ITU A|Z • Vol 19 No 2 • July 2022 • 335-351

Restrictions interface proposal for the selection of sustainable stormwater management tools

Nazife Tuğçe ONUK MADANOĞLU[1], Meltem ERDEM KAYA[2]
[1] onuknt@gmail.com • Department of Landscape Architecture, Faculty of Architecture, Istanbul Technical University, İstanbul, Turkey
[2] erdemme@itu.edu.tr • Department of Landscape Architecture, Faculty of Architecture, Istanbul Technical University, İstanbul, Turkey

Received: February 2021 • Final Acceptance: April 2022

Abstract

In leading countries, alternative stormwater management (SWM) approaches guide design process with local guides, databases and user interfaces which are mostly land depended by their priorities and targets. Their adoption as a reference is challenging for designers in countries where sustainable stormwater infrastructure is undeveloped. This study presents a proposed interface for the selection of SWM tools according to site restrictions, hydrological functions, land use and performances based on location independent data.

SWM approaches, local guides and web-based resources are reviewed to form a dataset for common 26 SWM tools and their land-independent features to create a MS Office-based algorithm for designing an interface to help the user to define the suitable tool for the site. Interface is demonstrated as a design tool to create a water quality performance based storm-water treatment chain in ITU Ayazaga Campus. As a result, appropriate SWM tools are succesfully selected to convey runoff water from parking lots to storm-water pond considering the land use changes. And SWM tools were gathered from interface were suitable to create a chain. Also using the interface was time saving with no need for additional research on tools. Since the proposed interface promotes the integration of SWM into design decision making process in undeveloped countries and can be used as an education tool, it is expected to have a widespread impact.

Keywords
Storm-water management, SWM tool selection interface, Location independent SWM tools, Storm-water treatment chain, ITU Ayazaga Campus.

doi: 10.5505/itujfa.2022.26817

1. Introduction

According to United Nations, % 55 of the current population of the world reside in urban areas and this number is expected to reach %68 by 2050 (United Nations,2018). This growing tendency of population in urban zones and urbanization process will have a growing threat on natural dynamics, resource availability and environmental quality (McGrane, 2016; EPA, 2021; Ahn et.al.,2005; Beach,2003; Brody,2007; Gaffield,2003). Especially changing land cover from rural to urban which also means that change of the topography and surface conditions from permeable to impermeable as a result of new constructions, demolition and redevelopment have widespread impacts on dominant runoff-generating processes, and ket flow-paths, having a substantial impact on catchment boundaries and drainage pathways (McGrane, 2016).

On the other hand, the climate change causes significant impacts on the precipitation regimes over 25-100 years that will make urban design interventions releated to water systems more critical and complex (Ashley et. al 2005; Hill & Barnett, 2008; Hill, 2009). Therefore advancing our knowledge on urban hydrological process and its relation to spatial design urgently needs to be adressed in planning and design agenda. This situation necessitated reconsidering the relationship between urban areas and stormwater management, which urges reconstructing the urban spaces with stormwater management features and resilliency. Today, while some developed countries deal with stormwater management in urban areas with both legal and practical aspects, the issue is not sufficiently prioritized in developing countries that are traditional infrastructure-dependent. As experienced in urban areas, overwhelmed stormwater management systems can lead to localized flooding or greater runoff of contaminants which damages back urban habitat itself (EPA, 2021).

Beginning from the 1980s, changes in the urban drainage approach has shifted beyond focusing on the removal of stormwater from cities to consider it as a resource and evolved to adaption of approaches that guide design process with water management policies and implementation tools. According to Marsalek (2005), main reasons for these changes are (a) introduction of the sustainable development concept, (b) acceptance of the ecosystem approach to water resources management, (c) improved understanding of drainage impacts on receiving waters and (d) acceptance of the need to consider the components of urban drainage and wastewater systems in an integrated manner. The shift in the management of urban waters has led to the emergence of approaches that adopt sustainable stormwater management as an alternative to the existing conventional infrastructure. The terminology of the leading approaches differ according to the country of origin, as follows: LID (USA), WSUD (Australia), SUDS (Britain), LIUDD (New Zelland), Sponge City (China) (Radcliffe, 2019). These approaches consist of water management policies, resource control and water management tools (Marsalek, 2005), while their objectives and priorities vary according to the hydrological, infrastructural, ecological, planning issues of the site (Radcliffe, 2019). For instance, while the main focus of WSUD is developing infiltration techniques for different types of soils due to prevalent clay soil in many cities in Australia, LID concentrates on source control to protect natural characteristic of watersheds, and SUDS concerns water quantity, water quality and amenity issues for water control (Lanarc Consultants Ltd. et al, 2012). While local stormwater management guides and design interfaces prepared with reference to these approaches relate to a certain region, they include water management policies and tools specialised according to the sensitive ecology of that region. For example, while climate compatibility of SWM tools are used as a selection criterion in local guides of cold climate regions, it is observed that SWM tools and treatment chains to clean runoff water are prioritized in regions where mostly sensitive water sources or high ground water level are widespread.

Therefore, these similar approaches, which essentially derive from a common structure, may indicate contextual variations during their implementation stage.

Among this diversity, sustainable stormwater management, supported by relevant directives, interfaces, and online databases, has become an integral part of the design process in developed countries. However, differences in local water management policies, variety in terminology and SWM tools, and differentiated features according to guidelines create challenges for designers to use these approaches and guides as a reference in countries which are still dependent on traditional infrastructure and lack of sufficient data basis for sustainable stormwater management. In this regard, interfaces supported by location-independent data are required for the selection of SWM tools in countries that have not developed sustainable stormwater management yet.

In this study, a selection interface for SWM tools is presented which was developed as a part of a checklist proposal for sustainable water design in University Campuses. This selection interface tool was developed in two phases; 1- the first step includes creation of a database, which consist of sustainable SWM tools and their restriction features. The second phase includes development of an interface that transforms the selected restriction criteria to sustainable water management tools list with the help of an algorithm specifically prepared for this study. It is thought that this interface will help designers to integrate stormwater management into landscape design process, especially in countries like Turkey where urban water management system depends on traditional infrastructure.

2. Methodology

This research is structured around combined methods that include qualitative method for data gathering process and a case-study method to test the proposed SWM interface tool. In this context, the methodology of the research was proceeded in two phases. The first phase of the research includes definition of database. For this purpose, the secondary data were obtained from an in-depth literature review that includes stormwater management guidelines of LID, SUDS and WSUD (County, 1999; Ballard et al., 2007; Ballard et al., 2015; BMT WBM Pty Ltd, 2009; Transport and Infrastructure Department of Planning, 2009), local sustainable stormwater design guidelines as; Maryland stormwater design manual, New York State stormwater management design manual, Vancouver Stormwater source control design guidelines, Saanich Stormwater management, Green stormwater infrastructure common design guidelines for The Capital Region, Low-impact development design strategies: An integrated design approach (Center for Watershed Protection,2003; Center for Watershed Protection, 2000; Lanarc et al., 2012; Golder Associates Ltd., 2016; District of Saanich, 2020; Opus International Consultants Limited et al., 2019; County,2014; Minnesota Stormwater Steering Committee, 2005; Bureau of Watershed Management, 2006, Center for Watershed Protection, 2015,) and additional resources for SWM Tools (Maryland Department of Environment, 2020; Lawson, 2005; Dyke et al., 2009; Fox. Et al.,2018; DeepRoot Green Infrastructure, 2014; Step,2011; Bray et al.2012; British Plastics Federation Group, 2018; Asadian and Weiler ,2009, Kumar et al, 2007). The data obtained from mentioned resources were classified and eliminated according to common SWM tools features included and an MS office–based algorithm was prepared to define the appropriate SWM tool.

For the second stage, the primary data were obtained from site visits which was conducted in 2020 to test the SWM selection interface tool on ITU Ayazağa Campus. Study area is chosen according to its diverse landscape character with dense built areas, natural areas and variable topography as a small prototype of a city. The Campus is also rated as the 71th in Green Metric 2020 ranking with its sustainable practices and management system in landscape. In this phase, hydrological, geological and topographic data of the area were collected, soil analysis, land use, land cover change, stormwater infrastructure analyzes were made and natural areas were determined. The obtained data were overlapped with the existing dimensional base map and the study area was divided into 88 micro-catchments considering hydrological features and landscape borders. In order to test the interface created in Stage 1, two adjacent micro-catchments, one with the connection to traditional infrastructure and provides stormwater transmission from an area of high construction rate to the second micro-catchment that includes protection area, were selected. With the results gathered from interface, a SWM tool chain with high water quality hydrological function is created between two micro-catchments.

