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The Meadoway Performance Assessment Project: A Systematic Review of Evaluation Methods for Ecosystem Services Provided by Urban Greenspace

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Executive Summary

This report presents a systematic review to reveal the ecosystem services (ESs) provided by urban greenspace, their key performance indicators (KPIs), and the methods used to monitor them. This review aims to find ESs possibly delivered by The Meadoway, a linear meadowland restored with native plants along a hydro corridor in Toronto, as well as KPIs and corresponding monitoring methods used to quantify/qualify these ESs to aid the establishment of an evaluation project for The Meadoway. Existing evaluation frameworks for urban greenspace were also identified in the review. The systematic review was conducted by retrieving relevant papers from two database platforms *Engineering Village* and *Web of Science* using keywords and screening returned records based on inclusion and exclusion criteria by critically reading titles, abstracts, and full texts. In total, 71 papers were selected and reviewed, and the results are presented and discussed in the report.

Many evaluation frameworks are developed and presented in reviewed papers. Some frameworks use monetary value to quantify ESs, while others use non-monetary methods such as predefined indices and scores. Some frameworks provide guidance on developing long-term monitoring plans, and some others suggest a list of ESs and KPIs that can be referred to evaluate the quality of a greening project or green infrastructure. An evaluation framework to assess the overall outcome of The Meadoway project can be established by analyzing the monetary value or determining the non-monetary value index of ESs in a local context, which is out of the scope of this study. The existing frameworks that suggest a list of ESs and KPIs and provide guidance on developing monitoring programs are very helpful and can be referenced for the proposed evaluation project.

Based on the results, the ESs provided by urban greenspace are very diverse, including climate regulation, air quality regulation, hydrological regulation, nutrient cycling, habitat services, and social & cultural services. Among these ESs, the social & cultural services are the most intensely studied (22 papers), followed by climate regulating services (13 papers). Many characteristics of urban greenspace can affect the delivery and quality of ESs, including vegetation composition, structure, and density, land typology, site area, shape, isolation, utilization level, and disturbance level. The restored meadows can potentially provide higher-quality ESs including improved cooling effect, air quality, runoff reduction and retention, carbon sequestration service, and social and cultural values compared with original turf lands due to the restoration

of native plants.

Many KPIs and corresponding monitoring methods are identified for each ES from reviewed papers. Indicators are variables with some logical link to the object or the process being measured that provide clues and guidance to policy- or decision-makers for better management (TEEB, 2010). The identified KPIs include field measurements, modeling results, or predefined indices. They reflect the status, drivers, or outcome of the investigated process in an unambiguous and usually quantitative way that simplifies information to make it easy to interpret by policy- or decision-makers (Ash et al., 2010). The applicability of identified KPIs and monitoring methods to The Meadoway is discussed to generate a specific list appropriate to The Meadoway evaluation project.

In general, this study completes its primary objective to generate a list of potential ESs, KPIs, and monitoring methods applicable to The Meadoway to aid the development of an evaluation framework and monitoring plans. The study provides guidance on the evaluation of similar restoration projects in GTA and contributes to the implementation and management of the 10-year strategic plan *Building the Living City*.

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1. Background

The Greater Toronto Area (GTA) is currently experiencing rapid urbanization with a sharply increasing population and expanding urbanized lands, which shrinks green areas and degrades urban ecosystems. The GTA population is projected to increase by 36.7%, from 7.0 million in 2019 to over 9.5 million by 2046 (Ontario Ministry of Finance, 2020). Adverse effects of ecosystem degradation caused by urbanization include water and air deterioration, urban heat island effects, increased flood risks, decreased biodiversity, losses and fragmentation of habitats, and aesthetic degradation (Das & Das, 2019; Zang et al., 2011). Intensified urbanization with changing land cover also contributes to climate change, causing intensifying rainfall events and higher temperature, and posing risks on municipal infrastructure and ecosystems (Allen et al., 2015; Chase et al., 2000). The Toronto and Region Conservation Authority's (TRCA) 10-year strategic plan *Building the Living City* aims to establish a regional system of natural areas that protects habitats, improves air and water quality, and create opportunities for nature enjoyment and outdoor recreation under the challenges of urbanization, climate change, rapid population growth, and economy transition (TRCA, 2013). One strategy to build a future living city is to rethink and maximize the value of urban greenspace by creating a green infrastructure network. This infrastructure network will provide residents with a sustainable landscape to live within, promote access to nature, and protect local ecosystems.

Many organizations and governments have proposed the concept of Green Infrastructure (GI) since the mid-1990s to mitigate the harmful influence exerted by urbanization on urban ecosystems, and it is currently adopted for land management and planning worldwide. Over the last few decades, the definition of GI has evolved and is now a multidisciplinary concept intensively studied in the fields of urban ecology, landscape ecology, sustainable development, and ecological engineering with multifunctional characteristics. The Government of Ontario's 2020 Provincial Policy Statement (Government of Ontario, 2020) defines GI as "natural and human-made elements that provide ecological and hydrological functions and processes including components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs". As a type of GI, urban greenspace plays a critical role in the sustainable development and management of cities, providing multiple urban ecosystem services to protect the urban environment and support residents' wellbeing.

Revitalization projects are recognized as an effective approach to maximize urban greenspace's potential by creating high-quality green areas and green infrastructure (TRCA, 2019a). Linear infrastructure corridors such as the Gatineau Hydro Corridor remain as the few unexploited open spaces in the GTA that are well-positioned for greenspace restoration. The revitalized corridors can provide better ecosystem functions in the city and enhance the connectivity for people across the city by developing an alternative low-impact transportation. Many linear revitalization projects have been proposed and under implementation in different cities, such as the BeltLine in Atlanta, the Arbutus Greenway in Vancouver, and The 606 Greenway in Chicago (TRCA, 2019c). These projects provide multiple benefits to residents including neighbourhood connections, recreation, transportation, natural environment conservation, and education opportunities, and are good examples of effective re-exploitation and restoration of linear infrastructure corridors in cities. The Gatineau Hydro Corridor stretching across the City of Scarborough was constructed in the 1920s to connect downtown Toronto to the hydroelectric power plants in Quebec's Gatineau region (TRCA, 2019a). The Scarborough Centre Butterfly Trail (SCBT), a part of the Gatineau Hydro Corridor, revitalized in 2015 with meadow habitats restored and trails improved, received great success in providing multiple ecosystem services and a sustainable transportation approach (TRCA, 2019a). Its success supports the Gatineau Hydro Corridor Revitalization Project, which aims to restore 200 ha of meadow habitats and complete a linear multi-use trail over 16 km along the Gatineau Hydro Corridor connecting downtown Toronto and the Rouge National Urban Park (TRCA, 2019b). The project will integrate existing greenspace and transportation networks across eastern Toronto to form a multi-use trail and meadow restoration project named The Meadoway (TRCA, 2019a).

GI, like The Meadoway, is expected to provide multiple ecosystem services (ESs) within four categories: regulating, supporting, cultural, and provisioning services (Figure 2) (Charoenkit et al., 2019). Ecosystem services are benefits provided by ecosystems to humans, including resources such as food and fuel, climate and environmental regulation, provisioning of habitats, and aesthetic and spiritual advantages. The identification and assessment of GIs' ecosystem services are critical in terms of project evaluation and city planning. Furthermore, the monitoring and evaluation of the benefits and performance of The Meadoway in terms of offered ecosystem services will provide very useful information for future revitalization project planning, development, and management.

There is a lack of evaluation frameworks specifically designed for urban open greenspace, although in recent years an increasing number of studies and projects have been conducted on the re-exploitation and restoration of urban open space into greenspace and parks with diverse vegetation types including meadows, shrubs, and forests. To evaluate the performance of The Meadoway, there is a need to establish a comprehensive evaluation framework for urban open greenspace by identifying and assessing potentially provided ecosystem services. Thus, a systematic review was conducted to identify possible ecosystem services (ESs) provided by urban greenspace and find key performance indicators (KPIs) that can be monitored and investigated to reflect and evaluate these services. The results of this systematic review are presented, analyzed, and discussed in this report. This work can help environmental agencies to monitor and assess such urban greenspace restoration projects and facilitate the development of performance evaluation systems.

Figure 1. The Overview Map of The Meadoway (Google, n.d.; TRCA, 2019b).

