Impetus

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Innovative Measurement Tool towards Urban Environmental Awareness

Street Scorecards

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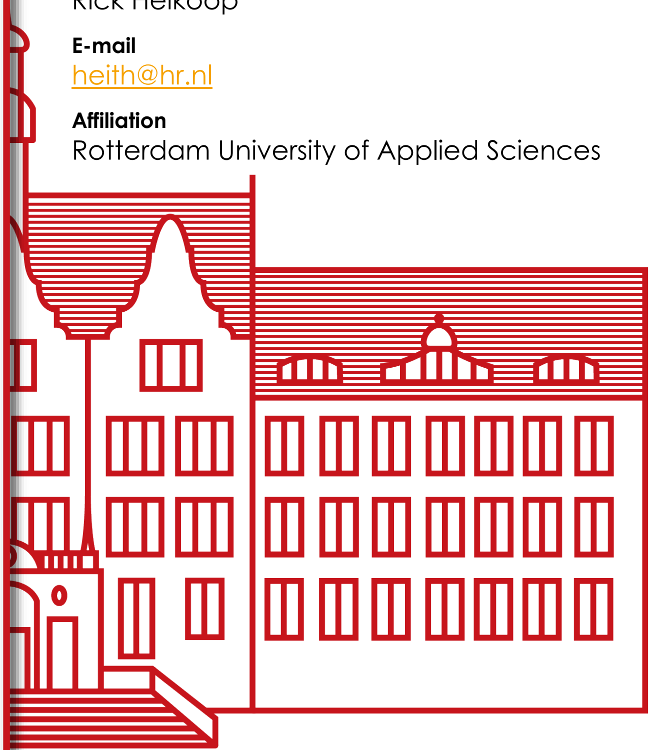

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1.1 Introduction

Human-induced climate change is causing dangerous and widespread disruption in nature and is affecting the lives of billions of people around the world, despite efforts to reduce the risks. The people and ecosystems least able to cope are being hardest hit, according to scientists in the latest Intergovernmental Panel on Climate Change report [1]. For cities, some aspects of climate change may be amplified, including heat, flooding from heavy precipitation events, and sea level rise in coastal cities [2]. The world has recorded the hottest decade on record (2010–2020) with 2019 being the second warmest year on record [3]. Implementing nature-based solutions on a larger scale would increase climate resilience and contribute to multiple Green Deal objectives. Blue green (as opposed to grey) infrastructures are “no regret” solutions and provide environmental, social, and economic benefits and help build climate resilience [4]. According to the European Environment Agency, cities have the potential to become a major driving force for a green and just recovery after the COVID-19 pandemic [5]. The challenge is now how to integrate these measures in our cities and to assume directive roles in their implementation [6].

In 2018, an estimated 55.3% of the world’s population lived in urban settlements. By 2030, urban areas are projected to house 60% of people globally [7]. All these people will be directly affected by the impacts of climate change. One of the solutions that has been suggested to make cities more resilient is the urban green infrastructure (UGI) [8]. Urban green and blue spaces and green infrastructure are very effective to combat the effects of climate change and to tackle water and heat risks. A common method to evaluate such contributions is to measure the ecosystem services (ES) provided by the vegetation or water bodies present in urban green and blue spaces (UGBS) that constitute the UGI [9]. Examples of urban ecosystem services are air purification, carbon storage, noise reduction, run-off retention, cooling, and recreation [10].

Urban communities are the most affected by changes in the microclimate as a result of climate change. There are examples resilience scorecards that help communities to become resilient [11], or scorecards that aim to assess disaster resilience on the city scale, such as the he United Nations Office for Disaster Risk Reduction (UNDRR) Scorecard [12], or scorecards with sets of indicators that assist communities to perform a self-evaluation, such as the Resilience Performance Scorecard [13]. Labdaoui et al. developed the Street Walkability and Thermal Comfort index (SWTCI) [14], which includes shade.

Most cities do know, on a city scale, which neighbourhoods have less trees, are densely populated, have less parks, and are less green, or in which neighbourhoods lush front yards and an abundance of urban green spots are present. At the level of the street, cities in general do not have much insight regarding which climate adaptation measures are present. In a changing climate that more often causes heat waves, for example, it would be crucial to know in which streets the climate adaptation measures are present and are more or less ready for the impacts of climate change, and which streets are not. In the streets that do not have climate adaptive measures, local governments should invest in the implementation of climate adaptation measures.

An instrument such as a scorecard that assesses the climate adaptive measures at the street level and attaches climate adaptation labels to street segments and streets, is accurate and is easy to use by residents and communities to self-assess streets and neighbourhoods, would be very valuable to identify the least adaptive streets and raise awareness about climate adaptation among the members of the community. In the literature, no such scorecard or instrument was found that systematically assess the presence of climate adaptation measures at street segments or entire streets. This paper therefore proposes a new method to assess climate adaptation measures at the street level, which has been proven to be very successful in scoring measures and labelling streets after testing in two districts in two different Dutch cities. With this method, we hope to equip communities and local government units with a new method to assess climate adaptation measures in their locality.

1.2 Street climate scorecard

To be able to compare streets in different districts, street segments were chosen as units of comparison. Streets are composed of one or more street segments and street segments are used in the virtual street audit of front yards [15] or in streetscapes studies [8,16], or in studies related to crime behaviour [17] or walking speed [18]. A street segment is typically defined as the portion of a public or private street, between its intersections with two other public or private streets [19] (see Figure 1.1).

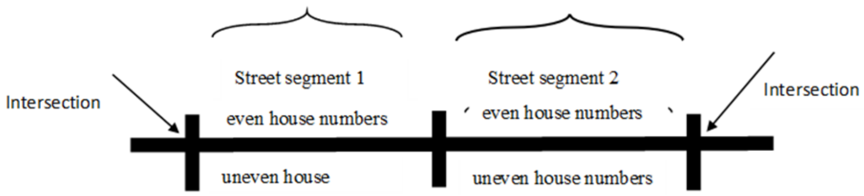


Figure 1.1. Street segment.

For this study, two different urban districts in the cities of Groningen and Rotterdam were selected by the civil servants of the two cities that were involved in the project "Citizen participation in climate adaptation". The two districts were selected based on the fact that the districts are considered as particularly vulnerable to climate change [19]. In order to make the assessment comparable, observations of specific street features and measures both in the street and the housing units at both sides of the street were included in the assessment, and observations were converted into a 100 m street length value. Google street view was used in the field to measure the length of the street segment, then a conversion factor was determined for each street, e.g., divided by 1.2 for a street length of 120 m, and the values were converted into a score for a length of 100 m of street length. In order to be able to score the microclimate adaptation facilities or measures at street level, a literature review was undertaken and a selection of scoreable adaptation facilities or measures was identified. These were divided into three main categories—the green, blue, and grey categories. Each category is a combination of a number of scorable measures at street level. Field visits were undertaken to the two cities for ocular inspection and assessment of the selected streets. In order to make the results of the assessments and the ocular inspection unambiguous, a reference card was made for easy reference. The QR code on the reference card can be opened with a mobile phone and opens an excel file, where the observations can be directly tabulated in excel.

