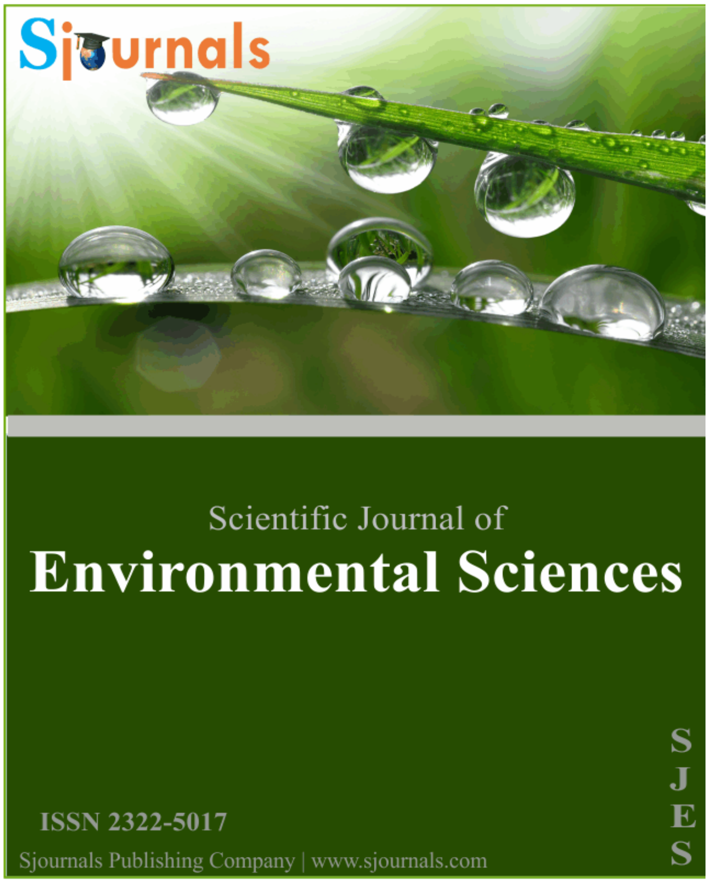
Sjournals
Scientific Journal of
Environmental Sciences
ISSN 2322-5017
Sjournals Publishing Company | www.sjournals.com
S
J
E
S

Scientific Journal of Environmental Sciences (2016) 5(9) 251-257
ISSN 2322-5017
doi: 10.14196/sjes.v5i9.2256

Contents lists available at Sjournals

Scientific Journal of **Environmental Sciences**

Journal homepage: www.Sjournals.com

Review article

Low impact development and green infrastructure

Zeynep Cansu Ozturk*, Sukru Dursun

Environmental Engineering Department, Engineering Faculty, Selcuk University, Konya, Turkey.

*Corresponding author; Environmental Engineering Department, Engineering Faculty, Selcuk University, Konya, Turkey.

A R T I C L E I N F O

Article history,
Received 12 August 2016
Accepted 11 September 2016
Available online 18 September 2016
iThenticate screening 15 August 2016
English editing 09 September 2016
Quality control 15 September 2016

Keywords,
Low impact development
Green infrastructure
Storm water
Management
Runoff

A B S T R A C T

Water is the main source of life for all living creatures and water resources should be protected from draining away. There are two main sources of water that is used for water supply such as ground water and surface water. Both of them are fed by precipitation water in order to stay stable for providing consumption requirements. Thus, only one drop of precipitation water should not be wasted so storm water management practices come to light. Two of the mostly known storm water management practices are low impact development (LID) which works with nature to manage stormwater at place closer to its source and green infrastructure which uses natural processes to provide infiltration and evapotranspiration or reuses runoff on the generation area. There are many LID practices that have been used to adhere to these principles such as bio retention facilities, rain gardens, vegetated rooftops, rain barrels and permeable pavements. Green infrastructure can be used in wide range of landscapes in addition to more traditional stormwater control systems to support the principles of LID. In this research, definition and main features of LID and green infrastructure was investigated, main practices used for implementation of these methods were reviewed and two methods were compared according to their benefits.

1. Introduction

Storm water management and control is raising trend nowadays. Low impact development (LID) and green infrastructure are two of the mostly known and developing methods. Water resources are getting decreasing because of the effects of growing population, increasing industrial activities and as a result of human impact global warming. Low impact development and green infrastructure approaches are developed in order to provide alternative method in addition to traditional storm water management systems which include ponds and wetlands, infiltration practices, filtering practices, open channel practices. Traditional methods are useful but have some problems such as clogging, overflow channel, concrete damage, animals, clogged outfall pipes, vandalism and sediment build-up. Moreover, impervious layers increase and water quality decreases because of the runoff due to unplanned urbanization (Dietz, 2007). Thus, new practices are necessary to improve storm water collection.

