Green roof adoption in the municipality of Groningen: barriers and opportunities

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Abstract

The pressure on the urban environment is rising as a consequence of urbanization and climate change. Flooding and heat problems are becoming more and more predominant and a partial solution to these problems is wide scale green roof adoption. This research aims to identify the main barriers and opportunities for green roof adoption in the municipality of Groningen, with a focus on homeowners and urban planners.

This research employs a mixed method to achieve this goal by using a survey among homeowners and in depth interviews with urban planners and a green roof owner. The results of the analyses indicate that the main barriers include a lack of knowledge on green roofs among homeowners, a discrepancy in perceived responsibility for local water management between homeowners and urban planners, and a lack of shared urgency and reactive approach

within the municipality. The proposed opportunities for increasing green roof adoption are community-based projects and increased proactive promotion of green roofs by the municipality. Furthermore, a linear regression analysis indicates that felt responsibility for local water management is significantly associated with gender, but not associated with other included sociodemographic factors.

Key words:

Green roofs - Homeowners - Urban Planners - Municipality - Adaptation Policy – Groningen - Participation - Climate Change

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1. Introduction

As a result of the increasing effects of climate change and an increasing amount of urbanization, the pressure on the built environment is rising. In urbanized areas of the Netherlands water nuisance is the predominant cause of this pressure and the problem is only expected to grow bigger during the 21st century (Hunt & Watkiss, 2011). Long periods of drought and heat, accompanied with periods of increased precipitation causing flooding, can impact the liveability of urban areas significantly. It is estimated that water shortages and surpluses caused by climate change will cause 71 billion euros in damage to the built environment by 2050 if no changes to current policies are made (Deltares, 2012). That could be a low estimate seeing as recent floodings have caused over 700 million euros in damage to the south of the Netherlands in June 2016 alone (NKWK, 2018). Therefore, adaptation of cities in preparation to further climate change is necessary (Hunt & Watkiss, 2011). Open bodies of water and extra green space are often mentioned as a solution by urban planners (Runhaar et al., 2012).

Implementing these proposed solutions can be a challenging task. This is mainly due to the lack of freely available space and conflicts of interest between different stakeholders regarding land use in cities (Hunt & Watkiss, 2011). The adoption of green roofs is a form of climate change adaptation that can help reduce the negative effects that arise with climate change, while only using previously unutilized roof surface (Mentens et al., 2006). Therefore, green roofs increase the amount of green space, a solution proposed by urban planners, while avoiding the difficulty of finding available urban space that usually accompanies this solution. Transforming regular roofs into green roofs will help relieve the effects of climate change by improving the water runoff, stormwater retention capacities, air quality and urban heat management of a city (Berndtsson, 2008). Moreover, green roofs offer multiple advantages over regular roofs, such as improved noise isolation, aesthetics and a natural home for flora and fauna to prosper (Berndtsson, 2008).

Groningen was one of the first cities in the Netherlands to try and achieve wide scale green roofing by formulating a subsidy policy for green roofs in 2008, which is still active today (Gemeente Groningen, 2019). While this policy has increased the amount of green roofs in Groningen, it has not made a large impact on the city yet. From 2009 to 2016, 20000 m² of green roof has been realized, which is only a third of a football field per year (Gemeente Groningen, 2016). On top of that, 7500 of that 20000 m² of realized green roof area was due

to only one building, at the Zernike Campus (Gemeente Groningen, 2016). This campus is located in the north of Groningen and not in a highly urbanized area, where the negative effects of climate change are expected to grow the largest (Hunt & Watkiss, 2011). Looking at these reports, one begins to wonder what is hindering the adoption of green roofing in Groningen, as green roof adoption seems advantageous in most respects.

A reason for this hindrance could be an ongoing shift in the responsibility for local water management from institutions to individuals (Bergsma et al., 2012). This shift has resulted in a lack of clearly defined accountability for local water management, due to an overlap of responsibility between individuals and the municipality (Bergsma et al., 2012). Furthermore, socio-demographic factors like gender and level of education are known to influence behaviour in response to and knowledge of climate change (Kollmuss & Agyeman, 2010). It is interesting to find out to what extent homeowners themselves feel responsible for local water management and which socio-demographic factors play a part in the adoption of green roofs.

Due to the multiple benefits of green roofs for society, it socially advantageous to know which barriers exist and to what extent they play a role in the adoption of green roofs. Only when these barriers are known, suitable solutions can be found. As of now, no research has focussed on socio-demographic factors and green roof adoption or focused specifically on homeowners in the Netherlands. Therefore, this research aims to fill this gap in scientific literature. The municipality of Groningen has a longstanding green roof subsidy and therefore makes an interesting case study.

1.1 Research problem

The urban environment is in need of adaptation to deal with the expected negative effects of future climate change. Increasing the amount of green space is often mentioned as a solution by urban planners, but this is hard to execute due to the lack of freely available space in most cities (Runhaar et al., 2012). The adoption of green roofs is a method that only makes use of previously unused roof surface and was therefore introduced as a partial solution to future climate change effects by the municipality of Groningen in 2008 (Berndtsson, 2008; Gemeente Groningen, 2016). Data indicates that despite the introduced subsidy policy, the adoption of green roofs has not yet been widespread in Groningen. Due to the multiple

societal and environmental benefits of large scale green roofing, it is interesting to find out where this process is hindered and how this process could be improved in Groningen.

1.2 Research goal

The goal of this research is to identify the main barriers and opportunities for green roof adoption among homeowners in the municipality of Groningen. The research aims to find a conclusive argument as to why green roofing is not being implemented on as large a scale as it can be. Furthermore, the research aims to propose (partial) solutions, in the form of policy, to overcome the barriers found in this analysis. Both the role of homeowners and urban planners from the municipality will be analysed and evaluated.

The main research question that aims to achieve the goals of this research is:

What are the main barriers and opportunities for green roof adoption among homeowners in the municipality of Groningen?

The secondary questions aiming to help answer the main research question are as following:

1. *To what extent do homeowners and urban planners in Groningen have knowledge on green roofs?*
2. *To what extent do homeowners and urban planners in Groningen feel responsible for local urban water management?*
3. *To what extent do socio-demographic factors of homeowners in Groningen influence green roof adoption?*
4. *How could the adoption of green roofs be stimulated in the municipality of Groningen?*

1.3 Thesis structure

In total this thesis consists of six sections. In this first section the relevance, research questions and the thesis structure have been presented. In section two an overview of the literature regarding green roof adoption will be discussed, as well as the conceptual model and the hypotheses. In section three the methodology, data collection and data analysis will be explained. In section four the results are presented and discussed using the four secondary questions as a framework. In section five conclusions are drawn and the main research

question is answered. Lastly, in section six the limitations of this research are discussed and suggestions for further research are made.

2. Theoretical Framework

2.1 Background information

For a description of green roofs, associated costs, technical requirements and the subsidy policy of green roofs in the municipality of Groningen, see Appendix A.

2.2 Roles and responsibilities

Most national policies on climate change in the Netherlands have focussed on mitigation (Bruin et al, 2009). However, various reports have concluded that climate change will take place and its effects will be noticeable, despite all mitigation efforts (KNMI, 2006). Therefore, adaptation to climate change is necessary. The government of the Netherlands has explained the responsibilities for adaptation to climate change in the National Climate Adaptation Strategy (IenM, 2018). The report states everybody is responsible for adaptation to climate change and encourages firms, institutions, waters boards, citizens, provinces and municipalities to work together. Though, as the effects of climate change are experienced locally and differ from location to location, the report states that adaptation to climate change is a process most suited by locally-based approaches (IenM, 2018). As municipalities are most familiar with local geographical characteristics, infrastructure and social conditions, they are encouraged to act on climate change adaptation, although no definitive responsibility is given by the government. This is in line with research that found municipalities are increasingly more often recognized by governments as the best institution to deal with climate change adaptation (Measham et al, 2011). Besides the role of municipalities, adaptation science has also been promoting community-based adaptation (Ebi & Semenza, 2008). This is a participatory form of adaptation to climate change, organised by local citizens based on normative preferences (Ebi & Semenza, 2008). A similar form of citizen participation is also encouraged in the National Climate Adaptation Strategy (IenM, 2018).

Recapitalitory, while everybody plays a part in the adaptation to climate change, municipalities and citizens are specifically addressed by the government and scientific

literature as leading actors in the adaptation to climate change (IenM, 2018; Measham et al, 2011; Ebi & Semenza, 2008).

As green roofs can play a significant role in local water management, it is important to state who is responsible for local water management as well (Berndtsson, 2008; Mentens et al, 2006). The responsibility for local water management is distributed among two actors in the Netherlands; municipalities and property owners (e.g. citizens and firms). Municipalities are responsible for the transportation of waste and runoff water from individuals to the water treatment plant. Property owners are in theory responsible for sufficient water storage and proper drainage on their land, although in practice municipalities have been held accountable for this responsibility as well (Bergsma et al, 2011). In the last decade, this accountability is shifting to the property owner, as the government is repeatedly emphasizing the responsibility of citizens for water management on their property in the most recent National Water Plans (VenW, 2009; IenM, 2015). Nevertheless, the National Water Plan of 2009 introduced a 'duty of care' for municipalities, shifting the drainage responsibility back to the municipality if individuals are not able to enact on their responsibility (VenW, 2009). Despite this duty of care, research expects municipalities will be held less accountable for the local water management of individuals by the government, as increased rainfall becomes less incidental and more structural as a result of climate change (Bergsma et al., 2012).

Concludingly, the primary responsible entity for local water management is the property owner, but municipalities are able to be held responsible as well for now.

