Grey to Green Schoolyard Assessment

An assessment to show the impacts of green schoolyard transformations

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Master thesis Environmental Technology Group submitted in partial fulfillment for the degree of Master of Science in Urban Environmental Management at Wageningen University, the Netherlands

This thesis is part of the New Water Ways project

Study programme:
Urban Environmental Management

Thesis track:
Urban Systems Engineering

Student registration number:
961016252040

Program code:
ETE 81836

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Date:
8 April 2021

Front page images: Dr. G.A. Wumkesskoalle (n.d.) and Mens (2018)

Acknowledgement

Throughout this thesis I was guided and supported by many individuals. I would first like to thank my three supervisors for their guidance. I would like to thank Thomas Wagner for being my daily supervisor, which made it possible for me to conduct this thesis, and for the weekly meetings where we discussed the progress of the thesis. I want to thank Koen Wetser for all his constructive feedback, and the meetings. I am grateful that Karianne de Bruin gave me the opportunity to work together with the New Water Ways project. I also want to thank her for scoping the project's topic, and the discussions during our additional meetings.

I would like to thank Isabel Seifert-Dähnn, who is the project leader of the New Water Ways project, for the initial discussion about my subject, the additional meetings and feedback on the thesis draft report.

I want to thank the water thesis-ring for the discussions and feedback. I would like to thank my friends for inspiring me and their support. Finally, I would especially like to thank my parents for their support and providing optimal working conditions to me.

Summary

There are two pressures on the urban water system: climate change and urbanisation. The increase of extreme weather events in combination with an increased impervious surface area, causes more urban pluvial flooding events. The traditional grey sewer system can be supported by additional green spaces, that retain and infiltrate water into the soil, but also provide co-benefits, such as temperature reduction, biodiversity increase and improving well-being. Schoolyards are often grey but have the opportunity to make cities greener. By transforming schoolyards into green schoolyards, the urban resilience can be supported on climate adaptation and mitigation, health and well-being, and social cohesion. The benefits from greening schoolyards can be evaluated using green infrastructure (GI) evaluation toolkits, which can be used after the design phase of a project, before the implementation phase, in order to show the amount of benefits.

However, no assessment exists that shows the effects of green schoolyard transformations, and the GI evaluation toolkits that exist are not developed for schoolyards. Therefore, this research is aimed to develop an assessment to show the impacts of green schoolyard transformations. The following questions are set as guidelines to fulfil this aim:

- Which existing GI evaluation toolkit is most applicable to quantify the performance of green infrastructure in schoolyards?
- How can this GI evaluation toolkit be adjusted to make it schoolyard specific?

A methodology of four steps was followed to answer the research questions. At first, a literature review was conducted to find the most applicable GI evaluation toolkit to quantify the benefits from schoolyards. This choice was made by scoring the GI evaluation toolkits on nine criteria. Secondly, the chosen GI evaluation toolkit was made more schoolyard specific by adding additional indicators from a literature review on schoolyard transformation projects. This created the Grey to Green Schoolyard Assessment (GGSA). Thirdly, three interviews were conducted regarding the applicability of the toolkit and the process of greening schoolyards in Amsterdam. At last, the GGSA was applied to a case study in Amsterdam.

The first outcome of the research was that eleven GI evaluation toolkits were found in literature. The NVE-city toolkit received most points (8/9 points). The NVE-city toolkit was chosen because it calculates its indicators on a schoolyard parcel scale, including 25 GI measures. Secondly, the NVE-city toolkit was made more specific by adding three groups of indicators. The first group were performance indicators, which show the performance of GI measures at the schoolyard, such as water retention and carbon-sequestration. The second group are design indicators, which are based on the principle that a greener and more varied schoolyard positively impacts social benefits for children. The third group are health, safety and education indicators. Health and safety indicators are requirements for water elements and education indicators are design principles that support outdoor education. All indicators together resulted in the GGSA. At last, the GGSA was applied to a schoolyard case-study of the elementary school De IJsbreker in Amsterdam. This showed that the green schoolyard transformation improved on all three indicator categories. The schoolyard performed best on water retention, biodiversity and nature education. The schoolyard design scored low on air quality and carbon-sequestration, and did not have an effect on local temperature reduction. The schoolyard was greener and more varied, which resulted in scoring 8 out of 9 points for the design indicators. The last indicator group were the health, safety and education indicators, which scored 4/5 points.

The first point of discussion is regarding the three categories of the GGSA. Interrelations were found between on one side the performance indicators, and on the other side the principles from the design, and health, safety and education indicators. A balance between these two sides must be found when

designing a green schoolyard. Therefore, a schoolyard is possibly most successfully designed when it provides most potential from performance indicators while not compromising the design, and health safety and education indicators. Secondly, regarding the applicability of the GGSA, it can be seen that it is applicable to countries alike the Netherlands, having a similar climate. However, the GGSA could also be applied to a city in a region with a different climate, such as Oslo. The design, and health, safety and education indicators do not have to be changed, since these are design principles. However, the GI performance indicators should be adjusted. The reason is that Oslo is different from the Netherlands on aspects, since Oslo has a different climate, and a shorter growing season.

This research showed that the NVE-city is the most applicable toolkit for the evaluation of GI performance at schoolyards, due to calculations that can be performed on schoolyard parcel level. The GI performance indicators of the NVE-city toolkit, plus additional indicators from literature, resulted in the development of the GGSA. The additional relevant indicators were found in the following three groups: GI performance indicators, design indicators (impacting social benefits), and health, safety and education indicators. By applying the GGSA to a green schoolyard transformation project, the full range of benefits was shown. It is therefore recommended to use the GGSA for future green schoolyard transformation projects.

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1 Introduction

1.1 Problem statement

Urban water systems are affected by climate change and urbanisation (Nie et al., 2009). The increasing concentration of greenhouse gasses in the atmosphere impacts the climate, resulting in for instance changing weather patterns (Liu et al., 2016). In North Western European countries such as the Netherlands and Norway, extreme weather events are expected to occur more frequently (Klein et al., 2014; Sorteberg et al., 2018). The second influence on the urban water system is urbanisation. Due to urbanisation, areas are densified, which can result in an increased impervious surface area (Jacobsen, 2011). As a consequence, the impervious surfaces affect the hydrological system by decreasing evaporation and infiltration. This results in a larger quantity of water that has to find its way to the sewer system, instead of infiltrating into the soil (Jacobsen, 2011). Together, the increase of extreme weather events in combination with an increased impervious surface area, causes more frequent combined sewer overflows and urban pluvial flooding (Nie et al., 2009), having negative effects on aesthetics, water quality and property damage (Stovin et al., 2013).

Traditional urban stormwater management in a combined or separate sewer system, referred to as grey infrastructure in this thesis, is designed to capture and transport runoff through hard engineered structures (curbs, pipes etc.), and is single-functional since it only manages urban water without providing additional benefits (Gordon, et al., 2018). A combined sewer system has one pipe where the wastewater is combined with stormwater, and in a separate sewer system each stream has a separate pipe. The urban sewer system is a reliable method to cope with moderate rainfall events (Alves et al., 2018). However, grey infrastructure is often costly to implement and maintain, and is inflexible (Depietri and McPhearson, 2017).

1.2 Green infrastructure

Green and blue spaces in urban areas can play a big role to deal with urban challenges, and this is often referred to as green infrastructure (GI) (Demuzere et al., 2021). Demuzere et al. (2014, p. 107) defined GI as “a hybrid infrastructure of green spaces and built systems, e.g., forests, wetlands, parks, green roofs and walls that together can contribute to ecosystem resilience and human benefits through ecosystem services”. In addition, GI are semi-natural structures in networks, which are multifunctional by providing multiple ecosystem services (Benedict and McMahon, 2012). GI is an opportunity to improve the current stormwater system on aspects such as multi-functionality and providing of co-benefits to society (Gordon, et al., 2018).

Several scholars pointed out that cities should rely on a mix of grey, green and blue infrastructure solutions for climate driven issues (Chow et al., 2014; Depietri and McPhearson, 2017; Gordon et al., 2018). GI should not replace grey solutions but instead complement them with their multi-benefits. Thus, by implementing GI complementary to existing grey infrastructure, the resilience of urban areas can be increased (Van Oijstaeijen et al., 2020).

While GI are often installed for flood management applications, secondary benefits exist, also called co-benefits. These co-benefits are the side effect for society and the environment obtained from GI measures (Raymond et al., 2017). GI can improve urban areas on environmental, social and economic challenges it faces through its (co-)benefits (Gordon, et al., 2018). For these three challenges, ten specific challenges for urban areas were found by Raymond et al. (2017) in their framework for assessing GI co-benefits: (i) environmental challenges are climate adaptation and mitigation, green space management, air quality and urban regeneration, (ii) societal challenges are participatory planning and governance, social justice and cohesion, and public health and well-being, and (iii) economic challenges are economic opportunities and green jobs.

The aspects on which GI can help these urban challenges can be shown through its benefits. Ecosystem services are a concept that shows what type of benefits are provided by in this case GI, to society (Millennium Ecosystem Assessment, 2005). The benefits GI provides to urban areas can be divided in three categories: provisioning, regulating and cultural ecosystem services (Table 1). The benefits GI supplies is different per type of GI measure (CIRIA, 2013). An example is a tree that has the most effect on local climate regulation through shade and evaporation, while a bioswale provides its largest benefit to water retention. Next to the benefits, implementation of GI in urban areas also generates costs during the design, implementation, maintenance and demolition phase (Van Oijstaeijen et al., 2020).

Table 1. Ecosystem services provided by GI to urban areas (Kabish et al., 2017)

Ecosystem services section	Ecosystem services class
Provisioning	Cultivated crops
	Surface/ground water for drinking
	Surface/ground water for non-drinking purposes
Regulation	Filtration/sequestration/storage/accumulation by ecosystems
	Global climate regulation (CO_2 reduction)
	Micro and regional climate regulation (temperature)
	Mediation of smell/noise/visual impacts
	Hydrological cycle and water flow maintenance
	Flood control
	Pollination and seed dispersal
Cultural	Physical and intellectual use of land-/seascapes in different environmental settings
	Scientific/educational
	Heritage and cultural
	Aesthetics

1.3 Green infrastructure evaluation toolkits

Planning practices of GI projects can benefit from using toolkits as a planning support (Kuller et al., 2017). These toolkits focus on stakeholder engagement, communication, conceptualisation of options and preferences (Kuller et al., 2017). One type of toolkit is the GI evaluation toolkit, which has the objective to evaluate the effect of implementing GI measures according to a set of performance indicators. GI evaluation toolkits use decision criteria to assess multiple benefits by providing quantification that can be monetized, and therefore act a justification of investments (Kuller et al., 2017).

GI evaluation toolkits are most effective when they are used in the right place of the GI planning process. A GI project can be structured in seven steps, following Naumann et al. (2011) (Figure 1). GI evaluation toolkits can be used to evaluate the design of GI projects (shown in grey). An evaluation of the GI project design will result in a quantification of benefits of the specific project. If the benefits of the design do not meet the objectives of the GI project, the design can be adjusted accordingly.

Figure 1. GI project planning process (Naumann et al., 2011), where the evaluation toolkits can be used at the design phase (grey marking)

Choices of stormwater management traditionally relied on economic efficiency, while nowadays decision makers have to include various social and environmental aspects, such as adapting to a changing environment (Alves et al., 2018). To make investment decisions, many evaluation toolkits are developed for a GI evaluation regarding socio-economic and environmental performance, that aim to show the added value of GI in stormwater management practices (Van Oijstaeijen et al., 2020). Van Oijstaeijen et al. (2020) found that evaluation toolkits can be used as a starting point the assessment of quantifying the benefits of GI projects.

However, these types of toolkits are often not used, and as a consequence local authorities are often not aware of the value of benefits from GI (Van Oijstaeijen 2020). The effect is that decision makers are not likely to invest in GI. Current evaluation toolkits are often not tailored on urban scale, are limited in economic valuation, and do not fully cover the topics of urban ecosystem (dis)services, multi-scalability, life-span assessment of co-benefits and social benefits (Van Oijstaeijen et al., 2020). To assess the value of GI, toolkits should assess ecological and social functions of GI in cities specifically (Chow et al., 2014; Van Oijstaeijen et al., 2020). Van Oijstaeijen et al. (2020) recommend using ecosystem services as a basis for performance indicators, since these are generally accepted and the field is improving. In addition, in order to stimulate the use of GI evaluation toolkits they have to take the needs of local authorities into account, in order to be applied to GI projects (Van Oijstaeijen et al., 2020).

1.4 Green schoolyards

Schoolyards are often grey, which means that they are covered with impervious surfaces that increase urban runoff to the sewer system. The impervious surfaces do not provide (co-)benefits that GI measures would provide. However, grey schoolyards could improve the urban resilience, by changing them into green schoolyards, since urban schoolyards in general are relatively small at individual scale but highly geographically distributed throughout a city (Flax et al. 2020). Greening schoolyards would create more multifunctional grounds that reduce impervious surfaces by implementing green elements: gardens, grasses, trees, porous surfaces, etc. (Flax et al., 2020).

Green schoolyards are better in managing environmental aspects such as extreme weather events by acting as rainwater buffer, mitigate climate change by sequestrating carbon, can be used for nature education, and have a positive impact on health (Stevenson et al., 2020; EPA, 2017). Flax et al. (2020) found that green schoolyards can improve urban resilience through; mitigation and adaptation of climate change, health and wellbeing and social cohesion (Table 2). In addition, green schoolyards can be beneficial for a community beyond the schoolground boundary, such as the neighbourhood. This is because next to climate, education, and health and well-wellbeing, green schoolyards attract a large and diverse proportion of the neighbourhood's population (Flax et al., 2020).

Table 2. Benefits of greening schoolyards for urban resilience (Flax et al., 2020)

Urban resilience category	Benefit on urban resilience
Mitigation & adaptation of climate change	Urban heat island effect
	Stormwater management
	Pollution reduction (PM10 deposition)
Health & Wellbeing	Cognitive and motor fitness of children
	Reduce gender differences of children
	Improve health of users
Social cohesion	Involvement of children educates about the decision making process
	Involvement of children educates about human impact on the environment
	Involvement of the community makes them familiar with each other

The process of greening schoolyards can be improved by initiatives that support schools with these greening projects. Such an initiative is Amsterdam Impulse Schoolyards (AIS) (Gemeente Amsterdam, n.d.). The municipality of Amsterdam initiated AIS to guide schools through the process of greening schoolyards on a financial basis and with design guidelines. AIS focuses on improving green (25% increase), active play, water management, nature/outdoor education, citizen partnership and sustainability. Regarding the design process, a new green schoolyard will be evaluated on these criteria by experts. This assessment is done by expert opinion, through observing the changes from a grey to green schoolyard, which is qualitatively described. One part of the assessment is done quantitatively, which is the change between grey and green schoolyard of grey, semi-grey and green area on the schoolyard.

A missing part of the AIS assessment would be the quantification of benefits that are provided by changing the schoolyard to the users and neighbourhood. An assessment for transforming grey to green schoolyards does not exist in literature. In addition, an evaluation of solely GI does exist by using evaluation toolkits, however, these are also not developed for schoolyard. Therefore, developing an assessment that shows the impact of greening schoolyards is the focus of this research. This assessment will include the quantification of benefits when changing grey to green schoolyards.

1.5 Aim and research questions

This thesis contributes to the New Water Ways project, which looks at different GI solutions for Northern European cities, with a main focus on the cities of Oslo, Copenhagen and Amsterdam. This thesis will focus on the city of Amsterdam but will also elaborate in the discussion on a wider perspective of grey to green schoolyard transformations in the city of Oslo.

The aim of this research is to show the (co-)benefits of transforming grey schoolyards to green schoolyards, by creating an assessment for schoolyards in the city of Amsterdam. The following questions are set as guidelines to fulfil this aim:

- Which existing GI evaluation toolkit is most applicable to quantify the performance of green infrastructure in schoolyards?
- How can this GI evaluation toolkit be adjusted to make it schoolyard specific?

