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Sustainable urban drainage systems (SUDS) – what it is and where do we stand today?

Uvini Srishantha and Upaka Rathnayake*

Department of Civil Engineering, Faculty of Engineering, Sri Lanka Institute of Information Technology, Malabe 10115, Sri Lanka.

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Abstract

Stormwater management is a topic of growing complexity. It includes all measures in mitigating stormwater runoff. Various studies have identified stormwater as a major carrier of various pollutants and other contaminants. The utmost motive behind the implementation of stormwater management strategies is to use a suite of Best Management Practices to reduce sediment load, nutrients and chemical pollutant loads in stormwater before they reach natural watercourses downstream. Mitigation of the flood threat is another objective. Mitigation measures have been implemented in many countries with the same objectives. The relevant factors to be considered when adopting stormwater management measures are the geophysical aspects such as the climate, hydrology, land, soil and topography, law and social factors as well as the technical and economic issues. The world is moving more towards green concepts in mitigating stormwater runoff. Some of these measures are Low Impact Designs, Sustainable Urban Drainage System (SUDS) and Water Sensitive Urban Design. SUDS are more attuned to the green concept. The primary goal of SUDS is to switch from pipe-engineered system to practices and systems that use and enhance natural processes, i.e. infiltration, evapotranspiration, filtration and re-use. While conventional drainage systems focus only on the stormwater quantity, SUDS pay attention to all three aspects of quantity, quality and amenity/biodiversity. These measures have their own advantages and shortcomings. This review targets the present the state of the art of SUDS and its importance in stormwater management.

Keywords: Best management practices, Green infrastructure, Green roofs, Stormwater management, Sustainable urban drainage systems, Urbanization

1. Introduction

Stormwater originates from precipitation and melting ice. A significant portion of stormwater infiltrates into the soil. The other portion flows on the surface and is known as surface runoff. Stormwater, when it is in a controllable state, is not a serious issue. However, it becomes one of the most critical issues when there is excessive stormwater runoff and it cannot be controlled. Unlike sewage, stormwater is not treated before it reaches the receiving water in most countries. Therefore, it carries various pollutants including suspended solids, heavy metals, biodegradable organic matter, organic micro-pollutants, pathogenic microorganisms and nutrients [1]. Stormwater washes these pollutants into nearby bodies of water. The impact is much higher in the first flush [2-4]. It has been identified that the largest mass of pollutants are often transported during the initial period/volume of stormwater runoff. This is commonly known as the “first flush” or the “first foul flush” [1]. Phosphorus and nitrogen are two of the most important components in fertilizers. They are very prominent in stormwater runoff. Therefore, many urban streams suffer from increased phosphorous concentrations due to the ubiquitous application of lawn and garden fertilizers. However, urban areas also contribute nitrogen to waterways. This comes from industries. Additionally, metals including lead, zinc, chromium, copper, manganese, nickel and cadmium are common in urban runoff [5-6].

Furthermore, the quantity of stormwater is also a problem [1, 7-8]. The discharge of stormwater into water bodies causes impact depending on the characteristics of the discharge (quality and flow velocity) and the volume and quality of the receiving water [1]. More importantly, the quantity of stormwater matters when it falls on hard or impervious surfaces such as paved roads, roofs, driveways and parking lots [1]. Impervious layers restrict the infiltration and increase surface runoff. Figure 1 clearly shows the accumulation of stormwater due to limited infiltration.

Urbanization increases the impervious area. It is well understood that urbanization increases surface water runoff [9]. Human activities including removal of vegetative surfaces, conversion of raw land into impervious pavement,

*Corresponding author. Tel.: +6140 6468212
Email address: upakasanjeewa@gmail.com
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Figure 1 Accumulated stormwater at the Sri Lanka Institute of Information Technology (SLIIT) (Photo curiosity: Mr. Babishya Khaniya, undergraduate student, Faculty of Engineering, SLIIT, Sri Lanka)

and filling in of natural ponds and streams. These directly increase the impervious area. Some studies show that impervious area increased by about 255% over a 34 year period. This research work was carried in the Snohomish water resources area of western Washington. It clearly shows the adverse impact to surface water runoff [10]. The situation is much worse in China. The amount of urbanized land increased by 43.46% in the years 2000 to 2008 in China. However, the impervious area increased by 53.30% in the same period [11]. This is a good example showing the relationship between urbanization and increased impervious area. Figure 2 further illustrates the temporal variation of impervious area in Urumqi, China from 1990 to 2010 [12]. Impervious area increased from 25% to 63% over 20 years.

