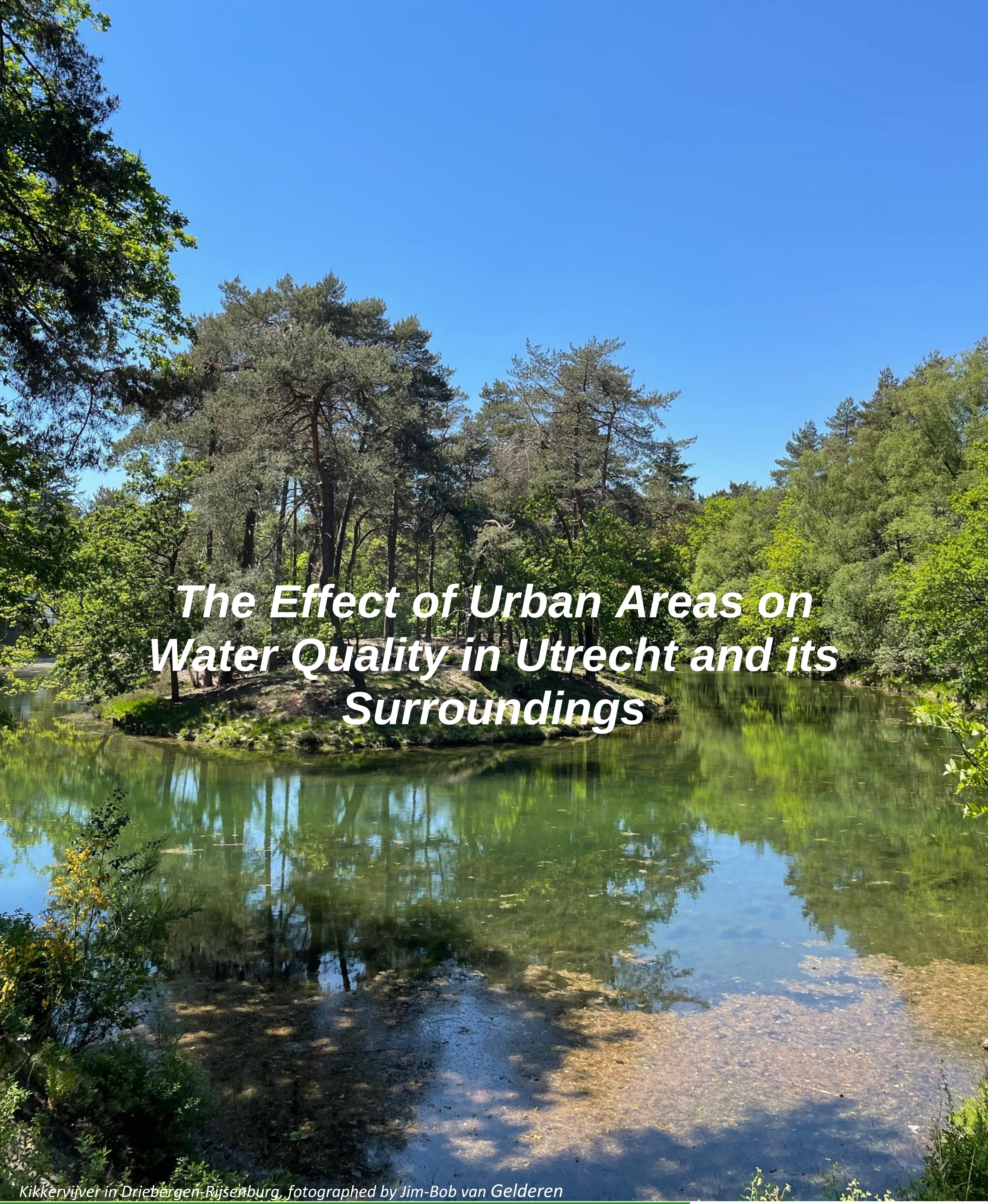
The Effect of Urban Areas on Water Quality in Utrecht and its Surroundings



Kikkervijver in Driebergen-Rijsenburg, fotographed by Jim-Bob van Gelderen

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1. Introduction

Water is essential for the survival of all life on Earth. Often, it is regarded as an infinite resource, but with an increasing population and improved living standards, water usage around the world has increased exponentially (Despommier, 2010). This can result in major complications for cities to provide sufficient and high-quality water to their residents.

The dictionary of Oxford describes "urbanization" as "the process in which more and more people start to live and work in towns and cities rather than in the country" (2021). The number of people living in cities in 2018 is around 4,5 times more than in 1950 (UN, 2018). Therefore, the amount of water used, and the amount of wastewater produced in these cities has increased significantly (Despommier, 2010). This will become an even more serious challenge in the future, as the United Nations estimates that by 2050, 68% of the world's population will be living in cities (2018). Currently, 150 million people live in cities with permanent water shortages, by 2050 demographic growth, urbanization, and climate change will increase this number to almost 1 billion people (McDonald et al., 2011). As a result, there will be increasing pressure on the global water resources and together with water pollution, they will become a significant problem in societies all around the world (Hibbs & Sharp, 2012). It is important to research urbanization and its influence on water quality since more people in the future will be living and visiting densely urbanized areas all over the world. In recent years, the effect of urbanization on water quality has been studied extensively (Goonetilleke & Thomas, 2003)

When it comes to urbanization, the Netherlands is no exception (Verweij, 2010). Utrecht, one of the largest cities in the Netherlands, is experiencing an increase in population (CBS, 2020). This might result in more water quality issues. Hoogheemraadschap De Stichtse Rijnlanden (HDSR) and Water&Klimaat are two institutions that are responsible for the water quality in Utrecht and its surroundings. The most recent research in this field completed by them was in 2018 (HDSR, n.d.). However, no case studies on the effects of urban areas on the water quality in Utrecht and its surroundings have been conducted. Providing high water quality is important for public health. To do that it is critical to comprehend the relationship between water quality and urbanization, particularly as the population of Utrecht and its surrounding is likely to grow in the future. This report aims at studying the effect urban areas have on the water quality in and around Utrecht. Therefore, the research question that forms the basis of our study is:

What is the influence of urban areas on the water quality in Utrecht and its surroundings?

To answer these questions, the following sub-questions will be discussed:

1. How do the different areas compare to each other in terms of urbanization?
2. What is the overall water quality in the testing locations?
3. How does mobility affect the water quality?

2. Literature review

Water quality in urban areas has become more important in recent years. In the literature review the concept of urbanization, eco scans performed by Hoogheemraadschap De Stichtse Rijnlanden, recent studies, and reviews conducted in our research area will be discussed.

