

Landscape Architecture as a Tool for Flood Risk Reduction in India: Challenges and Opportunities

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Abstract

Flooding, exacerbated by urbanization, climate change, and inadequate infrastructure, poses significant challenges worldwide. India, particularly vulnerable to riverine and monsoon flooding, faces serious concerns in its urban areas. Landscape architecture offers innovative flood mitigation strategies by integrating natural processes into urban planning. This paper explores the potential of landscape-based interventions, such as green infrastructure, Sponge city concepts, and rainwater harvesting systems, to manage stormwater and reduce flood risks in India. The study combines a review of existing literature with global case studies to evaluate the effectiveness of these interventions. Key challenges identified include high implementation costs, policy gaps, and the need for robust long-term maintenance. The paper concludes by recommending policy reforms, innovative financing, and community engagement to integrate landscape-based flood mitigation strategies into urban planning, aiming to achieve sustainable, resilient cities in India. By adopting these strategies, India can enhance its resilience against flooding while promoting environmental sustainability. The integration of natural processes in urban planning not only mitigates flood risks but also provides additional benefits such as improved water quality, enhanced biodiversity, and better urban living conditions. Implementing these recommendations can create more resilient and livable cities in India, ensuring a safer future for its urban populations.

Keywords: Landscape architecture, flood mitigation, green infrastructure, sponge cities, storm water management

INTRODUCTION

Floods, worsened by climate change, urbanization, and poor infrastructure, are frequent disasters worldwide (O'Donnell & Thorne, 2020; Abdrabo et al., 2022) [1, 2]. India is highly vulnerable, with over 40 million hectares at risk (Sharma & Mishra, 2023) [3]. The Ministry of Jal Shakti estimates 49.15 Mha as flood-prone, with Assam, Odisha, West Bengal, Bihar, and Uttar Pradesh most affected (National Remote Sensing Centre (NRSC), 2023) [4]. Major rivers, such as the Ganga and Brahmaputra, often flood causing economic losses and displacement (Roy et al., 2023).

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Flood risk is determined by exposure, hazard, and vulnerability (Abdrabo et al., 2022) [2]. Effective flood risk reduction (FRR) strategies include structural measures (e.g., flood walls) and soft strategies (e.g., land use planning, building codes) (Abdrabo et al., 2022) [2]. Nature-based solutions hold great potential for mitigating flood risks. Given the rising frequency of floods, urgent mitigation efforts are essential (Palazzo & Wang, 2022) [5].

RESEARCH OBJECTIVE

The primary objectives of this study are as follows:

- Analyze how landscape architecture can help in mitigating flood risks.
- Evaluate the effectiveness of landscape-based interventions in mitigating floods and managing stormwater.
- Study successful global implementation and derive insights that can be applied to Indian cities.
- Identify the key challenges associated with implementing these strategies in India.

LITERATURE REVIEW

Flood, Its Causes, and Its Types

Flooding, the most common natural disaster, occurs when excess water submerges dry land (World Health Organization (WHO), n.d.) [6]. While primarily defined as river overflow, the Water Law includes floods in reservoirs, canals, and coastal areas that pose threats (Rybak-Niedziółka et al., 2021) [7]. India is highly susceptible to floods due to intense monsoon rainfall, changing weather patterns, rapid snowmelt, river overflows, dam failures, landslides, and storm surges (Singh & Kumar, 2017) [8]. Coastal areas are particularly vulnerable to tropical cyclones, tsunamis, and storm surges, leading to frequent and severe flooding (National Remote Sensing Centre (NRSC), 2023; Roy et al., 2023) [4, 9].

Typically, floods are categorized as follows based on how long they last and how they look.

- *Long-standing floods*: Could go on for a week or more.
- *Short-standing floods or “flash floods”*: often last no more than 6 hours (Abdrabo et al., 2022) [2].

Besides this classification, there is another classification of Floods (National Remote Sensing Centre (NRSC), 2023) [4].