First LID practice was tested in Maryland in order to decrease the damaging impacts of urbanization and impervious layers. Protecting the hydrology of area is the main goal of LID. Low impact development is based on the design of site by providing natural habitat such as soil, aquatic life and vegetation (Dietz, 2007). Most of LID practices include microscale processes like vegetated rooftops, rain barrels, pervious pavements, retention facilities, rain gardensto collects, filtrate and reduce runoff of storm water (Newcomer et al., 2014). These practices are cheaper than traditional storm water management techniques and not required to qualified employee but retrofit cost are not so acceptable when compared with traditional systems. Furthermore, the construction, operation and maintenance periods of wastewater treatment plant which recharge recycled water are more expensive than LID. As a result of these benefits of LID, United States environmental Protection Agency (USEPA) produce new regulations forcing LID practices for storm water management and try to increase the benefits of LID on groundwater water level by infiltration (Newcomer et al., 2014).

Green infrastructure is another storm water management approach which focusing on all processes in natural areas and also environmental specifications providing several benefits to public settled in these areas. The most important principle of green infrastructure is if the area is healthy, it can give many benefits to ecosystems of that area (URL 1). Green infrastructure is supported by both USEPA and European Commission (EU) with different scales. USEPA gives consultancy to develop green infrastructure practices for many states, counties, municipalities, and non-profits across the United States and Canada by design manuals, tools, operation and maintenance support and funding. Moreover, EU supports the green infrastructure solutions for storm water management for all Europe and gives public consultation related to this subject.

All scales are appropriate for green infrastructure (GI). The working area of green infrastructure is wider than green storm water management practices that are cost effective systems despite mostly associated with it. Green infrastructure offers people sustainable liveable places and clean water and air with both regional and big city planning methods. Moreover, the requirements of wildlife is provided by green infrastructure by creating greenways for protect endangered species through settlement areas of human. Also, green infrastructure includes urban forests, parks and constructed wetlands as protection place for wildlife and local water control. Furthermore, as a small scale green infrastructure is used for transportation systems, green streets, and green roofs for providing benefits of nature in buildings (URL 2). In this investigation, mostly used LID and green infrastructure practices were reviewed one by one and their benefits were revealed. Then, LID and green infrastructure were compared with each with respect to cost-effectiveness, easiness and sustainability.

2. Low impact development practices

There are many LID practices in the literature. The mostly used ones are rain gardens, bio retention facilities, vegetated rooftops, rain barrels and permeable pavements. In figure 1 mostly used LID practices are summarized.

2.1. Rain gardens

For plant selection and design period rainfall and storm water is used by rain gardens which is small scale plant and may resist against extreme conditions like moisture and nutrients which are possible to be found in runoff of the storm water. Also, rain gardens are positioned close to runoff source because storm water runoff may gain momentum and lead to erosion. Rain garden serves as a barrier which slows the runoff, lets the storm water travel to downhill and gives it an opportunity to infiltrate easier. Under drained and self-contained are two of the basic types of rain gardens. They are good for using as treatment facility for improving water quality and infiltration device for decreasing storm water runoff (URL 4).

Surface of the rain garden looks like beautiful and charming garden which allows living some animals like butterflies and birds. It may be small good looking garden or big garden with borders and entrance, but special features of the garden related to storm water management makes it a rain garden (URL 4). Below part of the surface of rain garden several mechanisms are happening that imitate the hydrological behaviour of healthy garden. Special soil and suitable plants are used in rain gardens which work as bio-retention cell cleaning storm water and reducing the amount of runoff water by infiltration. The plants and growing media in rain garden work as removal mechanisms for nitrogen and phosphorus removal. If there are more than one rain garden in the area, they produce positive effect on both quality and volume of runoff (URL 4).

2.2. Bioretention facilities

Bioretention facilities are based on filtration process with plants and soil. Many pollutants can be removed with physical, chemical and biological treatment systems. In order to reach regulatory water quality standards, pollutant loads in storm water should be reduced (URL 5). In figure 2, main parts of bioretention facility are given.