2.1. Development of SWM tool selection interface

In the first step of the development of 'selection interface' for site restrictions of stormwater management; LID, SUDS and WSUD guides, sustainable stormwaterwater design local guides and additional resources as web based resources, thesis, book, reports were taken as a reference as stated above. Since the intention is to create a 'common pool' for the tools, these references were selected according to the SWM tools they include. The list of common tools in sustainable stormwater design and the list of restrictions, which are one of the selection criteria for these tools, have been gathered from the literature review. Afterwards, an MS Office-based algorithm was prepared, based on the obtained restrictions data and tool lists (Figure 1).

Within the scope of the study, the literature review carried out in two phases. In the first phase, determination of the water management tools has been done. Since the content of the local guides are prepared according to the local conditions of the region, variations in the SWM tools and the features they incorporate may differ from each other. For this reason, the list of tools obtained from the references was subjected to an elimination one more time, thus the list of common tools was obtained. The design variants and synonyms of the tools were determined through terminology research, and the final list of the sustainable tools that will generate the inputs to the algorithm, has been created (Figure 2). The list includes 26 tools namely; absorbent landscape, bioretention, cistern, conveyance swales, detention basins, dry well, filter trench, filter/buffer strip, flow-through rain planter, geocellular / modular systems, grass swale, green roof, infiltration basin, infiltration rain planter, infiltration trench, organic filter, perimeter sand filter, pervious pavement, stormwater ponds, rain barrel, rain garden, rainwater harvesting, stormwater wetlands, structural soil cell, surface sand filter, trees, underground sand filter, vegetated swale, wet swale.

The second phase of the literature review includes determination of the restriction categories. The content of the restrictions interface was determined by listing the common criteria in the selection matrices shaped under the titles such as restriction selection criteria in the reviewed guides. The selection criteria consist of 7 common criteria namely; hydrologic functions, slope restrictions, soil type, drainaige area, water table and land use. To determine the features of the tools for these criteria, websites with related databases and researches are also rewieved as well as approaches and local guides. The features to be used in the interface may vary according to the different resources. In this case, for the data selection of the features for interface, as a principle; the number of reference where the data has been published and the actuallity of these references were taken as a base. It is aimed to reveal the features of the tools which are independent of location.

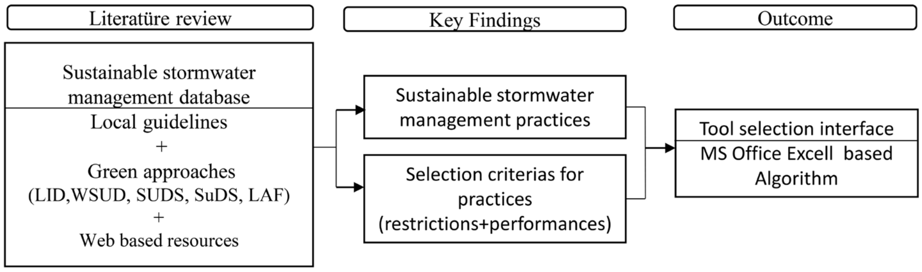


Figure 1. *Graphical abstract.*

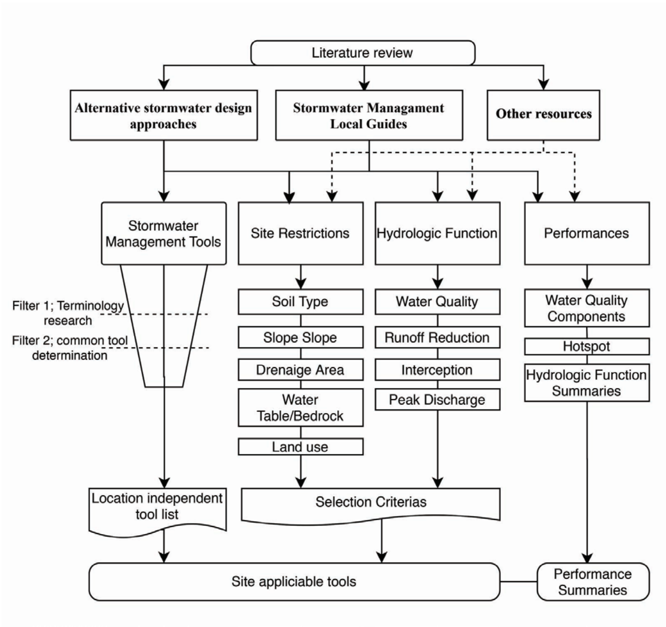


Figure 2. *Methodology of research.*

2.2. Restrictions interface design process

The interface, designed for the selection of SWM tools, contains a MS-Excel based algorithm and a suplemantary document named as 'Sustainable Stormwater Management Tools Design Criteria (SSDC)' which includes detailed information on the data in this interface and more features and of these tools as pretreatment needs. While this supplementary document contains all information of tools in detail, the algorithm functions as a practical interface for the selection of these tools. In this study, only the details and the working principle of the restrictions interface is presented.

The restrictions interface consists of 4 operation areas (Figure 3). First area, the 'Selection Table', contains sub-selection criteria specified for the main 6 restrictions types. The list of water management tools that are suitable for the selections made in the Selection Table in Area 1, appears in the 'Results Table' in Area 2. The 'Results Table', consisting of 6 columns, gives a list of tools that meet each criteria in separate columns. If some of the restrictions are not intended to engage in the algortihm, they are left in the 'Select' option and in the relevant column a list of all tools under the corresponding category (26) appear in Area 2. At the same time, in the 'Common Results Table' in Area 3, the common tools from the 6 different SWM tools lists presented in Area 2 appear. Thus, while different tools are listed for each restriction criteria in the 'Results Table' (Area 2), the common tools that are suitable to all selection criteria are listed in the 'Common Results Table' (Area 3). This list (Area 3) indicates the appropriate stormwater design tools to be used by the designer in the project area. The table, 'Performances of Common Results', in Area 4 contains the performance summaries of the tools listed in the 'Common Results Table' in three categories: hydrologic function performances, water quality performances and hotspot restrictions. The 'Performances of Common Results', provides summary information, helps user to identify the tools among the Common Tools with the most appropriate performance for the design. The contents of the 4 areas forming the interface and their relations with each other are shown in Figure 4.

2.2.1. Selection table

It is the table where the user specifies the tool selection criteria according to the characteristics of the site and the stormwater management goals and also includes the subcategories of the 6 main selection criteria.

Hydrologic Functions; SWM tools have various hydrological functions such as interception, depression storage, infiltration, groundwater recharge, runoff volume, peak discharge, runoff frequency, water quality, base flow, stream quality (County, 1999). In literature research, only common performance data for interception, runoff volume reduction, peak discharge and water quality functions used in the interface could be reached. For this reason, only these 4 subcategories were provided as selection criteria for the hydrological function of the interface. Since there is a lack of data in the literature for performance assessment on interception, this function is presented with only 2 options, as 'Yes' or 'No', while runoff volume reduction, peak discharge, and water quality can be rated as 'high, medium, low'. The relevant ratings have been added to the option-

Area 1	
DESIGN RESTRICTIONS	SELECTION TABLE
Hydrologic Function	Select
Slope Restrictions	Select
Soil Type	Select
Drenaige Area	Select
Water table/ Bedrock	Select
Land use	Select

