Determination of Appropriate Locations for Proposed Rain Gardens in the City of Isparta Turkey

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Abstract
This study aims to contribute sustainable urban drainage considering ecological, rather than conventional, approaches for urban sustainable stormwater management. The study consists of analysis of appropriate zones for rain gardens (Ayazmana, Bahçelievler, Çünür, Dere, Vatan neighborhoods) through remote sensing, determination of the best locations for rain gardens, and modeling rain gardens as street swales in cross-sectional configuration in densely built urban areas in Isparta, Turkey. With the help of the ArcGIS 10.1 program, thematic maps (including slope, precipitation, and slope-precipitation overlap) were prepared and regions with low slopes were determined. The sample street swales were presented as cross-sectional configuration for various public places (e.g. streets and avenues, parking areas, urban stream beds, refuges, and traffic islands) where surface flow is intense, close to the main road, and within the certain regions (slopes < 10 %; precipitation > 450 mm).

For slope-precipitation overlapping analysis; it has been observed that the runoff is less in regions where slopes are more than 10% and the precipitations are less than 450 mm; that the surface runoff is higher in regions where the slopes are less than 10% and the precipitations are more than 450 mm. In the neighborhoods of Ayazmana, Bahçelievler, Çünür, Dere, Modernevler and Vatan, public places (located close to the main road where surface runoff is intense) were selected and assessed among the regions determined (within the range of values appropriate for rain gardens: slopes < 10 %; precipitation > 450 mm). As a green infrastructure system, one of the supporting systems in stormwater management is street swales designed as rain gardens in cities. Findings of this paper will be useful to local governments and policy makers as well as city planners and landscape architects when developing appropriate, efficient, cost-effective, and site-specific green street strategies for cities.
Keywords: Rain gardens, street swales, stormwater management; sustainable urban drainage

1. INTRODUCTION

The future of stormwater has arrived, and that future is green.
Steve Wise

As a result of urbanization in developing countries, green areas in cities are continuously decreasing. Transforming green areas into impermeable surfaces used in construction prevent stormwater find its way to flow in cities. Therefore, stormwater accumulates in areas with low slopes and causes disruptions in transportation and many different social, economic and environmental problems.

Increase in impermeable surfaces has made stormwater runoff one of the most important environmental problems in many cities of the world. Impermeable surfaces such as streets, driveways, parking lots, and roofs are not only the main cause of increased stormwater runoff (Stone, 2004; Connelly, 2006), but also a major source of pollutants (Hall et al., 1998; Field, 1985).

Sustainable, or green, stormwater infrastructure uses systems such as rain gardens, green roofs, infiltration trenches, porous pavement, cisterns and vegetative swales. It is designed to capture surface runoff close to its source at distributed (decentralized) locations using some combination of detention, infiltration and evapotranspiration (Michael Baker Corporation, 2008; Shamsi, 2010).

Rain gardens (also known as bioretention cells) are one such practice that is being widely used these days to reduce non-point source pollution arising from urban areas. Physico-chemical and biological features of rain gardens positively help in remediating contaminants, storing runoff water, reducing peak-flow, nutrient cycling, sequestering heavy metals and also provides supplementary benefits such as recreational facilities (Malaviya et al., 2019).

Traditional drainage systems seek to remove precipitation from an area as quickly as possible (CIRIA, 2000; Environment Agency, 2003), however, this might have a range of effects, such as pollution, flood, loss of biodiversity, and reduced aesthetic.

Whereas the runoff enters in the surface of rain gardens, it is temporarily stored in a recessed space, which relieves the pressure on urban drainage system during heavy rain. As runoff travels down through the system, vegetation acts as a buffer, which reduces the peak velocity and allows some suspended particles to settle, which promotes removal of pollutants from water. The purified water flows into a perforated pipe at the bottom of rain gardens (under the gravel layer). When the runoff exceeds the capacity of rain gardens, excess water is discharged through an overflow pipe at the top of the rain garden.

Use of rain gardens and other ecological stormwater in urban scale management methods also contributes to sustainability of stormwater (Killion, 2011). Sustainability of underground water resources is at the forefront of the objectives in sustainable urban development. Accordingly, it is critical to manage stormwater as an important part of underground water resources. The impermeable nature of surfaces of the asphalt roads, pavements and buildings in cities is the main cause of surface runoff in such areas. Increase in paved and other impermeable surfaces also raise stormwater runoff pollution, even if that pollution is directed toward conventional stormwater infrastructure (Wise, 2008).

Turkey has its own climatic characteristics and therefore, it is among the most affected countries by climate change (Öztürk, 2002). The excessive precipitation, especially towards the end of the 21st century, has had negative impacts on city infrastructures. Among these, floods and economic losses can be considered as the significant negative impacts. Therefore, excess stormwater accumulated in areas with low slope causes floods (Müftüoğlu and Perçin, 2015). Today, design criteria in urban infrastructure may not take surface runoff into account caused by increasing precipitation because of climate change and changes in precipitation (Oruç, 2018).

Stormwater control is one of the sustainable development practices designed to capture surface runoff using some combination of detention, infiltration and evapotranspiration (Shamsi, 2012). In this context, significance of water resources has increased in recent years, and management policies related to the management of water resources have become important. It has become a necessity of today's world to search possible innovations involving sustainable management of stormwater (Hoyer et al., 2011). As a result, sustainable urban stormwater models have emerged and new design solutions have been sought for appropriate management of water resources using sustainable development approaches (Ekşi et al., 2016).

Rain gardens are one of the green infrastructure systems. Green infrastructure is described as a tool for providing ecological, economic, and social benefits through natural solutions, helping us to understand the advantages that nature offers human society and to mobilize investments that sustain and enhance these benefits (European Commission, 2013).

Green infrastructure might be, for example, a network of decentralized storm water management practices, such as green roofs, trees, rain gardens, and permeable pavements, that can capture and infiltrate rain where it falls, thus reducing storm water runoff and improving the quality of surrounding waterways.

These practices deliver multiple ecological, economic, and social benefits or services and has been made green infrastructures an increasingly popular strategy in recent years. In addition to reducing polluted storm water runoff, green infrastructure practices can also positively impact energy consumption, air quality, carbon reduction and sequestration, property prices, recreation, and other elements of community health and vitality that have economic or other social values. Moreover, green infrastructure practices provide flexibility to communities faced with the need to adapt their infrastructures to a changing climate.

For example, green infrastructure can be used to decrease flow rate of rainwater entering sewage systems and, through there, into lakes, rivers, and streams due to the retention and absorption capacity of the plant cover and the soil. In such a case, increased carbon storage, better air quality, decreased urban heat islands, as well as increased natural habitats and recreation areas can be mentioned among the benefits of green infrastructure. Furthermore, green spaces create an identity for sites, urban areas, and city surroundings where people live and work by contributing to cultural and historical areas (European Environment Agency, 2018).

