



Nature Based Solution for Flood Mitigation, Nowshera District, Khyber Pakhtunkhwa Province, Pakistan

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Abstract

Nowshera District of Khyber Pakhtunkhwa Province of Pakistan is badly hit by flooding as the district is located on the bank of Kabul and Indus River; a flood prone stretch of 15 km between M1 Kabul River Bridge and Nowshera makes it highly vulnerable to flood hazards. Recurrent flood events have also occurred in the area, in 2010 and 2022, due to high river discharges and heavy monsoon rains, resulting in damage to infrastructure, agriculture and communities in both floods. Flood damage and loss, estimated at around US\$10 billion and US\$3.7 billion respectively, was so great that up to 90 % of the families in the district were displaced and there was widespread damage to homes, public facilities and businesses. The nationwide devastation caused by the monsoon floods in 2022 further compounded flood effects across the country, with the total economic losses in the country estimated at over US \$30 billion as a result of widespread damage to roads, bridges, health facilities, schools and livestock (Government of Khyber Pakhtunkhwa, 2024; Khan et al., 2024; NDMA, 2022). In this study, NbS that can be applied to reduce flood risk in Nowshera, such as wetland restoration, riparian buffers, bioretention systems, permeable pavements, and floodplain reconnection, were reviewed. Global and Pakistan-specific studies were synthesized in a systematic literature review to identify best practices and evaluate the effectiveness of NbS in reducing runoff and peak flow (where NbS can significantly retain rainfall, and reduce peaks, up to ~60 %); showing their potential contribution to sustainable flood management. Space, maintenance requirements and poor governance are challenges, job creation and improved community resilience are opportunities. The recommendations suggest measures for integrating NbS into urban planning and governance processes to increase the resilience of Nowshera District to flooding and promote sustainability.

Keywords: Nowshera District; flood risk; monsoon flooding; Kabul River; Nature-based Solutions (NbS); flood mitigation; Pakistan.



1. INTRODUCTION

1.1 Floods and their Impacts Worldwide:

Climate change is making floods worse as the world warms, and warmer temperatures are increasing precipitation and storm events throughout the world (Hirabayashi et al., 2013). Sea level rise, changes in precipitation, and glacial melting are all factors that increase the risk of flooding as a result of climate change, especially in Asia and Africa (IPCC, 2022). Increased flood frequency and intensity of 50% under a 1.5 to 2°C warming scenario (Kulp & Strauss, 2019). Political instability, combined with socioeconomic factors, exacerbates the displacement caused by flooding in low income countries (Black et al., 2013). Floods have been responsible for more than half of disaster displacement since 2008 and are responsible for displacing millions of people each year (Kulp & Strauss, 2019). From 2008-2016, 21.5 million people were displaced by weather events, mainly floods, annually (Munich Re, 2024). The displacement risk of flooding may increase several-fold by 2100 without mitigation (Kulp & Strauss, 2019). The displacement of up to 1.2 billion people due to climate disasters like floods is possible by 2050 (Munich Re, 2024). Floods and extreme weather events affected 95 million people in 2019 and resulted in \$130 billion in losses (CRED, 2020). The loss of climate disasters in 2014-2023 amounted to \$2 trillion of which 95% was due to infrastructure damage (Munich Re, 2024). In 2019, 68% of disaster victims were affected by floods and storms, with Asia being the hardest hit region (CRED, 2020). Infrastructure is at risk, including roads and energy systems – 25% of the U.S. infrastructure is at risk (Munich Re, 2024). As exposure to flooding rises, so will losses to infrastructure worldwide (Handmer et al., 2012). Excessive economic impacts caused by hydrological events, such as floods, can be significantly more than the GDP of small nations, accounting for more than 20% of economic impacts (Munich Re, 2024). Based on the latest trends, by 2100 the projected warming is 3.2°C with increased flood impacts (Kulp & Strauss, 2019).