2.3 Benefits

Firstly, green roofs have a high water storing capacity and can reduce the runoff peak of rainfall significantly (Mentens et al, 2006). This reduction is due to the absorption of water by the vegetation, the reduction of the total runoff by retaining a portion of the precipitation and a slowed release of the captured water in the substrate (Berndtsson, 2008). Moreover, the plants on a green roof are known to take and filter polluting particulates, absorb carbon dioxide, emit oxygen and increase the biodiversity in the city. This reduces the amount of greenhouse gases in a city (Gedge and Kadas, 2005; Yang et al., 2008). Furthermore, green roofs isolate the building beneath it, mostly during the summer. This means buildings stay significantly cooler and less energy is needed in larger buildings with a climate control system (Fang, 2008). The roofs themselves heat up less as well, up to 50 percent (Fang, 2008). As a

result, the roofs emit significantly less radiant heat at high outside temperatures, reducing the urban heat island effect of a city (Fang, 2008). This creates a more liveable space, especially in the Netherlands where most of the homes do not have air conditioning. On top of that, green roofs are noise muffling, both for inside and outside noise. Outside noises get reflected less on rooftops which reduces the overall noise level of a city. Indoors there will also be less outside noise due to better insulation (Van Renterghem & Booteldoren, 2009). While green roofs require more maintenance and upkeep, they last up to twice as long as regular roofs. This means a roof needs to be replaced after approximately 40 years, instead of only 20 (Oberndorfer et al., 2007). Lastly, green roofs have been shown to have positive effects on the social, mental and physical well-being of inhabitants by increasing the amount of green space in the city (Abraham et al., 2010; Gedge and Kadas, 2005).

2.4 Barriers

Firstly, research indicates that a barrier to green roof adoption might be the monetary costs involved (Arcadis, 2008). A case study of the private and public costs and benefits of green roofing in Rotterdam found that the costs outweighed the benefits for the private sector, but not for the public sector (Arcadis, 2008). As a direct result of this study Rotterdam formulated a policy to start granting subsidies for green roofs in 2008 (Claus & Rousseau, 2012). Groningen followed in the same year, providing subsidies of up to 30 euro per m², bridging a large part of the gap in benefits and costs as can be seen in Appendix A (Gemeente Groningen, 2019). When factoring in government subsidies, green roofs were found to be both privately and socially financially desirable (Claus & Rousseau, 2012). However, in comparison to solar panels, where the financial gain can be directly observed, the benefits of green roofs are more difficult to quantify for homeowners. This may lead to an underestimation of the financial benefit and therefore monetary costs might remain a barrier (Claus & Rousseau, 2012). Furthermore, while green roofs are now profitable in the long-run, they still require a relatively large investment upfront. This could be a barrier for homeowners with low savings or for who have the intention to move relatively soon (Townshend & Duggie, 2007). For project developers, these long term savings would not have time to accrue if they intent to sell their property immediately after completion (Townshend & Duggie, 2007). Therefore, they would have little reason to supply the additional capital expense

required for a green roof, besides a hard to quantify increased property value (Townshend & Duggie, 2007).

Secondly, the adaptation to green roofing might be slowed due to a lack of willingness by urban planners in the Netherlands to change the urban environment solely for the sake of climate change. There seems to be a clear gap between the awareness and importance of proactive adaptation between climate scientists and urban planners (Runhaar et al., 2012). This does not mean urban planners do not know any spatial measures to act on the difficulties that come with climate change. For example, more public green space and open bodies of water are often mentioned as solutions (Runhaar et al., 2012). However, in practice these actions are usually not undertaken to reduce the effects of climate change, but for health reasons and spatial qualities in the urban landscape (Runhaar et al., 2012). Climate change risks are just another premise for planners to gather funds and investments for their projects instead of the main reason to change the urban landscape in preparation for further climate change (Runhaar et al., 2012).

Thirdly, another major barrier to the implementation of green roofs has been indicated to be a lack of promotional activities and incentives, leading to the lack of knowledge and awareness of green roofs and the associated benefits in the public and private sector (Zhanga et al., 2012). Germany has been using a combination of promotional activities, direct and indirect incentives to overcome this barrier and seems to be stimulating green roof construction very successfully since 1980. Municipalities in Germany have put direct and indirect private financial incentives in place in the form of a subsidy policy and tax breaks (Ngan, 2004). More than half of the municipalities tax private householders' waste and stormwater runoff separately. This means that adopting a green roof and thereby decreasing the total stormwater runoff, decreases a four person household tax burden by seventeen percent on average (Hennebrüder 2003 cited by Ngan 2004, p. 21). This means that the financial desirability of green roofs is not only greater, but also more noticeable in Germany than in Groningen, where no such tax break is in place. Regarding promotional activities, the German Landscape Construction and Development Research Society has published a detailed green roof guideline in cooperation with municipalities. This book covers construction, upkeep, design and detailed chapters on all the requirements and benefits of green roofs (Ngan, 2004). Lastly, some cities in Germany, for example Essen, have put even stricter regulations in place in the form of a ruling that all new buildings and restorations in the cities'

center must have green roofs installed. These incentives and promotions provide more widespread knowledge and awareness and are proving to be very successful. In 2003 fourteen percent of roofs were (partly) green roofs and nowadays it is estimated Germany has between 120 and 150 million square meter of green roofs (Herman, 2003; EFB, 2015). No such promotional activities have taken place in the municipality of Groningen, despite the active subsidy policy. For example, on the green roof policy page of the municipalities' website, only three of the many benefits are stated. Besides that, they are located all the way on the bottom of the page (Gemeente Groningen, 2019).

Fourthly, studies have indicated that women and higher-educated people have more knowledge of climate change adaptation and are more likely to act on this knowledge (Kollmuss & Agyeman, 2010). These results might indicate a need for targeting certain subgroups for promotional activities that increase knowledge and awareness in municipalities (Ebi & Semenza, 2008). Currently most municipalities have been known to regard their population as a homogenous group in regards to climate change (Measham et al, 2011). Furthermore, a lack of feeling responsible ("not my job") and a lack of practicality (no information, money, time or encouragement) have been shown to negatively influence pro-environmental behaviour by citizens (Kollmuss & Agyeman, 2010).

Lastly, Bergsma et al. (2012) concluded it is crucial for governments to create a transparent division of tasks, roles and responsibilities for authorities, stakeholders and consumers to effectively deal with the effects of climate change. As most policies in the Netherlands have focussed on climate change mitigation and no clear set of responsibilities have been given in regards to climate change adaptation, municipalities need to show leadership (IenM, 2018; Measham et al, 2011). Though, research indicates that municipalities are often constrained by the amount of resources available to them (Pini et al, 2007). A lack of resources has been linked to a reactive approach in regards to the management of climate change adaptation (Brackertz & Kenley, 2002). Research therefore questions whether municipalities can handle additional tasks in the form of proactive climate change adaptation, next to their existing responsibilities (Measham et al, 2011). A lack of clearly defined responsibility by the government and potential unawareness by homeowners of the ongoing shift in responsibility of local water management, might also lead to suboptimal climate change adaptation (Bergsma et al, 2012).

2.5 Hypotheses

As many factors were necessary in the calculations to conclude a private benefit of green roofing (Arcadis, 2008; Claus & Rousseau, 2012), it is not expected that local homeowners are aware of all these small, albeit cumulatively big, benefits. Lack of knowledge and awareness was also indicated by Zhanga et al. (2012) to be a barrier to green roof implementation. However, urban planners are expected to have knowledge on green roofing and these associated benefits (Runhaar et al, 2012). Therefore, the hypothesis for the first secondary question is that homeowners do not have sufficient knowledge on green roofs, whilst urban planners do.

Due to a lack of clearly defined responsibility and potential unawareness by homeowners of the ongoing shift in responsibility, the hypothesis for the second secondary question is that homeowners do not feel responsible for local urban water management (Bergsma et al., 2012). Furthermore, due to the shift in responsibility to homeowners and the low priority of climate change adaptation (Runhaar et al., 2012), it is hypothesized that urban planners do not feel very responsible either.

Based on the previously stated research by Kollmuss and Agyeman (2010), the hypothesis for the third secondary question is that being a female and a higher level of education and responsibility for local water management has a significant positive effect on green roof adoption.

Lastly, the hypothesis for the fourth secondary question is based on research by Zhanga et al. (2012) and the current successful policies in Germany (Ngan, 2004). It is hypothesized that increased promotional activities, to increase knowledge and awareness, and indirect financial incentives can stimulate green roof adoption in Groningen.

In conclusion, the hypothesis for the main research question is: green roof adoption is hindered by monetary considerations, lack of knowledge of green roofs and the associated benefits by homeowners, and a low rating of responsibility for local climate change adaptation by both parties. This process can be improved by increased promotional activities and additional financial incentives.

2.6 Conceptual model

This conceptual model (figure 1) shows a positive relation (+) between current trends, their effects and the pressure on the built environment (Hunt & Watkiss, 2011; Runhaar et al.,

2012). This means whenever climate change and urbanization effects are growing, so do their effects resulting in pressure on the built environment. To counteract this pressure, changes to the urban environment need to be made (Hunt & Watkiss, 2011). Green roofs can be an effective solution and are proposed by the municipality of Groningen to deal with certain effects of climate change as discussed in the theoretical framework (Berndtsson, 2008; Gemeente Groningen, 2018). The adaptation to green roofs will be reviewed for two parties in this thesis; homeowners and urban planners. Both these parties are encountering barriers, of which financial, a lack of knowledge and socio-demographic are known barriers (Arcadis, 2008; Zhanga et al, 2012; Kollmuss & Agyeman, 2010). The aim of this research is to test the known barriers and discover yet unknown barriers in the municipality of Groningen. By finding these barriers, suitable solutions can be proposed. The solutions have a positive relationship (+) with the green roof adoption in Groningen, meaning more and better solutions correlate to better policy adoption. The more green roofing gets successfully implemented, the less the built environment is pressured, showcased by the negative relationship (-) (Berndtsson, 2008).