In urban environments, green infrastructure involves everything from parks to street trees and green roofs to bioswales—anything that helps absorb, delay, and treat storm water, mitigating flooding and pollution downstream. Green infrastructure also creates oxygen, sequesters carbon, and provides wildlife habitats (ASLA, 2018).

Many cities have taken on the challenge of managing storm surge, storm water runoff, water conservation, and water pollution reduction, increasingly using green infrastructure. That challenge has become even more urgent with the advent of global climate change and the more frequent and intense storms that have accompanied it (Benepe, 2013).

In 1990, the concept of "rain garden" was first introduced in Prince George's County, Maryland, as a cost-effective way to control stormwater runoff. Handling the flooding problem at its source, some of the water seeps directly into the soil instead of flowing over impermeable surfaces before flowing into a transport system or overflowing elsewhere. A rain garden is usually located at the low points of the land and consists of both small and large plant species such as grasses, shrubs, and trees in a natural vegetation appearance (Beier, 1995).

Rain gardens are one of the management tools that can be applied to reduce stormwater runoff (Roehr et al., 2009). They restore, protect, and mimic natural hydrologic functions within the built environment (Wise, 2008).

Seepage practices such as rain gardens provide an effective approach to groundwater recharge. It is set in a shallow pit receiving stormwater from impermeable surfaces and focuses on recharging (Dussaillant et al., 2004). Rain gardens are increasingly being adopted in urban areas to reduce impacts of stormwater in cities (Yuan et al., 2017).

Stormwater management is becoming increasingly important as a groundwater management strategy (Alley et al., 2002). However, original, and local research on this subject in urban areas is still lacking (Lerner, 2002). Rain gardens can be considered as a new approach in this sense.

A rain garden should be placed near impermeable surfaces so that rainwater can drain into the pit or rift. The rain garden should be strategically placed near impermeable surfaces such as streets, sidewalks, driveways to capture the rain as close as possible to the point where it is falling (Stromme and Gardener, 2001).

Rain gardens, that can absorb, harvest and filter stormwater from various sources, controls the quality of stormwater under heavy rainfall conditions (Autixier et al., 2014). Concurrently, the rain gardens are shallow landscape pits that reduce precipitation runoff and reduce the impact of pollution (Urban Design London, 2019). The main duties of the rain gardens established in this direction are as follows; preventing stormwater runoff from over 90 % of storm events from entering the sewer collection system (Shamsi, 2012), improving the water quality in the underground and surface water resources in the immediate vicinity of these areas by improving the water accumulated by flowing on the surfaces; ensuring that the velocity of the flowing surface water is slowed down; producing solutions to drainage problems occurring on surfaces; creating an aesthetic appearance in the urban landscape; increasing the amount of evapotranspiration; ensuring the preservation of urban ecology (Katsifarakis et al., 2015; Müftüoğlu and Perçin, 2015); as well as improving public health and well-being; improving air quality; reducing the urban heat island effect; and developing wildlife habitat for biodiversity (Urban Design London, 2019). Rain garden uses natural process to manage stormwater runoff at the source, and it can improve street water environment, create attractive streetscape, and enhance neighborhood livability (Zhang, 2010).

A rain garden consists of a pit in the ground, soil with high permeability and native plants. The garden facilitates stormwater infiltration directly into the soil. It provides a more sustainable way to manage stormwater runoff than traditional stormwater systems.

2. MATERIAL AND METHODS

2.1. STUDY AREA

The city of Isparta is a residential and rural-tourism region with a total area of 8933 km^2 in the Mediterranean Region. According to the Koppen classification, it has the characteristics of a Mediterranean climate (Csa), with warm winter, very hot and dry summers. The city is between 30°20' and 31°33' east longitudes and 37°18' and 38°30' north latitudes. The city center consists of 44 neighborhoods in total. The city of Isparta is an example of a rapidly growing area in the Mediterranean region of Turkey having problems in urban water management. During the face-to-face interviews conducted with the staff in the Park and Gardens and Water-Sewerage Departments of the Isparta Municipality, we noticed that surface runoff was observed intensely after heavy precipitation in the neighborhoods (Ayazmana, Bahçelievler, Çünür, Dere, Modernevler and Vatan) shown in red color (Figure 1).

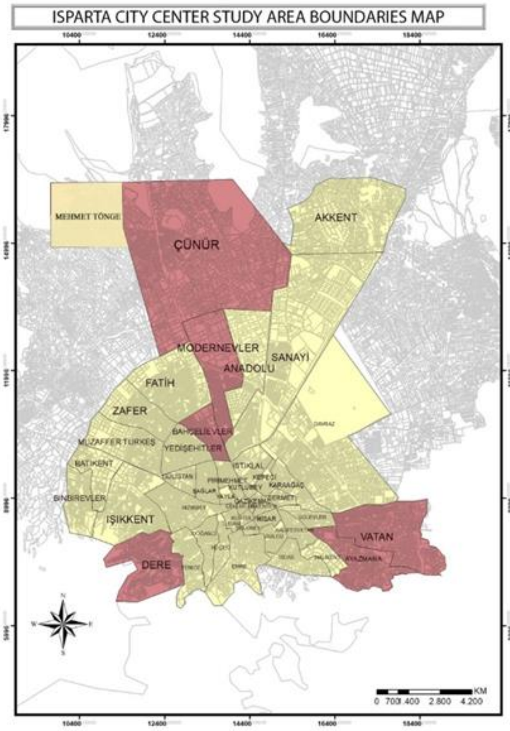


Figure. 1 The map showing the boundaries of study areas

Since the city of Isparta is located in highlands, there are too many slopes. Long-term and excessive precipitation is experienced due to its climatic characteristics. As a result of these precipitations, floods and intense surface runoff occur in areas where the slope is low. Neighborhood of Ayazmana (a) is a residential area close to the promenade areas of the city, consisting of sloping areas, where vehicle traffic is intense. Neighborhood of Bahçelievler (b) is a popular area with heavy pedestrian traffic and located very close to the city center. Neighborhood of Çünür (c) is an area with heavy intercity vehicle traffic. In addition, the transportation to two universities in the city is passes through in this neighborhood. The surrounding neighborhood of Dere (d) is densely built. There are degraded areas with very high development potential along the stream in the neighborhood of Dere. Neighborhood of Vatan (e) is a residential area with heavy intercity traffic. It is a neighborhood with a high development potential. Neighborhood of Modernevler (f) is one of the regions where surface runoff is intense after precipitation. It is a commercial and residential area close to critical areas in the city, where both pedestrian and vehicle traffic are intense. Views after precipitations in these neighborhoods are shown in the Table 1.