The following three sub-questions were developed:

- Which toolkits can quantify the performance of GI measures at schoolyard parcel scale regarding stormwater management and provisioning of co-benefits?
- What is missing in these toolkits regarding GI performance indicators and applicability to schoolyard parcel scale?
- How can lessons learned from grey to green schoolyard transformation projects be translated to indicators to assess GI measures at schoolyards?

2 Methodology

The methodology section consists of the steps that were taken to develop an assessment to shows the effects of green schoolyard transformation projects. This assessment was called the Grey to Green Schoolyard Assessment, abbreviated in the report to GGSA. The methodology was conducted according to the following four phases: the toolkit literature study, green schoolyard literature study, interview and assessment phase (Figure 2).

In the GI evaluation toolkit literature study phase, a literature study was conducted on existing GI evaluation toolkits, with the aim of choosing a generic toolkit that evaluated GI using performance indicators. Secondly, the green schoolyard literature study phase focused on the effects of greening schoolyards, in order to obtain additional indicators for the GGSA, regarding performance of GI, design indicators for social benefits, and health, safety and education indicators. In the interview phase, interviews were conducted with experts regarding applicability of the chosen toolkit to Amsterdam and to gather information on green schoolyard transformations in Amsterdam. In the assessment phase, the GGSA was applied to the schoolyard of De IJsbreker in Amsterdam, with the aim to test the GGSA and see what the effect is of the greened schoolyard of De IJsbreker.

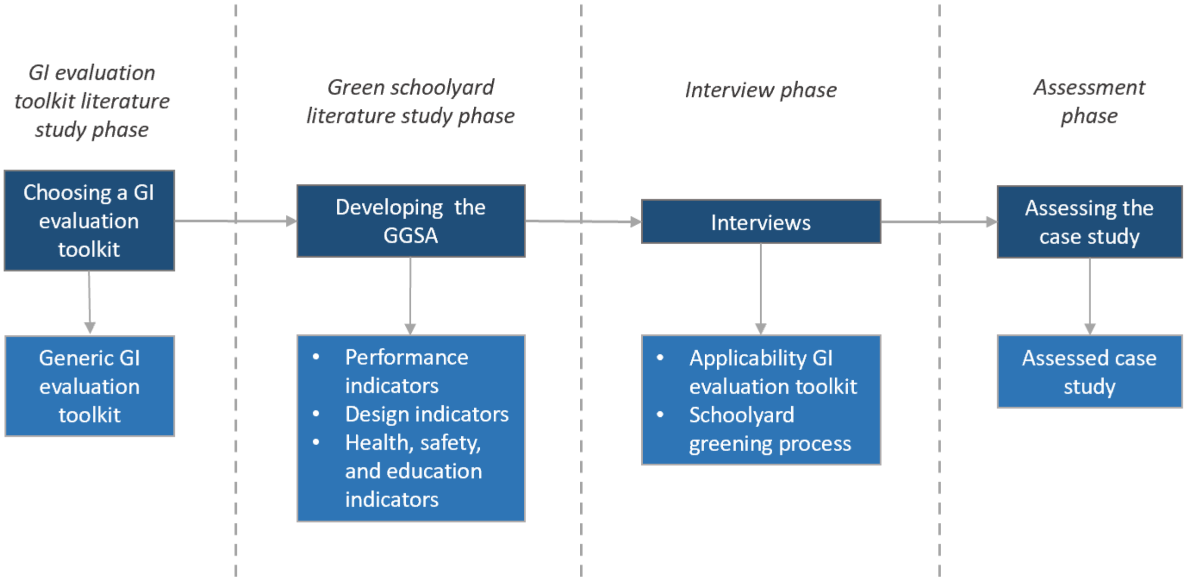


Figure 2. Schematic overview of the methodology. Dark blue coloured boxes are the approaches. Light blue coloured boxes are the results of the approach

2.1 Green infrastructure evaluation toolkit literature study phase

A literature study was conducted to identify existing GI evaluation toolkits. The search engine google scholar was used to search for literature using the following search terms: green infrastructure, evaluation, urban, toolkit, assessment, framework. When a few relevant articles were found on GI evaluation toolkits, more in-depth literature was gathered through the snowballing method, as described by Sayers (2007). For this methodology, citations within the found articles were checked to gather more relevant articles, which is called snowballing. This process was also done in reverse, by looking which articles citied the found articles (citation tracking), called reverse snowballing (Sayers, 2007).

Secondly, the obtained GI evaluation toolkits from the literature study were scored according to criteria shown in Table 3. The criteria used in this thesis were based on Van Oijstaeijen et al. (2020), that reviewed GI evaluation toolkits. These criteria were modified to make them more specific to schoolyards.

Each criterion was chosen due to relevance to the research. The criterion green infrastructure was included since schoolyards exist of many green, blue and grey infrastructure types. The criterion indicators was split in two parts. When the GI evaluation toolkit includes environmental, social and economic indicators, the toolkit can potentially show a wide range of benefits. Furthermore, indicators must be based on ecosystem services since these are reliable, and research is done on improving ecosystem services. The criterion scale is important since calculations must be performed on a schoolyard parcel scale. The first indicator regarding scale was the focus on urban scale, which was chosen to cancel out all toolkits that calculate on a scale larger than urban scale. The second scale indicators focused on a schoolyard parcel scale, which was chosen to select the toolkit with most detailed calculations. The criterion scientifically sound was chosen to ensure that the calculations of toolkits are valid. Double counting was chosen as an indicator to ensure benefits are not included twice in the result, to obtain a trustworthy result. The criterion output was chosen to select toolkits that quantifies (co-)benefits, to obtain exact numbers. At last, it was important that the calculations of the toolkit were adjustable, for example in Excel. In this way, the toolkit can be adjusted, if parts of the toolkit are not usable, or when new data is available.

In order to evaluate the criteria, manuals of the GI evaluation toolkits were used. The evaluation toolkits were scored by a dichotomous scale, with the following rules: If the toolkit included the criterion, it got 1 point, if not 0 points. A qualitative description was given to motivate the choice. No weight was given to the criteria, to keep them equally important.

Table 3. Selection criteria to obtain the most applicable toolkit for schoolyards

Criterion	**Description**	**Scoring**
Green infrastructure	Includes mainly dry/wet vegetation types. Includes relevant urban infrastructures types as well, such as green facades, concrete tiles, green roofs, etc.	The criterion is incorporated in the GI evaluation toolkit: 1 point The criterion is not incorporated in the GI evaluation toolkit: 0 points
Indicators	Includes GI performance indicators, regarding stormwater management and co-benefits.	
	Performance indicators are based on ecosystem services.	
Scale	The toolkit is applicable to urban scale.	
	The toolkit is applicable to evaluate green infrastructure on a schoolyard parcel scale.	
Scientifically sound	Based on scientific sources to ensure validity of calculations.	
Double counting	Includes description of double counting or takes double counting into account in the calculations.	
Output	The output is in quantitative numbers (e.g., m^3/year).	
Adjustability	Ability to adjust the toolkit.	

2.2 Green schoolyard literature study phase

The aim of the green schoolyard literature study phase was to develop the GGSA. The indicators of the chosen toolkit were supplemented with additional relevant indicators. Three categories were added to the GGSA: (i) GI performance indicators, (ii) design indicators, and (iii) health, safety and education indicators.

2.2.1 Green infrastructure performance indicators

Firstly, after choosing the most relevant GI evaluation toolkit in section 2.1, only the indicators applicable to schoolyards (Table 3) were added to the GGSA. This step was made since parts of the most relevant GI evaluation toolkit could still not be applicable to schoolyards. The selected indicators were added to the GGSA Excel model.

Secondly, the GGSA was made more elaborate by including indicators from other GI evaluation toolkits, which were not chosen as the most relevant one. Note that these GI evaluation toolkits were not the most relevant toolkits to schoolyards, but some indicators were. Indicators of the GI evaluation toolkits were considered if these were according to the criteria of Table 3. In the end, the chosen additional performance indicators were added to the GGSA Excel model.

2.2.2 Design indicators

The aim of this part of the literature phase was to develop indicators to assess the social impacts of transforming grey to green schoolyards on children.

Two search engines were used to gather information on schoolyards greening projects. The search engines Google and Google Scholar were used to search for literature. Since literature was scarce on the topic of schoolyard greening projects, mainly the search engine Google was used to review literature. Both Dutch and English search terms were used to find relevant information applicable to Dutch Schoolyards. The following search terms were used: green schoolyard, transformation, assessment, evaluation, social benefits. When articles were found, additional literature was found through the snowballing method of Sayers (2007), as described in section 2.1.

For the design indicators, a scoring method was used that distinguished between 0 and 1 points. If the schoolyard design complied to the requirement of the indicator, it received 1 point, if not 0 points. In addition, a qualitative description was added to each indicator, where the reasoning of the score was written down. The indicators and scoring were added to the GGSA Excel model.

2.2.3 Health, safety and education indicators

The design guideline indicators were included in the GGSA to elaborate on design practices regarding health, safety and education relevant to GI transformation projects.

The literature study and scoring method were the same as explained in section 2.2.2. The only difference was for the following search terms: green schoolyard, transformation, assessment, evaluation. This section did not include the effect of social impacts, which was part of 2.2.2.

2.3 Interview phase

During this phase, three interviews were conducted to improve the GGSA (Table 4). One interview was conducted with Inge Liekens, who is one developer of the NVE-city toolkit. The interviews with Douwe de Voogt and Sarah Marinussen were conducted to gather information on the evaluation process of schoolyards in Amsterdam.

Table 4. Interviewees and additional information

Name	Company	Additional information
Inge Liekens	VITO - Flemish Institute for Technological Research NV	Applicability of the evaluation toolkit in Amsterdam. Inge Liekens developed the NVE-city toolkit.
Douwe de Voogt	Waternet and Amsterdam Rainproof	Evaluation of schoolyards regarding stormwater management. Douwe de Voogt evaluates water management on schoolyards for AIS.
Sarah Marinussen	Gemeente Amsterdam	Process of the greening schoolyards in Amsterdam. One project of Sarah Marinussen is the Amsterdam Impulse Schoolyards.

2.4 Assessment phase

In the assessment phase, the GGSA was applied to a case study. The chosen case was the schoolyard of the elementary school De IJsbreker in Amsterdam North, the Netherlands. The schoolyard was recently transformed from a grey schoolyard with little vegetation (baseline) to a greener and more varied schoolyard (new design) (Figure 3, and the baseline in Appendix 1). All calculations were based on the difference between the new design and the baseline.

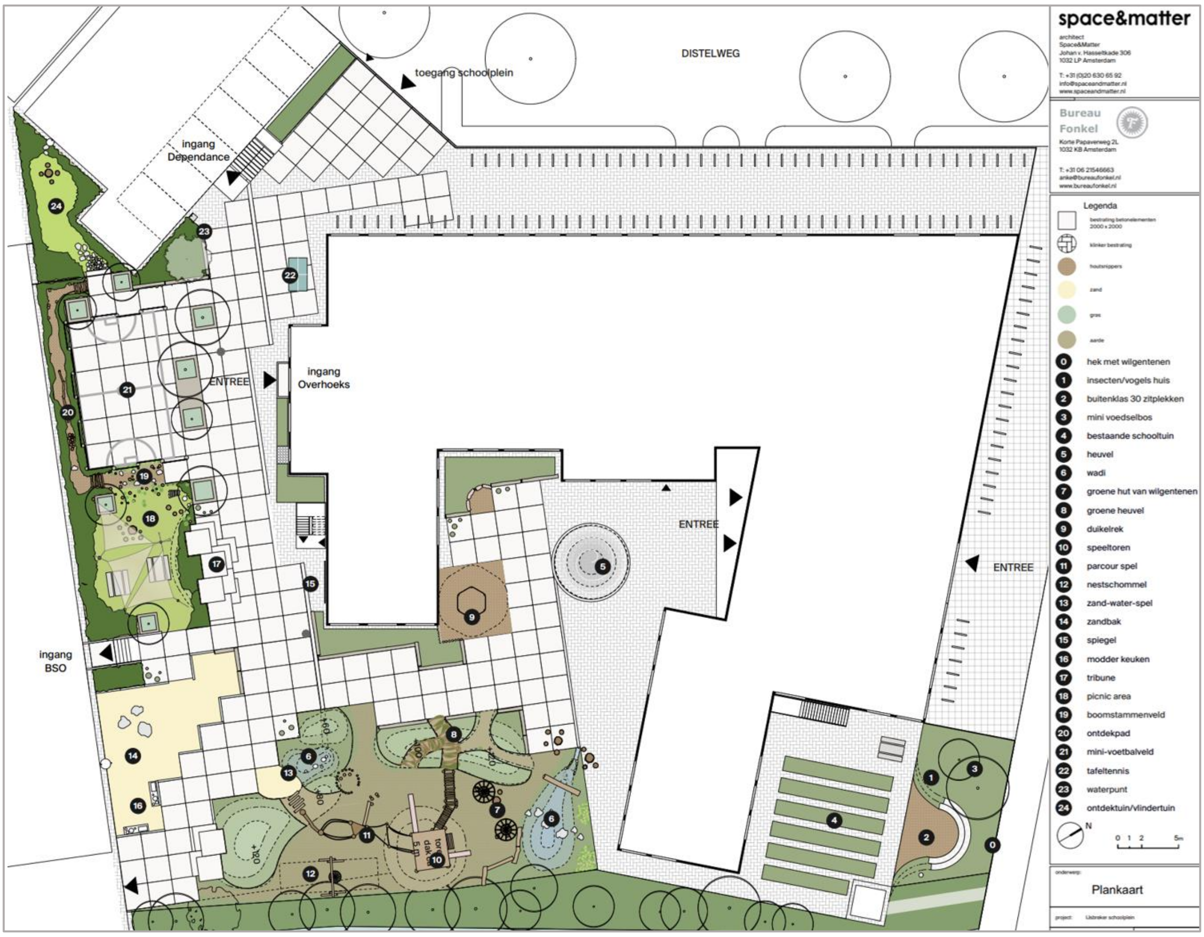


Figure 3. Map of the case study De IJsbreker, which is the new design (Space & Matter and Bureau Fonkel, 2019)

2.4.1 Green infrastructure performance indicators assessment

The performance indicators were quantified with the method found in the manuals of the toolkits, where the performance indicators originate from. Required information was the area of GI measures on the schoolyard, which can be found in Appendix 1. If additional information was required regarding the schoolyard, the school De IJsbreker was contacted.

2.4.2 Design indicators assessment

The design indicators were assessed using information on the schoolyard design in Appendix 1. For missing information, the school De IJsbreker was contacted. The result per design indicator was the change in points. Since the design indicators relate to the total expected social benefits a schoolyard can provide to children, the baseline and new design were compared by the total score of all design indicators.

2.4.3 Health, safety and education indicators assessment

The health, design and education indicators were assessed as the design indicators in section 2.4.2. The result per indicator was the change in points. The indicators were compared individually since these were not related to each other.

3 Results and discussion

3.1 Green infrastructure evaluation toolkits

3.1.1 Green infrastructure evaluation toolkits assessment

The literature study resulted in eleven GI evaluation toolkits (Table 5 and Appendix 2), from the papers of Kuller et al. (2017), Ferranti et al. (2020) and van Oijstaeijen et al. (2020). The TEEB-stad toolkit was found separately in the literature study. All toolkits focused on the evaluation of different GI measures, by quantification and monetization of ecosystem services. All toolkits included a manual with information of the toolkit and calculations. The toolkits can be separated in the following five groups: GIS-based, web-based, Excel-based, program-based, and textual guide.

First of all, GIS-based toolkits map the benefits from ecosystem services on high level of detail, due to the exact information of GIS calculations. The ECOPLAN-SE and InVEST are GIS toolkits. Typical to this type of toolkit is the focus on generic land-use types, not focussing on specific GI measures. To illustrate, GIS-based toolkits focused on GI measures, such as forests, and green areas instead of detailed GI measures, such as bioswales and urban deciduous trees.