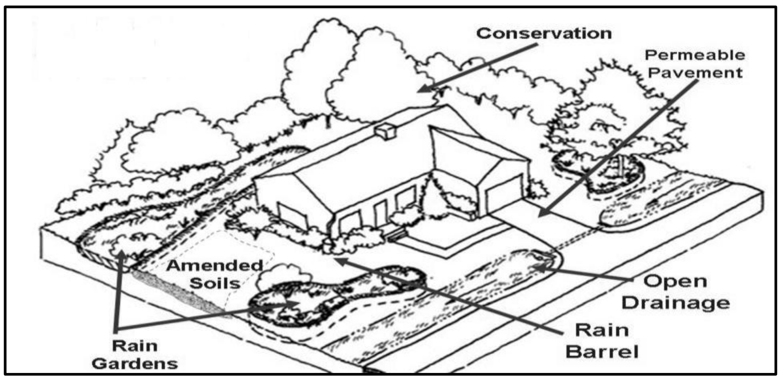

Fig. 1. Summary of mostly used LID practices (Adapted from URL 3).

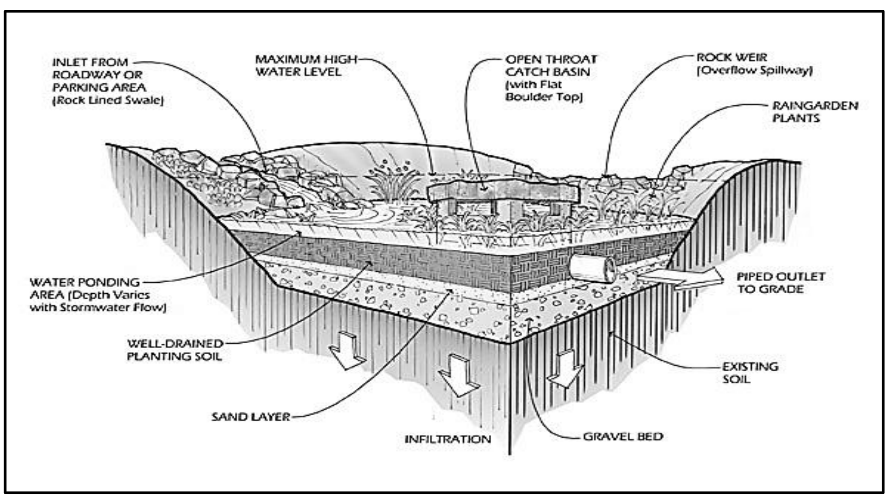

Fig. 2. Main parts of a bioretention facility (URL 7).

Heavy metal removal in bioretention facilities which are designed and constructed properly is very high. These systems can achieve more than 90% of lead, copper and zinc reductions. Especially for zinc and lead removal efficiencies are almost 98% and 99% respectively. The top layer of bioretention facility has a very important role in removal of these metals. The organic matter found in this layer creates very strong interaction with heavy metals. Moreover, removal of phosphorus may be achieved in the below layers with respect to depth of a facility in which it is removed 80% maximum about 60-90cm of depth. Removal mechanism of phosphorous is sorption of P into aluminium, iron and clayminerals in the soil of bioretention facility. Furthermore, nitrogen removal can be possible with these facilities by using the same mechanism of P removal. The studies according to removal of nitrogen species show that ammonia was removed 70-80% in lower levels of facility (URL 5).

2.3. Vegetated rooftops

Vegetated rooftops are one of the most valuable storm water management systems for reducing the amount of runoff by increasing the previous layers in urban places. These structures are mostly used in the areas that have combined sewer overflow (CSO) problems caused by impervious layers. There are synthetic grain layer, media, vegetative layer and geo-textile layer in the main parts of the vegetated rooftops that are constructed materials. Moreover, the benefits of vegetated rooftops in urban areas can be arranged like below:

- Increase the life of roofs,
- Decrease cost of energy,
- Conserve the land, which is required to control measurements for protecting from runoff.

Especially in Europe these roofs are used mostly because of the regulative rules for storm water runoff control. Total volume of runoff is reduced with vegetated roofs very effectively. A simple vegetated rooftop has a capacity of decrease the amount of storm water runoff 50% annually with substrate of 8 cm. Also, according to study conducted in Germany, the vegetated roof with 8 cm substrate is more cost effective than the other designs. Vegetated systems which are designed properly can be adapted to existing roofs easily and can meet the runoff reduction requirements (LID literature review, 2000).