Table.1 Views after precipitation

		
(a)	(b)	(c)

(d) (e) (f)

2.2. METHODS

This study consists of three stages. Analysis of appropriate zones for rain gardens through remote sensing was first carried out. The most convenient locations for rain gardens were then determined. Modeling of rain gardens as street swales was finally completed and presented in the form of cross-sections.

2.1.1. ANALYSIS OF APPROPRIATE ZONES FOR RAIN GARDENS THROUGH REMOTE SENSING

The average values of long-term (2000-2020) precipitation in the study areas were obtained from the Isparta Meteorology Directorate and were then evaluated. The thematic maps (slope, precipitation and slope-precipitation overlap) were prepared at neighborhood level using the ArcGIS 10.1 program, which is one of the remote sensing methods. The maps were presented for Ayazmana, Bahçelievler, Çünür, Dere, Modernevler and Vatan neighborhoods in the city of Isparta. The appropriate regions for rain gardens were determined through the analysis of the maps. The analysis and overlapping maps are included in the research findings section of the study.

2.1.2. THE EXISTING CONDITION OF THE STUDY SITES RESEARCH AND LOCATION OF RAIN GARDENS

The neighborhoods of Ayazmana, Bahçelievler, Çünür, Dere, Modernevler and Vatan were assessed by means of sightseeing, observation, and photography. Public areas (streets and avenues, parking area, urban stream bed, refuges, and traffic islands) close to the main road were preferred among regions where the slope was less than 10% and the precipitation was more than 450 mm. These criteria were determined in accordance with the analysis conducted on the level of neighborhoods for rain gardens using the ArcGIS 10.1 program. It is not appropriate to have a slope of more than 10% in rain gardens. The assessments of the existing situation with respect to the areas and the selected areas for street swales are also included in the research findings of the study.

2.1.3. MODELING THE RAIN GARDENS AS STREET SWALES

Rain garden areas for modeling were selected because of the analysis carried out with the help of the maps (slope, precipitation, slope, and precipitation overlapping) on-site observations, and photographs of the sites. The most important factors for the selection of these areas were volumes of water accumulation following precipitation and its adverse impacts on urban traffic and transportation due to the surface runoff. Photoshop CS6 was used to model the rain gardens as street swales in these areas. Models are presented as cross-sections. Attention has been paid to select appropriate sizes for street swales and choosing hydrophilic, heat and cold-tolerant local plant species. The cross-sections and their details are included in the recommendations section.

3. RESULTS

3.1. ANALYSIS OF APPROPRIATE ZONES FOR RAIN GARDENS THROUGH REMOTE SENSING

3.1.1. RESULTS OF THE SLOPE ANALYSIS IN STUDY AREAS

In the neighborhoods of Ayazmana (95%), Çünür (60%), Dere (80%) and Vatan (90%), slopes are found between the ranges of 0-6%; while Bahçelievler (80%) and Modernevler (45%) neighborhoods have slopes between 6-10%.

3.1.2. RESULTS OF THE PRECIPITATION ANALYSIS IN STUDY AREAS

With the help of interpolation (Isparta, Keçiborlu and Atabey Stations) long-term averages were calculated and maps showing that the precipitation per square meter was between 400 mm and 700 mm were prepared. The average amount of precipitation per square meter in the neighborhood of Ayazmana, Bahçelievler, Dere, Modernevler and Vatan was found as 510 mm while this value was 490 mm in the neighborhood of Çünür.

3.1.3 THE RESULTS OF SLOPE-PRECIPITATION OVERLAPPING ANALYSIS IN THE STUDY AREAS

For each neighborhood, the annual average precipitation and slope analysis maps were matched. It has been observed that the runoff is less in regions where the slope is more than 10% and the precipitation is less than 450 mm; that the surface runoff is higher in regions where the slope is less than 10% and the precipitation is more than 450 mm. Figure 2 shows the slope-precipitation analysis maps of the neighborhoods.

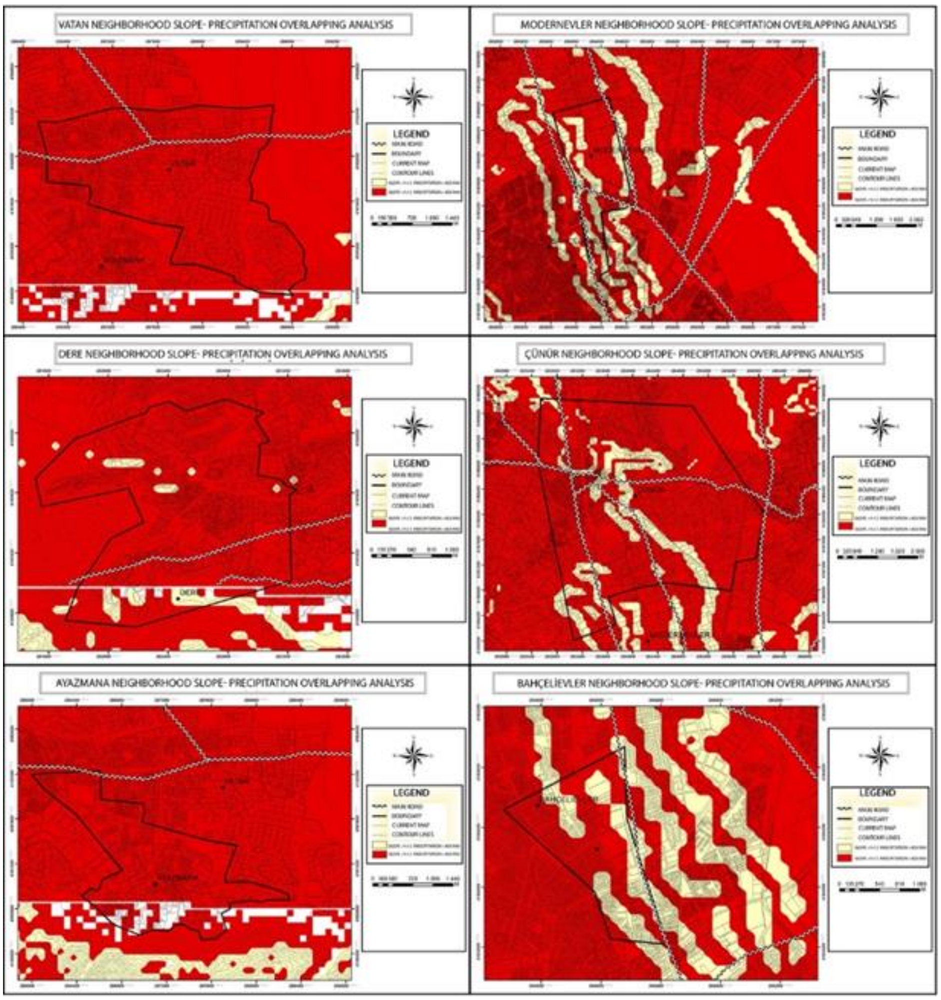
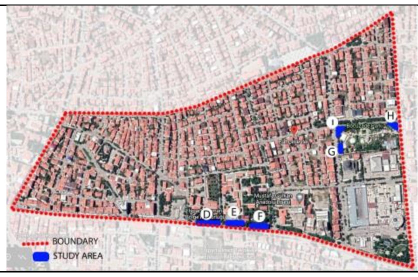
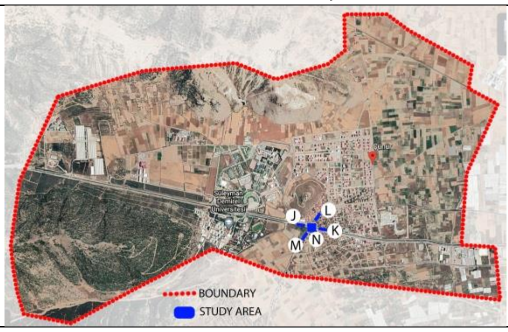


