iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VIII **Month of publication:** August 2021

DOI: https://doi.org/10.22214/ijraset.2021.37842

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com

A Study on Implementation of Low Impact Development as an Urban Stormwater Management Technique in Srinagar City: Current Trends, Issues and Challenges

Basrah Bilal[1], Er. Gulam Mohi-ud-din Rather[2]
[1]*B.E 8th Semester Student, Department of Civil Engineering, SSM College of Engineering, Divar, Parihaspora Pattan, Baramulla, Kashmir-193121, India*
[2]*Associate Professor, Department of Civil Engineering, SSM College of Engineering, Divar, Parihaspora Pattan, Baramulla, Kashmir-193121, India*

Abstract: The Severity as well as the frequency of short-duration, but damaging, urban area floods have increased in recent years across the world. Alteration to the urban micro-climate due to global climate change impacts may also exacerbate the situation in the near future. The events of floods have increased in Srinagar city as well over the past decades. Sustainable urban stormwater management using low impact development (LID) techniques, along with conventional urban stormwater management systems, can be implemented to mitigate climate-change-induced flood impacts in Srinagar. In this study, the supposed effectiveness of LIDs in the mitigation of urban flood in Srinagar city is analysed keeping in view their limitations at the same time. A critical research on the success of these techniques in urban flood mitigation planning in Srinagar city is also recommended. On summarising different LID approaches in the world, the results revealed that LIDs can be an efficient method for mitigating urban flood impacts. Most of the LID devices developed so far, however, are found to be effective only for small flood peaks. The major challenges include identification of the best LID practices for the region of interest, efficiency improvements in technical areas, and site-specific optimization of LID parameters. Research and improvements in these areas will allow better mitigation of climate-change-induced urban floods in a cost-effective manner and will also assist in the achievement of sustainable development goals for Srinagar city and will help us to tackle the increasing problems of water logging and floods in the summer capital of Jammu and Kashmir.
Keywords: Climate change, Urban floods, stormwater management, Low Impact Development, Srinagar city, Drainage in Srinagar, Pluvial flooding.

I. INTRODUCTION

Stormwater management means to manage surface runoff water. Urban water management systems, especially in cities and towns, are largely based on traditional Engineering approaches. Urban drainage Systems, for example, are usually developed to clear the city of stormwater as quickly as possible resulting in increased imperviousness in urban areas. However, in the last few decades, an increase in the frequency of extreme weather events such as high intensity rainfalls have been observed which has led to pluvial flooding in urban areas as a critical issue. Many contemporary cities are vulnerable to pluvial flooding including the Srinagar city and associated risks are projected to increase with global climate changes and urban population growth.

A. Srinagar City

Srinagar city is located in Kashmir basin of the Union Territory of Jammu and Kashmir (India).The City has two main physical divisions (the Right River Division and the Left River Division) with a total of 68 municipal wards. Right river division is spread over two administrative zones- east zone with eight administrative wards comprising 17 electoral wards and the north zone with nine administrative wards having 17 electoral wards. The left river division is also spread over two administrative zones –the west zone with eight administrative wards comprising 15 electoral wards and the south zone with nine administrative wards comprising 19 electoral wards (SMC 2011, www.smcsite.org/zonedetails.php). Srinagar is not only the largest urban center both in terms of population and areal extent but also the rapidly growing city amongst all Himalayan urban centers (Bhat, 2008), which is evident from the fact that the area of the city has increased from 12 sq.km in 1901 to 300 sq.km in 2011 (SMC, 2011). The city has also been listed as one of the hundred (92nd) fastest growing cities of the world on the basis of average annual growth rate from 2006 to

2020 (www.citymayors.com/statistics/urban_growth1.html). Owing to its geomorphicconfiguration and seismically active location, the Kashmir basin is exposed to various natural hazards such as floods, earthquakes, landslides and snow avalanches; however, flooding is the most recurrent phenomenon in the basin, especially in the Srinagar city. There are records of flood occurrences and associated losses in the city that date back to 3000 BC. Pertinently, simulations based on instrumental record of annual peak flows (1956-2014) from Ram Munshi Bagh gauging station of River Jhelum within the city points towards the fact that the frequency of floods may increase in future. Thus, it is imperative to have comprehensive and reliable estimates of flood risk in the Srinagar city and simultaneously study the necessary measures to tackle the issue at the earliest possible.

