before the project and the presence of new markings (questions 3 and 9) nor between ability to use LEK after the project and the creation of new forms of LEK (questions 7 and 10).

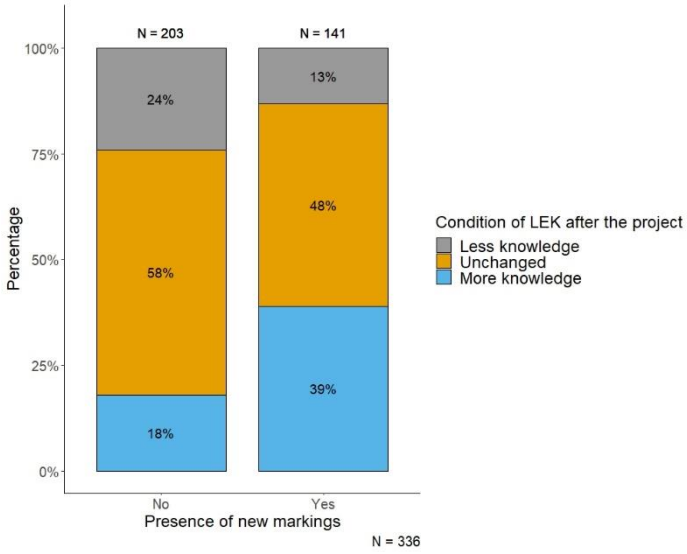

Figure 18: Adaptive capacity of LEK

There are also some correlations found between adaptive capacity and certain characteristics of respondents. There is a significant correlation between age groups and the perception of novel knowledge (questions 31 and 10, see figure 19). Of the youngest age group, almost half (47%) has not developed novel knowledge, while in the older age groups, this decreases to 30%. Also, younger age groups seem to be less aware if they have developed novel knowledge compared to older generations. The relation between both variables is statistically significant with the 'I do not know' group taken out of the chi²-test (Cramer's V= .17, p<.05). There is also a correlation existing between the time people have been living in the area and new knowledge of inhabitants (questions 33 and 10, results in appendix 4 figure 32, Cramer's V= .15, p<.05). Inhabitants who have been living in the area longer, seem to have more newly developed LEK compared to younger generations. In addition, they seem more aware whether they have knowledge or not. There is no significant correlation between the sex of the respondents and whether or not respondents claim to have novel knowledge.

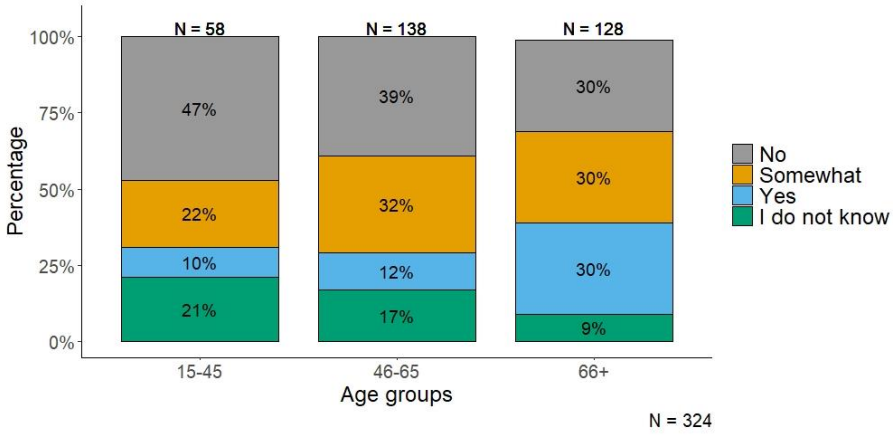

Figure 19: Newly developed LEK in different age groups

5.2.3. Adaptive capacity and vulnerability

As has been shown above, the adaptive capacity of the inhabitants has decreased somewhat, but that there is some new LEK developing. Therefore, although overall, the perception of vulnerability does not indicate increased vulnerability (see chapter 5.1.4), the vulnerability of some groups has increased, while the vulnerability of other groups has decreased. Firstly, graph 20 shows the development of new forms of LEK grouped by the perception of vulnerability. There is a small statistically significant negative correlation between newly developed LEK and vulnerability (questions 10 and 8, Spearman= -.13, p<.05). Inhabitants who feel less vulnerable perceive themselves to have developed novel forms of local ecological knowledge. Of the group which feels less vulnerable, 26% states that they have developed novel forms of LEK while 31% states this is not the case. Of the people who feel more vulnerable, only 12% states to have developed LEK while 51% states to have not developed LEK. This highlights the link between adaptive capacity and vulnerability. Those with more new LEK, feel less vulnerable. There is also a similar significant negative relationship between the variables of vulnerability and ease to read the river after the project. Respondents who find it easier to read the river, also feel less vulnerable (questions 7 and 8, results not shown, Spearman= -.18, p<.05). Finally, there is some statistically, significant

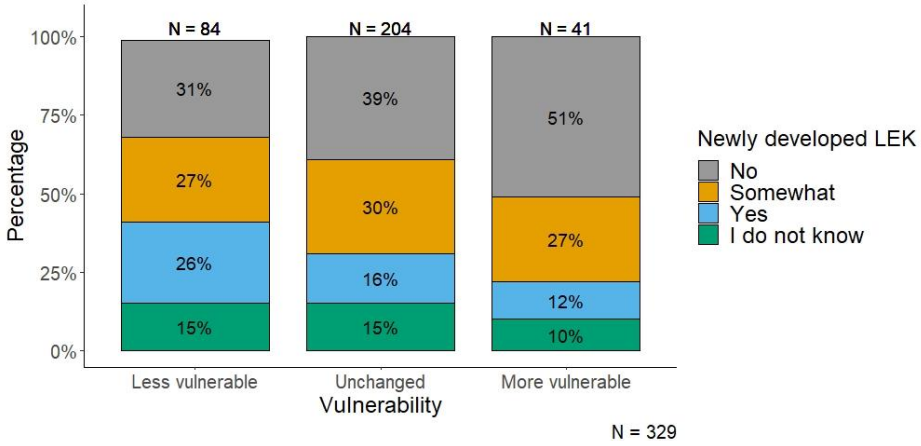

Figure 20: Adaptive capacity and vulnerability

correlations between the perception about vulnerability to demographics. Older people seem to feel less vulnerable and younger people more vulnerable. The middle age group, 45-65, seems to feel most vulnerable. (questions 31 and 8, see appendix 4 figure 33, Cramer's V = .2 with a p<.05). There is a similar correlation between vulnerability and the number of years respondents have been living in the area. Inhabitants who live in the area longer, seem to feel less vulnerable (questions 33 and 8, results not shown, Cramer's V = .15, p<.05).

5.2.4. Flood perception and personal measures

There are several significant correlations between measures taken as an indicator for susceptibility and personal protective measures and variables related to risk perception and perceptions about measure taking. Figure 21 shows the relationship between the importance to take measures and having measures in place (questions 20 and 23). Of the respondents who do not take measures, 46% finds it less than average important to take measures compared to 9% who take measures. Of the inhabitants who take measures, 64% finds it important compared to 20% of those who do not take measures. This relationship is also statistically significant, with Cramer's V=.48 and a p<.05. There is a strong correlation between the people who place a high importance on taking measures and the taking of preventative measures. Hence, importance is vital for implementing actual measures and vice versa (see also chapter 5.3.1). There is also a correlation between the personal measures taken and perception of personal damage inhabitants have (questions 20 and 17, results in appendix 4 figure 34 , Cramer's V=.27, p<.05). Respondents who have experienced a higher damage, also seem to have taken more measures (see also regression one in chapter 5.3). This shows the importance of memory and past experiences for measure taking. There is no correlation found between personal measures taken and threat perception (questions 20 and 12). In addition to this, the results show that there is no significant difference in personal measure taking between measure taking and age (question 20 and 31, results not shown). However, there is a difference observed taking personal measures and years living in the area (question 20 and 33, results in appendix 4 figure 35, Cramer's V = .16, p<.05). Generally, respondents who have been living in the area longer, have more measures taken.

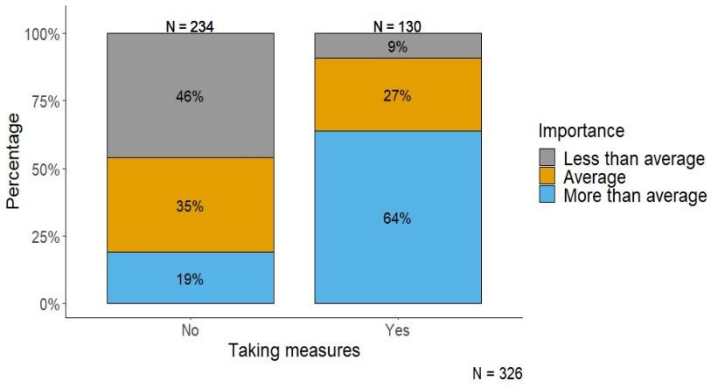

Figure 21: Measure taking and importance

There are also some correlations between several variables relating risk perception and perceptions around measure taking. Figure 22 shows the variables of threat perception after the project and the importance respondents place on taking measures (questions 12 and 23). Of the people that perceive there to be a higher than average threat, 49% finds it very important to take measures compared to 27% of people who perceive there to be a smaller threat. The higher respondents perceive the threat of high water, the more they are inclined to place importance on

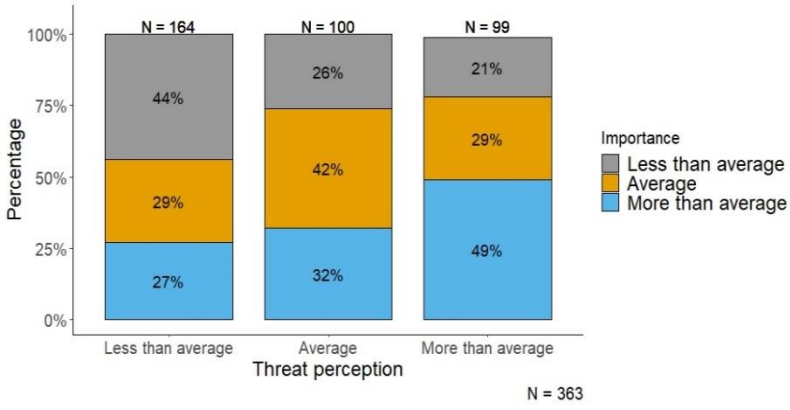

Figure 22: Threat perception and the perception of importance to take measures

measures (Spearman= .23, p<.05). This similar significant, but negative, relationship can be found between the perception of threat and the perception of preparedness (questions 12 and 24, results not shown, Spearman= -.16, p<.05). The higher the threat perception of the respondents, the lower the feeling of preparedness.

Figure 23 shows the variables of living years and the damage perception of flooding events (questions 31 and 17). There is a significant relationship between the number of years living in the area and the perception of personal damage (Cramer's V = .21, p<.05). The groups who came to live in the area after the flooding events of 1993 and 1995, which are the groups 25-40 and 41+, seem to have perceived more damage than people who came to live in the area after the flooding events.