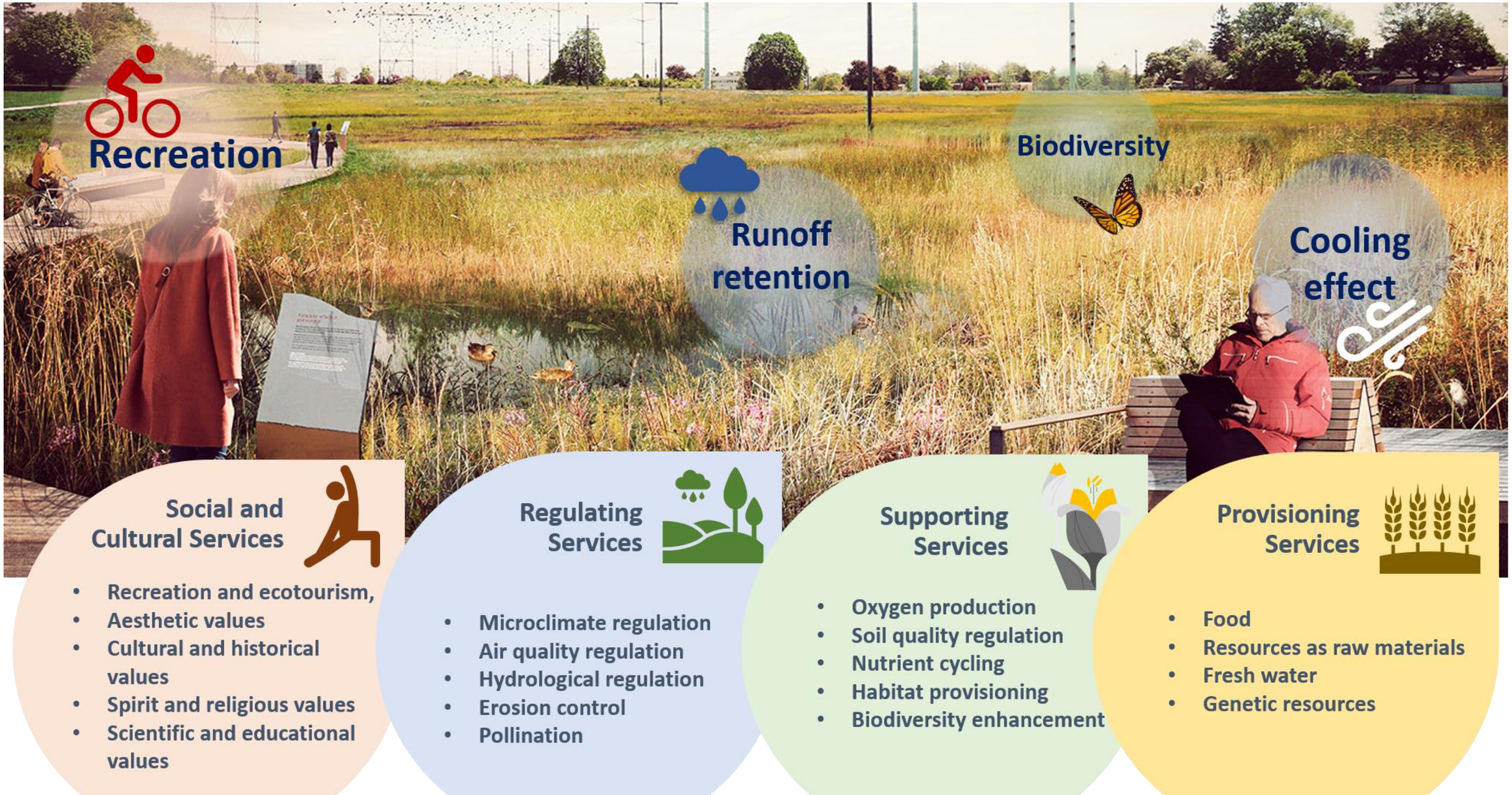

Figure 2. Ecosystem Services Provided by Green Infrastructures (Charoenkit et al., 2019, TRCA, 2019b).

1. Objectives and Scope

The objective of this systematic review is to identify (1) possible ecosystem services provided by urban restored meadows and prairies, (2) KPIs that can reflect provided ecosystem services, and (3) methods to monitor the identified indicators. The results will be analyzed and integrated to help build a framework to evaluate The Meadoway and other similar projects in terms of delivered ecosystem services. The systematic review answers the following questions:

1. What are some ecosystem services provided by urban restored greenspace including meadows and prairies?
2. What are environmental parameters that can be affected by urban meadow and prairie restoration and corresponding KPIs that can be used to reflect the enhanced ecosystem services?
3. What are methods that can be applied to qualify/quantify the identified potential KPIs? What KPIs and monitoring methods are applicable to the evaluation of The Meadoway project?

2. Methodology

The literature of the systematic review was selected through searching within two electronic database platforms *Engineering Village* and *Web of Science* using keywords and screening returned records based on inclusion and exclusion criteria by critically reading titles, abstracts, and full texts. These two database platforms were selected because studies on urban ecological restoration and ecosystem services are primarily in the field of environmental engineering, urban ecology, and natural sciences.

The first step is to use appropriate keywords to retrieve possibly relevant articles from database platforms *Engineering Village* and *Web of Science*. The keywords used for searching are *((ecosystem service*) AND ((green infrastructure* OR green space* OR green*way* OR low*impact development OR sustainable drainage system* OR water sensitive urban design* OR pollinator garden* OR rain*garden* OR urban garden*) OR (urban AND restor* AND (meadow* OR grassland* OR prairie*)))).* In the literature, urban ecological restoration projects are often associated with green infrastructure (GI), and regional stormwater/land use design approaches like Low Impact Development, Sustainable Urban Drainage Systems, and Water Sensitive Urban Design. These concepts all represent a group of urban infrastructures that regulate urban ecology and hydrology by protecting, restoring, or mimicking the natural cycle. Many GIs (e.g., green spaces, greenways, pollinator gardens, rain gardens, and urban gardens) share similar ecosystem characteristics with urban restored meadows and these terms were included in the keywords to avoid missing potentially relevant research. Also, keywords that directly refer to urban restored meadows and prairies, as well as the vague concept of grasslands, are added. When the language is limited to English, the use of this keyword set returned 2221 results from *Web of Science* and 1763 results from *Engineering Village* on June 25, 2020.

The second step is to screen returned papers based on inclusion and exclusion criteria to select only the articles of interest. In the returned results, the number of studies explicitly investigating the effects of urban meadow and prairie restoration was very small, while most of the relevant studies focused on the ecosystem services provided by urban greenspace such as parks and gardens. Provided that urban restored meadows and prairies are certain types of urban greenspace, it is expected that the analysis of ecosystem services provided by urban greenspace and their KPIs can provide useful implications for the performance assessment of urban restored meadows and prairies. Because The Meadoway is not expected to provide provisioning services (i.e., food, resources as raw materials, freshwater, and genetic resources), studies only focusing on the provisioning services of urban greenspace (e.g., urban farms) were not selected. Applying consistent criteria, two rounds of screening were conducted: the first round was based on abstracts and titles, and the second round was based on full-text reading. The employed inclusion criteria are:

1. studies investigating the ecosystem services provided by urban open greenspace including meadows, prairies, lawns, and grasslands at specific sites through analyzing some specific parameters,
2. studies developing an evaluation framework for urban greenspace quality based on ecosystem services,
3. studies should be written in English.

The employed exclusion criteria are:

1. studies analyzing green infrastructures other than urban meadows, prairies, lawns, and grasslands, such as urban forests, constructed wetlands, and green roofs,
2. studies not analyzing specific ecosystem services provided by urban green space at specific study sites by examining specific parameters,
3. Study only analyzing the provisioning services of urban greenspace,
4. studies not written in English,

5. literature reviews,
6. studies evaluating ecosystem services solely based on monetary values,
7. and studies analyzing ecosystem services at a regional or global scale.

Finally, 71 papers were selected for full-text review, from which data was extracted, analyzed, and integrated to provide valuable results including a list of ecosystem services provided by urban greenspace and evaluation KPIs. The extracted data includes basic information (i.e., authors, journal, and publication year), research theme (i.e., disciplinary orientation and goals), information on the study site (i.e., site location, landscape setting, greenspace shape, extent, and vegetation type), and information of primary interests (i.e., analyzed ESs and KPIs, applied monitoring methods, and main findings). A full list of papers selected for review is provided as Supplementary File 1. The complete data extraction sheet is provided as Supplementary File 2. In the data extraction sheet, the applicability of analyzed ESs and KPIs and applied monitoring methods to The Meadoway is also discussed and recorded.

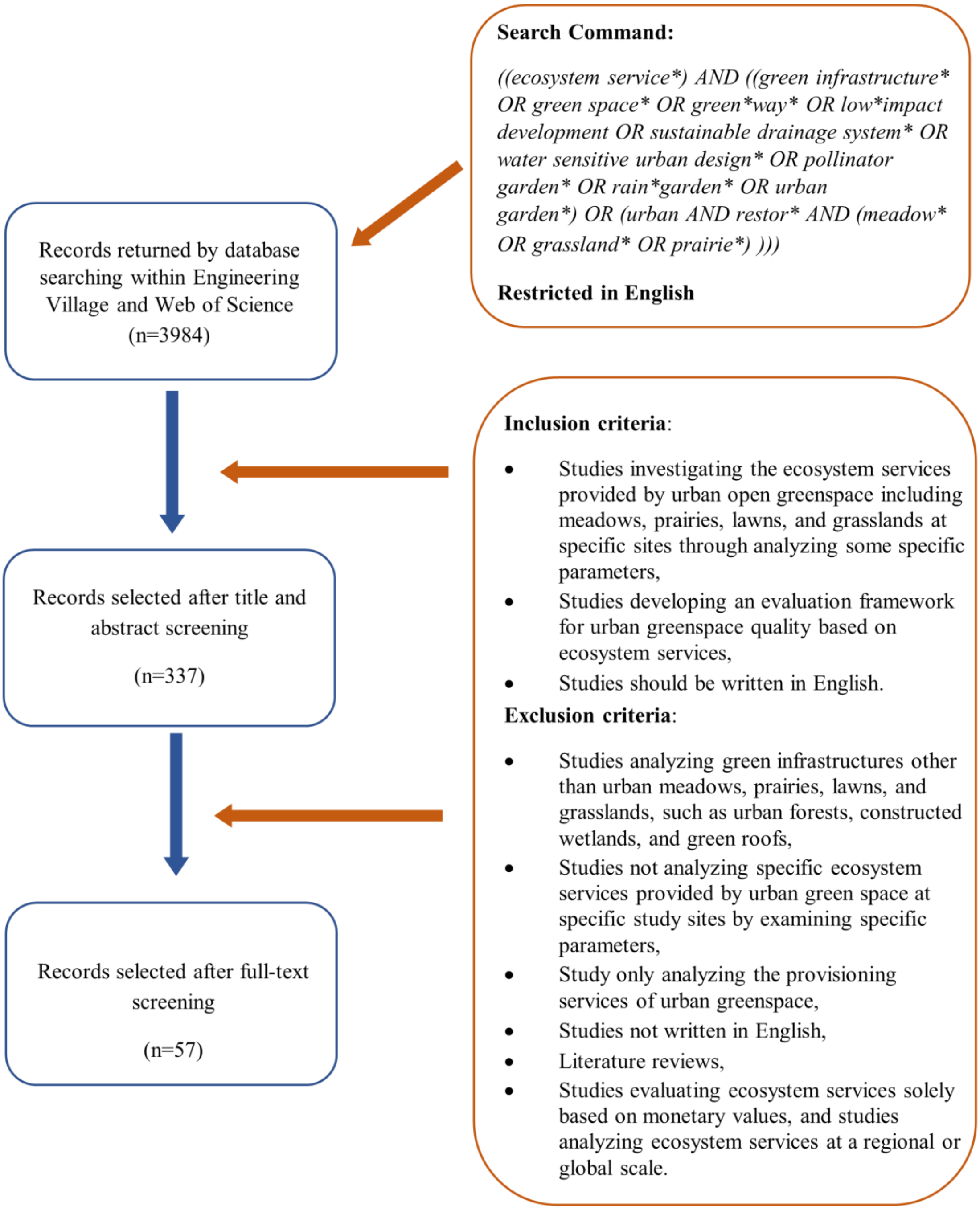

Figure 3. Procedures of the Systematic Review.