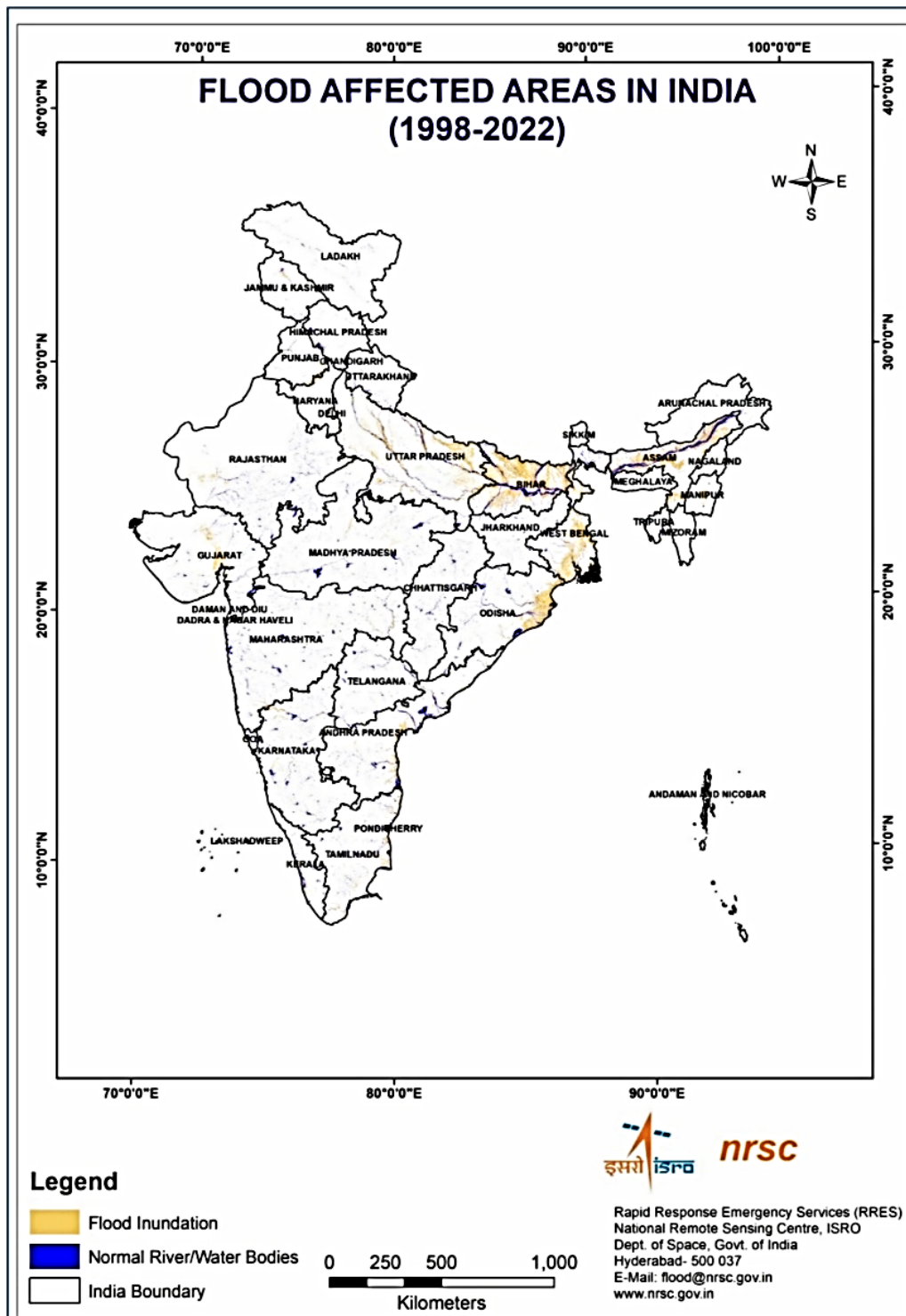
- *Riverine floods*: Occur when rivers overflow due to heavy rainfall or snowmelt, either gradually over days or suddenly.
- *Flash floods*: Result from intense rainfall overwhelming drainage systems, rapidly flooding low-lying areas, and posing extreme danger.
- *Coastal floods*: Caused by high tides, storm surges, or large waves, often linked to cyclones and extreme weather.
- *Pluvial floods*: Happen when heavy rain exceeds drainage capacity, leading to surface water accumulation in both urban and rural areas.
- *Urban floods*: Occur in cities due to poor drainage, impermeable surfaces, and infrastructure failures, causing water buildup.
- *Dam/levee failures*: Happen when structures collapse under flood pressure, releasing massive water volumes downstream.