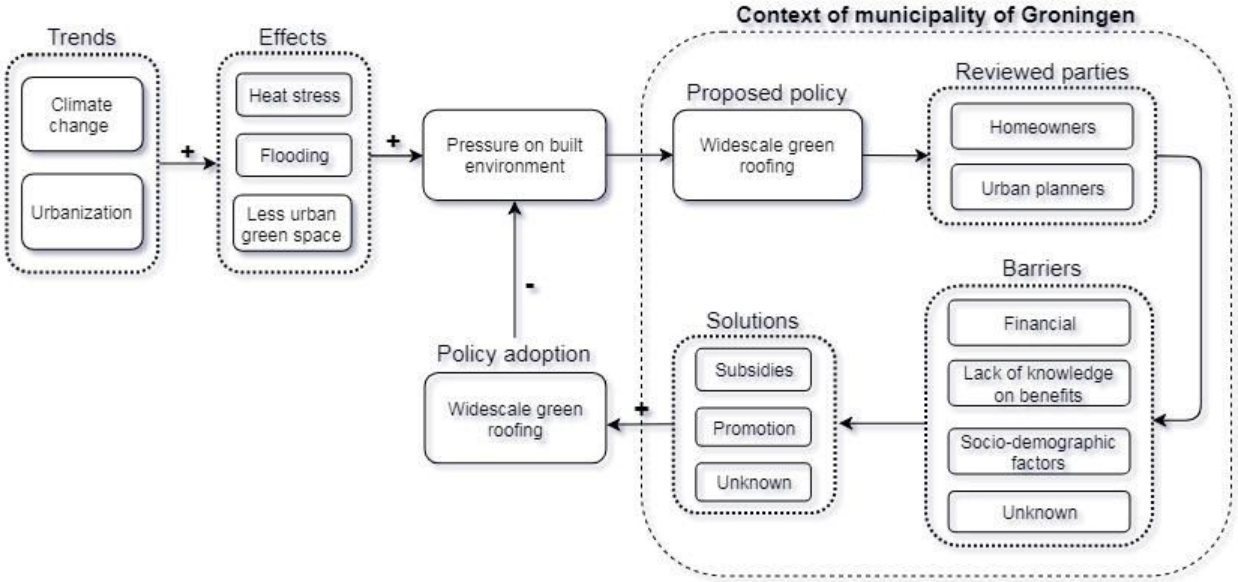


Figure 1. Conceptual model on green roof adoption in the municipality of Groningen.

3. Methodology

3.1 Research type

Considering the aim of this research is to reflect on green roof adoption by both homeowners and urban planners, both quantitative and qualitative research has been used resulting in a mixed method approach (Clifford et al., 2010).

Quantitative data is more suited for discovering facts about social phenomena and assumes a fixed and measurable reality (Clifford et al., 2010). Qualitative data is more concerned with understanding the human behaviour from the informant (interviewee's) perspective and assumes a dynamic negotiated reality (Clifford et al., 2010). Therefore, quantitative research has been used for the analysis of the survey results from homeowners and qualitative research has been used to analyze the professional opinions of the key informants, in this case planning experts. Also one interview has been conducted with a green roof owner in order to review the green roof adoption process from the consumer side more indepthly.

For an overview of the survey and prepared interview questions, see Appendix B.

3.2 Ethics

The research, the collection of data and the usage of data was conducted in an ethical manner, as beneficence and respect have been held in high regard (Clifford et al., 2010). The survey has asked for personal information like age, level of education and the district that the surveyee lives in**.** This information has been used to see if there are differences between people with different backgrounds and also to disclose any sample biases in the data. This is confidential information and has only been used for the purpose of this specific research paper. The data has nor will be shared and the anonymity of the respondents is guaranteed.

3.3 Collection of data

Survey

The data collection for the survey was done in different parts of Groningen to minimize any sampling biases. A location where the respondents feel at ease and familiar to

their surroundings is beneficial to the honesty in which the survey will be answered (Clifford et al., 2010). Therefore, shopping centres have been chosen as location. Usually people do grocery shopping close to home and thus, are familiar with the environment. The following shopping centres have been selected throughout the municipality: Boumaboulevard, Helperplein, Paddepoel, Selwerd, Overwinningsplein, Beijum, Vechtstraat, Hoogkerk and the city centre. Every tenth adult was asked to participate to ensure a random selection. Renters were excluded from the survey as they are not able to make decisions on the type of roof on their homes.

Because the survey was conducted during the day on weekdays, a solution had to be found for a potential sampling bias in only part time workers and jobless people participating in the survey. Week 43 of 2018 was an autumn break for a lot of companies and therefore also full time workers were present on weekdays at the shopping centres. For this reason, the survey was carried out in week 43 of 2018 only. Because of this, no sample biases were expected in the survey data by collecting the data around supermarkets during the day. In the end 83 responses were gathered of which 78 were useable. The distribution of the respondents, based on the municipalities' districts by the Central Bureau of Statistics (2018),

can be seen in Figure 2.

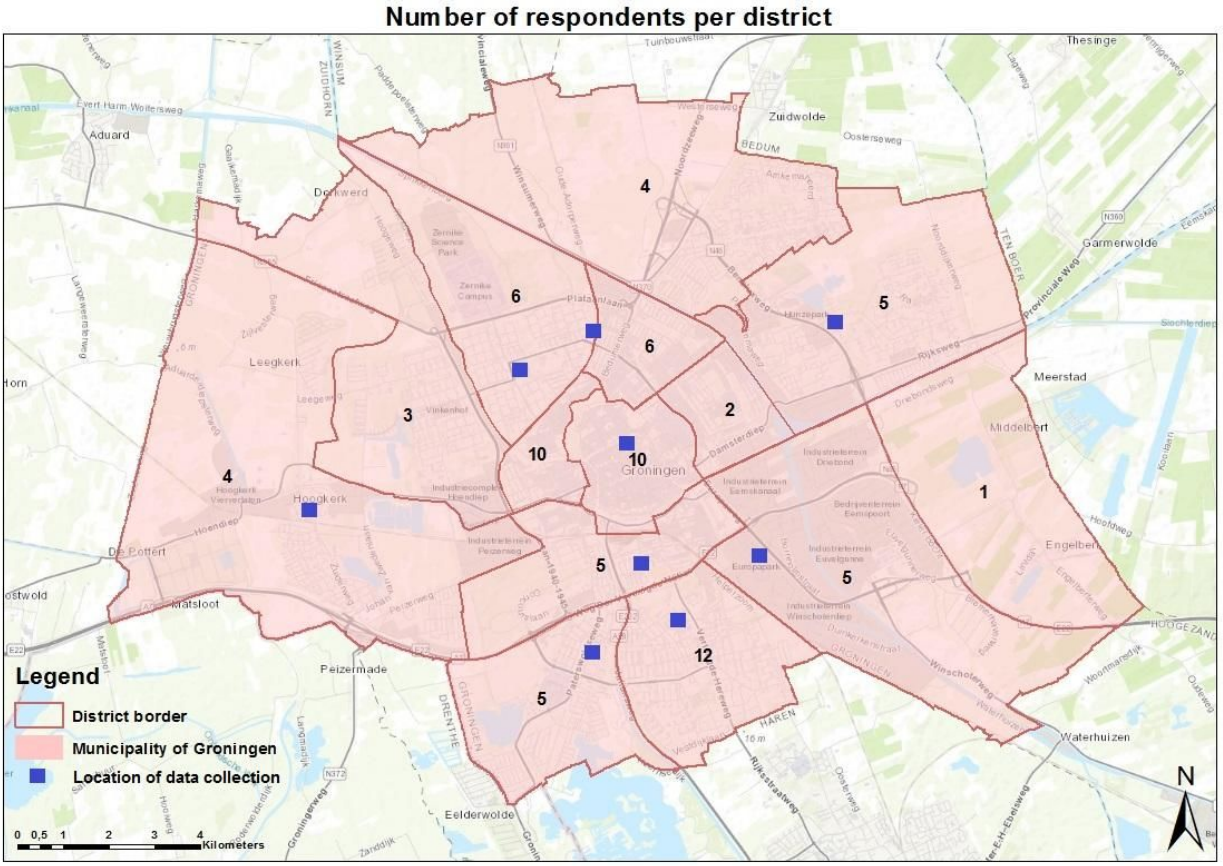


Figure 2. Number of respondents per district.

Interviews

Three experts and one green roof owner were interviewed as presented in Table 1. Dries Jansma is a water and drainage systems policy developer at the municipality of Groningen. Tamarka Ekamper is a sustainable designer and leader of the sustainable living environment programme at the municipality of Groningen. Allard Roest is a researcher on climate change adaptation and urban green infrastructure with a focus on citizen participation at the Hanze University. The experts were selected using their job description published online and by following the snowball method. When a person declined the invitation for an interview they were asked to name a candidate with similar professional activities, who was then asked to participate (Myers & Newman, 2007). This method proved successful as two out of the three professionals were found this way. The green roof owner was selected after he participated in the survey and was willing to share his experience on adopting a green roof.

The interviews have taken place at the location of choice of the interviewee, so the interviewee feels at ease and familiar with the surroundings (Myers & Newman, 2007). For two interviewees this has been their office, for one it was at the University of Groningen where he used to work and for the green roof owner this was his home. The interviewees have been asked for permission to record the interview and all agreed. Furthermore, all experts agreed for their name to be used in the interview. The green roof owner wanted to stay anonymous.

The interviews with the experts have been semi-structured. This means there was an incomplete script (Myers & Newman, 2007). The interviewer had prepared questions beforehand, but improvisation was allowed in order to capture as much important information as possible (Myers & Newman, 2007).

Name	***Function description***	***Organization***	***Date of interview***
Dries Jansma	Policy developer for water and drainage systems	Gemeente Groningen	24-10-2018
Allard Roest	Researcher on climate change adaptation and urban green with a focus on citizen participation	Hanze University	25-10-2018

Tamara Ekamper	Sustainable designer and leader of sustainable living environment programme	Gemeente Groningen	07-11-2018
Anonymous	Green roof owner	Private	07-12-2018

Table 1. Interviews

3.4 Analysis of data

Quantitative data analysis

The quantitative survey data has been entered in excel and was then transferred to SPSS 25.0, a statistical analysis program. This program was used for all statistical analysis.

The survey consists of different types of questions (see Appendix B). It contains four socio-demographic questions, three factual questions and five opinion questions. Some of the questions are fixed response and some of the questions are open-ended questions in order not to steer the surveyee in a certain direction (Clifford et al, 2010). One of the questions uses a five point Likert-scale and one of the questions ask the respondents to rate on a scale of one to ten. The open ended survey question answers have been categorized, allowing them to be analyzed quantitatively (Moore & McCabe, 2006). For example, the respondents were asked to name all benefits of green roofs they knew. Correct benefits were added up and categorized into a new variable for every respondent: 'amount of benefits known'.