Figure. 2 Slope-precipitation analysis maps

3.2. THE EXISTING CONDITION OF THE STUDY SITES AND LOCATION OF RAIN GARDENS

In the neighborhoods of Ayazmana, Bahçelievler, Çünür, Dere, Modernevler and Vatan, public places (streets and avenues, parking areas, urban stream beds, refuges, and traffic islands) where close to the main road and the surface runoff is intense were selected and assessed among the regions determined (within the range of values appropriate for rain gardens: slope of less than 10 % and precipitation with more than 450 mm) with the ArcGIS 10.1 program (Table 2).

Table. 2 Proposed Rain Garden Areas

	
Ayazmana Rain Garden Proposed Areas	Bahçelievler Rain Garden Proposed Areas
	
Çünür Rain Garden Proposed Areas	Dere Rain Garden Proposed Areas
	
Modernevler Rain Garden Proposed Areas	Rain Garden Proposed Areas

Locations of rain gardens within the boundaries of the neighborhood of Ayazmana; Bahçelievler, Çünür, Dere, Modernevler and Vatan are indicated in Table 3. The first two of these areas (A-B) are circular traffic islands where settlement and traffic flow are intense. C is a park area that is idle at the neighborhood level. The entire three areas are public areas. D, E and F are popular road axis very close to the main road where pedestrian traffic is quite intense. In these areas where surface runoff is observed intensely after precipitation, the existing plant designs are arranged on a flat ground by using single species of plants. There is no vegetal type or ground that can act as a sponge after precipitation, and there is no concave design. G, H and I are designed in a public park area. It is aimed to give the park area a more natural and ecologically based appearance rather than a cultural landscape view, and thus to support the park area within the scope of ecosystem services. J, K and L are the traffic islands on the axis where the intercity tariff is intense. M and N are the areas that are considered in the refuge in the same region. In this region, surface flow is very intense for Çünür. Despite the new arrangement of gray infrastructure works, accumulations and even floods occur on the roads after precipitation. Convex designs also cause stormwater to flow away and accumulate on the highway during heavy precipitation. In addition, plant species used are also insufficient to retain rainwater. The neighborhood of Dere is a mountainous region that takes its name from a stream running through it. It is known that stormwater accumulates around the stream after precipitation. O, P and Q are linearly considered on the carriageway line and in the idle areas along the stream. R and S are in an area close to the main road and prominent as an idle park area on the pedestrian route. Two rain gardens are considered in this area. The neighborhood Vatan has undergone urban transformation; however, it is still a neighborhood with old buildings and infrastructure system. Within the region, the areas close to the main road were preferred and three rain gardens were considered. These areas (T, U and V) consist of a circular traffic island and two refuge areas that complete it. The concave rain gardens and areas are considered as a precaution for accumulation of stormwater, which moves away from the idle appearance and flows into the surface, on roads.

4. DISCUSSIONS AND DESIGN RECOMMENDATIONS

A rain garden is characteristically suggested at a depth of between 7 cm and 30 cm (ponding zone). Because, in rain gardens deeper than 30 cm, ponding is not superficial, and late seepage will occur since it will fill the whole garden. In this context, a slight and appropriate slope should be sought in the application areas. If the slope is greater than 10 %, another site should be considered. The best field slope should be around 10 % optimally (Doğangönül and Doğangönül, 2008).

For the rain garden to retain as much water as possible, the long side of the garden should face the sloping direction. It should be approximately twice the width of the garden, and the minimum recommended width should be 3 m. (Dunnet and Clayden, 2007). Thus, the applied rain garden model can take any form as long as it captures the water flow and integrates with the existing landscape (A Northern Virginia Homeowner's Guide, 2017).

When rain gardens are created as street swales in areas close to the main road with busy pedestrians, it also provides an opportunity to increase awareness among the public regarding the significance of sustainable practices (Tarpey et al., 2017). It is suggested that rain gardens are best located at low points where surface water will flow (Urban Design London, 2019).

Plants are one of the most significant components of the rain gardens. In addition to their contribution to landscape improvement, they also improve the functionality of the rain garden by conserving water quantities and certain pollutants. Their selection is a significant and domain-specific issue (URL, 1). Native plants are the most suitable plants as they adapt to local environmental (wet and dry) conditions (Syafriana and Arifin, 2020) and require less maintenance (Prairie Rivers Network, 2017). The permanent crops with flowers and compositions of grasses and scattered shrubs are often ideal uses for biodiversity enrichment for rain gardens (Dunnet and Clayden, 2007).

4.1. MODELING THE RAIN GARDENS AS STREET SWALES

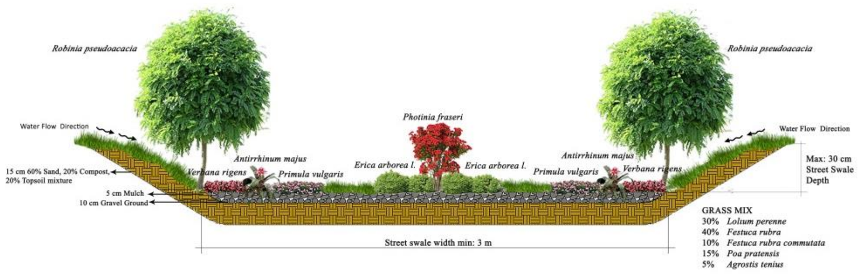
In line with the analysis made, the proposed rain gardens were modeled as cross-sections for selected locations. The main purpose of planting during the modeling was to reduce runoff, improve street view and bring more aesthetic and ecological solutions for the city. The dimensions considered for the street swales are presented on the models. If required, size of similar street swales can be extended to the desired dimensions and repeated at regular intervals. Moreover, in accordance with the convenience of the terrain conditions, it is ideal that the width of the street swales is up to min 3m.