Greater impervious area increases surface runoff and can cause local flooding. Additionally, high volume flows can cause other impacts to nature. River banks can be eroded due to higher flow rates and wildlife habitats can be destroyed. Uncontrolled stormwater runoff is one of the main causes of stream impairment in urban areas [13-14]. Therefore, stormwater planning and management are very important. Thus, this review paper presents the state of the art of sustainable urban drainage systems (SUDS) and its importance in stormwater management all over the world.

2. Stormwater management

Stormwater management is the management of the quantity and quality of stormwater. The general advantages of stormwater management include mitigation the damage to the property, protection of the natural water bodies from pollution, to provide the economic benefits, and to promote public health. However, unplanned stormwater runoffs have to be treated in an engineered system. Over the past couple of decades, many countries have implemented new policies to address stormwater runoff. Unplanned stormwater runoff (or excessive stormwater runoff) can be triggered due to reduced infiltration, altered riparian ecology and frequent peak stream flows [15]. It has a direct impact upon the livelihoods of people, irrespective of geographic or climatic regions [16]. Stormwater management frequently follows Best Management Practices (BMPs). BMPs are techniques or structural measures that can be used to better control stormwater flow and its quality. They are used to maintain an acceptable level of quality, including reducing sediment, nutrients and other contaminants before the stormwater reaches natural water bodies.

3. Sustainable urban drainage system (SUDS)

Structural and non-structural measures are quite common in stormwater management. Both developing and developed countries follow structural measures. However, several countries now use non-structural ways to control stormwater. The world has moved mostly towards green measures in mitigating stormwater runoff [17-19]. Under these measures, municipalities try to reduce stormwater runoff at its origin [20-21]. One of these emerging practices is "Sustainable Urban Drainage Systems”, commonly called SUDS.

In an organically rich environment (humus soil), a significant volume of rainfall soaks into the ground through infiltration [22]. However, this is reduced in urban areas where the land is paved by various impervious materials. Conventional drainage networks are designed to transport stormwater to natural water bodies or wastewater treatment plants. These can either be stormwater networks (where only stormwater is transported) or combined sewers (where stormwater it’s transported with wastewater) [23-24]. Separate drainage systems to collect stormwater and wastewater can be seen in Australia. However, combined systems are common in other places. During stormy periods, downstream floods are frequent due to this stormwater.

However, SUDS offers a sustainable solution to flooding. SUDS switches from piped engineered system to practices and systems that use and enhance natural processes (i.e., infiltration, evapotranspiration, filtration, retention and reuse). It provides drainage solutions by introducing alternatives to the direct channeling of stormwater runoff through pipes and sewers to nearby water resources [25]. SUDS uses a set of techniques that is collectively referred as the “Management Train”. This includes four key steps: source control, pre-treatment, retention and infiltration. The other objectives of implementing SUDS are reducing surface water flooding, improving water quality and enhancing the amenity and biodiversity of the environment. In achieving the above objectives, SUDS reduces flow rates, the transport of pollution to the environment and increases the water storage capacity.