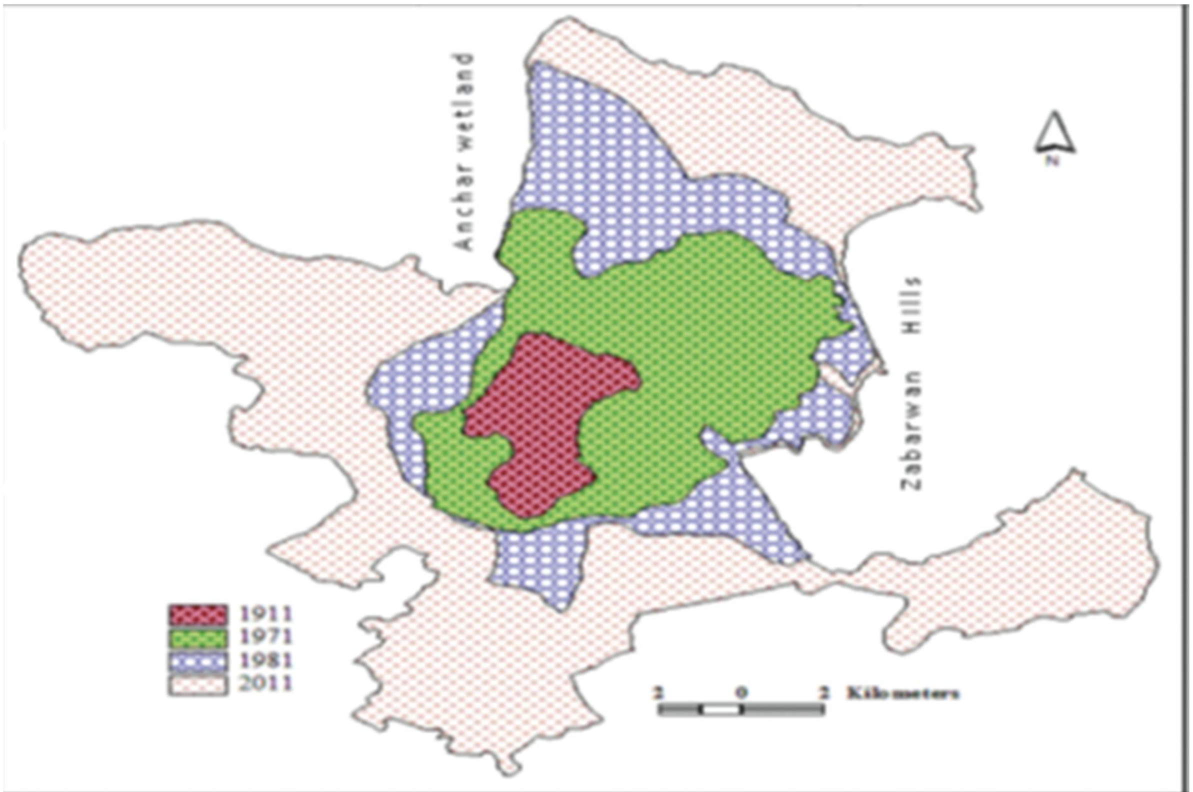


Fig 1. Srinagar City Urban Sprawl (1911-2011) for Urban Expansion.

B. 2014 Floods

Damage due to floods is always a consequence of both the water depth and the flow velocity. Spatial variation in intensity of the flood hazards is determined on the basis inundation i.e., more the flood water depth, more is the possibility of damage and vice versa is also true. During September 2014, extreme flooding was experienced in different parts of South Asia. The transboundary flood event resulted in widespread destruction and colossal loss of life and property in the Kashmir basin of union territory of Jammu and Kashmir. With estimated discharge of

approximately 1,15,218 cusecs upstream at Sangam and 72,585 cusecs downstream at Ram Munshi Bagh gauging stations in Srinagar city, the discharge was declared as the highest ever recorded on the trunk river (Jhelum) of Kashmir basin (Irrigation and Flood Control Department, 2014, www.jkirfc.com/). The flood resulted in death of 282 people and damage to 2.53 lakh houses across the union territory of Jammu and Kashmir (www.greaterkashmir.com/.../-282-people-died-2...jk-floods/181241.html). During this flood event, about 60 per cent of the Srinagar city's area was submerged under water witnessing the water depth up to 16 feet (e.g., in the localities of Rajbagh, Jawahar Nagar, Gogji Bagh) and extended inundation period of approximately 25 days in the residential areas including the Central Business District (CBD) of the city. More than 0.6 million people were stranded in the submerged housing colonies of Srinagar for more than a week without drinking water, food and other essentials. Although the impact of flood (2014) was evident in both the flooded and non-flooded zones, the built-up growth was reduced significantly in the flooded zone (−25.18% change) in comparison to the non-flooded zones (−17.32% change). Also, the long-term recovery was comparatively seen as higher in the non-flooded zone (31.84% growth) as compared to the flooded zone (28.03% growth).