The data resulting out of these questions was analyzed using binomial tests, linear regressions and descriptive statistics. Binomial tests are used to measure proportions and can be used to test the representativeness of the sample (Moore & McCabe, 2006). Linear regressions are used to model the relation between a dependent variable and one or more explanatory variables (Moore & McCabe, 2006). Descriptive statistics have been used to summarize and visualize answers to the survey (Moore & McCabe, 2006).

A significance level of 0.05 (5%) has been used for all statistical tests. As the sample for the quantitative analysis consisted, except for one, out of respondents who do not have a green roof, the outcome variable (green roof adoption) for the third secondary question had to be indirectly inferred. Use was made of proxy variables for green roof adoption, namely 'amount of known benefits' and 'felt responsibility for local water management'. Both variables have been shown to positively affect climate change adaptation (Bergsma et al,

2012; Kollmuss and Agyeman, 2010) and were therefore assumed to be appropriate candidates.

Qualitative data analysis

The qualitative interview recordings have been transcribed using F4 Transkript and coded using ATLAS.ti 8.3. In this research, axial coding with both an inductive and deductive approach has been used to analyze the transcripts (Clifford et al, 2010). For example, the categories 'financials', 'knowledge' and 'responsibility' were pre-set for the two reviewed actors (urban planners and homeowners) and applied to the transcript. Concurrently, new trends and themes were derived from the data, leading to the codes 'awareness' and 'participation' for example. A full overview of the code tree can be seen in Appendix D.

3.5 Data quality

Qualitative data

As the interviews were semi-structured, the interviewees had freedom in expressing their opinions and beliefs. This improves the quality and honesty of the answers (Myers & Newman, 2007). Quotes have been used in order to accurately express the statements of the interviewees in this research. As the interviews were in Dutch and this research is written in English, the quotes had to be translated. This process might have resulted in erroneous translations as the researcher is not a native English speaker. This could negatively influence the quality of representation and interpretation of the respondents. Little to no bias is assumed in the data as the interviewees were not afraid to critically reflect on their own organization (Myers & Newman, 2007). Overall, the qualitative data is assumed to be of high quality.

Quantitative data

In total 83 responses have been gathered in the survey. Five respondents answered 'no' on the last question asking for permission to use their data for the research. Therefore, five of the respondents' survey answers have been deleted. With 78 valid responses the data was sufficient for most statistical tests. In the sample 50 percent of the respondents are female, 44.9 percent are male and 5.1 percent did not want to disclose their gender or classified themselves as 'other'. The male-female ratio of the municipality of Groningen is

practically 50-50 (CBS, 2018). The male-female ratio of the sample can be seen as representative as proven by a binomial test (explained in Appendix C). The majority (82%) of the respondents in the sample answered 'University' or 'HBO' as their highest level of education. This is significantly higher than the average in Groningen of roughly 49.6 percent (Sociaal Planbureau Groningen, 2019). This makes the data unrepresentative of the population of Groningen (explained in Appendix C). A reason for this could be that people who have studied at a university are more willing to participate in research from a university than someone who has no experience and familiarity with a university. Another reason could be the fact that this is a research about homeowners. Higher educated people have a higher average income and could therefore be more likely to own a home, instead of rent one. However, more research would be needed to substantiate these claims.

The survey asked the respondents why they do not have a green roof and when they would want to adopt a green roof. The answers to these questions have been used to determine barriers and opportunities for homeowners. It must be said that not every roof is able to support a green roof. Therefore, even if all the barriers for the respondents would be taken away and they were willing to adopt a green roof, not all of them would be able to. Therefore, this data makes the total outlook on green roof adoption in Groningen seem more positive than it in reality is.

4. Results and analysis

4.1 Knowledge on green roofs

In line with the first hypothesis, a large difference between homeowners and experts in knowledge on green roofs was found. When asked about the benefits of green roofs over 38 percent (38.2%) of homeowners did not know any benefits of green roofs (Table 2). Over half of the homeowners (52.6%) knew one benefit or less, over three quarters (77.6%) knew two benefits or less and only five of the 78 homeowners (6.6%) could name more than three benefits. This is in sheer contrast to the experts that knew all the benefits of green roofs. Furthermore, the experts were able to place the benefits into the context of the urban environment, such as the reduction in flooding in the neighborhood due to a slower water runoff.

Amount of benefits known	*Frequency*	*Percentage*	*Cumulative percentage*
0	29	38.2	38.2
1	11	14.5	52.6
2	19	25	77.6
3	12	15.8	93.4
4	2	2.6	96.1
5	2	2.6	98.7
6	1	1.3	100

Table 2. Amount of benefits known.

Additionally, homeowners were asked about knowledge on the existence of the subsidy provided by the municipality of Groningen for green roofs. Almost 90 percent (88.5%) of the survey respondents were not aware of the subsidy. Moreover, in line with research by Claus and Rousseau (2012) 62.8 percent of homeowners stated financial considerations to be an important factor for green roof adoption. Although research by Claus and Rousseau (2012) concluded that since the implementation of the subsidy green roofs are both privately and socially financially desirable, people seem to lack awareness of this financial desirability. Zhanga et al. (2012) indicated that next to a lack of incentives, a lack of

promotion could also hinder green roof adoption. Thus, although the municipality of Groningen does have a monetary incentive in place, a lack of promotion, which results in a lack of knowledge on the subsidy and green roof benefit, could still hinder green roof adoption.

Lastly, the lack of promotion and general knowledge can be seen in responses of homeowners when asked about the reasons they do not have a green roof. Half of the answers by the survey respondents could be categorized as 'never thought about it'. Respondents also stated they were concerned about the maintenance costs of green roofs. This means they are unaware of the research done by Oberndorfer et al. (2007) which concluded green roofs had lower total maintenance costs as compared to normal roofs. This strengthens the indication that a lack of knowledge and awareness of green roofs, associated benefits and costs are a major barrier to green roof adoption. These issues are captured in the following quote:

"If people see the importance of something, if it saves money or if they can get a subsidy, then that helps a lot. People are being fried under their roofs and green roofs can relieve this pressure, but people don't even know this. And then they won't adopt. So people have too little knowledge.'' - Dries Jansma, 24-10-2018.

4.2 Responsibility for local water management

In the survey the homeowners were asked to rate the degree of responsibility they feel for local water management on a scale of one to ten (not responsible at all to very responsible). The mean response was 4.71 with a distribution skewed to the lower values of the range (see Figure 3). Out of the 78 respondents, more than half (57.7%) of the respondents rated their level of responsibility to be a five or less. Furthermore, ten of the respondents felt no responsibility for local water management at all, whilst only one respondent rated their responsibility as 'very responsible'. These results and the skewness of the response distribution entail that the majority of homeowners are on the lower end of the scale and almost none feel very responsible, which is in line with the second hypothesis. This is in contrast with recent policy guidelines indicating that the majority of responsibility for local water management increasingly lays with the homeowners (Bergsma et al, 2012).

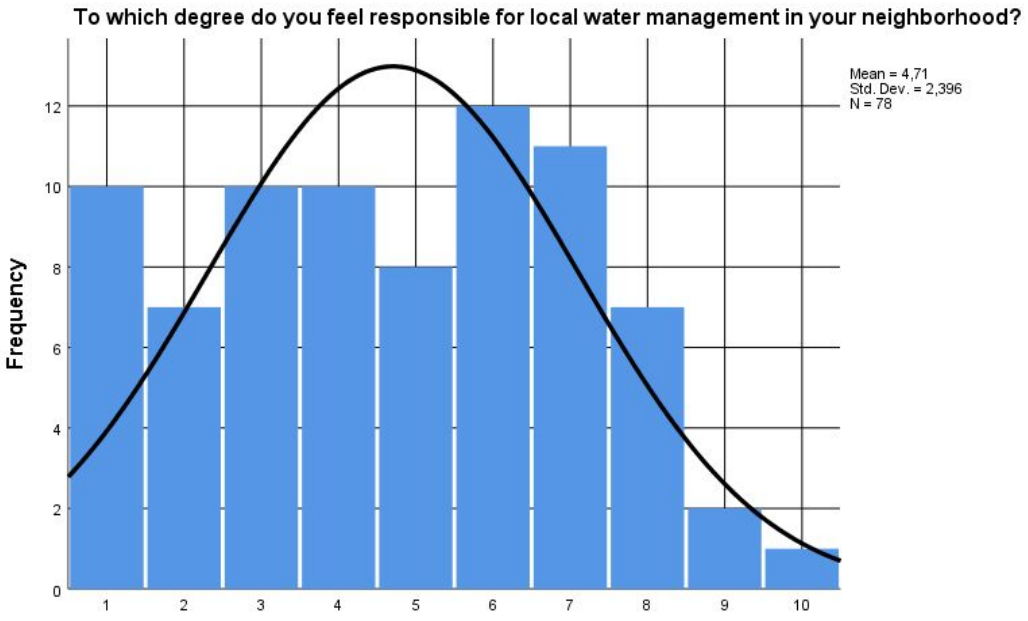


Figure 3. Histogram of responsibility for local water management.

In disagreement with the second part of the second hypothesis, the interviewed experts all felt very responsible for and were concerned with local water management and climate change. However, these results might be biased and ungeneralizable to all of urban planners, since for two of the three experts their job is related to urban water management. This was also expressed by the interviewees, who stated that concerns about local water management and climate change were not shared by everyone within the municipality. This finding is in line with research by Runhaar et al. (2012) who found that urban planners seem to underestimate the urgency of proactive adaptation to climate change in comparison to climate change scientists. The issue is captured in the following quote:

"At the moment our green team says: "Here you have to make sure the temperature doesn't rise too much and that you take care of water management." And then there are always plan economists, project managers and urban planners who say: "Well so what? Then it gets a little hotter, what is the problem?" So the urgency is not really being felt within the municipality." - Tamara Ekamper, 07-11-2018.