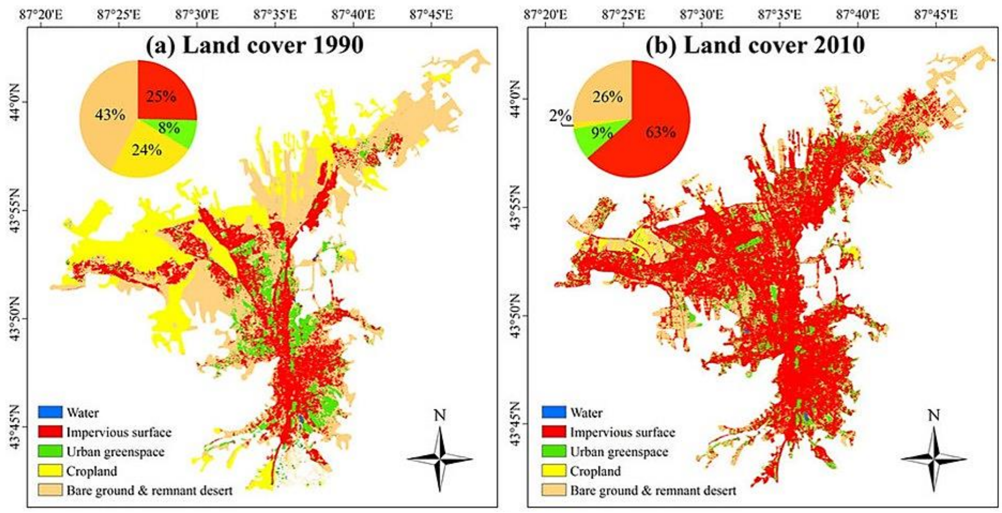

Figure 2 Land cover change over the years [12]

(a) (b)

Figure 3 a: An ecological swale with river gravel making up a flow flow channel [26]; b: SUDS at the Royal North Shore Hospital, Sydney, Australia (Photo curiosity: Ms. Uvini Sirishantha, Instructor, Faculty of Engineering, SLIIT, Sri Lanka)

Figure 3a shows an ecological swale [26] developed by the University of Sains in Malaysia to simultaneously reduce surface runoff velocity and increase infiltration. River gravel was used to enhance the porosity of the contact ground to increase the infiltration.

Figure 3b shows the application of SUDS at the Royal North Shore Hospital, Sydney, Australia. There is clear space for SUDS between the roads and the footpath. A green area with a highly porous soil allows infiltration of much stormwater and the nearby screen shown in the figure allows excessive stormwater to run into a drain.

While the conventional piped system mainly addresses the stormwater quantity control, SUDS pays attention to all three aspects of stormwater, i.e., its quantity, quality and amenity/biodiversity [27-28]. Figure 4 shows couple of plants (*Schoenoplectus tabernaemontani* and *Juncus edgariae*) [29] after being submerged for one year in a synthetic stormwater to experiment the capture of various pollutants in stormwater. The experiments were done in New Zealand yielding sound results.

Additionally, climate change [30-31] and urbanization [29, 32] are believed to be two of the main reasons for urban flooding. Many researchers have found that the frequency and magnitude of flooding are increasing as a result of climate change. Concurrently, urbanization plays an important role in degrading the quality of stormwater. Therefore, SUDS can be an effective solution to aforementioned issues of stormwater runoff.

Figure 4 Plants from vegetated floating mats [29]

4. SUDS renamed?

SUDS have been implemented in many countries under different names. In Europe, SUDS are being implemented with the goals of maintaining public health, protecting valuable water resources from pollution and preserving biological diversity and natural resources for future needs. In Australia, a similar catchment-wide approach is being practiced under the name, Water Sensitive Urban Design (WSUD), where SUDS is a part of the design. It sustainably integrates urban water management into city landscapes to minimize environmental degradation. In the United States and Canada, Low Impact Development (LID) measures are practiced. These acts as an approach promoting the

Minor and Major System

Micro, Minor and Major Systems

Figure 5 Comparison of conventional and renewed urban drainage system [33]

interaction of natural processes with urban environments to conserves and uses natural features to mitigate the adverse impacts of urbanization [1]. However, the main role of any system is to reduce the adverse impacts of increasing volumes of polluted stormwater runoff.