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com

II. RELATED WORKS

1) Ahiablame, l., Shakya, R., in 2016 did a project "Modeling flood reduction effects of low impact development at a watershed scale" published in Environ. Manage. 171, 81–91 and found out 3-47% reduction in runoff by using three types of LIDs in Central Illinois, USA.
2) Ahmed, K., Chung, E.-S., Song, J.-Y., Shahid, S. in 2017 published "Effective Design and Planning Specification of Low Impact Development Practices Using Water Management Analysis Module (WMAM): Case of Malaysia" and concluded that LID can reduce pick flow in the range of 17.5% to 20.95% in Johor, Malaysia.
3) Chen, Y., Tan, M., Wan, J., Weise, T., Wu, Z. in 2020 published "Effectiveness evaluation of the coupled LIDs from the watershed scale based on remote sensing image processing and SWMM simulation" and concluded that a reduction of runoff amount by 46.09% and peak flow rate by 11.45% was seen in Jinan, China.
4) Du, S., Wang, C., Shen, J., Wen, J., Gao, J., Wu, J., Lin, W., Xu, H. in 2019 did "Mapping the capacity of concave green land in mitigating urban pluvial floods and its beneficiaries" in Central Shanghai, China and found a reduction of flood volume by 23,6-98 4%, inundation extents by 26.1-82.4% and flood depth of 0.1-0.2m.
5) Eckart, K., McPhee, Z., Bolisetti, T. in 2017 published "Performance and implementation of low impact development – A review" using four different LID devices in Ontario, Canada and concluded that it is the most cost-effective LID in the reduction of flood peak.
6) Ghodsi, S.H., Zahmatkesh, Z., Goharian, E., Kerachian, R., Zhu, Z. in 2020 published "Optimal design of low impact development practices in response to climate change" and concluded a reduction of flood volume up to 18% and this research was done in Northeastern Tehran, Iran.

III. NECESSITY OF NEW AND IMPROVED STRATEGIES IN SRINAGAR CITY TO TACKLE FUTURE URBAN FLOODS

With a population of about 16.47 lakh, Srinagar city has a rainfall intensity of around 2853 mm or 112.3 inch per year. Stormwater runoff has historically been addressed by way of engineered systems with a standard technique being used drain/channel conveyance which is true for Srinagar as well. Drains as conveyance helps move the water to a specific discharge point through drains on roads. The Drainage channel conveyance systems, unfortunately, are singular in function and do not provide any additional ecological benefits. They do very little to prevent stormwater runoff from occurring in the first place. They are just a way of getting rid of stormwater. They do not facilitate source absorption and their use does not get us closer to the natural hydrologic cycle. Even though the National Mission on Sustainable Habitat suggests that 2-5 per cent of municipal area should be reserved for water bodies still there is no legal protection for city lakes, catchment and drainage systems. A Stormwater Management System (SWMS) is generally designed to handle runoff from a 10 to 20 year return period. It normally does not consider any changes to the land-use and associated landcover of catchment area in which it is located. Urban development, however, is a continuous process that leads to modified land use and an increased amount of paved (i.e. impervious) surface. This increases the surface runoff volume and thus can exceed the design capacity of the SWMS. In this case, retrofitting of the SWMS may be required, on the basis of revised design criteria (including return periods) which take account of the new catchment characteristics.

It is worth noting that in Srinagar City many urban water bodies and their catchment have been encroached upon or taken away for housing and other buildings. Nowadays, wetlands are being recognized as "wastelands" and have been serving as grounds for a variety of waste materials and the increasing trend of conversion of agricultural lands into urban areas is currently one of the dominant patterns of land use change in the valley of Kashmir. This pattern of land use change has the potential to alter the composition and functional processes of wetlands by changing the hydrological regimes and sedimentation processes along with the flux of nutrient materials. The ecological consequences of agricultural runoff and municipal wastewater discharges have resulted into widespread and the conversion of forested and agricultural areas into built up areas has impaired the water quality that has led to the extirpation of local populations of aquatic species. As a consequence, many freshwater wetlands have altogether vanished or are facing severe anthropogenic pressures. The harmful social, financial, and ecological impacts of declining biodiversity and degrading water quality are a serious matter of concern. Most of these wetlands used to act as buffers, soaking flood waters but encroachment and infrastructure development within these wetlands has reduced their water holding capacity, increasing the vulnerability of people toward flooding. The central business hub of Srinagar, the Capital City, is often affected during a normal precipitation event because the drainage channels that used to drain out storm water runoff have mostly been taken over by concrete surface changes in spatial extent of lakes and wetlands in Srinagar are presented in Table 3. As a result of unplanned urbanization, encroachments, and population pressures, about 91.2 km^2 of wetland area has been lost between 1911 and 2004.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com