When asked about the responsibility of homeowners for local water management, the experts all thought the citizens of the municipality are very responsible as well. This is in

contrast to the average opinion of the citizens, who only feel somewhat responsible for local water management, but in agreement with recent reports (Bergsma et al, 2012). The discrepancy in perceived responsibility for local water management between homeowners and urban planners, could be an explanation for the slow rate of climate change adaptation and therefore green roof adoption (Bergsma et al., 2012). For this reason, Bergsma et al. (2012) stated that leadership from municipalities is necessary to create a transparent division in responsibilities for local water management between citizens and the municipality. This leadership seems to be lacking in the municipality of Groningen, as the experts stated that they will only show strong leadership in promoting and raising awareness for local water management when water nuisance and (light) flooding are occurring. Otherwise, according to them, the public would not perceive local water management as urgent and their promotion efforts would not be effectual. Thus, although there is a discrepancy in perceived responsibility for local water management between homeowners and urban planners, the municipality is not tackling this issue by taking the lead in creating a clear division and raising awareness.

All experts also discussed their expectation of and desire for a 'snowball effect' of green roof adoption happening in the future. This effect entails that once a couple of 'pioneers' start to adopt green roofs, others will see this, awareness will grow and large-scale adoption will follow. This puts a great deal of responsibility on citizens to initiate green roofing. However, if most citizens do not feel the necessity and responsibility to act on local water management, it seems unlikely this snowball will start rolling anytime soon. This desire for a 'snowball effect' of green roof adoption initiated by citizens can be considered as a reactive approach of the municipality to climate change adaptation. Research indicates that municipalities are often constrained by available resources, which could lead to such a reactive approach (Brackertz & Kenley, 2002; Pini et al., 2007). This is expressed in the following quote:

''You just have to use time and manpower and that is what we are lacking. Look, there are always people taking the lead. The pioneers, you don't do anything with them, they will do it by themselves. Then there are forerunners, well those are the people you actually want. Once you get started with them, then there is a big group who never thinks about it that will also start.'' - Dries Jansma, 24-10-2018.

Considering a goal of the municipality of Groningen is to have an increased quality of life in 2035 and green roofs are explicitly mentioned in this goal, more proactivity of the municipality might be needed (Gemeente Groningen, 2018).

4.3 Influence of socio-demographic factors

Descriptive statistics of the survey data showed that on average men could name 1.26 benefits of green roofs, whilst women could name 1.58 benefits (Figure 4). Furthermore, almost half of the men (48.6%) knew zero benefits, whilst only 28.9 percent of women knew zero benefits. However, the difference in the average known benefits between men and women turned out to be statistically insignificant when using a linear regression analysis. Additionally, no significant differences in known benefits was found between different ages and education levels in the results of the linear regression analysis.

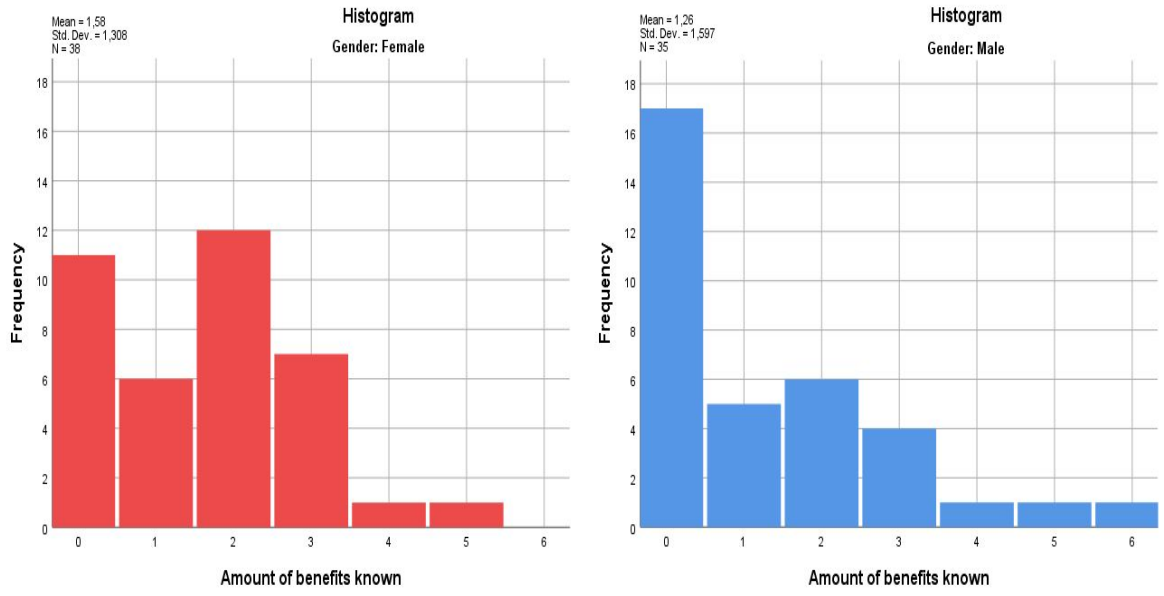


Figure 4. Amount of benefits known for females(left) and males(right).

A second linear regression analysis examined the influence of gender, age, level of education, as well as the known amount of benefits of green roofs, on the level of felt personal responsibility for local water management. In this case, a statistically significant difference between men and women was found. The analysis showed that women sample feel

significantly more responsible for local water management than men with a p-value of 0.032 and a positive B of 0.915 (Table 3). This result can be seen in the histograms shown in figure 5. The distribution of answers for women (left side) is left-skewed (higher responsibility), whilst the distribution of men (right side) is right-skewed (lower responsibility). Though, it must be said that the R-squared was 31.6 percent, meaning only a moderate amount of variation in responsibility could be explained by the included variables (including gender) in the regression analysis.

The second linear regression analysis also resulted in a significant correlation between the level of felt responsibility for local water management and the amount of benefits of green roofs known with a p-value of 0.012 and a positive B of 0.453 (Table 3). Thus, people who feel more responsible for local water management are on average also more likely to know more benefits of green roofs. Lastly, the analysis indicated that the level of felt responsibility is not significantly influenced by age or level of education.

These analyses provide mixed results regarding the validation of the third hypothesis. In contrast to the hypothesis and research by Kollmuss and Agyeman (2010), the known amount of benefits of green roofs was not significantly influenced by gender or level of education. However, in agreement with the hypothesis, the analysis indicated that females did feel significantly more responsible for local water management than men.

	p-value	*B*	*Beta*
Model (regression)	**0.005**	-	-
High school educated	0.195	-1.632	-0.143
HBO educated	0.399	-0.680	-0.98
University educated	0.126	0.884	0.174
Vrouw	**0.044**	**0.915**	**0.201**
18-24 years old	0.761	0.243	-0.309
35-44 years old	0.519	-0.512	-0.078
45-54 years old	0.813	0.201	0.030
55-64 years old	0.461	0.500	-0.95
65 years or older	0.496	-0.868	-0.76
# of benefits known	**0.012**	**0.453**	**0.288**

R-Square: 0.316

Table 3. Responsibility for local water management linear regression analysis results.

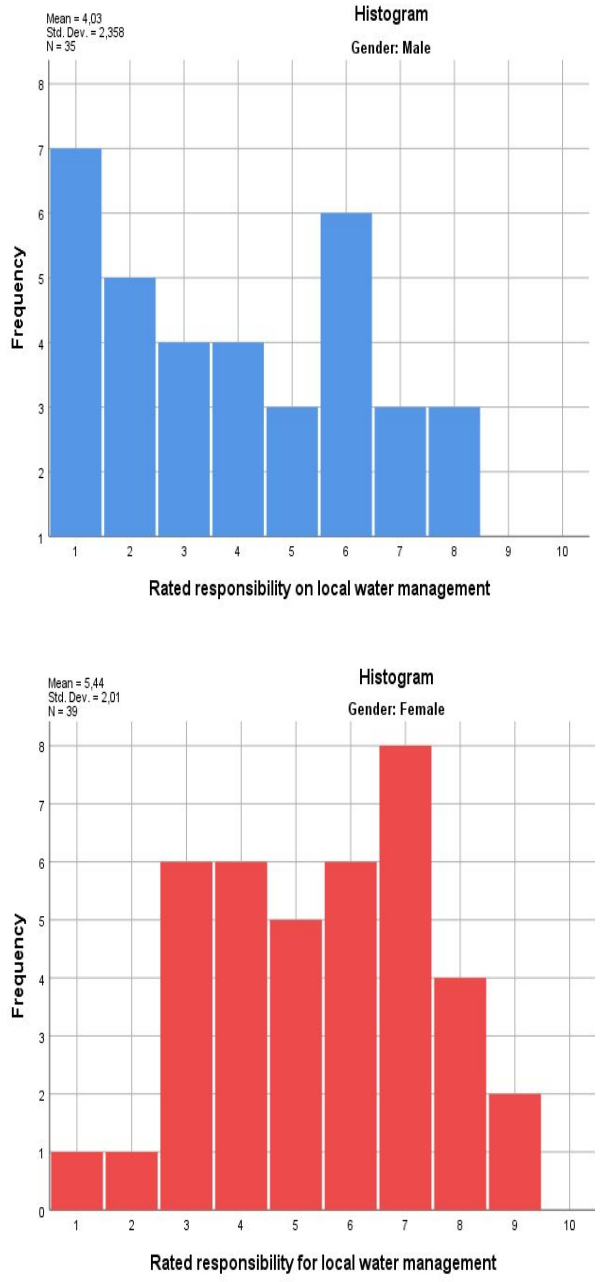


Figure 5. Histogram of local water management responsibility of females (left) and males (right).

4.4 Stimulating the adoption of green roofs

In order to find out how homeowners can be stimulated to adopt a green roof, they were asked when they would be willing to adopt such a roof. Their most cited requirements could be categorized as follows: 'affordability', 'little upkeep/maintenance', 'little effort' and

‘more provided information’. When citing these needs to municipality workers, they stated that meeting these needs is unfeasible, because this would require engaging with homeowners individually and the municipality does not have the manpower required to do so. Engaging with homeowners individually is a very time consuming and labor intensive process for relatively little gain, as single roofs are usually not made up of large surfaces. However, collectively these individual roofs make up a large percentage of the municipalities' surface, since in urbanized areas around 40-50% of the total surface is roof (Dunnett and Kingsbury, 2004). Furthermore, in Groningen 60 percent of the municipality is in private ownership (personal communication Tamara Ekamper, 07-11-2018).

