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Promoting the Use of Public Areas for Sustainable Stormwater Management in Cities with Mediterranean Climate †

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Abstract: The aim of this work is to identify and present small scale sustainable urban stormwater management techniques that can be implemented by local authorities into public spaces. We present areas that bioretention and other Sustainable Urban Drainage Systems (SuDS) can be adopted, causing the transformation of public areas into multifunctional spaces.

Keywords: SuDS; green roads; bioretention; permeable pavement; detention basin roundabout; sustainable urban stormwater management

1. Introduction

Flood protection and drainage rank highly among the needs of all societies, accompanied with the provision of safe drinking water and sanitation facilities. Since early civilization, various means have been used to provide these essential services. When it comes to the goals of designing drainage systems, they have remained the same for many centuries; to guide the water as quickly as possible away from the area of rainfall thus cities, into rivers or the sea [1]. The rapid conveyance of the runoff and its direct discharge to the recipients, contributes to the disturbance of the hydrologic cycle by diminishing the volume of soil infiltration, evapotranspiration, and surface and subsurface flows, resulting to the reduction of aquifer level, the increase of runoff and the deterioration of the recipients' quality. Moreover, those systems cause a false sense of safety to the public that do not consider that all pipe systems are designed to withstand certain rainfall intensity and duration.

Over the last decades, it is becoming more and more recognized by the authorities, professionals and the scientific community, that the philosophy behind the construction of urban drainage systems should change. Climate change has played an important part to this because, as reported by the IPCC [2] and has already been observed in many countries, climate change effects into less frequent and more intense rainfalls. The continuously rising intensity of rainfalls, lead to the increasing inefficiency of conventional drainage systems for handling the stormwater and thus cause more frequent and intense urban floods. Due to this recognition, a growing trend has been developed towards managing water in a more sustainable way, from the use of conventional drainage systems to the use of Sustainable Drainage Systems (SuDS). The goal of this new approach is to mimic the natural behavior and the processes of the water cycle and to incorporate them into the urban environment. Energy efficiency, biodiversity, social amenity, quality of water and all aspects of sustainability are considered along with the quantity of runoff and moreover, storm water is considered as a precious resource instead of a waste product, a problem and a nuisance.

Although their benefits have been extendedly recorded, their wide-scale implementation has been limited especially in Mediterranean cities [3,4], as most of cities are still investing heavily in the conventional approach [5]. Insights from different studies on integrated urban water management, reveal that barriers are mainly socio-institutional rather than technical [5] and recommendations call for collaborative planning and multi-stakeholder platforms that involve civil society [6,7].

The main purpose of this paper is to present small scale SuDS techniques that can be implemented by local authorities in public spaces, in order to promote more sustainable practices regarding stormwater management. Those techniques may be an alternative or supplementary to the conventional approach of urban drainage and can be gradually incorporated into the way of thinking and designing drainage systems.

2. Area of Interest

The area of interest is Limassol, located at the south part of the third largest island in the Mediterranean basin, Cyprus. Its climate is typical Mediterranean and includes mild winters and long, hot and dry summers. Sunshine is abundant during the whole year, with an average duration of sunshine of 11.5 h per day in summer and 5.5 h in winter. Evapotranspiration is high and on an annual basis, corresponds to 80% of the rainfall [8].

The average annual precipitation in Limassol is 457.5 mm and it is characterized by high seasonality due to the fact that as illustrated in Figure 1, 62% of annual rainfall falls during the winter months and almost none falls at summer months. During the 20th century a remarkable decrease in the amount of precipitation and a more extreme increase in temperature even in rural areas were observed [9].