Second, web-based toolkits have an online interface. These toolkits require specific input data that is different per web-based toolkit, such as GI measure, area, property value and PM_{10} concentration. The NVE-city and TEEB-stad toolkits are both web based. The NVE-city is based on local Flemish data, which is included in the maps of the web-tool and results in location specific calculations. The TEEB-stad toolkit is an online calculator focused on Dutch conditions, based on formulas with average Dutch values. The NVE-city toolkit focuses on the benefits from regulating, cultural and supporting ecosystem services of GI projects, while the TEEB-stad toolkit focuses on social benefits of GI projects.

Third, the largest group are the Excel-based toolkits, which use Excel models to automatically calculate the ecosystem services provided by GI measures. The difference from web-based toolkits is that Excel-based toolkits are adjustable, by making changes in the Excel interface. The literature study identified the following Excel-based toolkits: BEST, GI-VAL, GIBVT, NCPT and CAVAT. Differences exist between Excel-based toolkits. The BEST, GIVT and NCPT focus on more generic types of green infrastructure, such as green area, trees and green roofs. In contrast, the GIBVT focuses on 6 specific GI types, such as trees, bioswales and reed beds. The CAVAT toolkit focuses on trees and only provide a simple calculations of the monetary value of an urban deciduous trees.

Fourth, one computer program was found in the literature review, which was the i-Tree Eco toolkit. In contrast to the CAVAT toolkit that focuses solely on the monetary value trees, the i-Tree toolkit calculates benefits from trees, which are mainly based on regulating and cultural ecosystem services.

Finally, TESSA is a textual guide that helps non-specialists through a selection of methods to identify site specific ecosystem services and helps to quantify ecosystem services with local data of alternative land-uses. TESSA was developed to be incorporated into a regular monitoring program.

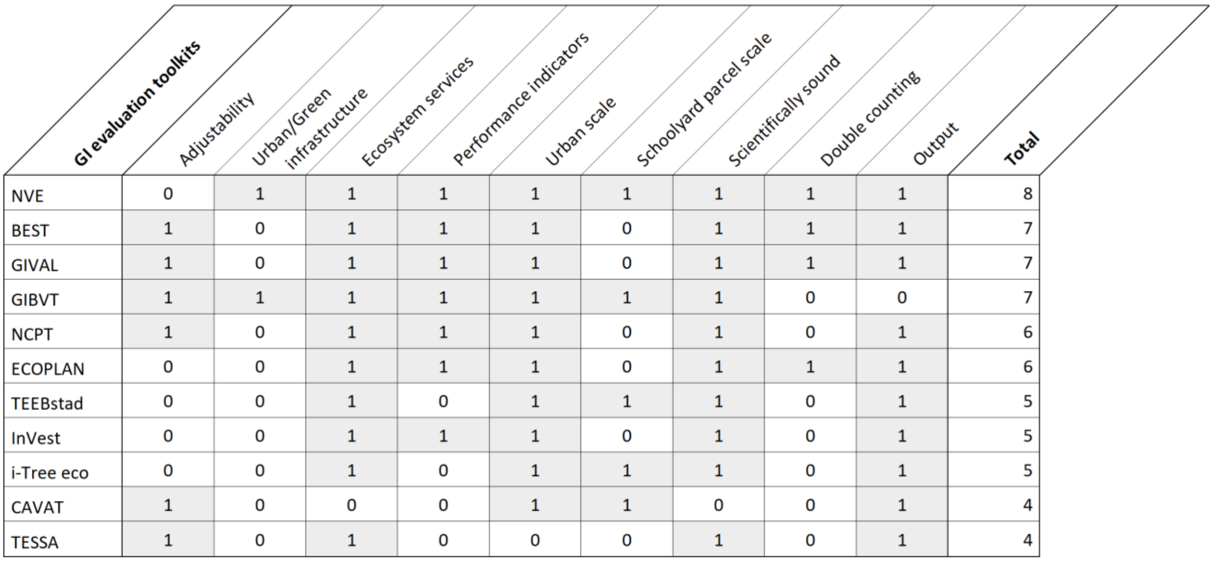
Table 5. Overview of GI evaluation toolkits from the toolkit literature study phase

Toolkit	Developer	Version	Objective	Reference	Reviewed by
NVE-city	VITO, BE	2018	Web-based toolkit that evaluates the effect of land use scenarios on the values of ecosystem services.	Hendrix et al. (2018)	Van Oijstaeijen et al. (2020)
i-Tree Eco	USDA Forest Service, US	2019	Program-based toolkit that quantifies environmental effect and value to society of trees.	i-Tree Eco (2020)	Ferranti & Jaluzot (2020); Van Oijstaeijen et al. (2020)

BEST	CIRIA, UK	2019	Excel-based toolkit that gives a quantification and monetization of ecosystem services.	Horton et al. (2019)	Kuller et al. (2017); Ferranti and Jaluzot, (2020); Van Oijstaeijen et al. (2020)
TEEB-stad	PBL, NL	2019	Web-based toolkit that monetizes social benefits of ecosystems to help new developments.	Does et al. (2019)	This thesis
GI-Val	The Mersey Forest, US	2018	Excel-based toolkit that assesses existing green assets or proposed green investment and translates findings into a business case.	GIVN (2010)	Kuller et al. (2017); Ferranti and Jaluzot (2020); Van Oijstaeijen et al. (2020)
CAVAT	LTOA, UK	2020	Excel-based toolkit that helps decision makers by giving a value per single tree.	Neilan (2010)	Ferranti and Jaluzot (2020); Van Oijstaeijen et al. (2020)
ECOPLAN-SE	University Antwerp, BE	2017	GIS-based toolkit that calculates the associated effects and presents the results in an understandable way.	Vrebos et al. (2017)	Van Oijstaeijen et al. (2020)
InVEST	Stanford University UK	2018	GIS-based toolkit that maps and values the goods and services from nature that sustain and fulfil human life.	Sharp et al. (2020)	Van Oijstaeijen et al. (2020)
GIBVT	Earth Economics, US	2018	Excel-based toolkit that monetizes benefits of GI.	Earth Economics (2018)	Van Oijstaeijen et al. (2020)
NCPT	CEEP, UK	2018	Excel-based toolkit that assess and compare plan/development designs.	Holzinger et al. (2018)	Ferranti and Jaluzot (2020)
TESSA	Birdlife int., UK	2017	Textual guide that helps to identify relevant services, data needed for measurement, methods to obtain data, and communicate.	Peh et al. (2013)	Van Oijstaeijen et al. (2020)

The eleven GI evaluation toolkits were scored, which resulted in scores ranging from 4-8 points out of 9 (Figure 4, and for an elaborate description see Appendix 2). First of all, ten GI evaluation toolkits were based on ecosystem services on an urban scale, only the CAVAT toolkit did not meet this requirement. The same ten GI evaluation toolkits are scientifically sound, and only the CAVAT toolkit did not include sources in its manual. Four GI evaluation toolkits (NVE-city, BEST, GIVT and ECOPLAN-SE toolkits) dedicate a section in their manual to double counting of their results. A requirement ten GI evaluation toolkits met was to provide quantitative calculations, except for the GIBVT that monetizes benefits, without providing a quantification. A downside of the applicability of GI evaluation toolkits regarding schoolyards is that most (except NVE-city and GIBVT) focus on generic green infrastructure types, such as trees, green roofs and green areas. Especially the latter one was found to be widely used. For a schoolyard parcel development, a higher level of detail is required, e.g., lawn, bioswale, plant boarder, instead of the generic terms park and green area. At last, five toolkits are easily adjustable, because data can be changed in the Excel interface. The other five toolkits do offer manuals, but it is more complex to adjust. The GIS models (ECOPLAN-SE and InVest) are too complex to manually calculate. The web-based models (TEEB-stad and NVE-City) are possible to adapt, but an Excel model has to be developed. The computer program i-Tree Eco is too complex to be transferred to Excel.

The NVE-city toolkit was chosen as a basis for calculation of GI performance indicators in the GGSA, since it received the highest score of 8 points. Especially its ability to calculate benefits on a schoolyard parcel scale and variety of GI measures and grey measures makes it highly applicable for schoolyards. Its eleven indicators are based on regulating, supporting and cultural ecosystem services, which are calculated for 21 GI measures and 4 grey measures on a schoolyard parcel scale. This level of detail was only found in the NVE-city toolkit. In addition, the NVE-city toolkit is based on a large list of scientific literature and took double counting of benefits into account, which makes it a scientifically sound toolkit. Its only missing point was regarding adjustability since it is a non-adjustable web-based toolkit. However, the calculations can be transferred to an Excel model.



GI evaluation toolkits	Adjustability	Urban/Green infrastructure	Ecosystem services	Performance indicators	Urban scale	Schoolyard parcel scale	Scientifically sound	Double counting	Output	Total
NVE	0	1	1	1	1	1	1	1	1	8
BEST	1	0	1	1	1	0	1	1	1	7
GIVAL	1	0	1	1	1	0	1	1	1	7
GIBVT	1	1	1	1	1	1	1	0	0	7
NCPT	1	0	1	1	1	0	1	0	1	6
ECOPLAN	0	0	1	1	1	0	1	1	1	6
TEEBstad	0	0	1	0	1	1	1	0	1	5
InVest	0	0	1	1	1	0	1	0	1	5
i-Tree eco	0	0	1	0	1	1	1	0	1	5
CAVAT	1	0	0	0	1	1	0	0	1	4
TESSA	1	0	1	0	0	0	1	0	1	4

Figure 4. Scoring of eleven GI evaluation toolkits on the nine criteria

3.1.2 Calculations of the NVE-city toolkit

The NVE-city toolkit was developed for Flanders in Belgium. All calculations were validated for average Flemish conditions, such as climate and soil type. This thesis it was assumed that the qualitative and quantitative calculations are applicable to Dutch situations. The reason is that climatic conditions and vegetation types are comparable between the Netherlands and Flanders (personal communication, Liekens, I., 2020). An elaborate explanation of the assumptions and calculations of the NVE-city toolkit can be found in manual of Hendrix et al. (2018).

The NVE-city toolkit includes eleven performance indicators, e.g., carbon-sequestration, and twenty-five types of GI measures (of which 4 are grey measures), e.g., bioswales, urban deciduous trees and wood chips. Furthermore, the NVE-city toolkit is based on the pyramid valuation method from Kettunen et al. (2009), which follows three valuation steps: qualitative scoring, quantification and monetization of ecosystem services, for each GI measure. In the scope of this research, monetization is not included, thus this research only focuses on the qualitative score and quantification of ecosystem services.

At first, the NVE-city toolkit provides a description of ecosystem services and a qualitative valuation. For each performance indicator a GI measure receives a qualitative score, from 1 to 10 points/m^2. An example is that for the performance indicator carbon-sequestration, the GI measure bioswale scores 1 point/m^2, urban deciduous trees 7 points/m^2 and wood chips 0 points/m^2. The aim of the qualitative score is to show the amount of influence specific GI measures have on ecosystem services.

Secondly, the NVE-city toolkit quantifies the bio-physical impact of a scenario using performance indicators. Each quantified performance indicator has a unit, for example annual carbon-sequestration is calculated in kg carbon per m^2 of a GI measure (kgC/m^2). Each GI measure in the NVE-city toolkit receives a different score, based on a literature study and expert knowledge. An example is that for carbon-sequestration a bioswale sequestrates 0.03 kgC/m^2, urban deciduous trees 0.6 kgC/m^2 and wood chips 0 kgC/m^2. By quantifying performance indicators, the difference in exact numbers from different GI scenarios can be compared.

3.2 From NVE-city to Grey to Green Schoolyard Assessment

3.2.1 The Grey to Green Schoolyard Assessment

The development of the GGSA (Figure 5) resulted in the following indicator categories to assess grey to green schoolyard transformations: GI performance indicators, design indicators, and health, safety and education indicators. An overview of the GGSA with a more elaborate description can be found in Appendix 3.

The first category are GI performance indicators, which quantify the benefits of GI measures that are implemented at a schoolyard. The second group are design indicators, which show whether social benefits can be expected. A schoolyard that includes the requirements of design indicators, are more likely to expect positive social benefits to children. The third category are health, safety and education indicators, which are requirements of water design at green schoolyards, and design principles that support outdoor nature education.

In this chapter the development of the GGSA is presented and discussed. Firstly, the choice of performance indicators based on the NVE-city toolkit and other relevant GI evaluation toolkits are given. Thereafter, design indicators for social benefits are given. At last, the health, safety, education indicators are presented.

Figure 5. The Grey to Green Schoolyard Assessment (layout inspired on C&NN, 2017)

3.2.2 Green infrastructure performance indicators

3.2.2.1 Green infrastructure performance indicators obtained from NVE-city

The first step of adjusting the NVE-city toolkit to the be applicable for the GGSA was by selecting GI measures applicable to Dutch schoolyards. The NVE-city toolkit is based on twenty-five different GI measures (including grey measures) that are relevant to urban areas, divided over seven categories (Table 6).

For the GGSA, GI measures were included or excluded. Included categories were green roofs, hard surfaces, and water and wet vegetation. Of the dry vegetation category, private gardens, heath and other agricultural forms were excluded since these are not often found at schoolyards. Heath could be planted at schoolyards, but this would be included in a flower meadow. Furthermore, forests were excluded due to the scale that does not fit schoolyards. A group of trees in schoolyards would be calculated in form of individual trees. In addition, tree orchards are not found in school either. A fruit tree or other related orchard tree would be categorised as urban deciduous tree.

Table 6. GI measures of the NVE-city toolkit, and selection of the relevant GI measures for the GGSA

Category	**GI measure**	**Included in GGSA**	**Motivation**
Green roofs	Extensive green roof	Yes	Applicable to schoolyards.
	Semi-intensive green roof		
	Intensive green roofs		
Hard surfaces	Closed pavements	Yes	
	Semi-pervious (wood chips, broken fractions)		
	Grasscrete		
Water & wet vegetation	Water	Yes	
	Wet vegetation (wadi)		
Dry vegetation	Bare soil	Yes	The soil type sand is added, which is often seen at schoolyards. For the indicator of water retention, artificial grass added to bare soil since artificial grass drains the water onto the soil of the school. A layer of sand is often used to install artificial grass.
	Flower, herbaceous meadow		Applicable to schoolyards.
	Grass lawn, bedding plant		
	Shrubs, hedges		
	Allotment garden		Vegetable gardens are often found at schoolyards.
	Private gardens	No	Private gardens are not part of schoolyards.
	Heath		Natural heath areas are not found in schoolyards.
	Other agricultural forms		Agricultural forms.
Forest	Deciduous forest	No	Forests are not part of schoolyards. A group of trees are calculated with the total surface area with the data in the urban tree category.
	Coniferous forest		
	Mixed forest		
	Forest edge		
Urban Tree	Deciduous tree	Yes	Applicable to schoolyards.
	Coniferous tree		
	Mixed trees		
	Tree orchard	No	Tree Orchards are not part of schoolyards. Urban trees are used for fruit trees.
Built surface	Built surface, walls	Yes	Applicable to schoolyards.

The second step of making the NVE-city toolkit applicable to the GGSA, was by choosing GI performance indicators relevant to schoolyards. Benefits of GI can be calculated for eleven indicators in the NVE-city toolkit: five regulating, five cultural and one supporting ecosystem services (Table 7).

The following five NVE-city indicators were included in the GGSA: water retention, air quality, carbon-sequestration, temperature and biodiversity. For schoolyards it is important to calculate on the schoolyard's parcel scale, which is allowed by calculating qualitative scores and quantifying these five indicators. The GI performance indicator calculations (qualitative and quantitative), as done in the GGSA Excel model, are presented in Appendix 4.

Six NVE-city indicators were not applicable to schoolyards and were excluded from the GGSA. At first, noise reduction is only applicable to areas that are separated from a road with a tree wall of 100-200 meters wide. It was assumed in this thesis that this tree wall is not applied to Dutch schoolyards (personal communication, Liekens, I., 2020). Recreation, physical and mental health, and social contacts were excluded since the methods of the NVE-city are applicable to public urban parks, which are not comparable to schoolyards (personal communication, Liekens I., 2020). Child development was also excluded since no quantification was provided. At last, private property value was excluded since this research does not focus on monetized values. In addition, private property value is an individual benefit, compared to all others being beneficial to a broader community.