To start, there is no general term defining urbanization. Boving and McCray (2007) emphasize the importance of a more thoughtful definition of urbanization. However, according to MacGregor-Fors (2011), urban areas can be defined by population density, total population, and the presence of specific structures such as housing, impervious surfaces, and percentage of non-agricultural activity. Regarding population density, a higher inhabitant's density and more tourism necessitate more housing and general services, such as stores and schools. This means that more impervious surfaces, such as asphalt and concrete are used to accommodate this higher population. These materials increase the difficulty of precipitation to enter the water systems, as it increases the time and surface, the rainwater must travel. As a result, rainwater has the potential to transport more polluting materials and chemicals into water bodies (Hall, 1985). This will affect the quality of the water as pollutants can accumulate over time affecting the aquatic system. Furthermore, anthropogenic alterations of landscape, such as the construction of buildings and infrastructure influence biodiversity, with more sensitive species disappearing and more tolerant species becoming more abundant (McGrance, 2016). However, understanding precisely the processes that influence biodiversity and the quality of the aquatic ecosystems is difficult.

Not only does urbanization contribute to an increase of the agricultural system and increase in the construction of housing, which is needed to sustain the growing population, it also has a significant impact on the hydrological cycle in cities (Subhasis & Zeyuan, 2016). This hydrological cycle can be described as the different pathways precipitated water uses to stream back to the sea (Hall, 1985). In Figure 1, an overview is given of the hydrological cycle and its components. Some key elements for urban areas are the surface and reservoir systems. The surface and its characteristics greatly influence water quality and the amount of precipitated water that can be transported.

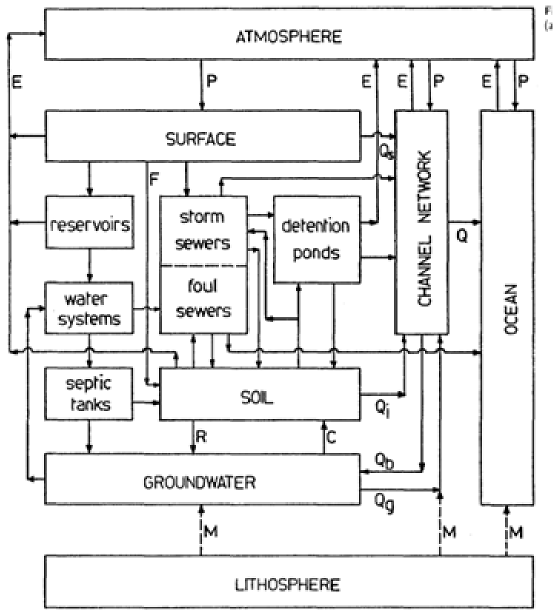


Figure 1: *Overview of the urban hydrological cycle (Hall, 1985)*

Several case studies have been performed related to urbanization and water quality. For example, between 2000 and 2005, research in San Luis, Argentina, studied the water quality of the Potrero de Los Funes river. The water was measured on different chemical elements, pH, and dissolved oxygen. Following a General Quality Index, the data from the river was evaluated. Also, the amount of tourism and urban activities close to the river were studied. The study found that the quality of water drastically decreased with higher levels of urbanization (Almeida, 2017).

Despite many studies on the deterioration of urban water quality, significant gaps in our understanding of water quality in urban areas in the Netherlands remain. Understanding the spatial and temporal variation in urban water necessitates a detailed understanding of the area, considering a variety of factors. In the middle of the Netherlands Hoogheemraadschap De Stichtse Rijnlanden (HDSR) oversees the local and regional water management. HDSR in cooperation with Water&Klimaat (before called Winnet), the waterschap, and the local municipalities are responsible for the ecoscans; which were created to improve the understanding of the development of the urban waters and to indicate the current ecological state. The ecoscans were conducted in 2015 and 2018 at different locations in and around the city of Utrecht, they were performed at the same locations and therefore provide an opportunity to compare the results and determine where improvement and deterioration have taken place. In 2018 the ecoscans were completed at 308 locations, as shown in Figure 2. One of the methods used for the ecoscans is the Winnet-score, this method will also be used in this research and will be further explained in the method section (HDSR, n.d.). The same measurements will be taken at different locations around Utrecht to assess the current condition of the water quality, as the last ecoscans were completed in 2018.

3. Research Method

In order to obtain the necessary areas, multi-stage cluster sampling was used. The locations were first divided into three categories: natural, semi-urbanized, and urbanized. We assume that the water quality will differ in the areas, due to different levels of urbanization: high in Utrecht, moderate in Zeist and low in the Utrechtse Heuvelrug and Amelisweerd. The tests will be performed in seven different locations, in four different areas: the first two locations are in the centre of Utrecht, the third and fourth in Zeist, the fifth and sixth locations are in the Utrechtse Heuvelrug, and the last one in Amelisweerd. The water quality will be measured at up to five different sites per testing location, each exposed to anthropogenic factors such as litter, benches, and roads. The research question can be answered by combining the results of the water tests with an estimate of the degree of urbanization in the area.

3.1 Urbanization

To define what an urban area and a nature area is, two key factors are used to identify a definition of urbanization:

1. **Buildings in the areas.** Maps of the testing areas in QGIS are going to be made, where the different buildings of every area into houses, shops and take away restaurants will be divided. This measure will be used to show how urbanized an area is in terms of buildings.
2. **The mobility.** This will be measured in two different ways, to account for a possible weather bias. First, the number of visitors is counted for fifteen minutes between twelve and one in the afternoon. This shows how much mobility there is. Second, a variety of factors that influence mobility will be considered, such as:
   i. The number of roads
   ii. Shop and take-away mobility
   iii. The number of benches and trash cans

These variables were chosen because they can provide a clear overview of how urbanized the three testing areas are. This will also be useful to differentiate between the degree of urbanization and other influences at the three locations later in this research. These variables will be implemented in an area of 200 meters length and 100 meters width around the water tests. To see a map and an explanation of the chosen areas see appendix 9.2

3.2 Water quality

The primary method used to identify the urban water quality is the strategy proposed by meetjewaterkwaliteit.nl (See appendix 9.1).

An estimation of the water quality can be made by looking at six different indicators (see text in bold below), which will mostly be identified by visual research. In Figure 3 the four different levels per category are indicated; the first level indicates a “low” standard of water quality, with abundant amounts of litter and no room for side vegetation. The next level is called “visible” and has observable amounts of litter, with bare room for side vegetation. The third level is “lively”, referring to higher amounts of diversity, with little to no litter in the testing area. The final level with the highest quality is “natural". It has enough room for nature, high biodiversity levels, and no litter and other disturbances by nature. The following six indicators about waterway will be studied:

1. **The algae and duckweed covering percentages** describe the overall water body coverage of duckweed and algae. Most of the time this number is low and will not hinder the water quality. However, if the whole water body is covered up the water quality will drastically decrease because of no light and lower uptake of O_2.