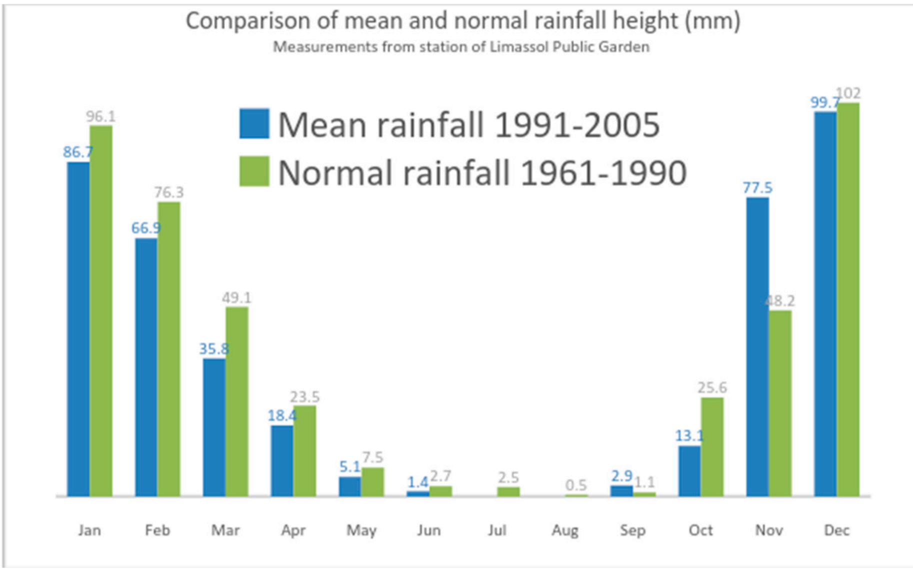
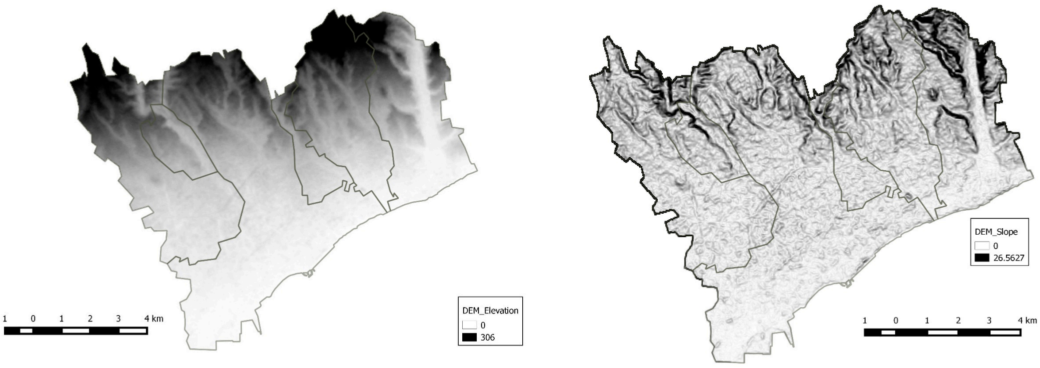


Figure 1. Comparison of mean and normal rainfall height (mm) in Limassol between years 1991–2005 and 1961 to 1990 (data from [8]).

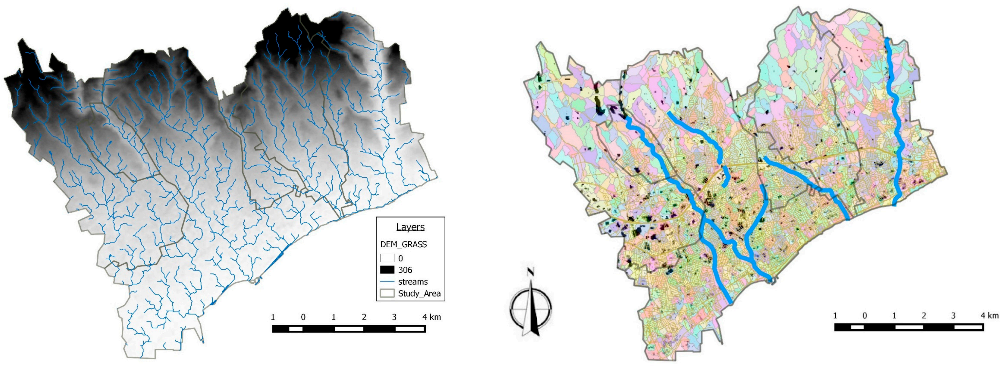
Limassol is a coastal city with flat topography on the south, near the beach, and with higher elevation and more intense slope in the northern part (Figure 2).