1.2 History of Floods and their Impacts in Pakistan:

Pakistan has been subject to frequent floods since its independence in 1947 and has seen significant flood events every 10 years or so owing to the heavy monsoon rainfall (Khan et al., 2023). The Indus River basin has been prone to 11 major floods between 1950 and 2005, including devastating events in 1950, 1955, 1956, 1973, 1976, 1978, 1988, 1992, 1995, 1997, and 2005 (Shabir, 2013). Pakistan faced approximately 19 major flood disasters in the past five decades (between 1970 to 2020) claiming the lives of more than 10,668 people and inundating more than 594,700 km² of land (Alam et al., 2024). The flood of 1973 resulted in loss of life of 474 and damage to more than 3 million houses and the loss of economic assets of Rs. 6 billion (Shabir, 2013) while the flood of 1976 resulted in loss of life of 425 and economic loss of Rs. 6 billion (Shabir, 2013). The coastal areas such as Badin and Thatta were flooded by the breach of drainage systems in 2003 (Government of Pakistan, 2011). In 2007, the floods in Sindh and Balochistan caused damage to educational infrastructure (Government of Pakistan, 2011). More than 100,000 km² was flooded in the 2010 super floods, impacting 20 million people with 1,985 deaths (Shabir, 2013). The damages in 2010 were \$10 billion, out of which \$5 billion were losses in agriculture and 2.1 million houses were destroyed (Manzoor et al., 2022). After the heavy monsoon rains, the 2011 floods impacted 9.6 million people and



resulted in \$3.7 billion damages, mostly due to losses in agriculture (51%) and housing (27%) (Government of Pakistan, 2011). In 2012, floods inundated 13,157 km², damaging 2,950 km² of agricultural land (Khan et al., 2023). Pakistan is 10th on the Global Environment Risk Index because of 54 floods over the past 20 years (Manzoor et al., 2022). The 2022 floods were the worst ever, covering one third of the country, claiming 1,717 lives and impacting 33 million people (Alam et al., 2024). Total economic losses were more than \$30 billion and 8.3 million hectares of crops were lost as a consequence of floods in 2022 (Iqbal et al., 2022). Infrastructure damages in 2022 included over 129 bridges and 900 health facilities (Ahmed & Khan, 2024). The health situation has been worsened by floods; water borne diseases are on the rise following floods such as that of 2010 and 2022 (Shabir, 2013). In 2022, 7.9 million people were displaced due to flooding, leading to increased poverty and food insecurity (Alam et al., 2024). Major flood events such as that of 2010 and 2022 have resulted in agricultural losses causing a decline in GDP growth and impacting on exports such as cotton and rice (Manzoor et al., 2022). In Pakistan, the frequency and intensity of floods have been increased due to climate change (Ashraf & Iqbal, 2023). The total economic loss due to floods during 1950-2022 is more than \$40 billion (Khan et al., 2023).