Area 2					
RESULS TABLE					
Tools for Hydrologic Functions Selection	Tools for Slope Restriction	Tools for Soil Type	Tools for Drenaige Area	Tools for Water Table	Tools for Land Use
Absorbent landscape	Absorbent landscape	Absorbent landscape	Absorbent landscape	Absorbent landscape	Absorbent landscape
Bioretention	Bioretention	Bioretention	Bioretention	Bioretention	Bioretention
Cistern	Cistern	Cistern	Cistern	Cistern	Cistern
Conveyance swales	Conveyance swales	Conveyance swales	Conveyance swales	Conveyance swales	Conveyance swales
Detention basins	Detention basins	Detention basins	Detention basins	Detention basins	Detention basins
Dry Well	Dry Well	Dry Well	Dry Well	Dry Well	Dry Well
Filter trench	Filter trench	Filter trench	Filter trench	Filter trench	Filter trench
Filter/Buffer strip	Filter/Buffer strip	Filter/Buffer strip	Filter/Buffer strip	Filter/Buffer strip	Filter/Buffer strip
Flow-through rain planter	Flow-through rain planter	Flow-through rain planter	Flow-through rain planter	Flow-through rain planter	Flow-through rain planter
Geocellular / modular systems	Geocellular / modular systems	Geocellular / modular systems	Geocellular / modular systems	Geocellular / modular systems	Geocellular / modular systems
Grass Swale	Grass Swale	Grass Swale	Grass Swale	Grass Swale	Grass Swale
Green roof	Green roof	Green roof	Green roof	Green roof	Green roof
Infiltration basin	Infiltration basin	Infiltration basin	Infiltration basin	Infiltration basin	Infiltration basin
Infiltration rain planter	Infiltration rain planter	Infiltration rain planter	Infiltration rain planter	Infiltration rain planter	Infiltration rain planter
Infiltration trench	Infiltration trench	Infiltration trench	Infiltration trench	Infiltration trench	Infiltration trench
Organic filter	Organic filter	Organic filter	Organic filter	Organic filter	Organic filter
Perimeter sand filter	Perimeter sand filter	Perimeter sand filter	Perimeter sand filter	Perimeter sand filter	Perimeter sand filter
Pervious pavement	Pervious pavement	Pervious pavement	Pervious pavement	Pervious pavement	Pervious pavement
Stormwater Ponds	Stormwater Ponds	Stormwater Ponds	Stormwater Ponds	Stormwater Ponds	Stormwater Ponds
Rain barrel	Rain barrel	Rain barrel	Rain barrel	Rain barrel	Rain barrel
Rain garden	Rain garden	Rain garden	Rain garden	Rain garden	Rain garden
Rainwater harvesting	Rainwater harvesting	Rainwater harvesting	Rainwater harvesting	Rainwater harvesting	Rainwater harvesting
Stormwater wetlands	Stormwater wetlands	Stormwater wetlands	Stormwater wetlands	Stormwater wetlands	Stormwater wetlands
Structural soil cell	Structural soil cell	Structural soil cell	Structural soil cell	Structural soil cell	Structural soil cell
Surface sand filter	Surface sand filter	Surface sand filter	Surface sand filter	Surface sand filter	Surface sand filter
Trees	Trees	Trees	Trees	Trees	Trees
Underground sand filter	Underground sand filter	Underground sand filter	Underground sand filter	Underground sand filter	Underground sand filter
Vegetated swale	Vegetated swale	Vegetated swale	Vegetated swale	Vegetated swale	Vegetated swale
Wet swale	Wet swale	Wet swale	Wet swale	Wet swale	Wet swale

Area 3	Area 4		
	PERFORMANCES OF COMMON RESULTS		
COMMON RESULTS TABLE	Hotspot Restrictions	Water Quality Peformance Summary	Hydrologic Function Performance Summary
Absorbent landscape	Recive directly from hotspot	NA	İnterception- Runoff volume reduction (high)- Peak discharge (high)- Water quality (high)
Bioretention	Recive directly from hotspot	Heavy Metals (high) - Nutirents (low)- TSS (high)	Interception (high)- Runoff volume reduction (high)-Peak discharge (medium)- Water quality (high)
Cistern	Recive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (high)	Runoff volume reduction (low)-Peak discharge (medium)- Water quality (low)
Conveyance swales	Does not recive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (high)	Interception- Runoff volume reduction (medium)- Peak discharge(medium) - Water quality(high)
Detention basins	Recive directly from hotspot	Heavy Metals (high) - Nutirents (medium)- TSS (high)	Interception - Runoff volume reduction (low)-Peak discharge (high)- Water quality (Medium)
Dry Well	Does not receive directly from hotspot	Heavy Metals (high) - Nutirents (high)- TSS (high)	Runoff volume reduction (high)-Peak discharge (low)- Water quality (high)
Filter trench	Recive directly from hotspot	Heavy Metals (high) - Nutirents (low/medium)- TSS (high)	Interception(low)- Runoff volume reduction (low)-Peak discharge (medium)- Water quality (high)
Filter/Buffer strip	Does not receive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (medium)	Interception (high) - Runoff volume reduction (poor)-Peak discharge (low)- Water quality (medium)
Flow-through rain planter	Does not receive directly from hotspot	Heavy Metals (medium/high) - Nutirents (NA)- TSS (high)	Interception (high) -Runoff volume reduction (high)-Peak discharge (medium)- Water quality (high)
Geocellular / modular systems	Does not receive directly from hotspot	Heavy Metals (none) - Nutirents (none)- TSS (high)	Runoff volume reduction (low)- Peak discharge (high)- Water quality (low)
Grass Swale	Does not receive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (high)	Interception (medium) - Runoff volume reduction (medium)-Peak discharge (medium)- Water quality (high)
Green roof	Recive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (high)	Interception - Runoff volume reduction (high)- Peak discharge (medium)- Water quality (high)
Infiltration basin	Does not receive directly from hotspot	Heavy Metals (high) - Nutirents (high)- TSS (high)	Interception - Runoff volume reduction (high)-Peak discharge (medium)- Water quality (high)
İnfiltration rain planter	Does not receive directly from hotspot	Heavy Metals (medium/high) - Nutirents (NA)- TSS (high)	Interception (high) - Runoff volume reduction (high)-Peak discharge (medium)- Water quality (high)
İnfiltration trench	Does not receive directly from hotspot	Heavy Metals (high) - Nutirents (high)- TSS (high)	Runoff volume reduction (high)-Peak discharge (medium)- Water quality (high)
Organic filter	Recive directly from hotspot	Heavy Metals (high) - Nutirents (medium)- TSS (high)	Runoff volume reduction (low)*-- Peak discharge (low)*-- Water quality (high)
Perimeter sand filter	Recive directly from hotspot	Heavy Metals (high) - Nutirents (low)- TSS (high)	Runoff volume reduction (poor)- Peak discharge (poor)- Water quality (high)
Pervious pavement	Recive directly from hotspot	Heavy Metals (high) - Nutirents (high)- TSS (high)	Interception - Runoff volume reduction (high)-Peak discharge (high)- Water quality (high)
Stormwater Ponds	Recive directly from hotspot	Heavy Metals (high) - Nutirents (medium)- TSS (high)	Runoff volume reduction (poor)-Peak discharge (high)-Water quality(high)
Rain barrel	Recive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (medium)	Runoff volume reduction (low)-Peak discharge (medium)- Water quality (low)
Rain garden	Recive directly from hotspot	Heavy Metals (high) - Nutirents (low)- TSS (high)	Interception- Runoff volume reduction (high)- Peak discharge (high)-Water quality (high)
Rainwater harvesting	Recive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (high)	Interception - Runoff volume reduction (low)-Peak discharge (low)- Water quality (low)
Stormwater wetlands	Recive directly from hotspot	Heavy Metals (high) - Nutirents (medium)- TSS (high)	Runoff volume reduction (poor)- Peak discharge (high)- Water quality(high)
Structural soil cell	Does not receive directly from hotspot	Heavy Metals (high) - Nutirents (NA)- TSS (high)	Interception - Runoff volume reduction (high)- -Peak discharge (high)-Water quality (high)
Surface sand filter	Recive directly from hotspot	Heavy Metals (high) - Nutirents (low) - TSS (high)	Runoff volume reduction (poor)- Peak discharge (poor)- Water quality (high)
Trees	NA	Heavy Metals (NA) - Nutirents (NA)- TSS (NA)	Interception(high) - Runoff volume reduction (medium)- Peak discharge- Water quality (medium)
Underground sand filter	Recive directly from hotspot	Heavy Metals (high) - Nutirents (low)- TSS (high)	Runoff volume reduction (poor)- Peak discharge (poor)- Water quality (high)
Vegetated swale	Does not receive directly from hotspot	Heavy Metals (NA) - Nutirents (NA)- TSS (medium)	Interception- Runoff volume reduction (high)- Peak discharge (high)- Water quality (high)
Wet swale	Does not receive directly from hotspot	Heavy Metals (high) - Nutirents (low) - TSS (high)	Runoff volume reduction (low)- Peak discharge(medium) - Water quality(high)

Figure 3. *The areas that form the Design Restrictions Interface.*

sets in the interface as obtained from the resources, and hydrological function performance with different ratings have been checked and clarified from different sources. The data considered poor in the relevant references is listed as low on the restriction selection list, and "Not available" data is entered into the algorithm for tools where hydrological function data are not available.