Table 7 GI performance indicators of the NVE-city toolkit, and selection for the GGSA

Performance Indicator	GI measure	Qualitative output	Quantitative output	Ecosystem service	Included in GGSA
Water retention	25 GI measures (including grey) (Table 6)	A score from 1 to 10 based on literature	m^3/yr	Regulating	Yes
Air quality			kg PM_{10}/yr		
Carbon-sequestration			kg C/yr		
Temperature			°C		
Biodiversity			Points/m^2	Supporting	
Noise reduction			dB	Regulating	No
Child development	Green area	Literature overview	n/a	Cultural	
Recreation	Parks > 0.5 ha	A score from 1 to 10 based on literature	visits/yr		
Property value	Vegetation within 50 m		€/house/yr		
Phys./mental health	Green area within 1 km		DALY		
Social contacts	Green area	Literature overview	n/a		

3.2.2.2 Additional green infrastructure performance indicators

Additional GI performance indicators were added to the GGSA, which were relevant GI performance indicators selected from the GIBVT, GI-Val, BEST and TEEB-stad toolkits. The Excel-based toolkits GIBVT, BEST and GI-Val are adjustable, and the TEEB-stad web-tool includes a manual with calculations that can be transferred to Excel. The toolkits ECOPLAN-SE, InVest, i-Tree Eco, CAVAT and TESSA were excluded. The ECOPLAN-SE, InVest and i-Tree Eco toolkits are based on detailed calculations, which are too detailed to transfer to Excel. The CAVAT toolkit does not calculate ecosystem services, and TESSA is not open source. The list of indicators considered from the GIBVT, GI-Val, BEST and TEEB-stad toolkits can be found in Appendix 5. The three additional indicators that were added to the GGSA were insulation, rainwater harvesting and nature education (Table 8).

Table 8. Additional performance indicators of the GGSA

Performance Indicator	Urban infrastructure type	Output	Ecosystem service	Toolkit
Insulation	Green roofs	m^3 gas/yr	Regulating	TEEB-stad
Rainwater harvesting	Grey infrastructure	m^3 water/yr	n/a	BEST
Nature education	Schoolyards	min./child/week	Cultural	BEST, GIBVT

The first GI performance indicator added to the GGSA was insulation of green roofs, from the TEEB-stad toolkit. Reduction of gas use has an effect on the school's CO_2 emissions. The calculation of this GI performance indicator focused on the reduction of heat loss during winter, due to insulation by green roofs (Does et al., 2019). Annual gas savings by implementing a green roof are on average 0.29 m^3/m^2. A green roof has a large isolation effect on old roofs with a low isolation effectiveness. The isolation effectiveness of green roofs on building roofs constructed before 1975, during 1975-1991 or after 1991 are 100%, 50% and 0%, respectively. Thus, this indicator can be applied to roofs constructed before 1992. This indicator can be quantified, but no qualitative score was given.

Second, rainwater harvesting was chosen from the BEST toolkit and was added to the GGSA. Water circularity can play a role at schoolyards. An often found measure at schoolyards is a rain barrel, which can be used to water plants, which as a consequence reduces tap water use. Rainwater harvesting systems are not GI measures but are part of making schoolyards more circular. Rainwater harvesting is quantified by local data on the tap water savings by using rainwater (Horton et al., 2019). This indicator is only quantified and no qualitative score is given. This is because no literature research was performed to indicate a low rainwater harvesting score (1 point) and high score (10 points).

The last GI performance indicator added to the GGSA is environmental education, which was found in the GIBVT and BEST toolkit. Nature education is quantified by the time spend on nature education in or outside the schoolyard premises. It is important to quantify nature education to see if the school's target is reached. For the GGSA, nature education was quantified by the number of hours children used the schoolyard for nature education, excluding the regular outside playing hours. The GI performance indicator was quantified and a qualitative score was given. This thesis developed a scoring scheme with intervals of 6 minutes (Table 9). Time intervals were based on the Dutch national goal set for nature education, which is 60 minutes per child per week (Sollart and Vreke, 2008).

Table 9. Scoring method of the GI performance indicator nature education of the GGSA

Score	1	2	3	4	5	6	7	8	9	10
Min./child/week	≤6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	≥55

3.2.3 Design indicators

In order to show the social benefits of green schoolyard transformations, design indicators were added to the GGSA. In literature it was found that transforming schoolyards from grey to green can have effects on several aspects of children (Table 10) (De Vries et al., 2013; De Vries et al., 2017; Wesselius, 2020). It was found that the most generic effect of transforming schoolyards is on appreciation and well-being of children (De Vries et al., 2013). Effects were mainly neutral or positive, while no notable negative effects were found (De Vries et al., 2013; De Vries et al., 2017; Wesselius, 2020).

De Vries et al. (2013) concluded there should be a match between the redevelopment and the children's needs to receive positive benefits. It was found that a more positive score on the appreciation of the schoolyard and/or well-being on the schoolyards go together with multiple benefits: the rating of the child's mood, concentration, playing outside afters school hours, competence test, self-confidence, nature attitude (less scared for nature). The appreciation could be positively related to how much children like nature.

Table 10. Effect of transforming a grey schoolyard to a green schoolyard on social aspects of children. A "+" means a positive effect, a '0' means overall no significant positive of negative effect, and a +/0 means in some cases a positive change and some no observed effect. Empty cells are not included in the literature review.

Social benefits	**De Vries et al. (2013)**	**De Vries et al. (2017)**	**Wesselius (2020)**
Appreciation	+/0	+	+
Social climate	0	+	
Well-being	+/0	+	+/0
Concentration	0	0	+
Mood	0	+	
Self-esteem	0		
Social skills	0		
Natural attitude	+/0	0	
Playing behaviour			+
Physical activity		+/0	

A list of nine design indicators were obtained from De Vries et al. (2013), Wesselius et al. (2020) and Maas (forthcoming) *in* Bos et al. (2019) for the GGSA (Table 11). The design indicators were based on the main principle that more social benefits are expected when the new schoolyard is greener, larger and more varied compared to the original grey schoolyard (De Vries et al., 2013). Design indicators that are based on the principles of being more varied and having a larger surface are not directly related to GI measures. In contrast, indicators that are based on the greener principle are directly related to GI measures.

The following four design indicators are directly related to GI measures: green surface, green volume, play green and robustness. When a schoolyard is transformed, a minimum of 25% green surfaces is required (Maas, forthcoming *in* Bos et al., 2019). In addition to the surface, the indicator green volume shows if mainly small sized plants are included (shrubs or flower perks) or also larger vegetation (high shrubs and full grown trees) (Maas, forthcoming *in* Bos et al., 2019). The indicator play green shows whether play areas are combined with vegetation, which is recommended when designing green schoolyards (De Vries et al., 2013; Maas, forthcoming *in* Bos et al., 2019). At last, a general design indicator is robustness of GI, given the high play pressure at schoolyard (De Vries et al., 2013). Fragile schoolyards can lead to nuisance, such as being unable to play on the grass after heavy rainfall.

The remaining five indicators do not have a strong relation with GI measures. However, they are part of green schoolyard transformations and are linked to impacting social benefits. Because of these reasons, they were included in the GGSA. The following do not have a strong relation with GI measures: surface, surface increase, playing possibility, sub area and loose parts. At first, two indicators are based on the schoolyard surface (surface and surface increase). According to Maas (forthcoming) *in* Bos et al. (2019), a larger schoolyard is preferred, and when a schoolyard is transformed De Vries (2013) states that an enlargement of the surface area is beneficial to the appreciation by children. Next, more playing possibilities are related to an increased appreciation of the schoolyard by children. For example, when a soccer field would be removed, appreciation of the schoolyard could reduce. Another indicator is sub-areas, which is based on the variation of different areas at the schoolyard (De Vries et al., 2013). A schoolyard with more sub areas enables children to find an area according to their liking. Parts of sub-areas do involve nature, especially resting areas surrounded by shrubs, such as butterfly gardens and willow tunnels. At last, loose parts is an important indicator to enrich playing situations, which can provide social benefits (De Vries et al., 2013; Wesellius, 2020). In addition, loose parts also include natural elements, such as tree branches, sand and water.

The design indicators from De Vries et al. (2013) and Wesellius (2020) were not based on scores, while the indicators from Maas (forthcoming) *in* Bos et al. (2019) were linked to scores. In this thesis one type of score is given to be able to compare all design indicators. The score of the GGSA design indicators were based on a dichotomous scale: yes (1 point) and no (0 points). First, the design indicators from De Vries et al. (2013) and Wesellius (2020) were scored by meeting the requirement (1 point) or not (0 points). Second, the design indicators of Maas (forthcoming) *in* Bos et al. (2019) were already developed on an ordinal scale: 1-5 points. This ordinal scale was changed to a dichotomous scale. From the existing scale (1 to 5 points) the average values of 3 points was taken. This average value was the minimum requirement to receive a yes (1 point) for the indicators of Maas (forthcoming) *in* Bos et al. (2019). The overall outcome of the design indicators is to see on which points the schoolyard design can improve. It will not indicate the amount of social benefits, but instead stimulates design that is more likely to provide social benefits.

Four design indicators are based on the difference between the old and new schoolyard: surface increase, playing possibility, sub area and loose parts. These indicators can only be used when there is a baseline schoolyard, which would receive 0 points. The new schoolyard receives 1 point if it improves on this indicator. The scoring of the other six indicators is separately done for the baseline and new design.

Table 11. GGSA design indicators that are expected to have a positive impact on social benefits provided to children. 0 points indicates that the schoolyard does not meet the requirement, and 1 point indicates that the schoolyard meets the requirement

Indicator	**Score**	**Description**	**Source**
Surface	0 or 1 point	Schoolyard size > 900 m^2.	Maas, (forthcoming) *in* Bos et al. (2019)
Surface increase		Surface area increased of the new design (baseline=0).	De Vries et al. 2013
Green surface		Minimum of 25% coverage by GI measures (excluded are hard and semi-hard surfaces, such as tiles and wood chips).	Maas (forthcoming) in Bos et al. (2019)
Green volume		Requirement is not met when the schoolyard has: no vegetation or small vegetation (small area with lawns, shrubs, flower perks, and few young scattered trees). Minimum requirement: mainly small size plants. Some large vegetation is found, e.g., full-grown trees and high shrubbery.	Maas (forthcoming) in Bos et al. (2019)
Playing possibility		There is an increase of playing possibilities at the new design (baseline = 0).	De Vries et al. (2013)
Sub areas		There is an increase of sub areas at the new design (baseline = 0).	De Vries et al. (2013)
Play green		Requirement is not met when: vegetation is not part of the play area, and is just for decorative purpose (lawns, flower perks, small shrubs). Minimum requirement: play areas are next to decorative vegetation or play areas are integrated with vegetation.	De Vries et al. (2013); Maas (forthcoming) in Bos et al. (2019)
Loose parts		There is an increase of loose available at the new schoolyard: sand, water, branches, wood blocks, etc. (baseline = 0).	De Vries et al. (2013); Wesselius (2020)
Robustness		Vegetation is robust; it can cope with weather conditions and pressure from children's activities (grass is not recommended).	De Vries et al. (2013)

3.2.4 Health, safety and education indicators

The last group of indicators added to the GGSA are a mix of three categories related to GI measures: health, safety and education (Table 12). The health and safety indicators are requirements for water-related measures at green schoolyards, and nature education are design principles that supports outdoor nature education. Health, safety and education indicators are also design related indicators, like the design indicators in section 3.2.2, but are not related to social benefits.

The indicator health and safety are applicable to water bodies and wet vegetation on schoolyards, such as ponds and bioswales. Health of children could be influenced by pollutants and pathogens in stagnant water, which can be solved when design drains well (Duggin and Reed, 2006). Regarding safety, water elements must be made to make it difficult to fall into, but also allowing children to get out of it easily. Examples are designing shallow slopes and edges, and implementing barrier vegetation (Duggin and Reed, 2006).

Three education indicators were added to the GGSA. These indicators stimulate nature education through design principles. At first, water management design principles can be used for education, such as installing a rain barrel used to water plants and including visible drains (Duggin and Reed, 2006). Second, education about food can be supported by measures such as school gardens and fruit trees (De Vries et al., 2017). At last, educational facilities can support the use of schoolyards for nature education, such as outdoor working places and animal houses (Gemeente Amsterdam, n.d.). These three indicators cover the same topic as the GI performance indicator nature education. The difference is that the GI performance indicator measures the times spent on nature education, while these three education indicators focus on design elements stimulating nature education. Improving these education indicators, could affect the time spent outside for nature education.

In order to score the design indicators in the GGSA, a dichotomous scale was used: yes (1 point) and no (0 points). The health, safety, education indicators were not based on a score initially, thus no changes were made to the indicators to apply the dichotomous scale. The overall outcome was to see whether health and safety requirements regarding water design are met, and to show if schoolyards include design principles to support outdoor nature education.

Table 12. Health, safety, education indicators added to the GGSA. 0 points indicates that the schoolyard does not meet the requirement, and 1 point indicates that the schoolyard meets the requirement

Indicator	Scoring	description	Source
Health (water)	0 or 1 point	Design with water must be made to prevent stagnant water, which can contain pollutants or pathogens.	Duggin & Reed (2006)
Safety (water)		GI measure with water must be safe: shallow slope and edges, and use barrier vegetation.	Duggin & Reed (2006)
Education (water)		Include water management for outdoor nature educational purposes: e.g., rain barrel to use for watering plants, and visible drain to show the rain's stream.	Duggin & Reed (2006)
Education (food)		Include school gardens, apple trees for outdoor nature education.	De Vries et al. (2017)
Education (facilities)		Include working spaces, animal houses, and other facilities for outdoor nature education.	Gemeente Amsterdam (n.d.)

3.3 Case study De IJsbreker

Transforming the grey schoolyard of De IJsbreker to a green schoolyard, showed positive effects on the three categories of the GGSA. Regarding GI performance indicators, 6 out of 9 improved. Furthermore, the due to the fact that the new design was greener and more varied than the baseline, it was expected that the new design has positive impacts on social benefits to te children. At last, the bioswale is not expected to negatively affect health and is safe, and outdoor nature education is supported by 2 out of 3 education indicators.

This section, 3.2, shows the results of the case study De IJsbreker, for which the maps in Appendix 1 were used. The surfaces of the schoolyard's baseline and new design, used for the GI performance indicators, are shown in Table 13.

Table 13. GI measure surfaces of the baseline and new design

Category	**GI measures**	**Surface area (m²)**	
		Baseline	**New design**
Green roofs	Extensive		
	Semi-intensive		
	Intensive		
Hard structures	Pavements	2133.5	1450
	Artificial grass	188	
	Semi-pervious (wood chips)		200.5
	Grasscretes		
Water, wet vegetation	Water		
	Wet vegetation (bioswale)		28
Dry vegetation types	Bare soil and sand	76	177
	Flower and herbaceous plant meadow		77.5
	Grass lawn, bedding pant		140
	Shrubs and hedges		324.5
	Allotment garden	62.5	62.5
Urban trees	Deciduous trees	69.08	194.79
	Coniferous trees		
	Mixed trees		
Walls	Green walls and facades		20
Grey	Built surface		
Total surface (excluding crown surface and green walls and facades)		2460	2460

3.3.1 Green infrastructure performance indicators

The qualitative scores of the GI performance indicators showed that new design of De IJsbreker improved on all 6 indicators compared to the baseline (Figure 6). These qualitative scores showed the effect of GI measures on biophysical GI performance indicators (water retention, air quality, carbon-sequestration, temperature and biodiversity).

The total score of 6 GI performance indicators increased from 3.4 to 13.7 points, out of the 54 points. This increase was caused by replacing tiles with GI measures, since hard impervious surfaces do not or barely provide benefits. To illustrate the change, the impervious surfaces reduced from 87 to 59%. The influence of GI measures can be further increased by reducing impervious surfaces, and by choosing the most effective GI measures for GI performance indicators.

For the baseline, all qualitative scores were equal to or below 1.5 points. Water retention received the highest score of 1.5 points out of 10. This difference can be explained by the effectivity of GI measures for water retention. For example, water retention was the only indicator that received 1 point/m^2 for the pavements, where other four indicators received 0 points/m^2 for pavements. This point difference resulted in a higher score for water retention, due to the impervious surface of 87%. Regarding nature education, this received a score of 1 since the children did not often use the schoolyard, according to the school board of De IJsbreker.