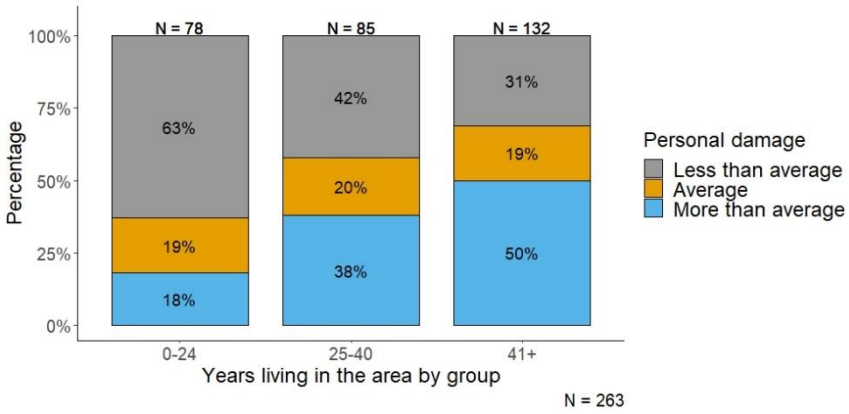

Figure 23: Perception of personal damage

5.2.5. Narrative of the flood free future

There are no significant correlations between the narrative of a flood free future and flood risk perception. The narrative is indicated by question 15 about the likelihood of large flooding events (see chapter 4.4.1). The biggest group of respondents do believe that flooding events will occur more often than 1:250 years (see chapter 5.1.2). However, there are no significant correlations between this variable and other variables. There is no significant relationship between the prediction of flooding events and threat perception after the project (question 15 and 12). There are also no significant correlations between the flood free future narrative and personal measure taken (question 15 and 20) nor between the narrative and the perception of importance (questions 15 and 23). However, as mentioned in section 4.4.1, the variables of likelihood (question 13) and trust (question 11) were not used in any correlations, although these variables were relevant in relation to the narrative.

5.3. Regression analyses

This section elaborates on the three regression analyses which were conducted for this research. The first analysis looks at the variable of taking measures, the second regression looks at vulnerability and the third one at local ecological knowledge.

5.3.1. Regression one: Taking measures

This first regression analysis (n=292) in table 6 shows which factors are important and significant for predicting which groups take personal measures to prevent flooding events from occurring. The predictors were threat perception, trust in the project, damage from flooding events, importance of measures taking, if parents were born in the area, connected to the area and years living in the area.

Predictor compared to base value	Effect on taking personal measures	Significance
Average threat	0.99 times as likely	Not significant
High threat	0.69 times as likely	Not significant
Average trust in the project	2.68 times as likely	Not significant
High trust in the project	1.57 times as likely	Not significant
Average personal damage	1.84 times as likely	Not significant
High personal damage	2.5 times as likely	Significant
Average importance to take measures	3.94 times as likely	Significant
High importance to take measures	21.54 times as likely	Significant
Parents born in the area	0.47 times as likely	Significant
Average connection to the area	2.25 times as likely	Not significant
Large connection to the area	3.55 times as likely	Not significant
12-24 years living in the area	1.99 times as likely	Not significant
25-40 years living in the area	3.62 times as likely	Significant
41+ years living in the area	3.97 times as likely	Significant

Table 6: Regression 1 taking measures

There are several interesting and significant observations when predicting measure taking. Threat perception and trust in the project are not significant predictors for measure taking, showing that threat appraisal and administrative appraisal are not predicting measure taking. However, threat experience is a predictor for taking measures. Respondents who perceived to have high personal damage during flooding events are 2.5 times more likely to take measures compared to low damage. The regression also shows that importance is the best predictor with regards to measure taking. Respondents who agree that measure taking is averagely or highly important are 3.94 and 21.54 more likely to take measures compared to those who place low importance on taking measures. Interestingly, respondents whose parents were born in the area, are .47 times as likely to take measures compared to those whose parents were not born in the area. Respondents whose parents were not born in the area are therefore more likely to take measures. Furthermore, connection to the area was not a significant predictor for taking measures. This shows that knowledge about possible flooding events, is not per se transferred to next generations and that ties to the land, does also not mean that more measures are taken. Also not significant were respondents who have been living in the area for 12-24 years compared to 1-11 years. However, respondents who started living in the area before the flooding events of 1993 and 1995 are 3.62 and 3.97 times more likely compared to respondents who came living in the area 1-11 years ago, to take measures.

5.3.2. Regression two: Vulnerability

The second regression analysis (n=264) in table 7 shows which factors are important and significant for predicting the perception of vulnerability. The predictors are difficulty of predicting high water, novel forms of LEK, if parents were born in the area, connection to the area and years respondents have been living in the area.

Predictor compared to its base value	Effect on vulnerability	Significance
Unchanged predictive ability	0.44 times as likely	Significant
Increased predictive ability	0.45 times as likely	Significant
Some newly developed LEK	0.93 times as likely	Not significant
Newly developed LEK	0.69 times as likely	Not significant

Parents born in the area	1.54 times as likely	Not significant
Average connection to the area	0.25 times as likely	Significant
High connection to the area	0.26 times as likely	Significant
12-24 years living in the area	0.59 times as likely	Not significant
25-40 years living in the area	0.53 times as likely	Not significant
41+ years living in the area	0.40 times as likely	Not significant

Table 7: Regression 2 Vulnerability

The regression analysis highlights that there are only two predictors which are significant for predicting vulnerability. Firstly, respondents who have unchanged or increased predictability are respectively .44 and .45 times as likely to feel neutrally or more vulnerable compared to respondents who have decreased predictive ability. Furthermore, respondents who have an average or high connection to the area are, compared to a low connection, respectively .25 and .26 times as likely to feel neutrally or more vulnerable compared to less vulnerable. Hence, the higher the connection, the lower the feeling of vulnerability.

5.3.3. Regression three: Local ecological knowledge

The third regression (n=292) in table 8 shows which factors are important for the determination of LEK. The predictors were ability to use LEK before the project, years living in the area, if parents were born in the area and connection to the area.

Predictor compared to its base value	Effect on local ecological knowledge	Significance
Average ability before the project	1.95 times as likely	Not significant
High ability before the project	9.05 times as likely	Significant
12-24 years living in the area	2.26 times as likely	Not significant
25-40 years living in the area	3.25 times as likely	Significant
41+ years living in the area	3.55 times as likely	Significant
Parents born in the area	1.4 times as likely	Not significant
Average connectedness to the area	0.86 times as likely	Not significant
High connectedness to the area	2.15 times as likely	Not significant

Table 8: Regression 3 LEK

This regression analysis shows that two predictors are significant for predicting LEK, namely ability of using LEK and years living in the area. Respondents who were skilled in using LEK, feel 9.05 times as likely compared to those who feel not skilled, to occasionally or oftentimes use LEK compared to never. Additionally, the number of years that inhabitants have been living in the area is an important indicator for the amount of LEK that they have. Respondents who have been living in the area for 25-40 years and 41+ years are respectively 2.26 and 3.55 times as likely compared to respondents who have been living in the area for 0-11 years to have 'occasionally using LEK' and 'often or always using LEK' compared to 'almost never'. Hence, the longer respondents have been living in the area, the more knowledge they have. There is no significant relationship between the other variables and using LEK.

6. Discussion

The following section will interpret the results based on the analyses done in chapter five. It will link the results to the wider literature. This section is also ordered per research question as can be found in the conceptual model. However, sub-question two is divided into two section and sub-questions three and four on flood risk perception, measures and the narrative are taken as one. Furthermore, limitations of the research, further research and recommendations are also discussed.

6.1. Altered landscapes and local ecological knowledge

In general, it can be stated that the Grensmaas project has altered the landscape in significant ways. This research shows that LEK is wide-spread throughout the area, but that the project has only meagerly impacted the LEK that inhabitants have. Before the project, LEK was prevalent and frequently used for predicting flooding events and in addition to this many inhabitants state that LEK was useful for doing so. Respondents who used LEK more often have a higher ability to read the river which results in some experts who have accumulated LEK and in others who do less so, demographically, LEK has accumulated in inhabitants who have been living in the area for longer time as is shown in the regression. Although the presence of LEK might not be surprising for inhabitants of the region themselves, in Europe, many people do not know that LEK is still used and valuable. This research shows that LEK is still present in a highly urbanized and industrialized European country and that LEK is valuable as a means of understanding an ecological system and dealing with ecological dynamics which is in line with literature (F. Berkes, 2012) The presence of LEK and the accumulation of LEK in some inhabitants is important because it highlights that there are specific groups and people who are able to give more detailed information about the behavior of the river during flooding events (LJ McEwen et al., 2012). This is valuable for devising strategies to minimize damage. Markings in the landscape such as gauges, river borders and possible flooding areas were used most often for LEK showing that LEK is highly local and context-specific, as is confirmed by literature (Lindsey McEwen & Jones, 2012; LJ McEwen et al., 2012). There is meager evidence that markings and LEK are disappearing. With regards to the markings, this research has shown the markings are still largely present, however, markings that were used most also seem to have disappeared most often. With regards to LEK, the descriptive analysis shows that the majority agrees that LEK has not or only partly decreased and that the ability to read the river has not decreased either. The correlation analyses show the same evidence. LEK still seems to be largely be present. Only one correlation shows evidence of some disappearance, namely that the disappearance of markings relates to less knowledge after the project. Therefore, there is limited evidence of a decreased and disturbed interaction between the social and ecological systems in the area. Hence, this research is not in line with research of Engel et al. (2014), who argue that LEK has decreased. This research shows that the project has not disabled local communities to read the river and that LEK has not disappeared in a changed landscape. Instead, this thesis shows that LEK is persistent and that it has a dynamic and adaptive nature as is often mentioned in literature (Godoy et al., 2009; Gómez-Baggethun & Reyes-García, 2013; Mathez-Stiefel et al., 2012).

6.2. LEK and adaptive capacity

The majority of all respondents stated that already existing LEK has not decreased and that markings are still present, highlighting that LEK is persistent. Although the social-environmental interaction has not decreased because of the continued presence of LEK, adaptive capacity seems to have relatively decreased more than LEK has. The descriptive analysis states that for just over 50%, adaptive capacity has not decreased, although it has for 30%, which is a higher percentage than for LEK. The correlation analyses show that respondents who frequently used LEK and that respondents who argue that markings

are not or partly present, both have a decreased ability to predict high water after the project, evidence of a decreased adaptive capacity. It also points out that those who are most reliant on the markings and on LEK in general, are impacted most by the decreased ability, as was hypothesized. Elderly and inhabitants who have been living in the area for a longer time also have a lower ability to read the river after the project. This decrease in capacity is relevant because certain groups of inhabitants might not recognize flooding patterns anymore, while they used it before the project to predict possible flooding events (Lindsey McEwen & Jones, 2012). This is evidence that there seems to be some form of lowered adaptive capacity as is consistent with Engel et al. (2014) who also state that the ability of inhabitants to read the river has decreased. However, the decrease in adaptive capacity is countered by other evidence and it does seem to be large. Another correlation shows that the ability to use markings before and after the project has not changed. Results are somewhat contradictory, but it seems that the project has at least some negative impact on the adaptive capacity of inhabitants.