A rain garden is a vegetated area that allows stormwater runoff to be absorbed and filtered before it arrives to the sewage system (Lam et al., 2011). From landscape design perspectives, natural landscapes are tried to be created with native species, since such plants contribute to the biodiversity and require relatively less maintenance. Selected plant species are resistant to hard conditions and better adapted to humid soils and are also effective at filtering and tolerating pollutants. In addition, they are hardy and drought tolerant and their unique qualities are included in the descriptions of each cross section. Grass mixtures consist of *Festuca rubra (*40%)*, Lolium perenne (30%), Poa pratensis (*15%)*, Festuca rubra commutate* (10%), *Agrostis tenius (*5%) grass species. There is a 5 cm mulch layer on the top layer of each street swale to keep the soil moist and to protect the plants from extreme cold in winter and extreme heat in summer. Other layers may differ within themselves in line with the requirements specific to each location.

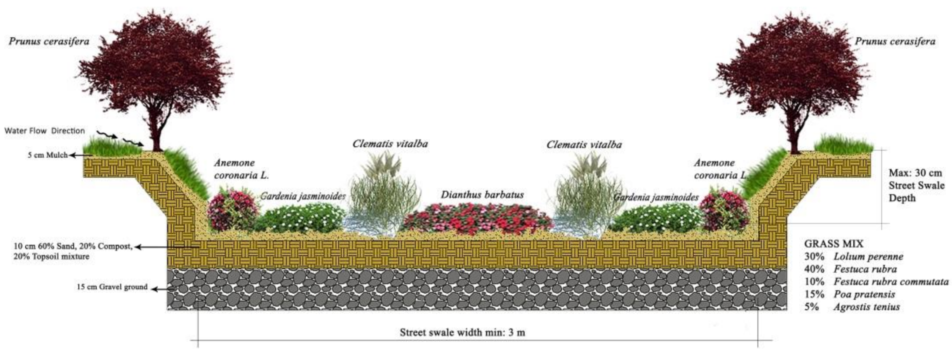
With these design principles in mind, this study will show the feasibility and effectiveness in provision of rain gardens in stormwater management (Table 3).

Table. 3 Cross-sections of street swales

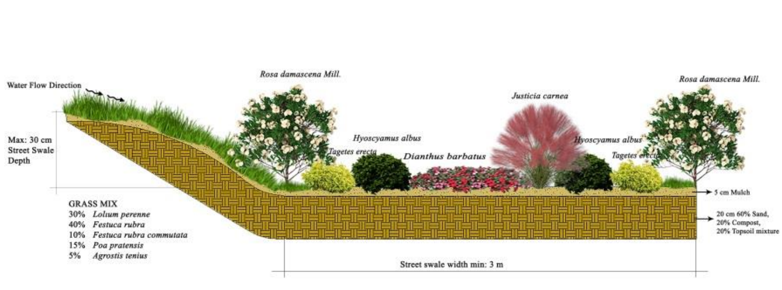
Site 1. The Neighborhood of Ayazmana



Cross section A: In the cross section of this street swales, there is 60% sand, 20% compost, 20% topsoil mixture” in the lowest layer. In the upper layer, there is a 10 cm gravel ground, as it provides up to 42% seepage. *Robinia pseudoacacia*, which can be preferred as a road tree, *Verbana rigens* and *Primula vulgaris*, *Antirrhinum majus* and *Photinia fraseri*, *Erica arborea* L. is preferred due to their tolerance to cold and water.



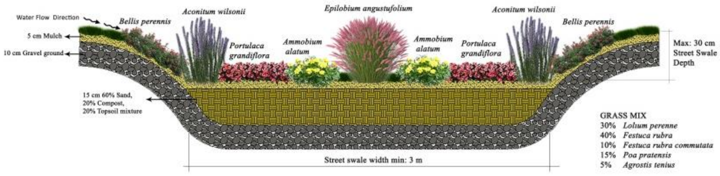
Cross section B: 15 cm of gravel is available in the lower layer, as this provides up to 42% seepage in the cross section of the street swales. A top layer consists of 10 cm “60% sand, 20% compost and 20% topsoil mixture”. Water-tolerant *Prunus cerasifera* and *Dianthus barbatus, Anemone coronaria* blooming in winter, *Gardenia jasminoides* and *Clematis vitalba* were preferred for their aesthetic qualities.



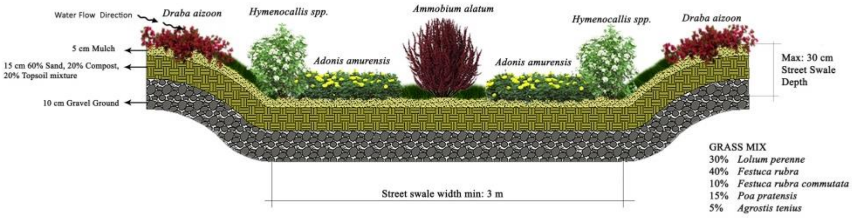
Cross section C: In the cross section of this street swale, there is 20cm of “60%

sand, 20% compost and 20% topsoil mixture" in the lowest layer. *Rosa damascena* Mill (Isparta rose) was used in this area. *Tagetes erecta,* since it adapts to every soil, *Hysocyamus albus* since it is herbaceous plant, *Justicia carnea* for its aesthetic quality, and water-tolerant *Dianthus barbatus* were preferred.

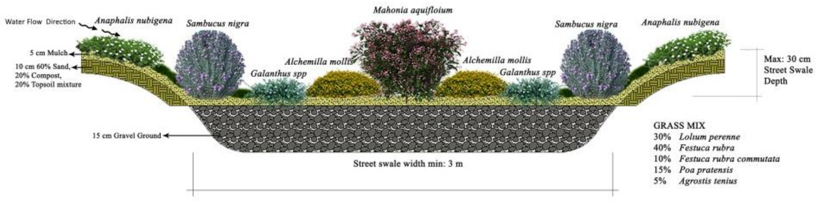
Site 2. The Neighborhood of Bahçelievler



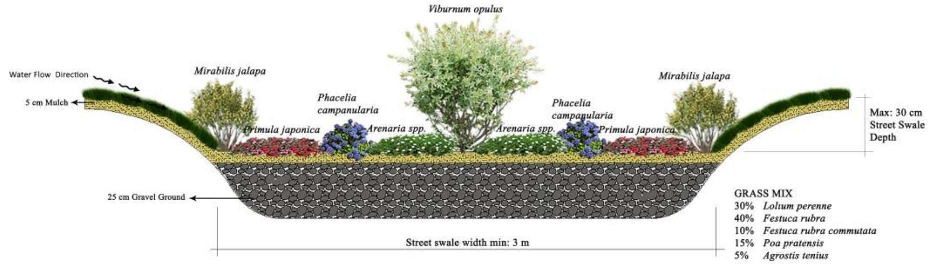
Cross section D: 10 cm of gravel is available in the lowest layer, as this provides up to 42% seepage in the cross section of the street swale. A top layer consists of 15 cm "60% sand, 20% compost and 20% topsoil mixture". *Bellis perennis* and *Aconitum wilsonii* since it likes moist soil, *Portulaca grandiflora* (Silk flower), *Ammobium alatum* (Paper button flower), *Epilobium angustufolium* (Passage rose) were preferred since they grow well in the moist soil.