No data has been found whether the organic filter has an interception function or not, it has been added to the interface as 'Yes' as a result of the analyzed information.

Slope Restrictions; is the area where the maximum slopes for the relevant tools can be selected. The selection criteria are defined as flat, max. 4%, max.5%, max. 6%, max. 8%, max. 15%, max. 20%, max. 33% and not available.

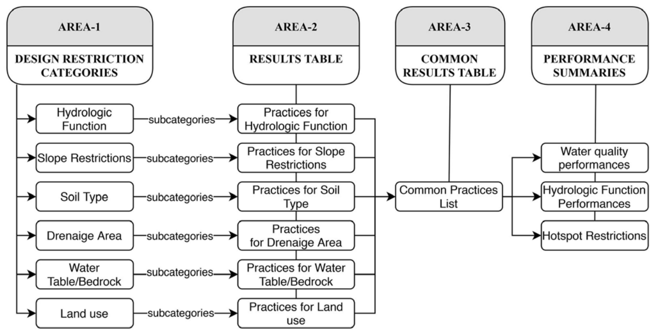


Figure 4. *Contents of the areas that form the interface and their relation with each other.*

The tools with a defined slope range appear not only on the maximum slope option to which they can be applied, but on all slope options they can be applied to. For example, a bioretention tool with a slope restriction max 6%, will appear for the following slope options; flat, max. 4%, max.5%, max 6%. For the tools that can be applied on slopes in a certain range, the slope ranges between the maximum and minimum values are determined and entered into the algorithm. Information for optimum, minimum or maximum slope for some tools were not available. These tools are classified as "not available" in the slope category, and since they do not have any restrictions on slope, they are included in the algorithm to appear in all slope options and as 'not available'. For instance, the cistern tool which has no restrictions on slope appears on all slope options and in the "not available", allowing the user to include it in the design. In order to avoid such situations from causing confusion about the maximum slope rate to which the relevant tools can be applied, all the data used in the algorithm related to the tools are included in 'SSDC' (such as Cistern slope restriction is not availabe).

Cistern, rain barrel, stormwater harvesting tools are specified as 'not available' to the algorithm.

Soil Type; The selection list, indicating the soil type in the area where the stormwater management practice will be applied, includes categorization of Hydrologic group A, Hydrologic group B, Hydrologic group C, Hydrologic group D and made soil. Made soil is determined for tools operates in offline system that require special soil (such as bioretention). Each practice has a soil type for optimal application while there are alternate soil types that the practice can be applied with modifications to the soil or with the practice itself. For example, many tools with infiltration capacity, preferably applied in A and B group soils, can also be applied to group C soils in sensitive areas by using a linear impermeable surface if groundwater is likely to be contaminated. In addition, there are cases where some tools suitable for application in A, B, C group soils can be applied in D group soils with soil modification. In the restrictions interface, the soil groups in which tools can be optimally used are added to the selection criteria, and their suitability in alternative soil groups are specified in 'SSDC'. In case of no restriction on soil type, A, B, C, D soil types are specified for the respective practice and if appropriate according to the type of practice (such as bioretention or pots), made soil is added.

Drainage Area; As a result of the literature review drainage areas where SWM tools can be applied are specified in 7 categories as max.4.000 m², max.8.000 m², max.15.000 m², max.20.000m², max.30.000 m², max. 40.000 m², min. 100.000m² and not available. Tools with larger drainage area appear in selections made for smaller drainage area. Since no clear data has been obtained about Pervious pavement and Structural soil cell, they are specified as "not available", and the principles for determining the drainage area of these tools have been provided in 'SSDC'.

Water table; Determines the minimum distance between the water table's seasonally highest level or from the upper water levels of the existing aquifers to the planned SWM tools. The criteria is particularly important in the management of waters with risk of pollution in sensitive areas, and in the use of infiltration tools to prevent contamination of groundwater. Based on the data in the references reviewed, the restriction options are defined as min.1.2 m, min.1 m., min.0,6 m., groundwater level and not available.

While all the tools specified as 'not available' appear on the selections over water table (min.1.2 m., min.1 m., min.0,6 m.), only the wet swale practice appears on the 'groundwater level' option. Cistern, Green roof, Rain barrel, Stormwater harvesting and Stormwater wetlands are the practice that are listed as 'not available' in the algorithm.

Land use; focuses on the development type of the project area as a limitation for the selection of the SWM tools. The selection criterias were grouped under 8 categories as residential, commercial/industrial, high density, contaminated sites, retrofit, parks and open spaces, local streets, parking lot. The criteria is important to protect sensitive sites. As in the contaminated sites stormwater can not be collected or infiltrated, tools like rainbarrel, dry well, infiltration trench are not preferred to be used. Also some tools are designed to be preferably applied to a unique area as rain planters are created to act like raingardens, bioswales, or infiltration tools in high density areas. And some practice's features may not be met with the development types; like ponds and stormwater wetlands are not suitable to be used in high density area due to the lack of available space and contamination risks. So, the criteria helps user to identify the best option that is suitable for the project area.

2.2.2. Performances of common results

The 'Performances of Common Results' table contains the performance summary of the tools in the 'Common Results Table' which is the last list the user will get in this interface. This table was created in order to support the user to identify the most suitable practice through an additional elimination in the last list according to their performance. The table consist of three information columns; summary information about the performances of water quality and hydrologic functions and practice's suitability for direct water intake from the hotspot are given.

Hydrologic function performans summary; if the practice that appears in the Common Results Table is known to have a hydrological function, however, any performance data is not available, only the name of relevant hydrologic function appears in this table without any rating. If the practice does not have the relevant hydrological function, the criteria is not included in the performance summary. While the performance ratings (high, medium, low) of all tools in the categories of runoff volume reduction, peak discharge and water quality are indicated in the table, the performance ratings of the in the interception category for the following ten tools could not be obtained; Absorbent landscape, detention basins, green roof, infiltration basin, pervious pavement, rain garden, stormwater harvesting, structural soil cell, vegetated swale.

Water quality performans summary; this column is added to the interface to guide the user in choosing the most appropriate tools in order to create a treatment chain according to the water quality in the project area. The table that summarizes the water treatment performances of the tools for heavy metal, nutrients and TSS pollutants is presented in 5 categories as high, medium, low, none and not available. The indication of 'none' next to the component indicates that the related practice can not treat that component. The performance evaluation of some tools are obtained as ratings (high, medium or low), some are presented only through numerical performance values (such as nutrient removal capacity %50), and some have both rating and numerical performance values. In these cases, numerical data are evaluated by accepting EOR, 2004 performance ranges (removal rate (r.r.) >%60=high, %60>r.r>%40=medium, %40>r.r= low), and added to the algorithm. The references with both performance rating and numerical performance values, the given performance rating (high, medium or low) for the practice is selected as data for the algoritm.

In the examination of the references, TP, TN ve NO3 from the nutrients, and copper, lead and zinc among the heavy metals, were found to be the common components in the treatment performance table of the tools. For this reason, if no rated data about the Nutrients and Heavy metals treatment performance is obtained, the performance ratings are obtained by transforming the numerical percentage value of the specified constituent according to EOR, 2004 performance ranges and is added as the performance rating of the practice in the respective pollutant category in the interface.