2.4. Rain barrels

In order to manage rooftop runoff, rain barrels which are cost-effective and useful devices for supply maintenance of retention and detention may be used. Classic rain barrel consists of screened input, which allows flow top to down, a sealed lid, an overflow pipe and spigot at the bottom of the barrel. To discharge excess water or fill the barrel spigot is used. The purpose of screen is protecting water from insects and mosquitoes. Collected water may be used for watering of garden, supplying water to domestic usage and daily usage at home with help of small treatment like filtration and disinfection. Besides, storage of rain water in bigger volumes can be achieved with connection and the usage of large systems can be achieved by pumps and filtration devices for industrial and commercial purposes. Figure 3 shows the configuration of a typical rain barrel (URL 6).

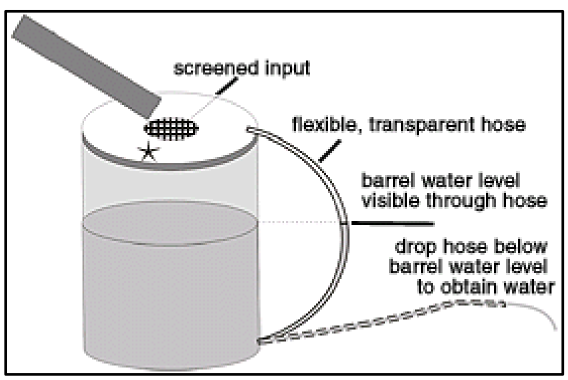

Fig. 3. Configuration of a typical rain barrel (URL 6).

2.5. Permeable pavements

The purpose of permeable pavements is increasing the permeability of drainage basin effectively. According to the previous studies if the impervious cover of the area is more than 10%, this leads to decrease in the quality of runoff water coming to lake, stream and wetland. Those kinds of pavements are good for parking areas and sidewalks. Especially the areas which have sand soil and straight slope serves best place for the most successful installations of permeable pavements. Permeable pavements also help pollutant treatment and recharge by infiltration mechanism of soil layer (LID literature review, 2000).

3. Benefits of green infrastructure and case studies

Green infrastructure has many benefits which can be classified as environmental, economic and social. In order to achieve these benefits green infrastructure uses many tools. In table 1 benefits of green infrastructure summarized.

Table 1
Benefits of green infrastructure (GI case studies, 2010).

Benefits	Type
Environmental	✓ Rising carbon restraint ✓ Improving quality of air ✓ Improving human health ✓ Protection from flood ✓ Reducing combined sewer overflow ✓ Improving health of watershed ✓ Meeting regulatory requirements
Economic	✓ Increasing value of land ✓ Decreasing energy consumption ✓ Reducing construction costs of infrastructure ✓ Encouraging development of economy
Social	✓ Producing nice looking places for public ✓ Educating people related to storm water management ✓ Creating urban greenways

Green infrastructure includes comprehensive methods in order to protect water quality at very different scales. To achieve comprehensive storm water management by using green infrastructure, protection and preservation of natural sources should be supplied, the place of direct development of community should be determined and type of development on individual sites should be selected (GI case studies, 2010). There are three scales of green infrastructure namely large scale or watershed scale, neighbourhood scale and site scale. Large scale green infrastructure focuses on the protection of natural water sources and land and mostly includes habitat corridors and water resource protection. Neighbourhood scale focuses on planned and design of mixed use development, forestry of urban areas and reduction of parking in order to create good walkable areas and increase perviousness. Site scale of green infrastructure is interested in storm water management by taking advantage of some mechanisms such as infiltration, evapotranspiration, which uses trees and vegetation to turn it into vapour and capturing and reusing water with rain barrels (GI case studies, 2010). According to the study of EPA, 12 cases were analysed with respect to hydraulic regime, population and political shape of the communities. Common policy approaches related to public and private are given in the table 2.

In table 2 case studies of 12 cities were compared according to approaches in private and public sectors. Public sector includes demonstration projects, streets retrofits, education projects and private sector are mostly related to regulative approaches. Accordingly table 2, creating storm water regulation and implementing demonstration projects were the mostly used approaches of green infrastructure for these cities (GI case studies, 2010).

4. Comparison of LID and green infrastructure

The main scope of LID is managing storm water in order to decrease the impact of it less to natural environment and prevent problems in water quality and aquatic life. LID practices are mostly used for site scale implementation (URL 8). LID practices provide equalization of water area and pervious areas and recover storage capacity of cities (Gao et al., 2013). While there are so many benefits of LID, design and practice of LID may affect the result. In order to reach main goals of LID such as preservation of natural pathways, minimization of impervious areas and decreasing the soil compaction and disturbance, engineering design should be made very carefully (LID and GI guidance manual, 2015).