4. Results

4.1. Ecosystem Services Provided by Urban Greenspace

Although the ecosystem services provided by urban greenspace are very diverse, they can be classified into six categories: climate regulation, air quality improvement, hydrological regulation, nutrient cycling, habitat services, and social and cultural benefits (Charoenkit et al., 2019). The social and cultural values of urban greenspace were the most intensely investigated ESs with 22 papers, followed by climate regulating services with 13 papers. Based on the classification of ESs, a large number of the studies focused on the regulating services of urban greenspace, while supporting services were studied less frequently with only 5 papers on nutrient cycling and 4 papers on habitat services.

Based on the results, The Meadoway is expected to provide all six types of ecosystem services. In this section, the findings from reviewed papers on each category of ecosystem services will be presented and discussed in terms of how the restoration of The Meadoway can enhance the service.

4.1.1. Social and Cultural Services

Urban greenspaces provide important social and cultural services including aesthetic, spiritual, and psychological benefits to visitors. Studies on this topic have applied a broad range of methods (e.g. questionnaire surveys, interviews, and photo-elicitation method) to investigate visitors' perception and usage of urban greenspace and recognized that urban greenspace had a positive effect on both mental health and physical health by helping reduce stress levels and providing opportunities for informal and formal physical activities (Chiesura, 2004; Kabisch & Kraemer, 2020; Ko & Son, 2018; Nath et al., 2018; Subiza-Perez et al., 2019; Wood et al., 2018). The study by Kristine et al. (2018) revealed that living at a high level of urban greenspace especially during the earliest childhood years could decrease the risk of developing schizophrenia. Urban greenspace can also mitigate the heat exposure and heat stress imposed on vulnerable elderly citizens (Venter et al., 2020). A study in Zimbabwe found that urban greenspace could deliver spiritual services to residents by providing worshipping places (Rall et al., 2017). Some specific types of urban greenspace such as nature parks and historic gardens can provide tourism and education values (Chiesura, 2004; F. Sun et al., 2019). The study by Harris et al. (2018) found that the establishment of a linear greenway named The 606 in Chicago significantly decreased nearby crime rates in both high disadvantage and low disadvantage neighborhoods. Urban greenspace types, park facilities, and biodiversity can influence the cultural benefits perceived and received by visitors. The study by Wood et al. (2018) found that biodiversity significantly influenced the restorative benefits provided by urban greenspace, while another study (Shwartz et al., 2014) showed that the enhancement of species diversity in an urban park had a limited influence on biodiversity perception of frequent visitors. The study by Brown et al. (2018) revealed that the park size and type had significant effects on the distribution and types of park benefits. Specifically, linear parks tended to deliver significant health benefits because they provided opportunities for residents to participate in high-intensity aerobic physical activities such as walking, running, and cycling. Kabisch and Kraemer (2020) found that park facilities (i.e., infrastructural and vegetation characteristics of parks) determined the park usage by age groups as different generations tended to use different park facilities (e.g., sports fields vs. benches) and did different physical activities (e.g., jogging, walking vs. team sports).

The Meadoway can enhance the accessibility of residents to nature and provide opportunities for physical activities by creating a trail for walking, jogging, and cycling. Visitors are expected to perceive a greater number of cultural services (e.g., enjoy nature, release the stress, social opportunities, and leisure and recreation activities) from the restored meadows than original turf lands.

4.1.2. Climate Regulation

Urban open greenspace delivers climate regulating services by providing cooling effects through vegetation. Vegetation influences both microclimate and mesoclimate primarily through the interception of radiation (i.e. shading), the deflection of winds by plant canopies, and plant evapotranspiration, which help reduce air and land surface temperature (Spronken-Smith, 1994). The study by Estoque et al. (2017) examined the relationship between land surface temperature (LST) and the spatial pattern of impervious areas and greenspace in three megacities of Southeast Asia and discovered a 3 °C increase in the mean LST of impervious surface compared to that of greenspace. Another study (Giannakis et al., 2016) revealed a relatively low cooling effect (0.5 °C) of linear parks along urban rivers in Cyprus. Kong et al. (2016) conducted ENVI-MET modeling validated using in-situ meteorological measurements to simulate the 3D microclimate of a university and revealed that greenspaces positively regulated the microclimate during hot summers and reduced high air temperature.

Many factors can affect the cooling effects of urban open greenspace, including vegetation type, structure, and density, land typology, and site area and shape. Different vegetation types have different cooling capacities, primarily due to their different canopy sizes and evapotranspiration capacities (QIU et al., 2013; Richards et al., 2020). Vegetation structure can also affect air circulation and wind speed, which is another important factor influencing air temperature. Therefore, vegetation composition and structure significantly affect the cooling effects of urban greenspace. Specifically, urban forests have greater cooling effects than urban parks, and cooling effects are positively related to tree canopy areas and the percentage of trees/shrubs at the site (Jaganmohan et al., 2016; Monteiro et al., 2016). However, a study by Sun and Chen (2017) found that the land conversion between grasslands and forest lands did not significantly influence local land surface temperature in Beijing from 2002 to 2012 based on historical air photos and remote sensing images. This inconsistency might be explained by the low temperature resolution obtained from remote sensing images at regional scale compared with the high-resolution temperature data from field measurements. Another study (Wang et al., 2018) investigated the cooling effects of and visitors' thermal perception towards three types of urban greenspace and discovered that although the grove site yielded better cooling capacity than the central grassland, it was perceived as the hottest by visitors due to its high relative humidity and low wind speed.

The size and shape of urban greenspace also influence cooling capacity in a way that the greenspace with a greater area and a more circular shape has greater cooling potential (Monteiro et al., 2016). The study by Breuste et al. (2013) revealed that urban parks should be of a certain size to positively affect microclimate and large greenspaces could provide microclimate services at a local scale. The conclusion was supported by the results of another study (Jaganmohan et al., 2016) showing that some small greenspace had negative effects on temperature regulation and the increasing complexity of small greenspace negatively affected the temperature while large greenspace with areas greater than 5.6 ha did not. Estoque et al. (2017) found that the cooling effect of fragmented or dispersed vegetation was generally less effective than that of clustered vegetation.

The Meadoway project replaced original turf lands covered with short grass by meadows planted with high native species. Some features of native plant species are very different from that of short turfs such as greater leaf area index (LAI), more branches, and different transpiration patterns. All these features can potentially alter the cooling capacity of the green corridor. The greater LAI and denser branches of native plant species create a larger plant canopy, which can increase the shading effect. On the other hand, the tall stems of native species might restrain air circulation and decrease wind speed, reducing the cooling capacity. The evapotranspiration patterns of the restored native species and original turfs have not been very clear yet. Thus, the influence of the meadow restoration in The Meadoway on cooling effects is determined by multiple factors and is hard to predict. Most of the literature studied the differences in cooling capacity between grass, shrubs, and trees, but very few papers studied the differences between various herbaceous plant species. For assessment projects on climate regulating services of greenspace especially at a city- or regional scale, researchers tend to assign the same cooling capacity to different herbaceous species (meadows vs. grasslands). It is hypothesized here that the restoration of native plants will deliver better climate regulating services.

4.1.3. Air Quality Regulation and Hydrological Regulation

Urban greenspace improves air quality by removing particulate matters (PM 2.5/10) through deposition on foliage and reducing harmful gases (CO, NO, NO_2, O_3) through dispersion and absorption (Qiu et al., 2019). The air purifying capacity of urban greenspace is strongly influenced by plant types, vegetation structure, and the area of the site. De Valck et al. (2019) acknowledged that the filtration and ventilation capacity of plant species was directly proportional to their total leaf surface area and then used the relationship to calculate an average of 584 kg of PM being filtered from the local atmosphere by vegetation in the studied green corridor. Another study (Qiu et al., 2019) discovered that urban areas with higher green coverage rates had greater potential to reduce airborne particulate matters, and vegetation structure (e.g. lawn, shrubs, one-/more-than-one-layered broad-leaved/coniferous trees/mixed trees) had significant effects on air pollutant reduction. The study by Xing & Brimblecombe (2019) found opposite results showing that tree canopy cover in urban greenspaces caused higher levels of air pollutants due to reduced wind speeds and turbulence.

The restoration of The Meadoway can also possibly enhance the air purifying capacity due to the greater LAI, higher stems, and more intense branches of restored native plants, which facilitate pollutant deposition and dispersion. However, there is a controversy on whether the presence of vegetation causes higher levels of air pollutants due to reduced wind speeds and turbulence. And this might be the case for The Meadoway as the restored high plants can cause higher levels of turbulence and further impede the dispersion of air pollutants. Therefore, the air-purifying capacity of The

Meadoway compared with turf lands or open space without vegetation is uncertain and should be tested through field experiments.

Urban greenspace can provide hydrological regulation services including runoff retention and reduction through infiltration, soil moisture retention, and evapotranspiration, as well as runoff quality improvement through sediment and pollutant filtration and nutrient (N & P) absorption. Vegetation composition and structure, as well as soil characteristics, affect runoff retention and reduction capacity of urban greenspace by controlling the infiltration and percolation capacity. The study by Reyes Gomez et al. (2015) discovered that grass cover enhanced infiltration compared with bare lands without vegetation. The study also demonstrated that rather than preferentially promoting native grass species, species-specific functional traits really determined the infiltration capacity and should be considered for restoring soil-water-related ecosystem services in degraded grasslands. Many studies estimated the volume of runoff reduction from greenspace sites based on land cover and surface typology through modeling or using pre-defined index (Farrugia et al., 2013; Hepcan & Hepcan, 2018; Yang et al., 2015).