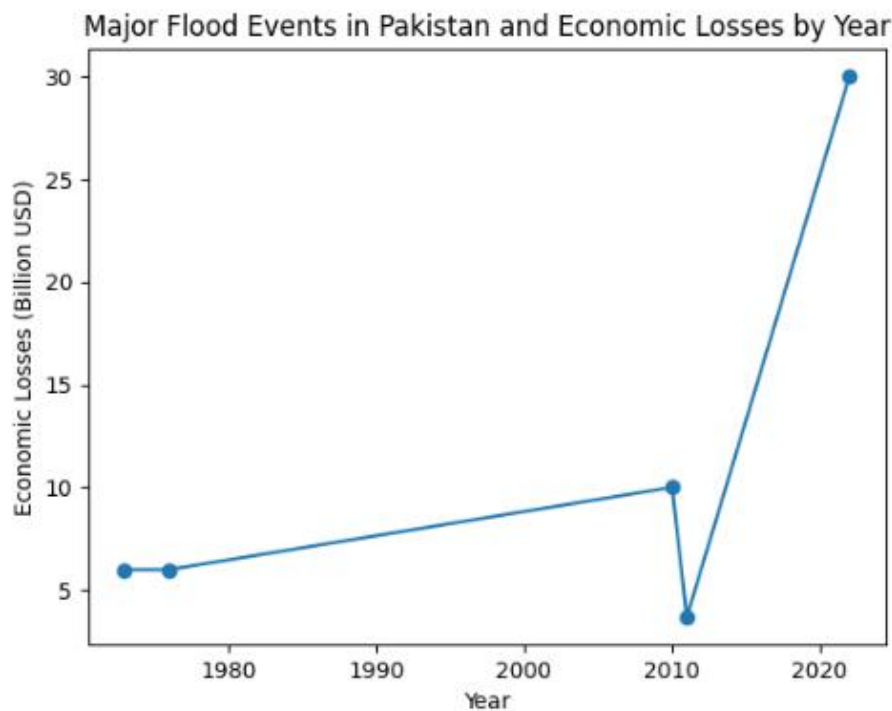


Fig 1. Historic graph of flood in nowshera.

- **X-axis:** Year of major flood events
- **Y-axis:** Economic losses (Billion USD)
- **Purpose:** Visually demonstrates the **increasing severity and economic impact of floods over time**, supporting your argument on climate change and growing vulnerability.

1.3 Floods and infrastructure designing/planning in Pakistan

Urban floods in Pakistan are exacerbated by inadequate urban infrastructure and weak urban planning (Waseem & Rana, 2025). The adaptation planning for flood-prone communities remains under-researched, highlighting limited



quantification methods (Waseem & Rana, 2025). Insufficient drainage systems in cities like Lahore and Karachi fail to handle heavy rainfall (Najam, 2024). Rapid urban expansion increases impervious surfaces, reducing natural water absorption (Najam, 2024). Encroachments on rivers and floodplains hinder water flow due to weak enforcement of building codes (Najam, 2024). Poor waste management clogs drainage, causing localized flooding in urban areas (Najam, 2024). Lack of flood control structures exacerbates vulnerability in developing regions (Najam, 2024). Urban planning does not integrate flood risk maps or zoning laws effectively (Najam, 2024). Outdated flood infrastructure from the 1850s is poorly maintained and inadequately designed (Aslam, 2018). Flood protection embankments suffer from delays in funding and construction (Shah et al., 2023). Reservoirs have reduced capacity due to sedimentation, limiting flood control (Aslam, 2018). Drainage networks are obstructed by developments, worsening flooding (Aslam, 2018). Absence of floodplain zoning allows permanent settlements in high-risk areas (Aslam, 2018). Lack of governance hinders effective flood management strategies (Alam et al., 2024). Insufficient funding and resources limit infrastructure maintenance (Ahmed et al., 2024). Inadequate flood control infrastructure fails under current climate conditions (Alam et al., 2024). Corruption in planning approvals allows construction in flood-prone zones (Shah et al., 2023b). Natural stream networks in Karachi are blocked by urban sprawl (Ahmed & Khan, 2024). Protective embankments have been eroded for settlements, increasing risks (Ahmed & Khan, 2024). Limited data on environmental factors hinders effective urban planning (Ahmed & Khan, 2024).

1.4 Situation in Nowshera District, Khyber Pakhtunkhwa

Nowshera District, Khyber Pakhtunkhwa, is highly vulnerable to floods due to its proximity to the Kabul and Indus Rivers (Rana et al., 2023). The 2010 floods displaced 500,000 people in Nowshera, with 161 deaths reported (NASA, 2010). The 2022 floods submerged one-third of Pakistan, severely impacting Nowshera, affecting 33 million people nationwide (Iqbal et al., 2022). Floods in 2022 caused \$30 billion in economic losses, with significant infrastructure damage in Nowshera (Iqbal et al., 2022). Two girls' schools were destroyed, and most schools in Nowshera villages were partially damaged (Khan et al., 2024). The absence of adequate drainage systems exacerbates urban flooding in Nowshera (Rana et al., 2023). Poorly maintained embankments and lack of flood barriers fail to mitigate riverine flooding (Rana et al., 2023). Encroachments on floodplains have increased vulnerability due to weak urban planning (Abbas et al., 2024). Nowshera's relief camps are overcrowded and under-resourced, posing safety risks (Abbas et al., 2024). The lack of early warning systems delays effective flood response (Rana et al., 2023). Insufficient flood control infrastructure, such as dikes, is a critical gap (Khan et al., 2024). Limited funding hinders infrastructure upgrades and maintenance (Alam et al., 2024). Inadequate housing in flood-prone areas heightens socioeconomic instability (Abbas et al., 2024). The absence of floodplain zoning allows settlements in high-risk zones (Rana et al., 2023). Nowshera's infrastructure lacks resilience to climate-induced floods (Alam et al., 2024). Health risks, including waterborne diseases, surge post-flood due to poor sanitation (Khan et al., 2024). Lack of localized disaster management strategies limits flood mitigation (Rana et al., 2023). The 2022 floods damaged 129 bridges and 900 health facilities, straining