As LEK has disappeared for a minority and as the ability of some inhabitants to respond to river dynamics has been inhibited, it could be that the knowledge-action-belief framework as described by Berkes (F. Berkes, 2012) has been altered. When some adaptive capacity is lost, warning signals that the river might flood cannot be understood and can lead to a slower and more reactive response. This can lead to a slower initiation of flood management schemes which are oftentimes very local and communal as described by Engel et al. (2014). This loss of local agency to respond and the changed knowledge-action-belief framework is also highlighted by the fact that inhabitants feel more reliant on authorities for flood protection which is in line with (Engel et al., 2014). Because of the slower response, damages might be larger.

The descriptive section has also shown that new knowledge has not yet been developed and inhabitants do generally not see new markings yet. The development of new forms of LEK takes time and so does the development of new forms of adaptive capacity (F. Berkes, 2012). That some new forms of LEK have developed is seen in some correlation analyses, highlighting that there are some groups who have developed new knowledge and therefore have increased their adaptive capacity. Elderly and respondents who have been living in the area for a longer time, seem to have a higher adaptive capacity as they mention more new markings. In addition, inhabitants who frequently used LEK before the project and those who state that markings are still present now, also state that there are new markings. Interestingly, these are also the groups who stated that LEK has disappeared. Hence, it shows that for those who have a lot of LEK and who are impacted most by the project, also are the ones who adapt quickest to new environments. They are already somewhat adjusting to new circumstances and that through new observations and experiences with the landscape some new LEK is slowly developing. This is in line with the research that LEK is dynamic (Godoy et al., 2009; Gómez-Baggethun & Reyes-García, 2013; Mathez-Stiefel et al., 2012).

6.3. Adaptive capacity and vulnerability

It is difficult to link adaptive capacity to vulnerability as the regression analysis provides contradictory results. The regression analysis shows that a changed ability to read the river does predict vulnerability, however, the second indicator of adaptive capacity, newly developed LEK, does not. Therefore, it cannot be argued that the Grensmaas project is directly linked to increased vulnerability. However, there is more nuance to this conclusion and there are still some groups who feel more vulnerable because of a decreased adaptive capacity.

Generally, the descriptive analysis shows that respondents do not feel more vulnerable as a result of the disappearance of markings, hinting that vulnerability has not increased. However, although generally inhabitants might not perceive themselves as being more vulnerable, some groups do feel more vulnerable. This is highlighted by the correlation analyses, which stated those who state that they have less newly developed forms of LEK feel more vulnerable. In addition, this is also the case for older age groups and respondents who have been living in the area longer. The regression analysis also shows that respondents who have a decreased adaptive capacity, feel more vulnerable. Therefore, a minority seems to feel more vulnerable. In contrast, the regression analysis shows that newly developed LEK does not predict vulnerability. Hence, and as stated before, it is difficult to link adaptive capacity to vulnerability directly. Although some correlations are in line with research by Engel et al (2014), stating that vulnerability has increased because of decreased LEK, part of the regression analysis counteracts this and the small increase in vulnerability is only seen for a very selected group of inhabitants. Thus, the Grensmaas project cannot be directly linked to changed forms of vulnerability and therefore, altered forms of LEK do not directly influence vulnerability. This research is therefore not in line with the research of Engel et al. (2014), stating that vulnerability has increased. This means that there is no evidence that inhabitants experience negative effects to actively and adequately respond to flooding signs in the case of possible flooding events.

6.4. Flood perception, measures and the narrative

The Grensmaas project has vastly decreased the likelihood that flooding events will occur as official flood risk has been lowered to 1:250. Therefore, the overall vulnerability of the inhabitants has decreased. However, this research indicates that the susceptibility of the inhabitants to flooding events has increased; although flooding events are less likely to occur, once they occur, respondents seem not to be prepared.

25 years after the last flooding event, risk perception and aspects of preventative personal measure perception are low. Once a flooding event occurs, respondents do not seem prepared because there are not many private preventative measures taken. Although almost all inhabitants are aware of living in a flood-prone area, almost 2:3 of the respondents has not taken private precautionary measures, while the majority states to feel sufficiently prepared. The large majority agrees that the threat appraisal is low, with smaller perceptions of threat, likelihood and damages from the river as a result of the project. Interestingly, it is not believed that the actual risk is 1:250. There is also a low threat experience after the project and lower administrative appraisal as the large majority has trust in the project. Finally, the perception around measure taking also indicates a low risk perception. Only 1:3 finds it important to take measures and respondents see a decrease in necessity to take measures after the project as well as a decreased perception of importance. This hints at the fact that many respondents do not see the benefits or the positive effects of personal measures and highlights an indifferent attitude.

These indicators described above show that groups which are associated with taking precautionary measures are relatively small. Low forms of risk perception and measure taking indicate a relatively high susceptibility because inhabitants are not prepared in case of flood events. This is worrisome because of different reasons. Firstly, risk perception is highly relevant in valuation of and actual risk aversive behavior (Birkholz et al., 2014). There are many factors influencing risk aversive behavior, but these results show that generally these factors seem to lead to a lower risk perception. In addition to this, personal measures are likely to not be valued given the fact that it is known that personal measures are needed and highly effective in decreasing flooding damage (Grothmann & Reusswig, 2006; Terpstra, 2011). Furthermore, the descriptive analysis shows the large trust in the project and the somewhat higher

dependency on official authorities for flooding prevention. There seems to be a lot of faith in the project and although official measures have decreased flooding risk and although risk perception has decreased, once a flooding event will occur, it is more likely that damages in the area will be higher (Engel et al., 2014). This is underestimated by the inhabitants who state that damages are lower after the project. This is just one of the examples that there is not one technocratic way of looking at risk and risk perception, but that this is dependent on the social context with complex social dynamics. This is also aligned with literature arguing that risk perception is socially produced (Messner & Meyer, 2006). An example of this is the found in the trust and likelihood perception. Although virtually everyone has trust that the measures will lead to less flooding events, most people do not believe that the measures protect as to what is promised, which is contradictory. These different and contradictory attitudes show that risk perception is complex and provide difficulties in predicting what works for increased measure taking. Respondents do not seem to be aware of measures of their neighbors and believe that others take little measures. The majority also states that they have taken similar numbers of measures as others have. This indicates that respondents copy the behavior of others and that there is little communication about flood prevention measures in the area. Engel et al. (2014) argue that there is a communal spirit in the area, however, with regards to flooding experiences and preparedness, it seems to be missing. Weinstein (1989), among others, states that collective action and community-level activities is very important for risk perception, and this research indicates that this is lacking. Finally, several authors have argued that there is a general distrust of authorities in Limburg (Engel et al., 2014; Roth et al., 2017; Warner, 2016). However, the results show that with regards to the GM project, this distrust is currently not there.

The correlation and regression analyses also point to the fact that there are some indicators that susceptibility seems relatively high. In addition, this research shows that there is some evidence that risk perception is linked to measure taking, but not in all cases. Firstly, contrary to what is predicted by Grothmann & Reusswig (2006), the regression analysis shows that there is no relationship between administrative measures and measure taking and therefore, this does not matter for the susceptibility directly. Although respondents generally have trust in the project, this does not mean they have taken no measures. This research therefore indicates that the Levee effect (Baan & Klijn, 2004) cannot fully explain the lack of preventative measures, but that there are other dynamics at play. This is also highlight by the fact that this research is clear in showing that, contrary to Engel et al. (2014), there is no evidence for the 'narrative of the flood free future'. This research shows that there is no relationship between inhabitants who think that flooding events will never occur and a lower risk perception. Therefore, inhabitants seem to show that flooding events are still somewhat part of their daily lives. With regards to threat appraisal, the research is aligned somewhat, but not strongly, with the theorem of Grothmann & Reusswig (2006). The correlations show that inhabitants with a higher threat perception tend to place a higher importance on measure taking and on feelings of preparedness. However, not with actual taking of private measures. The largest alignment with theory is with threat experience. Both the correlation analyses and the regressions are significantly relating that inhabitants who have experienced the flooding events of 1993 and 1995 and inhabitants who have experienced higher damage take more measures and find measure taking more important. Therefore, this thesis supports that threat experience and memory is important for risk perception and private measure taking (Grothmann & Reusswig, 2006; Weinstein, 1989). In other words, self-protective behavior and private measure taking increases once one has experienced a severe flooding damage. As the group who have experienced large damage are relatively small (35%), this supports a higher susceptibility. This is also somewhat the case for perception of importance. The best predictor with regards to private measure taking are respondents who place a high importance on it. Grothmann & Reusswig (2006) state that simply increasing awareness might be insufficient for pro-active behavior. Although this might be the case, this research highlights that until now, awareness of the importance is still the best predictor for measure taking. The group

which states that measure taking is not important is 33%, highlighting that at least 30% is more susceptible. Therefore, it is key to increase the importance of awareness.

Hence, this research has shown that there are some indicators that susceptibility is high, namely the majority indicating a low threat experience and the majority indicating less importance of measure taking. However, in this research, susceptibility, in the form of measure taking, seems to be only partly dependent on the components described by Grothmann & Reusswig (2006). Although risk perception is low, it is not directly linked to the Levee effect, but indictors such as memory and importance are more important. Ending on a positive note, currently, those who have taken measures do not feel the need to decrease measures, which hints at some resistance of the system against the fact that risk perception seems to be low and against the fact that not many respondents have actual measures in place. Therefore, with the right incentives, measure taking could be more likely to in- than to decrease

6.5. Limitations

There are several limitations of this research which could have impacted the research in some ways. There are constraints in the research design and execution, and conceptual constraints. Firstly, a part of this thesis research tries to measure trends and changes over time with regards to risk perception and LEK. This is difficult to reflect in a survey especially when there have been no baseline studies before the project. Now, inhabitants were asked to remember the situation before the project, which increases the chances of a faulty memory. Furthermore, as is usual in research, there were limited resources such as funding and time available. These resource constraints affect the research design. The sampling method, which was not random because of funding constraints, could lead to bias in the sample. Related to this, with regard to the execution of the study, In the field, surveys were handed out in person based on convenience. Not in all villages surveys were handed out and therefore, there is a bias in response for villages in which surveys were handed out. In addition, the design of survey has an impact. Survey questions are perceived differently by everyone and it is not always sure that the manner in which the question is meant, is also the manner in which it is perceived. There are ambiguous questions and it is not possible to clarify if questions are unclear. For example, there is the possibility that respondents have LEK, but are not aware of it. LEK is a very academic term and although it has been operationalized through the use of markings to predict the river dynamics, this might not have come across perfectly in this research and can be researched better in a more qualitative setting. This relates to the fact that it is always difficult to create indicators which perfectly capture the theory without altering it. Indicator questions have to be to the point, not too detailed and understandable and they always approximate the theory without fully covering it. For example, it is difficult to capture the adaptive capacity of respondents in a short question. Also, some concepts could have been referred to differently. Coping appraisal was not conceptualized and could be researched in more detail (see 6.6). Income could have been added in order to see a relationship between resources available and measure taking. moreover, questions related to LEK are hard to convey when not asked in person and when asked in a quantitative survey. This is the case because LEK is very much based on experience, it is very context specific and does not per se follow scientific ways of expressing and writing.