The hydrological regulating services can potentially be altered by the restoration of The Meadoway because of the different root traits of native plants and turfs. Also, the changes in soil properties caused by the tillage of native plants can also change the infiltration capacity of the land. Therefore, site experiments are needed to reveal the hydrologic response of the soil to meadow restoration. Due to possibly different soil hydraulic properties and plant nutrient uptake patterns, the water quality might also be different after being filtered through meadows and turf lands.

4.1.4. Nutrient Cycling and Habitat Services

Urban greenspace can improve soil quality and promote nutrient cycling by carbon sequestration and nutrient transformation (P and N) through plant-soil-air interactions. Vegetation types influence the amount and rate of carbon storage as well as the nutrient regulating capacity of urban greenspace. The study by De Valck et al. (2019) calculated the approximate amount of CO_2 being captured annually by vegetation in the green corridor based on valuation factors derived from a meta-analysis of previous studies. Edmondson et al. (2014) found that the soils under trees and shrubs in gardens had significantly higher soil organic carbon (SOC) concentrations than those in urban herbaceous greenspaces. Another study (Klimas et al., 2016) had different results showing that soil carbon stocks were not significantly different between greenspace types except for the forest which yielded the highest value, indicating a relatively even distribution of soil carbon in human-modified areas. The study by Ziter and Turner (2018) revealed that open spaces and developed lands (e.g., residential yards) had the highest C storage compared with deciduous forests and grasslands, and both C and P storage increased with time since the development in developed land covers.

The restoration of meadows can potentially increase the carbon storage in the soil and plants as higher native plants with deeper roots have greater biomass than turfs. Also, the different patterns in nutrient utilization of native plants and turfs might change how nutrients are cycled and distributed in the ecosystem.

Urban greenspaces provide habitats for various species such as plants, birds, beetles, and microbiomes. They are of great importance in enhancing biodiversity and preserving local native species and should be managed well to maximize their valuable supporting services. Vegetation composition and structure and the age, shape, isolation, utilization level, and disturbance level of the site can all influence the habitat services provided by urban greenspace by altering biodiversity and ecosystem structure. Breuste et al. (2013) found that urban greenspace was an important habitat sheltering breeding birds in cities and the bird species responded to the differences in green space size, structure, comparable utilization level, and disturbance. The study by Fattorini and Galassi (2016) revealed that the vegetation types and site isolation affected the abundance and composition of tenebrionid species in urban greenspaces. Some studies also investigated the influence of vegetation composition on the microbial community in urban greenspace (Hui et al., 2017; Mills et al., 2017). It was discovered that plant functional groups and site age significantly affected soil bacterial and fungal communities in an urban environment and the effects were greater for older sites. Besides, it was found that urban greenspace harboured more diverse soil microbial communities than control forests due to continuous anthropogenic disturbance.

The restored meadows with native plants are expected to harbour more other native species including birds and insects and increase the biodiversity in the area. Based on a recently proposed Microbiome Rewilding Hypothesis which states that restoring biodiverse habitats in urban greenspace can rewild the environmental microbiome, the restored meadows might also enhance the diversity and richness of microbiomes at the site.

Table 1. Ecosystem Services Provided by Urban Greenspace.

Ecosystem Service Category	**ESs**	**Number of Papers**	**Description**	**Conclusions**
Regulating Service	Climate Regulation	13	Urban greenspace provides cooling effects through the interception of radiation (i.e., shading), the deflection of winds by plant canopies, and evapotranspiration, which help reduce air temperature (AT) and land surface temperature (LST).	1. Urban greenspace decreases mean AT and LST compared with impervious surface.2. Factors that affect the cooling effects of urban greenspace include vegetation types, structure, and density, land typology, site areas and shapes, and surrounding built-up structures.
	Air Quality Improvement	5	Urban greenspace can purify the air through air pollutant dispersion and absorption, air particle deposition on foliage, and O2 generation.	1. Air pollutants removed by vegetation include particulates (PM 2.5/10) and harmful gases (CO, NO, NO_2, O_3). 2. Plant types, vegetation structure, and green area influence the air purifying capacity of urban greenspaces.
	Hydrological Regulation	7	Urban greenspace can regulate runoff quantity through infiltration, soil moisture retention, and evapotranspiration and improve water quality through sediment and pollutant filtration and nutrient (N & P) absorption.	1. Urban greenspace can reduce runoff volume and facilitate runoff retention. 2. Vegetation composition and structure as well as soil characteristics affect runoff retention and reduction capacity of urban greenspace.
Supporting Service	Nutrient Cycling	5	Urban greenspace can store carbon in soil and plants and regulate nutrient cycling (P & N) through plant-soil-air interactions.	1. Urban greenspace can sequestrate a considerable amount of carbon in both soil and vegetation and be actively involved in the nutrient cycle. 2. Vegetation types influence the carbon storage amount and rate as well as the nutrient regulating capacity of urban greenspace.
	Habitat Services	4	Urban greenspace acts as important habitats for various species (e.g., plants, birds, beetles, and microbiomes).	1. Urban greenspace enhances the biodiversity in cities and preserve local ecosystems. 2. Vegetation composition and structure, site age, shape, isolation, utilization level, and disturbance level can all affect the biodiversity and ecosystem structure of the urban greenspace.
Cultural Service	Social & Cultural Values	22	Urban greenspace can provide important social and cultural services including aesthetic, spiritual, health, and psychological benefits to visitors.	1. Urban greenspace has a positive effect on both mental health and physical health. 2. Urban greenspace types, park facilities, and biodiversity can influence the cultural benefits perceived and received by visitors.

4.2. ESs Evaluation Frameworks for Urban Greenspace

4.2.1. Existing Evaluation Frameworks

Researchers and regulators from different regions of the world have established evaluation frameworks for the quality of urban greenspace based on regional regulations and relevant studies. These frameworks are usually developed to aid decision-making in land planning and project management. In this systematic review, 8 papers on evaluation frameworks for urban greenspace are identified and reviewed (Table 2).

Some frameworks are developed to quantify the overall outcome of an implemented or planned greening project or green infrastructure. Some of them are utilized to conduct ex-ante assessment on the potential shifts in the value of ESs under different urban greening scenarios, while others are used to evaluate the ESs provided by green infrastructures that have been implemented. In these frameworks, potential ESs provided by the assessed infrastructure are usually identified first based on literature review or interviews with stakeholders. Then the values of identified ESs will be quantified either using non-monetary or monetary valuation.

Evaluation of ESs based on monetary values is widely adopted in decision-making worldwide, in which the values of ESs are quantified using monetary units (e.g., market prices, estimates of costs that would be incurred if the ESs were created by artificial means). These evaluation frameworks estimate the overall outcome of a project by summing all components of (dis)utility derived from ecosystem services using money or any market-based unit of measurement that allows comparisons of the benefits of various goods (TEEB, 2010). For example, in the framework developed by Zhong et al. (2020), the value transfer method was applied to determine the value per unit area (i.e., value coefficient) of different ecosystem services for different types of green space cover. The monetary value data were collected from previous relevant studies and converted to value coefficients based on purchasing power parity (PPP) of the year to make the valuation information comparable. The value coefficients for all the cover types in each greening scenario were utilized to estimate the initial value of ecosystem services.

Some other evaluation frameworks quantify the value of ESs using non-monetary indices. In the framework developed by Andersson-Skold et al. (2018), a group of indicators that contribute to ecosystem services are identified. For each indicator, an effectivity score is assigned on a 3-point scale: 1 (weak), 2 (moderate), and 3 (strong) based on literature to reflect its contribution to certain ecosystem services. Then the standardized abundance of the indicator is calculated as the ratio to the most abundance value among all assessed sites, which is multiplied by the effectivity of the indicator to obtain the effect score of the indicator for certain ecosystem services. The effect score is then multiplied by a perceived value factor of the ecosystem service determined by some civil servants who daily dealt with green infrastructure and landscape planning issues, reflecting the value/benefit level of this ecosystem service to humans. Finally, the weighted effect scores of all indicators are summed to give a total benefit estimation of this certain ecosystem service provided by the site. Another framework established by Farrugia et al. (2013) has similar evaluation procedures but uses pre-defined indices to quantify ESs. In this framework, the Green Space Scores for different habitat types or surface cover types are pre-defined based on information from previous studies using the Joint Nature Conservation Committee Phase 1 habitat maps. These Green Space Scores are then weighted by areas and summed to calculate the Green Space Factor of a specific ES. Finally, the Green Space Factors for different ESs are averaged to obtain a final score for the site.

Other frameworks do not aim to estimate the value of the overall outcome from a project or green infrastructure. The framework developed by Herrick et al. (2006) helps regulators to establish a monitoring program for a restoration project. The whole monitoring framework includes monitoring program design before the initiation of the project, short-term monitoring that provides feedback on the project success helping to adjust project management, and long-term monitoring that reflects project success helping the adjustment of management strategy. This study emphasized that for restoration projects, both vegetation composition and ecological process indicators reflecting soil and site stability, hydrologic functions, and biotic integrity should be monitored in short and long terms.

Some studies summarized a list of ESs and KPIs that can be used to reveal the delivered functions and check the quality of a project/green. In the framework developed by Pakzad and Osmond (2016), 30 qualitative and quantitative indicators in 4 groups (ecological, health, socio-cultural, and economic indicators) were selected based on literature review and semi-structured interviews with 21 stakeholders in Australia. Another study by Jerome et al. (2019) identified objective-led principles for high-quality green infrastructure which are categorized into 4 groups: core principles, principles to enhance health and wellbeing, principles for sustainable water management, and principles to enhance nature conservation. Some principles are sub-divided into essential and desirable principles. The ESs and KPIs proposed in these studies are primarily based on the review of current guidelines and standards, academic literature, and national and local policies related to green infrastructure. Although their background is regional, the ESs and KPIs in these frameworks have broad applicability to an international context. The study by Mathey et al. (2015) not only proposed 3 ESs (habitat services, microclimate regulation services, and recreational services) and their KPIs but also developed methods including field experiments and modeling to quantify each KPI. Ji and Lu (2014) developed the annual ecological service efficiency criteria of per hectare greenbelt for grassland and forestland based on data from past literature.