The new design of De IJsbreker improved on all GI performance indicators compared to the baseline. Regarding the bio-physical GI performance indicators, the new design scored highest on water retention, with 2.6 points difference compared to the baseline. This was because a large share of GI measures were more effective for water retention than other biophysical GI performance indicators. These GI measures were wood chips, shrubs and meadow plants, scoring 7, 8 and 10 points/m^2, respectively. Furthermore, biodiversity increased with 2.2 points compared to the baseline. This was caused by the increase in surface of plant meadows and shrubs, with an effectivity 10 and 9 points/m^2, respectively. Next, the scores of temperature, carbon-sequestration and air quality improved with 1.3, 1.2 and 0.8 points, respectively. These indicators have in common that urban trees have a large effect on their scores. However, the new design had a small percentage of trees on the schoolyard. The crown surface of urban deciduous trees covered 8% of the total surface, while the total amount GI measures covered 59% of the total schoolyard. For temperature reduction, a bioswales is effective as well, but this covered only 1% of the total schoolyard surface. At last, the qualitative score of nature education increased with 3 points, which is caused by more use of the schoolyard by the children.

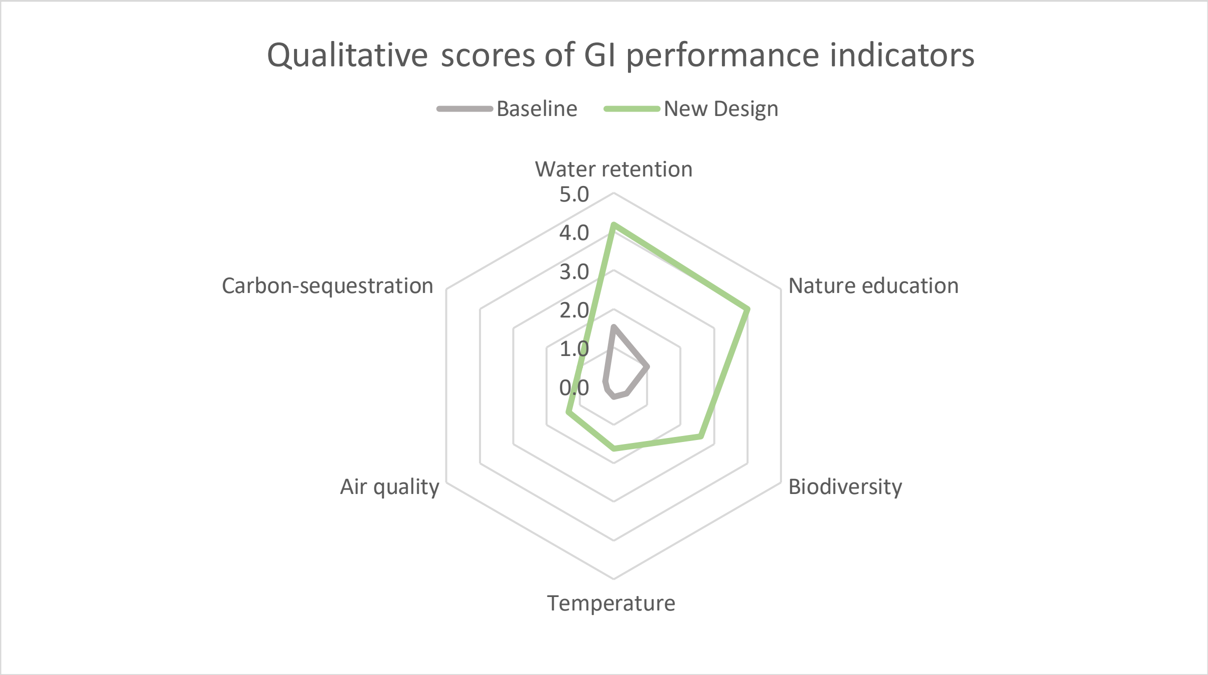


Figure 6. Spider chart of the performance indicators. Qualitative data on a scale from 0 to 10 is visualised for the baseline and new design

The following analysis was performed on the quantitative calculations of the performance indicators. These results do not show if the schoolyard design has a sufficient performance, since no targets were set for the quantitative indicators. To illustrate, the city of Amsterdam could set schoolyard water retention targets per m^2, which could then be used to see whether the new design has the desired water storing capacity.

The GI performance indicators show a large improvement for 4 out of 8 indicators (Figure 7 a, b, c and d). Air quality, water retention and carbon-sequestration (high value) increased with 445, 385 and 335%, respectively. These values could have been higher when the schoolyard implemented more GI measures. For water retention, it would be more difficult to improve since the qualitative value (Figure 6) was relatively high, due to the GI measures that already have a large influence on water retention. Furthermore, regarding nature education, the time spent in the school garden out of the total time for nature education in the curriculum, improved from 3 to 19 minutes per child per week. This value increases with 16 minutes, which is a positive trend. This value is an addition on the indoor nature education classes, which were not included in Figure 7d. The absence of the indicator temperature was caused by the low qualitative score (Figure 6), which should be above 2 points to expect temperature effects between 0-0.5 °C. The two performance indicators rainwater harvesting and insultation were not included in Figure 7 because there were no rainwater harvesting measures and no green roofs implemented at the new design.

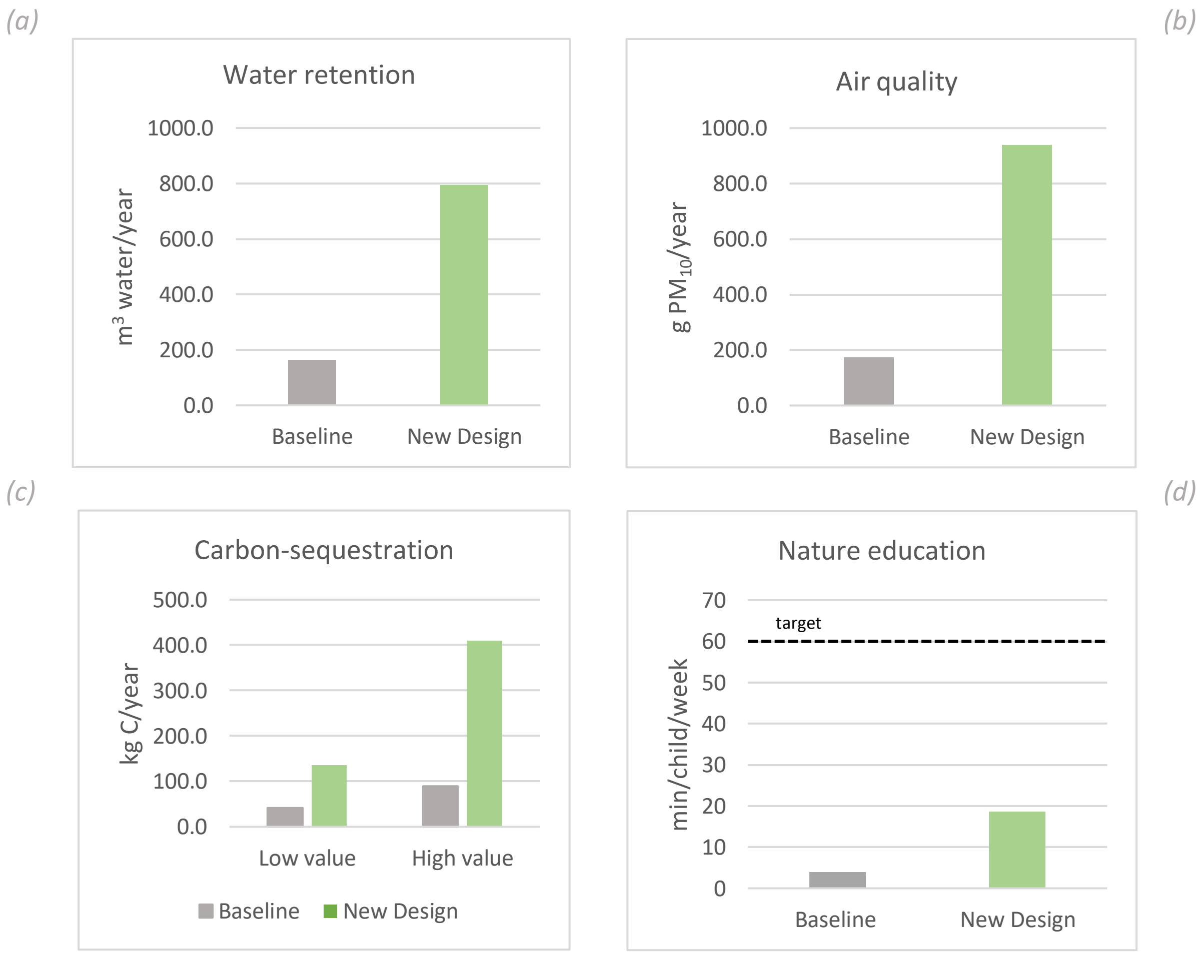


Figure 7. The four quantitative outcomes of the case study De IJsbreker, for which the baseline is compared to the new design. The quantitative results are annual values of (a) water retention, (b) air quality, (c) carbon-sequestration and (d) nature education

3.3.2 Design indicators

The design indicator analysis shows that the new design includes many design criteria, which positively impacts the social benefits for children. This is shown from the score of the new design that scored 8 out of 9 points, which is an improvement of 6 points compared to the baseline (Table 14).

Table 14. Scoring schoolyard on design and general indicators

Design indicators	Score baseline	Score new design
Surface	1	1
Surface increase	0	0
Green surface	0	1
Green volume	0	1
Playing possibility	0	1
Sub-area	0	1
Play green	0	1
Loose parts	0	1
Robustness	1	1
Total	**2**	**8**

Three indicators received the same score for the baseline and new design, which were surface, surface increase and robustness. The baseline and new design did not increase in size, and therefore received 0 points for the indicator surface increase. Furthermore, the baseline and new design met the requirement of the indicator schoolyard surface and robustness. The baseline was robust since only 3% was green area, which were an allotment garden and trees in wooden pots. The new design consisted of 41% pervious area, of which 25% is vegetation. Being less robust is a negative aspect of green schoolyards, however design decisions were made that enhanced robustness, such as choosing for wood chips instead of grass, and more shrubs instead of bedding plants.

The baseline scored lower than the new design on six design indicators. The baseline incorporated little vegetation and was not varied. The schoolyard was covered with tiles and some small plants and trees, which only covered 3% of the total area. The vegetation was not incorporated with the playing facilities of children. Furthermore, the baseline was not varied, since there were only three sub-areas: a vegetable garden, playing area and social area. Four different playing possibilies were found on the old schoolyard: a tumble bar, sand box, slide and soccer field. Regarding the indicator loose parts, a sand box was found.

The new design improved on six indicators, compared to the old design. The surface of vegetation increased 25%, which is equal to the requirement. In addition, the new design included mainly large shrubs and trees, which makes the schoolyard feel greener than a schoolyard with small bedding plants. Concerning the indicator play green, the new schoolyard included playing areas next to vegetation and on grass or wood chips. Included varieties of play green were the sand-water-game area, and a willow relax and play area. The sub areas of the green schoolyard included a vegetable garden, five relax areas, moving and playing area, social zones, and butterfly garden for discovery. At last, the amount of loose parts also improved, since the new schoolyard included a sand box, mud kitchen and water to play. However, still more loose parts can be added to the schoolyard.

When indicators that improved of the new design are compared, differences in quality were found. For example, while the playing possibilities improved from 4 to 14, the loose parts improved by just 3, but both received one point. By scoring on a scale from 0 or 1 point, the extent to which an indicator improves is difficult to define. Therefore, the results should be interpreted as a simple way to see whether criteria are met or not met, and that the result distinguished between different types of improvement but not on the amount of obtained improvement.

3.3.3 Health, safety and education indicators

The new design showed to meet the health and safety requirements of the bioswales. In addition, the new design facilitates outdoor nature education better than the baseline (Table 15).

The baseline did not include water related measures, thus the indicators health and safety were not included. Regarding education, the baseline included a vegetable garden, but no water or facility related design principles.

The new design included water measures according to health and safety requirements. In terms of health, the bioswales contain drainage to ensure no stagnant water for long periods of time, preventing pollutants and pathogens from accumulating. Regarding safety, the bioswales are surrounded by barrier vegetation and are shallow (maximum 0.3 m deep), reducing the risk of children falling into them, but making it easy to get out. Regarding education, the new design improved the vegetable garden by adding fruit trees, and implemented outdoor education facilities, such as working benches, and insect and bird houses. With regard to water education, no relevant measures have been included, such as a visible drainage or rain barrel.

Table 15. De IJsbreker's score of GGSA health, safety and education indicators

Indicator	Score baseline	Score new design
Safety	n/a	1
Health	n/a	1
Education (water)	0	0
Education (vegetable garden)	1	1
Education (facilities)	0	1

3.4 Potential of the Grey to Green Schoolyard Assessment

From the case study it could be seen that the GGSA showed the effect of transforming grey to green schoolyards on 22 indicators, regarding GI performance, design, and health, safety and education. The wide spectrum of indicators taken into account show that a green schoolyard consists of many different aspects. These aspects can be taken into account during green schoolyard design, such as safety, GI measures, variety of play areas, and can also provide many benefits, such as water retention, improve biodiversity and possibly enhances well-being of children. Since the GGSA is based on scientific literature and applicable for Dutch conditions, it gives a good indication on the impacts of green schoolyard transformations in the Netherlands.

The GGSA was developed since no GI evaluation toolkits were found in literature for green schoolyard transformation projects. Therefore, the GGSA is different from all GI evaluation toolkits, since it is made specifically to assess green schoolyard transformation projects. GI evaluation toolkits were mostly made for urban scale projects, which are not on schoolyard parcel scale, thus the calculations of the GGSA are much more detailed. The GGSA can best be compared to the NVE-city toolkit, which was used as a basis for the GGSA GI performance indicators. To illustrate the level of detail required for schoolyards, 6 out of 11 GI performance indicators were excluded from the NVE-city toolkit, since these did not focus on a schoolyard parcel scale. In addition, only GI measures of the NVE-city toolkit were included to the GGSA if they were applicable to schoolyards, for example forests and heath landscapes were excluded from the GI measures. In addition, the GGSA toolkit includes more indicators that are specific to green schoolyards, regarding GI performance, design, and health safety and education, which is the largest difference from the NVE-city toolkit.

Regarding the three categories of the GGSA, interrelations were found between on one side the GI performance indicators, and on the other side the principles from the design, and health, safety and education indicators. A balance between these two sides must be found when designing a green schoolyard. Schoolyards designed to retain large quantities of water might choose for a bioswale that covers a large area, which reduces the playing space for children compared to the old schoolyard. As a consequence, more points are scored on water retention, but a lower score of the schoolyard design indicators is expected. Thus, the framework will show the user if the balance is not achieved, when design principles are not met, while performance indicators are receiving high qualitative scores. In addition, the health and safety indicator would influence the choice of a bioswale as well, if this makes the schoolyard more dangerous or risky to health. So, because a schoolyard is a multifunctional area it needs a balance between GI measures and different activities that are expected on schoolyards. In addition to this, a green schoolyard has a chance of being successful when the children appreciate the new schoolyard more than the old schoolyard. The design criteria are namely the preconditions to expect effects on children's well-being and appreciation (De Vries et al., 2020). Therefore, a schoolyard is possibly most successfully designed when it provides most potential from performance indicators while not compromising the design criterion.

3.5 Zooming out

3.5.1 Effects on a neighbourhood scale

As Flax et al. (2020) stated, greening schoolyards could help the resilience of cities to cope with environmental problems, such as heat stress, air pollution and urban flooding. It was found in this thesis that the greening of the schoolyard De IJsbreker had most influence on the GI performance indicators of water retention and biodiversity improvement. However, the redevelopment of De IJsbreker's schoolyard did not have a large influence on air quality, carbon-sequestration and was not enough to reduce heat stress, which was caused due to a lack of effective GI measures. However, as seen at De IJsbreker, there is a trade-off between maximizing benefits and other functions schoolyard should perform, such as providing play areas.