1.3 Scoring and labelling scorecard 1.0

The scorable adaptation measures at the street level were calculated per street segment. In total, a street segment could be awarded a score of 100 points (Figure 1.2). The scores of 1–100 for each street segment were divided into 10 climate adaptation labels with different colors. The presence of many adaptation measures translated into a high score and corresponded with a dark green color. Street segments with few or no adaptation measures translated into a low score and the corresponding color was dark red. A deduction of score points was applied in the grey category. The scoring was composed of three categories, and each category contained one or more measures. For each category, weight was given. The highest weight was given to measures that were most common with the highest chance to be present in a street, and at the same time provided a combination of ecosystem services. Large urban trees and (green) front yards were the most common and provide shade, coolness, and increased infiltration capacity, among other ecosystem services. After testing different measures with different weights totalling 100 points, it was decided to do a full test in two districts with the measures and weights presented in Table 1.1, divided over three categories.

Label	Points
A+	91-100
A	81-90
A-	71-80
B	61-70
C	51-60
D	41-50
E	31-40
F	21-30
G	10-20
H	0-10

Figure 1.2. Climate adaptation labels.

Table 1.1. Climate adaptation measures and weight.

Category	Measure	Maximum Score
Green category	Urban trees	+40
Green category	Green walls	+4
Green category	Façade gardens/front yards	+16
Green category	Green strips	+13
Green category	Climate adaptive roofs	+2
Green category	Green parking spaces	+2
Blue category	Rain barrels	+1
Blue category	Permeable pavement	+3
Blue category	Bioswale	+6
Blue category	Surface water	+6
Grey category	Shaded areas, natural or artificial	+2
Grey category	Additional grey parking spaces	−2 to +2
Grey category	Unpaved surfaces	+2
Grey category	Soil sealed driving lanes	+ 1 or −1 per lane

As awareness among community members was an important objective of the scorecard, reference cards were designed that showed examples of the measure, complementary to the excel file, and supported the researcher in the field while doing the assessment in the field. The front and the back of the reference card are presented in Figure 1.3 and Figure 1.4.

Figure 1.3. Reference card ver. 1.0, front.

Figure 1.4. Reference card ver. 1.0, back.

Green Category Climate Adaptation Facilities and Measures

The green measures are the combined value of the following adaptation facilities or measures, namely trees, green walls, façade gardens, green strips, climate-adaptive roofs, and green parking spaces.

Urban Trees

Urban trees represent a large portion of the urban tree canopy and provide a significant amount of ecosystem services for mitigation of the negative environmental impact [20]. The World Health Organization has described in detail the beneficial aspects of urban green spaces [21], such as reduced exposure to air pollution and a reduction of the heat island effect. Trees planted along streets and roads may dampen noise and air pollution levels in residential houses and mitigate the adverse health effects of proximity to busy roads. Wang showed that [22] in the urban green infrastructure, the outdoor human thermal comfort and indoor environment improves [23].

The trees category is divided into three subcategories, namely 0–10 m, 10–15 m, and above 15 m, so as to make the indicator trees scorable. The average floor height in the Netherlands is between 2.4–2.6 according to article 4.28 of the National Building Code [24]. Including the floor material itself, the average floor is about 3 m high. A tree with a height that is just slightly higher than the height of a typical Dutch single-family dwelling, up to 10 m in height, will be tagged as a category 1 tree, with a value of 2. A tree between 10–15 m in height will be tagged as a category 2 tree, with a value of 3, and very tall and older trees that are above 15 m in height will be tagged as a category 3 tree, with a value of 4. The categorization of trees into different categories of 0–10 m, 10–15 m, and above 15 m was chosen so that the three categories could easily be assessed through ocular observation. This categorization was not presented in other studies, but proved to be very efficient for easy analysis. The number of trees on both sides of the street segment was counted, categorized, and tabulated. The maximum score for the urban trees measure was set at 40.

Green Walls

Wall shrubs and climbing plants provide significant thermoregulation around brick walls and appear to be a feasible green wall system for retrofitting existing housing stock in temperate climates [25]. Green wall installation can simultaneously provide multiple benefits such as noise reduction, contribute to urban ecosystems, pollutant removal, and cooling. The green wall had potential to mitigate daytime air temperature in the cooler seasons in all of the investigated climate zones, except in Csb, where a slight increase was found. Such a decrease could be as high as ~5 °C and it might be decisive for mitigating UHI in some cities [26]. Because of the thermal resistance effect of green walls, the temperature reduction at the pedestrian level of the canyon center was 1.16 °C in the flat street canyon, such as residential areas, in a situation where streets are composed of mainly green walls [27]. Streets that do not have green walls represent a value of 0. Streets that are composed of 1–25% green roofs represent a value of 2, 25–50% a value of 2, 51–75% a value of 3, and 76–100% a value of 4.

Façade Gardens / Front Yards

Paving over of front yards (soil sealing) reduces the environmental and social benefits of front yards and trees. Front yards in private residences play an important role in the soil sealing problem of cities worldwide [15]. The impervious cover of front yards contributes to the problems of the urban heat island effect and urban floods, and makes urban neighbourhoods less pleasant. Private gardens play an important role as urban green space and can improve microclimate and address the impacts of climate change – specifically the urban heat island (UHI) effect. Paving over front yards, thus soil sealing, reduces the environmental benefit of front yards. Residential (front) yards comprise a considerable portion of land and green space in the suburbs of cities. A recent study in Rotterdam shows that in an older district, most front yards are soil sealed [18]. The European commission formulated a green infrastructure (GI) strategy to enhance Europe's natural capital [28]. Ecosystem-based approaches are strategies and measures that harness the adaptive forces of nature [29]. Cities are encouraging private citizens more and more to involve citizens, municipalities, and other stakeholders in replacing pavements with vegetation [30]. Cities even provide grants and subsidies to citizens for unhardening private gardens, such as in the city of Rotterdam, which has a subsidy of €10 per m2 for realised green space, to €500 per m3 water storage up to €1500 [31]. Unsealed urban gardens provide patches of natural surfaces that help reduce run-off, reducing the likelihood of urban flooding and replenishing groundwater by allowing rainwater to infiltrate. Small changes households make to their gardens over an extended period of time can add up to major environmental impacts. Adding more paved areas to gardens increases the risk of urban flooding: rainfall cannot seep into the ground and, instead, water runs off the paved surfaces into storm water and sewage systems [32]. It contributes to the development of "sponge cities", where cities are designed as sponges and are designed to absorb and capture rainwater for reducing flooding worldwide [33]. Cities should also invest in nature-based solutions to tackle water and heat risks [34]. In addition to this, urban gardens as a form of urban greenspace are an important resource for the psychosocial restoration of urban dwellers [35], and private gardens are important in terms of the ecological value of cities in complementing public green areas [36]. Not all houses are constructed with (space for) front yards. In order to reduce the temperature and heat stress during a heat wave, residents in Rotterdam are encouraged by the local government to create façade gardens and green facades, which have proven to be effective tools [26]. An example of this is the thousand façade gardens initiative in Rotterdam [37]. Street segments that do not have any façade gardens or front yards are given no points. Streets that have façade gardens in 1–50% of the houses in the street segment represent 5 points, streets with façade gardens in 50–100% of the houses represent 6 points. Houses that have front yards in 1–25% of the housing units represent a value of 10 points, 25–50% represent 12 points, 50–75% represent 14 points, and 75–100% represent 16 points.