4.2.2. Applicability of Existing Evaluation Frameworks to The Meadoway

The primary objective of this proposed evaluation project of The Meadoway is to compare the values of ESs provided by the restored meadows and original turf lands. One big challenge in using existing evaluation frameworks for The Meadoway is that in these frameworks there is usually no clear distinction between high native plants and low grass, and meadows and turfs are treated the same in terms of the value of many ESs. For example, in the framework developed by Farrugia et al. (2013), there are no habitat categories for meadows and turf lands but only two vague categories named unimproved neutral grassland and semi-improved neutral grassland. And the same values of the Green Space Scores are assigned to these two habitat categories for urban cooling and flood control services. Therefore, the potential improvement in ESs resulted from meadow restoration will be neglected if these evaluation frameworks are adopted.

Another problem with these frameworks is that the non-monetary index or the monetary value of ESs are usually developed based on data collected from previous literature and studies or interview and consultation with stakeholders. The results from past studies usually reflect the characteristics of the local context, which can be unrepresentative of the conditions in other regions. For example, the Green Space Score indices of different surface types for flood control services in the framework established by Farrugia et al. (2013) were developed based on scoring systems used in Northern European cities. Thus, this scoring system might not apply to urban greenspace in other parts of the world such as The Meadoway. In the framework developed in another study (Andersson-Skold et al., 2018), the perceived value factor of each ecosystem service was determined by the opinions of local civil servants who daily worked on green infrastructure and land planning issues. Thus, the values of these factors are rather subjective and can be very site-specific.

Although the monetary valuation method has been widely adopted, there are still some challenges. Firstly, real ecosystems are usually internally heterogeneous and the receivers of different ESs vary greatly, making it difficult to quantify ESs using the same monetary units (Vejre et al., 2010). And the value of intangible ecosystem services such as aesthetic and cultural benefits is difficult to be quantified in monetary units. In addition, in many studies, the monetary value of each ES is determined based on the data from past literature, which unavoidably adds inaccuracy and errors in value estimation. For example, in the study by Zhong et al. (2020), in order to assess the outcome of different greening scenarios in Shanghai, the monetary valuation information from similar case studies of green spaces in dense urban areas in other similar megacities worldwide was extracted, adjusted, and adapted to fit the social-economic contexts of Shanghai due to the limited studies in Shanghai. In addition, The Meadoway restoration project plans to replace turf lands with meadows, which will possibly enhance some ESs, but the improvement can be too subtle to be quantified using monetary units since the two surface types do not differ much in terms of vegetation structure and park facilities. And the value transfer approach using referenced monetary value from other studies can make the evaluation for The Meadoway inaccurate and unrepresentative.

In conclusion, if the overall outcome of The Meadoway restoration project is evaluated based on non-monetary value, then efforts should be taken to establish a comprehensive and complete list of value indices for different ESs. This type of framework is usually used to evaluate various greening/restoration projects and green infrastructures in a region/context where the determination of indices is based on. If such framework is developed, then it can be adopted to assess all similar restoration projects in the GTA and aid decision-making and land planning. If the monetary valuation approach is adopted, then difficulties in value transfer of various ESs should be overcome and the defined monetary values should be representative of the specific context of The Meadoway. The establishment of these two evaluation systems is out of the scope of this report. This report will focus on identifying ESs potentially delivered by The Meadoway restoration project and KPIs to quantify these functions. The identified ESs and KPIs can be used to establish a monitoring program including specified methods to measure KPIs and evaluate the comprehensive benefits generated by the project. Therefore, the existing frameworks that generate lists of ESs and KPIs and provide guidance on developing monitoring programs are very helpful and can be referenced for the proposed evaluation project for The Meadoway.

Table 2. Existing Evaluation Frameworks Applicable to Urban Greenspace.

Framework Category		**Description**	**Example Reference**
Overall outcome evaluation	Monetary evaluation framework	The values of ESs are quantified using monetary units (e.g., market prices, estimates of costs that would be incurred if the ESs were created by artificial means). These evaluation frameworks estimate the overall outcome of a project by summing all components of (dis)utility derived from ecosystem services using money or any market-based unit of measurement that allows comparisons of the benefits of various goods. The monetary values of ESs can be transferred using either biophysical methods or preference-based methods.	Zhong et al. (2020)
	Non-monetary evaluation framework	Each of the ESs provided by a project/green infrastructure is scored based on its quality, which is determined by either investigating KPIs or using pre-defined values from past literature. The overall outcome is then calculated as the weighted average of the scores of all ESs. The weight of each ES can be defined based on the value/benefit level of the ES to humans. This type of standardized evaluation system generates overall outcome scores which can be compared and help regulators compare between different greening scenarios.	Andersson-Skold et al. (2018), Farrugia et al. (2013)
Project monitoring program design		The framework guides to establish a complete monitoring program for a project/green infrastructure. The monitoring framework includes a monitoring program before the initiation of the project, short-term monitoring which provides feedbacks on the project success and helps to adjust project management, and long-term monitoring that reflects project success and helps adjust management strategy. Different KPIs are suggested for different monitoring stages.	Herrick et al. (2006)
Evaluation of specific ESs		The evaluation framework does not assess the overall outcome of a project/green infrastructure but provides methods to assess certain ESs.	Farrugia et al. (2013), Ji & Lu (2014), Mathey et al. (2015)
ESs and KPIs proposal		These frameworks do not develop methods to quantify the performance of a project/green infrastructure but provide a list of ESs and KPIs that can be used to reveal the delivered functions and check the quality of the assessed project/green infrastructure.	Jerome et al. (2019), Mathey et al. (2015), Pakzad & Osmond, (2016)

4.3. Key Performance Indicators and Methods

In the selected literature, the ESs were investigated in many studies through the analysis of specific key performance indicators. Indicators are variables with some logical link to the object or the process being measured that provide clues and guidance to policy- or decision-makers for better management (TEEB, 2010). They reflect the status, drivers, or outcome of the investigated process or object in an unambiguous and usually quantitative way that simplifies information to make it easy to interpret by policy- or decision-makers (Ash et al., 2010).

In this section, KPIs for all six categories of ESs used in the reviewed papers and the methods adopted to measure them are presented (Table 3,Table ***4***Table 5Table 6) and discussed. Their applicability to The Meadoway is also discussed to help develop the KPIs appropriate for The Meadoway evaluation project.

4.3.1. Social and Cultural Values

KPIs used to reflect the social and cultural values provided by urban greenspace include visitors' perception of parks' benefits and services, frequency of visiting, purposes of visiting, physical activities, and visitors' perception and sensitivity to biodiversity.

The most frequently applied methods to investigate these KPIs are questionnaire surveys and interviews. For example, the study by Chiesura (2004) used exploratory questionnaires on randomly selected visitors in the park to estimate their motives for nature, emotional dimension and perceived benefits, and public satisfaction with the number of green areas in cities. Another study by Shwartz et al. (2014) conducted semi-structured interviews in situ with regular garden users before and after increasing the biodiversity of the garden using close-ended questionnaires to explore the respondents' biodiversity perception and their sensitivity to the changes in biodiversity. Based on previous literature both in philosophy and empirical sciences, Subiza-Perez et al. (2019) developed a comprehensive self-report tool for the assessment of the aesthetic qualities of urban parks using a questionnaire with 36 statements and three open questions focusing on the perceived aesthetic qualities of environments.

The study by Brown et al. (2018) investigated the physical health benefits provided by urban green parks by participatory mapping methods and used the MET (metabolic equivalent of task) to estimate physical activity services of urban green parks. In this method, a physical activity score was used as a KPI, which was calculated for each park by summing the products of mapped park activities multiplied by the nominal MET category for the activity. Another study by Kabisch and Kraemer (2020) conducted systematized observation on park uses and activity patterns and structured quantitative counting of park visitors by age groups to analyze the usage patterns of the studied urban green parks.

Some novel methods were used to investigate visitors' perception towards certain services provided by urban greenspace. The study by F. Sun et al. (2019) used a visitor-employed photography (VEP) method and the Social Values for Ecosystem Services (SolVES) mapping tool to generate a map with different spatially-scored social values. In this method, visitors were asked to take photos using iPhone Map Plus software and identify the major object in each photo and score different social values provided by the component. In another study by Southon et al. (2017), the photo-elicitation method was conducted to assess the preference of site users for meadow style plantings relative to other planting styles commonly used in parks. Respondents were asked to assign a preference score between 1–10 to two generic per planting style based on photos. Another two studies collected information from visitors' tweets to investigate their sentiment towards urban greenspace (Johnson et al., 2019; Roberts et al., 2018).

The study by De Valck et al. (2019) used the estimated number of visits as a KPI to reflect recreation values, which was calculated by multiplying the number of residents in the buffer zone of studied greenspaces by the distance weighting factor and the average number of visits per resident per year.

Table 3. KPIs and Monitoring Methods for Social and Cultural Services.