Table 1. Land system changes within Dal Lake from 1859 to 2013

Class name	Area (km^2)								
	1859	1903	1962	1972	1979	1992	2001	2010	2013
Aquatic vegetation	2.91	1.35	3.85	8.23	9.42	7.75	8.75	10.40	8.64
Builtup	0.05	0.06	0.84	0.68	0.80	1.83	2.10	2.03	2.02
Floating gardens	0.78	0.82	5.66	1.1288	1.39	1.36	2.52	2.70	2.89
Marshy land	1.49	1.44							
Plantation	6.02	3.99	3.63	3.16					
Water	20.59	23.98	13.84	13.19	12.41	13.10	10.68	8.91	10.50
Total	31.84	31.64	27.82	26.40	24.02	24.04	24.04	24.04	24.04

Table 2. Long-term water quality changes in Anchar Lake

Parameter	1970–1972	1975–1976	2018
pH	7.4–9.6	7.5–9.5	7.2–8.3
Dissolved oxygen (mg L^{-1})	6.88–12.32	4.2–10.85	3.5–6.5
Conductivity (μS cm^{-1})	132–385	388–555	200–475
Total alkalinity (mg L^{-1})	53–80	75–130	100–399
Ca (mg L^{-1})	16–30	22–24	48.5–74.5
Mg (mg L^{-1})	10–14	9–13	5.3–9.9
PO_4-P (μg L^{-1})	9–25	12–29	182–698
NO_3-N (μg L^{-1})	90–57	95–580	558–641
NH_4-N (μg L^{-1})	70–85	5–18	231–381
Total P (μg L^{-1})	-	92–666	550–910
Cl (mg L^{-1})	8–10	-	23.5–42

Table 3. Changes in spatial extent of lakes and wetlands of Srinagar between 1911 and 2004

S. No.	Class name	Area (km^2)	
		1991	2004
1	Open water surface	40.00	30.65
2	Wetland/marshy area	134.25	64.07
3	Built-up land	17.45	107.91
4	Others	505.05	494.13
	Total	696.77	696.77

Even though clearly identified pluvial flooding as a major issue in cities during monsoon, the authorities responsible in Indian cities often lack the knowledge and tools required to deal with stormwater management. Development authorities often make use of conventional approaches implemented in developed countries during the 20th century, which aims to evacuate the runoff from the city as quickly as possible rather than endeavour to store and reuse it. Alternative and additional measures (storage /infiltration/delayed surface runoff) remain relatively unknown or unused in cities including Srinagar.

Imperatively we realise the risks of not addressing stormwater management in the early stages of planning and design causes constraints to new development or (re)development, missed opportunities for cost saving, poor quality of urban environment and overall unsustainable urban development.

The need is for more integrated land and stormwater management from early stages to reduce the incidences of urban floods like the 2014 flood.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com

IV. LOW IMPACT DEVELOPMENT

The term *low impact development* (LID) refers to systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater so as to protect water quality and associated aquatic habitat.

At both the site and regional scale, LID practices aim to preserve, restore and create green space using soils, vegetation, and rainwater harvest techniques. LID is an approach to land development (or re-development) which works with nature to manage stormwater as close to its source as possible. LID employs principles like preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. There are many practices that have been used to stick to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels and permeable pavements. By implementing LID principles and practices, water can be managed in a way that decreases the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can balance or restore a watershed's hydrologic and ecological functions.

LID measures can usually be built into the public spaces without compromising their primary function. Another infiltration strategy is to direct runoff from impervious surfaces to pervious surfaces or retention facilities and effective non-structural LID practice is to cluster development at a higher density so as to leave open more natural land, which could be used for infiltration and evapotranspiration. Treatment trains consisting of LID solutions in series or parallel may be effective in managing runoff. A combination of LID and piped systems or BMPs, such as detention ponds, can be the best option for meeting stormwater control objectives. Thus, the main goals of LID principles and practices include runoff reduction (peak and volume), infiltration increase, groundwater recharge, stream protection, and water quality enhancement through pollutant removal mechanics such as filtration, chemical sorption, and biological processes.