2. **The transparency of the water** will be measured with a Secchi disk or a measure rake. This is a black and white disk with a measurement on the rope, which indicates the depth when the disk is no longer visible.

3. **The number of water plants.** This category is based upon the different amounts of plants in the water. The more water plants, the higher the score will be.

4. **The vegetation on the side of the water.** This category is based upon the amount of vegetation that is allowed on the side of the waterbody. A low score is for instance a docking wall, whilst a high score is a shoreside with a lot of coverage of different plant types.

5. **The biodiversity** of the water body is calculated by looking at the different species of shore vegetation and the vegetation in the water.

6. **The amount of litter around the water.** The amount of litter will be counted in and around the water body. These individual pieces of litter will also be pinpointed on the QGIS map. For reference, a piece of litter is every man-made material that is discarded into nature and can be seen with the human eye.

The data will be analyzed following the guidelines of *Winnet;* the score that is the lowest decides the level of water quality. This will give an indication of what the water quality is at that location. For an overview on the *Winnet* guidelines, refer to the appendix 9.3.

3.3 Data Analysis

During the fieldwork week, 123survey was used to fill in the form from meetjewaterkwaliteit.nl. The data was inserted into excel to get a clear overview. To analyse the data, the necessary information was processed in SPSS and different numbers were given to the categories measured: 1 for low, 2 for visible, 3 for lively, and 4 for natural. After finalizing the data, it was inserted into Excel and SPSS, where the different correlations on significance were tested; To test the significant difference in the water quality between the different areas, a Kruskal Wallis test was performed to compare the 3 sample groups. A Spearman Rank Correlation test was performed to determine if there is a correlation between mobility and the water quality and if it is significant or not. Additionally, we used the Spearman to compare one scale variable and one ordinal variable, neither normally distributed.

4. Results

4.1. How do the different areas compare to each other in terms of urbanization?
To get a grip on the comparison of urbanization between the areas, the different areas; natural, semi-urbanized, and urbanized were mapped, as well as their respected testing locations using QGIS. To determine in what category the chosen areas belong, the following indicators were considered: the number of buildings and their respective purpose, the number of trash cans and benches, the amount of litter, and the mobility. Based on all these aspects the different locations are divided into three categories: natural (Amelisweerd and Utrechtse Heuvelrug), semi-urbanized (Zeist), and urbanized (Utrecht city centre). The following is a brief overview of the findings.

First, the mobility was quantified in the different areas; In the area of Utrecht city centre there was a total mobility of 1375 people per fifteen minutes. In the area of Zeist, a mobility of 52 people in fifteen minutes was counted and in Utrechtse Heuvelrug and Amelisweerd there was a mobility of twelve people per fifteen minutes. As high mobility suggests a higher degree of urbanization, there is already a distinction between the urban, semi-urban, and natural areas.

Secondly, the number of buildings in the areas will be discussed. In figures 3.1 and 3.2 below, maps are shown of the Utrecht city centre, an area with a high building density; A lot of room has been appointed to shops and restaurants, which in term explains the increase in mobility in said area. The areas in Zeist (Fig. 3.3 and 3.4), only have some residential buildings with no shops; This can also be seen in the moderate amount of mobility. Lastly, the areas in Amelisweerd (Fig. 3.5) and the Utrecht Heuvelrug (Fig. 3.6 and 3.7), have no buildings at all, and this shows that the primary use of the area is for natural recreation.

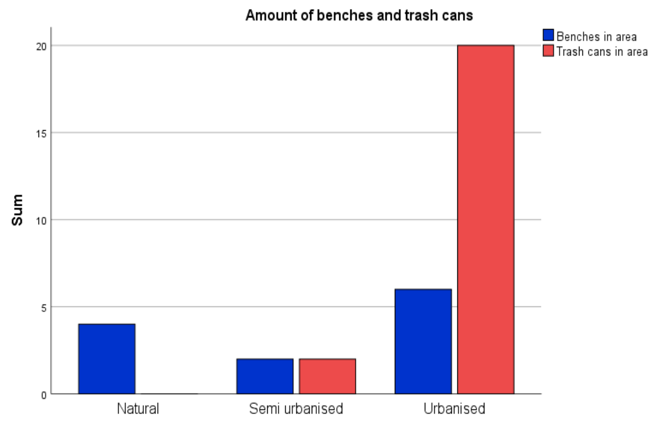


Figure 2*: number of benches and trash cans in each of the areas*

The maps also indicate the number of trash cans and benches. Figure 2 visualizes the comparison in the number of benches and trash cans between the locations. In the natural areas (Utrechtse Heuvelrug and Amelisweerd) there is a significantly lower number of benches and trash cans compared to the urbanized area (Utrecht city centre); In the natural areas, no trash cans were found. In the semi-urbanized areas, only one or two benches and trash cans were identified. The urbanized area distance themselves the most from the other areas especially in terms of trash cans. The urbanized areas have around eight-twelve trash cans and six benches. Even though there are more trashcans, there was a significantly higher amount of litter in the urbanized area, compared to the semi-urbanized and natural areas; At most of the urbanized testing spots, there were more than thirty individual pieces of litter, whilst the semi urbanized area had eleven pieces in total, with the natural area following closely with a total of ten individual pieces of litter.