Flood and Its Impact in India

After Bangladesh, India is among the nation’s most vulnerable to flooding worldwide (Arun & Senthilkumar, 2021) [10]. Floods affect around 30 million people in the nation, and they claim about 1500 lives annually, making up around one-fifth of all flood-related deaths worldwide (Singh & Kumar, 2017) [8]. Table 1 gives a brief list of damage caused by floods. (Latif Far & Nikookar, 2024) [11]. Floods result in more than just damage and human casualties, but also impact industry, agriculture, public utilities, etc. (J. Zhang, 2024) [12]. Beyond the financial toll, floods displace millions, leaving long-term social impacts, especially in rural areas, where recovery is even more challenging due to limited resources and slower economic development. Frequent floods of varying sizes impede and slow the nation’s overall growth by causing unplanned development and unregulated environmental deterioration (Singh & Kumar, 2013; Kadaverugu et al., 2021) [13, 14].

Environmentally, floods cause soil erosion (Figures 1–3), degrade farmland, and carry pollutants like industrial waste, contaminating water sources, and harming biodiversity (Ravindra et al., 2024) [15].

They also pose severe health risks, spreading diseases such as gastroenteritis, zoonotic infections, and skin conditions (Paterson et al., 2018) [16].



Disclaimer : Flood affected area map is a cumulative of flood inundation areas mapped from multi-date satellite data acquired and processed during 1998-2022 covering major flood & cyclone events. Flood inundation may include rain water accumulation / flood water in low lying areas. Estimated flood extent depends on availability of satellite data, its date of overpass coverage over flooded areas. Some of the Flash flood events could not be mapped due to non availability of satellite data for short duration. Flood affected area estimated in the study excludes river portion, permanent water bodies, salt pans, aquaculture lands in flood plains. Hence, actual flooded area may be more than the area estimated by satellite images.

Figure 1. Flood affected areas in India (1998–2022).

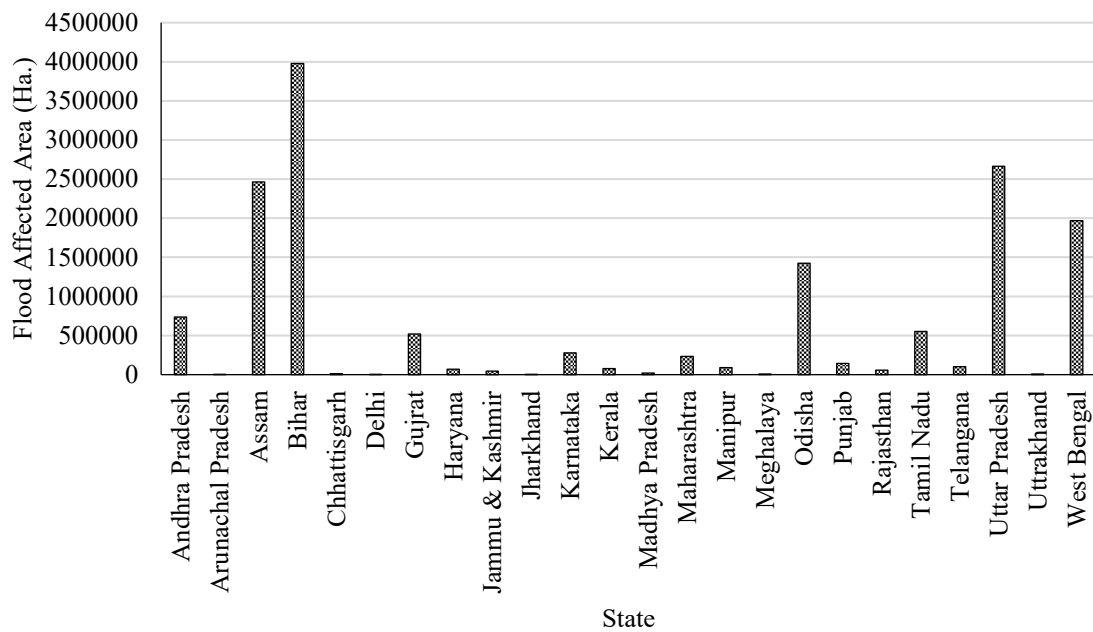


Figure 2. Flood-affected areas in India (1998–2022) statistics at state level.