A. Overview of Low Impact Development Techniques

Following the LID goals and principles, a large number of techniques are generally classified as LID practices (Table 4). Hunt and Szpir and Hunt et al. published examples of structural and non-structural practices which promote these main goals. Structural practices include bioretention, infiltration wells/trenches, stormwater wetlands, wet ponds, level spreaders, permeable pavements, swales, green roofs, vegetated filter/buffer strips, sand filters, maller culverts, and water harvesting systems (rain barrels/cisterns). However, non-structural practices include minimization of site disturbance, preservation of natural site features, reduction and disconnection of impervious surfaces (i.e., elimination of curbs and gutters), strategic grading, native vegetation utilization, soil amendment and aerification, and minimization of grass lawns. LID promotes processes such as infiltration, filtration, onsite storage and detention, evapotranspiration, absorption, adsorption, precipitation, biodegradation, phytoremediation, and percolation, among others, that reduce the need for a centralized best management practice.

LID Tool	Acronym	Description
Green Parking	RP	A combination of approaches used to reduce parking area and its imperviousness for lowering runoff amount
Green roof or eco-roof	GR	Vegetation planted on water proof membrane on rooftop to provide rain water buffer and reduction of runoff
Rain garden	RG	A vegetated concave with urban landscape designed to store and infiltrate stormwater
Bioretention ponds/cell	BRC	Same as rain garden with some hydraulic structures to enhance storage and subsurface percolation
Bioretention Swales or green swales	SW	Shallow grassed or vegetated channels with side slopes and flat bottom used for runoff water collection and movement
Filter strips/vegetated swales	VS	A long-vegetated ditch designed to slowdown the runoff rate and enhance infiltration
Stream naturalisation	SN	A process of vegetation of riverbed to reduce flow rate and enhance infiltration
Porous pavements	PV	A permeable surface (e.g., pervious concrete, permeable asphalt) to allow subsoil infiltration of surface runoff
Infiltration trench	IT	Shallow concaves with highly permeable soils used for temporary storage of runoff and quick subsurface seepage
Detention pond/rainwater harvesting	DP/RH	An artificial depression in urban landscape to hold stormwater runoff for a longer period
Retention pond	RP	An artificial depression to collect and gradually release runoff collect and water to drainage system.
Rain barrel	RB	Small surface tank for collection of rainwater from rooftop drainpipes
Cisterns	CS	Large subsurface reservoir for storage of surface runoff
Tree boxes	TB	Small bioretention cell placed underneath trees to collect runoff

Table 4. Different LID Tools

B. Effectiveness of Different LIDs in Flood Mitigation

Hydrological performance of LIDs has been assessed in work conducted in various climate regions. Literature related to the use of LID practices to mitigate urban floods is briefly reviewed under this section. Table 5 shows LID practices used in a number of cities and provides an indication of their success in the reduction of flood peak and volume.