Figure 3.1: *Water testing area: Oudegracht*

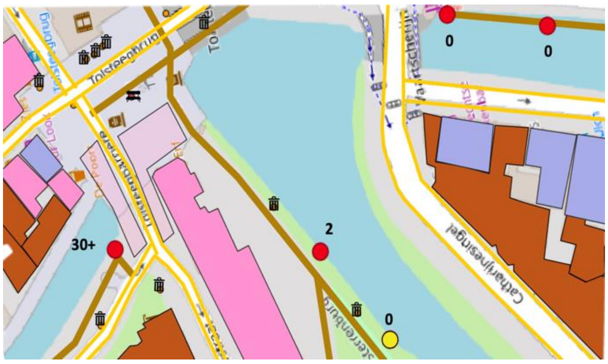


Figure 3.2: *Water testing area: Vaartse Rijn*

Figure 3.3: *Water testing area Zeist de Brink*

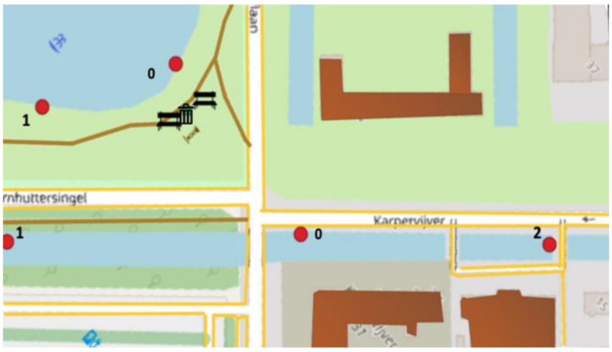


Figure 3.4: *Water testing area: Slot*

Figure 3.5: *Water testing area: Amelisweerd*

Figure 3.6: *Water testing area: Bosmeer 2*

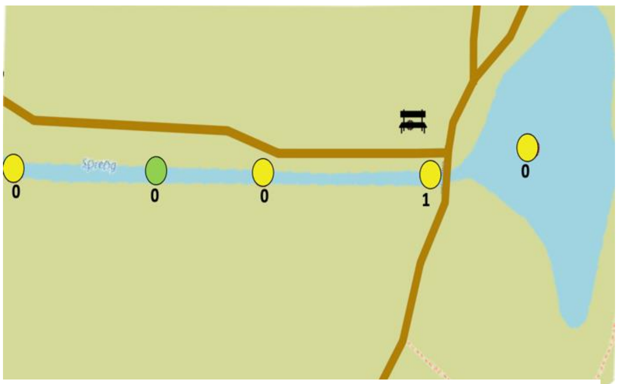
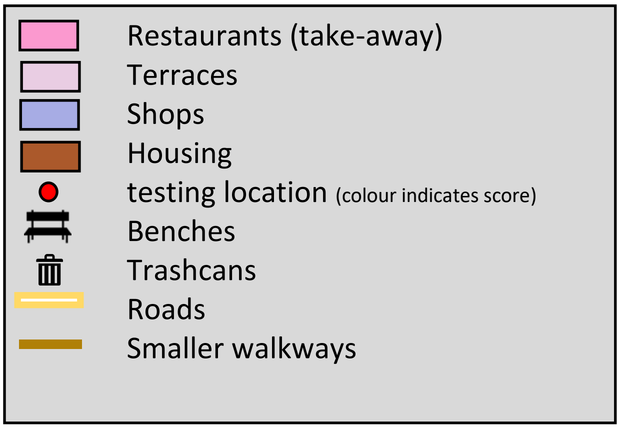


Figure 3.7: *Water testing area: Bosmeer 1*



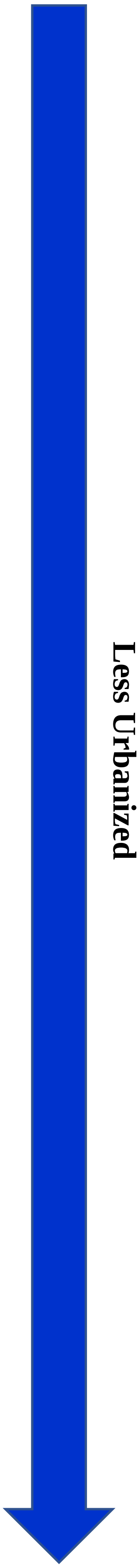


Figure 3: The maps of the seven different testing areas. Every map is 200 by 100 metres in size

4.2. What is the overall water quality in the testing locations?

The graph below shows an overview of the final water quality in the three different categories. The count per measuring scale is included in the slices. To see all the different water measurements made, refer to appendix 9.4.

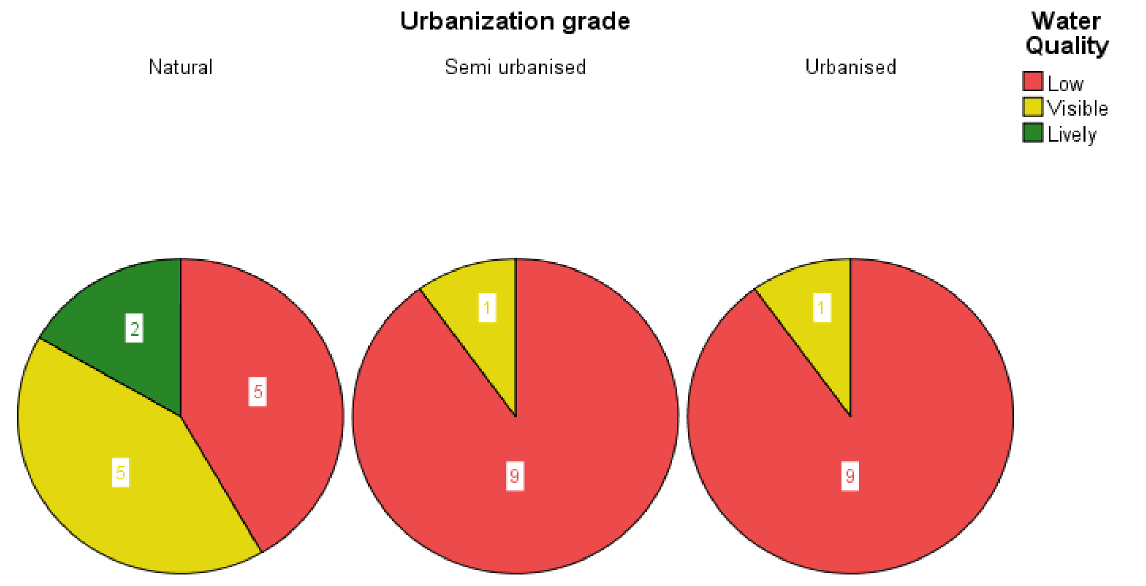


Figure 4: the overall water test score in the different Areas.

The water quality is significantly higher in the natural areas compared to the semi-urbanized and urbanized areas. The semi-urbanized and urbanized locations did not have any lively measurements, with most of the tests coming out as low, except for one visible location. However, there is no significant change in water quality between the semi-urbanized and urbanized area. The Kruskal Wallis test gave a p-value of 0,012. which is lower than the 0,05 p-value. We can therefore conclude that there is a significant difference in water quality between the varying degrees of urban areas.

Figure 5 shows the sum of the counted measurements (low, visible, lively, natural) divided by the different areas. This gives a different overview of how the areas score on these categories in contrast to the final water quality score. It can clearly be seen that in the natural areas there were more natural and lively scores (38 natural, 13 lively), with the least number of low scores. The highest number of low scores were in the urbanized areas (29 low). With this figure, we can see a different picture of how the areas scored on the water tests. The Kruskal Wallis test gave a p-value of 0,000 for all the measurements. This value is lower than the 0,05 therefore we can conclude that there is statistically a significant difference in the water quality measurements between the varying degrees of urban areas.