Green Strips

Green strips constitute similar benefits as front yards. Green strips could be larger in size than front yards. Green strips are often provided as a beautification project or as a place for dogs in densely populated urban areas. In order to provide water storage or to increase the infiltration capacity, green strips should be placed lower than street level. Street segments that have green strips of max 25 sqm represent a value of 9 points, 25–100 m represent a value of 11 points, and more than 100 sqm represent a value of 13 points.

Climate-Adaptive Roofs

The presence of climate-adaptive roofs can be established by using Google Maps (satellite view). Examples of climate-adaptive roofs are green roofs, roofs with a high albedo (highly reflective roofs, which absorb less heat [38], and blue roofs. Green roofs can easily be recognized on Google Maps, because from above plants/grass and other greenery can be spotted. A high albedo roof is easy to spot because it is often bright white. Houses in the street segment that do have climate-adaptive roofs in 1–50% of the houses represent 1 point, and if more than 50% of the houses in the have climate-adaptive roofs, they represent a value of 2.

Green Parking Spaces

Green parking spaces differ from regular parking spaces because they allow the water to infiltrate, and they contribute significantly to reducing runoff [39]. If the parking lots are made of porous paving materials, between the tiles of parking spots, there are often patches of grass [40]. Houses in the street segment that do have green parking spaces in 1–50% of the houses represent 1 point, and if more than 50% of the houses have green parking spaces, they represent a value of 2.

Blue Category Climate-Adaptation Facilities and Measures

Rain Barrels

Rain barrels or rainwater tanks store water and relieve some stress on the sewage system during heavy precipitation. Rain barrels delay the time that it takes for water to flow into the system. Water from a roof connected to a rain barrel does not flow immediately into the sewage system, and rainwater harvesting can be used as a remedial measure and can help in flood reduction [41]. If one or more rain barrels are present in the street segment, the segment represents a value of 1.

Permeable Pavement

Water-permeable pavements are porous or are laid to allow voids, have an open structure, or are made of partially pervious materials. They allow water to pass through or around them into the soil. This has various advantages: rainwater can infiltrate into the ground, groundwater is replenished, and sewerage systems are relieved [40]. If there is permeable pavement in the street, on the sidewalk, or both, they represent a value of 1, 2, or 3, respectively.

Bioswale

A bioswale is an adaptive measure that has the ability to store water during heavy rain and it redirects surface water to groundwater. It also aids in infiltration and often looks aesthetically pleasing [40,42]. If a bioswale is located within 50 m of the street segment, it represents a value of 6.

Surface Water

Surface water nearby functions as natural water storage. If the surface water is located nearby and is lower than the street level, water can be channelled into the surface water with natural gravity. If the surface water is located within 50 m of the street segment, it represents a value of 6.

Grey Category Climate-Adaptation Facilities and Measures

Shaded Areas (Canopy)

Bonus points can be earned for shaded areas. Shade is beneficial for heat stress relief [43]. Shade may be provided through canopy, natural shadows from trees, or by artificial shadow facilities. If natural canopy is present or there is artificial shade provision, it represents a value of 1 or 2 respectively.

Unpaved Surfaces

If unpaved areas are present, they provide an additional storage capacity for precipitation and may provide cooling facilities through natural vegetation. If unpaved surfaces are located lower than the street level, they represent a value of 2.

Grey Parking Spaces

Paved surfaces, especially parking lots, occupy a significant proportion of the horizontal surface area in cities. The low albedo of many of these parking lots contributes to the urban heat island (UHI) and affects the local microclimate around them. Parking spaces heat up during the day and contribute to a higher temperature. At night, these warm surfaces contribute to the urban heat island effect [44]. If the cars are parked on the driving lane, without additional parking places, the street segments represent a value of 2. If additional designated parking places are present, the segments represent a deduction of 2 points.

Driving Lane

Impermeable "grey" driving lanes with a low permeability similar to the grey parking spaces occupy a significant proportion of the horizontal surface area in cities. The low albedo of many of these driving lanes contributes to the urban heat island (UHI) and affects the local microclimate around them. Driving lanes heat up during the day and contribute to a higher temperature. At night, these warm surfaces contribute to the urban heat island effect [44]. For sustainable urban development, permeable pavement promotes urban water management [40]. If the street segment is a car free street, without soil sealed driving lanes, it represents a value of 2. For each soil sealed driving lane, one point will be deducted.

1.4 Case study – Scores Hillesluis district Rotterdam using scorecard 1.0

Rotterdam, Hillesluis District

The Hillesluis district is located on the southern part of the city of Rotterdam and has a population of around 12,050 residents with a population density of 14,433 [45] residents per square kilometer in 2020. The district is characterized by small streets and a high population density. The narrow streets are alternated by green spaces. The district was constructed between 1920 and 1930 for workers in the port of Rotterdam. Renovation projects have replaced some of the older apartment blocks with newer housing units, but around 70 % of the housing stock date back before 1945.

The district consists mostly of multifamily dwellings and are predominantly social housing (47%) or rental units (27%), with 25% owner-occupied. The population is relatively younger and lower educated compared with other parts of the city with a lower average household income. Around 73% of the population has a non-Western background. About half of the households (47%) are single-person households [46].

In the Hillesluis district, 21 streets were assessed with a total of 42 street segments. The scores per street segment were categorized and a corresponding label (Figure 1.2) was given to each street segment and is visualized in Figure 1.5. The span of the distribution ranges between the lowest score of 3, which corresponds with the lowest climate-adaptiveness label H, and the highest score of 63, which corresponds with climate-adaptiveness label B. The average segment score in Paddepoel was 42, which corresponds to label climate-adaptiveness label D in Table 1.2.

Table 1.2. Scores per segment in the Hillesluis district.