5. SUDS vs conventional drainage systems

Conventional drainage systems were designed and implemented with the main goal of managing stormwater volumes to avoid or reduce urban flooding. Conventional drainage systems are comprised of many structural components, e.g., concrete pipes, manholes and storage facilities. Therefore, the construction and installation costs of conventional drainage systems are high. Additionally, the burden on the existing drainage systems is high because of increased stormwater flows resulting from climate change and urbanization. Therefore, new construction is necessary if the authorities are to rely on conventional drainage systems. However, such construction disrupts the general public. So, this solution is not sustainable. Conventional drainage systems are more challenging. SUDS can overcome these issues. The early objectives of SUDS were to provide a convenient cleaning mechanism to promote public hygiene and to provide flood protection [9]. Nevertheless, SUDS today have enhanced capabilities by adding recreational value, ecological protection to aquatic environments and pollutant control along with the provision doe other water uses.

Figure 5 shows another example of a practical application of SUDS [33]. This shows a comparison of a conventional approach to a SUDS upgraded drainage system in Colarado, in the USA. Stormwater runoff from impervious surfaces drains into a micro-flow system, where a filtration process takes place. Porous pavers, grass swales and bio-retention basins can be fitted into this micro-flow system. The overflow from this layer is directed to drains along the streets. However, conventional systems only collect stormwater through the roadside drains.

6. SUDS in action

SUDS gives equal importance to stormwater quantity, quality and biodiversity/amenity. It considers the technical, environmental, social and economic impacts of stormwater runoff [28]. Various techniques have been adopted to satisfy the three goals of SUDS, runoff attenuation and mitigation, pollutant reduction and amenity construction. The filters and infiltration trenches, permeable surfaces, water storage areas, swales, water harvesting, detention basins, wetlands and ponds are major devices that have been used. From a hydrological point of view based on the impacts on water runoff and routing processes, SUDS act as a source control measure, an on-site control measure and a downstream measure [34]. It is expected to keep the excess stormwater runoff upstream to delay the downstream flow. Next on-site control is necessary to prevent flooding and to minimize flood damage. Finally, downstream measures are required to efficiently control the upstream flow to reduce the runoff and increase the infiltration.

SUDS have many advantages. They reduces the peak flow in the hydrograph. It helps to improve the water quality and naturally mitigate waterborne deceases. Additionally, SUDS provide a temporary storage in the event of extreme rainfall to keep downstream areas safe from flooding while recharging the ground water table. SUDS have some disadvantages too. The stormwater infiltration trenches can become clogged by sediment over time and their life span reduced [35]. This is costly. Therefore, sediment traps are necessary in the upstream infiltration trenches [36].

7. Implementing Green Infrastructure (GI) in stormwater runoff mitigation

Green infrastructure (GI) is an intergral component of SUDS approaches [37]. GI can be defined as any green spaces that are interconnected to protect nature and benefit mankind, flora and fauna [38-39]. It is a way of managing stormwater runoff by infiltration into the soil or reducing runoff through reuse [40]. The utmost motive behind implementation of GI is to improve the quality of prevailing surface conditions while managing stormwater in a sustainable manner.

GI can be implemented through structural and non-structural measures such as green roofs, rainwater tanks, wetlands. Pervious pavements, bio-swales, planter boxes, cisterns and rain barrels are examples of structural GIs [39]. Non-structural measures include policy decisions to design buildings and roads to minimize impervious area, improve the infiltration capacity of soils and increase vegetation cover [41].

Computer models play an important role in implementing GIs. They can make highly accurate predictions. Therefore, their use in GIs is becoming popular. RECARGA [42], P8 Urban Catchment Model [43], SWMM 5.0 [44-45], MUSIC [46], SUSTAIN [47] and WinSLAMM [48] are few computer models used by researchers and industrial designers. Computer models of green architecture enhance the accuracy of simulation results. SWMM by United States Environmental Protection Agency (US EPA) provides for more benefits than other models as it can be used in more complex, large-scale projects. It is one of the most sophisticated tools in modeling stormwater quality, quantity and GI performance [39, 44].