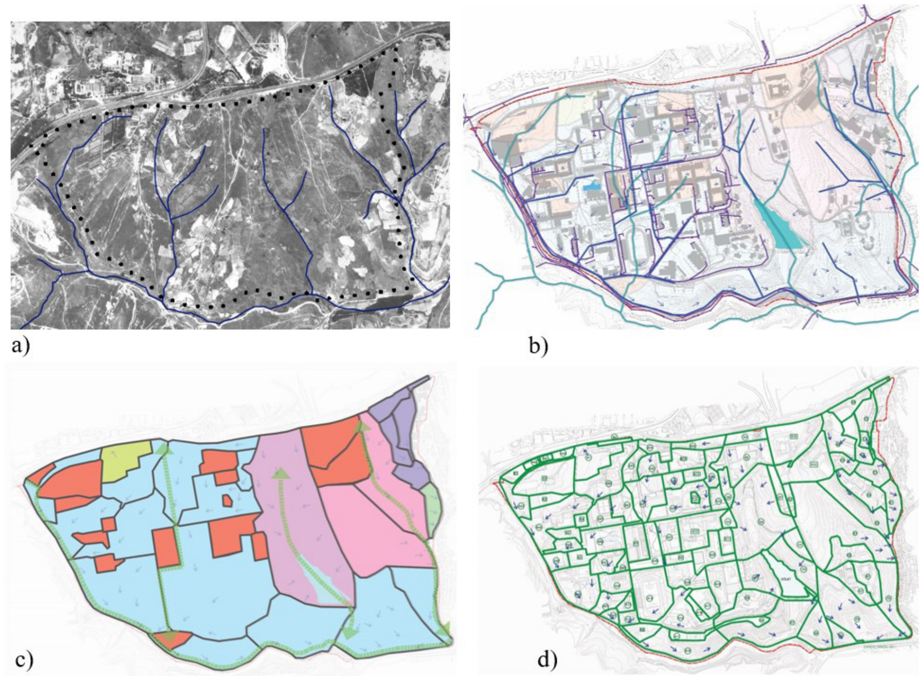
In the table, the water quality performance of absorbent landscape and 'Nutrients' removal performance of flow-through rain planter and infiltration rain planter were specified as 'not available'.

Hotspot restrictions: the tools listed in the Common Results Table are grouped in three categories, as "receive directly from hotspot", "does not recieve directly from hotspot" and "not available". 'Trees' is the only tool included in the algorithm as Not Available.

3. Case study: Restrictions interface usage

Istanbul Technical University Ayazaga Campus (Turkey) is located on an area of 247ha with both natural and built sites including 8 faculties, 4 institutes, rectorate and administrative buildings, student dormitories, a library, technopolis structures and student centers and a natural park(64ha) with stormwater pond (2ha). The campus is ranked as 71th in UI Green Metrics in 2020. As a part of green campus studies, all runoff water is aimed to be collected in the stormwater pond located in the campus. To promote this approach two parking lots (1928m2) located in the same micro basin with stormwater pond are selected as pilot area in order to demonstrate the restrictions interface by determination of suitable SWM Tools for runoff conveyance.

In order to understand the hydrological change of the study area due to construction, the site plans for the years 1970-2015 were compared and waterways before construction were determined from the satellite image of 1970 (Figure 5a). By overlapping the existing and disappearing water ways with the current topographic map, site plan and rainwater infrastructure plan (Figure 5b), it is observed that most of the natural water ways before construction of the campus turned into vehicle roads and surface waters are transmitted by conventional infrastructure. Determining natural stormwater flow directions on built site topography and overlapping them with natural waterways revealed 3 different basin characteristics for the campus (Figure 5c) named as; regular basin (drained by transferring runoff water to neighboring basin), pit basin (unable to drain stormwater without conventional infrastructure) and stormwater-pond basin (draining runoff waters into stormwater pond). Following the hydrological, topographic, geological, soil, land use, infrastructure facilities and natural areas analyzes, the campus area was divided into 88 micro-catchments (Figure 5d). Different stormwater management strategies were determined for each basin and 2 microcatchments draining into the stormwater-pond basin were selected for the SWM Tool Selection Interface demonstration. One of the micro-catchments has natural features including a rainwater pond, and the other contains parking lots that transmit water from the built-up area to this



a) b) c) d)

Figure 5. *a) Natural waterways of ITU Ayazaga Campus in1970 (İstanbul Sehir Haritası, (n.d.) b) Overlapping dissepeared and existing waterways, with base map and stormwater infrastructure c) Basins with proposed rehabilitation waterways in ITU Ayazaga Campus d) Microbasins of ITU Ayazaga Campus.*

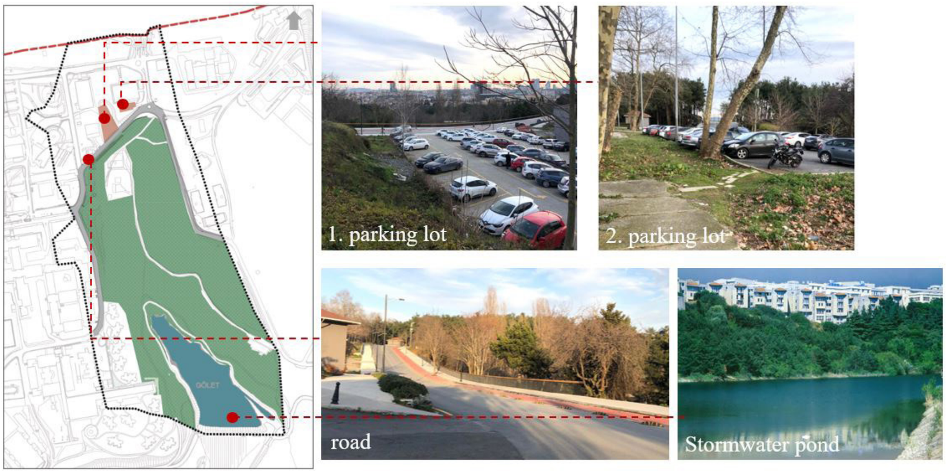


Figure 6. *Project area in ITU Ayazaga Campus.*

basin and contain potential pollutants. Since the amount of solids, metals, nutrients and organic pollutants exist in runoff water from parking lots is high (Revitt et al., 2014), the SWM Tools are expected to have water treatment effect, thus the primarily hydraulic function of the stormwater design is aimed to increase runoff water quality.

The parking lots designated as pilot areas are located on the vehicle roads surrounding the nature park where stormwater pond is located (Figure 6). Runoff water collected from the parking lots is aimed to be cleaned at the source with appropriate treatment methods, then conveyed to the beginning of the valley of stormwaterpond with pipes through the roads. Planned runoff water route includes different land use charasteristics as parking lots, vehicle road, pedestrian way and vegetated natural buffer zone of ITU stormwater pond which leads differentiation in appropriate SWM Tools determination. In this study, appropriate SWM Tool alternatives to convey water from source till stormwater pond will be searched by the restrictions interface and only the water conveyance through valley will be detailed.

Following the stage of collecting technical data and performing survey analysis, the SWM Tools determination process has been started. As a summary the analyze phase is as follows; sites natural waterflow ways are identified from the aerial photos of pre-construction period in 1970. The slope of the area was calculated from the dimensional drawing and base map overlap, and an appropriate water conveyance route was determined by considering the topography, existing vegetation characteristics+layout and determined natural waterways. Runoff water collected from parking lots was decided to be transmitted in a route with a slope of 7.44%, which is divided into two parts, 6% and 8%, to promote usage of different SWM tools to create treatment chain for increasing the runoff water quality. The hydrological soil group of the study area had been accepted as HSC-C according to the ground survey reports in ITU Ayazaga Campus. Hydrological maps were examined to check groundwater existence for water table determination.

Restrictions Interface was tested as a design tool to list the most appropriate SWM tools for pilot area meeting design expectatitons with high hydrological performances in water quality, runoff water conveyance and creating treatment chain.

Following selection criteria were chosen according to pilot area's characteristics and the operation of the interface was presented step by step through the areas as defined in Figure 3. From the 'Selections Table' in Area 1, the selections were made according to the restrictions of the project area (Figure 7a). If any of the restrictions were unnecessary and not desired to make a selection for the project area, the relevant field was left as 'Select'. For ITU Ayazağa Campus example, there is no restriction for the water table characteristics so the criteria was left as the 'Select' option.

In the "Results Table" in Area 2, a list of tools that meet the selection criteria applied in the previous step do appear. In this area, since the tools that meet each criteria are listed in different columns, the user has the chance to observe the changes in the tools that meet that criteria by changing the selection criteria. In this example, all 26 tools appeared in the 'Results Table' for water table, which is not considered as a restriction and similarly for drainage area as all tools meet the specified selection criteria (Figure 7b).

In the 'Common Results Table' in Area 3, the common tools from 6 different columns in the Results Table (Area 2) are listed. Thus, a list of 4 SWM tools that meet all the criteria in the Selection Table (Area 1) is obtained (Figure 7c).