(**a**) (**b**)

Figure 2. (**a**) The Digital Elevation Model (DEM) of the study area. The higher elevations are shown with darker pixels; (**b**) The ground slope of the study area extracted from the Digital Elevation Model. The flat areas are shown with light pixels.

The topography of Limassol is typical coastal plain that rises gradually from sea level to low lying hills in the north and north east. A number of rivers and streams with temporary flow, limited during and shortly after rainfalls, run the city from north to south conveying the stormwater to the sea (Figure 3).



(**a**) (**b**)

Figure 3. (**a**) The hydrographic network of the study area extracted from the Digital Elevation Model; (**b**) the depressions of the ground extracted from the Digital Elevation Model are shown with black. The calculated basins are with several colors and the rivers are shown in blue.

The fragmentation of stormwater management between the authorities is prevailing in the country. However, efforts of sustainable stormwater management, particularly in Limassol, have been initiated several years ago, at 1992 by the Sewerage Board of Limassol Amathus which is the implementing authority for drainage systems in the city and prepared a Stormwater Management Plan [10]. The plan was later updated in 2003 and is gradually implemented since then. Right from the start it was identified that the management of stormwater should not only be done only by increasing the capacity of conveyance pipes, but also using sustainable practices that incorporate local treatment, retention, attenuation, infiltration and conveyance of water runoff. The Limassol Stormwater Management Plan in addition to the underground drainage system comprises of four retention ponds, aiming to provide protection during extreme events, additionally to the environmental benefits that they comprise. In addition, natural watercourses in the area are extensively used to the maximum, therefore reducing the use of pipe-based drainage systems.

The case of Limassol is a fine example in Cyprus as the participation of all local authorities was achieved. Some of the measures taken to mitigate the impacts of urbanization are the implementation by the building permit laws and certifications, of a soakaway into every new development.

But apart from the abovementioned already adopted techniques which in the case of retention ponds are costly, the aim of this work is to further promote other SuDS techniques that are currently of limited use in the island. Areas that bioretention and other SuDS systems can be adapted are presented, causing the transformation of public areas into multifunctional land cover.

3. Description of the Techniques Proposed

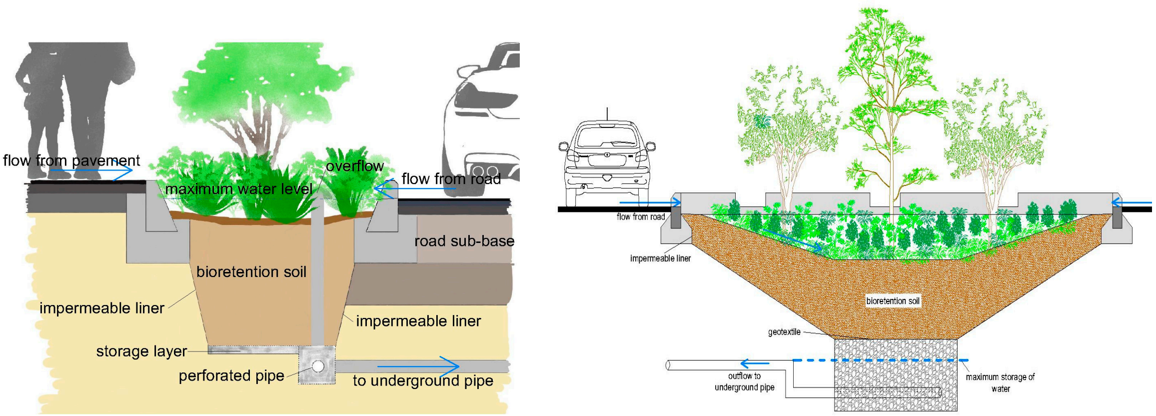
Depending on the area of implementation and its specific characteristics, various techniques of SuDS can be applied. In order to present those techniques problem areas identified during rain events were selected. Opportunities to implement such practices into public spaces such as roads, cul-de-sacs, traffic islands, green spaces etc. are also introduced.