Green infrastructure has growing public interest in recent years due to its provision for eco-system services. Energy savings, air quality improvement, mitigation of climate change impacts can be achieved by reducing greenhouse gases, and increasing the green cover. These are a few of the eco–system services of GI [39].

8. Source control as an approach

As was previously discussed, the increase of impervious surfaces associated with urban development is partially responsible for the current stormwater management issues. Structural infrastructure has been introduced to address these management issues. However, they provide temporary and short term solutions in storing excess water. Source control is a good solution due to the area limitations in urban zones. It has many benefits over traditional approaches [49-51]. Identifying stormwater problems and implementing necessary solutions at the origin is the basis of the source control [52]. Green roofs and pervious pavements are widely used source control structures.

9. Green roof - an emerging trend

Green roofs reduce stormwater runoff volume by retaining a portion of the precipitation. They use the existing roofs and space limitations are not an issue in urban areas. Many researchers have shown that the there is a significant reduction in stormwater runoff from green roofs [53-54]. Additionally, green roofs keep buildings cooler during the summer months [55]. Furthermore, green roofs can return water to the atmosphere by evapotranspiration [56]. Land use information, basin information, precipitation and the potential for evapotranspiration are important input variables when designing green roofs [52]. Researchers found that the total the area coverages is more important than the thickness of the green roof. The initial costs for construction of these green roofs is high. However, over a longer term, green roofs are economical [56].

Figure 6 [57] shows green roofs that were tested by the United States Environmental Protection Agency (US EPA). Successful application of green roofs can be clearly seen by the growth of the plants in green roof after a six month and one year timeframe.

10. SUDS in various climatic regions

SUDS have been successfully applied in many climatic regions. However, there are some differences from region to region. Scandinavian countries have a six month winter season. Therefore, countries like Norway, Sweden and Finland have to implement their SUDS during the non-winter seasons. They also have to maintain their systems properly. However, these countries use country specific guidelines for stormwater control [58].

However, there is a slight advantage in stormwater control in cold climates in winter. Snow takes a time to melt and there is no sudden stormwater flow during the winter. Instead, the snow can infiltrate into the soil later. Nevertheless, there can be problems in the spring. There may be sudden snow melting due to the rising temperatures. Additionally, frozen soil and dormant biological functions lead for poor stormwater management during the winter months [59]. However, the findings of Roseen *et al.*, [59] showed that LIDs were not affected by seasonal effects whereas hydrodynamic separators and swales exhibited large seasonal variations. Therefore, these structures have to be oversized.

Stormwater management in dry or desert areas is interesting and has not been given enough attention. Many people believe there are no significant issues in stormwater management in arid regions as they receive little precipitation on an annual basis [60]. There are some arid regions with significant amounts of precipitation, but with lower event frequencies. The characteristics of the precipitation in areas with large inter-storm durations should be considered in stormwater management for arid areas. This is similar the case of humid and trophic environments [61]. Consideration of the climatic region is an important factor in selecting the correct SUDS approach in stormwater management.

11. Final remarks and conclusions

Stormwater runoff has recently been a topic under discussion. This is largely due to the immeasurable damage it causes socially, environmentally and economically. Therefore, measures addressing this issue should be implemented. Recent research has shown green adoption measures to be more sustainable and eco-friendly than most

(a) (b)

Figure 6 An example of a green roof in a SUDS: (a) in November 2003 and (b) in June 2005 [57] of the structural mitigation measures. Thus, green approaches have gained popularity. One such emerging green trend is Sustainable Urban Drainage Systems (SUDS). This review touches the state-of the-art of SUDS as practiced in today's world.

SUDS have augmented conventional drainage pipe networks with their economic and environmentally friendly benefits. They have proven to be a good solution for stormwater management. These systems avoid floods by providing temporary water storage during extreme rainfall events. They adds aesthetical value to the areas in which they are located. Furthermore, the can attract wildlife thus creating new habitats promoting bio-diversity. In this way, SUDS increase the amenity of the environment.