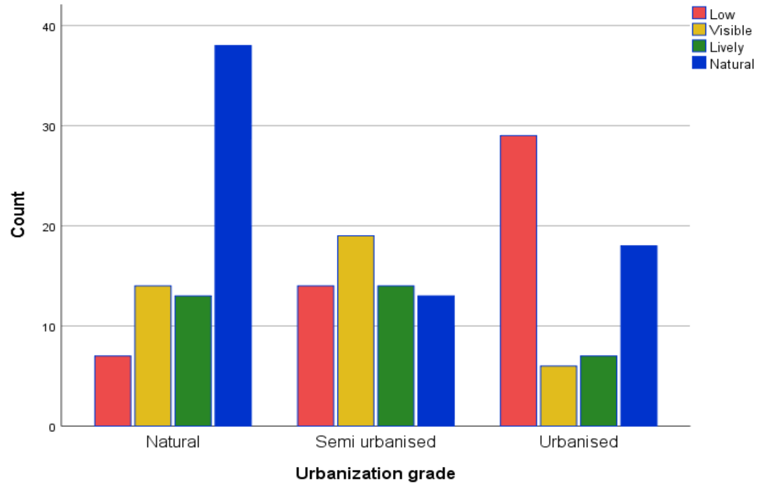


Figure 5: the different scores of the meetjewaterkwaliteit tests in the areas.

4.3. How does mobility affect the water quality?

The graph below shows the correlation between the mobility in each of the areas compared to the water quality. This scatter plot graph combines the counted mobility (x-axis) with the final water qualities (y-axis) on a logarithmic scale to show the results more clearly. As seen in the graph, there are not as many results as the amount of water quality points that were tested. This is due to the fact that the mobility (amount of people walking by) was only tested at one spot per area, whereas the water quality was tested five to seven times per area. The trendline gives an R-squared of 0,092 which indicates that there is no trend between the two different variables. The p-value of the Spearman's R-test was p=-0,463; with a significance value of 0,04. This means that there is a small significant (as 0,04<0,05) correlation between mobility and water quality.

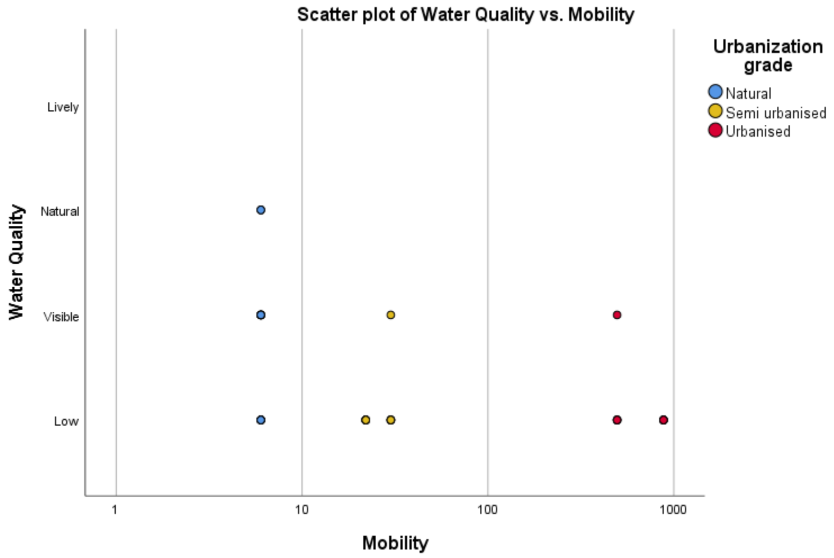


Figure 6: a scatter plot showing the correlation between the mobility and the water quality

5. Discussion

The purpose of this study was to investigate if urban areas have a significant impact on water quality in Utrecht and its surroundings. The following sub-questions will be discussed in the discussion:

1. How do the different areas compare to each other in terms of urbanization?
2. What is the overall water quality in the testing locations?
3. How does mobility affect water quality?

In the results, the urbanization in the areas is compared: natural in Amelisweerd and the Utrechtse Heuvelrug, semi-urbanized in Zeist and urbanized in Utrecht city centre. The difference in water quality and urbanization was substantial between natural and (semi)-urbanized areas, but there was no significant difference found in the final water quality score between the semi-urbanized and urbanized areas.

5.1. Defining and measuring urbanization

Urbanization is a difficult term to define, therefore assessing it is challenging due to the many variables involved. Due to time constraints, not all components of urbanization could be considered or measured extensively in this research. The mobility, for example, was only measured one time per area which can result in an unreliable correlation with the water quality tests. As the weather circumstances can greatly influence the mobility number. However, the data was only used to get a rough overview of the mobility between the different areas and since it was all measured in the same timeslot to limit variation, it can still be a good indicator. In further research, with less time limitation it would be recommended to measure the mobility more than once. Nonetheless, the method used in this research does provide a useful indicator to compare the urbanization between the different areas. Furthermore, restaurants, shops and other recreational buildings attract more people, this can explain the high mobility number in the urbanized area.

5.2. Relation between litter and different worldviews

The results showed that the highest number of litter was found in the more urbanized areas. Moreover, less litter was found in the natural areas, where few to no people live. In a literature review from Aaron and Witt (2011), the authors mentioned: "People living in rural areas, who have greater access to nature, are thought to have more affective connections to nature (Schultz 2000), more interest in pro-nature issues, (Pooley and O'Conner 2000), and more associations with nature as a part of their identity (Clayton and Opotow 2003)." In other words, people that live in more natural areas tend to be more caring for nature than people from urban areas because the people from the natural areas tend to be more connected to nature, according to Aaron and Witte (2011). Making sure that litter does not end up in nature also belongs to "Caring". A possible explanation of the low litter scores in natural areas can be explained by the resident's and visitors' perception of nature. The people in the city centre of Utrecht might be less mindful of the waste they create and leave behind in the waterways since they are less connected to nature. However, more research is necessary to see if the relationship between litter and the perception of nature is correct. Besides the perceptions of nature, social conformity can also be an explanation of the difference in litter presence in the three areas. Social conformity can be described as "a type of social influence involving a change in belief or behaviour to fit in with a group" (McLeod, 2016). In line with social conformity, Rangoni and Jager (2017) researched the “social dynamics of littering”: an area that has no litter influences the people who will visit the area. They will (unconsciously) think that “no litter” is the norm and therefore people will not pollute the area. However, in an area with much litter, the opposite will happen. In other words: trash creates trash, and no trash creates no trash, positive feedback.