The city of Amsterdam has a vision to make more schoolyards green and publicly accessible in the period of 2020-2050, in order to provide more green and adventurous playgrounds to the city (Gemeente Amsterdam, 2020). These new green playgrounds can also act as rainwater buffer and provide additional benefits. Examples are the effects of the GI performance indicators in this thesis. Especially when more schoolyards in Amsterdam are transformed to be greener, this possibly has positive impacts on the neighbourhood. The extent to which a green schoolyard like De IJsbreker can improve the neighbourhood's environment differs per performance indicator.

The GI measures at the new design of De IJsbreker's schoolyard had most influence on water retention, according to the qualitative assessment. Amsterdam aims to be rainproof, for which a schoolyard can contribute to the water retention of its surrounding neighbourhood. Using the GGSA, the annual reduction of stormwater can be quantified and reduces a part of the stormwater going to the sewer system. As stated by Van Oijstaeijen et al. (2020), a combination between green, blue and grey solutions is necessary to increase the urban resilience. Thus, the green schoolyard of De IJsbreker can support its neighbourhood to reduce the surface runoff to the sewer system. In addition, rainwater harvesting systems can also play a small role in reducing stormwater going into the sewer system, especially in summers, when there is a demand to water vegetation.

Greening the schoolyard of De IJsbreker did not show a reduction of local air temperatures. In research, it was found that parks smaller than 3 ha can reduce the temperature by 1 °C on the location itself but will not have an effect on its surrounding environment (Van Hove et al., 2011). This can be supported by a study of Antoniadis (2020), where they found that vegetation has a positive effect on a schoolyards' microclimate, since it improves the heat stress perception by children, and improves the thermal comfort. If more vegetation such as trees were added to the IJsbreker's schoolyard, it will possibly results in a reduction of the local air temperature of the schoolyard itself.

For the GI performance indicators carbon-sequestration and air quality, most effective way to improve the situation in Amsterdam would be to look at the source of the problem. A report of Moorselaar and Van der Zee (2020) found that deposition of PM_{10} on urban vegetation should not be the solution to cope with air pollution. In contrast, Litschke and Kuttler (2008) found that small scale local planting campaigns could be beneficial for reduction of PM_{10} concentration, however, more research is needed to confirm this. Thus, even though the effect might be little, it is still important to show that urban vegetation has a positive effect on PM_{10}, but also CO_2. A method of reducing the CO_2 from the source was shown in the GGSA by implementing a green roof, which was not implemented on De IJsbreker. Roofs constructed before 1991 have a low isolation effectiveness, which will have an effect on the gas saved by heating a building, and thus reduce the CO_2 emissions of the school.

Regarding nature education, no effect is expected outside of the schoolyard since this is only related to the school's curriculum. The target of nature education is one hour per child per week in the Netherlands (Sollart and Vreke, 2008). This hour per week should be spent to indoor or outdoor classes regarding nature and the environment. The GGSA showed that an increased amount of time is spent on being in nature and working at the De IJsbreker's vegetable garden, which is additional time spent on nature education. In addition, a green schoolyards allows children to stay within school premises to learn about nature, which makes nature more easily accessible.

The design criteria of the GGSA can support social benefits of children on the schoolyard, but also have effects outside of the boarder by neighbours using the schoolyard. This can only happen if the schoolyard is publicly accessible outside of school hours. In addition, the health, safety and education indicators are design principles that affect the schoolyard design but are not expected have effects outside the schoolyard premises.

3.5.2 Using the Grey to Green Schoolyard Assessment in Oslo

The GGSA is developed to be applicable to Dutch schoolyards but could also be used in other countries. The research on design indicators was based on Dutch reports, for which it cannot be said if these are applicable to non-Dutch countries, but they could act as basic principles and be adjusted according to the country's wishes. Regarding health, safety and education indicators of the GGSA, it is assumed that these are applicable to other countries, since these are general design principles. Regarding GI performance indicators, these could possibly be adjusted to be applicable to North Western Europe. For example, when using the GGSA to provide an indication of the impacts, the qualitative and quantitative outcome might not be exactly correct but will still provide a good indication of the results.

To further elaborate on the biophysical GI performance indicators, it is important to consider climatic differences. It can be seen that parts of France, England, Denmark, Belgium and Germany have a similar climate as the Netherlands. These countries have a Cfb climate, from the Koppen-Geigers climatic zones, which indicates a moderate sea climate with precipitation throughout the whole year (Rijenga and Brassier, 2016). For Oslo, which is a city with a different climate than Amsterdam, it can be seen that it has a moderate continental climate, with precipitation all around the year (Rijenga and Brassier, 2016). With some adjustments, the biophysical GI performance indicators of the GGSA are probably applicable to assess Oslo schoolyards.

Differences are to be expected with regard to water retention. In Oslo there is less rainfall than in Amsterdam with 740 and 805 mm, respectively. But in Oslo, more intense rainfall can be expected in summer than in Amsterdam (Climate-Data, n.d.). To illustrate, the most intense month is August for Oslo, with 118 mm in 11 days, while this is July for Amsterdam with 88 mm in 11 days (Climate-Data, n.d.). Water retention data in the NVE-city model is representative of intense summer rainfall for Flemish conditions, which means that different retention coefficients have to be used for Oslo.

The second point is the growing season, which is shorter in Oslo. This means that for deciduous vegetation types, the effectivity is possibly reduced. Indicators affected by a shorter growing season could be air quality and carbon-sequestration. However, on some parts Oslo possibly has larger effects on these two indicators than expected in Amsterdam. Regarding trees, often coniferous trees are found in colder climates, which sequestrate more carbon and have a larger PM_{10} deposition value than deciduous tree. In order to get larger effects, design choices were found to have a large influence.

Regarding the biodiversity performance indicator, it is recommended not to use it for Oslo. Biodiversity in the GGSA is based on qualitative scores of different GI measures based on Flemish biodiversity data, which are expected to be different for Oslo.

3.6 Limitations and further research

A general limitation of the GI performance indicators obtained from the NVE-city toolkit is that these are very specific, since they are based on 25 GI measures. Because calculations are done on a high level of detail, it might be difficult to update calculations with new data. This detailed information is often not found for specific locations, but a combination of different sources from different locations has to be used. The current data included in the NVE-city toolkit still gives a reliable and high detailed indication of the benefits from GI measures on different performance indicators (Liekens, I., personal communication, 2020). In recent years more research was started into benefits of different GI measures, but these were not sufficiently quantitatively available to be included into the NVE-city toolkit. The NVE-city toolkit will be revised in 2022, for which it is likely that new data will be included (Liekens, I., personal communication, 2020). The other option would be to use a GI evaluation toolkit with less detailed indicators, however the amount of benefits would differ too much from the actual benefits the green schoolyard provides. Thus, it can still be concluded that using these specific indicators is preferred in the case of green schoolyard transformation projects.

A limitation and improvement were identified concerning the design indicator scoring. The paper of Maas (forthcoming) *in* Bos et al. (2019) used a scale from 1 to 5, which was changed in this thesis from a 0 to 1. Further research is adviced to be conducted to use a scale from 1 – 5, like the report of Maas (forthcoming). This would mean that all design indicators should be categorised from 1 – 5, by including different levels of quality to the indicators. This result would show the different levels of improvement that can be made per design indicator to achieve a greener and more varied schoolyard that positively impacts the social benefits for children.

The quantitative analysis of the GI performance indicators can be improved by comparing the results to targets. The targets are recommended to be made on a neighbourhood scale, because challenges of different neighbourhoods can differ within a city, such as Amsterdam. It is recommended to set these goals together with stakeholders. To illustrate a target, a hypothetical goal of a schoolyard is presented in Figure 8. When the municipality of Amsterdam would say that the minimum annual retention of a schoolyard should be 250 mm, for this schoolyard it would mean in total 605 m^3 water must be retained annually. This target communicates clearly if the schoolyard design is sufficient. In addition to the target, it must be taken into account that this is an annual value for most performance indicators. This might not be in line with current strategies. An example is that in the future more extreme weather event occur, for which Amsterdam aims to cope with 60 mm of rainfall within one hour. These goals cannot be covered by the GGSA, since it is based on average annual values. For specific calculations, models are recommended to be used, such as a hydraulic model.

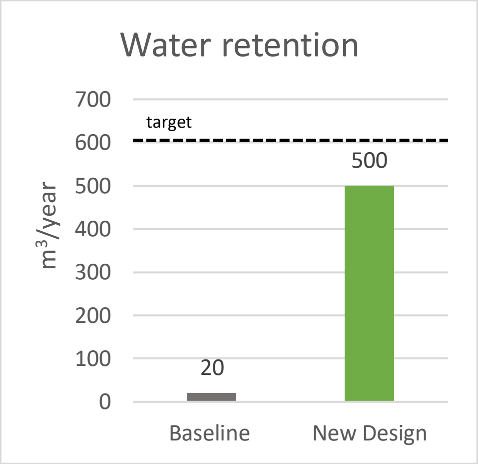


Figure 8. Hypothetical annual water retention target

The current GGSA can be developed into a decision support tool to make better green schoolyard designs, according to GI performance. The GGSA in this research was used to assess the existing schoolyard design of De IJsbreker. The qualitative analysis gave the influence of GI measures on GI performance indicators. In order to use the GGSA as a decision support tool to develop new green schoolyards, the use of the GGSA can be changed and weights can be added (Figure 9). To start with, the aim of the schoolyard has to be reflected in weights of GI performance indicators for step 4, for instance a weight of 1 for carbon-sequestration and a weight of 3 for water retention. Since schoolyards are expected to have an effect to its neighbourhood, these aims and weights should be developed on neighbourhood scale. Second, the most effective GI measures that match the aim of the schoolyard must be chosen. This is facilitated by the already existing qualitative scores in points/m^2 of GI measure per GI performance indicator. To illustrate, more emphasis in the design will be given to effective water retaining GI measures, compared to carbon-sequestrating GI measures, such as bioswales. Third, the schoolyard design is made, for which the areas per GI measure are chosen. A larger bioswale, will generate a higher qualitative score for water retention. At last, the assessment of the schoolyard is calculated in the GGSA Excel model. The qualitative results are now weighted, and the total scores are analysed. At this step also the quantitative GI performance, design, and health, safety and education indicators are analysed. From this step, a feedback loop can be made if the result is not as desired, by selecting different GI measures or adjusting the area per GI measure.

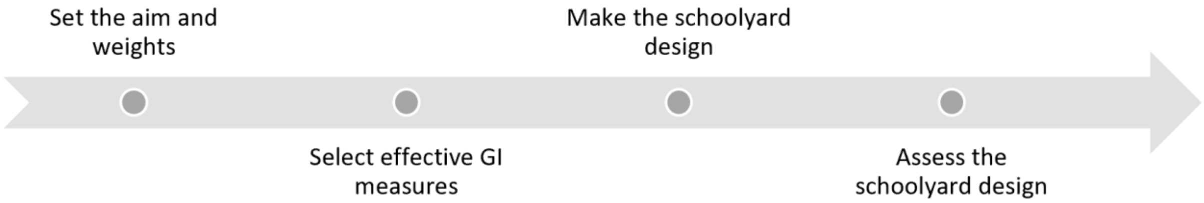


Figure 9. The four steps of using the GGSA as a decision support tool

At last, the GGSA has the opportunity to be used for an economic assessments. The biophysical GI performance indicators, except biodiversity, provide a quantification of the benefits. Next to this quantification of benefits, decision makers indicate that economic value is often required to convince relevant stakeholder, in order to mainstream GI investments in urban areas (Van Oijstaeijen et al., 2020). To adjust the GGSA for economic assessment, a monetization step according to Dutch monetary data for each GI performance indicator is required. The monetized benefits can be an input for a cost-benefits analysis. When the GGSA is used for a cost-benefit analysis, the costs of the full lifecycle are also taken into account, such as design, implementation, maintenance and demolition. This will provide a comprehensive picture of green schoolyard transformation projects.

4 Conclusions and recommendations

In this research the Grey to Green Schoolyard Assessment (GGSA) was developed to show the impact of green schoolyard transformation. The development of the GGSA resulted in 22 indicators in the following categories: GI performance indicators, design indicators, and health, safety and education indicators.

The first part of the research was performed to choose a relevant GI evaluation toolkit that is applicable to schoolyard transformation projects. By scoring eleven GI evaluation toolkits on nine criteria, the NVE-city toolkit was found to meet most requirements. The NVE-city toolkit was the most detailed toolkit, and became the basis of the GGSA GI performance indicators. The GI performance indicators of the NVE-city toolkit included water retention and four GI co-benefits.

The second part of the research was to make the GGSA more schoolyard specific. At first, three additional GI performance indicators were added, for which the following three toolkits were used TEEB-stad, BEST and GIBVT. Secondly, design principles for social benefits were added to the GGSA. The design indicators were based on the principle that social benefits are expect for children when a schoolyard is greener and more varied than the old grey schoolyard. Thirdly, health, safety and education indicators related to GI measures were added to the GGSA. This last group of indicators were requirements of health and safety regarding water design, and design principles to support outdoor nature education.

The third part of the research was to apply the GGSA on De IJsbreker's schoolyard that transformed from grey to green. The analysis of De IJsbreker showed many positive effects on all three indicator categories. The assessment showed that De IJsbreker's new green schoolyard improved most on water retention, biodiversity and improved on time spend on outdoor nature education. The indicators temperature, carbon-sequestration and air quality made small improvements. Furthermore, the new IJsbreker's schoolyard design was greener and more varied than baseline, which showed an improvement on most design indicators. At last, the health, safety and education indicators also improved by designing a bioswale that is according to health and safety requirements, and design principles for outdoor education were improved.

For the next step regarding new schoolyard transformation projects, it is recommended to use the GGSA to show the impacts of green schoolyard transformations on GI performance, design for social benefits, and design principles regarding health, safety and education.

The current GGSA can be improved on the quantitative analysis, for which targets are recommended to be developed according to the neighbourhood's needs. The GGSA design indicators, and health safety and education indicators can be used to see whether different types of criteria are met or not met. However, it is recommended conduct further research to change the scoring from a dichotomous scale (0-1 point) to an ordinal scale (1-5 points) to show the level of improvement.

Two recommendations are given for further research on changing the GGSA to be used for a different purpose. At first, further research could make the GGSA a decision support tool. Research would be adviced to be performed on weighting the relevance of performance indicators, to allow the tool to be made as support during the design process. Second, the GGSA can be used for economic valuation processes, such as a cost-benefit analysis. Further research could be conducted on monetizing the GI performance indicators with Dutch monetary prices. By using the GGSA as a basis of a cost-benefit analysis, the total lifecycle of green schoolyard transformation projects could be shown.

