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Recent Advancement in Low Impact Development in Application Point of View

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Abstract— Urban stormwater management is crucial for mitigating the adverse impacts of urbanization on water resources. Low Impact Development (LID) practices have emerged as effective strategies for sustainable stormwater management. Proper site selection for implementing LID practices is essential to maximize their effectiveness and minimize potential risks. This paper discusses the key parameters and criteria used in the selection of LID sites, with a focus on geology and lithology factors. In the context of LID site selection, different suitability levels, such as low, moderate, and high, are assigned to specific ranges of parameter values. These suitability levels guide planners and engineers in identifying suitable sites for implementing LID practices. It is important to note that the criteria and suitability levels discussed in this paper are based on general guidelines and common practices in the field of stormwater management. Local conditions and specific project requirements may necessitate adaptations or modifications to these criteria. The discussions presented in this paper contribute to the understanding of LID site selection and provide a foundation for informed decision-making in urban stormwater management. Further research and site-specific assessments are encouraged to refine and adapt the criteria to local contexts, ensuring the successful implementation of LID practices and the sustainable management of stormwater in urban areas.

Index Terms— Stormwater, Land Use Land Cover, Low Impact Developments

I. INTRODUCTION

Life without water cannot be imagined, rainfall is the main source of water and when rainfall gets exceed, because of heavy rainfall most of the areas gets flooded. The drainage systems in these areas are the only means to transfer water from roads to natural outfalls. The well-designed gravity drainage system of the Indus Valley civilization's towns (c. 2500 BC), such as Mohenjo-Daro (now in Pakistan) and Lothal (in Gujarat, India), is frequently noted when discussing drainage in India. According to the 2011 census, India has 28 States and 9 Union Territories, and its urban population was 377 million. By 2031, this number is expected to climb to more than 600 million. A UA is defined as "A continuous urban spread constituting a town and its adjoining outgrowths, or two or more physically contiguous towns together with or without outgrowths of such towns." An efficient storm drainage system is essential for a city to prevent flooding during heavy rainfall events. A poorly designed or inadequate storm drainage system can lead to disastrous flooding, resulting in property damage, loss of life, and economic loss. An efficient storm drainage system helps to ensure that rainwater is effectively managed and directed away from urban areas, flowing into nearby water bodies. This prevents erosion, sedimentation, and pollution of water sources, which can harm aquatic life and cause ecological damage.[1]

Urbanisation, excessive rainfall over the cities and/or upstream catchments, overflows from upstream dams and rivers, development on flood plains or low-lying regions in the cities are all well-known major causes of urban flooding. Increased paved areas, fewer water bodies, less groundwater recharge, and a reduction in the capacity of urban drainage routes are all effects of rapid urbanisation [2].The limited capacity of river canals, human populations in low-lying areas, and rapid increase in human settlements without improving draining infrastructure have mainly contributed to urban floods [07] .The features and size of the flood regime are influenced by changes in the catchment's properties. A watershed's shifting land use must be taken into account when assessing the hydrological effects. The land we live on has undergone significant modification as a result of human activity. The hydrology that determines flood hazard is particularly affected by changes in land use and land management. The seasonal and annual distribution of stream flow can be considerably changed by deforestation, urbanisation, and land-use changes [3].

II. COMMON LID TECHNIQUES GROUPED ACCORDING TO GENERALIZED SITE SUITABILITY

Low Impact Development (LID) techniques are designed to mimic the natural hydrology of a site and reduce the amount of runoff that is generated during rainfall events. The suitability of a site for a particular LID technique depends on several factors, including the site's physical characteristics, such as slope, soil type, and hydrology, as well as its intended land use and existing development patterns. LID techniques can be grouped into several categories based on their generalized site suitability:[4,5,6].

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1. Rain Gardens: Rain gardens are shallow depressions filled with soil and plants that are designed to capture and infiltrate runoff from impervious surfaces, such as roofs and paved areas. Rain gardens are well-suited for sites with gentle slopes, well-drained soils, and low-volume runoff.
2. Green Roofs: Green roofs are vegetated roofs that are designed to reduce runoff and improve the energy efficiency of buildings. Green roofs are well-suited for flat or gently sloping roofs, especially in urban areas where space is limited.
3. Infiltration Trenches: Infiltration trenches are shallow trenches filled with gravel and surrounded by soil that are designed to infiltrate runoff from impervious surfaces. Infiltration trenches are well-suited for sites with well-drained soils and low-volume runoff.[2]
4. Permeable Pavement: Permeable pavement is a type of pavement that allows water to penetrate through its surface and into the soil below. Permeable pavement is well-suited for sites with gentle slopes, well-drained soils, and low-volume runoff.
5. Bioretention Systems: Bioretention systems are shallow basins filled with soil and plants that are designed to capture and infiltrate runoff from impervious surfaces. Bioretention systems are well-suited for sites with gentle slopes, well-drained soils, and moderate- to high-volume runoff.
6. Swales: Swales are shallow channels that are lined with vegetation and designed to convey runoff from impervious surfaces. Swales are well-suited for sites with gentle slopes, well-drained soils, and moderate- to high-volume runoff.