ESs	KPIs	Methodology	References
Social and Cultural Services	Visitors' Physical Activity	• A physical activity score is used as a KPI, which is calculated for each park by summing the products of mapped park activities multiplied by the nominal MET (metabolic equivalent of task) category for the activity. • Systematized observation on park uses and activity patterns and structured quantitative counting of park visitors by age groups are conducted to analyze the usage patterns of the studied urban greenspaces.	Brown et al. (2018), Kabisch & Kraemer (2020)
	Visitors' perception of park's benefits and services, frequency and purposes of visiting, and visitors' perception and sensitivity to biodiversity	Questionnaire surveys and interviews are conducted to collect information on visitors' perception of provided benefits and services and their usage of study sites.	Chiesura (2004), Enssle & Kabisch (2020), Giannakis et al. (2016), Ko & Son (2018), Nath et al. (2018), Ngulani & Shackleton (2019), Shwartz et al. (2014), Subiza-Perez et al. (2019), Wong et al. (2018), Wood et al. (2018)
		Visitors' sentiment towards greenspaces expressed in tweets is collected and analyzed.	Johnson et al. (2019), Roberts et al. (2018)
		• Visitor-employed photography (VEP) method and the Social Values for Ecosystem Services (SolVES) mapping tool are used: visitors were asked to take photos using iPhone Map Plus software and identify the major object in each photo and score different social values provided by the component. • Photo-elicitation methods: respondents were asked to assign a preference score between 1–10 to two generic per planting style based on photos to show their preference to different planting styles.	Southon et al. (2017), F. Sun et al. (2019)
	Estimated number of visits	The estimated number of visits is calculated by multiplying the number of residents in each buffer zone by the distance weighting factor and the average number of visits per resident per year.	De Valck et al. (2019)
	Crime rates in nearby communities	A quasi-experimental matched case-control approach is applied to compare per capita crime rates in green corridor-proximate neighborhoods with different socioeconomic statuses.	Harris et al. (2018)
	Gallup-Healthways Wellbeing Index	The data is from the US national database.	Larson et al. (2016)

4.3.2. Climate Regulation

Land surface temperature and air temperature are the two most frequently used measurements to quantify climate regulation services. Air temperature and land surface temperature in studied urban greenspace are usually measured using in-situ or mobile sensors. These measurements then can be fitted into models to calculate different indices such as temperature reduction and cooling distance to reflect the cooling effects of the site. For example, in the study by Breuste et al. (2013), the mobile temperature was measured along a 500 m transect starting from the greenspace boundary to the nearest neighborhood. Then the temperature measurements along the transect were fitted into polynomial functions to calculate KPIs including the cooling distance and two temperature reduction indices of the site. Similarly, in the study by Monteiro et al. (2016), the two KPIs (cooling distance and cooling magnitude) were parameters in the regression models generated using best-fit curves based on the measurements of temperature vs. distance within the greenspace and in its surrounding along transects. These methods can be applied to different types of greenspace and allow for a straightforward comparison between their cooling capacities in a consistent manner. In addition to field temperature measurements, some other studies utilized Landsat images to extract the distribution of land surface temperature within a region (Estoque et al., 2017; R. Sun & Chen, 2017). This method is usually used to monitor the shift of surface temperature caused by land cover changes with time or analyze the surface temperature of different land cover areas. It involves procedures to retrieve land surface temperature data from the thermal-infrared band using specific methods.

Some studies evaluated the climate regulating services of greenspaces based on the thermal perception of visitors. In addition to using questionnaire surveys to collect the thermal comfort perception of visitors, different indices for thermal comfort can be calculated using meteorological data. The study by Wang et al. (2018) calculated several thermal comfort indices including the mean radiant temperature (Tmrt), operative temperature (Top), and physiological equivalent temperature (PET) using the RayMan model based on Matzarakis et al. (2010) with the input of measured microclimatic data (i.e., air temperature, air velocity, and relative humidity). It also collected people’s thermal perception (thermal sensation vote, thermal comfort vote, thermal preference vote, humidity sensation vote, humidity preference vote, wind speed sensation vote, and wind speed preference vote, and their visiting frequency) by questionnaire surveys. Another study by Giannakis et al. (2016) calculated Thom’s discomfort index using measured air temperature and relative humidity data and related the index to visitors' perception of thermal comfort collected by questionnaire surveys.

Others used computational models to characterize the cooling effects of greenspace. Fernandez (2019) applied a novel GIS-based method for mapping temperature reduction ecosystem services (TRES) based on a multiple-class vegetation distance-decaying function approach. In this model, the maximum distance of cooling effect of each vegetation class of interest was estimated and then the cooling effects of all vegetation classes were integrated using a distance-decaying function to generate the distribution of TRES in the study area. Another study (Kong et al., 2016) used ENVI-met models to generate daytime 3D temperature profiles in the study area and the results were validated using in-situ meteorological measurements. The study by Zhao et al. (2019) estimated the annual total amount of heat absorption and the average temperature reduction (TR) of greenspaces using modeled values of the daily length of cooling service provision, cooling ability, and daily vegetation coverage of classified vegetation types.

The study by Farrugia et al. (2013) used predefined indices named Green Space Scores for different surface and habitat types to quantify the cooling effects provided by greenspace. Two sets of Green Space Scores were defined for different surface and habitat types. One set was determined based on the relationships between surface types and land surface temperatures discovered by Gibson (2009), and the other set was defined using presumed LAI as a surrogate. To evaluate the overall quality of cooling effects, a Green Space Factor was calculated by summing the area-weighted Green Space Scores of all surface/habitat types in the study area.

Table 4. KPIs and Monitoring Methods for Climate Regulation Services.

ES	**KPIs**	**Methodology**	**References**
Climate Regulation	Mean land surface temperature & air temperature	• Temperature data are collected from meteorological stations. • Temperature is measured by in-situ or mobile sensors.	Breuste et al. (2013), Jaganmohan et al. (2016), Monteiro et al. (2016)
		Temperature data are extracted from remote-sensing imagery.	Estoque et al. (2017), R. Sun & Chen (2017)
		Temperature distribution is modeled (e.g., ENVI-MET model).	Fernandez (2019), Kong et al. (2016)
	Cooling distance & magnitude	Temperature measurements are fitted into regression models, parameters of which are calculated as KPIs.	Jaganmohan et al. (2016), Monteiro et al. (2016)
	Annual total amount of the heat absorption & the average temperature reduction	The values are calculated using the estimated daily length of vegetation cooling service provision, vegetation cooling ability, and daily vegetation coverage of different vegetation types.	Zhao et al. (2019)
	• Thom's Discomfort Index • Urban Heat Index • Thermal comfort indices (i.e., mean radiant temperature, operative temperature, and physiological equivalent temperature) • Thermal perception of visitors	Thermal comfort indices are calculated using micro-meteorological data (e.g., air velocity, air temperature, and relative humidity).	Giannakis et al. (2016), Wang et al. (2018), Wong et al. (2018)
		Thermal perception of visitors is collected through questionnaire surveys.	
	Green Space Factor for cooling effects	The index is calculated using pre-defined Green Space Scores of different habitat/surface types for cooling effects.	Farrugia et al. (2013)

4.3.3. Air Quality Regulation

The concentrations of air pollutants are usually used as KPIs for air quality regulating services of urban greenspaces. The study by Qiu et al. (2019) measured PM 2.5 and PM 10 concentrations using a hand-held particle counter (Aerocet 831) to quantitively analyze the effects of green coverage rates on air quality. Another study (Xing & Brimblecombe, 2019) re-analyzed the rate of pollutant decay along transects away from roads and into parks based on existing studies and used a simple numerical model ENVI-MET 4.0 to reproduce the concentrations of NO_2, black carbon, and PM 2.5 along transects.

The amount of pollutant removal is another commonly used KPI. The study by De Valck et al. (2019) estimated the mass of particulate matters (PM) filtered per square meter of the studied greenspace per year based on the relationship that the filtration and ventilation capacity of plant species was directly proportional to their total leaf surface area. Another study by Xie et al. (2019) calculated the economic values of different air quality regulating services (e.g. CO_2 sequestration, O_2 generation, air temperature amelioration, SO_2 removal, NO_x removal, and dust interception) based on estimated pollutant removal rates, O_2 generation rate, water transpiration amount, and dust interception rate and the unit economic value of each service using a carbon tax, market value, and shadow project price methods.

In the study by Vieira et al. (2018), lichen diversity and pollutants accumulation in lichens were used as novel environmental indicators to reflect differences in air quality due to different forest structures, compositions, and management.

4.3.4. Hydrological Regulation

Different parameters used to evaluate the water quantity regulating services of urban greenspaces include runoff volume and rate, time of concentration, and recharge volume. Tang et al. (2020) suggested that a V-notch weir, flow gauge, and flow monitoring meter could be installed to measure inflow and outflow volume and rate of studied green infrastructure. The study by Hepcan and Hepcan (2018) applied the SCS-CN method to estimate the runoff volume over the studied garden. Another study by Yang et al. (2015) developed a new model to simulate hydrographs and quantify the impact to runoff peak magnitude and timing of replacing urban impervious parcels with green infrastructure parcels. The authors presented a theoretical analysis of the advection-diffusion equation and developed a spatially distributed model to simulate runoff along a flow path with varying surface roughness for the land parcels. Infiltration capacity can also be used to reflect the hydrologic functions of urban greenspace. The study by Reyes Gomez et al. (2015) measured the rate of accumulated infiltration in the soil (0-15 cm) and determined percolation using the "Beerkan" protocol. Soil porosity was analyzed linked to soil saturation moisture and the Green and Ampt infiltration model and the transfer functions of the soil were used to calculate parameters of the model used for percolation calculations.

In the study by Farrugia et al. (2013), similar to cooling effects, the Green Space Factors of different habitat/surface types were developed for flood control functions based on their potential infiltration capacity, which can be area-weighted to assign an overall Green Space Factor to the site.

Water quality parameters including water turbidity, total suspended solids (TSS), nitrogen and phosphorus content, biochemical oxygen demand (BOD), pH, dissolved oxygen, and microbial composition in water samples from infiltration and groundwater layers can be used as KPIs to reflect the water treatment performance of some types of green infrastructure. In the paper by Tang et al. (2020), the authors suggested that multiple monitoring wells could be installed under green infrastructure with one in the infiltration layer and another in the groundwater layer. The chemical analysis of water samples collected from monitoring wells showing the nutrient and pollutant levels before and after being filtered by subsoil can reflect the water quality regulating performance of the studied green infrastructure.

Table 5. KPIs and Monitoring Methods for Air Quality Regulation and Hydrological Regulation Services.