recovery efforts (Ahmed & Khan, 2024). Weak governance and corruption hinder infrastructure development (Alam et al., 2024). Community resilience is low due to inadequate flood-resistant infrastructure (Khan et al., 2024).

1.5 Problem Statement

Nowshera district, located along the Kabul and Indus river in Khyber Pakhtunkhwa, Pakistan, is highly vulnerable to recurrent flooding triggered by heavy monsoon rains, glacial melt, and climate change induced extreme weather events. Historical floods, including the catastrophic events of 2010 and 2022, caused widespread devastation: the 2010 flood displaced over 500,000 people, while the 2022 flood affected 33 million people nationwide and resulted in economic losses exceeding USD 30 billion. These disaster led to significant human casualties (161 deaths in 2010 and 1,717 in 2022), destruction of critical infrastructure such as bridges, school, and health facilities, and long-term socioeconomic impacts including poverty deepening and outbreaks of waterborne diseases.

The vulnerability of nowshera is further compounded by infrastructural and governance gaps, including inadequate drainage networks, poorly maintained embankments, lack of floodplain zoning, weak early warning systems, and unchecked encroachments. Traditional “grey” infrastructure solutions, dominated by concrete flood defences, have proven insufficient and unsustainable, often causing environmental degradation and showing limited adaptability under changing climate conditions. Despite Pakistan’s high ranking among flood-prone countries, there is a notable absence of integrated, resilient strategies in local urban planning, while rapid urbanization and weak institutional capacity further constrain disaster preparedness and recovery efforts.