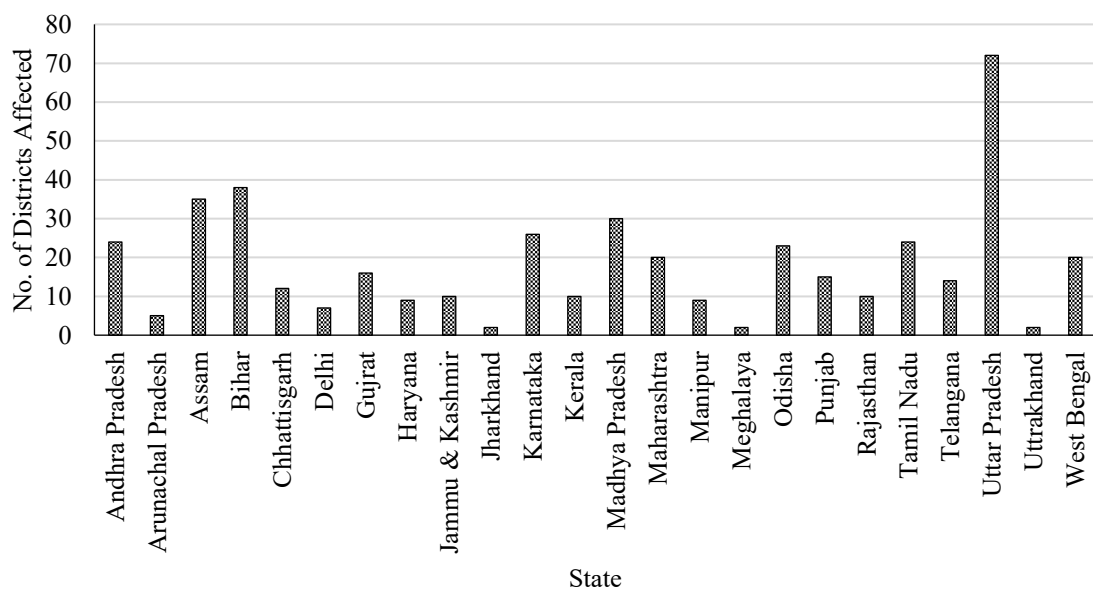


Figure 3. Flood-affected areas in India (1998–2022) statistics at district level.

Source: National Remote Sensing Centre (NRSC), 2023.

Mitigation Measures for Flood Risk Reduction

To mitigate flood risk, a comprehensive approach incorporating both structural and non-structural measures is essential.

- *Structural measures:* Use physical infrastructure to prevent flood damage, including dams, floodwalls, detention facilities, and channel modifications (Arun & Senthilkumar, 2021) [10]. Urban water quality is managed through sedimentation basins, infiltration systems, and wetlands, though these can be costly and disrupt ecosystems (Abdrabo et al., 2022) [2].
- *Non-structural measures:* Requiring less capital, focus on keeping people safe through land use regulations, floodproofing, relocation, building elevation, early warning systems, and insurance

programs. While structural measures offer protection, non-structural approaches emphasize damage reduction and sustainable urban planning (National Remote Sensing Centre (NRSC), 2023) [4].

Table 1. Flood-affected areas and flood damages in India during 1953–2010.

S.N.	Items	Unit	Flood Damage Averages	Minimum Damage	Maximum Damage
1	Area affected	Million ha	7.25	0.5 (2006)	17.50 (1978)
2	Population affected	Million	32.36	3.61 (1965)	70.45 (1978)
3	Human live lost	Numbers	1620	37 (1953)	11,316 (1977)
4	Cattle lost	Numbers	91000	5000 (1963/1964)	618,000 (1979)
5	Cropped area affected	Million ha	3.68	0.45 (1957)	15.18 (2005)
6	Value of damage to crops	Rs. Billion	70	0.5 (1965)	424 (2000)
7	House damaged	Thousands	1213	113 (1965)	3508 (1978)
8	Value of damage to houses	Rs. Billion	28	0.02 (1965)	13,078 (1995)
9	Value of damage to public utilities	Rs. Billion	81.6	0.10 (1962)	560 (2001)
10	Value of total loss	Rs. Billion	182	0.7 (1965)	886 (2000)

Source: Singh & Kumar, 2017 [8].