SUDS also have some barriers to their application. Expert knowledge is required when implementing and maintaining them. Additionally, the cost to convert from conventional drainage systems to SUDS is high. Furthermore, their infiltration trenches can become clogged over time providing hindering the performance of such systems. Every system has its benefits and its shortcomings. Efficient performance can be expected when the necessary modifications are made before adopting the measures. This review examines green measures that have been implemented so far, the reasons for using them and their shortcomings. It is important to note that different measures can be adopted considering the various characteristics that change from region to region. Appropriate modifications should be made to design the best systems possible.

12. References

[1] Barbosa AE, Fernandes JN, David LM. Key issues for sustainable urban stormwater management. Water Res. 2012;46:6787-98.

[2] Hathaway JM, Tucker RS, Spooner JM, Hunt WF. A traditional analysis of the first flush effect for nutrients in stormwater runoff from two small urban catchments. Water Air Soil Pollut. 2012;223(9):5903-15.

[3] Miguntanna NP, Liu A, Egodawatta P, Goonetileke A. Characterising nutrients wash-off for effective urban stormwater treatment design. J Environ Manag. 2013;120:61-7.

[4] Schiff KC, Tiefenthaler LL, Bay SM, Greenstein DJ. Effects of rainfall intensity and duration on the first flush from parking lots. Water. 2016;8:320-9.

[5] Reddy KR, Xie T, Dastgheibi S. Removal of heavy metals from urban stormwater runoff using different filter materials. J Environ Chem Eng. 2014;2(1):282-92.

[6] Jang A, Seo Y, Bishop PL. The removal of heavy metals in urban runoff by sorption on mulch. Environ Pollut. 2005;133(1):117-27.

[7] Brattebo BO, Booth DB. Long-term stormwater quantity and quality performance of permeable pavement systems. Water Res. 2003;37(18):4369-76.

[8] Dotto CB, Mannina G, Kleidorfer M, Vessaro L, Hentichs M, McCarthya DT, et al. Compassion of different uncertainty techniques in urban stormwater quality and quantity. Water Res. 2012;46(8):2545-58.

[9] Zhou Q. A review of sustainable urban drainage systems considering the climate change and urbanizatinon impacts. Water. 2014;6:976-99.

[10] Powell SL, Cohen WB, Yang Z, Pierce JD, Alberti M. Quantification of impervious surface in the Snohomish Water Resources Inventory Area of Western Washington from 1972–2006. Rem Sens Environ. 2008;112(4):1895-908.

[11] Kuang W, Liu J, Zhang Z, Lu D, Xiang B. Spatiotemporal dynamics of impervious surface areas across China during the early 21st century. Chin Sci Bull. 2012;58(14):1691-701.

[12] Yan Y, Kuang W, Zhang C, Chen C. Impacts of impervious surface expansion on soil organic carbon – a spatially explicit study. Sci Rep. 2015;5: 1-9.

[13] Paul MJ, Judy LM. Streams in the urban landscape. Annu Rev Ecol Systemat. 2001;32:333-65.

[14] Pitt R, Field R, Lalor M, Brown M. Urban stormwater toxic pollutants: assessment, sources, and treatability. Water Environ Res. 1995;67(3):260-75.

[15] Loperfido JV, Noe GB, Jarnagin ST, Hogan DM. Effects of distributed and centralized stormwater best management practices and land cover on urban stream hydrology at the catchment scale. J Hydrol. 2014;519:2584-95.

[16] Gautam MR, Acharya K, Stone M. Best management practices for stormwater management in the Desert Southwest. J Contemp Water Res Educ. 2010;146:30-49.

[17] Rushton B. Low-impact parking lot design reduces runoff and pollutant loads. J Water Resour Plann Manag. 2001;127(3):172-9.

[18] Bliss DJ, Neufeld RD, Ries RJ. Stormwater runoff mitigation using a green roof. Environ Eng Sci. 2009;26(2):407-18.

[19] Stovin V. The potential of green roofs to manage urban stormwater. Water Environ J. 2010;24(3):192-9.

[20] Sieker F. On-site stormwater management as an alternative to conventional sewer systems: a new concept spreading in Germany. Water Sci Tech. 1998;38(10):65-71.