Name of the street	Segment 1	Segment 2	Segment 3	Segment 4	Total Score
Imobilialaan	51				51
Imobiliastraat	24				24
Zeeuwsestraat	3				3
Vlasakkerstraat	10	37	42	14	103
Drentsestraat	48	7			55
Riederstraat	35				35
Overijsselsestraat	27	50	7	20	104
Utrechtsestraat	20				20
Hollandsestraat	6	4	37	28	75
Donkerslootstraat	24	52			76
Riederlaan	63	37			100
Zaadakkerstraat	5				5
Westerbeekstraat	28	45	43		116
Friesestraat	24				24
Brabantsestraat	32				32
Breeweg	50				50
Beijerlandsestraat	45	41			86
West-Varkenoordseweg	36	29	33		98
Beukelaarsstraat	12	39			51
Blokweg	28	17			45
Beverstraat	13	38	24		75
Total number of segments:	42				
Total score:	1228				
Average segment score:	29				

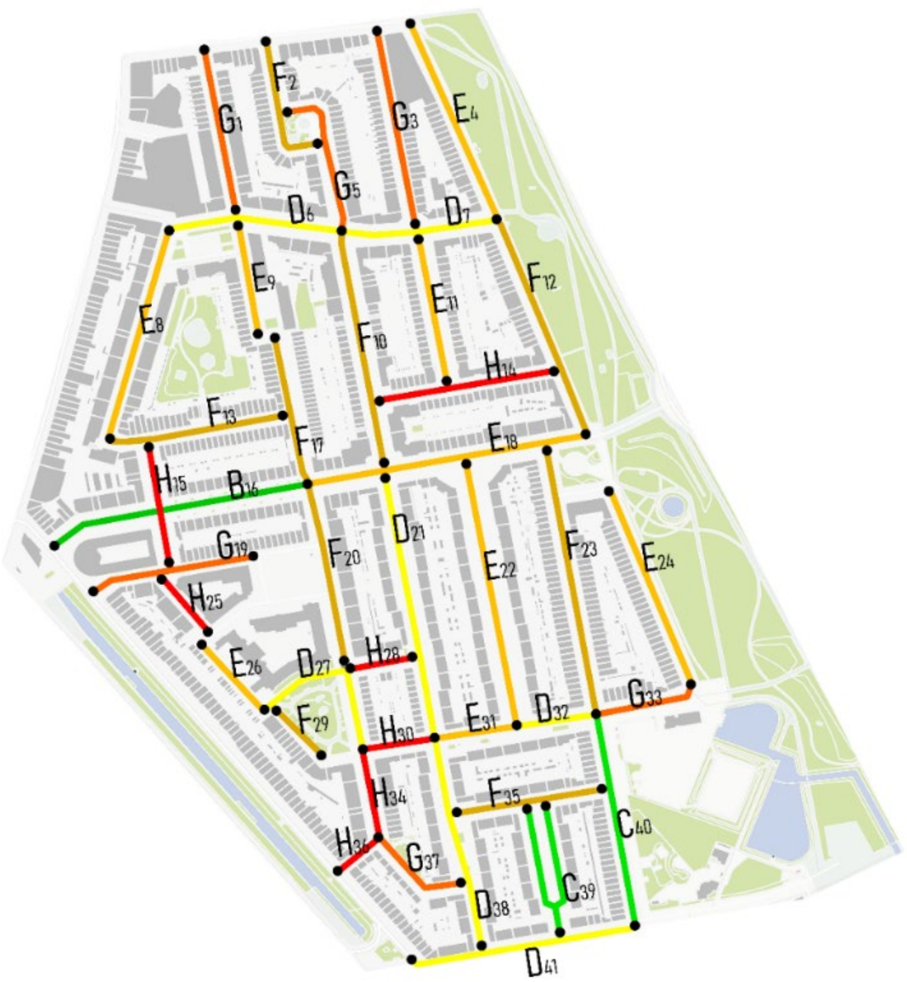


Figure 1.5. Visualization of labels for the Hillesluis district.

Hillesluis District Green Category Climate Adaptation Facilities and Measures

In total, 21 streets in the Hillesluis district were assessed with a total of 42 street segments. The scores of the green category of each street segment are presented in Table 1.3.

The assessment of the streets shows that all streets in the Hillesluis district had trees, except for three street segments. Just four street segments in the Hillesluis district scored the highest score for trees. The average score for trees was 20, which is half of the maximum score of 40. When we look at the green walls score, just five street segments fall in the lowest 1–25% green walls category.

In the façade garden/front yard category, nine street segments did not have any façade garden and/or front yard. Out of the remaining 43 street segments, 20 segments fell into the category of 1–50% façade garden and two street segments fell into the category of 50–100% façade garden. In 10 street segments, front yards were present, although six fell in the lowest category of 1–25% front yard and only four street segments fell in the category 50–75% green front yards.

Hillesluis District Blue Category

The scores of the blue category of each street segment are presented in Table 4. No rain barrels were observed in the Hillesluis district at all, and no permeable pavement in the street or sidewalk was observed. No bioswales were present either. Just three street segments had surface water within 50 m distance away from the street segment. Only three street segments scored 6 points out of a total of a maximum of 16 points.

Hillesluis District Grey Category

The scores of the grey category of each street segment are presented in Table 5. Most of the street segments had shaded areas from trees (one point), but none of the streets had artificial shaded areas (two points). Only 9 segments out of 42 segments did not have any shade at all.

In none of the streets were open unpaved (green) areas observed that were located lower than the level of the paved areas so as to provide infiltration capacity. Neither were unpaved areas observed that were located higher than street level.

In all 42 street segments, designated parking spaces were present (deduction of two points), contributing to urban heat stress.

In 26 street segments, one driving lane was present while in 16 street segments, two way driving lanes were present (deduction of one point per driving lane).

None of the streets scored the maximum 7 points. In total, 18 street segments scored two deduction points, 20 streets scored three deduction points, and 4 street segments scored four deduction points.

Total Score Hillesluis District

When we look closer at the total score of the individual street segments in the Hillesluis district, it can be seen that the maximum score is 58 in Westerbeekstraat, segment 2, and the lowest score in Zaadakkerstraat, segment 1 (see Table 1.3). For more detailed information about the scores per street, please see the Case Study Hillesluis.docx.

Table 1.3. Total score street segments in the Hillesluis district.

	Points	Beverstraat segment 1	Beverstraat segment 2	Beverstraat segment 3	Blokweg segment 1	Blokweg segment 2	Beukelaarsstraat segment 1	Beukelaarsstraat segment 2	West-Varkenoordseweg segment	West-Varkenoordseweg segment	West-Varkenoordseweg segment	Beijerlandsestraat segment 1	Beijerlandsestraat segment 2	Breeweg segment 1	Brabantse straat segment 1	Friesestraat segment 1	Westerbeek segment 1	Westerbeek segment 2	Westerbeek segment 3	Zaadakkerstraat segment 1	Riederlaan segment 1	Riederlaan segment 2	Donkerslootstraat segment 1	Donkerslootstraat segment 2	Hollandsestraat segment 1	Hollandsestraat segment 2	Hollandsestraat segment 3	Hollandsestraat segment 4	Utrechtsestraat segment 1	Overijsselsestraat segment 1	Overijsselsestraat segment 2	Overijsselsestraat segment 3	Overijsselsestraat segment 4	Riederstraat segment 1	Drentsestraat segment 1	Drentsestraat segment 2	Vlasakkerstraat segment 1	Vlasakkerstraat segment 2	Vlasakkerstraat segment 3	Vlasakkerstraat segment 4	Zeeuwsestraat segment 1	Imobiliastraat segment 1	Imobilialaan segment 1	Average
Total score	100	13	38	24	28	17	12	39	36	39	33	45	41	50	32	24	28	58	34	5	51	37	24	39	19	4	37	28	20	27	50	7	17	31	48	7	10	37	42	14	3	24	51	29