Landscape Strategies Being Implemented in the World (Table 2)

In Table 2, it is discussed how various landscape strategies are being implemented around the world to manage urban flooding and rainwater. These strategies demonstrate a shift toward integrating natural processes and green infrastructure into urban planning. Approaches such as Blue-Green Infrastructure, Sponge Cities, Water Sensitive Urban Design, and Low Impact Development emphasize sustainability, resilience, and the multifunctional use of urban spaces. Each model highlights how different countries adapt ecological and technological innovations to reduce flood risks, enhance water management, and improve overall urban livability.

LANDSCAPE ARCHITECTURE INTERVENTIONS FOR FLOOD PREVENTION

Landscape architecture offers sustainable flood prevention by integrating green infrastructure into urban environments. Green roofs absorb rainfall, reducing stormwater runoff (Beecham et al., 2018) [17], while permeable pavements allow water infiltration, preventing urban flooding (VanDerZanden & Cook, 2011, pp. 55–57) [18]. Vegetation buffers along water bodies slow runoff, trap sediments, and reduce flood intensity (ICAEN (Institut Catala d’Energia), 2004) [19]. Grass ditches (swales) and rain gardens filter pollutants and recharge groundwater while enhancing urban aesthetics (Ekka et al., 2021; Viklander, M. (2015); Stormwater, 2013) [20–22].

Other key solutions include infiltration wells for groundwater recharge, rainwater tanks for water storage, and impounding reservoirs to manage stormwater during heavy rainfall. Wet swales, mimicking wetlands, help reduce runoff and support biodiversity (*Connecticut Stormwater Quality Manual*, 2004; Sumi et al., 2022) [23–24].

Combined, these interventions not only mitigate floods but also improve water quality, enhance biodiversity, and expand urban green spaces. A brief Table is presented about the overview and potential of ecological benefits is compared (Table 3). Integrating them into urban planning strengthens city resilience against future flood risks (Xu et al., 2023) [25].

LIMITATIONS AND CHALLENGES

Implementing landscape architecture for flood mitigation in India faces key challenges. The lack of detailed contour maps (Arun & Senthilkumar, 2021) [10] and flood hazard mapping makes planning effective green infrastructure difficult. Poor coordination between national, state, and local agencies leads to inefficiencies, with many cities relying on reactive approaches (Arun & Senthilkumar, 2021) [10].

Table 2. Landscape strategies related to flood mitigation and urban rainwater management.

Strategy	Aim and Definition	The Principal Form of Practice	Application Area
Blue-Green infrastructure	A strategy for addressing urban flood resilience and climate-related issues leverages the advantages of incorporating urban green spaces and natural water flows.	Green roofs, Urban forestry, rain gardens, down-spout interrupters, bio-swales, man-made wetlands, green streets, and green water infrastructure.	US, UK and EU.
Sponge City	Planning approach that prioritizes flood management through the reinforcement of green infrastructures rather than solely relying on drainage systems.	Wetlands, permeable pavements, retention ponds, green roofs, rain gardens, and wet swales.	China.
Water Sensitive Urban Design (WSUD)	Incorporate urban planning and design with the management of the urban water cycle.	Reduce hazards, such water scarcity, contamination of fresh and marine receiving waters, and flash flooding.	Australia.
Best Management Practices (BMPs)	A tool designed for storm water management to attain enhancement in water quality and adherence to regulatory standards (Fletcher et al., 2015).	Mitigate the impact of stormwater runoff and adopt optimal management techniques. aim to minimize the influx of pollutants and sediments into water bodies during storm events.	US.
Low Impact Development (LID)	An approach to reduce the effects of increased impervious surfaces (VanDerZanden & Cook, 2011)	By incorporating a site's natural features into the design, storm water management expenses can be decreased. A variety of methods and technologies to effectively manage storm water drainage in a more environmentally friendly way compared to traditional systems.	US, New Zealand.
Nature-Based Solution	Managing runoff using natural or altered ecosystems, by restoring riverine habitats	Supporting biodiversity and securing ecosystem services, using floodplains to manage floodwaters	North America, India, Africa, European Union.
Sustainable Urban Drainage (SUDS)	Sustainable drainage is a viable alternative and supplement to conventional methods in achieving long-term sustainability in system design (Fletcher et al., 2015).	Mitigation of microplastic pollution, Bioswales, Permeable Pavement, Wetlands, Detention basin.	UK
Room For Water	As a paradigm shift aligns seamlessly with the current shift toward embracing the concept of "living with water".	Green roofs, permeable pavement, rain gardens, and other sustainable infrastructure to prevent flooding, improve water quality, and enhance biodiversity.	Netherlands
Urban River Revitalization	Especially concentrating on continuous initiatives to purify the contaminated river in Foshan. Mitigate the flow of harmful substances into the river system.	The installation of infrastructure works aims to address the issue of a malodorous, repugnant, and contaminated urban waterway by implementing necessary measures for its purification.	Japan
Clean River Scheme	An infrastructure program, which encompasses the utilization of green infrastructure (GI), to mitigate the occurrence of combined sewer overflows (CSOs) into the waterways of the district.	Remove trash, debris, and pollution from rivers and promote conservation efforts to maintain clean water sources.	Korea
Active Beautiful and Clean	Improving physical surroundings, encouraging an active lifestyle, and nurturing a feeling of communal responsibility and pride.	Parks, green spaces, and recreational facilities.	Singapore