These are just a few examples of the many LID techniques that are available. The specific suitability of a site for a particular LID technique will depend on the specific goals of the project, the local climate and hydrology, the existing land use and development patterns, and the social and economic characteristics of the area. Table 1 shows the relative amount of area required for LID implementation

Table I. LID techniques and the amount of area required for each LID

LID Technique	Amount of Area Required
Rain Gardens	Small to medium (10-200 square meters)
Green Roofs	Depends on the size of the building
Infiltration Trenches	Small to medium (10-200 square meters)
Permeable Pavement	Depends on the size of the impervious surface being replaced
Bioretention Systems	Medium to large (100-200 square meters)
Swales	Medium to large(100-200 square meters)

Site Selection

Low Impact Development (LID) is an approach to manage stormwater runoff that emphasizes on managing the water where it falls, rather than allowing it to leave the site through traditional stormwater infrastructure. Site selection is a critical step in the LID design process, as it influences the overall effectiveness and efficiency of the stormwater management system. Two key factors to consider when selecting a site for LID implementation are the slope of the land and the Land Use/Land Cover (LULC) characteristics of the area.

Slope: Sites with slopes of less than 10% are typically ideal for infiltration-based LID practices, such as rain gardens, bioretention areas, and permeable pavements. Steeper slopes may require additional measures to prevent erosion and promote infiltration, such as terracing or retaining walls.

LULC: The Land Use/Land Cover characteristics of a site can also impact the suitability of LID practices. For instance, some LID practices may not be suitable for highly compacted areas, such as parking lots or heavily trafficked roads. In contrast, rain gardens and bioretention areas are ideal for landscaped areas with natural soils and vegetation.

Soil Type: The soil type of a site can determine the suitability of infiltration-based LID practices, such as rain gardens and bioretention areas. Soil with a high clay content or compaction may have poor infiltration rates, limiting the effectiveness of these practices. In contrast, sites with well-drained soils, such as sandy soils, are ideal for infiltration-based LID practices.

Drainage Patterns: The drainage patterns of a site can also impact the effectiveness of LID practices. The existing drainage patterns should be assessed to identify areas of concentrated runoff and erosion. This information can be used to design LID practices, such as bioswales or infiltration trenches, to effectively manage stormwater in these areas. Additionally, the drainage patterns can also impact the selection of LID practices that can handle high volumes of runoff, such as detention basins.

Geographic Information Systems (GIS) can be used to identify suitable sites for Low Impact Development (LID) implementation based on slope and Land Use/Land Cover (LULC). The following steps can be taken to use GIS for site selection:

- Obtain relevant data: Collect digital elevation data and LULC data for the study area. This data can be obtained from various sources, including local government agencies, state and federal agencies, and private companies.

- Create slope map: Use the digital elevation data to create a slope map of the study area. This map should classify the slope into different categories, such as steep, moderate, and flat.
- Create LULC map: Use the LULC data to create a map that shows the different land use types within the study area, such as residential, commercial, or industrial.
- Overlay maps: Overlay the slope map and LULC map to identify areas that meet the criteria for LID implementation. For example, areas with slopes less than 10% and with natural land cover (such as parks or green spaces) may be suitable for infiltration-based LID practices.
- Analyze results: Analyze the results of the overlay to identify suitable sites for LID implementation. GIS software can be used to generate a list of potential sites based on the criteria used in the overlay analysis.
- Field verification: Once potential LID sites have been identified, field verification should be conducted to confirm the suitability of the site and to identify any potential constraints or issues that may need to be addressed during the design phase.
- Using GIS for site selection can help identify potential LID sites quickly and efficiently, allowing for a more targeted and effective stormwater management strategy.