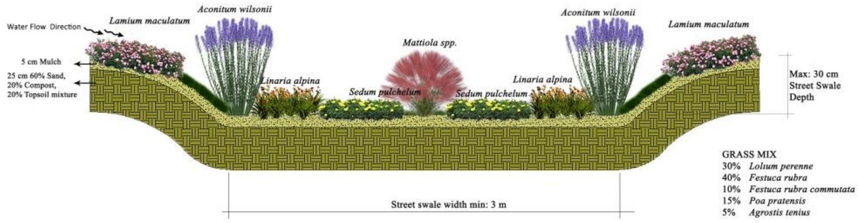
Cross section E: 10 cm of gravel is taking place in the lowest layer, as this provides up to 42% seepage in the cross section of the street swale. *Draba aizoon* ssp, *Hymenocallis* spp and *Ammobium alatum*, winter blooming *Adonis amurensis* were preferred since they are tolerant to cold weather.



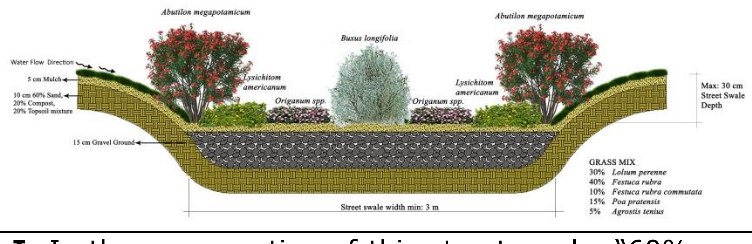
Cross section F: In the cross section of this street swale, 10 cm consisting of "60% sand, 20% compost and 20% topsoil mixture" is available in the lowest layer. There is 15 cm gravel ground, as an upper layer provides up to 42% seepage. Cold and water tolerant *Anaphalis nubigena, Galanthus* spp and *Mahonia aquifloium, Sambucus nigra*, moist soil loving *Alchemilla mollis* were preferred.



Cross section G: 25 cm of gravel is located in the lowest layer, as this provides up to 42% seepage in the cross section of the street swale. *Mirabilis jalapa*, cold-tolerant *Primula japonica* and *Phacelia campanularia*, moist soil-loving *Arenaria* spp and *Viburnum opulus* were preferred because of the high-water demand.

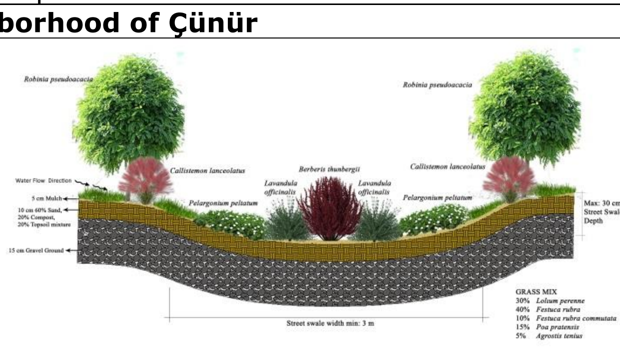


Cross section H: In the cross section of this street swale, 25 cm consisting of "60% sand, 20% compost and 20% topsoil mixture" is available in the lowest layer. *Lamium maculatum,* moist soil-loving *Aconitum wilsonii,* cold-tolerant *Linaria alpina, Sedum pulchelum* with its aesthetic quality, cool and moist environment-loving *Mattiola* spp were preferred because it can grow in all soil types. *Lamium maculatum*, moist soil-loving *Aconitum wilsonii,* cold-tolerant *Linaria alpina, Sedum pulchelum* with its aesthetic quality, cool and moist environment-loving *Mattiola* spp were preferred because it can grow in all soil types.

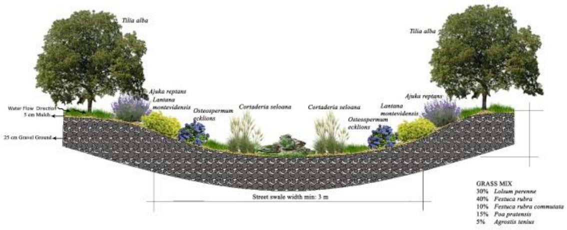


Cross section I: In the cross section of this street swale, "60% sand, 20% compost and 20% topsoil mixture" is available in the lowest layer. There is 15 cm gravel ground, as an upper layer provides up to 42% seepage. Cold tolerant *Abutilon megapotamicum* and *Lysichitom americanum,* moist soil loving *Origanum* spp and *Buxus longifolia* were preferred

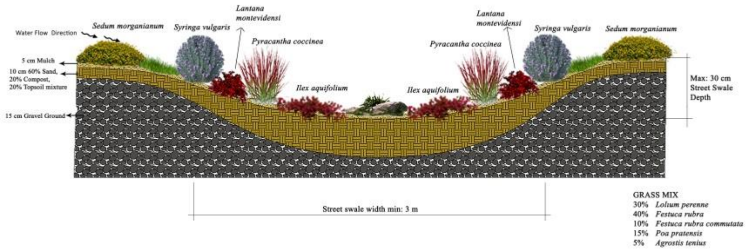
Site 3. The Neighborhood of Çünür



Cross section J: 15 cm of gravel is available in the lowest layer, as this provides up to 42% seepage in the cross section of the street swale. A top layer consists of 10 cm "60% sand, 20% compost and 20% topsoil mixture". *Robinia pseudoacacia*, which can be preferred as a road tree, water-tolerant *Callistemon lanceolatus,* cold-tolerant *Pelargonium peltatum* and *Lavandula officinalis, Berberis thunbergii* were preferred because it grows in all kinds of soils.

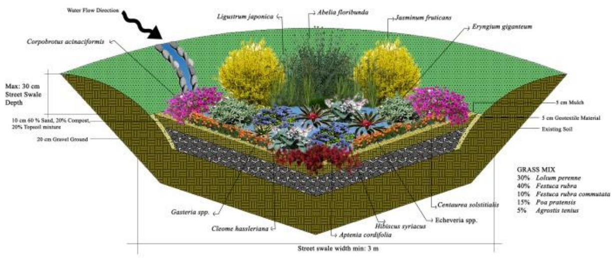


Cross section K: 25 cm of gravel is available in the lower layer, as this provides up to 42% seepage in the cross section of the street swale. *Tilia alba* was preferred due to its ability to grow in cool and deep soils, *Ajuka reptans* was preferred due to its perennial nature, *Lantana montevidensis* was preferred due to its perennial spruce, *Osteospermum ecklions* and *Cortaderia seloana* were preferred to being tolerant to cold.