As a solution to overcome the lack of manpower for individual targeting, the experts suggested implementing more street or neighborhood oriented projects, organized by the municipality and starting with problem areas. Hereby, more surface would be converted into green roof in one effort. By using one or two contact persons for each neighborhood, the required labor for the municipality would be significantly reduced as opposed to trying to talk to and convince homeowners individually.

Since homeowners were also concerned about the necessary upkeep and maintenance of a green roof, one of the interviewees proposed that a service contract could be provided for the neighborhood or street relieving them of this work as well. Furthermore, this method reduces construction and maintenance costs as a result of economies of scale. Claus & Rousseau (2012) already concluded that green roofs were financially desirable in the long run if coupled with a subsidy. Lower construction costs and a smaller annual maintenance fee would only increase this financial desirability.

By using this method, homeowners should in theory become more willing to adopt a green roof, as important barriers, such as lack of knowledge and monetary considerations, have now been taken away. The homeowners would receive information and a financially desirable green roof, whilst having to exert very little effort and no maintenance. For the municipality this is an interesting method as well, as they get closer to their climate and livability goals (Gemeente Groningen, 2018). Furthermore, this method is in line with research by Ebi and Semenza (2008) and reports by the government (IenM, 2018), who state that a community-based approach is an effective approach to climate change adaptation. An interviewed green roof owner was very positive about this neighborhood approach as well, although in this case this approach was not initiated by the municipality. His neighbor came

up with the idea of installing a green roof on their sheds and convinced the entire street to do the same. It must be said this is a newly built housing project and the adoption was therefore easier to achieve. A picture of the neighborhood from above can be seen in Appendix E. The green roof owner described the event in the following way:

"We received a group discount and an extra discount for helping ourselves. On top of that there were subsidies, so basically we could have our cake and eat it too. As there is a lot of ugly concrete in front our bedroom window, I am very happy we now have some extra green space instead of bitumen on our sheds. I think it is a beautiful result." - Anonymous green roof owner, 07-12-2018.

Next to this neighborhood method, increased general promotion of green roofing is also proposed in the literature (Zhanga et al., 2012). This proposed strategy would tackle multiple indicated barriers, namely a lack of knowledge among homeowners, a discrepancy in perceived responsibilities between homeowners and urban planners, and the reactive approach of the municipality. Although a subsidy for green roofing is already in place in Groningen, the survey data showed that around nine out of ten people are not aware of the existence of this subsidy. At the same time, the majority stated affordability as an important prerequisite for green roof adoption. Furthermore, many were unaware of most of the benefits of a green roof. Promotion would increase knowledge on the available subsidy, private financial desirability (Claus & Rousseau, 2012), and benefits of green roofs and could thereby stimulate green roof adoption.

Promotion could also be used to overcome the gap in perceived responsibility between homeowners and urban planners, by making property owners more aware of the policy plans that show a shift in responsibility for local water management towards property owners (Bergsma et al., 2012). This strategy is in accordance with research by Measham et al. (2011), who advocate that municipalities should take the lead in defining a clear division of responsibilities to facilitate climate change adaptation.

Lastly, increased promotion seems like it might be a more effective alternative to the reactive approach of simply waiting on the 'snowball effect'. Despite an active subsidy for the past ten years, this snowball does not seem to be gathering speed very quickly. Interviewed experts were apprehensive towards increased promotion, stating that promotional efforts are

unlikely to be effectual at this moment, since the public does not perceive local water management as urgent. For this reason, the experts stated that they were waiting for water nuisance and flooding before increasing promotional activities in the form of awareness raising. However, waiting for flooding to occur seems like a highly controversial strategy and is not in line with the living environment goals and policies set by the municipality (Gemeente Groningen, 2018). Therefore, agreeing with Bergsma et al. (2012) and Measham et al. (2011), a more proactive approach in the form of promotion would be advised.

5. Conclusion

This research aimed to find a conclusive argument as to why green roofing is not being implemented on as large a scale as it can be, with a focus on homeowners and urban planners in the municipality of Groningen. The main research question was: *What are the main barriers and opportunities for green roof adoption among homeowners in the municipality of Groningen*?

The mixed method approach, using both quantitative and qualitative analyses, resulted in multiple found barriers and opportunities.

Firstly, in line with literature (Zhanga et al., 2012), a main barrier to green roof adoption was a lack of knowledge and awareness on green roofs, associated benefits and costs. Especially noteworthy was the finding that nine out of ten homeowners had no knowledge of the subsidy policy for green roofing in Groningen, even though this subsidy has been active for over ten years now. Secondly, this research concluded that another barrier could be the discrepancy in perceived responsibility for local water management between homeowners and urban planners. Although policy guidelines indicate that the majority of responsibility for local water management increasingly lays with homeowners (Bergsma et al., 2012), the survey results indicate that homeowners on average do not feel very responsible. Thirdly, the interviewed experts stated that, out of the employees within the municipality working on urban planning, not everybody feels the urgency to proactively adapt the urban environment to climate change. This can also be seen in the reactive approach (waiting for a 'snowball effect') that the municipality is currently using for green roof adoption. Within the municipality, the lack of commonly felt urgency and reactive approach can therefore be seen as a barriers for green roof adoption

Furthermore, a linear regression analysis indicated that felt responsibility for local water management was positively associated with being a female on average, but not associated with age or level of education. No significant results were found using the amount of benefits known of green roofs as the outcome variable.

Lastly, as an opportunity for green roof adoption, interviewed experts and literature (Ebi & Semenza, 2008; IenM, 2018) proposed community-based projects, possibly accompanied by a service contract. This method would target large groups of homeowners, decreasing total costs for the municipality and homeowners. Lastly, increased general promotion of green roofing has been proposed by literature (Zhanga et al., 2012), which could

tackle indicated barriers, such as a lack of knowledge among homeowners, a discrepancy in perceived responsibilities between homeowners and urban planners, and the reactive approach of the municipality.

6. Reflection

Methodology and content

This study is limited by the fact that there is no income variable in the socio demographic factors. This was a conscious decision, since asking survey respondents on income would most likely result in less answers and respondents. Due to time constrictions, the idea was to extrapolate the average income of the neighborhood and assign that to the respondents from that neighborhood. This method could work with a larger sample size, but data included only a couple respondents per neighborhood or less. The possible income gap between an individual respondent and that of the neighborhood would be too large and could not be averaged out by the amount of respondents. The income variable would not be representative and biased. In hindsight, income should have been asked in the survey and respondents could have been reassured that it is not necessary to answer all the questions if they are not willing to. This way, respondents would not have felt pressured to answer questions and the results of the respondents that did disclose their income could have been used effectively.

Furthermore, the neighborhood of the respondent was also not included in the regression analysis. Even after grouping different neighborhoods into districts the requirements for statistical tests could not be met.

Literature

There is very little research on the implementation of green roofs, with most of the existing literature concerning the associated (technical) benefits. This means that current implementation practices in the municipality of Groningen are hard to review and link to academic literature. Even if there were more papers of implementation practices they are often hard to review as most countries have vastly different policies, geographical characteristics and political systems. It would be more beneficial to make comparisons between cities or municipalities within the same country. Germany seems to be doing this effectively. Researchers are mapping all the different rules and policies in cities in regards to green roof implementation and are then comparing the results of these cities. Unfortunately, most of this research is written in German and is therefore hard to access and read for people who do not

speak German. With more time for translation, more comparisons between Groningen and German cities could have been made in this study, as they have similar political systems.

Suggestions for further research

This research focused solely on homeowners and urban planners. While some housing corporations were asked for an interview to expand on that, they were not willing to cooperate. In order to paint a complete picture of green roof adoption, housing corporations and renters are needed. It is therefore recommended this research will be expanded upon by including these actors in the future.

References:

Abraham, A., Sommerhalder, K. & Abel, T. (2010). Landscape and well-being: a scoping study on the health-promoting impact of outdoor environments. *International Journal of Public Health*, 55(1), 59-69.

Arcadis (2008). Groene daken Rotterdam – Maatschappelijke kosten-batenanalyse. 110643/WA8/050/000894. Rotterdam: Gemeente Rotterdam.

Bergsma, E., Gupta, J. & Jong, P. (2012). Does individual responsibility increase the adaptive capacity of society? The case of local water management in the Netherlands. *Resources, Conservation and Recycling,* 64(1), 13-22.

Berndtsson, J., C. (2008). Green roof performance towards management of runoff water quantity and quality: A review. *Ecological Engineering,* 36(4), 351-360.

Brackertz, N & Kenley, R. (2002). A service delivery approach to measuring facility performance in local government. *Facilities*, 20(3), 127-135.

Bruin, K., Dellink, R.B., Ruijs, A., Bolwidt, L., Buuren, A., Graveland, J., Groot, S., Kuikman, P.J., Reinhard, S., Roetter, R. P., Tassone, V.C., Verhagen, A. & Ierland, E.C. (2009). Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives. *Climate Change,* 95(1), 23-45.

Centraal Bureau Statistiek (2018). *Bevolking; leeftijd, migratieachtergrond, geslacht en regio.* Retrieved on January 16, 2019 from https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37713/table?dl=FE77. Den Haag: Centraal Bureau Statistiek

Claus, K. & Rousseau, S. (2012). Public versus private incentives to invest in green roofs: A cost benefit analysis for Flanders. *Urban forestry and greening,* 11(4), 417-425.

Clifford, N., French, S. & Valentine, G. (2010). *Key Methods in Geography.* 2nd Edition. Thousand Oaks: SAGE.

Deltares (2012). *Schades door watertekorten en -overschotten in stedelijk gebied*. 1205463-000. Delft: Deltares.

Dunnet, N. & Kingsbury, N. (2008). *Planting green roofs and living walls.* 2nd edition. Portland: Timber.

Ebi, K.L. & Semenza, J.C. (2008). Community-based adaptation to the health impacts of climate change. *American Journal of Preventive Medicine,* 35(5), 501-507.

European Federation Green Roofs and Walls (2015). *2015 White paper.* Retrieved on December 31, 2018 from https://efb-greenroof.eu/wp-content/uploads/2016/12/efb_whitepaper_2015.pdf. Vienna: EFB.

Fang, C.F. (2008). Evaluating the thermal reduction effect of plant layers on rooftops. *Energy and Buildings*, 40(6), 1048-1052.