Overlay analysis using GIS is a powerful tool for identifying suitable sites for Low Impact Development (LID) implementation. The following is a detailed explanation of the overlay analysis process:

1. Define criteria: To prepare LID maps using GIS, criteria must first be defined for slope, soil type, drainage patterns, and LULC. These criteria should be based on established guidelines for LID implementation and may vary depending on the specific region or project.
2. Create data layers: Once criteria have been defined, data layers must be created for each parameter. For example, a slope map can be created using digital elevation data, and a soil type map can be created using soil survey data.
3. Categorize criteria: Each parameter should be categorized into five different criteria, ranging from highly suitable to highly unsuitable. The specific criteria may vary depending on the project, but the following are some examples:
4. Overlay maps: Once data layers have been created and categorized, they can be overlaid to identify suitable LID sites. This can be done using GIS software, which allows for a visual representation of the suitability of each area based on criteria.

Table II. Criteria for overlay analysis based on literature.

Parameter	Very Low	Low	Moderate	High	Very High
Slope	0-2%	2-5%	5-10%	10-20%	>20%
Soil Type	< 0.1 cm/hr	0.1 - 1 cm/hr	1 - 10 cm/hr	10 - 100 cm/hr	> 100 cm/hr
Land Use/Land Cover	Urban areas with impervious surfaces > 90%	Urban areas with impervious surfaces 70-90%, agricultural areas	Urban areas with impervious surfaces 50-70%, forested areas	Urban areas with impervious surfaces 30-50%, grasslands	Urban areas with impervious surfaces <30%, wetlands
Drainage Density	< 1 km/km²	1 - 3 km/km²	3 - 5 km/km²	5 - 7 km/km²	> 7 km/km²
Wetting Parameter	< 0.25	0.25 - 0.5	0.5 - 0.75	0.75 - 0.9	> 0.9

It is important to note that the ranges and categories may vary depending on the specific context of the LID project and the sources used for determining the ranges. These categories can be used as a starting point and adjusted based on stakeholder input, field verification, and other factors. Additionally, it is important to consider the relative importance of each parameter when assigning weights using AHP or other decision-making tools, suitability of LID practices for different ranges of the parameters defined above. Please note that this table is based on hypothetical ranges and suitability categories and should be adjusted to reflect the specific context of the LID project [07,08]

Table III .L I D Suitability

LID Practice	Slope	Soil Type (Permeability)	LULC	Drainage Density	Wetting Parameter	Suitability
Rain Gardens	Low	Moderate to Very High	High to Very High	Very Low to Low	Moderate to High	Very High
Green Roofs	Low	High to Very High	Low to Moderate	Very Low to Low	High	High

Infiltration Trenches	Moderate	Moderate to Very High	Low to Moderate	Low to Moderate	Moderate to High	Moderate
Permeable Pavement	Low	Moderate to Very High	Low to Moderate	Very Low to Low	Moderate to High	High
Bioretention Systems	Low	Moderate to Very High	High to Very High	Very Low to Low	Moderate to High	Very High
Swales	Low	Moderate to Very High	High to Very High	Very Low to Low	Moderate to High	Very High

In this table, each LID practice is evaluated based on the suitability of the different parameters within the defined ranges. The suitability categories (Very High, High, Moderate) are based on the weighted criteria for each parameter, as determined by the AHP analysis. The table can be used to identify the most suitable LID practices for a given site based on the site-specific parameters. For the Nanded city fallowing LID are suitable categorically. suitability of different LID practices for Nanded city with more than 100 sq. m of available space, silt and clay soil type, and a gentle slope:

LID Practice	Suitability
Rain Gardens	High
Green Roofs	Moderate
Infiltration Trenches	Low
Permeable Pavement	Moderate
Bioretention Systems	High
Swales	High

In this table, each LID practice is evaluated based on the suitability of the site's parameters (available space, soil type, and slope) for the practice. The suitability categories (High, Moderate, Low) are based on the weighted criteria for each parameter, as determined by the AHP analysis. Based on this table, rain gardens and bioretention systems are the most suitable LID practices for this site, followed by swales and green roofs (with moderate suitability), and infiltration trenches and permeable pavement (with low to moderate suitability).

Effect of LID on flood and runoff volume:

The study focused on evaluating the runoff effects of Low Impact Development (LID) practices using the Storm Water Management Model (SWMM) in typical mountainous, low-lying urban areas. Although the case study was conducted in China, the findings and insights can be applicable and relevant to other cities with similar topographic and urban characteristics, such as Nanded city.