[21] Van der Sterren M, Rahman A, Shrestha S, Barker G, Ryan, G. An overview of on-site retention and detention policies for urban stormwater management in the Greater Western Sydney Region in Australia. Water Int. 2009;34(3):362-72.

[22] Martens D, Frankenberger W, Modification of infiltration rates in an organic-amended irrigated. Agron J. 1992;84(4):707-17.

[23] Brombach H, Weiss G, Fuchs S. A new database on urban runoff pollution: comparison of separate and combined sewer systems. Water Sci Tech. 2005;51(2):119-28.

[24] De Toffol S, Engelhard C, Rauch W. Combined sewer system versus separate system - a comparison of ecological and economical performance indicators. Water Sci Tech. 2007;55(4):255-64.

[25] Mohammadhossein K, Zulkifli BY, Ali H. Advancing stormwater management practice in Iran using water sensitive urban design approach. Int J Water Resour Environ Eng. 2013;5(9):515-20.

[26] Ghani AA, Zakaria NA, Chang CK, Ainan A. Sustainable Urban Drainage System (SUDS) - Malaysian experiences. 11th International Conference on Urban Drainage; 2008 Aug 31 – Sep 5; Edinburgh, Scotland. 2008. p. 1-10.

[27] Apostolaki S, Jefferies C, Wild T. The social impacts of stormwater management techniques. Water Pract Tech. 2006;1(1):1-8.

[28] Perales-Momparler S, Andres-Domenech I, Joaquin A, Escuder-Buenob I. A regenerative urban stormwater management methodology: the journey of a Mediterranean city. J Clean Prod. 2015;109:174-89.

[29] Tanner CC, Headley TR. Components of floating emergent macrophyte treatment wetland influencing removal of stormwater pollutants. Ecol Eng. 2011;37:474-86.

[30] Brouwer R, Akter S, Brander L, Haque E. Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh. Risk Anal. 2007;27(2):313-26.

[31] Botzen WJW, Van den Bergh WJCJM. Insurance against climate change and flooding in the Netherlands: present, future, and comparison with other countries. Risk Anal. 2008;28(2):413-26.

[32] Suriya S, Mudgal BV. Impact of urbanization on flooding: The Thirusoolam sub watershed - a case study. J Hydrol. 2012;412-413:210-19.

[33] Guo CYJ. Green concept in stormwater management. Irrigat Drain Syst Eng. 2013;2(3):1-8.

[34] Hoang L, Fenner RA. System interactions of stormwater management using sustainable urban drainage systems and green infrastructure. Urban Water J. 2015;13(7):739-58.

[35] Heal KV, Hepbum DA, Lunn RI. Sedimentation and sediment quality in sustainable urban drainage systems. Proc. Second National Conference on Sustainable Drainage Coventry University; 2003 Jun 23-24 June; Coventry, UK. 2003. p. 215-26.

[36] Revitt DM, Shutes RBE, Jones RH, Forshaw M, Winter B. The performances of vegetative treatment systems for highway runoff during dry and wet conditions. Sci Total Environ. 2004;334-335: 261-70.

[37] Mguni P, Herslund L, Jensen M. Sustainable urban drainage systems: examining the potential for green infrastructure-based stormwater management for Sub-Saharan cities. Nat Hazards. 2016;82(S2):241-57.

[38] Benedict MA, McMahon ET. Green infrastructure: smart conservation for the 21st century. Washington: Sprawl Watch Clearinghouse; 2005.

[39] Jayasooriya VM, Ng AWM. Tools for modeling of stormwater management and economics of green infrastructure practices: a review. Water Air Soil Pollut. 2014;225(2055):1-20.

[40] Wise S. Green infrastructure rising. Planning. 2008;74: 14–9.

[41] Elliot AH, Trowsdale SA. A review of models for low impact urban stormwater drainage. Environ Model Software. 2007;22:394-405.