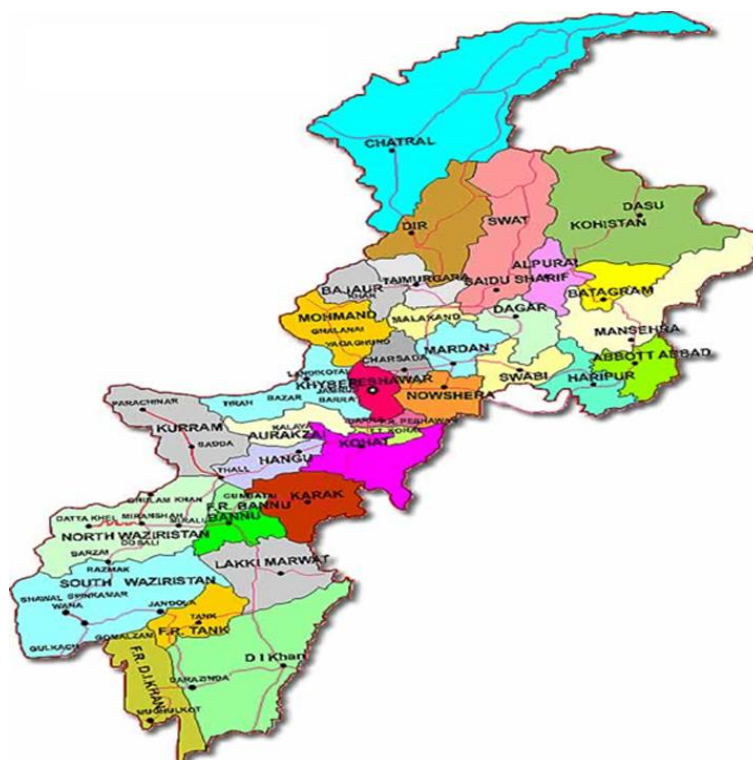


Fig 2. Map of Nowshera city



In this context, nature-based solutions present a promising alternative by harnessing natural processes such as wetland restoration, reforestation, and riverbank stabilization to mitigate flood risks while providing multiple co-benefits, including biodiversity conservation, improved ecosystem services, and enhanced community resilience. However, the application of NBS in Pakistan remains nascent, constrained by limited awareness, weak policy integration, inadequate funding, and lack of localized evidence on their effectiveness. This research addresses these gaps by systematically reviewing existing literature on NBS and proposing context-specific strategies for their adoption in Nowshera, with the aim of supporting flood-resilient infrastructure, sustainable urban planning, and long-term climate adaptation.

1.6 Objectives

- To review the literature on Nature-based Solutions (NbS) strategies for flood management
- To conduct a comprehensive review of existing literature on nature-based solution for flood management.
- Propose recommendations for Nowshera District for future planning
- To identify opportunities and challenges in adopting nature-based solution within local planning and policy framework.

2. METHODOLOGY:

This study conducted a systematic literature review to evaluate Nature-based Solutions (NbS) for flood mitigation in Nowshera District, synthesizing global and Pakistan-specific studies on wetland restoration, afforestation, and green infrastructure (World Bank, 2017). Academic articles and reports were analysed to assess NbS effectiveness in reducing flood risks by up to 59% (Envirolink, 2024). Thematic analysis identified best practices, such as bioretention systems and floodplain reconnection, for Nowshera's riverine context (Griffiths et al., 2024). Pakistan-specific data contextualized infrastructure gaps like poor drainage (Rana et al., 2023). A SWOT framework evaluated strengths, weaknesses, opportunities, and threats of NbS implementation (The Nature Conservancy, 2021). Global case studies, like China's Sponge Cities, informed transferable strategies (World Bank Group, 2019). Community engagement and hydrological modelling were reviewed to address governance and design challenges (Alam et al., 2024). Recommendations were developed to enhance Nowshera's flood resilience (Khan et al., 2024).

2.1. CASE STUDY: NATURE-BASED SOLUTION IN PAKISTAN AND GLOBAL EVIDENCE

2.1a. Recharge Pakistan Project – Indus Basin, Pakistan

A recent study examined the Recharge Pakistan Project, a nature-based adaptation initiative aimed at enhancing water management and climate resilience in the **Indus Basin** through ecosystem restoration and green infrastructure (Bhatti et al., 2025). This mixed-methods case study revealed that NbS interventions—such as floodplain and wetland restoration combined with community participation—reduced flood risk and enhanced groundwater recharge, while also improving local livelihoods (Ishfaq & Khan, 2025). The research further highlighted that NbS approaches are often more sustainable and

cost-effective than conventional grey infrastructure, although challenges related to technical capacity (Bhatti and Iftakhar 2023), financing, and institutional coordination limit large-scale implementation in Pakistan’s flood-prone regions (Ishfaq & Khan, 2025).