ESs	KPIs	Methodology	References
Air Quality Regulation	Air pollutant concentrations (e.g., PM 2.5, PM 10, NO_2, and O_3)	Air pollutant concentrations are measured at the site using monitoring and sampling equipment.	Qiu et al. (2019)
		Air pollutant concentrations along transects are simulated using ENVI-MET model.	Xing & Brimblecombe (2019)
	Air pollution removal (particulate immobilization, SO_2 removal, NO_x removal, and dust interception), O_2 generation	The amount of air pollutant removal and O_2 generation is calculated based on the data from previous studies.	De Valck et al. (2019)
	Economic values of air pollutant removal	Economic values of air pollutant removal are estimated using a carbon tax, market value, and shadow project price methods.	Xie et al. (2019)
	Lichen diversity and pollutants accumulation in lichens	• Lichen diversity was assessed on the trunk of Quercus spp. between 50 and 150 cm above ground, following the standard European method. • Lichen transplants were made and placed in mesh bags which were hung in tree branches or trunks at approximately 2 m height for 3 months of exposure. The total metal content was determined after acid digestion.	Vieira et al. (2018)
Water Quantity Regulation	Runoff volume and rate, time of concentration, recharge volume	• SCS-CN methods are used to estimate runoff and infiltration volume. • Hydrological Modelling • Water quantity monitoring tools (e.g., V-notch weir, flow gauge, and flow monitoring meter) are installed on-site.	Hepcan & Hepcan (2018), Tang et al. (2020), Yang et al. (2015)
	The rate of accumulated infiltration & percolation	Infiltration is measured and the rate of accumulated infiltration and percolation are determined using the “Beerkan” protocol. The Green and Ampt infiltration model and the transfer functions of the soil are used to calculate parameters of the model used for percolation calculation.	Reyes Gomez et al. (2015)
	Green Space Factor (flood control index)	Green Space Factor (GSF) is calculated from Green Space Scores of specific habitat types for flood control weighted by the specific habitat type areas which are all pre-defined.	Farrugia et al. (2013)
Water Quality Regulation	Water turbidity, total suspended solids (TSS), nitrogen and phosphorus content, biochemical oxygen demand (BOD), pH, dissolved oxygen, and microbial composition in discharge water	Multiple monitoring wells can be installed under green infrastructure with one in the infiltration layer and another in the groundwater layer. Water samples can be collected from monitoring wells to measure nutrient/pollutant levels before and after treatment by subsoil.	Tang et al. (2020)

4.3.5. Nutrient Cycling Services

Soil organic carbon is a frequently used parameter to reflect the nutrient cycling function of urban greenspaces. The study by Edmondson et al. (2014) collected soil samples to investigate the soil organic carbon concentrations and storage in different land types at different depths in Leicester to reveal the effects of land covers on soil carbon stocks. The study by Klimas et al. (2016) estimated the spatial and temporal variation in soil carbon stocks within a 30-hectare heterogeneous green space. Another study by Ziter and Turner (2018) also collected soil samples and analyzed soil organic carbon concentrations to investigate the effects of historical land uses on soil quality.

The carbon sequestration rate of vegetation is another KPI for nutrient cycling services. In the study by Othman et al. (2019), the carbon sequestration rate was calculated by biomass equations, using field data inventory, measurements, plan analysis, and survey data analysis. De Valck et al. (2019) estimated carbon sequestration by translating each square meter value of vegetation into its equivalent potential CO_2 uptake in kilograms using valuation factors derived from a meta-analysis of results of different climate model studies.

4.3.6. Habitat Services

The supporting and habitat services of urban greenspace are usually quantified by the richness, composition, and diversity of different species (e.g., plants, bees, insects, and microbiomes). Some parameters related to pollination are also used as KPIs such as floral resources and bee community composition. In a study in Linz, Austria, the number of breeding birds was used as an indicator for the biodiversity services provided by different public parks (Breuste et al., 2013). It was stated that birds are more sensitive indicators for biodiversity than for vegetation in response to differences in green space size, structure, comparable utilization level, and disturbance, reacting very sensitively to different environmental qualities. The study by Monberg et al. (2019) investigated the plant species richness and cover, species composition, and beta-diversity, and floral resources to assess the ecological quality of a restored grassland. Field surveys were conducted in different treatments before and after restoration to collect vegetation data. Floral resource availability was assessed using a Floral Resources Index, which was constructed by assigning all registered forb species a score (0–3) indicating their approximate pollen and nectar value as a floral resource for four groups of bees. In the study by Wood et al. (2018), the richness of plant, bird, and bee/butterfly species and Shannon’s Diversity Index for habitats were integrated to generate an ecological richness score to reflect the overall biodiversity of the study sites. Another study by Papanikolaou et al. (2017) analyzed the species richness and total abundance of wild bees in habitats with different landscape structures, which indicated the pollination services of greenspaces.

The Microbiome Rewilding Hypothesis was proposed in the paper by Mills et al. (2017) stating that restoring biodiverse habitats in urban greenspaces can rewild the environmental microbiome to a state that helps prevent human disease as an ecosystem service. In the case study, the authors analyzed microbial composition and structure in the soil using e-DNA metabarcoding methods to investigate the response of the microbial community to plant functional groups and park age. Similarly, another study by Hui et al. (2017) analyzed bacterial and fungal community richness, diversity, and evenness in the soil in urban parks and rural forests with different plant functional groups.

Table 6. KPIs and Monitoring Methods for Nutrient Cycling and Habitat Services.

ESs	KPIs	Methodology	References
Nutrient Cycling	Soil organic carbon	Soil organic carbon density of soil cores at randomly selected locations is measured to calculate the carbon storage and total storage.	Edmondson et al. (2014), Klimas et al. (2016), Ziter & Turner (2018)
	Carbon sequestration rate (CSR)	The carbon sequestration rate was calculated by biomass equations, using field data inventory, measurements, plan analysis, and survey data analysis.	De Valck et al. (2019), Othman et al. (2019)
Pollination	Floral resources availability	Floral resource availability is assessed using a Floral Resource Index, which is constructed by assigning all registered forb species a score (0–3) indicating their approximate pollen and nectar value as a floral resource for four groups of bees.	Monberg et al. (2019)
	Wild bees community	The composition and structure of the wild bee community are monitored using on-site flight traps.	Papanikolaou et al. (2017)
Species Richness/Diversity	Plant species richness and cover, species composition and beta-diversity.	Vegetation data is collected by vegetation surveys.	Monberg et al. (2019)
	The status/abundance of breeding birds	Breeding Number was calculated as a weighted sum of breeding bird species numbers counted at the site.	Breuste et al. (2013)
	Bacterial and fungal community richness, diversity, and evenness	Soil samples are collected and analyzed. Microbial composition/structure is analyzed using e-DNA metabarcoding methods.	Hui et al. (2017), Mills et al. (2017)

5. Discussion: Possible KPIs and Monitoring Methods for The Meadoway

In this section, KPIs and corresponding monitoring approaches are discussed to develop an ES evaluation plan for The Meadoway (Table 7). All those KPIs were identified through the systematic review with their applicability to The Meadoway being analyzed specifically.

The Meadoway is expected to provide social and cultural values by providing accessibility to nature and opportunities for physical activities. Visitors' perception of parks' benefits and services, frequency of visiting, purposes of visiting, and visitors' perception and sensitivity to biodiversity can all be used as KPIs to evaluate the social and cultural services provided by The Meadoway. Questionnaire surveys and interviews can be conducted at the site to collect visitors' preference towards meadows and turf lands and the benefits they have received by visiting each site. In addition to the information collected by questionnaire surveys, the frequency of visiting and the usage patterns can also be investigated by systematized observation and structured quantitative counting of park visitors. Based on the data on park activities, a physical activity score can then be calculated for both meadows and turf lands by summing the products of mapped park activities multiplied by the nominal MET (metabolic equivalent of task) category for the activity. As The Meadoway does not have various types of park facilities, the Visitor-employed photography (VEP) method and the Social Values for Ecosystem Services (SolVES) mapping tool are not recommended to use for The Meadoway due to its lack of park components.

For The Meadoway, the climate regulating services can be evaluated by comparing the air temperature in the restored meadows and original turfs. There are no existent meteorological stations near the restored meadows and turfs, so microclimatic data should be measured at the site using in-situ or mobile sensors. Since visitors will primarily use the trail along The Meadoway, the air temperature on the trail at a pedestrian level can reflect the thermal conditions experienced by visitors and is the parameter that should be measured and analyzed. The pedestrian-level air temperature measurements in meadows and turf lands can be compared to calculate the temperature reduction by meadow restoration. The thermal comfort of visitors in meadows and turf lands can be analyzed using Thom's Discomfort Index, Urban Heat Index, and other thermal comfort indices, which are calculated using measured microclimatic data (i.e., air temperature, air velocity, and relative humidity). Questionnaire surveys can also be conducted to collect visitors' thermal perceptions of different land covers. The cooling distance and magnitude of the restored meadows showing the temperature gradient from meadows to surrounding areas can also be used as KPIs. The cooling distance and magnitude can be calculated by fitting temperature measurements along transects from the restored meadows to surrounding areas into regression models.

If remote-sensing imagery of the city covering The Meadoway is available, then the temperature distribution within the restored meadows and original turf lands can be analyzed to reflect potential temperature reduction. One problem with this method is that The Meadoway is quite narrow, so the temperature contrast might be too subtle to be interpreted using remote-sensing photos. Land surface temperature distribution can also be simulated using models (e.g., ENVI-MET). However, many existent models are not able to simulate the differences between meadows and turf lands since they do not differ significantly in vegetation structure. The KPIs calculated using pre-defined factors for different vegetation types are not recommended (e.g., the Green Space Score) for The Meadoway project since a lot of these factors do not distinguish between meadows and grasslands and many of them are only representative of the conditions in the region where the study was conducted.