Source: Latif Far & Nikoogar, 2024; Xu et al., 2023.

High initial costs (Zhang et al., 2022) [26] and inadequate policies hinder large-scale adoption, while neglected maintenance reduces long-term effectiveness. Limited public awareness further complicates

implementation, making widespread adoption of nature-based solutions challenging (Singh & Kumar, 2017) [8].

Table 3. Landscape interventions and their comparison.

Measure	Runoff Reduction Rate (%)	Peak Reduction Rate (%)	Rainwater Retention Rate (%)	Flood Peak Delay Time (min)
Green roof	62–80	30.5–67	55–88	10
Permeable pavement	40–90	20–80	42.5–52.5	6.3–16.3
Rainwater Garden	9.8–85.9	11.2–93.3	54.9–84.7	10–40

CONCLUSIONS

Landscape architecture provides a sustainable approach to flood mitigation in India through nature-based solution like green infrastructure, wetlands, and rainwater harvesting. These strategies enhance resilience, biodiversity, and socioeconomic benefits.

However, challenges hinder their implementation. India must improve coordination among agencies, integrate flood risk reduction into urban planning, and develop supportive policies. Investing in advanced forecasting and community engagement is crucial. Addressing these gaps will enable landscape architecture to create flood-resilient urban environments.

REFERENCES

- O'Donnell EC, Thorne CR. Drivers of future urban flood risk. *Philos Trans R Soc A Math Phys Eng Sci.* 2020;378(2168):20190216. doi: 10.1098/rsta.2019.0216.
- Abdrabo KI, Kantosh SA, Saber M, Sumi T, Elleithy D, Habiba OM, et al. The role of urban planning and landscape tools concerning flash flood risk reduction within arid and semiarid regions. In: Springer Nature Singapore; 2022. pp. 283–316. doi: 10.1007/978-981-16-2904-4_11.
- Sharma H, Mishra N. Adapting to flood and sea-level rise through amphibious architecture in India. *Int J Future Multidiscip Res.* 2023.
- National Remote Sensing Centre (NRSC). Flood affected area atlas of India – Satellite based study. Hyderabad: National Disaster Management Authority, Ministry of Home Affairs, Government of India; 2023.
- Palazzo E, Wang S. Landscape design for flood adaptation from 20 years of constructed ecologies in China. *Sustainability (Switz).* 2022;14(8):4511. doi: 10.3390/su14084511.
- World Health Organization (WHO). Floods. Geneva: WHO. Available at https://www.who.int/health-topics/floods#tab=tab_1 [Accessed on October 2025].
- Rybak-Niedziółka K, Grochulska-Salak M, Maciejewska E. Resilience of riverside areas as an element of the green deal strategy: Evaluation of waterfront models in relation to re-urbanization and the city landscape of Warsaw. *Desalination Water Treat.* 2021;232:357–371. doi: 10.5004/dwt.2021.27588.
- Singh O, Kumar M. Flood occurrences, damages, and management challenges in India: A geographical perspective. *Arab J Geosci.* 2017;10(5):1–12. doi: 10.1007/s12517-017-2895-2.
- Roy PS, Dwivedi RS, Vijayan D. Remote sensing applications. Chapter 12. 2023.
- Arun L, Senthilkumar R. Gaps in flood disaster management in India. *Int J Curr Microbiol Appl Sci.* 2021;10(1):313–320. doi: 10.20546/ijemas.2021.1001.039.
- Latif Far F, Nikookar M. Assessing landscape planning strategies for riverine flood management: An exploration of implemented projects. *ENG Trans.* 2024;5(1):1–9. doi: 10.61186/engt.5.1.2905.
- Zhang J. Exploring the utility of sponge cities and RHS for rainwater utilization and urban flood prevention. *Highlights Sci Eng Technol BEEFM.* 2024.
- Singh O, Kumar M. Flood events, fatalities and damages in India from 1978 to 2006. *Nat Hazards.* 2013;69(3):1815–1834. doi: 10.1007/s11069-013-0781-0.
- Kadaverugu A, Nageshwar Rao C, Viswanadh GK. Quantification of flood mitigation services by urban green spaces using InVEST model: A case study of Hyderabad city, India. *Model Earth Syst Environ.* 2021;7(1):589–602. doi: 10.1007/s40808-020-00937-0.