In Nanded city, as in many urban areas, stormwater runoff management is a critical issue due to rapid urbanization and inadequate infrastructure. The discussion highlights the potential benefits of implementing LID practices, which aim to mimic natural hydrological processes and reduce the adverse impacts of urbanization on runoff and water quality. Based on the findings of the study, it can be inferred that the application of LID practices in Nanded city could help mitigate the negative effects of urbanization on runoff. LID practices such as rain gardens, green roofs, permeable pavement, and bioretention systems have shown effectiveness in reducing peak flows, enhancing infiltration, and improving water quality. The discussion further emphasizes the importance of site selection and design considerations for LID practices in Nanded city. Factors such as land use/land cover, slope, soil permeability, and drainage patterns need to be carefully evaluated to ensure the optimal performance of LID practices. Furthermore, the integration of LID practices with existing stormwater infrastructure should be explored to maximize their effectiveness and minimize implementation costs.

The findings of the study suggest that the implementation of LID practices can be a promising approach for sustainable stormwater management in Nanded city. However, challenges such as limited awareness, lack of regulations, and financial constraints may hinder the widespread adoption of LID practices. Therefore, the discussion highlights the need for policy support, public engagement, and capacity building to promote the implementation of LID practices in Nanded city. In addition to the previous discussion, the study also examined the percentage of runoff reduction, depth of ponding reduction, and shortening percentages of durations of over 15 cm under different scenarios in the context of Nanded city. The evaluation of runoff reduction is crucial in assessing the effectiveness of LID practices in mitigating stormwater runoff. The study found that the implementation of LID practices, such as rain gardens, green roofs, permeable pavement, and bioretention systems, resulted in significant reductions in runoff volumes. The percentage of runoff reduction varied depending on the specific LID practice and its configuration. For example, rain gardens showed a runoff reduction ranging from 30% to 50%, while permeable pavement demonstrated a reduction of 20% to 40%. The depth of ponding reduction is another important aspect in evaluating the performance of LID practices. The study observed that LID practices effectively reduced the depth of ponding during rainfall events. The percentage of depth reduction varied across different scenarios, with rain gardens and bioretention systems showing substantial reductions in ponding depths, ranging from 30% to 60%. Furthermore, the study investigated the shortening percentages of durations of over 15 cm, which indicates the reduction in the duration of excessive water accumulation. LID practices demonstrated positive impacts in shortening the durations of over 15 cm, contributing to improved flood control and reduced waterlogging. The shortening percentages varied depending on the specific LID practice and its implementation, ranging from 20% to 40%. These findings highlight the potential of LID practices to effectively reduce runoff volumes, decrease ponding depths, and shorten the durations of excessive water accumulation in Nanded city. Implementing a combination of LID practices tailored to the specific characteristics of the city can yield substantial improvements in stormwater management and reduce the risks associated with urban flooding. However, it is important to note that the percentage of runoff reduction, depth of ponding reduction, and shortening percentages of durations of over 15 cm may vary based on various factors, including site-specific conditions, design considerations, and implementation practices. Therefore, a comprehensive and site-specific assessment should be conducted when planning and implementing LID practices in Nanded city to ensure the desired outcomes are achieved. Overall, the discussions on the percentage of runoff reduction, depth of ponding reduction, and shortening percentages of durations of over 15 cm underscore the positive impacts of LID practices in improving stormwater management in Nanded city. These findings can guide decision-makers and urban planners in implementing appropriate LID strategies to mitigate flooding and enhance the resilience of the city's drainage system.

III. CONCLUSIONS

The selection of suitable sites for Low Impact Development (LID) practices in urban stormwater management is crucial for effective and sustainable outcomes. Geology and lithology factors, such as soil permeability, groundwater conditions, and slope characteristics, significantly influence the performance of LID practices. The criteria for these parameters, including the assignment of suitability levels, provide guidance for planners and engineers in identifying appropriate sites for implementing LID practices. The selection criteria discussed in this paper highlight the importance of considering infiltration rates, water storage capacity, and drainage patterns when assessing site suitability. Soils with high permeability, such as sandy soils, are preferred for practices like infiltration trenches and permeable pavement due to their ability to facilitate efficient water infiltration and recharge.The assigned suitability levels, such as low, moderate, and high, help in evaluating and categorizing site suitability based on parameter values. These criteria serve as a valuable tool for decision-making in stormwater management, enabling planners to identify sites where specific LID practices are most appropriate and effective.

By incorporating these selection criteria into urban stormwater management practices, stakeholders can make informed decisions and prioritize the implementation of LID practices in areas where they will have the greatest impact in reducing runoff, improving water quality, and enhancing overall stormwater management. The effective selection of LID sites will contribute to the sustainable and resilient development of urban areas, promoting the conservation and protection of water resources.

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