The air quality regulating services of the restored meadows can be estimated by comparing the air pollutant concentrations in the restored meadows and original turf lands. Possible air pollutants to be analyzed include particulate matters (PM 2.5 & PM 10), SO_2, and NO_x, the concentrations of which can be sampled passively or measured using in-situ sensors. Once the air pollutant concentrations in the meadows and turf lands are measured, the removal of air pollutants by the restored meadows can be calculated and the economic values of air pollutant removal can be estimated using value transfer methods. The air pollutant concentration distribution can also be simulated using models (e.g., ENVI-MET), but the same problem exists with that for temperature modeling that meadows and turf lands are not distinguished in many existent models due to their similar vegetation structures. Therefore, the differences in their air quality might not be identified using these models. The lichen diversity and pollutants accumulation in lichens used as KPIs for air quality in one study (Vieira et al., 2018) are not applicable to The Meadoway since lichens are good indicators for forests but not for herbaceous vegetation.

The water quantity regulating services of The Meadoway can be indicated by infiltration capacity. The Meadoway is not a green infrastructure specifically designed for stormwater management, so it can be hard to install runoff monitoring facilities at the site as there are no inlet and outlet points. The infiltration capacity measured by on-site infiltration tests can be used to conduct water balance analysis and hydrologic modeling, which can provide a good profile of the hydrologic regulating function of The Meadoway. The water balance analysis and hydrologic modeling can be conducted for both the restored meadow scenario and the original turf land scenario, and the hydrologic response of two land types to storms can then be compared.

The water quality regulating services can be assessed by analyzing the water chemical properties (e.g., water turbidity, total suspended solids, nitrogen and phosphorus content, biochemical oxygen demand, pH, dissolved oxygen, and microbial composition) in water samples in the infiltration and groundwater layer. However, The Meadoway is not a green infrastructure specifically designed for stormwater treatment. It might not be worth doing such experiments and analysis as the water quality in infiltration and groundwater layers is not likely to differ a lot in meadows and turf lands.

Soil organic carbon storage and carbon sequestration rate (CSR) can be used as KPIs for the nutrient cycling and soil quality regulating services of The Meadoway. The soil organic carbon density in the restored meadows and original turf lands measured by collecting and analyzing soil samples can be used to calculate soil organic carbon storage. The carbon sequestration rate of the restored meadows and original turf lands can be calculated using pre-defined empirical formulas. However, the same formulas are usually used for meadows and turfs, making it impossible to compare between two vegetation types. Other methods such as field plant surveys can be used instead to make a more accurate estimation of CSRs that makes the comparison between meadows and turf lands feasible. Soil nutrient content (e.g., P and N) was not used as a KPI in the reviewed literature, but it can possibly be affected by meadow restoration. The content of P and N in the soil can be easily measured by analyzing collected soil samples.

The supporting services provided by The Meadoway are expected to be significant due to the restoration of native plants. The KPIs that can be used to evaluate the supporting services of The Meadoway include plant species richness, composition, and diversity, the status and abundance of breeding birds, wild bee diversity, floral resources, and microbial community richness, diversity, and evenness. The richness, composition, and diversity of plants, bees, and birds can be measured by field surveys in both restored meadows and original turf lands. Floral resource availability can be calculated based on the results of the plant survey by assigning all registered forb species a score indicating their approximate pollen and nectar value as a floral resource for bees. The bacterial and fungal community richness, diversity, and evenness can be measured by collecting and analyzing soil samples from both restored meadows and original turf lands. By comparing all these KPIs between the two land types, the supporting services provided by The Meadoway can be revealed.

Table 7. Possible KPIs and Monitoring Methods Applicable to The Meadoway.

ES Category	ESs	KPIs	Methods
Cultural Service	Social & Cultural Values	Visitors' perception of park's benefits and services, frequency of visiting, purposes of visiting, and visitors' perception and sensitivity to biodiversity	Questionnaire surveys and interviews can be conducted at the site to collect visitors' preference towards meadows and turf lands and the benefits they have received by visiting each site.
			The frequency of visiting and the usage patterns can be investigated by systematized observation and structured quantitative counting of park visitors.
			Based on the data on park activities, a physical activity score can be calculated for both meadows and turf lands by summing the products of mapped park activities multiplied by the nominal MET (metabolic equivalent of task) category for the activity.
Regulating Service	Climate Regulation	Air temperature reduction at a pedestrian level on the trail by meadow restoration compared with turf lands	Microclimatic data in meadows and turf lands can be measured at the site using in-situ or mobile sensors.
		Thermal comfort index (e.g., Thom's Discomfort Index, Urban Heat Index)	These thermal indices are calculated using measured microclimatic data at the site (i.e., air temperature, air velocity, and relative humidity).
		Visitors' thermal perception	Questionnaire surveys can be conducted to collect visitors' thermal perception of different land covers.
		Cooling distance and magnitude	The cooling distance and magnitude can be calculated by fitting temperature measurements along transects from the restored meadows to surrounding areas into regression models.
		Land surface temperature distribution	Remote-sensing imagery covering The Meadoway can be used to generate the temperature distribution within the restored meadows and original turf lands to reflect potential temperature reduction.
	Air Quality Improvement	Air pollutant concentrations (particulate matters, SO_2, and NO_x) in the restored meadows and original turf lands	Air pollutant concentrations can be sampled passively or measured using in-situ sensors.
		The removal of air pollutants by the restored meadows	The removal of air pollutants can then be calculated using air pollutant concentration measurements in meadows and turf lands.
		Air pollutant concentration distribution	The air pollutant concentration distribution can be simulated using models (e.g., ENVI-MET).

	Hydrological Regulation	Infiltration capacity in meadows and turf lands	The infiltration capacity can be measured by on-site infiltration tests.
		Hydrologic response of meadows and turf lands to storm events	Soil parameters (e.g., bulk density, porosity, gradation, and infiltration capacity) obtained through field tests and lab analysis can be used to conduct water balance analysis and hydrologic modeling, which can provide a good profile of the hydrologic regulating function of two land types to storm events.
Supporting Service	Nutrient Cycling	Soil organic carbon storage	The soil organic carbon density can be measured by collecting and analyzing soil samples in meadows and turf lands, which can be used to calculate soil organic carbon storage.
		Carbon sequestration rate (CSR)	The carbon sequestration rate of meadows and turf lands can be calculated using pre-defined empirical formulas. Other methods such as field plant surveys can be used to make a more accurate estimation of CSRs that makes the comparison between meadows and turf lands feasible.
		Soil nutrient content (e.g., P and N)	The content of P and N in the soil can be measured by analyzing collected soil samples.
	Habitat Services	Plant species richness, composition, and diversity, the status and abundance of breeding birds, wild bee diversity	Those KPIs can be measured by field surveys in both restored meadows and original turf lands.
		Floral resources	Floral resource availability can be calculated based on the results of plant survey by assigning all registered forb species a score indicating their approximate pollen and nectar value as a floral resource for bees.
		Microbial community richness, diversity, and evenness	These KPIs can be measured by collecting and analyzing soil samples from both restored meadows and original turf lands. Microbial composition/structure can be analyzed using e-DNA metabarcoding methods.

6. Conclusion

In this study, a systematic review was conducted to find out ESs provided by urban greenspace, KPIs used to reflect them, and corresponding monitoring methods to help establish an assessment framework for The Meadoway, a linear restored greenway in GTA. Existing evaluation frameworks for urban greenspace were also reviewed. The applicability of existing evaluation frameworks, identified ESs, KPIs, and monitoring methods to The Meadoway was discussed.

It is discovered that many challenges occur when existing evaluation frameworks are applied to The Meadoway. The first challenge is that in many frameworks there is no clear distinction between high native plants and low grass. Therefore, meadows and turf lands will be treated as the same in terms of the value of many ESs, making comparison impossible. Another challenge is that the non-monetary evaluation indices and monetary value of ESs used in existing frameworks are typically determined based on data collected from previous literature and studies or from interviews and consultation with local stakeholders, which are representative of the local context but not applicable to the conditions in other regions. In conclusion, if the overall outcome of The Meadoway restoration project is evaluated based on non-monetary value, then efforts should be taken to establish a comprehensive and complete list of value indices for different ESs in the context of GTA. If the monetary valuation approach is adopted, then difficulties in value transfer of various ESs should be overcome and the monetary values should be defined based on the specific context of The Meadoway. Once such a framework to evaluate the overall outcome of green infrastructure is established, it can be adopted to assess different restoration projects in GTA as they share a similar context. In addition, monitoring plans can be developed for The Meadoway by identifying provided ESs and selecting appropriate KPIs to quantify/qualify ESs at different stages of the restoration project. The monitoring results can provide feedback on the project's success, helping to adjust the project management strategy.

Based on the results of the systematic review, The Meadoway can potentially provide multiple ESs including climate regulation, air quality improvement, hydrological regulation, nutrient cycling, habitat services, and social and cultural values. The replacement of turfs with high native plants alters many plant characteristics (e.g., leaf area index, evapotranspiration pattern, stem height, nutrient uptake pattern, and root density), which have effects on air circulation, air pollutant deposition and dispersion, water, energy, and nutrient transfer, and soil hydraulic properties. The introduction of native plants can potentially attract more diverse species (e.g., birds, insects, and microbiomes) and improve the ecosystem structure. The restored meadows can attract more visitors than original turf lands due to the enhancement of biodiversity. Various KPIs for these ESs and corresponding monitoring methods were identified from the selected literature and they were discussed to generate a specific list applicable to The Meadoway. The suggested KPIs can be direct measurements, observed and collected information, calculated or pre-defined indices, or modeling results. And corresponding monitoring methods include field investigation, lab analysis, questionnaire survey, and modeling. It should be noticed that pre-defined indices from other studies might be inapplicable to The Meadoway and many models used in previous studies are not capable to distinguish between the quality of ESs provided by meadows and turf lands. Therefore, particular care should be taken when these pre-defined indices and models are applied to The Meadoway.

In general, this study completes its objectives to identify existing evaluation frameworks for urban greenspace, reveal delivered ESs, KPIs, and monitoring methods. More importantly, the study generates a list of potential ESs, KPIs, and monitoring methods specifically for The Meadoway to aid the development of an evaluation framework and monitoring plans. The study provides guidance on the evaluation of similar restoration projects in GTA and contributes to the implementation and management of the 10-year strategic plan *Building the Living City*.

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