1.5 Hillesluis district results

The highest score in the Hillesluis district was observed in Westerbeekstraat, segment 2 (Figure 1.6 and Figure 1.7). Westerbeekstraat segment 2, scored 58 points for trees, which is just below the maximum of 40 points, as well as zero points for green walls, fourteen points for green front yards (75–100%), zero points for green strips, zero points for climate adaptive roofs, and zero points for green parking lots. In the blue category, Westerbeekstraat, segment 2, does not score any points for the presence of rain barrels, permeable streets or pavements, or nearby surface water. In the grey category, Westebeekstraat, segment 2, scored one point for shadows from canopy, zero points for green areas, and a deduction of two points for the presence of (soil-sealed) parking spaces and a deduction of 1 point for a (soil-sealed) driving lane.

Figure 1.6. Westerbeekstraat [47].

Figure 1.7. Westerbeekstraat [47].

The lowest score in the Hillesluis district, of three points, was Zeeuwsestraat, but as this street was very short, about 35 m, with only four housing units, the next street with the lowest score will be discussed here. The street with the second lowest score, of five points, was observed in Zaadakkerstraat (Figure 1.8 and Figure 1.9).

Zaadakkerstraat scored just three points for trees. Zero points for green walls, five points for façade gardens (1–50%), zero points for green strips, zero points for climate adaptive roofs, and zero points for green parking lots.

In the blue category, Zaadakkerstraat did not score any points for the presence of rain barrels, permeable streets or pavements, or nearby surface water.

In the grey category, Zaadakkerstraat scored zero points for shadows from canopy, zero points for green areas, and a deduction of two points for the presence of (soil-sealed) parking spaces and a deduction of one point for one (soil-sealed) driving lane.

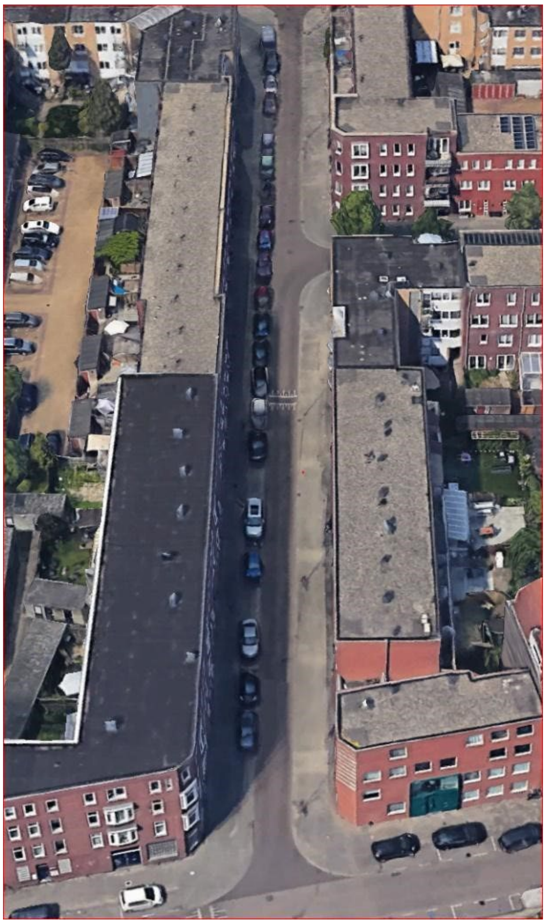


Figure 1.8. Zaadakkerstraat [48].

Figure 1.9. Zaadakkerstraat [48].

1.6 Discussion

The aim of the study was to create a tool, a score card, that was relatively easy to use by community members and stakeholders that could assess the presence of climate adaptive measures in streets and give insight into the level of climate adaptation for a street segment or an entire street. At the neighbourhood level, studies have already shown that there is a mismatch between demand and supply of ecosystem services in neighbourhoods and values for different ecosystem services for cooling and run-off retention and air purification [9]. These studies do not assess and score climate adaptation measures for an entire street. The objective was therefore to come up with a scorecard that can label a street segment or an entire street with a score of 1–100 and a label from A+++ to G, similar to the new EU energy labels for selected appliances, which were effective as of 1 March 2021 [53].

The method that was used in this research enabled the assessment of the presence of climate adaptive measures in different street segments. The results show that the scorecard method generated a clear numerical distinction between streets and street segments that contain climate adaptive measures and streets that do not have such climate adaptive measures.

As streets vary in length and longer streets tend to differ in terms of the date of construction for the housing units and building style, it is more effective to work with street segments as the unit of analysis. Other research in other fields of study also use street segments as units of analysis, such as virtual street audits of front yards [18] or streetscapes studies [8,16], or studies related to crime behaviour [17] or walking speed [18]. To make the analysis of different streets segments comparable, a conversation factor was used to recalculate the values for a 100 m street length. This recalculation of values for 100 m of street length was not discussed in other literature, but it was effective to compare the street segments.

A literature review was undertaken and the most important climate adaptation measures were selected. The selected measures are not complete as many other climate adaptation measures were found in the literature and on websites about green and blue measures 6. The selection of climate adaptation measures was based on the most common measures that are present in Dutch streets and cities. The contribution of urban green infrastructure (UGI) to human well-being has been demonstrated in several studies.

The first selected climate adaptation measure was urban trees, as they represent a large portion of urban tree canopy and provide a significant amount of ecosystem services for mitigation of the negative environmental impact [20], and they improve the outdoor human thermal comfort and indoor environment [23]. Front yards in private residence play an important role in the soil sealing problem of cities worldwide [27]. The impervious cover of front yards contributes to the problems of the urban heat island effect and urban floods, and makes urban neighbourhoods less pleasant. Private gardens play an important role as urban green spaces, and can improve the microclimate and address the impacts of climate change—specifically the urban heat island (UHI) effect. Green strips constitute similar benefits as front yards.