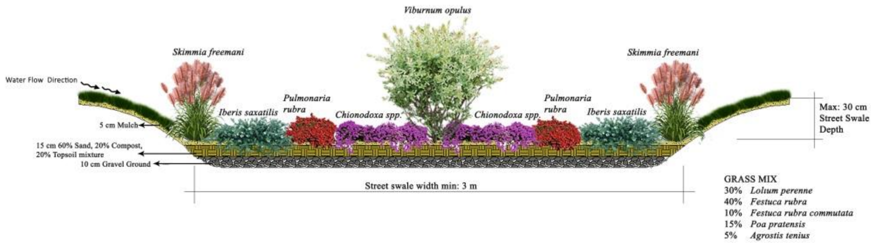
Cross section L: 15 cm of gravel is available in the lower layer, as this provides up to 42% seepage in the cross section of the street swale. A top layer consists of 10 cm "60% sand, 20% compost and 20% topsoil mixture". *Sedum morganianum,* which can grow in well-drained soils, *Syringa vulgaris* and *Lantana montevidensis,* which can grow in moist soils, *Pyracantha coccinea, Ilex aquifolium,* which are cold and drought tolerant, were preferred.

Cross section M: In the cross section of this street swale, 25 cm "60% sand, 20% compost and 20% topsoil mixture" is available in the lowest layer. Chlorophytum comosum was preferred because it is evergreen, Cotinus coggygria and Rosa dumalis was preferred for its aesthetic quality, *Anthemis cretica,* evergreen *Feijoa sellowioana* was preferred because it grows in all kinds of soil types.

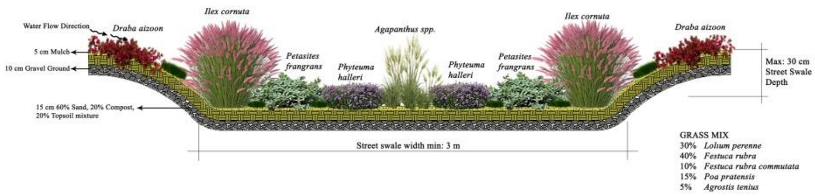


Cross section N: The cross section of this street swale has 20 cm of gravel as it provides up to 42% seepage. A top layer contains 10 cm of "60% sand, 20% compost and 20% topsoil". In the intermediate layer, there is 5 cm geotextile material. Evergreen *Corpobrotus acinaciformis,* and *Ligustrum japonica,* cold tolerant *Abelia floribunda, Jasminum fruticans* for its aesthetic quality, *Cleome hassleriana, Aptenia cordifolia* and *Echeveria* spp, *Eryngium giganteum, Hibiscus syriacus* and *Gasteria centa* spp were preferred since they grow in all types of soil.

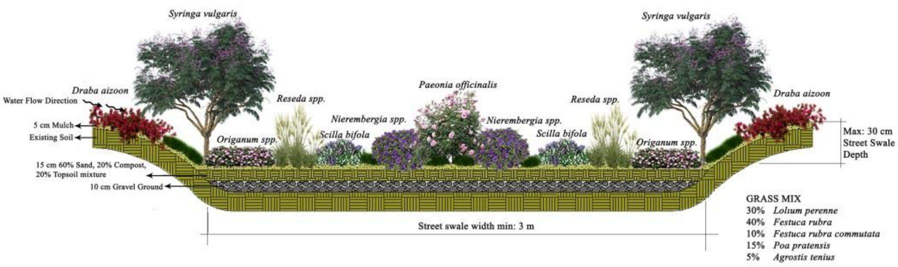
Site 4. The Neighborhood of Dere



Cross section O: 10 cm of gravel is available in the lowest layer, as this provides up to 42% seepage in the cross section of the street swale. In the upper layer, there is 15 cm "60% sand, 20% compost and 20% topsoil mixture". Cold tolerant *Skimmia freemani, Iberis saxatilis* and *Chionodoxa* spp, water tolerant *Pulmonaria rubra*, moist soil loving *Viburnum opulus* were preferred.

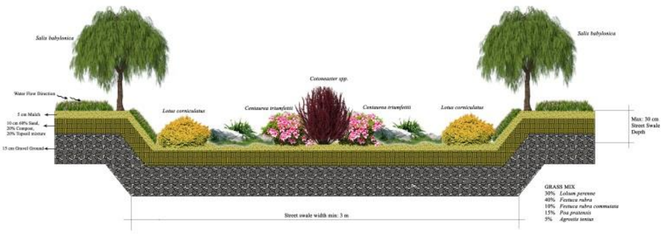


Cross section P: 30 cm of gravel is available in the lowest layer, as this provides up to 42% seepage in the cross section of the street swale. In the upper layer, there is 30 cm "60% sand, 20% compost and 20% topsoil mixture". *Ilex cornuta* and *Phyteuma helleri,* cold tolerant and moist soil loving *Petasites fragrans, Agapanthus* spp and *Draba aizoon* were preferred for their aesthetic quality.

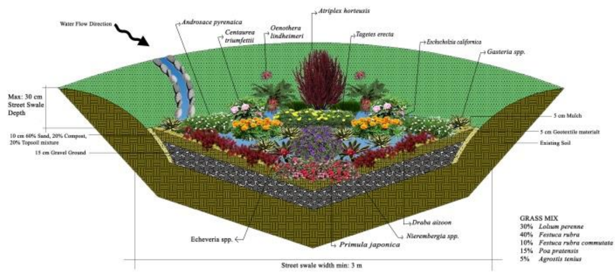


Cross section Q: 10cm of gravel is available in the lowest layer, as this provides up to 42% seepage in the cross section of the street swale. In the upper layer, there is 15 cm "60% sand, 20% compost and 20% topsoil mixture". Cold tolerant *Draba aizoon, Scilla bifola, Nierembergia* spp and *Paeonia officinalis* were preferred, *Syringa vulgaris,* moist soil loving *Origanum* spp and *Reseda* spp were preferred for their aesthetic quality.

Site 5. The Neighborhood of Modernevler

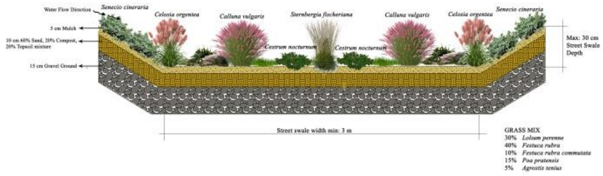


Cross section R: 15 cm of gravel is available in the lowest layer, as this provides up to 42% seepage in the cross section of the street swale. A top layer contains 10 cm of "60% sand, 20% compost and 20% topsoil". *Salix babylonica*, which can grow in all kinds of soils, *Lotus corniculatus, Centaurea triumfettii* and *Cotoneaster* spp, which can be used for rain gardens, were preferred.