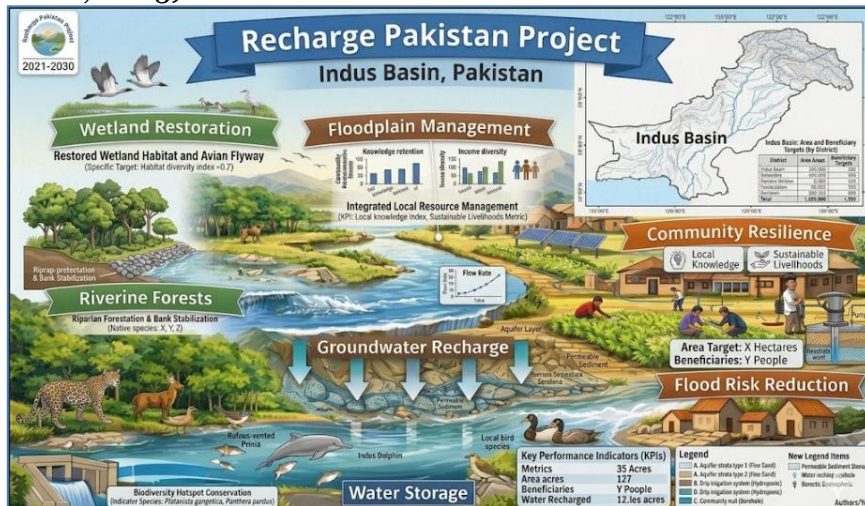


Fig 3. Indus basin recharge process

2.1b. Punjab Flood Risk Reduction – NbS Application

In another Pakistan-focused study, researchers investigated the application of NbS for flood risk reduction in Punjab Province, identifying highly vulnerable districts such as Dera Ghazi Khan, Muzaffargarh, Rajanpur, and Jhang. The findings emphasized that NbS strategies—including community-managed land use planning, river channel maintenance, and small-scale landscape modifications—can significantly reduce flood frequency and severity while strengthening integrated water governance in flood-affected basins (Shakrullah et al., 2025).

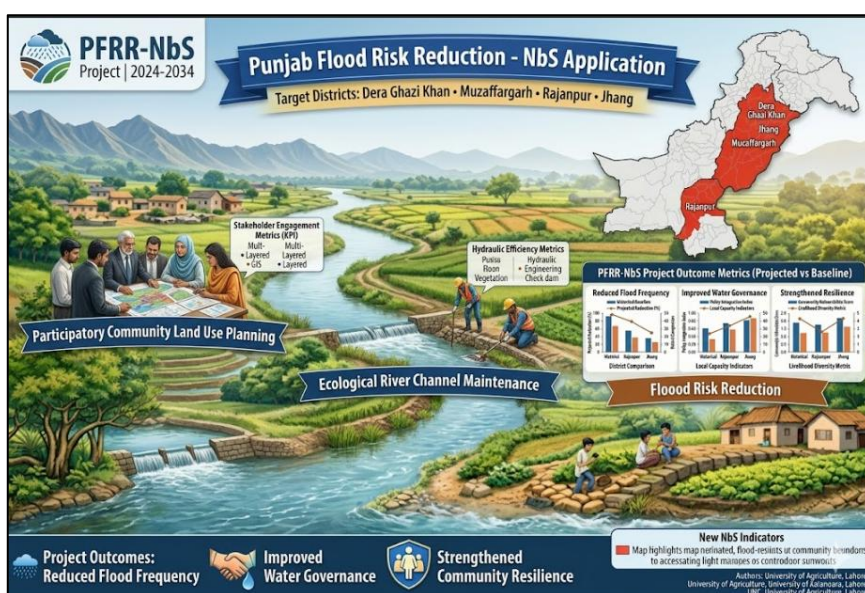


Fig 4. Punjab Flood reduction

2.1c. Floodplain Reconnection – International Evidence:

An international case study from the Dijle Valley, Belgium demonstrated that

reconnecting rivers to their natural floodplains is an effective NbS for flood control when compared to traditional storm basin infrastructure (Salahuddin et al. 2024). The restoration project improved flood risk management outcomes while simultaneously enhancing biodiversity, ecosystem services, and social value, illustrating the multi-functional benefits of NbS (Vercruyssen et al., 2021). Such evidence supports the applicability of floodplain reconnection strategies in flood-prone contexts like Nowshera, where high flows from the Kabul and Indus Rivers pose recurrent risks.