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Appendix 1 De IJsbreker design maps

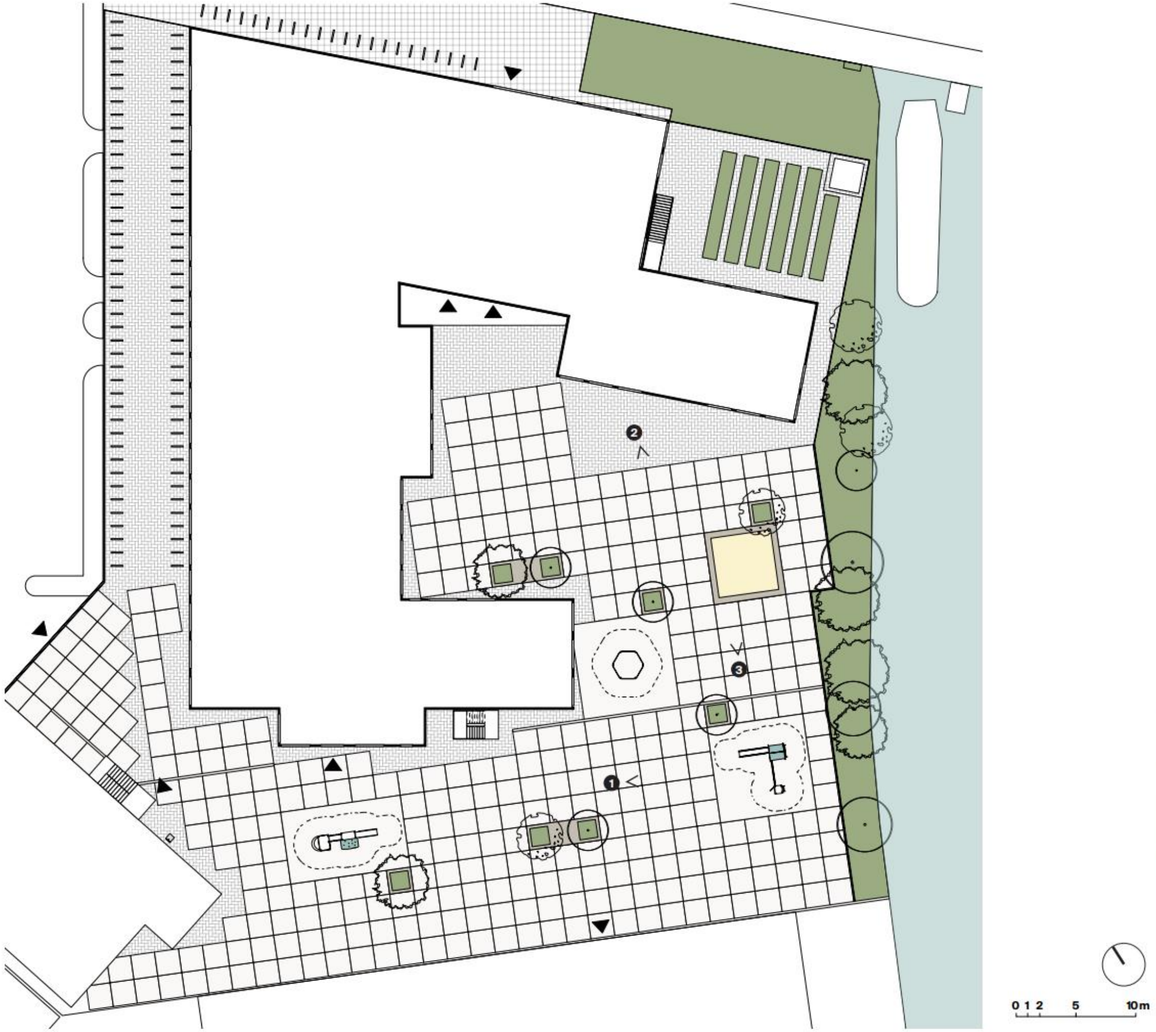


Figure 10. De IJsbreker's schoolyard before transformation of the baseline

Figure 11. De IJsbreker's new design after transformation

Figure 12. De IJsbreker's different types of GI measures (including grey measures)the new design

Figure 13. De IJsbreker's GI measures description of the new design

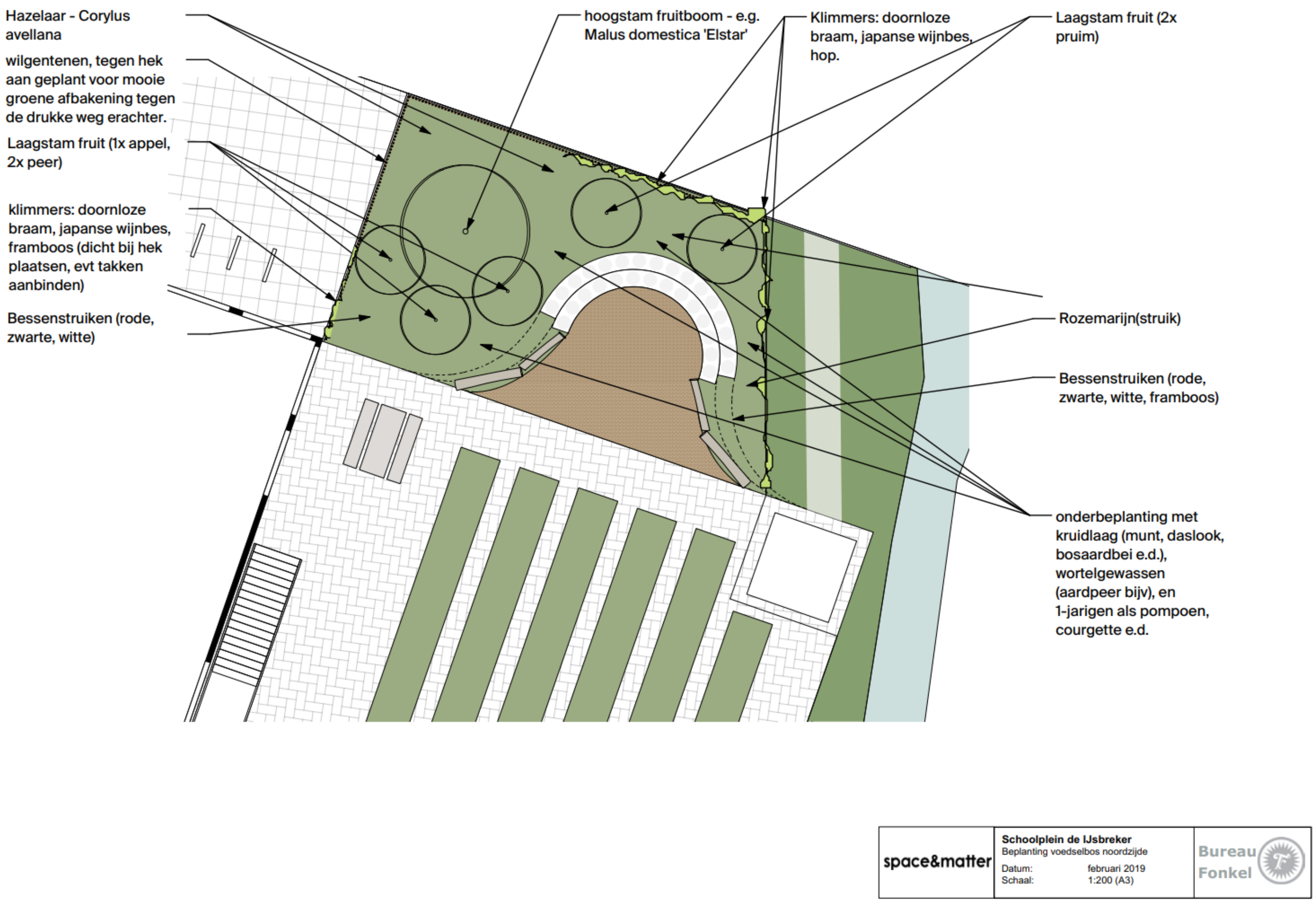
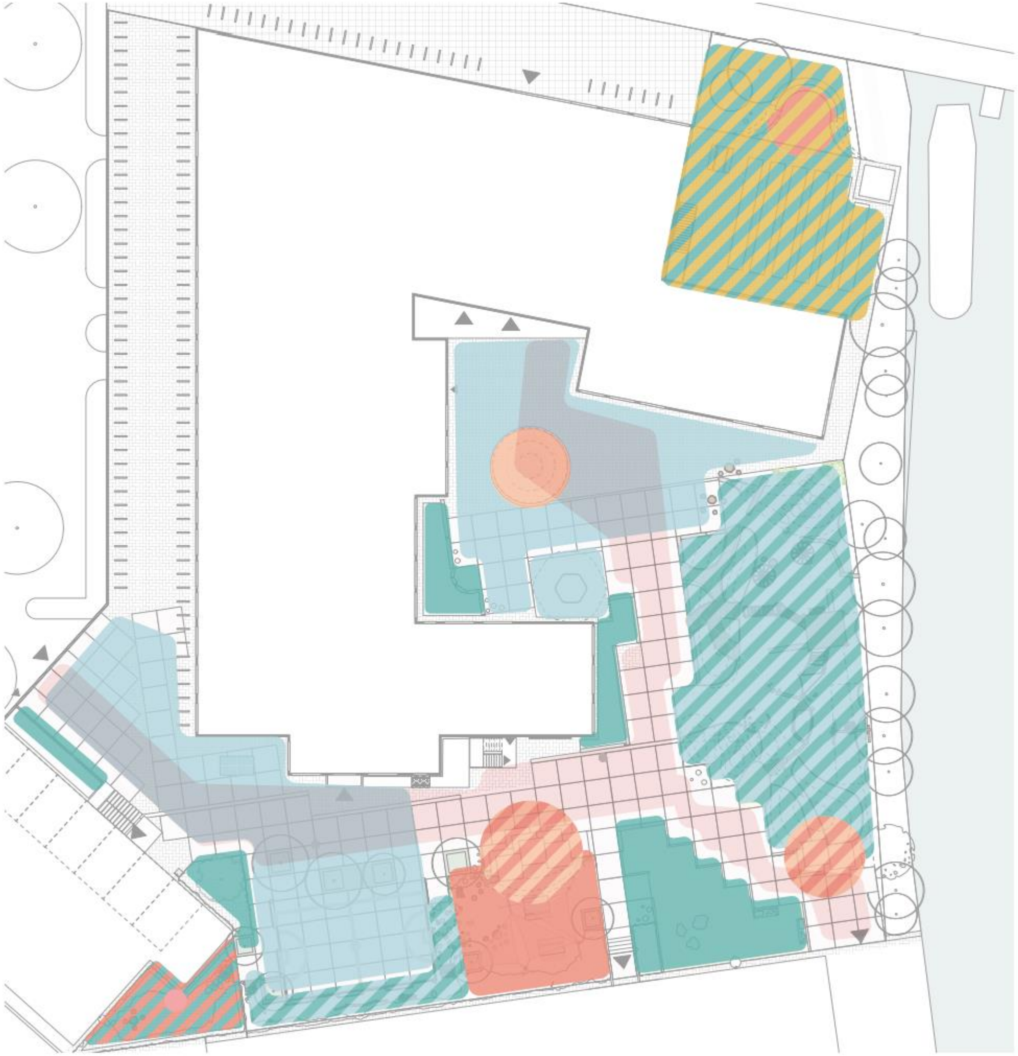


Figure 14. De IJsbreker's GI measures at the food garden of the new design

Figure 15. De IJsbreker's surfaces of the baseline (huidige situatie) and new design (nieuwe plan) schoolyards of the elementary school De IJsbreker

Zones



● ontspanning

● onderzoeken en ontdekken

● bewegen sport en spel

● expressie

● educatie

● sociale ruimte

Figure 16. De IJsbreker's different zones of the new design

Wilg **Els** **Krent** **Veldsdoom**

Hazelaar **Rode Kornoelje** **Schijnhulst** **Hertshool**

Figure 17. De IJsbreker's main vegetation types

Appendix 2 Green infrastructure evaluation toolkit assessment

Table 16. Elaborate assessment of the 11 GI evaluation toolkits, which was used as a basis for the GI evaluation toolkit scoring.

Toolkits	Platform	Urban infrastructure	multi-benefit indicaotrs	performance indicator topic	Urban scale	Parcel scale	Double counting	Output	Scientifically sound	Adjustability	Description	Reference	Developer	Version
Nature Value Explorer	Web	25 types	8	ES	Urban	yes	Yes, Included in the calcualtions	Ql, Qt, Mo	Yes, based on scientific articles	Calculations of manual can be used	Evaluate the effect of land use scenarios on the values of ES, based on CICES report. The online tool can be used to explore important GI measures and their effects. This tool gives an estimate. The results show the lower limit of the	Hendrix, et al. 2015	VITO, BE	2018
B£ST	Excel	Different per indicator	19	Ecosystem services and non-ES indicators	Urban, rural	no	Yes, overview where there is a potential risk of double counting	Ql, Qt, Mo	Yes, based on scientific articles	Excel file can be adjusted	Quantificationa and monitization of ES. It is adviced that most benefits will come out at a larger scale. Small scales must be concidered to the budged. It is possible to adjust the tool with own data. Input for stakeholdersis needed for	Horton et al., (2019)	CIRIA, UK	2019
TEEBstad	Web	Different per indicator	13	Ecosystem services and non-ES indicators	Urban	no	Not included	Qt, Mo	Yes, based on scientific articles	Calculations of manual can be used	Monetize social benefits of ecosystems to help new developments. Focus is on monetary value up to 2018. Categories are based on ES, but the performance indicators are mostly economic indicators.	Does et al., (2019)	PBL, NL	2018
Green Infrastructure Valuation Toolkit	Excel	Different per indicator	11	ES	Urban, rural	no	yes, it is mentionetd to take into account	Ql, Qt, Mo	Yes, based on scientific articles	Excel file can be adjusted	Assess existing green assets or proposed green investment and translate findings into a business case. Assumptions and data is based on UK. Green infrastructure type is deifferent for each performance indicator.	GIVN (2010)	The Mersey Forest, US	2018
Green Infra benefit valuation tool	Excel	6	9	ES	Urban, rural	yes	Not included	Qt, Mo	yes/no. Some sources are used.	Excel file can be adjusted	Show monetized benefits of GI. Per GI different performance indicators can be monetzied, thus gaps exist. Tool made with American data, but adjustable. Output provides graphs with investment.	Earth Econoomics (2018)	Earth Economics, US	2018
Natural Capital Planning Tool	Excel	Land use types	10	ES	Urban, rural	no	Not included	Ql, Qt	Yes, based on scientific articles	Excel file can be adjusted	Assess and compare plan/development designs. Hight data input requirement, and difficult to work with. Final result is in yes or no change.	Holzinger et al. (2018)	CEEP, UK	2018
ECOPLAN - Scenario Evaluator	GIS	Land use types	18	ES	Urban, natural	no	Incororated in calculations	Qt, Mo	Yes, based on scientific articles	Difficult to adjust. Caclulations in manual are given, but are based on GIS models	ECOPLAN-SE calculates the associated effects of projects on ES, both current and future projects with af focus on Flanders. The user has to choose which ES are relevant for a project. Restults are relatively compared to averages. Scale: only mentioned that it can be used for projects/developments, so assumed is urban scale. GI can be chosen by selecting land use types.	Vrebos et al. (2017)	University Antwerpen, BE	2017
InVest	GIS	Land use types	19	ES	Urban, natural (focus)	no	Not included	Qt	Yes, based on scientific articles	Difficult to adjust. Caclulations in manual are given, but are very detailed and based on GIS model	Map and value the goods and services from nature that sustain and fulfill human life. Only 2 performance indicators are for urban scale: urban heat island effect and flooding	Sharp et al. (2020)	Stanford Univesity, UK	2018
TESSA	Tekst guide	Land use types	10	ES	Urban, natural (focus)	no	Not included	Qt	Yes, based on scientific articles	Model was not open access.	Identify relevant services, data needed for measurement, methods to obtain data, and communicate. Scale: site scale to global scale. Access is more difficult, since it is not open source. The data from this sheet was found through	Peh et al. (2013)	Birdlife int., UK	2017
CAVAT	Excel	1	n.a.	Tree characteristics	Urban	yes	Not included	Qt, Mo	No sources can be found	Excel file can be adjusted	A basis for managing trees in the UK as public assets rather than liabilities. It is aimed to help decision makers by giving value per single tree.	Neilan (2010)	London tree Officers Association (LTOA), UK	2020
i-Tree eco	Program	1	10	ES and non-ES services	Urban	yes	Not included	Qt, Mo	Yes, Peer-reviewed software	Not adjustable. It is a computer program (model). Manual does not provide calculaltions.	Quanitfy environmental effect and value to society of trees or urban forests. The tree has to be existing for site specific measurements. Based on 12 ES. Life cycle and forest structure are also taken into account	i-Tree Eco (2020)	USDA Forest Service, US	2019

Appendix 3 Grey to Green Schoolyard Assessment overview

Table 17. GGSA framework

Grey to Green Schoolyard Assessment			
	Indicator	**Output**	**Description**
GI performance indicators	Water retention	m^3/yr	Annual amount of water retained
	Air quality	kgPM$_{10}$/yr	Annual amount of PM10 deposition
	Carbon-sequestration	kgC/yr	Annual amount of Carbon sequestrated
	Temperature	°C reduction	Reduced temperature on schoolyard on a warm day
	Biodiversity	points	Biodiversity score
	Insulation	m^3gas/yr	Gas saved by insulating roof
	Rainwater harvesting	m^3/yr	Captured rainwater
	Education	min/child/yr	Use of green schoolyard for nature education
Design indicators	Surface	0 or 1	Schoolyard size is 900 m2 or higher
	Surface increase		Schoolyard size increased after renovation (baseline=0)
	Green surface		Minimum of 25% vegetative coverage (no hard or semi-hard surfaces)
	Green volume		Requirement is not met when schoolyard has: no vegetation or small vegetation (small area with lawns, shrubs, flower perks, and few young, scattered trees). Minimum requirement: includes mainly small size plants. Some large vegetation is found, e.g., full-grown trees and high shrubbery.
	Playing possibilities		Playing possibilities that were on the schoolyard is the same or improved on the green schoolyard (baseline=0)
	Sub areas		There is an Increase of sub areas after renovation (baseline=0)
	Play green		Requirement is not met when: vegetation is not part of the play areas, only are for decorative purpose (lawns, flower perks, small shrubs). Minimum requirement: play areas are next to decorative vegetation or when play areas are integrated with vegetation (e.g., tree, shrubbery)
	Loose parts		There are loose available parts on the schoolyard: sand, water, branches, wood blocks etc.
	Robustness		Vegetation is robust; it can cope with weather conditions and children's activities.
Health, safety and education indicators	Health (water)	0 or 1	Design with water must be made that there is no long standing water, which can contain pollutants or microbiological contaminants
	Safety (water)		GI measure with water must be safe: shallow slope, edges, use barrier vegetation
	Education (water)		Water management for educational purposes: e.g., rain barrel to use for watering plants, and visible drain to show the rain’s stream
	Education (natural elements)		Include school gardens, apple trees for education
	Education (facilities)		Inclusion of working spaces, animal houses and other facilities

Appendix 4 Calculations NVE-city green infrastructure performance indicators

All biophysical calculations of the GI performance indicators, that were based on the NVE-city toolkit are presented in this Appendix. All data in this Appendix is from the NVE-city toolkit (Hendrix et al., 2018), except for the examples given for a hypothetical schoolyard of the Great Oak.