5.3. Assessing the overall water quality

The difference in the water quality between the natural and (semi)-urbanized areas can be explained by the fact that (semi)-urbanized areas have a larger mobility number than the natural areas, which can also explain the high number of litter located in the area, which in turn negatively affects the water quality and the surrounding shores. In the natural areas, there was often more room for vegetation to grow, which justifies the difference in plant diversity: relatively high in the natural areas compared to (semi)-urbanized areas. Another possible explanation for the low plant diversity in the (semi)-urbanized areas is that there might be more maintenance by the municipalities along the waterways, for example mowing and planting of specific plant species. Another possible interesting aspect is the effect that the trees have on the water quality. During the fieldwork days, it was observed that waterways that had trees close to it had almost no water plants growing on the bottom due to the leaves falling off the trees and accumulating on the bottom of the waterway. Because of this, almost no water plants could grow since the leaf litter depletes the dissolved oxygen levels in the water (Bayarsaikhan et al., 2018). This resulted in some testing locations scoring low on the water plants category, which ultimately grades down the entire water quality to low. However, to determine a relation between those two variables further research needs to be done.

There was no significant difference found in the final water quality score between the semi-urbanized and urbanized areas. The semi-urbanized area scored higher, in general, looking at the six different categories individually compared to the urbanized area, however, in the final water quality score there was no difference between the areas. A reason for this is because the guidelines of *Winnet* were followed, which say that the lowest score out of all six categories determines the final water quality. In the semi-urbanized areas, four out of ten times the limiting factor was the low score for the plant diversity, which in turn resulted in an overall low water quality final score. These guidelines greatly influence the results of the final water quality, as all five categories could score natural, but the water quality would still end up with a low score. Therefore, a different system to analyze the final water quality score could be helpful to get a better overview of the actual water quality, based upon all six categories. Furthermore, the method used to determine the water quality is from meetjewaterkwaliteit.nl using the guidelines of *Winnet*. It is designed to be an easy-to-access tool for everyone to use. However, the method also has its limitations. The different categories used to measure the water quality are to some extent related to each other. As the water vegetation, shore vegetation and plant diversity are all measuring similar aspects; mainly plant diversity. Furthermore, with this method the water quality itself is not measured, instead, indicators of the measuring water quality are used, which are objective and can result in biases. However, the method can still give a good general indication of the water quality and is used frequently by HDSR which is specialized in water management.

6. Relevance

The results that are attained by conducting water quality tests, as well as the analysis of variables of human interference help us to explain to what extent urbanization affects water quality.

When it comes to the topic of Sustainable water management, this subtopic “water quality in urban areas” is of high relevance. However, an interdisciplinary approach is required to properly assess the goal of reaching and maintaining healthy waterways in and around Utrecht. This interdisciplinary approach taking all subtopics into account is vital to reach the best possible water management. Even though testing the water quality at several locations and analyzing human interventions is an important step towards cleaner waters, it is also necessary to for instance to prevent contaminants from reaching waters in the first place. This can be done by including other subtopics such as analyzing groundwater levels, working with farmers to minimize the usage of pesticides, or increasing the biodiversity along flood defenses to support the ecosystem to recover and cleanse itself. More importantly, a legitimate form of water governance is required to ensure that such measures will be adhered to.

This research in particular or more generally the data collection of the water quality in urban areas has a very high relevance considering the impacts of poor water quality on plants, animals, and ultimately humans and planet earth. By collecting water quality data at several different locations in and around Utrecht and more importantly analyzing the variables of human interference that influence this quality, this research will be contributing to a large database that helps to identify possible risks over time and solutions that can be implemented before more damage can be done. When it comes to identifying possible risk areas of low water quality this data can support the municipalities of Utrecht and the Utrechtse Heuvelrug in locating them and implement solutions. These solutions include, for instance, managing urban development in a way that when creating new urban spaces and housing, natural elements should be included to turn the urban area into a semi urbanized area. Adding these natural elements contribute to the area being able to individually sustain itself in terms of water quality, which saves the municipality a lot of money in the future. Besides these health effects, the costs to taxpayers will exponentially rise with water getting more polluted since the municipality often has to pay for the treatment of the water (Smith, 2020). Finally, it should be in the interest of the municipality of Utrecht to keep urban waterways clean, since it also affects the overall attractiveness of Utrecht and its surroundings, which plays a big role in drawing in tourists, companies, and other actors boosting the economy (HDSR, n.d.).

7. Conclusion

The purpose of this research was to establish a concise overview of the influences of urbanization on the water quality in Utrecht and its surroundings. After conducting research on these influences and performing the data analysis it can be concluded that there is, as expected, a correlation between low water quality and level of urbanization. The data suggests that, as an area gets more exposed to the effects of urbanization, the water quality goes down accordingly. When comparing the areas to each other, differentiation between the natural, semi-urbanized and urbanized areas and the amount of mobility and urbanization can be made. When moving away from natural areas and transition towards semi-urbanized and urbanized areas, an increase can be seen in building density as well as mobility. Plus, this also gives a growing amount of trash/ pollution. Consequently, as these factors increase, the water quality goes down.
To adequately assess water pollution and improve the water quality in and around the city of Utrecht this data can support the municipalities of Utrecht and the Utrechtse Heuvelrug in implementing solutions at the tested areas using the correlations between urbanization factors and water quality. Nonetheless, our research is only a small part of what it takes to ensure clean waterways in and around Utrecht. More research and especially more efficient management activities have to be conducted to create a sustainable environment for water bodies to thrive, in decades to come. We believe that more research should be done on how to adapt to people's worldviews concerning the pollution activities of people with different backgrounds and more importantly in different areas. Furthermore, the influence of the municipalities´ maintenance works on water quality should be studied more. In particular, the efficiency of that maintenance and what can be done to reach even better water quality levels. Lastly, we recommend that the HDSR should improve their methods regarding testing the water quality. Since the water quality level is ultimately graded down by the lowest score, the variables that might have got a higher score are excluded. Therefore, people/residents do not have a starting point on how to improve these variables, because they only see, for instance, a low score instead of the exact scores for every variable.

Generally speaking, low water quality brings considerable health problems both for humans and the environment. As the world is getting more urbanized since more and more people move from rural into urban areas the challenge of managing and sustaining clean waterbodies will become bigger and bigger. Therefore, studying the effects of different levels/variables of urbanization on water quality is vital to ensure that the municipalities of Utrecht and the Utrechtse Heuvelrug can identify possible risk factors as soon as possible and establish a sustainable water management plan that safeguards clean waterways for future generations to come.