15. Ravindra K, Vig N, Chhoden K, Singh R, Kishor K, Maurya NS, et al. Impact of massive flood on drinking water quality and community health risk assessment in Patna, Bihar, India. *Sustain Water Resour Manag.* 2024;10(3):1052. doi: 10.1007/s40899-024-01052-z.
16. Paterson DL, Wright H, Harris PNA. Health risks of flood disasters. *Clin Infect Dis.* 2018;67(9):1450–1454. doi: 10.1093/cid/ciy227.
17. Beecham S, Razzaghamanesh M, Bustami R, Ward J. The role of green roofs and living walls as WSUD approaches in a dry climate. In: *Approaches to Water Sensitive Urban Design: Potential, Design, Ecological Health, Urban Greening, Economics, Policies, and Community Perceptions.* Elsevier; 2018. pp. 409–430. doi: 10.1016/B978-0-12-812843-5.00020-4.
18. VanDerZanden AM, Cook TW. *Sustainable landscape management: Design, construction, and maintenance.* Hoboken (NJ): John Wiley & Sons; 2011.
19. Institut Català d’Energia (ICAEN). *Sustainable building design manual.* New Delhi: The Energy and Resources Institute; 2004;2.
20. Ekka SA, Rujner H, Leonhardt G, Blecken GT, Viklander M, Hunt WF. Next generation swale design for stormwater runoff treatment: A comprehensive approach. *J Environ Manag.* 2021;279:111756. doi: 10.1016/j.jenvman.2020.111756.
21. Fletcher TD, Shuster W, Hunt WF, Ashley R, Butler D, Arthur S, et al. SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water J.* 2015;12(7):525–542. doi: 10.1080/1573062X.2014.916314.
22. Virginia Department of Stormwater Management. 10 Dry swales. Version 2.0. 2013. Available from: https://swbmpvwrrc.wp.prod.es.cloud.vt.edu/wpcontent/uploads/2018/07/BMP_Spec_No_10_DRY_SWALE.pdf [Accessed on October 2025].
23. Connecticut Department of Energy and Environmental Protection. *Connecticut stormwater quality manual.* Hartford (CT): Connecticut DEEP; 2004. Available at https://portal.ct.gov/media/DEEP/water_regulating_and_discharges/stormwater/manual/StormwaterManualCompletepdf.pdf [Accessed on October 2025].
24. Sumi T, Kantoush SA, Saber M. *Natural disaster science and mitigation engineering: DPRI reports wadi flash floods challenges and advanced approaches for disaster risk reduction.* Singapore: Springer; 2022. doi: 10.1007/978-981-16-2904-4.
25. Xu J, Dai J, Wu X, Wu S, Zhang Y, Wang F, et al. Urban rainwater utilization: A review of management modes and harvesting systems. *Front Environ Sci.* 2023;11:1025665. doi: 10.3389/fenvs.2023.1025665.
26. Zhang D, Ding X, Liu J, Mei C. Review on mechanism and technical measures of urban rainwater harvesting. *IOP Conf Ser Earth Environ Sci.* 2022;983(1):012106. doi: 10.1088/1755-1315/983/1/012106.