6.6. Further research

This thesis research has shed light on the quantitative aspect of risk perception and LEK dynamics. However, in order to fully grasp these concepts in depth, qualitative research is needed. This research has showed that LEK exists, that it is used and that it is dynamic. However, detailed information on LEK dynamics and social-environmental interactions is unknown. What are the practical manifestations and uses of LEK, and what is the perception of value of inhabitants of LEK? Qualitative research can look

further into this by researching different aspects of LEK. Firstly, further qualitative research into LEK could shed a light on how the importance of LEK for inhabitants and the possibility that inhabitants are unaware of the term LEK and maybe refer to the same knowledge differently. Secondly, it can be researched how LEK is used and how fine-grained knowledge of respondents is. LEK-holders can describe the movement of water in streets and where it might lead to problems. This can be tested and fine-tubed by models. This will show the added value of LEK and it can provide policy makers with information to be used in flood prevention planning, decreasing economic damages of LEK. This fine-grained knowledge also depends on different villages and parishes, which is especially interesting in the periods after the project has ended. Some villages have seen a complete alteration of their surrounding while in other villages, nature development was relatively small. Finally, research into the timespan needed before social-ecological interactions are developing new forms of LEK, the different stages of this development and how it differs per village and parish is also of added value. Research can show how the knowledge-practice-believe framework has been impacted by the project and hereby problems can be expected in communities who are self-reliant when it comes to flood protection. When it is known how the institutions, believe systems and practices of villages and parishes have been impacted by landscape changes and by introducing new institutions for dealing with flooding events, replacing traditional institutions, it can provide valuable information on how these groups can build new LEK and deal with the new circumstances.

With regard to flood risk perception, there are several exciting possibilities for further research as well. This research has highlighted that individuals have not taken sufficient amounts of preventative measures and that on a communal level, risk perception is not sufficient. Firstly, coping appraisal can be researched in more detail as it is proven to lead to increased preventative measures. The level of coping appraisal and its effect on taking measures is needed as in the future flooding events are more likely to be more severe and more prevalent. It has to be known which dimensions of coping appraisal are important for measure taking. Is income as an indicator predicting measure taking or does coping appraisal also include technical skills, time- and monetary costs and does it depend on certain measures? Secondly, communal responses are also effective with regards to measure taking. It is needed to know what communal practices are with respect to measure taking and flooding events, how these interact communal practices interact with existing policies, what knowledge sharing channels exist and how are they impacting preventative measure taking. Next to the practical and landscape implications of the GM project, the Grensmaas now falls under national jurisdiction. This means that there are different rules and regulations in place and that new schemes on dealing with flooding events are being and have been set up as for example building restrictions. What are the effects of these new schemes on inhabitants and their preparedness and what is their knowledge on these new rules and regulations?

6.7. Recommendations for policy makers

Based on the results and the discussion chapters, there are two recommendations in order to tackle the issues found in this research. Generally, these recommendations should not stand on their own but should be included in existing plans such as the *'rampbestrijdingsplan Hoogwater Maas'* (high water disaster management plan for the river Maas).

1. Currently, there is a trend of bottom up governance, meaning that it is tried to involve all the different stakeholders in creating policy. For minimizing economic and personal damage when flooding events occur, it is important that the behavior of the water is modelled on a very detailed level. This means that administrative employees can work together with modeling engineers and local inhabitants to create models and to test if these models represent the real situation. This is where inhabitants who

have good levels and ability of LEK are important as they can describe the movement of the water in much detail and are able to describe where water congestion or other problems can occur. They know the terrain and know where pressure points occur. Models, at this moment, are not able to capture all of these pressure points and here, LEK could be of use (Lindsey McEwen & Jones, 2012). Working closely with inhabitants for better flood risk management can also be beneficial for respondents who have stated they have lost LEK and for those who have become less adaptive. They can, in collaboration with local experts, gain new knowledge. In addition to this, these local experts should also be called upon once a flooding is likely to occur. They have useful knowledge. In accordance with this, plans can be set up to increase inhabitants' LEK by promoting and placing new markings. When this happens in collaboration with inhabitants, knowledge can spread within the villages.

2. Parallel to recommendation one, a campaign in order to increase private measures should be initiated. This research has shown that it is not likely to assume that respondents take sufficient measures when official measures have been taken, the opposite is more likely. It makes sense that respondents have a lowered risk perception after the project. Therefore, a campaign should incentivize increasing private measures. It is not possible to target all inhabitants and that is also not needed. Because these villages have a communal atmosphere, only certain groups and inhabitants need to be targeted, especially leaders and vulnerable groups. Vulnerable groups are those which have been shown to take little measures, such as younger people and people who have been living in the area for a short time. This research has shown that memory and importance to take measures is vital for taking measures. Thus, awareness weeks in which flooding events are commemorated and neighborhood visits can increase taking measures. Then, information flows are very important. Inhabitants need to know how they can contribute, which private measures are most cost-efficient, which subsidies they can apply for and how they can get help on implementing these measures (see also chapter 6.6). An important role is there for the GC. They are widely present and known in the area and they have established trust and authority. They can highlight that the inhabitants have their own responsibility and that there should not be an underestimation of personal measures. In addition, they can highlight that flooding events can and will still occur in the future despite the GM project. Finally, when flooding events have hit, there must be a plan devised on how to effectively increase preventative measures as that is the time when inhabitants are very responsive to it, which is a good window of opportunity as shown in this research.

7. Conclusion

The Grensmaas project is seen by inhabitants as very positive and it has officially decreased flooding risk to 1:250. New nature is added, river dynamics are being restored and wildlife is moving back into the area. Moreover, some jobs are created and the project is self-financed for a large part. However, there are also downsides to the project. This research looked at the effects of this NbS project on social-ecological interactions through flood perception and LEK and how this might have increased susceptibility and vulnerability of the inhabitants.

This research has shown that successful flood risk reduction bears the risk that inhabitants forget about the presence of potential flooding events. Although vulnerability has decreased because of the project, susceptibility seems to be relatively large. Although there is a wide-spread awareness about living in a flood-prone area, this research has shown that overall risk perception is low and that most inhabitants have not taken sufficient measures to protect themselves against flooding events. This is relevant as personal measures are important in minimizing flooding damages and as damages are likely to be larger rather than smaller when flooding events occur. Generally, some components that are described by Grothmann & Reusswig (2006) link lower forms of risk perception to decreased (perception of) measure taking. Most respondents which have answered questions related to flood perception, fall in the low categories. In addition, inhabitants are polarized when it comes to importance of taking measures. This is the case despite that fact that it is the largest predictor of actual taking of protective measures. Moreover, memory plays an important role, and there are significant relations between those who take measures and those who have experienced the flooding events of 1993 and 1995. Therefore, threat experience is also seen as a predictor for preparedness. Finally, there seems to be little communication and communal agreements with regard to flooding events in the villages and parishes, this despite the fact that these parishes and villages have strong collective bonds, a high cohesiveness and a general distrust towards national authorities.

With regard to LEK, results show that LEK is very valuable and inhabitants used LEK often, showing that LEK is existing in a Western context and highlighting its value. This research has shown that LEK has not disappeared and that social-ecological interactions are therefore not impacted by the project. This research, however, has also pointed out that the adaptive capacity of inhabitants has been somewhat decreased. This is potentially harmful as signs of flooding events might not be rightly interpreted anymore which increases vulnerability and thereby potential forms of personal damages. It might be the case that it has become harder for some to predict river potential flooding events based on LEK. However, it cannot be concluded that vulnerability has increased because of decreased adaptive capacity and therefore, there is no evidence that the GM project has led to an increase in vulnerability and that inhabitants are negatively impacted by the project. Finally, LEK is dynamic and has the capacity to proliferate and although generally there is no new adaptive capacity, there are some signs of new LEK.

This social-ecological research has shown that LEK is used by many, that adaptive capacity has somewhat decreased and that there is no evidence that the inhabitants have become more vulnerable. It has also pointed out that LEK is valuable for inhabitants and that its continuation is important. Looking at risk perception, this research has highlighted that risk perception is low and so are private preventative measures. This is relevant as private measures are important for minimizing damages. Finally, memory and importance to take measure is vital for increasing measures taken and there is some evidence that susceptibility is relatively large. A saying by the most famous Dutch football player ever, Johan Cruijff, translates roughly to "oftentimes something needs to happen, before something happens". Acting by the words of the most famous Dutch football player: Might we act proactively and not in hindsight.

8. References

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9. Appendices

Appendix 1 – The survey

Beste Grensmaas bewoner,

Mijn naam is Vince van 't Hoff en ik ben een student aan de Universiteit van Wageningen. Ik ben bezig met mijn afstudeeronderzoek binnen de master Milieuwetenschappen. Mijn afstudeeronderzoek gaat over het Grensmaas gebied en hierbinnen kijk ik hoe dit gebied wordt ervaren door inwoners. Ik heb voor dit onderwerp gekozen omdat ik erg begaan ben met Limburg en omdat ik benieuwd ben naar de beleving van bewoners. Ook kunnen de resultaten zeer bruikbaar zijn voor beleidsmakers, met wie ik mijn resultaten ook zal delen. Ik word begeleid door Universitair Hoofddocent Dr. Andries Richter. Voor meer informatie en vragen over dit onderzoek kunt u contact opnemen met vince.vanthoff@wur.nl

Graag zou ik u willen uitnodigen deel te nemen aan deze vragenlijst. Het zal u ongeveer 20 minuten kosten om deze vragenlijst in te vullen. Uw gegevens worden vertrouwelijk behandeld, ze zijn niet herleidbaar naar individuele personen en ze worden anoniem verwerkt. Uw deelname aan dit onderzoek is geheel vrijwillig. U hebt ten allen tijde het recht te stoppen met de vragenlijst. Alvast bedankt voor uw medewerking.

Aan het einde van de vragenlijst zal u worden gevraagd of u mee wilt doen om een prijs te winnen.

De prijzen zijn:

- 100 euro VVV diner of activiteiten bon
- 50 euro VVV diner of activiteiten bon
- 25 euro VVV diner of activiteiten bon

Ik heb de informatie in deze vragenlijst begrepen en ik stem vrijwillig in met deelname aan de vragenlijst

Nee ☐ Ja ☐

Leest u alstublieft iedere vraag goed door en geef zo eerlijk mogelijk antwoord. Er zijn geen goede of foute antwoorden, het gaat om uw mening. Denk niet te lang na over uw antwoord. Het antwoord dat als eerste in u opkomt, is meestal het beste.