In the 'Performances of Common Results' table in Area 4, performance summaries for resulting four SWM tools are indicated. In the Hydrologic Function Performance Summary column, no rating for 'interception' for the green roof and vegetated swale states that this practice provides interception but its performance raiting is not defined. The absence of 'interception' in the Hydrologic Function Performance Summary presented for the stormwater ponds and stormwater wetlands means that these practices do not have interception features.

While four SWM Tools appeared in the Common Results List are compatible with the demands of the pilot area, vegetated swale is the only option that

a)

Area 1	
DESIGN RESTRICTIONS	SELECTION TABLE
Hydrologic Function	Water quality (high)
Slope Restrictions	Max. 8%
Soil Type	Hydrologic group C
Drenaige Area	Max. 4.000 m2
Water table/ Bedrock	Select
Land use	Parks - Open spaces

b)

Area 2					
RESULS TABLE					
Tools for Hydrologic Functions Selection	Tools for Slope Restriction	Tools for Soil Type	Tools for Drenaige Area	Tools for Water Table	Tools for Land Use
Absorbent landscape	Absorbent landscape	Cistern	Absorbent landscape	Absorbent landscape	Absorbent landscape
Bioretention	Cistern	Conveyance swales	Bioretention	Bioretention	Bioretention
Conveyance swales	Conveyance swales	Detention basins	Cistern	Cistern	Conveyance swales
Filter trench	Geocellular / modular systems	Filter/Buffer strip	Detention basins	Detention basins	Dry Well
Flow-through rain planter	Green roof	Flow-through rain planter	Dry Well	Dry Well	Filter trench
Grass Swale	Infiltration basin	Geocellular / modular systems	Filter trench	Filter trench	Filter/Buffer strip
Green roof	İnfiltration trench	Green roof	Filter/Buffer strip	Filter/Buffer strip	Flow-through rain planter
Infiltration basin	Stormwater Ponds	Organic filter	Flow-through rain planter	Flow-through rain planter	Geocellular / modular systems
İnfiltration rain planter	Rain barrel	Perimeter sand filter	Geocellular / modular systems	Geocellular / modular systems	Grass Swale
İnfiltration trench	Rainwater harvesting	Pervious pavement	Grass Swale	Grass Swale	Green roof
Organic filter	Stormwater wetlands	Stormwater Ponds	Green roof	Green roof	Infiltration basin
Perimeter sand filter	Trees	Rain barrel	Infiltration basin	Infiltration basin	İnfiltration rain planter
Pervious pavement	Vegetated swale	Rain garden	İnfiltration rain planter	İnfiltration rain planter	İnfiltration trench
Stormwater Ponds		Rainwater harvesting	İnfiltration trench	İnfiltration trench	Organic filter
Rain garden		Stormwater wetlands	Organic filter	Organic filter	Perimeter sand filter
Rainwater harvesting		Structural soil cell	Perimeter sand filter	Perimeter sand filter	Pervious pavement
Stormwater wetlands		Surface sand filter	Pervious pavement	Pervious pavement	Stormwater Ponds
Structural soil cell		Trees	Stormwater Ponds	Stormwater Ponds	Rain garden
Surface sand filter		Underground sand filter	Rain barrel	Rain barrel	Rainwater harvesting
Trees		Vegetated swale	Rain garden	Rain garden	Stormwater wetlands
Vegetated swale			Stormwater wetlands	Stormwater wetlands	Trees
Wet swale			Structural soil cell	Structural soil cell	Underground sand filter
			Surface sand filter	Surface sand filter	Vegetated swale
			Underground sand filter	Underground sand filter	
			Vegetated swale	Vegetated swale	
			Wet swale	Wet swale	

c)

Area 3	Area 4		
	PERFORMANCES OF COMMON RESULTS		
COMMON RESULTS TABLE	Hotspot Restrictions	Water Quality Peformance Summary	Hydrologic Function Performance Summary
Green roof	Recive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (high)	Interception - Runoff volume reduction (high)- Peak discharge (medium)- Water quality (high)
Stormwater Ponds	Recive directly from hotspot	Heavy Metals (high) - Nutirents (medium)- TSS (high)	Runoff volume reduction (poor)-Peak discharge (high)- Water quality(high)
Stormwater wetlands	Recive directly from hotspot	Heavy Metals (high) - Nutirents (medium)- TSS (high)	Runoff volume reduction (poor)- Peak discharge (high)- Water quality(high)
Vegetated swale	Does not receive directly from hotspot	Heavy Metals (high) - Nutirents (low/medium)- TSS (medium)	Interception- Runoff volume reduction (high)- Peak discharge (high)- Water quality (high)

Figure 7. *a) Main selection table of the interface b) Results table for the selection criteria c) Common Results Table and Performance Summaries of the interface.*

can be used for runoff water conveyance criteria from the list. In the performance table of common results, it is proved that this tool also promotes water quality with high performance in heavy metals and TSS and low/medium in nutrients. Since the runoff water from parking lot is not considered as a hotspot, vegetated swale can be considered as suitable for the pilot area. Proposed interface helped to eliminate wet swale and dry swale options due to slope restrictions which is max %4 for these SWM tools. Only wet swale can ben considered as an alternative for end of the vegetated swale where it is connected to pond and wet ground can be achieved by terrain gradiation.

In order to increase the quality of the runoff water before entering the stormwater pond, the SWM tool to be located after the vegetated swale is searched with the following criteria by restrictions interface. Since the runoff water collected from the parking lot was not highly contaminated, the selection phase was carried out in two stages as hydrological function with medium water quality (Şekil8a) and high water quality (Şekil 9a), to reveal the alternative SWM tools (Figure 8b, Figure 9b). Additionally, the suitability SWM tools for natural buffer zone was also checked due less intervention to field is required and filter buffer strip was deemed to be the most appropriate tool among the results obtained (Figure 8b, Figure 9b). Considering the pilot area's priorities, results of selection in Figure 8b also reveals to be more appropriate to be implemented close to parking lots far from the buffer zone.

From the selections above, a runoff treatment and conveyance chain for the nature park zone has been created (Figure 10a). The vegetated swale is supported with forebay as an additional pretreatment process, so the high water quality is guarantied. Considering runoff management requirements in parking lots, selections with the Restrictions Interface has carried out and high performance based runoff treatment chain for all demonstration area was suggested as Figure 10b.

Stromwater design implementation shows that the usage of Restrictions Tool let the designer directly choose

a)

Area 1	
DESIGN RESTRICTIONS	SELECTION TABLE
Hydrologic Function	Water quality (medium)
Slope Restrictions	Max. 6%
Soil Type	Hydrologic group C
Drenaige Area	Max. 4.000 m2
Water table/ Bedrock	Select
Land use	Parking lot

b)

Area 3	Area 4		
COMMON RESULTS TABLE	PERFORMANCES OF COMMON RESULTS		
	Hotspot Restrictions	Water Quality Peformance Summary	Hydrologic Function Performance Summary
Filter/Buffer strip	Does not receive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (medium)	Interception (high) - Runoff volume reduction (poor)-Peak discharge (low)- Water quality (medium)

Figure 8. *a) Selection phase of Interface for parking lots b)SWM Tool Results of Interface for parking lots.*

a)

Area 1	
DESIGN RESTRICTIONS	SELECTION TABLE
Hydrologic Function	Water quality (high)
Slope Restrictions	Max. 6%
Soil Type	Hydrologic group C
Drenaige Area	Max. 4.000 m2
Water table/ Bedrock	Select
Land use	Parks - Open spaces

b)

Area 3	Area 4		
COMMON RESULTS TABLE	PERFORMANCES OF COMMON RESULTS		
	Hotspot Restrictions	Water Quality Peformance Summary	Hydrologic Function Performance Summary
Green roof	Recive directly from hotspot	Heavy Metals (medium) - Nutirents (low)- TSS (high)	Interception - Runoff volume reduction (high)- Peak discharge (medium)- Water quality (high)
İnfiltration trench	Does not receive directly from hotspot	Heavy Metals (high) - Nutirents (high)- TSS (high)	Interception(medium)-Runoff volume reduction (high)- Peak discharge (medium)- Water quality (high)
Organic filter	Recive directly from hotspot	Heavy Metals (high) - Nutirents (medium)- TSS (high)	Runoff volume reduction (low)- Peak discharge (low)- Water quality (high)
Perimeter sand filter	Recive directly from hotspot	Heavy Metals (high) - Nutirents (low)- TSS (high)	Runoff volume reduction (poor)- Peak discharge (poor)- Water quality (high)
Stormwater Ponds	Recive directly from hotspot	Heavy Metals (high) - Nutirents (medium)- TSS (high)	Runoff volume reduction (poor)-Peak discharge (high)- Water quality(high)
Stormwater wetlands	Recive directly from hotspot	Heavy Metals (high) - Nutirents (medium)- TSS (high)	Runoff volume reduction (poor)- Peak discharge (high)- Water quality(high)