In this paragraph some examples where such systems could be adapted are presented. Some of the areas of implementation shown below were chosen from field investigations during rain. It is not necessary that they should be implemented in areas with flooding problem. Their main purpose is to retain the water on the source, before it flows downstream.

3.1. Bioretention Systems

Bioretention areas or otherwise mentioned as raingardens, are shallow landscaped depressions which are typically under-drained and rely on engineered soils, enhanced vegetation and filtration to remove pollution and reduce runoff downstream [11]. They aim at managing and treating runoff from frequent rainfall events and they are an effective method for managing stormwater runoff volumes, peak flow rates and at the same time they improve water quality by providing extra storage space which allows the water to collect and pool [12,13]. Moreover, they provide high aesthetic value and can be adapted into a large variety of shapes depending on the site.

Raingardens can be implemented both in a low density built area (with gentle slopes) and in a high density built area (where they may have a hard edge with vertical sides). Common areas of implementation include landscaping islands, cul-de-sacs, parking lot margins, open space, rooftop drainage and street-scapes (i.e., between the curb and sidewalk) as shown in Figure 4.



(**a**) (**b**)

Figure 4. (**a**) Sketch of a street scape bioretention system. It is usually placed in main roads with no parking allowance. In case of the presence of a parking lane, a pavement of about 0.60 m should be installed between the system and the road; (**b**) conceptual sketch of a bioretention system in a roundabout.

Making a simplified calculation, a green space of 50 m^2 area transformed into a rain garden and having the level of the ground adjusted at 15 cm below the road level, could store over 7 m^3 of peak runoff water, without considering the amount of water stored below the bioretention soil which depends on the depth of the storage layer [14].

Despite SuDS systems are preventative and not on the point of the problem solutions and are usually implemented at higher grounds where the runoff starts, an application could be in the coastal road of Limassol. During rains, due to the fact that the road is relatively flat and also due to the incapacity of the storm sewer, parts of the road usually flood. Taking into consideration that almost all of the road's length that is over 30 km, the transformation of the green area that separates the road from the bicycle lane into a bioretention planter is proposed.

The system which is shown in Figure 5, may consist of impermeable liner to prevent seepage in the road's subbase. Depending on the length of the system, a permeable pipe may be placed in order to distribute the water uniformly. The bicycle lane could also be transformed into a permeable pavement with storage space beneath. As the system will not have infiltration capacity because of its proximity to the sea, a pipe can convey the stored water from the storage layer through the pedestrian road, to the beach.

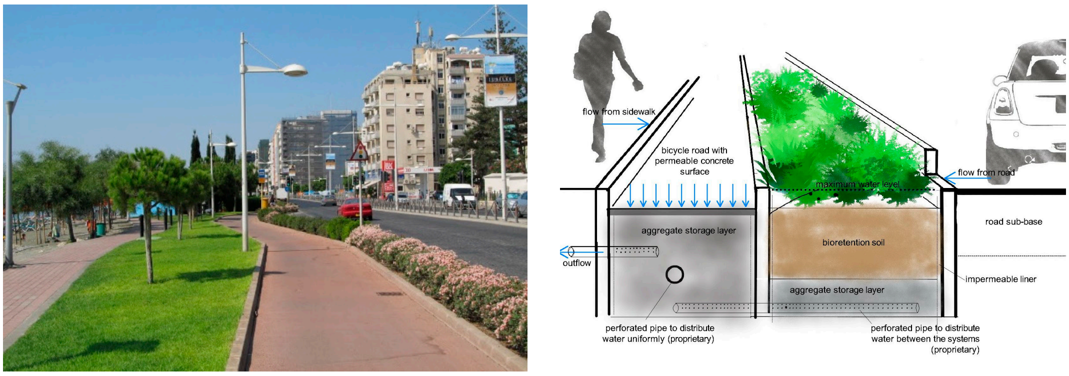
By adapting 100 m of the green stripe shown below in Figure 5 into a bioretention planter, could result in the detention of over 15 m^3 of water just in the surface of the planter.

$$V = W \times L \times D = 100 \times 1 \times 0.15 \text{ m} = 15 \text{ m}^3 \quad (1)$$

where:

V = Volume of Surface storage
L = Length of Bioretention Planter
W = Width of Bioretention Planter, assumed 1 m and
D = Depth of Bioretention soil surface which usually corresponds to the maximum level of water and is assumed 15 cm

More water could also be stored within the bioretention soil and the aggregate storage layer, which depends on the bioretention media used and the depth of the layers. Moreover, the combination of the bioretention planter with a permeable bicycle lane could provide even more storage space, which also depends on the depth of the storage layer. Assuming the width of the bicycle lane at 1.5 m and the depth of the storage layer at least 1 m, the amount of water stored would be around 50 m^3.