Deze vragenlijst bestaat uit drie onderdelen. Het eerste onderdeel gaat over hoogwater beleving, het tweede onderdeel gaat over persoonlijke maatregelen die u neemt tegen wateroverlast en het laatste onderdeel vraagt naar uw relatie tot hoogwatermarkeringen binnen het Grensmaas gebied.

1. Hoezeer bent u op de hoogte dat u woont in een gebied met het risico op overstroming?
   Helemaal niet op de hoogte Niet goed op de hoogte Een beetje op de hoogte
   Goed op de hoogte Zeer goed op de hoogte

2. Op welke manieren bent u ervan bewust dat u in een gebied woont met overstromingsrisico? (Meerdere antwoorden mogelijk)
   Familie/vrienden/buren ☐ Musea ☐ Markeringen en herinneringen in de openbare ☐
   ruimte Voorstellingen Informatie via de gemeente ☐ Media ☐ Anders, namelijk

3. Hoe ervaart u het om in het Grensmaas gebied te wonen?

Heel negatief 1 2 3 4 5 6 7 Heel positief

1. De volgende vragen gaan over de beleving omtrent hoogwater voor na de uitvoering van het Grensmaas project

De volgende termen wil ik graag eerst verduidelijken dus neemt u deze goed door.

- Het Grensmaas project: Het rivierenproject in Zuid-Limburg met drie hoofddoelstellingen, namelijk ontgrinding, hoogwaterbescherming en natuurontwikkeling.
- Hoogwater: een kritisch waterpeil van de Grensmaas, wat kan leiden tot overstromingen
- Overstroming: Gebieden buiten de uiterwaarden die normaal niet onderwater staan, komen onderwater te staan
- Wateroverlast: Overstroming die uw huis binnentreedt

Het eerste gedeelte gaat over de situatie na voltooiing van het Grensmaas project. Mocht het project in uw omgeving nog niet voltooid zijn, ga dan uit van een toekomstige situatie waarin het project wel voltooid is.

4. Is het Grensmaas project al afgerond in uw omgeving
   Ja ☐ Nee, het project is nog niet afgerond☐

5. (Question 11) In hoeverre heeft u vertrouwen dat de maatregelen die getroffen zijn binnen het Grensmaas project leiden tot minder wateroverlast?
   Geen vertrouwen 1 2 3 4 5 Veel vertrouwen

6. (Question 12) In hoeverre beschouwt u hoogwater, na voltooiing van het Grensmaas project, als een bedreiging?
   Geen bedreiging 1 2 3 4 5 Zeer grote bedreiging

7. (Question 13) Denkt u dat de kans op wateroverlast groter of kleiner is geworden door het Grensmaas project?
   Veel kleiner Kleiner Even groot Groter Veel groter

8. (Question 14) Denkt u dat de mogelijke schade van wateroverlast, mocht een overstroming komen, groter of kleiner is geworden door het Grensmaas project?
   (Met schade wordt alle vormen van schade bedoeld, dus emotionele, sociale, economische en financiële schade)
   Veel kleiner Kleiner Even groot Groter Veel groter

9. (Question 15) Hoe vaak verwacht u nu dat grote overstromingen zoals 1993 of 1995 zullen plaatsvinden?
   1 in 10 jaar 1 in 25 jaar 1 in 50 jaar 1 in 100 jaar 1 in 250 jaar nooit meer

10. (Question 16) Verwacht u dat deze kans in de toekomst (2050) verandert, bijvoorbeeld door klimaatverandering?
    Veel kleiner Kleiner Even groot Groter Veel groter

    De volgende vragen gaan over de situatie voor het Grensmaas project. Herinnert u zich nog de situatie voor aanvang van het Grensmaas project? Ik heb de display logic eruit gehaald
    Nee☐ Gedeeltelijk☐ Ja☐

11. (Question 18) In hoeverre beschouwde u hoogwater als een bedreiging?
    Geen bedreiging 1 2 3 4 5 Zeer grote bedreiging

    (Question 17) Welke mate van persoonlijke schade ervaarde u door wateroverlast?
    (Met schade wordt alle vormen van schade bedoeld, dus emotionele, sociale, economische en financiële schade)
    Geen schade 1 2 3 4 5 Grote schade

12. (Question 19) De kans dat een overstroming plaats zou vinden was … dan de kans dat een overstroming na het Grensmaas project plaats zal vinden
    Veel kleiner Kleiner Even groot Groter Veel groter

2. De volgende vragen gaan over uw beleving over persoonlijke maatregelen als bescherming tegen hoogwater na de uitvoering van het GM project

13. (Question 20) Treft u persoonlijk maatregelen om wateroverlast te voorkomen?
    Nee☐ zo ja, volgende vragen☐

14. (Question 21) Welke maatregelen heeft u genomen om uzelf te beschermen tegen wateroverlast? Meerdere keuzes mogelijk
    Betegelde vloeren en wanden op de beneden verdieping☐ Een transistor radio☐
    Noodverlichting en batterijen☐ Extra voedsel en drinkwater☐
    Dekens en droge handdoeken☐ Waterschotten☐ Zandzakken☐
    Een waterpomp☐ Hogergeplaatste elektrische apparaten☐
    Mogelijkheid tot ophogen meubels☐ Overstromingsverzekering☐
    Anders, namelijk:

15. (Question 22) Treft u naast maatregelen in huis ook andere maatregelen?
    Afspraken met buren ☐ Waarschuwingssystemen in de buurt ☐
    Nee ☐ Anders, namelijk:

16. (Question 28) Treffen uw buren/vrienden/kennissen die binnen de Grensmaas wonen maatregelen om wateroverlast te voorkomen?
    Geen maatregelen☐ Weinig☐ Veel☐ Zeer veel maatregelen☐ Weet ik niet☐

17. (Question 29) In verhouding tot hen, treft u meer of minder maatregelen?
    Veel minder☐ Minder☐ Neutraal☐ Meer☐ Veel meer☐ Weet niet☐

    De volgende vragen gaan over de huidige situatie, dus na de uitvoerig van het Grensmaas project

18. (Question 23) Vindt u het belangrijk om zelf maatregelen te treffen om wateroverlast te voorkomen?
    Onbelangrijk 1 2 3 4 5 Heel belangrijk

19. (Question 24) Voelt u zichzelf voldoende voorbereid tegen wateroverlast?
    Slecht☐ Onvoldoende ☐ Voldoende☐ Goed☐ Zeer goed ☐

20. (Question 25) Ziet u, in vergelijking met voor de ingrepen van het Grensmaas project, nu meer of minder noodzaak om persoonlijk maatregelen te treffen?
    Veel minder noodzaak ☐ Minder noodzaak ☐ Evenveel noodzaak ☐
    meer noodzaak ☐ Veel meer noodzaak ☐

21. (Question 26) Voor de ingrepen van het Grensmaas project, in hoeverre vond u het belangrijk om zelf maatregelen te nemen om wateroverlast te voorkomen? (omcirkel het goede antwoord)
    Niet belangrijk 1 2 3 4 5 Heel belangrijk
    Weet niet

22. (Question 27) Bent u van plan om genomen persoonlijke maatregelen om uw huis te beschermen aan te passen omdat u meer of minder noodzaak tot persoonlijke maatregelen ziet of heeft u dat recentelijk al gedaan?
    Nee ☐ Minder maatregelen ☐ Meer maatregelen ☐

Vragen omtrent kennis over hoogwater markeringen binnen een veranderd landschap:

Deze vragen zijn allemaal gerelateerd aan de uw kennis over het 'gedrag' van de rivier tijdens hoogwater en mogelijke overstromingen gerelateerd aan het Grensmaas project.

- Hoogwater markeringen: Markeringen in het landschap die het mogelijk maken om indicaties te geven hoe de rivier zich gedraagt in tijden van hoogwater en waar mogelijk overstromingen op kunnen treden

De eerste vragen gaan over de situatie voor aanvang van het Grensmaas project.

23. Kunt u zich deze situatie nog herinneren?
    Nee ☐ Ja ☐ (vragen 24 tm 27 worden overgeslagen in geval van nee)

24. (Question 1) Gebruikte u markeringen in het landschap om het 'gedrag' van de Grensmaas rivier te voorspellen in tijden van hoogwater met risico op overstromingen?
    Nee niet echt af en toe vaak altijd

25. (Question 2) Wat waren in uw omgeving markeringen waaraan u hoogwater en overstromingsgevaar kon waarnemen?
    Hekken ☐ Bomen ☐ Mogelijke overstromingsgebieden ☐ Bewegwijzering ☐
    Peilschalen ☐ Akkers ☐ Oeverranden ☐ Anders, namelijk:

26. Welke markeringen waren het belangrijkst voor u? Geef een top 3 aan
    1: 2: 3:

27. I(Question 3) In hoeverre kon u aan de hand van deze markeringen het gedrag van de Grensmaas rivier inschatten en mogelijk wateroverlast aan zien komen?
    Helemaal niet 1 2 3 4 5 Zeer goed

De volgende vragen gaan over de huidige voltooide situatie, de uitvoering van het Grensmaas project. Mocht het project in uw omgeving nog niet voltooid zijn, ga dan uit van een toekomstige situatie waarin het project wel voltooid is.

28. (Question 4) Zijn de markeringen aan de hand waarvan u hoogwater kon waarnemen voor het begin van het Grensmaas project nog steeds aanwezig na de uitvoering van het project?

Ja ☐ Deels ☐ Niet meer ☐ Weet ik niet ☐

29. (Question 5) Welke markeringen zijn nu niet meer aanwezig/voor u herkenbaar?
    Hekken ☐ Bomen ☐ Mogelijke overstromingsgebieden ☐ Bewegwijzering ☐
    Peilschalen ☐ Anders, namelijk:

30. (Question 6) Is uw kennis om hoogwater en mogelijke overstromingen aan te zien komen veranderd door het project?
    Ik heb nu minder kennis ☐ Onveranderd ☐ Ik heb nu meer kennis ☐

31. (Question 7) In hoeverre is het moeilijker om naar eigen waarneming hoogwater met het risico op overstroming aan te zien komen?
    Onmogelijk ☐ Moeilijker ☐ Onveranderd ☐ Wat makkelijker ☐
    Veel makkelijker ☐

32. (Question 8) In hoeverre voelt u zich meer of minder kwetsbaar door het verdwijnen van de markeringen? Omcirkel uw antwoord
    Veel minder kwetsbaar 1 2 3 4 5 Veel kwetsbaarder

33. In hoeverre voelt u zich nu meer of minder afhankelijk van de officiële autoriteiten dan van uw eigen kennis om hoogwater waar te nemen? Omcirkel uw antwoord
    Afhankelijker 1 2 3 4 5 Onafhankelijker

34. Deze afhankelijkheid maakt mij oncomfortabel
    Helemaal niet oncomfortabel 1 2 3 4 5 Zeer oncomfortabel

35. (Question 9) Zijn er nieuwe markeringen ontstaan in het landschap waaraan u hoogwater kunt herkennen?
    Nee ☐ Ja ☐

36. Zo ja, welke markeringen zijn dit? (open vraag + leg uit)

37. (Question 10) Heeft u nieuwe kennis om op basis van eigen ervaringen en markeringen in het landschap een inschatting te kunnen maken over hoogwater en overstromingsgevaar?
    Nee, deels, ja, dat kan ik niet zeggen

38. Hoe heeft u deze nieuwe kennis opgedaan? Open vraag

4. Afsluitende algemene vragen

39. (Question 30) Geslacht
    Man ☐ Vrouw ☐

40. (Question 31) Wat is uw geboortejaar?