Climate adaptive roofs are green roofs, roofs with a high albedo (highly reflective roofs, which absorb less heat [38]), and blue roofs. Green roofs were chosen as an upcoming adaptive measure that can easily be recognized on Google maps, because, from above, plants/grass and other greenery can be spotted. Green parking spaces are an upcoming climate adaptive measure and they differ from regular parking spaces because they allow the water to infiltrate and contribute significantly to reducing runoff [39]. If parking lots are made of porous paving materials, between the tiles of parking spots there are often patches of grass [44]. Rain barrels or rain water tanks store water and relieve some stress on the sewage system during heavy precipitation. Rain barrels delay the time that it takes for water to flow into the system. Water from a roof connected to a rain barrel does not flow immediately into the sewage system, and rain water harvesting can be used as a remedial measure and can help in flood reduction [41]. Water-permeable pavements are porous or laid so as to allow voids, have an open structure, or are made of partially pervious materials. They allow water to pass through or around them into the soil; rainwater can infiltrate into the ground, groundwater is replenished, and sewerage systems are relieved [44]. A bioswale is an adaptive measure that has the ability to store water during heavy rain and redirects surface water to groundwater [42]. The surface water nearby functions as natural water storage. If the surface water is located nearby and is lower than the street level, water can be channelled into the surface water with natural gravity, and is an important adaptive measure in times of heavy precipitation. If unpaved areas are present, they provide an additional storage capacity for precipitation and may provide cooling facilities through natural vegetation. Paved surfaces, however, especially parking lots, occupy a significant proportion of the horizontal surface area in cities. The low albedo of many of these parking lots contribute to the urban heat island (UHI) and affect the local microclimate around them. Parking spaces heat up during the day and contribute to a higher temperature. At night, these warm surfaces contribute to the urban heat island effect. Similarly, impermeable "grey" driving lanes with a low permeability similar to the grey parking spaces occupy a significant proportion of the horizontal surface area in cities. At night, these warm surfaces contribute to the urban heat island effect [44].

The weight that was given to the different climate adaptive measures is based on their perceived impact to address the impacts of climate change and address heat stress and water management problems. After testing the scorecard with different weights, the maximum score for the urban trees measure was set at 40. Three different categories were given a different number of points. The maximum score for urban trees was 40 points, or 40% of the maximum score. Green walls is a less common adaptive measure and this was given a maximum of 4 points or 4% weight. Façade gardens/front yards were given a maximum of 16 points or 16% weight. Green strips were given 13 points, or 13% weight. Climate adaptive roofs were given 2 points, or 2% weight. Green parking places were given 2 points or 2% weight. Rain barrels were given one point or 1% weight. Permeable pavements were given 3 points, or 3% weight. Bioswale was given 6 points or 6% weight. Surface water was given 6 points or 6% weight. Shaded areas/artificial shade were given 2 points 2%. There was a deduction of 2 points for the presence of designated parking areas, or 2% weight, and a deduction of 1 point per soil sealed driving lane or 2% of the weight.

The weight that was given to the climate adaptation measures was mainly given after testing several times with different weights for each factor. An important criterion for the future successful application of the scorecard is easy assessment and the scorecard should be able to distinguish adaptive from non adaptive streets. (Large) Trees are an important factor for reducing heat stress and water storage in roots and leaves. After testing, the maximum score and weight for trees was set at 40%. Façade gardens and front yards are also an important factor in climate adaptation and provide a lot of ecosystem services. The weight was set at 16% after testing. Similarly, the weight for green strips was set at 13%. The other climate adaptive measures were set at lower weights.

The feedback from the community members that participated in the climate adaptation training in Rotterdam was that the scorecard method gave them insights into the lack of adaptation measures in their street and neighbourhood, as well as the lack of ecosystem services in their outdoor living environment. The community members mentioned that the scorecard method enabled them to better understand climate change and the local effects, as well as the actions they could take themselves to address the effects of climate change in their locality with simple measures, such as green yards, more facade gardens, planting trees, and increasing the infiltration capacity. They could also see which streets are greener and are better prepared for the effects of climate change, which, according to the community members, puts them in a better position and leaves them better prepared to discuss these issues with the local government.

A weakness of this method is that after the comparative study between the two districts in Groningen and Rotterdam, it became clear that some measures were not present at all in the two districts. In the green category, these were climate adaptive roofs and green parking lots. In the blue category, these were rain barrels, permeable streets and sidewalks, bioswales, and surface water. For the scorecard 2.0, these adaptive measures could be left out of the scorecard. Bio swales and other climate adaptation measures can be linked to climatescan [54] during future climate cafes [55] and city scan activities [56]. The three categories, namely green, blue, and grey measures, could be omitted in scorecard 2.0 as the distinction between the categories was not relevant for the scorecard. Another weakness is that the weights of the different measures were not based on the geospatial data analysis, but through ocular inspection. Although, for the purpose of this scorecard, namely creating awareness and being easy to use by stakeholders in the community, this suffices.

The scores—numerical values—are non-dimensional and the scores are interpreted by the user. A reference card with reference pictures has been provided in order to reduce the chance of different interpretations. Different users of the method may interpret climate adaptive measures, for example the height of the trees, differently, which could lead to inaccurate scoring. However, as the scores were non-dimensional, and the scores were mainly used for comparing the different streets with each other in order to identify adaptation gaps, this might not impose a serious problem.

1.7 Conclusions

The objective of this study was to test a method that assesses the presence of climate adaptive measures in street segments and streets, and to provide a score between 1 and 100 that indicates to what degree the street is climate adaptive. Based on the score, a label can be given between A+++ and G, so that residents and decision makers are aware which streets are adaptive and which streets have an adaptation potential. In the Paddepoel North district in the city of Groningen, 17 streets were assessed, composed of 45 street segments with an average climate adaptiveness score of 47. In the Hillesluis district in the city of Rotterdam, 21 streets were assessed, composed of 21 streets with an average score of 29 points. The climate adaptive measures that were observed in the street segments were tabulated and each climate adaptive measure was given a weight based on the perceived ecosystem service of the measure. Based on the adaptive measures multiplied by the weight, a score for a street segment could be given. Each score corresponds with a climate adaptation label.

The results show that the method is useful to score street segments and to attach labels to streets segments and entire streets, so that residents that live in these communities are aware of the level of adaptation of their street. Similarly, local governments and other stakeholders know which streets score low and which streets have a larger adaptation "potential".

The study developed and tested a new method to label the level of adaptation of street segments and entire streets, so that streets can be compared with each other. The method was proven to be relatively simple and useful for street assessments, as the assessment was done after a short training with several community groups in the Hillesluis district in Rotterdam. The method can easily be duplicated and used by local governments and community groups in order to have better insight into the level of climate adaptation of their street. Labels for entire streets can be used to encourage residents to take action and expand the number of climate adaptation measures in their own street.