8. Reference List

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9. Appendix

9.1 Meetjewaterkwaliteit.nl form

MEET JE WATER KWALITEIT test form for the field work. For more info check:
https://meetjewaterkwaliteit.nl
Date:
Time:
Name:

Step 1: photo and weather conditions. *Circle what is applicable*

1. PHOTO: Take at every measurement a photo of the waterway and riverbank, so that you can compare this over time.

2. Weather conditions: Sunny / Rainy / Foggy / Cloudy / Variable cloudy

Step 2: water test part 1: type, transparency,
Water way's width (estimation in m): _________________

Type of water way. *Circle what is applicable:*
Narrow water way (<5m)/ wide water way (>5m)

Greenery/ vegetation present: *Circle what is applicable* Yes/No

Depth water way (in cm):_____________

Mud thickness (in cm):_______________

Informative: the more transparency, the better the water quality. Transparency up until the bottom indicates a good water quality. The transparency test has to be performed as close as possible to the middle of the water way. ATTENTION: Hold the sechi disk vertical while measuring, you can do it for example from a bridge or scaffold.
Can you see the bottom? *Circle what is applicable* Yes/No
Transparency: (in cm):_______________

In which water quality range belongs your findings? *Circle what is applicable:*

A) Low: transparency less than 20 cm.
B) Visible: transparency between 20 and 40 cm.
C) Lively: transparency between 40 and 60 cm.
D) Naturally: transparency more than 60 cm. Bottom is visible.

Stream velocity: throw a little branch in the water and estimate the distance it moved IN 5 SECONDS in cm) _____________________________________

The water is smelly *Circle what is applicable:* Yes/No
Personal water experience. What grade would you give the water?
1 2 3 4 5 6 7 8 9 10

Part 2: Algae coverage and/ or duckweed

Informative: the less algae and/or duckweed, the better the water quality.
Which situation looks most similar with the area you are measuring?

Floating plants

Floating plants
Water

A. None | B. Little | C. Present | D. Cleary visible | E. A lot

Which situation looks most similar with the are you are measuring?

Underwater plants

Underwater plants
Water

A. None | B. Little | C. Present | D. Clearly visible | E. A lot

Part 3: biodiversity Informative: the more plant species, the better the water quality
ATTENTION: for these measurements, the plants names do not have to be named!

1. How many floating plant species? ……
2. How many underwater plants? ……
3. How many plants that protrude above water? ….
4. How many side plant species? ……
5. How many wall plant species? ……
6. Total amount of species: ……

A. Low Less than 13	B. Visible between the 13 and 20 species	C. Lively between the 21 and 29 species	D. Natural 30 and more

Part 4: litter

Informative: The less litter, the better the water quality.
Tip: Throw all the litter that you found in a trash bin.
How many pieces litter are in the measurement area, in the water and on the side bank (100 m^2)?

____

Which water quality range is the measurement area? *Circle what is applicable:*

A. Low
less than 10 pieces of litter
B. zichtbaar
between 3 and 10 pieces of litter

C. levendig
1-2 pieces of litter
D. natuurlijk
No pieces of litter

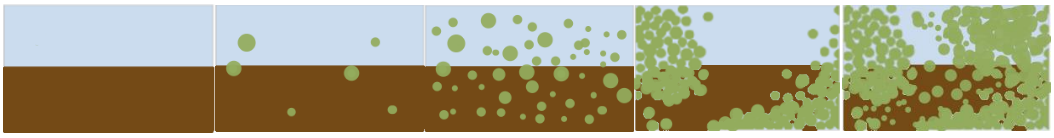
Part 5: Shore vegetation

Informative: An average amount of shore vegetation indicates a good water quality
1. Is een aanwezigheid van een kadermuur? *Circle what is applicable:* Ja/nee

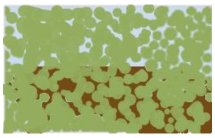
If the answer is yes, skip question two

2. Which situation looks most similar with the are you are measuring?

shore vegetation
Water
Land



A. None	B. Little	C. Present	D. Quite much	E. Much
Value: 0%	*Value: 5%*	*Value: 30%*	*Value: 50%*	*Value: 70%*



F. Dominant
Value: 95%

Part 6: Maintenance

Has there been any noticeable maintenance in the last couple of weeks, such as mowing or maintenance? Yes/No

Has there been any noticeable maintenance in the last couple of weeks around the waterway? Yes/No

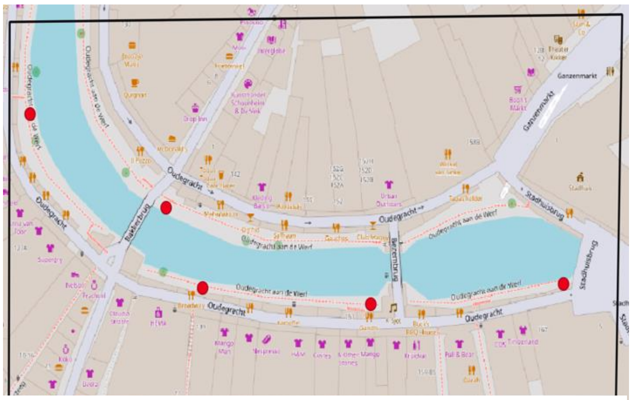
9.2 The different categories, envisioned by Winnet

10. criterium	Low	visible	lively	natural
coverage	>40%	11-40%	5-10%	<5%
transparency	<20cm	>20cm	>40cm	>50cm or visible floor
water vegetation	0 species with floating leaves or species under the surface	1-3 species with floating leaves or species under the surface	4-5 species with floating leaves or species under the surface	6+ species with floating leaves or species under the surface
shore vegetation	0%	0-10% or 90-100% with quay wall	10-40% or 90-100% with quay wall	40-80% of total shore
plant diversity	<13 different species	13-20 species	21-29 species	30 or more species
litter	>10 pieces	3-10 pieces	1-2 pieces	0 pieces

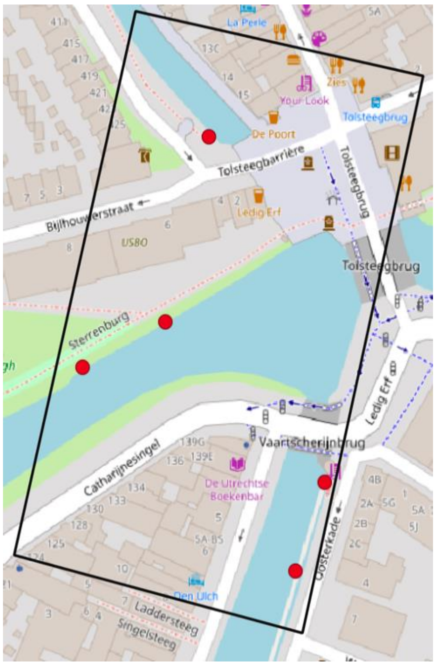
9.3: The testing areas

Testing area 1: Urbanized Area

As the most urbanized area we chose the Oudegracht and the Vaartse Rijn, both located in the city centre of Utrecht. This is an area with a high building density, many stores, and (takeaway) restaurants. We therefore estimate that the mobility in this area will be relatively high on the testing day. The black squares in Figures 4 and 5 indicate the testing area, where we will locate the different trash cans, benches, and (takeaway) restaurants to see how they might influence the water quality. The five red dots on the map in Figure 5 show the testing locations we will use.