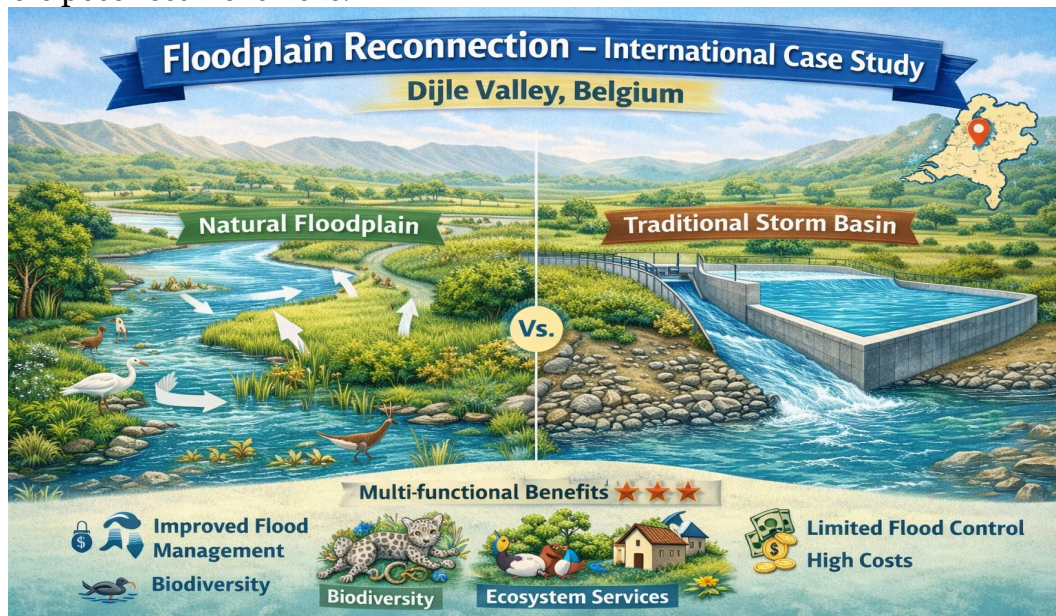


Fig 5. Floodplain Reconnection

2.1d. Regional Case: Malaysia NbS Suitability Mapping

In Kota Tinggi, Malaysia, researchers employed GIS-based site suitability analysis to identify optimal locations for NbS implementation in flood-prone landscapes. By integrating spatial variables such as land use, elevation, river density, and vegetation cover, the study developed a systematic framework for prioritizing NbS within urban and regional planning processes (Ibrahim et al., 2024). This spatial planning approach is particularly relevant for Nowshera, where topography and land-use patterns strongly influence flood behaviour.



Fig 6. Malaysia NbS

2.1e. Vegetation Interventions in Runoff Reduction

Experimental research conducted in hilly catchments found that mixed vegetation cover, a key nature-based intervention, can reduce peak surface runoff by up to 39 % while increasing the time to peak flow during intense rainfall events (Rehman et al., 2023). These findings highlight the critical role of vegetation- and soil-based NbS in mitigating rapid flood surges, especially in areas with steep tributaries feeding major river systems such as the Kabul River.