Green infrastructure focuses on larger design of same principles. Community wide solutions and big scale projects are main goals of GI. When the site scale GI is considered, it supports the ideas and scopes of LID and uses same principles for storm water management by taking advantage of natural environment and preserving natural resources (LID and GI guidance manual, 2015).

Table 2
Case studies and policy approaches (GI case studies, 2010).

	Public					Private			
City	**Demonstration Projects**	**Street Retrofits**	**Capital Projects**	**Local Code Review**	**Education**	**Stormwater Regulation**	**Storm water Fee**	**Fee-based Incentives**	**Other Incentives**
Alachua County	X		X			X			
Philadelphia	X	X	X	X	X	X	X	X	
Portland	X	X	X	X	X	X	X	X	X
Seattle	X	X	X	X	X	X	X	X	X
San Jose	X	X		X		X			
Santa Monica		X	X	X	X	X	X		X
Stafford County	X			X		X			
Wilsonville	X	X	X	X		X			
Olympia	X	X		X	X	X	X		
Chicago	X	X	X	X	X	X			X
Emeryville	X	X		X		X	X		
Lenexa	X	X	X		X	X	X		
Total	11	10	8	10	7	12	7	3	4

5. Conclusion

Water resources of all worlds are decreasing fast and people are incapable to stop this, but with the help of some strategies, water resources can resist more. LID and GI are two of the simple ways of protecting water resources by reusing storm water, increasing infiltration of storm water and decreasing runoff. LID principles have come to the light after 1990's while green infrastructure is a new concept. Both of them are based on managing storm water with most suitable design and concept. The cost effective solutions like rain barrels, bioretention facilities, vegetated roof and permeable pavements are basic types of mostly used LID practices. Besides, site scale of GI offers similar solutions for storm water management, such as bioretention facilities and rain barrels. With the help of LID and GI more green and sustainable cities can be created. Especially in Turkey, both of them are very new concepts and they are required more effort.

References

Dietz, M.E., 2007. Low impact development practices: A review of current research and recommendations for future directions. Water. Air. Soil. Pollut., 186, 351–363, DOI 10.1007/s11270-007-9484-z.

Gao, C., Liu, J., Zhu, J., Wang, Z., 2013. Review of current research on urban low-impact development practices. Res. J. Chem. Environ., 17(S1), September.

Newcomer, M.E., Gurdak, J.J., Sklar, L.S., Nanus, L., 2014. Urban recharge beneath low impact development and effects of climate variability and change. Water. Resour. Res., 50(2), DOI: 10.1002/2013WR014282.

Pima County, City of Tucson, 2015. Low impact development and green infrastructure guidance manual.

United States Environmental Protection Agency, 2000. Low impact development (LID) a literature review. Office of Water (4203) EPA-841-B-00-005 Washington, DC 20460.

United States Environmental Protection Agency, 2010. Green infrastructure case studies: Municipal policies for managing stormwater with green infrastructure. EP-841-f-10-004.

URL 1, Green Infrastructure, European Commission, 2016. web page: http://ec.europa.eu/environment/nature/ecosystems/index_en.htm, retrieval date: 19.04.
URL 2, 2016. Green Infrastructure, American Society of landscape and Architects 636 Eye Street, NW Washington, DC 20001-3736, web page: https://www.asla.org/greeninfrastructure.aspx, retrieval date: 19.04.
URL 3, 2011. Top ten ways to reduce stormwater runoff, web page: https://mdseagrantstormwater.wordpress.com/2011/05/, retrieval date: 22.04.2016.
URL 4, 2007. What is a rain garden?, Low impact development center, Inc. web page: http://www.lowimpactdevelopment.org/raingarden_design/whatisaraingarden.htm, retrieval date: 20.04.2016.
URL 5, Bioretention, Urban Design Tools Low Impact Development, 2016. Web page: http://www.lid-stormwater.net/bio_benefits.htm, retrieval date: 20.04.
URL 6, Rain Barrels and Cisterns, Urban Design Tools Low Impact Development, 2016. web page: http://www.lid-stormwater.net/raincist_home.htm, retrieval date: 20.04.
URL 7, web page: http://www.pinterest.com/pin/403142604115675953, retrieval date: 23.04.2016.
URL 8, Low Impact Development vs. Green Infrastructure, Huron River Watershed Council, 2016. web page: http://www.hrwc.org/the-watershed/watershed-protection/green-infrastructure/lid-vs-gi/, retrieval date: 23.04.

How to cite this article: Cansu Ozturk, Z., Dursun, S., 2016. Low impact development and green infrastructure. Scientific Journal of Environmental Sciences, 5(9), 251-257.