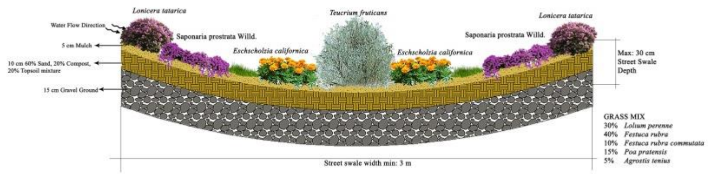


Cross section S: The cross section of this street swale has 20 cm of gravel as it provides up to 42% seepage. A top layer contains 10 cm of "60% sand, 20% compost and 20% topsoil". There is 5 cm geotextile material in the intermediate layer. *Androsace pyrenaica* were preferred due to its green leaves and white flowers, *Centaurea triumfettii* and *Atriplex horteusis* were preferred as ornamental plants, *Echeveria* spp, cold-tolerant *Oenothera lindhcimeri, Eschscholzia californica, Draba aizoon, Nierembergia* spp and *Primula japonica* and *Primage erectica*, *Tagetes erecta* and *Gasteria* spp were preferred because it adapts to all kinds of soil.

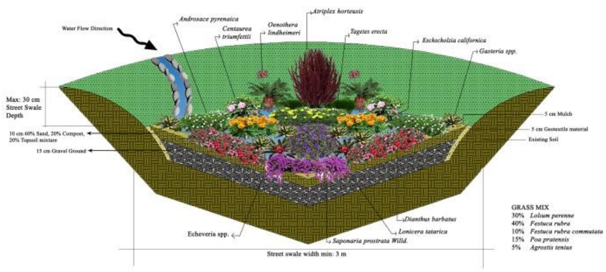
Site 6. The Neighborhood of Vatan



Cross section T: Cross section T: In the cross section of this street swale, A pebble ground of 20 cm is available on the upper layer for the purpose of providing infiltration up to 42%. In the upper layer, there is a mixture of 10 cm of 60% sand, 20% compost and 20% topsoil. *Senecio cineraria* that can grow in well-ventilated soil, water-tolerant *Celosia orgentea*, cold-tolerant *Calluna vulgaris*, moist soil favoring *Sternbergia fischeriana* and *Cestrum nocturnum* due to its long life are preferred.



Cross section U: In the cross section of this street swale, A pebble ground of 20 cm is available on the upper layer for the purpose of providing infiltration up to 42%. In the upper layer, there is a mixture of 10 cm of 60% sand, 20% compost and 20% topsoil. As having an aesthetic outlook, Lonicera tatarica, moist soil favoring *Saponaria prostrata* willd, cold-tolerant *Eschscholzia californica* and green at all times *Teucrium fruticans* are preferred.



Cross section V: Soil is currently available at the lowest layer in the cross section of this street swale. A pebble ground of 20 cm is available on the upper layer for the purpose of providing infiltration up to 42%. In the upper layer, there is a mixture of 10 cm of 60% sand, 20% compost and 20% topsoil. There is a 5 cm of geotextile material in the intermediate layer. Due to its green leaves and white flowers, *Androsace pyrenaica, Centaurea triumfettii* as ornamental plants, *Atriplex horteusis, Echeveria* spp. and *Lonicera tatarica,* water-tolerant *Dianthus barbatus*, cold-tolerant *Oenothera lindheimeri* and *Eschscholzia californica,* easily adapting to all sorts of soils *Tagetes erecta* and *Gasteria* spp., moist environment-favoring *Saponaria prostrata* wild plants are preferred.

5. CONCLUSIONS

Ecological solutions are considered as green infrastructures constituting an alternative to gray infrastructures in cities and providing advantages for human health and the environment. Rain gardens serve as an alternative green infrastructure system to gray infrastructures both providing an ecological sustainability and producing solutions to the issues resulted from impermeable surfaces in the city.

As a result of heavy rains, due to the low inclination in certain parts of the city, flooding and surface run-offs occur. Following the rapid urbanization occurred because of globalization, green spaces in the urban fabric have been replaced by rough and impermeable surfaces. Led by the increase in impermeable surfaces, sustainability and ecological balance in cities have been lost.

Therefore, rain gardens contribute to small and large scale water management serving as ecological solutions actively supporting the retention and seepage of stormwater for integrated stormwater management and sustainable drainage systems in cities, conservation of underground and surface water resources, and mitigation of flooding and deluge risks.

Only current technology is applied for improving the potential of the area in the implementation of rain gardens. Although overall urban planning practices seem to be sufficient, the ecological functions of the landscape can be further improved with the implementation of the rain gardens. Moreover, rain gardens are required to include native plant species designed to adapt with the potential of the area.

Introducing rain gardens into cities provides numerous benefits such as improved aesthetic quality of an area, substantially reduced flood, and increased public awareness of significance of the sustainability.

Rain gardens are such aesthetic designs use natural plant species and materials such as stone and rock, allowing the surface run-offs to drain into underground water resources. The most substantial feature of the rain gardens is to ensure the protection of the nature against the soil erosion, floods, deluges and water pollution by retaining the excessive surface run-off following heavy rainfalls. This will contribute to the supply of the underground water resources and the natural water cycle.

Rain gardens are of importance for sustainable and healthy cities. It is highly required to determine alternative approaches for the purpose of establishing livable cities for both ecology and urban public. It is considered that these alternative approaches are required to be adopted and put into practice throughout the country. By this way, local authorities will be able to take prospective measures in this context in accordance with the changing climatic conditions. We believe that modern cities are required to be considered within the scope of water susceptible urban design. This study suggests establishing rain gardens in low elevations where the stormwater is accumulated.

It is expected that this study will lead further research in this subject and serve as a guide for relevant institutions and organizations. This study provides models for the innovative integration of stormwater management functions alternative to traditional infrastructure systems at various scales in the public realm as well as increasing the aesthetic quality of street views and contributing to the ecology of the city.

Street swales, which are modeled as an alternative to traditional infrastructure solutions in cities, can be applied in all kinds of areas with a similar methodology in accordance with climatic conditions.

We have the opportunity of reconsidering how we design and manage the public and private outdoor areas today. Landscape architects are involved in regional master planning, conservation and restoration efforts, urban design, and park and stormwater management design and construction. At all scales, they bring a critical eye for social and artistic value to the design process.

Stormwater could become a design opportunity of reviving the urban landscape by means of rain gardens instead of perceiving the stormwater as a distress in urban setting. Therefore, we are compelled to have a better grasp of technologies and governance mechanisms paving the way to development of nature-based solutions. Designing and implementing drainage systems and improving the local environment are required to go beyond the conventional approaches.

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