41. Bent u werkzaam binnen het Grensmaas gebied?
    Nee ☐ Ja ☐

42. (Question 32) Wat is uw postcode + woonplaats?

43. (Question 33) Sinds welk jaar bent u woonachtig in het Grensmaas gebied?
    Open vraag

44. (Question 34) Komt minimaal een van mijn uw ouders uit het Grensmaas gebied?
    Nee ☐ vader☐ moeder☐ beiden☐

45. (Question 35) Voelt u zich verbonden tot het Grensmaas gebied? (omcirkel uw antwoord)
    Niet verbonden 1 2 3 4 5 Zeer verbonden

De vragenlijst is hiermee beëindigd, dank voor uw medewerking

46. Wilt u kans maken op de prijs?
    Nee ☐ Ja ☐

47. Vul dan hieronder uw emailadres in:

48. In het kader van het wetenschappelijke project Grensmaas, zouden wij u mogen benaderen voor een vervolgonderzoek via de bovenstaande opgegeven email?
    Nee ☐ Ja ☐

Appendix 2 – The flyer

GRENSMAAS VRAGENLIJST

MASTER THESIS – VINCE VAN 'T HOFF

Beste inwoner van het Grensmaasgebied,

Mijn naam is Vince van 't Hoff en ik ben een student aan de Universiteit van Wageningen. Ik ben bezig met mijn afstudeeronderzoek van de master Milieuwetenschappen. Dit doe ik als onderdeel van het wetenschappelijke project **Living Lab: Grensmaas**, waarin onderzoek wordt gedaan naar de effecten van het Grensmaas project. Mijn afstudeeronderzoek wordt begeleid door universitair hoofddocent Andries Richter. In mijn onderzoek kijk ik hoe het Grensmaas gebied wordt ervaren door inwoners. Ik ben er zeer enthousiast over.

Ik kijk specifiek naar de **veranderende risico beleving** omtrent hoogwater onder bewoners in het Grensmaas gebied en wat de invloed hiervan is. Ook kijk ik naar het **veranderende landschap en de kennis** die bewoners hierover hebben. Ik doe dit door middel van een **vragenlijst**. Deze vragenlijst zal zeer veel inzicht geven wat van belang kan zijn voor bewoners maar zeker ook voor **beleidsmakers**, om meer rekening te houden met **de behoeftes van de inwoners**.

Ik hoop dat u mij hierbij wilt helpen door middel van het invullen van de vragenlijst. Dit kost u ongeveer 15-20 minuten.

Alvast een fijne kerstviering toegewenst.

Bij voorbaat dank en met vriendelijke groet,

Vince van 't Hoff

WAGENINGEN
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Link naar de vragenlijst:

https://tinyurl.com/grensmaasproject

Met uw deelname kunt u een aantal prijzen winnen door middel van een loting

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VOOR VRAGEN EN OPMERKINGEN, MOEDIG IK U AAN CONTACT MET MIJ OP TE NEMEN

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Appendix 3 – Some extra historical context of the Grensmaas project

In appendix three, there is some more information on the background of the Grensmaas project. It discusses the flooding events of 1993 and 1995 in more detail which sped up developments. Furthermore, it discusses the new form of the project after severe protests which almost led to an ending of the project.

New developments of the Grensmaas project: The securitization frame

As discussed above, the disruptive flooding events of 1993 and 1995 provided a window of opportunity for the GM project to kickstart and it represented a changed flood management paradigm (Engel et al., 2014; Wesselink et al., 2013). The objective of flood prevention and securitization gained in prominence and became the most important way of framing. The flooding events and the subsequent framing of securitization enabled the GM project to become a national issue (Meulen, Rijnveld, Gerrits, Joziasse, & van Heijst, 2006; Roth et al., 2017). Measures that were already developed and that were waiting to be implemented, now found their way forward by the alternative way of framing. An emergency law was passed which gave green light to speed up several phases of the GM project without the need of certain regulations and licenses, leading to the construction of levees around cities directly in the GM surrounding to lower flood risk in 1/50 event (Warner, 2016; Wesselink et al., 2013).

However, when the emergency laws expired in 1997, some momentum was lost. To keep the momentum and interest going, the GM project was incorporated with river development plans in the bordering southern part of the Meuse, the Sandy Meuse, together called the 'Maaswerken' (Warner, 2016). In 1998, the planning phase of the project was finished (Rebel, 2018). However, in the phase between 1995 and 1998, some issues started to play out. Nature development through gravel extraction was still politically sensitive and there was limited trust between the partners of the project (Warner, 2013). Moreover, as the project took longer and longer to develop, driving up the costs, more gravel needed to be extracted predicting less nature in return, leading from an initial of 35 to 48 million tons in 1994 53 million tons in 1998 (Rijkswaterstaat, 1994; Warner, 2013). However, until 1998, the developments of the GM project was relatively in the public eye and saw enough publicly support (Warner, 2013).

Protests and a loss of trust

Starting in 1998, the project slowly disappeared from the public eye as stakeholder consultations and meetings take place behind closed doors. In 2001, when the final plan was presented, the GM project became national news once again. In the final plan, the gravel quota suddenly exceeded 70 million tons (Warner, 2013). Dissatisfaction of different stakeholder groups because of the novel gravel quota, communication and other issues, erupted into large protests, putting a halt to the original GM project. The protestors consisted mainly of the residents of the GM area, and several environmental organization who together formed grassroot organizations. The protestors were successful in that the original plan was abandoned by the province of Limburg as it feared a legitimacy crisis, not being able to represent the public anymore (Warner, 2013).

Views on the problems causing the protests diverge, as according to the Dutch government, the original project, was not approved because of financial and technical feasibility (Rebel, 2018). However, this is not the whole story according to others. Warner (2016) and Roth et al., (2017) state that between 1998-2001, limited information was provided by the initiators of the Grensmaas project and as the negotiations were behind closed-doors, there was very limited trust-building between the inhabitants and the local- and national government and the GC (Warner, 2013). Moreover, there was limited trust between the partners involved in the GM project. In addition, Roth et al., (2017) and Warner (2016) argue that the top-down approach of public institutions, Natuurmonumenten and regional powerful gravel companies

created friction with actors in the area. As Limburg still sees itself somewhat independent from the Netherlands and retains a strong regional character, the central decision-making of the national authorities was not trusted nor appreciated and felt as a 'colonial' interference (Wesselink et al., 2013). Moreover, gravel extraction and the gravel companies were also seen as problematic. Much was for the 'national need' and would be transported out of Limburg while the nuisance of extraction would be felt by the Limburgers. Gravel extraction also created friction because it did not feel as a sufficient replacement after the closing of the mines in Limburg as it provides less employment. Thirdly, inhabitants felt restricted in their choice as there were restrictions imposed on building on flood plains because of flood protection while they were not there before. It was hard to sell the 'Room for the river' approach when there used to be no restrictions: '*Why not just build a dike and let us use the land behind it*?' an inhabitant mentioned (Wesselink et al., 2013). Finally, locals were not convinced about the nature development in the area as this felt imposed on them by 'outsiders' (Wesselink et al., 2013).

A new project

The province of Limburg felt threatened that their political base would lose trust in them if the project continued as planned, hence they started to develop an alternative plan through actively consulting citizens and other organizations (Warner, 2013, 2016). These new dialogues were structurally continued in a united citizen platform called Bewoners Overleg Maaswerken (BOM) which was more inclusive and participatory, focusing on trust and relation management (Warner, 2013). However, in the end, participation in the actual decision-making process by local groups was low and decisions were still made behind closed doors (Roth et al., 2017). Therefore, citizens seem not to have increased their influence in the decision-making process and it seemed that, no matter what, the project were to be continued in some form. On the other hand, it can be noted that the citizens had some degree of power as the project was politically sensitive to the public opinion, meaning that there was some form of indirect influence from the inhabitants on the issues at hand (Meulen et al., 2006). After all, the inhabitants were the instigators of the abandonment of the old project. Continuing with the project, in 2003, the environmental effect report (m.e.r.) was concluded and in 2005, the Grensmaas Consortium could start their project.

Appendix 4 – Graphs from results

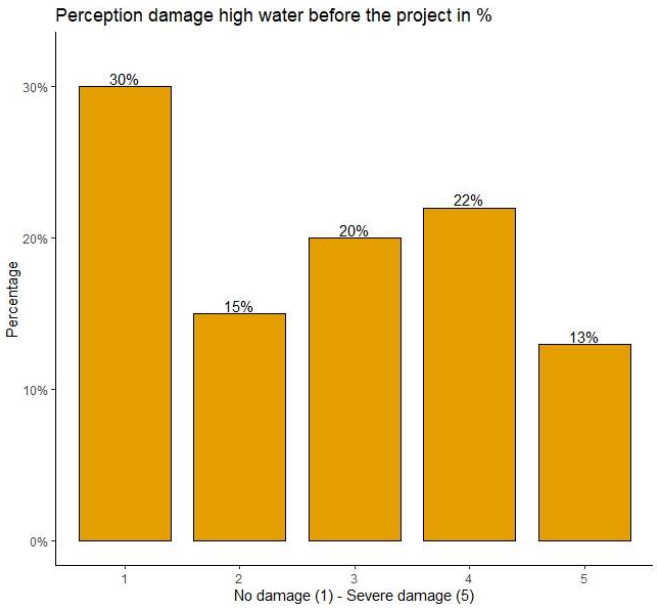

Figure 24: Graph of the perception of personal damage as a result of the Grensmaas river, ranging from no damage to severe damage 1-5.