Gedge, D. & Kadas, G. (2005). Green roofs and biodiversity. *Biologist*, 52(3), 161-169.

Gemeente Groningen (2016). *Groningen klimaatbestendig*. 5596. Groningen: Gemeente Groningen.

Gemeente Groningen (2018). Omgevingsvisie 'The Next City': de Groningse leefkwaliteit voorop. 7708. Groningen: Gemeente Groningen.

Gemeente Groningen (2019). *Subsidie groen dak aanvragen*. Retrieved on January, 12 2019 from https://gemeente.groningen.nl/subsidie-groen-dak-aanvragen. Groningen: Gemeente Groningen.

Herman, R. (2003). Green Roofs in Germany: Yesterday, Today and Tomorrow. *Greening Rooftops for Sustainable Communities Symposium*. City of Portland, Oregon, 29-30 May.

Hunt, A. & Watkiss, P. (2011). Climate change impacts and adaptation in cities: a review of the literature. *Climate change*, 104(1), 13-49.

KNMI (2006). *Klimaat in de 21e eeuw, vier scenario's voor Nederland*. Bilthoven: Koninklijk Nederlands Meteorologisch Instituut.

Kollmuss, A. & Agyeman, J. (2010). Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, 8(3), 239-260.

Measham, G. T., Preston, B. L., Smith, F. T., Brooke, C., Gorddard, R., Withycombe, R. & Morrison, C. (2011). Adapting to climate change through local municipal planning: barriers and challenges. *Mitigation and Adaptation Strategies for Global Change.* 16(8), 889-909.

Mentens, J., Raes, D. & Hermy, M. (2006). Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? *Landscape and urban planning*, 77(3), 217-226.

Ministerie van Infrastructuur en Milieu (2015). *2016-2021 Nationaal Waterplan.* IENM/BSK-2015/230376. Den Haag: Ministerie van Infrastructuur en Milieu.

Ministerie van Infrastructuur en Milieu (2016). *Aanpassen met ambitie. Nationale Klimaatadaptatie-strategie 2018-2019 (NAS)*. IenW/BSK-2018/59199. Den Haag: Ministerie van Infrastructuur en Milieu.

Ministerie van Verkeer en Waterstaat (2009). *2009-2015 Nationaal Waterplan.* VENW/BSK-2009/190321. Den Haag: Ministerie van Verkeer en Waterstaat.

Moore, D. S. & McCabe, P. (2006). *Statistiek in de praktijk.* 5th edition. Den Haag: Academic Transfer.

Myers, M. D. & Newman, M. (2007). The qualitative interview in IS research. *Information and Organization*. 17(1), 2-26.

Nationaal Kennis- en innovatieprogramma Water en Klimaat (2018). *Zomerse piekbuien zijn moeilijk te voorspellen.* Retrieved on September 16, 2018 from https://waterenklimaat.nl/onderzoekslijnen/klimaatbestendige-stad/kenniskrant-voor-een-klimaatbestendige-stad/natte-krant/zomerse-piekbuien-zijn-moeilijk-te-voorspellen.

Ngan, G. (2004). Green roof policies: Tools for encouraging sustainable design. *Landscape Architecture Canada Foundation.*

Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R.R., Doshi, H., Dunnett, N., Gaffin, S., Köhler, M., Liu, K. Y. & Rowe, B. (2007). Green roofs as urban ecosystems: ecological structures, functions, and services. *Bioscience*, 57(10), 823-833.

Pini, B., Wild River, S. & McKenzie, F. M. H. (2007). Factors inhibiting local government engagement in environmental sustainability. *Australian Geographer*, 38(2), 161-175.

Renterghem, T. van & Booteldooren, D. (2009). Reducing the acoustical façade load from traffic with green roofs. *Building and Environment*, 44(5), 1081-1087.

Runhaar, H., Mees, H., Wardekker, A., Sluijs, J. Van Der, & Driessen, P. (2012). Adaptation to climate-change related risks in Dutch urban areas: stimuli and barriers. *Regional Environmental Change*, 12(4), 777-790.

Sociaal Planbureau Groningen (2019). *Opleidingsniveau van de beroepsbevolking.* Retrieved on January 16, 2019 from https://sociaalplanbureaugroningen.nl/leefbaarheid/werk-en-inkomen/opleidingsniveau-beroepsbevolking/. Groningen: CMO STAMM

Townshend, D. & Duggie, A. (2007). *Study of green roof application in Hong Kong. Final Report.* Hong Kong: Architectural Services Department.

Yang, J., Yu, Q. & Gong, P. (2008). Quantifying air pollution removal by green roofs in Chicago. *Atmospheric Environment*, 42(31), 7266-7273.

Zhanga, X., Shena, L., Tamb, W.Y. & Lee, W.W.Y. (2012). Barriers to implement extensive green roof systems: A Hong Kong study. *Renewable and Sustainable Energy Reviews,* 16(1)*,* 314-319.

Appendix A.

Description

Green roofs are roofs with a substrate layer (which holds water), drainage layer (which discharges excess water) and a vegetation layer. There are two types of green roofs depending on the depth of the substrate layer: extensive and intensive green roofs (Berndtsson, 2008).

- Intensive green roofs have a substrate layer of more than 15 cm and therefore usually a high diversity of vegetation. These are basically gardens on top of a roof. This makes them heavier, higher maintenance and only placeable on roofs with a slope of less than 10 degrees.
- Extensive green roofs have a substrate layer of approximately 15 cm. The vegetation is made up of sedum plants, which are capable of surviving a long time without water and are also able to store a lot of water. Besides that, they require little attention and upkeep and are able to be placed on slopes of up to 45 degrees. This makes extensive green roofs the most practical variant.

Subsidy policy in the municipality of Groningen

The subsidy policy has been in effect in Groningen since May 2008 (Gemeente Groningen, 2019). With this policy, homeowners, firms and institutions can get a subsidy for green roofs. The amount of subsidy depends on the size of the to-be-realized green roof. To be eligible for this subsidy certain requirements need to be met (Gemeente Groningen, 2019):

- The applicant is owner of the building where the green roof will be realized. Renters can also apply if they have explicit permission from the owner of the building where the green roof will be realized.
- The green roof will at least be 6 m2.
- The green roof will be built by a specialist.
- The building process may only start after the subsidy application has been approved.
- The green roof gets built within a year of the subsidy approval.
- The green roof substrate must comply with the assessment directive 'BRL 9341' for stony substrates. Applicants are advised to ask their specialist for this certificate.

The amount of subsidy an applicant receives depends on the amount of green roof surface:

- 30 euro per m2 for surfaces between 6 and 100 m2.
- 20 euro per m2 for surfaces from 100 to 250 m2.
- 10 euro per m2 for surfaces from 250 to 1000 m2.

The costs of green roofs are usually between 50 and 80 euro per m2. Therefore, in some cases more than half of the cost of a green roof can be subsidized.

Roof requirements

Green Roof type	*Saturated weight*	*Thickness in mm*	*Slope*
Extensive			
Lightweight	40-45 kg/m2	60-70	0-15°
Flat	80-85 kg/m2	80-110	0-5°
Shallowed pitch	95-100 kg/m2	90-120	5-25°
Steeply pitched	100-105 kg/m2	90	25-45°
Intensive			
Biodiverse	220-230 kg/m2	200-215	0-10°

Table 1. Roof requirements based on European Federation Green Roofs and Walls (2015).

Appendix B

Question template for the urban planner interview:
Ask for permission to record the interview.

Introduction

- Who am I, what do I do, what am I researching, small introduction to green roofs.
- Ask them to tell something about themselves, their job and their role in urban planning.

Questions:

1. To what extent do you think climate change will have an effect on the urban environment?

- Do you consider planning accordingly a responsibility of yours?
- Could you go give an example of this?

2. To what extent do you, as an urban planner, feel responsible for local urban water management?

- *To what extent do you think homeowners are responsible for local urban water management?*
- *Could you elaborate on this?*

3. What do you know about green roofs?

- *What do you know about green roof projects in Groningen?*
- *Could you elaborate on this?*

4. *To what extent are you hindered during the process of green roofing?*

- *Could you give an(other) example of this?*

5. How could the adoption of green roofing be stimulated in Groningen?

- *To what extent would you make changes in green roofing policy?*
- *Could you give an(other) example of this?*

6. *How do you see the future for green roofing in Groningen?*

- *Could you go into more detail?*

Close the interview and thank the interviewee for participating.

Question template for the green roof owner interview:

Ask for permission to record the interview.

Introduction

- Who am I, what do I do, what am I researching, small introduction to green roofs.
- Ask them to tell something about themselves, their job and their role in urban planning.

1. *Kunt u mij vertellen hoe uw groene dak tot stand is gekomen?*

-In welke mate voelt u zich verantwoordelijk voor lokaal watermanagement?

1. *Bent u tevreden met dit proces?*

- Zou u nog iets veranderen in het proces?

1. *Hoe ging het aanvragen van de subsidie?*

- Zou u nog iets veranderen in het proces?

1. *Heeft u veel interesse van anderen over uw groene dak?*
   -Leidt uw groendak denkt u tot nieuwe adoptie?

1. *Hoe zou u groene daken willen bevorderen in de gemeente?*

-Could you elaborate on this?

Survey for homeowners

Introduction

- Who am I, what do I do, what am I researching, ethics.

1. Gender:
   - Male
   - Female
   - Other
   - Prefer not to answer

2. Age:
   - 18-24
   - 25-34
   - 35-44
   - 45-54
   - 55-64
   - 65+
   - Prefer not to answer

3. Level of highest education:
   - None
   - Highschool
   - Mbo

- Hbo bachelor
- University bachelor
- University master and higher
- Prefer not to answer

4. In which neighborhood do you live?

5. Do you experience flooding in your district after (heavy) rainfall?
- Always
- Often
- Sometimes
- Seldom
- Never
- Prefer not to answer

6. Do you have a green roof?
- Yes
- No
- Don't know
- Prefer not to answer

6A. If answered no: Why do you not have a green roof?
6B. If answer yes: Why did you choose to take a green roof?