[42] Neilson I, Turney D. Green infrastructure optimization analyses for combined sewer overflow (CSO) control. Low Impact Development international conference 2010; 2010 Apr 11-14; California, United States. Virginia: American Society of Civil Engineers; 2012. p. 1533-41.

[43] Haris H, Chow MF, Usman F, Sidek LM, Roseli ZA, Norlida MD. Urban stormwater management model and tools for designing stormwater management of green infrastructure practices. IOP Conf Ser: Earth Environ Sci. 2016;32:1-18.

[44] Rathnayake US. Migrating storms and optimal control of urban sewer networks. Hydrology. 2015;2(4):230-41.

[45] Rathnayake US. Enhanced water quality modeling for optimal control of drainage systems under SWMM constraint handling approach. Asian J Water Environ Pollut. 2015;12(2):81-5.

[46] Beck HJ, Birch GF. The magnitude of variability produced by methods used to estimate annual stormwater contaminant loads for highly urbanised catchments. Environ Monit Assess. 2012;185(6): 5209-20.

[47] Zhen X, Yu S, Lin J. Optimal location and sizing of stormwater basins at watershed scale. J Water Resour Plann Manag. 2004;130(4):339-47.

[48] Pitt R, Clark S. Integrated storm-water management for watershed sustainability. J Irrigat Drain Eng. 2008;134(5):548-55.

[49] Delleur J. The evolution of urban hydrology: past, present, and future. J Hydraul Eng. 2003;129:563-73.

[50] Urbonas BR, Jones JE. Summary of emergent urban stormwater themes. In: Urbonas BR, Editor. Engineering Foundation Conference 2001: Linking Stormwater BMP Designs and Performance to Receiving Water Impact Mitigation; 2001 Aug 19-24; Colorado, USA. Virginia: American Society of Civil Engineers; 2012. p. 1-8.

[51] Petrucci G, Rioust E, Deroubaix JF, Tassin B. Do stormwater source control policies deliver the right hydrologic outcomes?. J Hydrol. 2013;485:188-200.

[52] Versini PA, Jouve P, Ramier D, Berthier E, Gouvello B. Use of green roofs to solve stormwater issues at the basin scale-Study in the Hauts-de-Seine County (France). Urban Water J. 2016;13(4):1-11.

[53] Uhl M, Schiedt L. Green roof storm water retention-monitoring results. 11th International Conference on Urban Drainage; 2008 Aug 31 – Sep 5; Edinburgh, Scotland. 2008. p. 1-10.

[54] Gregoire BG, Clausen JC. Effect of a modular extensive green roof on stormwater runoff and water quality. Ecol Eng. 2011;37(6):963-9.

[55] Barrio EPD. Analysis of the green roofs cooling potential in buildings. Energ Build. 1998;27(2):179-93.

[56] Oberndorfer E, Lundholm J, Bass B, Coffman RR, Doshi H, Dunnett N, et al. Green roofs as urban ecosystems: ecological structures, functions and services. BioScience. 2007;57(10):823-33.

[57] Berghage RD, Beattie D, Jarrett AR, Thuring C, Razaei F, O'Connor TP. Green roofs for stormwater runoff control. Cincinnati: US EPA; 2009.

[58] Nie LM, Lindholm OG, Thorolfsson S, Sægrov S, Åstebøl SO. Integrated urban stormwater management in Norway. 12th International Conference on Urban Drainage; 2011 Sep 10-15; Porto Alegre, Brazil. 2011. p. 1-9.

[59] Roseen RM, Ballestero TP, Houle JJ, Avellaneda P, Brigg J, Fowler G, et al. Seasonal performance variations for stormwater management systems in cold climate conditions. J Environ Eng. 2009;135(3):128-37.

[60] Gautam MR, Acharya K, Stone M. Best management practices for stormwater management in the Desert Southwest. J Contemp Water Res Educ. 2010;146(1):39-49.

[61] Rivard G, Rinfret L, Davidson S, Morin PL, Corrales MV, Kompaniets S. Applying stormwater management concepts in tropical countries. J Water Manag Model. 2006;53-74.