All calculations were based on a qualitative and quantitative calculation. In this introduction the qualitative score is explained, which is the same for each GI performance indicator. The quantitative score will be explained per indicator in the following sections after this introduction.

For the qualitative score, the scores of water retention are used (Table 18). The qualitative calculation was based on the amount of m^2 per GI measure. The schoolyard of the Great Oak Elementary school is 100 m^2 and has 10 m^2 crown surface of deciduous urban trees, 30 m^2 of closed pavement, and 60 m^2 of wood chips. The qualitative score is done the following way:

$$\frac{10(m^2)\cdot 5 + 30(m^2)\cdot 1 + 60(m^2)\cdot 7}{100\ (m^2)} = 5$$

Water retention

The quantification of water retention is based on retention coefficients (RC) (Table 18). The RC values are based on a typical 48 hour rainwater storm typical for Belgium conditions (precipitation length of 53 mm, with a maximum intensity of 72 mm/hour).

The input required:

- RC: *see Table 18* (%)
- Annual precipitation: *fill in* (example: 0.8 mm or m^3/m^2)
- GI measure area*: fill in* (m^2)

The formula:

$$Annual\ precipitation\ \left(\frac{m^3}{m^2}\right)\cdot GI\ measure\ area\ (m^2)\cdot retention\ coefficinet\ (\%)$$

The Great Oak retains the following amount of water:

$$0.8\ (10\cdot 0.51 + 30\cdot 0.02 + 60\cdot 0.7) = 47.7\ m^3/year$$

Table 18. Input for water retention calculations of the NVE-city toolkit

Category	GI measures	NVE-city data	
		Qualitative	Retention coefficient
Green roofs	Extensive	6	58%
	Semi-intensive	7	70%
	Intensive	8	81%
Hard structures	Closed pavements	1	2%
	Semi-pervious (wood chips, broken fractions)	7	70%
	Grasscrete	1	2%
Water, wet vegetation	Water	10	100%
	Wet vegetation (wadi, repirian zone)	9	90%
Dry vegetation types	Bare soil	7	70%
	flower and herbaceous plant meadow	10	100%
	Lawn, bedding pant	7	72%
	Shrubs, hedges and hedges	8	78%
	Allotment garden	9	90%
Urban trees	Deciduous trees	5	51%
	Coniferous tree	6	59%
	Mixed trees	5	55%
Walls	Green walls and facades	2	18%
Grey	Built surface	0	1%

Air quality

Air quality is based on annual PM_{10} deposition by GI measures.

The input required:

- Unit correction: 3.1536 (-)
- Deposition: *different per GI measure* (m/s)
- Concentration schoolyard: *fill in* (example: 20 ug/m^3)
- Resuspension: *fill in* (50% is taken when no data is available).
- GI measure area: *fill in* (m^2)

First for each GI type the deposition was calculated, of which numbers are given in Table 19. This was calculated in the following way:

$$Deposition\left(\frac{kg}{m^2}\right) = \frac{Deposition\left(\frac{m}{s}\right) * concentration\left(\frac{\mu g}{m^3}\right) * 3.1536 * resuspention\ (\%)}{10000}$$

PM_{10} uptake by vegetation is calculated according to the following formula:

$$Deposition\ (kg) = GI\ measure\ area\ (m^2) \cdot deposition\ (\frac{kg}{m^2})$$

The Great Oak has an annual deposition of:

$$(10 \cdot 0.0016 + 30 \cdot 0 + 60 \cdot 0.0003) \cdot 1000 = \frac{34\ g\ PM_{10}}{year}$$

Table 19. Input for air quality calculations of the NVE-city toolkit

Category	GI measures	NVE-city data		Input
		Qualitative score	Deposition (m/s)	Deposition (kg/m^2)
Green roofs	Extensive	0.24	0.2	0.0006
	Semi-intensive	3	0.2	0.0006
	Intensive	3	0.3	0.0009
Hard structures	Closed pavements	0	0	0.0000
	Semi-pervious (wood chips, broken fractions)	0	0.1	0.0003
	Grasscrete	0	0	0.0000
Water, wet vegetation	Water	0	0.1	0.0003
	Wet vegetation (wadi, repirian zone)	3	0.2	0.0006
Dry vegetation types	Bare soil	0	0.1	0.0003
	flower and herbaceous plant meadow	3	0.2	0.0006
	Lawn, bedding pant	3	0.2	0.0006
	Shrubs, hedges and hedges	4	0.3	0.0009
	Allotment garden	1	0.2	0.0006
Urban trees	Deciduous trees	6	0.5	0.0016
	Coniferous trees	9	0.7	0.0022
	Mixed trees	7	0.6	0.0019
Walls	Green walls and facades	3	0.2	0.0006
Grey	Built surface	0	0	0.0000

Carbon-sequestration

Carbon-sequestration is based on the uptake of GI measures of carbon. In this section only carbon-sequestration per GI measure is given. For the carbon-sequestration for deciduous trees per diameter group and crown size, see the manual of the NVE-city toolkit in Hendrix et al. (2018).

Input required:

- Area GI surface: *fill in* (m^2)
- Low/high carbon sequestration value: *(Table 20)* (kgC/m^2)

The following formula was used:

$$Carbon\ sequestration\ (kg) = \ GI\ measure\ area\ (m^2) \cdot carbon\ sequestration\ value\ \left(\frac{kgC}{m^3}\right)$$

The low value of carbon sequestration of the Great Oak is:

$$10 \cdot 0.55 + 30 \cdot 0 + 60 \cdot 0 = 5.5 \frac{kgC}{year}$$

Table 20. Input for water retention calculations of the NVE-city toolkit

Category	GI measures	NVE-city Data		
		Qualitative	Low kgC/m^2	High kgC/m^2
Green roofs	Extensive	2	0.05	0.4
	Semi-intensive	4	0.4	0.74
	Intensive	6	0.45	0.79
Hard structures	Closed pavements	0	0	0
	Semi-pervious (wood chips, broken fractions)	0	0	0
	Grasscrete	0	0	0
Water, wet vegetation	Water	0	0	0
	Wet vegetation (wadi, repirian zone)	1	0.025	0.2
Dry vegetation types	Bare soil	0	0	0
	flower and herbaceous plant meadow	2	0.05	0.4
	Lawn, bedding pant	1	0.025	0.2
	Shrubs, hedges and hedges	2	0.05	0.4
	Allotment garden	2	0.05	0.4
Urban trees	Deciduous trees	7	0.55	0.94
	Coniferous trees	8	0.74	1.08
	Mixed trees	9	0.77	1.13
Walls	Green walls, facades	2	0.05	0.4
Grey	Built surface	0	0	0

Temperature

The temperature indicator of the NVE-city toolkit gives the heat reduction in degrees Celsius and a PMV value. The PMV value is an international indicator that shows if people feel comfortable with the temperature. A PMV value of -4 is too cold and 4 too warm. A score of 0 is the optimum comfort (with some people still not feeling comfortable).

A qualitative score is calculated (as described in the introduction of this Appendix, for which Table 21 is used. The Great Oak has a qualitative score of 1.8.

Table 21. Input for qualitative temperature calculation

Categories	GI measures	NVE-City
		Qualitative
Green roofs	Extensive Semi-intensive Intensive	2 4 6
Hard structures	Closed pavements Semi-pervious (wood chips, broken fractions) Grasscrete	0 2 0
Water, wet vegetation	Water Wet vegetation (wadi, repirian zone)	6 6
Dry vegetation types	Bare soil flower and herbaceous plant meadow Lawn, bedding pant Shrubs, hedges and hedges Allotment garden	2 2 2 4 2
Urban trees	Deciduous trees Coniferous trees Mixed trees	6 6 6
Walls	Green walls and facades	2
Grey	Built surface	0

The following step is to compare the qualitative score of 1.8 to Table 22, to see which quantitative effect the design of the Great Oak has on temperature. The qualitative value of the Great Oak is beneath 2 points, which means heat reduction is negligible. If the Great Oak would have had a qualitative score of 4, this would mean that the design would have little heat reduction, which indicates a temperature reduction of 0.5 Celsius, and a PMV value of 3.

Table 22 quantitative effect of GI measures on local climate

Score	Reduction (Celsius)	Heat reduction	PMV value
>10	-2	very large	0
8-9.9	-1.5	large	1
6-7.9	-1	average	2
4-5.9	-0.5	little	3
2-3.9	between -0.5 and 0	very little	3
<2	negligible	negligible	4

Biodiversity

The indicator biodiversity is based on the Flemish biodiversiteitstoets (Eng.: biodiversity test), which was developed with 19 nature experts. The biodiversity score is calculated in only a qualitatively, from the data in Table 23, according to the method given in the introduction of this Appendix.

The Great Oak received a qualitative biodiversity score of 2 points.

Table 23. input for the Biodiversity calculation

Categories	GI measures	NVE-City
		Qualitative
Green roofs	Extensive Semi-intensive Intensive	2 4 6
Hard structures	Closed pavements Semi-pervious (wood chips, broken fractions) Grasscrete	0 2 2
Water, wet vegetation	Water Wet vegetation (wadi, repirian zone)	8 8
Dry vegetation types	Bare soil flower and herbaceous plant meadow Lawn, bedding pant Shrubs, hedges and hedges Allotment garden	2 10 6 6 4
Urban trees	Deciduous trees Coniferous trees Mixed trees	8 6 7
Walls	Green walls and facades	4
Grey	Built surface	0

Appendix 5 Indicators from green infrastructure evaluation toolkits

Table 24. GIBVT indicators, GI measures and calculations

Green Infra benefit valuation tool		
Performance indicators	**GI measure**	**Calculation**
Flood risk	wetland, urban forest	water volume (m^3); percent water captured;
CSO Reduction	Bioswale, retention pond, pavement, wetland, green roof	water volume (m^3); percent water captured; no. CSO events;
Recharge groundwater		water volume (m^3); percentage capture; rainfall events; value litre captured water
SW Quality		water volume (m^3) from drainage area to GI (not falling into GI); cost of conventional treatment
Environmental Education		hours spend on education
Urban Heat Island Effect	Urban forest, green roofs	number from literature
Aesthetic Value	Bioswale, retention pond, wetland, green roof	monetized
Air Quality	green roof	air pollutants deposited
Carbon Sequestration	wetland, urban forest	number of C sequestrated (literature averages)

Table 25. GIVAL toolkit indicators, GI measures and calculations

GI VAL		
Performance indicators	**GI measure**	**Calculation**
Climate adaptation/mitigation		
Temperature regulation	green roof, tree	local scale 0.5-5 C green cover/trees
Carbon-sequestration	tree	only large-scale tree-planting/reinstatement or loss of moorland (per GI, no estimation is allowed to be made; not enough literature)
Flood alleviation/water management		
Energy and CO2 saving	n/a	monetized
Wastewater treatment costs	n/a	monetized
avoided infrastructure cost	n/a	monetized
Place and communities		
landscape/visual amenity	green area	willingness to pay to a green asset within 250 m
community cohesion	n/a	hours of voluntary work
Health and wellbeing		
reduced mortality	green area	extra no. local population physical exercise
Avoided costs for air pollination control	tree	removed SO_2, PM_{10}, CO
land and property value		
Residential	park, green area	property uplift within 450 m
Commercial	n/a	n/a
Investment		
Private sector	green area	companies expected to occupy where green space is made
Labour productivity		
Short term absent form work	green area	walking or cycling through green park.
Tourism		
Expenditure	green area	number of visitors expenditure per day
Recreation/leisure		
Recreational value	green areas	number of people using GI for recreational purpose (sports)
Biodiversity		
Willingness to pay	natural area	all infrastructures support
Land management		
Employment	public space	0.026 jobs/ha
Social		
Social contacts	"	n/a

Table 26. BEST indicators, GI measures and calculations

BEST		
Performance indicators	**GI measure**	**Calculation**
Air quality	tree, green roof	NO_2, SO_2, O_3, PM_{10} tonnes/year
Amenity	green area	no. People within 450m (however, people will not use it. children will)
Pumping wastewater	water	kW/year
Treating wastewater	water	hydraulic model required
Biodiversity and ecology	land use (?)	hectares of green space (?)
Building temperature	tree, green roof	Energy reduction
Carbon reduction	tree	less energy = less CO2 emitted
Carbon sequestration	tree, green roof	C uptake
Education	GI schemes	number of nature-based school trips (within the school premises)
Enabling development	-	land becomes available because of less floods
Flooding	-	flooding risk
Health and wellbeing	green area	additional walking/cycling trips
Noise	green wall, green roof, tree belt	reduction in dB
Recreation	parks or larger areas	adult visitors
Traffic calming	road safety measures	reduction in accidents
Water quality	Green scheme	align with WFD wate quality
Flows waterbody	-	water modelling river basin
Groundwater recharge	-	m3 infiltrated
Rainwater harvesting	RWH measure	m3 not used by
Crime	green area	local evidence: reduction of crime
Economic growth	green area	local evidence: green jobs created
Tourism	green area	local evidence: visitors

Table 27. TEEB-stad toolkit indicators, GI measures and calculations

TEEB		
Performance indicators	**GI measure**	**Calculation**
Health		
Less healthcare costs	green area	no. inhabitants within radius of 1000m
less labour loss	green area	no. inhabitants within radius of 1000m
Less healthcare costs	grass, green roof, tree, reed	kg PM_{10}/ha
Energy loss		
Shelter from wind	tree	10% less gas use (buildings shelter within 50 m from a tree hedge)
Isolation	green roof	5% less gas use (per building)
Property value		
Existing house	green, park, water	€ when nearby or have a view on
New house)	green, park, water	€ when nearby or have a view on
Existing house, better maintenance	public green	€ when nearby or have a view on
Recreation		
New GI	green area	people/year
improvement GI	green area	people/year
Greening shopping streets	greening street	no. Shops & revenue
Social cohesion (fewer moving houses)		
More green area/water surface	green area/water surface	
Water management		
Water nuisance	unknown	% change water nuisance & amount of houses
Less investment costs	unknown	m^3 of water capturing