7. What benefits of a green roof do you know?

8. Do you know that Groningen has a green roof subsidy?
- Yes
- No
- Prefer not to answer

9. To what extent do you feel responsible for local water runoff?
- 1-10
- Prefer not to answer

10. When would you be willing to own a green roof?

11. Do you give consent for your answers to be used in the research?
- Yes
- No

Appendix C

1. Binomial tests for representativeness of sample

Binomial tests have been executed in order to determine if the survey data is representative of the population of Groningen. The male-female proportion and the low-high education level proportion of the survey have been tested against the proportions of the population of the municipality of Groningen. The null hypotheses are: 'In the population the proportion of males to females is equal to 0.499477 in Groningen' (CBS, 2018) and 'In the population the proportion of low-skilled to high-skilled is equal to 49.62 in Groningen' (Sociaal Planbureau Groningen, 2019). The test proportions are based on the demographic data of the municipality of Groningen. This null hypothesis gets accepted if the p-level is insignificant (higher than 0.05) and rejected if the p-value is significant (lower than 0.05). The male-female ratio of the survey data has a insignificant p-value of 0.37 and is thus assumed to be representative of Groningen**.** The low-high skilled proportion of the survey data has a significant p-value of 0.000 and can be assumed to be unrepresentative of Groningen**.**

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (1-tailed)
GESLACHT	Group 1	,00	35	,472973	,499477	,367[a]
	Group 2	1,00	39	,527027		
	Total		74	1,000000		

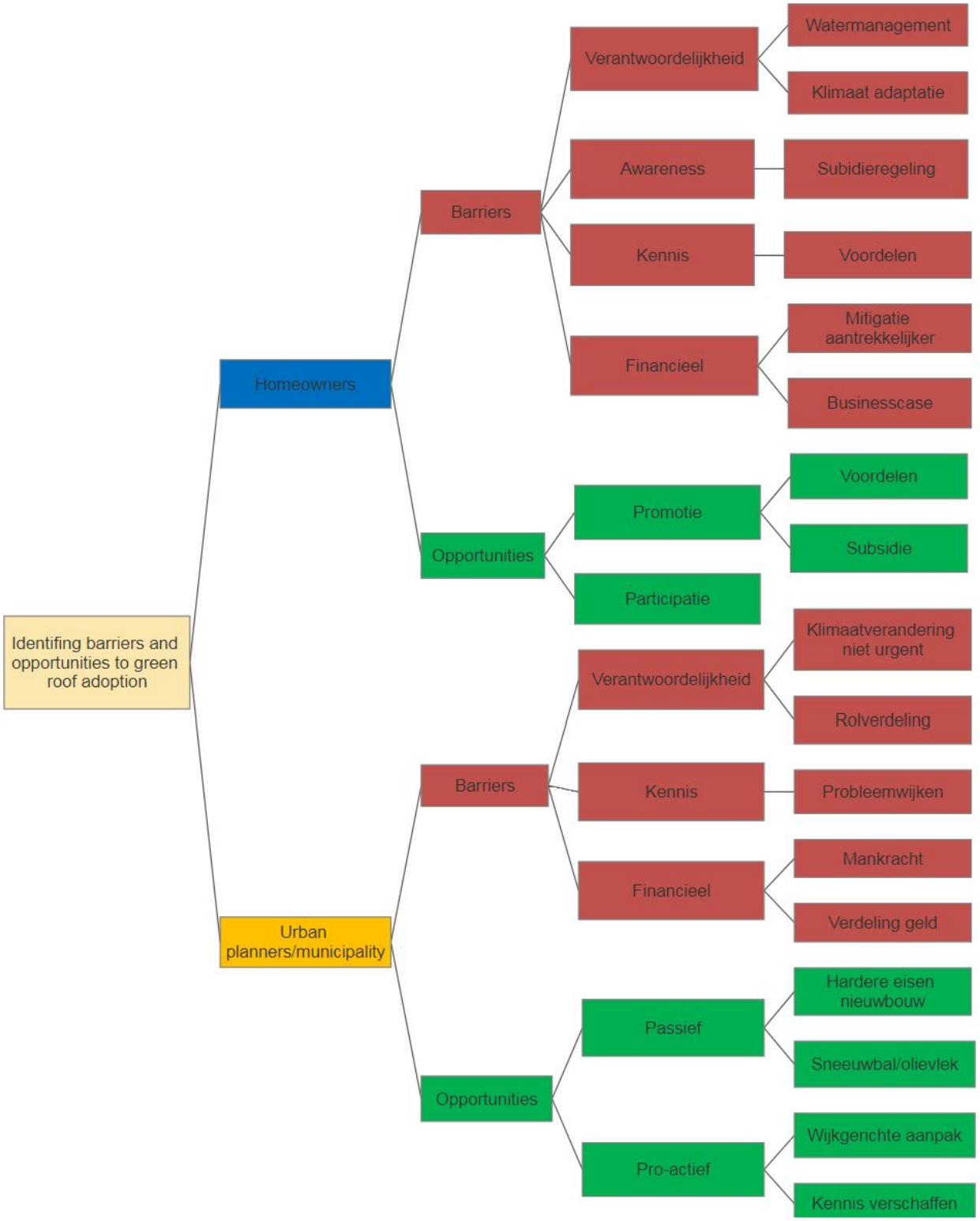
Table 1. Binomial Test for male-female proportion.

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (1-tailed)
Opleiding.Nieuw	Group 1	<= 3	13	,168831	,4962	,000[a]
	Group 2	> 3	64	,831169		
	Total		77	1,000000		

Table 2. Binomial Test for high-low skilled proportion.

Appendix D


Identifing barriers and opportunities to green roof adoption
Homeowners
Barriers
Verantwoordelijkheid
Watermanagement
Klimaat adaptatie
Awareness
Subidieregeling
Kennis
Voordelen
Financieel
Mitigatie aantrekkelijker
Businesscase
Opportunities
Promotie
Voordelen
Subsidie
Participatie
Urban planners/municipality
Barriers
Verantwoordelijkheid
Klimaatverandering niet urgent
Rolverdeling
Kennis
Probleemwijken
Financieel
Mankracht
Verdeling geld
Opportunities
Passief
Hardere eisen nieuwbouw
Sneeuwbal/olievlek
Pro-actief
Wijkgerichte aanpak
Kennis verschaffen

Appendix E

Picture of green roofs

The anonymous green roof owner sent a picture of his neighbourhood. On the left are all the sheds with no green roof and on the right are all the sheds with a green roof. This picture was allowed to be used in the research.

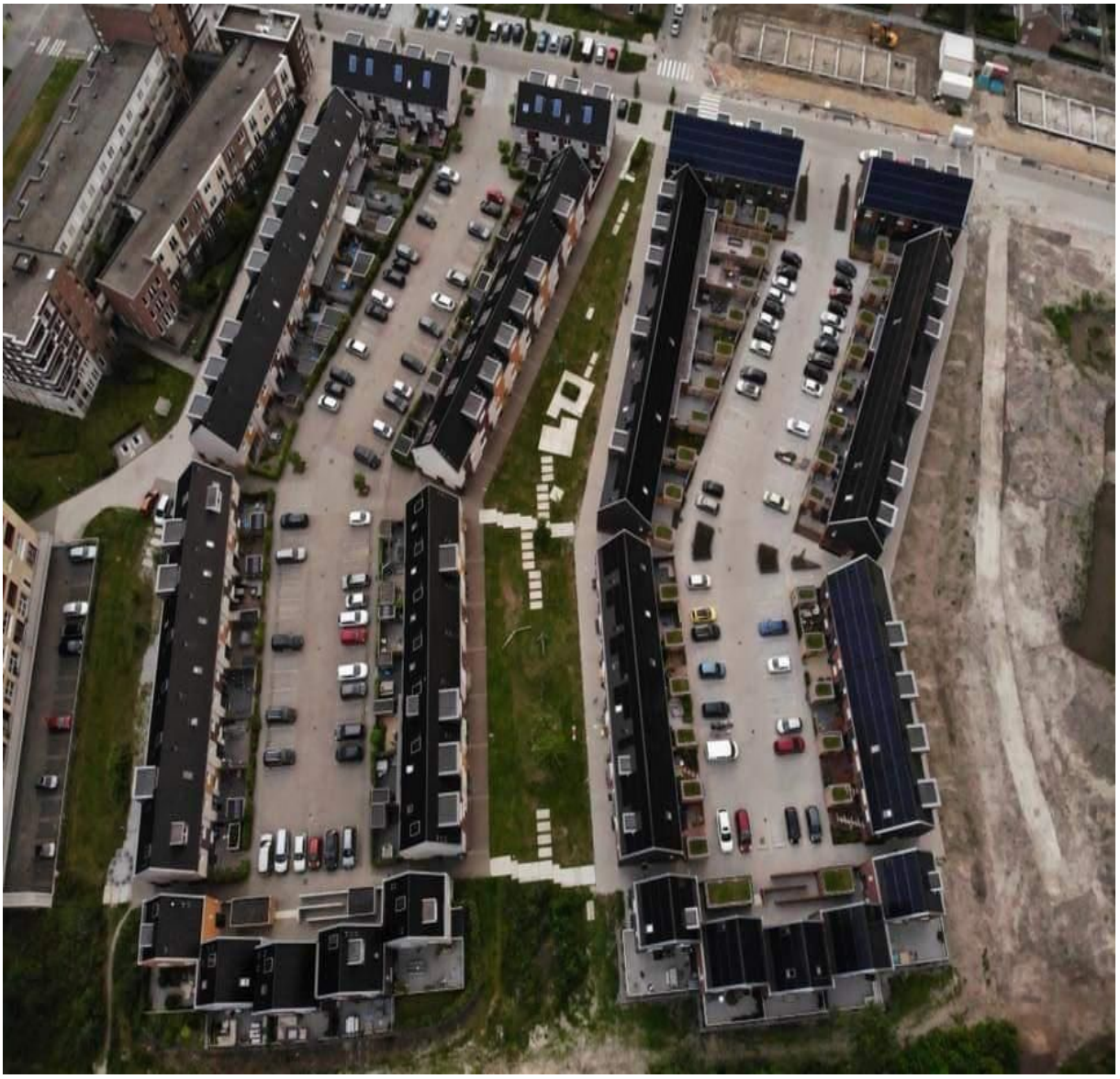


Figure 1. Picture of green roofs.