Reference	LID	City/Country	Impact
Li et al., (2019)	DP	SA city, China	Nearly 92% reduction of peak flowrate
Palermo et al., (2020)	PV,GR	Paola, Italy	Runoff and peak flowrate reduction up to 45.8% and 54.3% respectively
Chen et al., (2020)	Coupled PV	Jinan, China	Reduction of runoff amount by 46.09% and peak flow rate by 11.45%
Zhang et al., (2020)	Combination of GR, RB,SW	Beijing, China	Reduction of runoff volume by 48.59% peak flow rate 67.29%
Du et al. (2019)	RG	Central Shanghai, China	Reduction of flood volume by 23,6-98 4%, inundation extents by 26.1-82.4% and flood depth of 0.1-0.2m
Ghodsi et al. (2020)	VS, BRC, PV, IT	North-eastern Tehran, Iran	Reduction of flood volume up to 18%
Goncalves et al. (2018)	RG, IT, DP, DP+ RG, DP+ IT	Joinville, South Brazil	Reduction of total flood volume between 30% and 75%. Integration of centralized and decentralized LIDs can provide the best reduction of flood volume
Hu et al. (2018)	Different types of PV	Nanjing, China	PV reduces flood volume by 1–40% and flood peak by 7–43%
Eckart et al. (2018)	RB, PV, BRC, IT	Ontario, Canada	IT is the most cost-effective LID in the reduction of flood peak
Wu et al. (2018)	PV, GR	Shenzhen & Guangdong, China	PV and GR can reduce flood depth by 3–29%; flood coverage by 7–55 %, and flood duration by 0–43%
Zhu et al. (2019)	PV, BRC	Guangzhou, China	PV and BRC can control flood volume. Limited PV coverage can have a significant effect on flood volume
Huang et al. (2018)	PV, BRC, IT, RB, VS, GR, TB	Taipei, Taiwan	Reduce flood peak and timing in the range of 5.75–29.80% and 12.50–20%, respectively at local; and 9.52%–23.49% and 12.50%–37.5% at the sub-catchment scales
Hu et al. (2017)	RH, PV	Nanjing, China	Reduce flood inundation areas by 2–17% and flood hazard level by 6–80%
Juan et al. 2017	RB, SW, GR, RG	Houston, Texas, USA	Varying degrees of reduction in peak discharge and runoff volume
Kong et al. 2017	GR, PV, VS, RG	Bazhong, China	LIDs contribute to a significant reduction of flood
Li et al. 2017a	BRC, RB, SW, GR, PV	Xi'an, China	The effectiveness of LIDs in mitigating floods can be ordered as BRC > RB > SW > GR > PV. BRC and GR are the optimal LID combination
Ahmed et al. 2017	IT	Johor, Malaysia	LID can reduce pick flow in the range of 17.5% to 20.95%
Zhu and Chen, (2017)	BRC, PV, IT, RB, VS, RG and GR	Guangzhou, China	LIDs are effective in future flood reduction due to the increase in rainfall intensity, duration or peak
Tredway and Havlick (2017)	PV, RG, SN	Colorado, USA	Reduction of runoff by 18.8% using the PV, 4.7% using RG, 12.3% using SN and 32.7% using a combination of the LIDs
Ahiablame and Shakya (2016)	PV, RG, RB	Central Illinois, USA	3- 47% reduction of runoff

Table 5. Summary of the studies on the effectiveness of LID practices in the reduction of flood peak and volumes

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com

The performance of LIDs in flood mitigation has been evaluated at a number of various scales. These studies imply that site-specific LIDs can be a substitute for a traditional SWMS. LIDs can be effective even under unfavourable conditions, including unsatisfactory performance due to high groundwater level, unexpected storm characteristics, and seasonal variations in rainfall extremes and studies reveal that LIDs can also be used for flood reduction at the scale of a watershed. The use of LIDs can significantly alter the hydrological cycle and reduce flood volume for the same rainfall intensity when compared to the same event in the absence of any LID installations. Thus LID technique can be implemented in Srinagar as well based on the above review. However, using small-scale LID installations tends to be more cost-effective than using large-scale LIDs. Studies have also been conducted to evaluate the effect of LIDs on a wide range of climatic and geographical regions; from the humid, tropical climate found on the equator, to arid and cold mountainous regions. The effectiveness of different LIDs was seen to vary according to the specific environment. Moreover, the porous surfaces were more effective in reducing flood peaks resulting from short duration rainfall events, while bioretention cells were more effective in reducing flood peaks from the longer duration rainfall events.

Space limitation is normally the major problem in the implementation of LIDs in denser urban areas but if implemented successfully, they can effectively reduce flood volume. A study in Nanjing (China) revealed that LID implementation reduced total flood volumes by up to 36.8% (Zhang et al., 2016). Most LID studies have been focused on the reduction of flood peaks and volume, but a few studies have also looked at the ability of LIDs to reduce the amount of area inundated by flooding, and have shown the effectiveness of LIDs in reducing inundation depth as well as area affected (Hu et al., 2017).

LIDs can be adjusted in response to climate change, therefore can be more efficient in mitigating floods due to climate change when compared to conventional flood management systems (Zhou et al., 2018). Studies have indicated that if LIDs are designed to take account of rainfall characteristics projected for future climate change scenarios, they can effectively reduce urban flooding resulting because of changing climate. Several studies have pointed out some of the challenges. Some other studies have indicated that while LIDs are effective for small rainfall events, they are less able to control floods resulting from extreme rainfall occurrences. However combined use of different LID practices, and optimization of specific LID parameters particular to the physical environment where the LID is being implemented, can improve the effectiveness of the mitigation provided.