Figure 9. *a) Selection phase of Interface for natural park b) SWM Tool Results of Interface for natural park.*

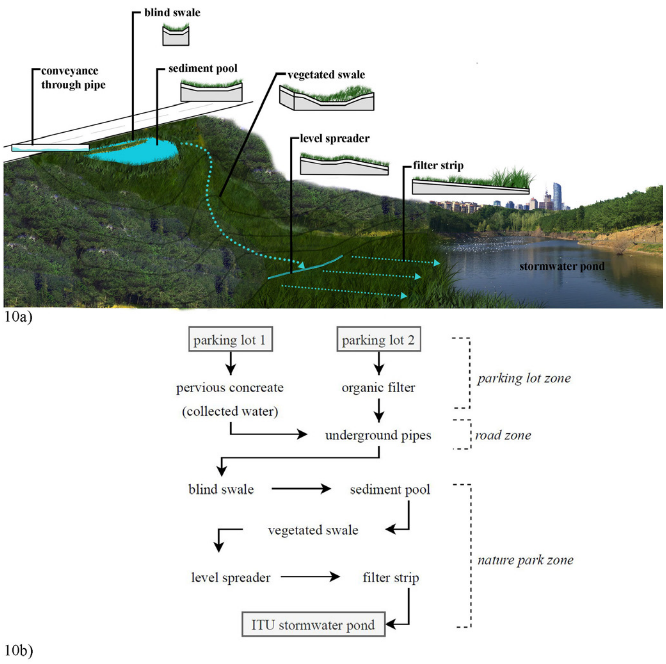


Figure 10. *a) Proposed runoff conveyance and treatment chain for ITU natural park b) Proposed runoff conveyance and treatment chain form parking lots to ITU stormwater pond.*

the appropriate SWM Tools which is most suitable for the project area considereing the local characteristics of the site and the results can be implemented to the landscape design field in order to save time.

4. Conclusion

Within the scope of the study, a common database for SWM tools had been created by taking into consideration the sustainable stormwater management approaches adopted in Australia, USA, Canada, and the local stormwater management design guides derived from these approaches. The SWM tools database is created with the intention to be location-independent as the selection of the tools for inclusion is based on their presence in at least 2 resources which are suitable for different climates. The algorithm, which was developed with reference to the practice selection matrices of the relevant approaches and guides, offers designer a list of tools suitable for the project area, as well as feedback on the performance summaries and the features of the tools. Since the selection and results tables are operated and presented progressively, the interface informs the user about the features of the tools, so the usage of proposed interface is considered as a selection tool as well as an educational tool. Interface's introductory feature of the SWM tools will help the students to learn actively during the application phase.

The interface, created with the transformation of the scattered data in the references into an algorithm, qualifies as a tool that the user can integrate sustainable stormwater management into the landscape design process. The interface considers the restriction features of the project area such as soil condition, drainage area, groundwater table, and slope, also performs elimination on the tools according to aimed hydrological functions and site uses. Thus, users can obtain the most suitable stormwater design tools for the project area by entering the data obtained during the analyzes phase of the project. The tools listed in the Common Results Table have different hydrological features such as filtration, source control, infiltration, treatment, enhanced physical properties and variety of benefits (such as biodiversity, carbon capture, heat island effect) offer alternative spatial solutions for the project area. This situation shows the impact of the proposed interface on the space formation during the decision process of urban water management and urban space design.

In this study, the interface is used to select the appropriate SWM Tools for parking lots located in basin of the stormwater-pond of ITU Ayazaga Campus. Considering that the runoff water collected in the stormwater-pond will be reused for campus irrigation, it is important that the conveying stormwater reaches the pond with high quality. For this purpose, within the scope of this study SWM Tools with treatment quailities are aimed and the interface is used to determine the most appropriate ones among 26 SWM tools, considering the constraints revealed in the analyses phase. The use of the interface in the design process allowed the evaluation of all spatial data obtained during the analysis phase. Content of Common Results Table let the designer to prewiew performances for the hydrological functions, thus results in high performance-based stormwater design in landscapes with simple and time saving tool. Also, the fact that design constraints are included in the interface as selection criteria has ensured that these constraints are taken into account during the design phase which is crucial while dealing with natural lands and water management.

During the creation of a database for structural and non-structural tools, conflicts and confusions related to the terminology of the tools in literature were observed. Considering that sustainable stormwater control methods and tools are recommended under the leadership of developed countries and referenced by designers in countries that do not have that type of infrastructure, there is a need to establish a 'common water management tools terminology' with international validity, without being affected by the different approaches or geographical differences. Additional researches regarding the performance of the absorbent landscape / trees, which is an effective unstructural practice in the creation of sustainable landscapes, is needed.

Although the cost-effective criteria are commonly seen in the selection matrices of the reviewed references, it could not be added to the restrictions interface due to the differences like material and currency. In order to evaluate the financial constraints of water management tools at the selection stage, it is necessary to conduct a unit price analysis of the tools on local scale.

For Turkey and similar countries, since they have different geographical, hydrological, climatic, socio-cultural and urban development featured regions, it is recommended to create water management guides that consider the regional differences and support these guides with the following studies; 1- sharing the necessary local data through open web-based platforms to be used during the sustainable water design analysis phase; 2- Considering climate diversity, observation of the hydrological performance and durability of the tools in different climate scenarios and recommending alternative adaptable tools in regional level if necessary. At the same time, it is recommended to develop similar databases in different climate scenarios and open it to international use in order to be used by designers in regions that lack sustainable drainage infrastructure.

The study creates a common pool for the SWM Tools that is appropriate to be used anywhere. Since SWM tool selection interfaces in developed countries contain local SWM tool names and ready-made information such as local precipitation and soil, their use is limited outside the borders they are prepared for. The difference of the proposed interface from the existing ones is, that it contains more SWM Tools. As LID focuses on source control tools, WSUD concentrates on infiltration tools, the proposed interface includes all these SWM tools. Also 57 different SWM Tools obtained from the literature study is filtrered (terminology and common features) and reduced to 26 common SWM Tools with land independent features to be appropriate to be used anywhere.

The interface prepared will contribute to two areas;

- The proposed interface is a practical tool that can be part of the design process in the field of Urban Design and Landscape Design. SWM tools, obtained according to prior hydrological function and determined by data entry of the appropriate site features, will help designers to develop solutions with the most effective results for storm water management. As the interface can be used by the designers in production phase, public institutions will also benefit in the control process of the suitability of the project.
- Students can use the proposed interface on SWM-specific topics as an educational tool. In planning and design education, it can be used as a practical educational tool for students to see the results of their decisions regarding the relationship between water and design, to compare different design decisions, and to develop spatial design decisions for water management with site-specific data. In this way, water and design awareness can be brought to students at the undergraduate level in practice.

For future research, performances of 26 SWM tools in benefits as biodiversity, carbon capture, heat island effect can be evaluated, and results can be used as another data entry to form a base to argue the sustainability of the projects in all aspects.

This study is considered to have a widespread impact since it can be used in other countries similar to Turkey, which are lack of sustainable stormwater design guides and do not have sufficient performance studies to support these alternative infrastructures. It can also be a basis for the development of SWM guidelines in these developing countries.

References

Ahn, J. H., Grant, S. B., Surbeck, C. Q., DiGiacomo, P. M., Nezlin, N. P., & Jiang, S. (2005). Coastal water quality impact of stormwater runoff from an urban watershed in southern California. *Environmental science & technology, 39*(16), 5940-5953.

Asadian, Y., & Weiler, M. (2009). A new approach in measuring rainfall interception by urban trees in coastal British Columbia. *Water Quality Research Journal, 44*(1), 16-25

Ashley, R. M., Balmforth, D. J., Saul, A. J., & Blanskby, J. D. (2005). Flooding in the future–predicting climate change, risks and responses in urban areas. *Water Science and Technology, 52*(5), 265-273.IWA Publishing.

Ballard, W. B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffer, P. (2007). *The SUDS manual (C697).* London: CIRIA

Ballard, W. B., Wilson, S., Udale-Clarke, H., Illman, S., Scott, T., Ashley, R., & Kellagher, R. (2015). *The SUDS manual (C753).* London: CIRIA

Beach, D. (2003). Coastal sprawl: *The effects of urban design on aquatic* ecosystems in the United States, Pew Oceans Commission 2002.

BMT WBM Pty Ltd. (2009). *Evaluating options for water sensitive urban design – A national guide.* Joint Steering Committee For Water Sensitive Cities (JSCWSC)

Bray, B., Gedge, D., Grant, G., Leuthvilay, L., (2012). Rain Garden Guide, Retrieved from https://raingardens.info/ . Retrieved 05.06.2020

British Plastics Federation Group, (2018). Guide to designing geocellular drainage systems to CIRIA report C737. Retrieved from https://www.bpfpipesgroup.com/media/29721/Guide-to-designing-geocellular-drainage-systems-to-CIRIA-Report-C737.pdf. Retreved January 3, 2020.

Brody, S. D., Zahran, S., Maghelal, P., Grover, H., & Highfield, W. E. (2007). *The rising costs of floods: Examining the impact of planning and development decisions on property damage in Florida.* Journal of the American Planning Association, 73(3), 330-345.

Bureau of Watershed Management. (2006). *Pennsylvania stormwater best management practices manual.*(Document No. 363-0300-002). Department Of Environmental Protection

Center For Watershed Protection, Maryland Department of the Environment Water Management Administration. (2000). *Maryland stormwater design manual*, Vol. I. & II. Maryland. https://mde.maryland.gov/programs/water/stormwatermanagementprogram/pages/stormwater_design.aspx

Center for Watershed Protection. (2003). *NewYork State stormwater management design manual.* New York State Department of Environmental Conservation. New York State.

Center for Watershed Protection. (2015). *NewYork State stormwater management design manual.* New York State Department of Environmental Conservation. New York State.

County, P. G. S. (1999). *Low-impact development design strategies: An integrated design approach.* Department of Environmental Resources, Programs and Planning Division, Prince George's County, Maryland.

County, P. G. S. (2014). *Stormwater management design manual.* Department of Permitting, Inspectations and cement.

DeepRoot Green Infrastructure, 2014. Section 32 94 50 Soil Cells. Retrieved from https://www.deeproot.com/silvapdfs/resources/standardDetails/SC-Spec-2%204-Performance.pdf. Retrieved January 20,2020.

District of Saanich. (2020). *Stormwater management.* Retrieved from https://www.saanich.ca/EN/main/community/natural-environment/environmental-planning/stormwater-management.html. Retrieved September 04, 2020.

Dyke, D., J. Boggs, W. D. Shuster, S. Foltz, P. Grewal, K. Power, H. Utrata-Halcomb, J. Koehn, B. J. Bohl, H. Yang, AND G. D. Derringer, (2009) *Sustainable Landscape Systems for Managing Storm Water 2nd Edition.* Hamilton County Soil & Water Conservation District, Cincinnati, OH.

EOR-Emmons and Oliver Resources, CWP-Center For Watershed Protection. (2004). ISSUE PAPER "A" - *Final BMP list and selection matrix, Minnesota stormwater manual.* Minnesota Stormwater Manual Sub-Committee

EPA, (2021). *Climate Adaptation and Stormwater Runoff.* Retrieved from https://www.epa.gov/arc-x/climate-adaptation-and-stormwater-runoff. Retrieved February 12, 2022.

Fox, L. J., Robinson, D. J., Sample, D. J., Nelson, G. E., (2018). Stormwater Management for Homeowners Fact Sheet 4: Grass Swales. Virginia Tech. Retrived from https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/spes/spes-12/SPES-12.pdf. Retrieved September 15, 2019.

Gaffield, S. J., Goo, R. L., Richards, L. A., & Jackson, R. J. (2003). *Public health effects of inadequately managed stormwater runoff.* American Journal of Public Health, 93(9), 1527-1533.

Golder Associates Ltd. (2016). *Best management practice toolkit,* Volume II, City of Vancouver Sewerage & Drainage https://vancouver.ca/files/cov/integrated-stormwater-management-best-practice-toolkit-volume-2.pdf

Hill, K., & Barnett, J. (2007). *Design for rising sea levels.* Harvard Design Magazine, 27, 1-7.

Hill, K. (2009). *Urban design and urban water ecosystems.* In The water environment of cities (pp. 141-170). Springer, Boston, MA.

İstanbul Sehir Haritası, (n.d.). (Maps of Itu Ayazaga Campus in 1970) İstanbul Büyükşehir belediyesi), Retrieved January4, 2019) from https://sehirharitasi.ibb.gov.tr/

Jensen, C. A. (2012). A hydrologic assessment of using low impact development to mitigate the impacts of climate change in Victoria, BC, Canada (Doctoral dissertation).

Kumar, R.S., Shivali, J., Mahreen, M. (2017). *Mainstreaming Rainwater Harvesting in Nodai.* Centre for Science and Environment, New Delhi

Lanarc Consultants Ltd., Kerr Wood Leidal Associates Ltd., Ngan, G. (2012). *Stormwater source control design guidelines.* Metro Vancouver. http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/StormwaterSourceControlDesignGuidelines2012StormwaterSourceControlDesignGuidelines2012.pdf

Lawson, J. (Ed.). (2005). *River basin management: progress towards implementation of the european water framework directive.* CRC Press.

Marsalek, J. (2005). *Evolution of urban drainage: from cloaca maxima to environmental sustainability* [Conference presentation]. ACQUA E CITTÀ I CONVEGNO NAZIONALE DI IDRAULICA URBANA, Sant'Agnello (NA).

Maryland Department of Environment, (2020). Facts about stormwater management. Retrieved form https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Pages/FactsBMPs.aspx. Retrieved December 12, 2020.

McGrane, S. J. (2016). I*mpacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review*. Hydrological Sciences Journal, 61(13), 2295-2311.

Minnesota Stormwater Steering Committee. (2005). *The Minnesota stormwater manual.* Minnesota Pollution Control Agency. https://stormwater.pca.state.mn.us/images/b/b8/Minnesota_Stormwater_Manual.pdf

Opus International Consultants Limited, Kerr Wood Leidal Associates Ltd. , Colquitz Engineering. (2019). *Green stormwater infrastructure common design guidelines for The Capital Region.* Capital Regional District's Integrated Watershed Management –Inter-Municipal Group. https://www.crd.bc.ca/education/stormwater-wastewater-septic/green-stormwater-infrastructure

Radcliffe, J. C. (2019). History of water sensitive urban design/ low impact development adoption in Australia and internationally. In A. K. Sharma, T. Gardner, & D. Begbie (Eds.), *Approaches to water sensitive urban design; potential, design, ecological health, urban greening, economics, policies, and community perceptions* (pp.1-24). Candice Janco.

Revitt, M., Lundy, L., Coulon, F., Fairley, M., (2014). The sources, impact and aanagement of car park runoff pollution: A review. *Journal of Environmental Management, 146.* 552-567. https://doi.org/10.1016/j.jenvman.2014.05.041

STEP,Sustainable Technologies Evaluation Program, (2011). Permeable Pavement and Bioretention Swale Demonstration Project,Seneca College, King City, Ontario. . Retrived from https://sustainabletechnologies.ca/app/uploads/2013/03/PP_FactsheetSept2011-compressed.pdf. Retrieved May 05.2020.

Transport and Infrastructure Department of Planning. (2009). *Water sensitive urban design – Greater Adelaide Region technical manual.* Government of South Australia, Department of Planning. https://www.watersensitivesa.com/resources/technical-aides/guidelines/technical-manual-for-water-sensitive-urban-design-in-greater-adelaide/

United Nations, (https:/www.un.org).
Department of Economic and Social Affairs (2018). 68% of the world population projected to live in urban areas by 2050, says UN. Retrieved from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html#:~:text=News-,68%25%20of%20the%20world%20population%20projected%20to%20live%20in,areas%20by%202050%2C%20says%20UN&text=Today%2C%2055%25%20of%20the%20world's,increase%20to%2068%25%20by%202050