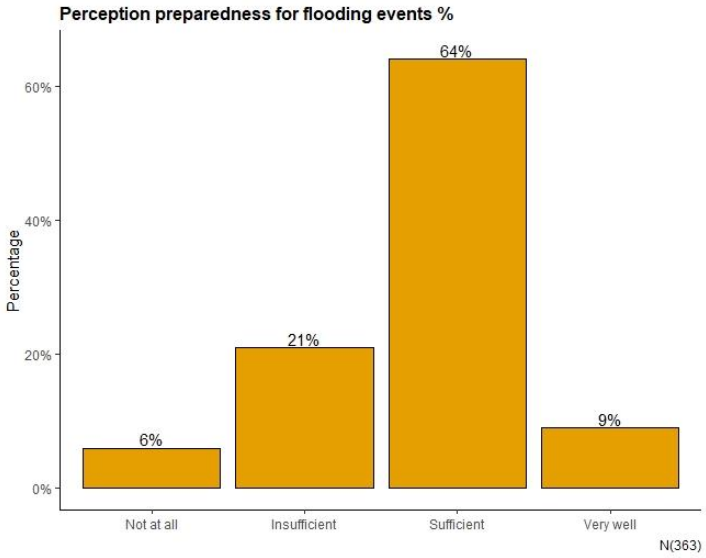

Figure 25: Perception of preparedness for flooding events

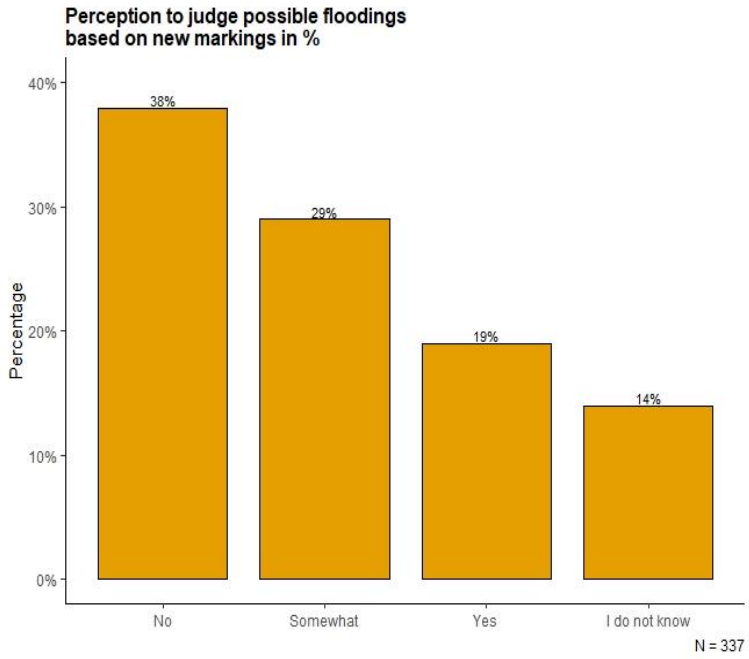

Figure 26: Adaptive capacity after the project

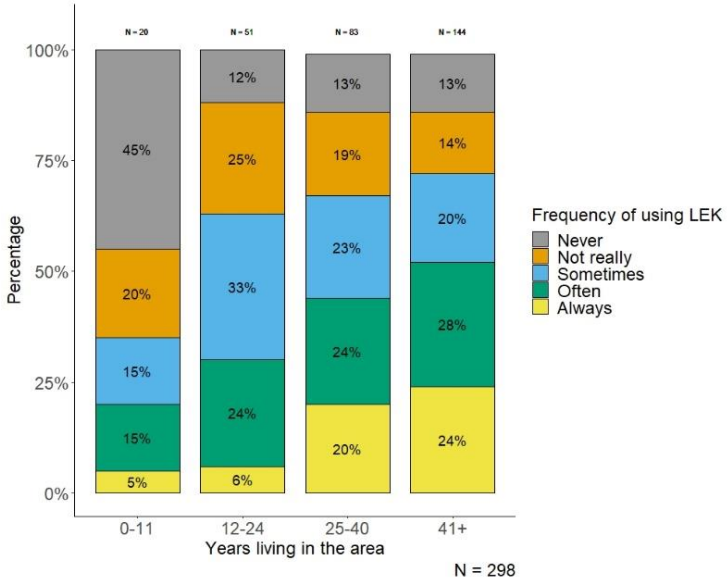

Figure 27: LEK grouped by living in the area

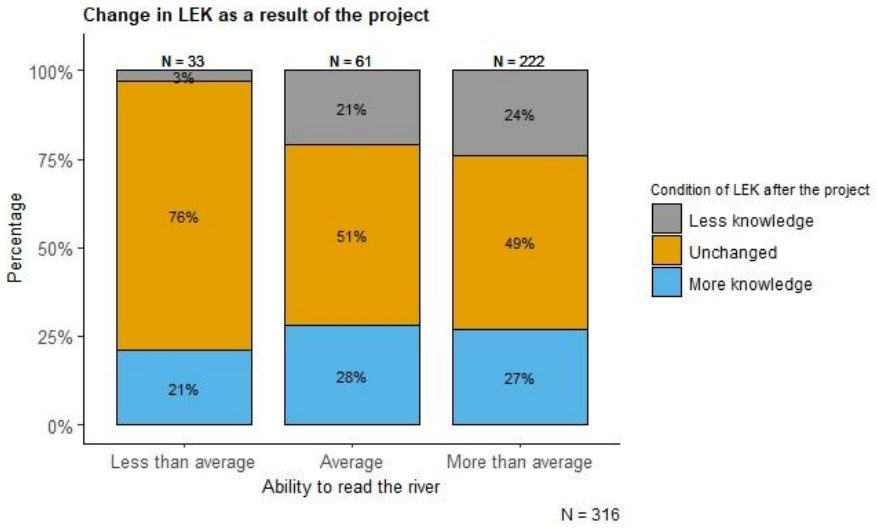

Figure 28: Adaptive capacity of inhabitants

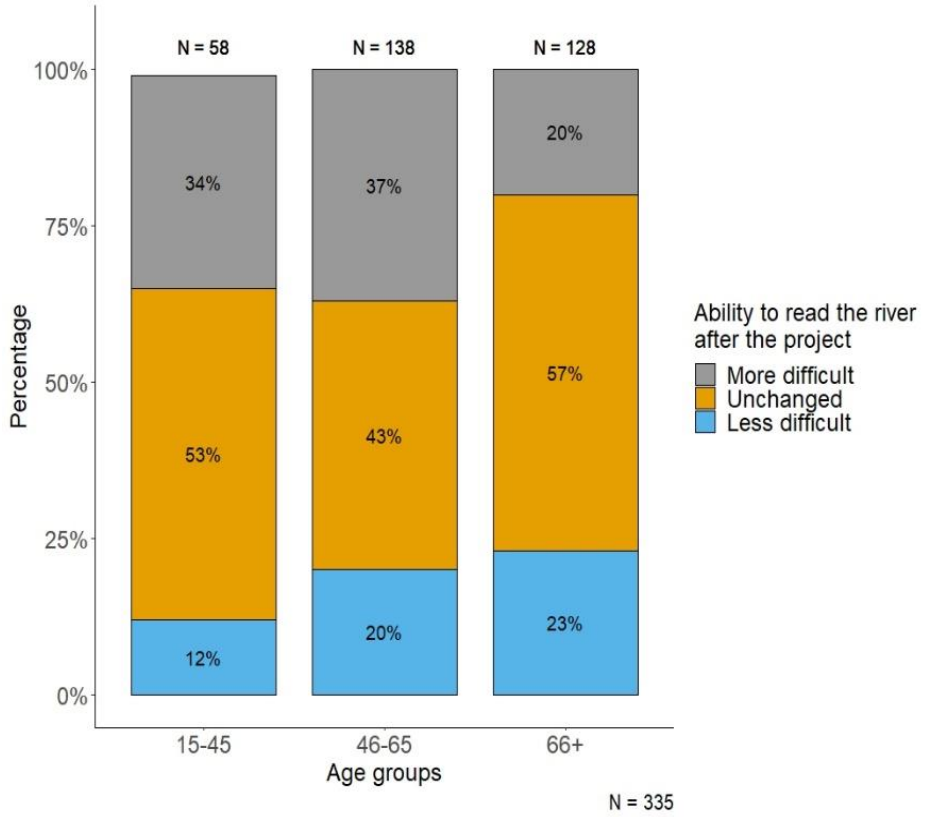

Figure 29: Adaptive capacity per age group

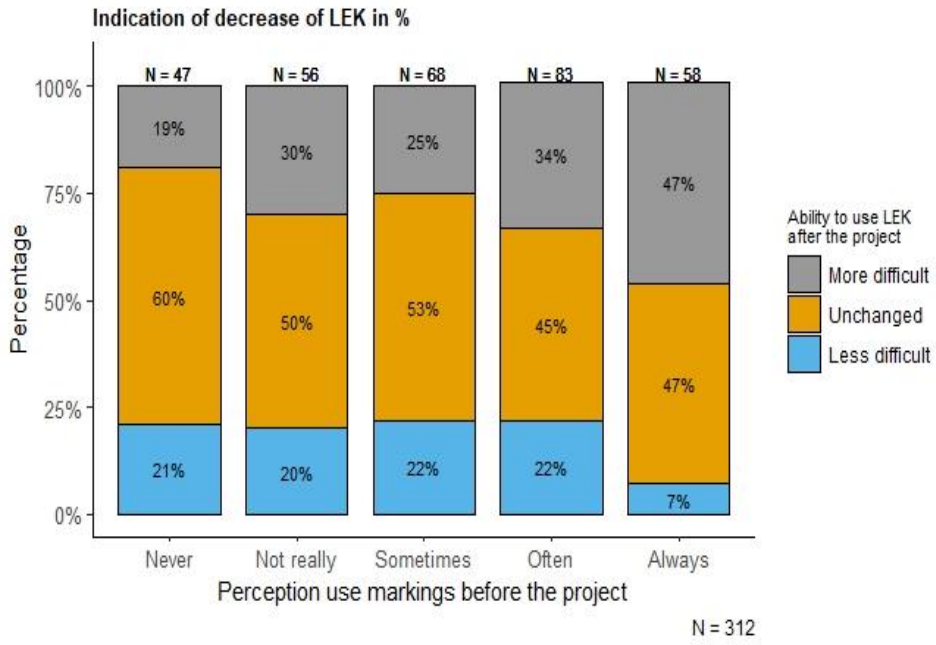

Figure 30: The adaptive capacity of LEK