***Map 1**: The testing area Oudegracht in the Utrecht City centre.*



***Map 2:** The testing area Vaartse Rijn in the Utrecht City centre*

Testing area 2: Semi-Urbanized area

Our semi-urbanized areas are located in Zeist near de Brink and near Slot Zeist. There are no (takeaway) restaurants or stores in the area; it is exclusively a residential area. We, therefore, expect there to be lower mobility. There will, however, be people that live there, and we believe that the counted mobility will be higher than in the natural areas, but lower than the urbanized areas.

***Map 3:** The testing area Slot Zeist, located in Zeist*

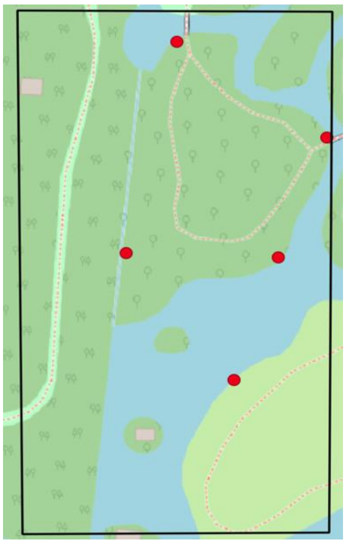
***Map 4:** The testing area De Brinkt, located in Zeist*

Testing area 3: Natural Area

Our nature area is located in the middle of the Utrechtste Heuvelrug near Driebergen-Rijsenburg and in Amelisweerd. In these areas, there is a lot of room for nature, as there are no residential or shopping areas. We therefore believe that there will be less mobility, as there are only small walkways which might affect the mobility.

Map 5: *The testing area Bosmeertje, located in Driebergen-Rijsenburg*

Map 6: *The testing area Bosmeertje extra, located in Driebergen-Rijsenburg*



Map 7: *The testing area located Amelisweerd*

9.4 The water quality test scores

name	transparency	water coverage	water vegetation	shore vegetation	plant diversity	amount of litter		final water quality of testing point
Heuvelrug								
heuvelrug bosmeertje test 1	natural	natural	natural	natural	visible	natural		visible
heuvelrug bosmeertje test 2	lively	lively	natural	natural	visible	lively		visible
heuvelrug bosmeertje test 3	natural	visible	natural	natural	visible	natural		visible
heuvelrug bosmeertje test 4	natural	lively	natural	natural	lively	natural		lively
heuvelrug bosmeertje test 5	natural	visible	natural	natural	visible	natural		visible
heuvelrug extra test point 1	visible	low	visible	natural	low	visible		low
heuvelrug extra test point 2	natural	natural	natural	natural	lively	lively		lively
Amelisweerd								
amelisweerd test 1	natural	natural	visible	natural	lively	lively		visible
amelisweerd test 2	lively	natural	low	natural	visible	natural		low
amelisweerd test 3	natural	lively	low	natural	visible	natural		low
amelisweerd test 4	natural	natural	visible	natural	low	natural		low
amelisweerd test 5	lively	lively	low	visible	low	natural		low
Zeist								
De Brink test 1	natural	lively	visible	natural	visible	lively		visible
De Brink test 2	visible	visible	visible	visible	low	lively		low
De Brink test 3	lively	natural	visible	lively	low	visible		low
De Brink test 4	natural	natural	visible	natural	low	natural		low
De Brink test 5	visible	visible	lively	lively	low	natural		low
Slot Zeist test 1	low	lively	visible	visible	low	natural		low
Slot Zeist test 2	natural	low	visible	visible	low	lively		low
Slot Zeist test 3	natural	low	low	visible	low	natural		low
Slot Zeist test 4	lively	low	low	lively	visible	lively		low
Slot Zeist test 5	visible	natural	low	lively	visible	lively		low
Utrecht City Centre								
Utrecht City Centre test 1 (macdo)	lively	natural	low	low	low	low		low
Utrecht City Centre test 2 (tegenover broodje mario)	natural	natural	low	low	low	low		low
Utrecht City Centre test 3 (broadway restaurant)	lively	natural	low	low	low	low		low
Utrecht City Centre test 4 (Gandhi point)	Lively	natural	low	low	low	low		low
Utrecht City Centre test 5 (Stadsschouwbrug)	visible	natural	low	low	low	low		low
Utrecht City Centre test 6 (Vaartsche rijn brug)	natural	natural	low	visible	low	natural		low
Utrecht City Centre test 7 (Vaartsche rijn station)	natural	natural	low	visible	low	natural		low
Utrecht City Centre test 8 (Sterrenburg)	lively	natural	low	natural	visible	lively		low
Utrecht City Centre test 9 (Catharijne singel)	lively	natural	visible	natural	visible	natural		visible
Utrecht City Centre test 10 (oudegracht)	lively	natural	low	low	low	low		low

9.5 An overview of the mobility related data

This table includes the different mobility factors that were measured during the fieldwork week.

	testing area	**mobility per area**		**total mobility**	**trash cans**	**benches**
Natural area	Utrecht Heuvelrug	Bosmeertje	6	**12**	0	2
	Amelisweerd	Amelisweerd	6		0	2
Semi-urbanized area	Zeist	de Brink	30		1	0
	Zeist	Slot Zeist	22	**52**	1	2
urbanized area	Utrecht	Oudegracht	880		12	5
	Utrecht	Vaartse rijn	495	1375	9	1

9.6 Data management plan

This research is mostly focused on natural-science observations and results, the data will be coming from the selected points in waterways in and around Utrecht.

The collected data from the different measuring points will be written down/inserted in a survey, which will be transported to a connected GQIS map. The map will be accessible for every colleague in the research team. This stored data is then evaluated using this GQIS map and consequently we will create different charts and graph in Excel to illustrate our findings. Our findings and graphics will be combined in a Word Document, into our projects Teams channel. When our research is finished and the data is no longer needed, the information will be deleted.

No interviews will be conducted; hence we will not have to include a privacy policy for possible participants. It is important to mention that all selected measuring points are not on private terrain or on illegal to enter grounds and will thus not violate any rules.