V. CONCLUSION AND SUGGESTIONS

This study has presented information on the role climate change has played in urban flooding events in Srinagar city, and has assessed the possible strengths of implementing LID practices for controlling urban floods resulting from a changing climate. The intensity of observed changes in Srinagar may have arisen due to a combination of local urban climate variability and global warming-induced climate change. These factors can result in a higher frequency as well as severity of rainfall extremes, and consequent flooding of the city. It is evident that the use of LIDs can be a cost-effective alternative. LIDs can be used to supplement the conventional urban stormwater management system and assist in handling the large uncertainties in flood peaks, as well as mitigating possible flooding risk, in a cost-effective manner. It appears that the effectiveness of a certain type of LID, within a specific region, depends on the selection of optimum LID parameters, taking into consideration rainfall patterns along
with a combination of different LIDs operating in an integrated manner. The optimum design specification of LIDs, and best combinations of LIDs based on the projected rainfall patterns, are important factors to consider when using LIDs as tools to combat increasing levels of urban flooding and it is suggested that further research should be done in this field so as to implement this technique in Srinagar City. Although there are a few challenges faced in the implementation of LID technique in certain countries including a lack of knowledge of best LID practices, difficulty in obtaining optimum design specifications, the lack of suitable space required for successfully implementing these practices in densely-populated and highly-developed urban areas, etc. a research aimed at improving the technology supporting LIDs, as well as improving the structure longevity and reducing maintenance costs according to the topography, climate and other factors of Srinagar is important if these methods are to gain wider acceptance. It is expected that this study will help implement and promote LID practices in Srinagar, practices which have the potential to assist in mitigating urban flooding. This will in turn assist in achieving the millennium goal of developing a sustainable city.

REFERENCES

[1] Ahiablame, L., Shakya, R., 2016. Modeling flood reduction effects of low impact development at a watershed scale. J. Environ. Manage. 171, 81–91. https://doi.org/10.1016/j.jenvman.2016.01.036

[2] Ahmed, K., Chung, E.-S., Song, J.-Y., Shahid, S., 2017. Effective Design and Planning Specification of Low Impact Development Practices Using Water Management Analysis Module (WMAM): Case of Malaysia. Water 9, 173. https://doi.org/10.3390/w9030173

[3] Chen, Y., Tan, M., Wan, J., Weise, T., Wu, Z., 2020. Effectiveness evaluation of the coupled LIDs from the watershed scale based on remote sensing image processing and SWMM simulation. Eur. J. Remote Sens. 1–15. https://doi.org/10.1080/22797254.2020.1758962

[4] Du, S., Wang, C., Shen, J., Wen, J., Gao, J., Wu, J., Lin, W., Xu, H., 2019. Mapping the capacity of concave green land in mitigating urban pluvial floods and its beneficiaries. Sustain. Cities Soc. 44, 774–782. https://doi.org/10.1016/j.scs.2018.11.003

[5] Eckart, K., McPhee, Z., Bolisetti, T., 2017. Performance and implementation of low impact development – A review. Sci. Total Environ. 607–608, 413–432. https://doi.org/10.1016/j.scitotenv.2017.06.254

[6] Ghodsi, S.H., Zahmatkesh, Z., Goharian, E., Kerachian, R., Zhu, Z., 2020. Optimal design of low impact development practices in response to climate change. J. Hydrol. 580, 124266. https://doi.org/10.1016/j.jhydrol.2019.124266

[7] Goncalves, L.R.M., Zischg, J., Rau, S., Sitzmann, M., Rauch, W., Kleidorfer, M., 2018. Modelling the Effects of Introducing Low Impact Development in a Tropical City: A Case Study from Joinville, Brazil. Sustain. . https://doi.org/10.3390/su10030728

[8] Huang, C.L., Hsu, N.S., Liu, H.J., Huang, Y.H., 2018. Optimization of low impact development layout designs for megacity flood mitigation. J. Hydrol. 564, 542–558. https://doi.org/10.1016/j.jhydrol.2018.07.044

[9] Hu, M., Sayama, T., Zhang, X., Tanaka, K., Takara, K., Yang, H., 2017. Evaluation of low impact development approach for mitigating flood inundation at a watershed scale in China. J. Environ. Manage. 193, 430–438. https://doi.org/10.1016/j.jenvman.2017.02.020