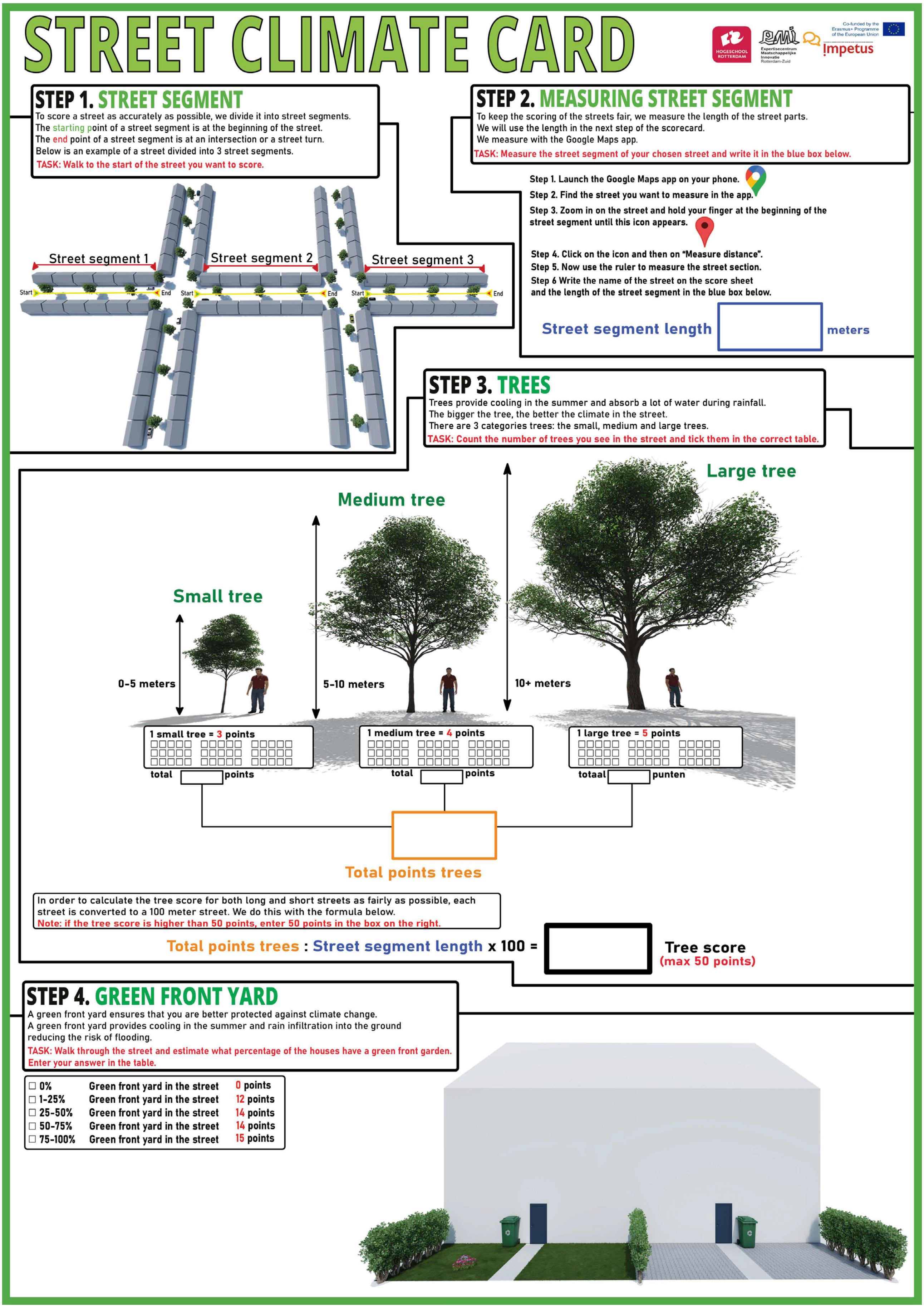
1.8 Climate Scorecard 2.0

Two approaches of field measures were developed: The Scorecard 1.0 described above and Scorecard 2.0 with similar indicators, but presented in a different form to make it more easy and ready to use by non-professionals. In the Scorecard 2.0, the indicators and instructions to follow are presented on an A3 laminated card. It is convenient to be used when you walk through a street or street segment and do the visual assessment (see Figure 1.10 and Figure 1.11 below).

The steps to the field survey are as following:

Step 1	Street segment
Step 2	Measuring street segment
Step 3	Trees
Step 4	Green front yard
Step 5	Green façade garden
Step 6	Green wall
Step 7	Green roof
Step 8	Green parking space
Step 9	Field of grass
Step 10	Bioswale
Step 11	The total

Following the steps, you put the values on the card and get the total amount of points. Comparing the sum with the Street Score Sheet ver.2.0, you can assess the level of the street adaptiveness to the climate changes.



STREET CLIMATE CARD

STEP 1. STREET SEGMENT

To score a street as accurately as possible, we divide it into street segments.
The starting point of a street segment is at the beginning of the street.
The end point of a street segment is at an intersection or a street turn.
Below is an example of a street divided into 3 street segments.
TASK: Walk to the start of the street you want to score.

STEP 2. MEASURING STREET SEGMENT

To keep the scoring of the streets fair, we measure the length of the street parts.
We will use the length in the next step of the scorecard.
We measure with the Google Maps app.
TASK: Measure the street segment of your chosen street and write it in the blue box below.

Step 1. Launch the Google Maps app on your phone.
Step 2. Find the street you want to measure in the app.
Step 3. Zoom in on the street and hold your finger at the beginning of the street segment until this icon appears.
Step 4. Click on the icon and then on "Measure distance".
Step 5. Now use the ruler to measure the street section.
Step 6 Write the name of the street on the score sheet and the length of the street segment in the blue box below.

Street segment length [ ] meters

STEP 3. TREES

Trees provide cooling in the summer and absorb a lot of water during rainfall.
The bigger the tree, the better the climate in the street.
There are 3 categories trees: the small, medium and large trees.
TASK: Count the number of trees you see in the street and tick them in the correct table.

1 small tree = 3 points — total [ ] points
1 medium tree = 4 points — total [ ] points
1 large tree = 5 points — totaal [ ] punten

Total points trees

In order to calculate the tree score for both long and short streets as fairly as possible, each street is converted to a 100 meter street. We do this with the formula below.
Note: if the tree score is higher than 50 points, enter 50 points in the box on the right.

Total points trees : Street segment length x 100 = [ ] Tree score (max 50 points)

STEP 4. GREEN FRONT YARD

A green front yard ensures that you are better protected against climate change.
A green front yard provides cooling in the summer and rain infiltration into the ground reducing the risk of flooding.
TASK: Walk through the street and estimate what percentage of the houses have a green front garden. Enter your answer in the table.

☐ 0%	Green front yard in the street	0 points
☐ 1-25%	Green front yard in the street	12 points
☐ 25-50%	Green front yard in the street	14 points
☐ 50-75%	Green front yard in the street	14 points
☐ 75-100%	Green front yard in the street	15 points

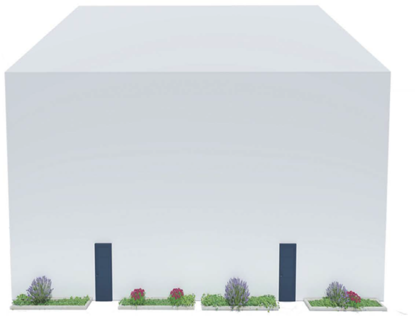
Figure 1.10. Street Climate Card 2.0 front side.

STEP 5. GREEN FACADE GARDEN

Just like a green front yard, a green facade garden makes sure you are better protected against climate change on a smaller scale.

TASK: Walk through the street and estimate what percentage of the street consists of a facade garden.

☐ 0%	Green facade garden in the street	0 points
☐ 1-25%	Green facade garden in the street	3 points
☐ 25-50%	Green facade garden in the street	4 points
☐ 50-75%	Green facade garden in the street	5 points
☐ 75-100%	Green facade garden in the street	6 points

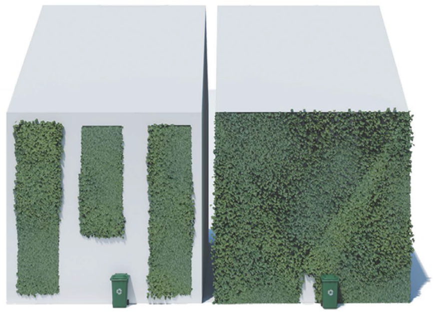


STEP 6. GREEN WALL

Green walls cover a house and keep the temperature both inside and out cooler in the summer.
Green walls absorb water during rainfall and ensure a higher biodiversity in a street.

TASK: Walk through the street and estimate what percentage of the houses have a green wall.

☐ 0%	Green wall in the street	0 points
☐ 1-25%	Green wall in the street	1 point
☐ 25-50%	Green wall in the street	2 points
☐ 50-75%	Green wall in the street	3 points
☐ 75-100%	Green wall in the street	4 points

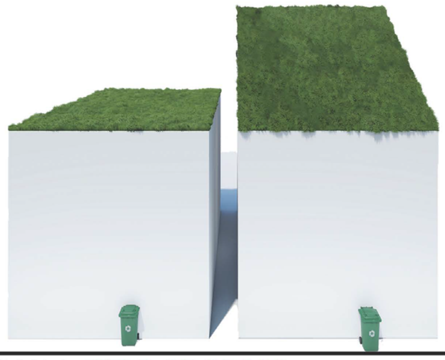


STEP 7. GREEN ROOF

Green roofs have the same advantages as green front yards and facade gardens.
What makes green roofs even better is that they don't take up any space on the street.

TASK: Walk through the street and estimate what percentage of the houses have a green roof.
Use satellite view in the Google Maps app to spot green roofs in the street.

☐ 0%	No green roof in the street	0 points
☐ 1-25%	Green roof in the street	1 point
☐ 25-50%	Green roof in the street	2 points
☐ 50-75%	Green roof in the street	3 points
☐ 75-100%	Green roof in the street	4 points

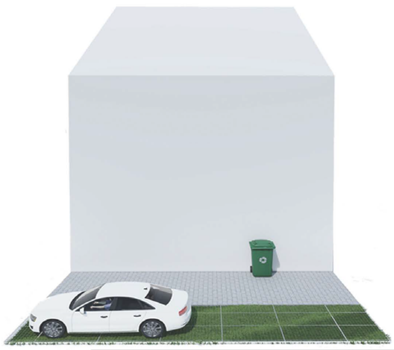


STEP 8. GREEN PARKING SPACE

A car and a parking space are important to many people, but the climate is also important.
Green parking spaces allow rain to infiltrate into the ground and at the same time also provide parking space.

TASK: Walk through the street and estimate the percentage of green parking spaces in the street.

☐ 0%	No green parking in the street	0 points
☐ 1-50%	Green parking in the street	2 points
☐ 50-100%	Green parking in the street	4 points

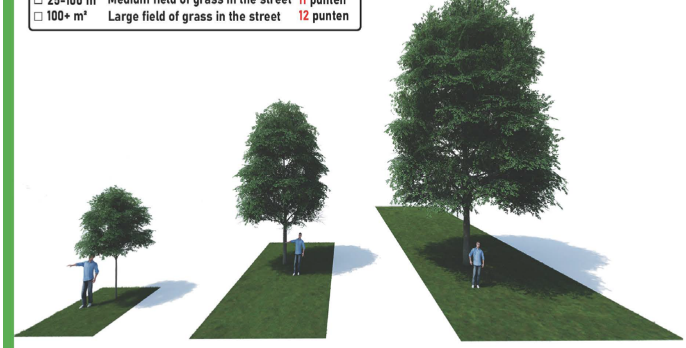


STEP 9. FIELD OF GRASS

A field of grass is generally good for a street.
The environment brightens up with it, people can use the field for sports or recreation and it is good against the changing climate.
A field of grass can absorb a lot of rainwater and let it infiltrate into the ground.
Grass generally also provides cooling in a street on a hot day.
The bigger the lawn, the better the climate in the street.

TASK: Walk down the street and estimate the size of the field of grass.

☐ 0 m²	No field of grass in the street	0 punten
☐ 1-25 m²	Small field of grass in the street	10 punten
☐ 25-100 m²	Medium field of grass in the street	11 punten
☐ 100+ m²	Large field of grass in the street	12 punten



STEP 10. BIOSWALE

A bioswale is a low-lying field of grass
Rainwater flows to the wadi after which it infiltrates into the ground.
A bioswale can absorb a lot of water, be full of water and therefore store a lot of water.

TASK: Walk down the street and look for a bioswale

☐	No bioswale in the street	0 points
☐	There is a bioswale in the street	5 points

STEP 11. THE TOTAL

TASK: Now add up all the points from steps 3 to 10 and fill them in on the score sheet. The climate labels are on the back of the score sheet.

Erase all your answers and now move on to the next segment of your chosen street or choose another street.

Figure 1.11. Street Climate Card 2.0 back side.

1.9 Final results description

There are two approaches which you can use to measure the street adaptiveness towards climate changes. The one, more sophisticated and the other one dedicated to higher education students and the other one simplified in order to be used by non professionals. The measures can be done manually or using an app and the results can be sent directly to the Climate Scan database.

For the version 1.0 use the scorecards: Street Climate Card ver.1.0, front.jpg, Street Climate Card ver.1.0, back.jpg and Street Score Table ver.1.0.xlsx.

For the version 2.0 use the set of files: Street Climate Card ver.2.0, front.pdf, Street Climate Card ver.2.0, back.pdf and Street Score Table ver.2.0.pdf.

For the presentation of the methodology you can use Street Scorecards presentation.pptx.

For the students' knowledge income verification use Street Scorecards pre-post test to print.doc and Street Scorecards pre-post test key.doc.

1.10 External materials

See: https://impetus.aau.at/outputs/

Folder: Street Scorecards

- Street Scorecards instruction.pdf
- Street Scorecards pre-post test to print.doc
- Street Scorecards pre-post test key.doc
- Street Climate Card ver.1.0, front.jpg
- Street Climate Card ver.1.0, back.jpg
- Street Score Table ver.1.0.xlsx
- Street Climate Card ver.2.0, front.pdf
- Street Climate Card ver.2.0, back.pdf
- Street Score Sheet ver.2.0.pdf
- Street Scorecards presentation.pptx
- Case Study Hillesluis.docx

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