(**a**) (**b**)

Figure 5. (**a**) The coastal road of Limassol; (**b**) Graphical representation of a combined system with a bioretention planter and a permeable pavement to store or retain water that could be applied.

3.2. Detention Basins

Detention basins are surface storage basins that provide flow control through attenuation of stormwater runoff. They are normally dry and this permits the additional use of the land as a recreational facility.

The retrofit of large roundabouts or green spaces into storm water detention basins could also solve many flooding problems and at the same time enhance the urban environment. In Figure 6, a sketch of such a roundabout is presented. The transformation of a roundabout with a diameter of about 30 m into a detention basin could result in the storage of over 1000 m^3 of peak runoff water.

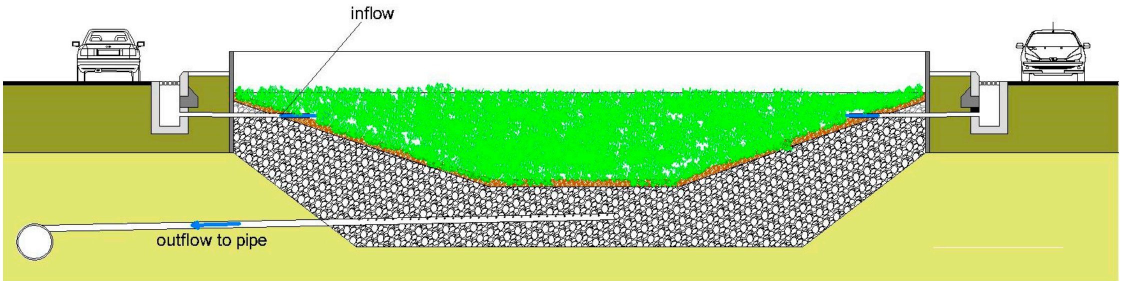


Figure 6. Conceptual sketch of a roundabout detention basin.

3.3. Permeable Pavements

Permeable pavements are surfaces that allow runoff to infiltrate into a storage reservoir underneath. The water can then infiltrate into the subsoil or in cases of low infiltration soils, an underdrain that convey the water to the storm sewer can be used. This system provides exceptional hydrologic performance in reducing the peak runoff [15].

Permeable pavements could function as an alternative or a complement to the underground stormwater system. In Figure 7 below, we can see two possible sites of implementation in Limassol.

(**a**) (**b**)

Figure 7. (**a**) A bus stop after rain; (**b**) A side parking lane after rain.

Making a simplified calculation, if a permeable pavement would be constructed in the areas presented above, occupying area of about 20 m^2 and filled with aggregate of 1.5 m depth which would have 30% pores, the amount of water stored would be about 20 m^2 × 1.5 m × 30% = 9 m^3. This water could then either infiltrate the subsoil or be conveyed to the storm sewer at a slower pace, thus reducing the peak runoff and at the same time reducing the flooding areas.

4. Conclusions

In this paper a number of SuDS techniques were presented which can improve urban stormwater management. A common characteristic of the systems proposed above is that they usually have a large impact on the urban landscape, enhancing the presence of plants in the urban environment and providing all the benefits to the public health, while also reducing the peak runoff, the volume of water flowing to the recipient and its quality.

The creation of tools such as technical guides, fact sheets and maps would facilitate the implementation of such systems. These, combined with the creation of showcases in public properties, will help designers, authorities and professionals familiarize with sustainable stormwater urban management. The goal is to incorporate sustainable practices into the way of thinking and designing infrastructure, thus guiding the city closer to a sustainable city.

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