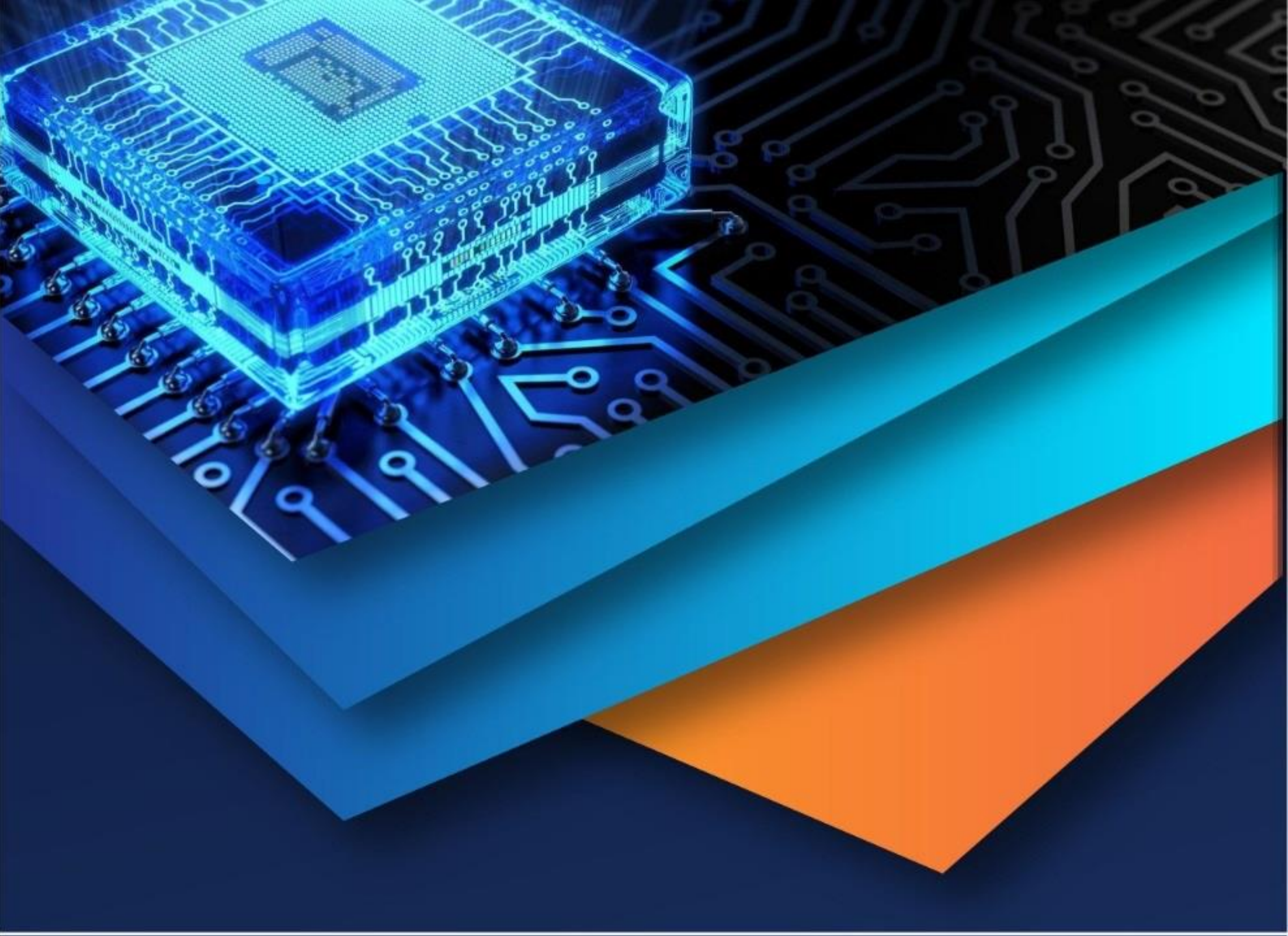
[10] Kong, F., Ban, Y., Yin, H., James, P., Dronova, I., 2017. Modeling stormwater management at the city district level in response to changes in land use and low impact development. Environ. Model. Softw. 95, 132–142. https://doi.org/10.1016/j.envsoft.2017.06.021

[11] Zhu, Z., Chen, X., 2017. Evaluating the effects of low impact development practices on urban flooding under different rainfall intensities. Water 9, 548. https://doi.org/10.3390/w9070548

[12] Zhu, Z., Chen, Z., Chen, X., Yu, G., 2019. An assessment of the hydrologic effectiveness of low impact development (LID) practices for managing runoff with different objectives. J. Environ. Manage. 231, 504–514. https://doi.org/10.1016/j.jenvman.2018.10.046

[13] www.smcsite.org/zonedetails.php

[14] www.citymayors.com/statistics/urban_growth1.html



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY