Sustainable Drainage and Urban Landscape Upgrading Using rain gardens. Site Selection in Thessaloniki, Greece

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Abstract

Use of rain gardens and other ecological rainwater management methods in urban areas can contribute to: 1) reduction of total rain water runoff and of its peak, 2) storage of rainwater, in order to cover low quality water demand, such as irrigation of gardens, 3) local aquifer replenishment, 4) reduction of property damage and activity disruption, which is due to insufficient sewer network capacity, 5) improvement of rain runoff quality through pollutant retention, filtration, decomposition, plant uptake, etc. 6) mitigation of pollution of runoff receiving water bodies and 7) upgrading of urban and suburban landscape. In this paper the main features of rain gardens are outlined, criteria for selection of construction sites (such as rain water collection efficiency, landscape improvement and cost) are discussed and certain suitable public or municipal sites in the area of Thessaloniki, Greece, namely in a densely built urban environment, are briefly described. Examples include degraded street and square sections, flower beds, a park, an urban stream bed, a schoolyard and traffic islands.

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1. Introduction

Urbanization is a global trend with adverse effects on water resources, including:
  a. Increase of surface runoff, resulting in higher flood risk, in particular for lower altitude areas and underground constructions.
  b. Reduction of aquifer replenishment.
  c. Degradation of the quality of water bodies that receive surface rain run-off, due to the pollution load picked by rainwater run-off.

These effects are due mainly to the dramatic increase of impervious ground surface, but also to trespassing of stream areas and to appearance of additional pollution sources. Urbanization affects water resources indirectly, too, since it aggravates urban thermal island phenomena.

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To mitigate the aforementioned adverse effects, ecological rain water management techniques can be used. The most prominent among them is construction of rain gardens.

2. Brief description of rain gardens

Rain gardens may look like common gardens, but they have some specific features that favor increase of rain run-off infiltration and temporary storage to underlying soil layers. In this way, they contribute to reduction both of total run-off and of its peak. A typical rain garden consists of the following parts (e.g. Auckland Council, 2014; Bray et al., 2014; Web link a, 2014):

a) Ponding area: It is a natural or artificial ground depression. In rather flat areas it is constructed by excavating soil from the ground surface. In sloping terrain it is formed by soil excavation combined with building of an earth berm at the downslope side, using excavation material. Surfaces with large slope are not that suitable for rain garden construction.

Ponding area bottom is usually covered by a mulch layer, before adding the top soil. A gravel layer could also be constructed on its bottom, if water infiltration rate in the underlying strata is not adequate. A perforated under-drain pipe could be used for the same reason.

b) Inflow structure that directs rainwater from downspouts or surrounding impermeable areas (streets, sidewalks) to the ponding area.

c) Overflow structure that allows water to exit the rain garden when the ponding area is full. This structure is necessary in order to reduce erosion risk and to direct outflowing water towards the desired place (usually the sewer network).

Plants are one of the most important rain garden features. Besides their contribution to landscape upgrading, they enhance rain garden function by retaining water quantities and certain pollutants, too. Their selection is an important and site-specific issue (e.g. Web link b, 2014). Native plants are in most cases the best choice, since they are adapted to local environmental conditions and require less care. Nevertheless, they should be able to tolerate periodic inundation. For this reason, the majority of xerophytes of Greece, and in particular the classic herbs, are not appropriate for use in rain gardens (InGreenCi project, 2013; Katsifarakis, 2013).

Run-off quality improvement is the second important rain garden asset. It is achieved in the following ways (Davis et al., 2009):

a) Adsorption, namely retention of pollutants by soil grains, due to ion exchange.

b) Filtration

c) Plant uptake.

d) Biological decomposition of nitrates and organic substances, due to the presence of suitable aerobic and anaerobic microorganisms.

e) Dissolution of certain soil ingredients, due to the presence of pollutants.

f) Oxidation or reduction of pollutants.

g) Sedimentation.

2.1. Restrictions in rain garden construction

Rain gardens can be constructed in many kinds of sites, such as pre-existing green spaces, stream zones, squares, parking spaces, house yards, open spaces of building blocks, school and church yards, along streets, etc. Nevertheless, observance of the following restricting rules is necessary:

a) Rain garden distances from adjacent buildings should be large enough (distances larger than 3 m are usually recommended), to avoid water infiltration to underground structures. Moreover, water should be carried away from these buildings, for the same reason.

b) Utility networks should not be affected.

c) Rain garden construction over septic tanks should be avoided.

d) The underlying aquifer should be low enough to allow draining of rain water.

e) Adequate insolation should be available for rain garden plants.

It follows that restrictions are more severe in densely built areas. This paper deals with preliminary selection of rain garden sites in Thessaloniki, Greece, namely in a densely built urban area.
3. Selection of sites for rain garden construction in the city of Thessaloniki

Thessaloniki, named after the sister of King Alexander, is the second largest city of Greece. With its large port, its proximity to international highways, its universities and its historical background, it is nowadays an important commercial and cultural center of Southeastern Europe. Its central part, which has been continuously inhabited since 315 B.C., is densely built, rendering application of rain gardens a challenging task.

It is true that Thessaloniki metropolitan area is not prone to major floods, for the following reasons: a) It is developed across the Thermaikos Gulf, namely across the final rain run-off recipient, b) The hydrologic basins of urban streams are rather small and c) It is partially protected by an artificial ring channel. It suffers, though, by damages caused by medium rain events, in particular where ground slope changes abruptly. Moreover, the sewage network is insufficient in many parts of the city. So, rain gardens fit exactly to the needs of the city and they can become an efficient part of local flood protection measures and plans.

A survey to locate sites that are suitable for rain garden construction in the area of the municipality of Thessaloniki, has been undertaken in the framework of “Integrated green cities”, a project co-funded by the European Regional Development Fund. The main site selection criteria were the following:

1. Rain garden efficiency in mitigation of flood phenomena and of disruption of human activities.
2. Upgrading of degraded areas (in particular those of high development potential).
3. Minimization of required additional cost (e.g. for shaping slopes or asphalt pavement removal).

A list of around 40 sites is included in Web link a (2014) and Web link b (2014). In this paper, some interesting examples are briefly presented. A site from the adjacent municipality of Kalamaria (Skarliou-Nikolettou and Katsifarakis, 2014) has been also included. Their main attractive features are summarized in section 4, too.

Regarding their dimensions, they are decided by free space availability. The respective discharge areas are then calculated, taking into account a design rain event of rather small period of return, because the consequences of failure, namely of overflow of a rain garden are rather light. Proposed rain event features for the area of Thessaloniki are: Return period \( T = 1 \) year and rain duration \( t = 2 \) hours.

3.1. Kazantzakis street area

It is a rather degraded residential and commercial area with small shops that sell cheap goods, which is found close to the Port and the Justice Hall of the city. There is adequate space for rain garden construction, at locations where water is ponding during rain events. It is expected that local residents will gladly support such a neighborhood upgrading plan. Some shop owners may have objections, though, since space for uncontrolled parking will be reduced. One of the suitable locations for rain garden construction is shown in the photo of figure 1.

3.2. Area of Agion Apostolon Church
The Agion Apostolon (Saint Apostles) church is one of the most important monuments of Thessaloniki. Moreover, it is located next to a well preserved part of the western city wall and a byzantine cistern. The surrounding neighbourhood, though, is densely built, most of the apartment houses are old and open space around the monuments needs further upgrading.

A rain garden can be constructed at the small undeveloped square north of the church, to receive runoff from adjacent buildings and from the small Amazonon Street, whose grade is large. The aforementioned square is shown in the photo of figure 2, while the church and cistern appear in the photos of figure 3. Moreover, parts of the flower beds of the nearby Paparrigopoulou Street could be transformed to rain gardens, observing the required distance limit from adjacent buildings and accommodating runoff of the latter.
3.3. Area of Byzantine walls along Stournara street

Stournara Street follows the north-western part of the city walls, which have been preserved rather well up to now and they should attract the interest of tourists. Unfortunately, part of the adjacent area is neglected. This is the case of the Stournara Street section, which is shown in the photo of figure 4. A very suitable site for rain garden construction is the lowest part of this section, where water is ponding during rain events.
3.4. Rotonda area

Rotonda is one of the most important monuments of Thessaloniki. Agiou Georgiou Square, which is located east of Rotonda, includes an underdeveloped part with thin vegetation, which could be developed to rain garden, receiving runoff from the roofs of adjacent buildings and from the impermeable paver of part of the square. It will contribute to aesthetic improvement of the square, too. The main problem in this case is that the lot is privately owned.

The proposed site is shown in the figure of photo 5, together with part of the fence of Rotonda.

3.5. Junction of St. Kyriakidou and Agiou Dimitriou streets (neighborhood of Saranta Ekklisies)

The neighborhood of Saranta Ekklisies is rather close to the centre of Thessaloniki. Buildings are generally low and green spaces are rather abundant, compared to other parts of the city. There is one problem, though: Most of the ground surface exhibits large slopes, which result in quick concentration of rain waters at lower points with small slope, such as Agiou Dimitriou Street, which separates Saranta Ekklisies from the university campus of Aristotle University of Thessaloniki. For this reason construction of rain gardens could be very beneficial.

One typical example is the junction of Agiou Dimitriou and St. Kyriakidou streets, where runoff of an impermeable area with large slope is ponding, even during usual rain events. Part of this rain runoff could be diverted to the adjacent park, which could be easily developed in rain garden, as its ground level is lower than that of the street. The rain garden could receive runoff from one more sloping street at its other end, too.

The sloping section of St. Kyriakidou Street is shown in the photo of figure 6, which is taken from the park. The runoff ponding problem is evident in the photo of figure 7, which shows the junction of St. Kyriakidou and Agiou Dimitriou streets, during a short, but intense, rain event.

Fig. 5. Proposed rain garden site site in Rotonda area
3.6. Doxa stream bed

There is a number of remnants of urban streams in Thessaloniki area. They have very small hydraulic function, but they are very interesting green spaces. Moreover, the soil usually exhibits high infiltration rates, namely it is suitable for rain garden construction. One such stream remnant exists in Doxa neighborhood, between Agiou Dimitriou and Egnatia streets. A small concrete canal along the stream bed serves to carry the insignificant water
flow rates. The rest of the bed is covered by thick vegetation, partly hiding a number of sheds, most of which are inhabited.

The Doxa stream bed needs cleansing and rehabilitation, to become more accessible. In a period of devastating financial crisis, demolishing of inhabited buildings is wrong, from the humanitarian point of view. Further trespassing should be avoided, though.

A suitable site for rain garden construction exists at the lower part of the stream bed, close to Egnatia Street (shown in the photo of figure 8). More locations along the stream bed could be selected to receive rain runoff from adjacent streets and buildings.

![Fig. 8. Proposed rain garden site in the Doxa stream bed (towards Egnatia Street)](image)

### 3.7. Yard of an elementary school

Rain gardens in school yards have an additional asset: They can be used for educational purposes. Unfortunately, school complexes of the Municipality of Thessaloniki have usually small schoolyards that can hardly satisfy the needs of their students. In such cases, it is not reasonable to occupy space used for other activities (e.g. sports), in order to create a rain garden. Only pre-existing flower beds could be used for this purpose, provided that the minimum requirements concerning distances from buildings, are fulfilled.

One of the rather few exemptions is the 88th Elementary School. It is located in an average neighborhood, south of the city center, between Paraschou, Zambeliou and Karakasi streets. As seen in the photograph of figure 9, the yard around the school has a flower bed that can be widened and turned into a rain garden. Moreover, isolated parts of the yard towards Zambeliou Street can be developed in the same way.

Furthermore, a rain garden (in the form of a strip) can be developed next to the school complex at the border with the asphalted parking place, which is located between the school and Karakasi Street, in order to collect outflowing rain waters.
3.8. Rain garden along the traffic island of Hilis Street

Traffic islands may be turned into rain gardens, if their dimensions permit it. One favorable case is that of Hilis Street, close to the centre of Kalamaria municipality, which is part of Thessaloniki metropolitan area. Due to the opposite slopes of successive street sections (shown in the photo of figure 10), rain runoff accumulates in the lower parts during average rain events, impeding both pedestrians and vehicle traffic. Transformation of the rather wide traffic islands to rain gardens would contribute greatly in alleviating the aforementioned problem.

4. Discussion and conclusions

Selection of sites that are suitable for rain garden construction is a challenging task in densely built areas. In this paper, some cases from Thessaloniki, the second largest urban area in Greece, are presented and briefly discussed. The criteria used for their selection are summarized in the following paragraphs.

Location 3.1 (Kazantzakis Street area): Medium to high efficiency, application to a degraded area close to important sites, rather low additional cost.

Location 3.2 (Area of Agion Apostolon Church): High efficiency, application to a degraded area with very high development potential, low additional cost.

Location 3.3 (Area of Byzantine walls): High efficiency, application to a degraded area with very high development potential, very low additional cost.

Location 3.4 (Rotonda area): Medium to high efficiency, application to the city centre, low additional cost.

Location 3.5 (Junction of St. Kyriakidou and Agiou Dimitriou streets): Very high efficiency, very low additional cost.

Location 3.6 (Doxa stream bed): High efficiency, application to a degraded area, very low additional cost.

Location 3.7 (Yard of elementary school): Rather high efficiency, low additional cost, special educational benefits.

Location 3.8 (Traffic island of Hilis Street): Very high efficiency, low additional cost.

The diversity of the aforementioned sites shows that, despite the constraints, there are many choices available even in densely built areas.
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References