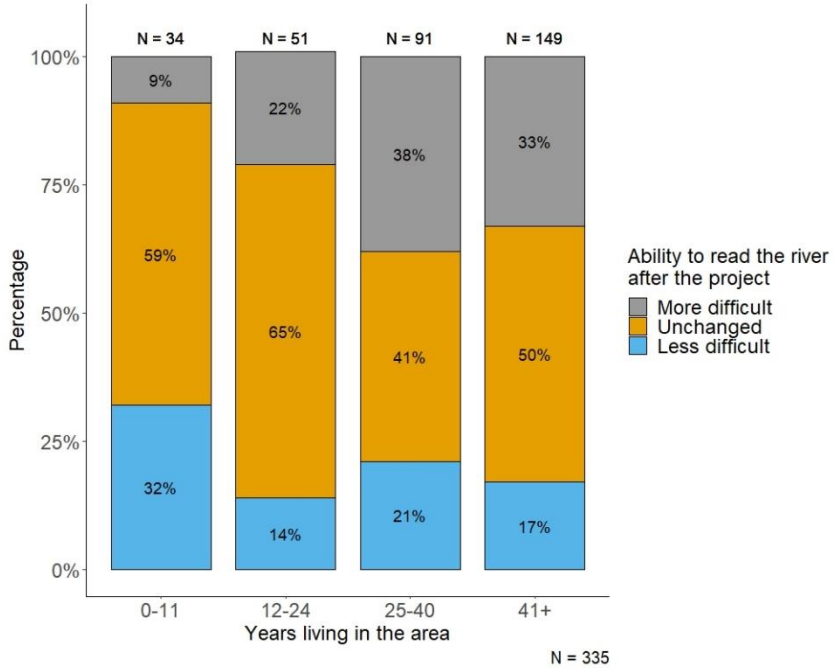

Figure 31: Adaptive capacity grouped by years living in the area

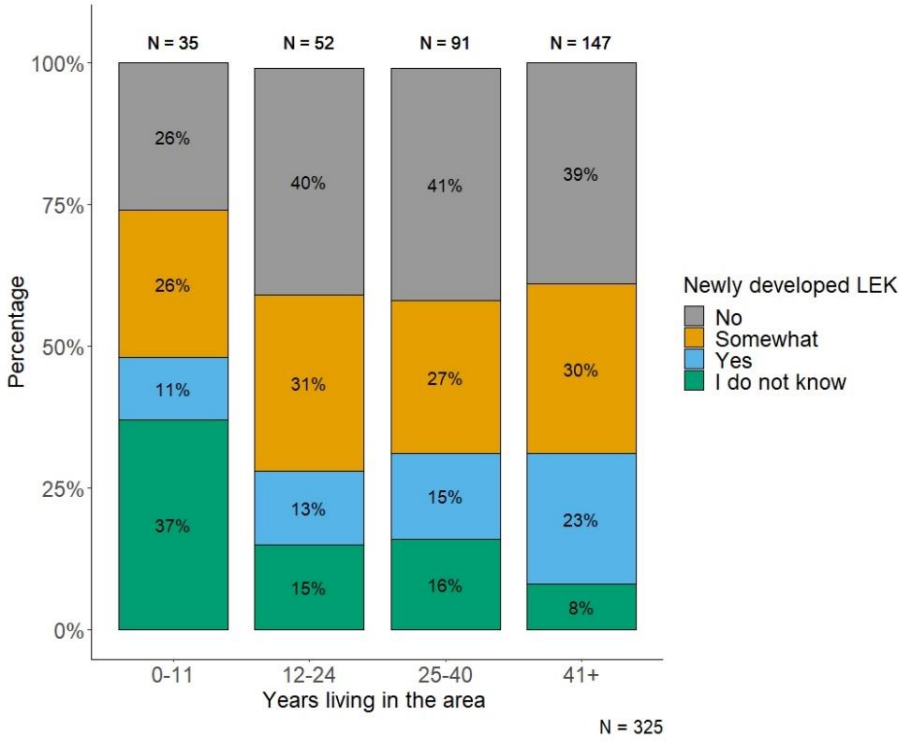

Figure 32: Newly developed LEK by age group

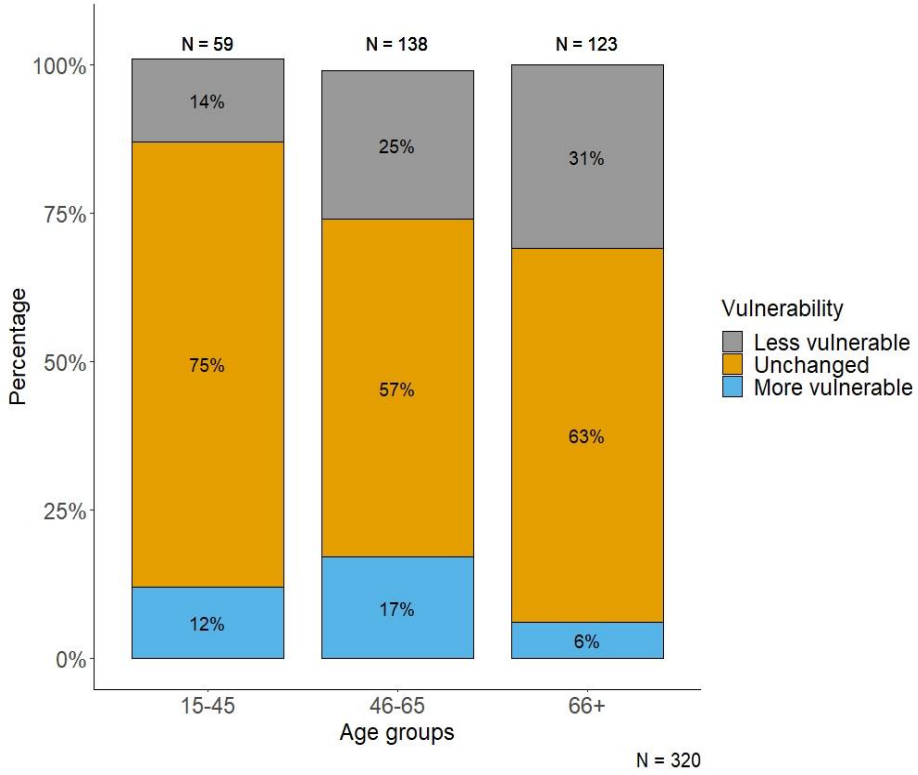

Figure 33: Vulnerability per age group

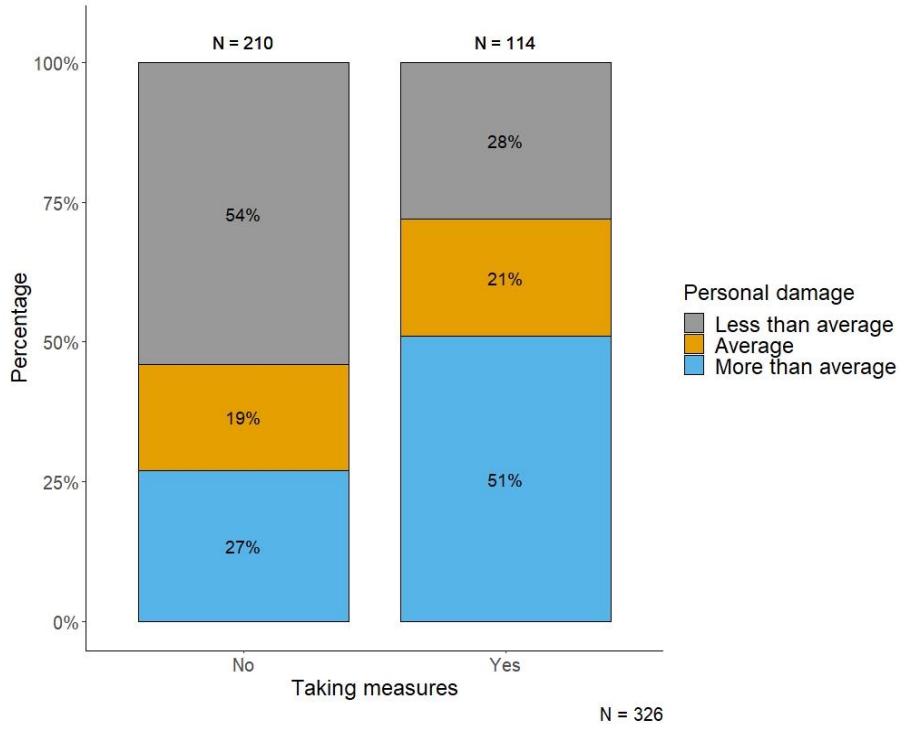

Figure 34: Measures and personal damage

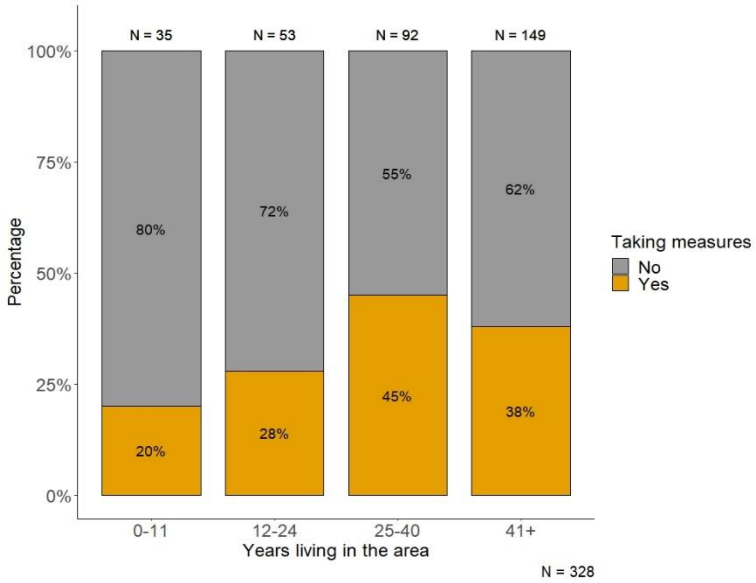

Figure 35: Measure taking by years living in the area

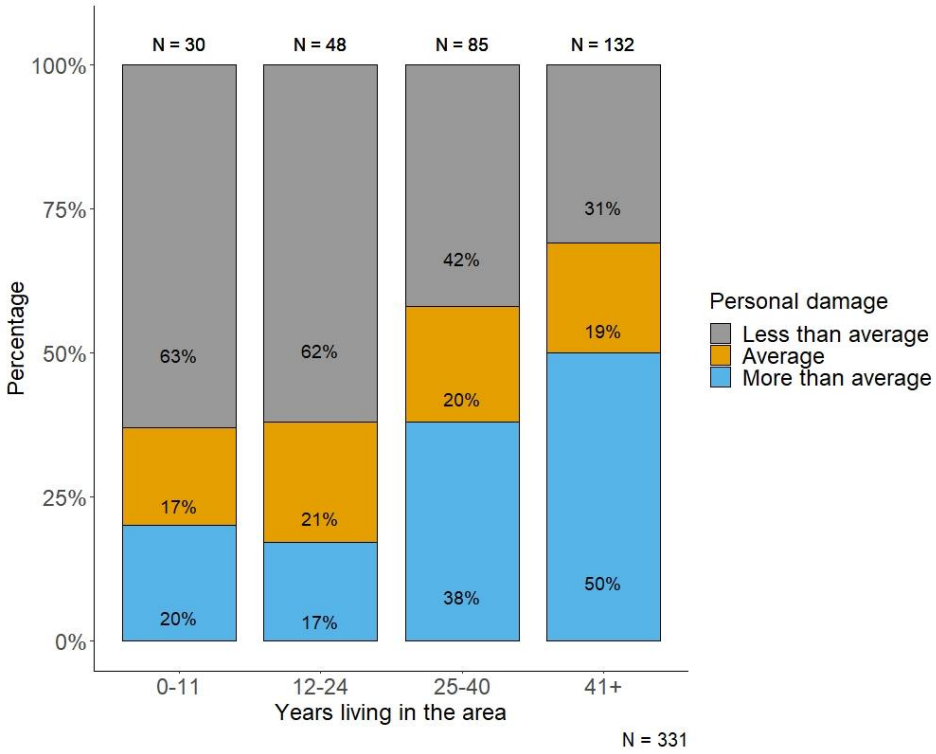

Figure 36: Personal damage by years living in the area

GRENS

MAAS