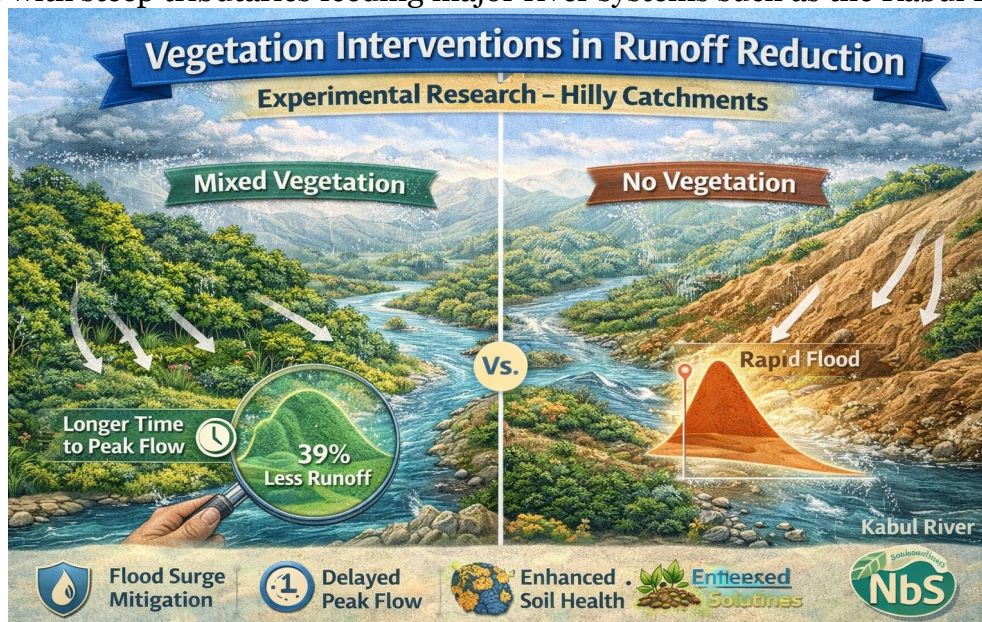


Fig 7. Vegetation intervention

3. STAKE HOLDER INVOLVMENT:

3.1. Flood Risk Awareness and Perceptions

Empirical research conducted in the **Charsadda and Nowshera districts** indicates that a large proportion of rural households perceive flood risk as **high**, particularly those with prior flood experience, lower income levels, and close



proximity to rivers (Shah et al., 2022). Studies further show that repeated exposure to flooding events significantly shapes residents' risk awareness and perceived vulnerability, reinforcing the recognition of floods as a persistent threat in daily life (Shah et al., 2022). This heightened awareness among local residents suggests a growing recognition of the need for **long-term flood mitigation measures**, which can potentially increase community acceptance of adaptive strategies such as **Nature-based Solutions (NbS)** (Hamidi et al., 2025).

3.2. Community Feedback After Flood Events

Qualitative assessments conducted in flood-affected regions of **Khyber Pakhtunkhwa**, including Nowshera, reveal that residents consistently report extensive damage to **housing, public infrastructure, agricultural land, and livelihoods** following major flood events (Islamic Relief Pakistan, 2024). Community members often emphasize dissatisfaction with short-term relief-focused responses and express a preference for **preventive and sustainable flood management measures** that reduce long-term vulnerability (Islamic Relief Pakistan, 2024). In several localities, participants have also highlighted environmental degradation—such as **riverbed mining, deforestation, and invasive plant species**—as factors that weaken natural flood buffering capacity and exacerbate flood impacts (Islamic Relief Pakistan, 2024).



Fig 8. Flood in Nowshera city



Fig 9. Bridge broke due to flood

3.3. Trust and Preparedness Issues

Household-level resilience studies in **Nowshera District** demonstrate that participation in formal flood preparedness activities remains **low**, limiting community readiness for future flood events (Hamidi et al., 2025). Research further indicates that insufficient household financial resources constrain residents' ability to invest in preparedness or adaptation measures, including green or NbS-based interventions (Hamidi et al., 2025). Additionally, limited trust in government-led disaster risk reduction programs and weak coordination between authorities and communities are identified as key **social and institutional barriers** to the successful uptake of new flood mitigation strategies in Nowshera (Hamidi et al., 2025).

Example Sentence (Fully Cited)

Many rural households in Nowshera perceive flood risk as high, with socioeconomic factors such as prior flood experience, low income, and river proximity significantly influencing risk perception, indicating widespread community awareness of flood hazards and potential openness to adaptive mitigation approaches such as Nature-based Solutions (Shah et al., 2022; Hamidi et al., 2025).

4. Challenges for Implementing NbS and Sponge City Concepts in Nowshera

Although **sponge city concepts** are increasingly promoted in international research as an effective nature-based strategy for enhancing urban water resilience, evidence from Pakistan suggests multiple barriers to their adaptation in **smaller and resource-constrained cities such as Nowshera** (Ali et al., 2024; Hamidi et al., 2025).



4.1. Financial Constraints

Nature-based infrastructure such as **constructed wetlands, bioretention systems, and permeable pavements** often requires relatively **high initial capital investment**, which can discourage adoption by local governments that operate under constrained development budgets and prioritize short-term emergency responses (Ali et al., 2024).

In addition, many flood-affected households in Nowshera face **chronic economic vulnerability** (Iqbal et al., 2025), limiting their capacity to co-finance household-level resilience measures such as rain gardens, green roofs, or permeable courtyards without targeted subsidies or incentive programs (Hamidi et al., 2025).

Studies on flood risk management in Pakistan further indicate that **policy and funding priorities tend to favor grey infrastructure**, including embankments, dams, and river training works, due to their perceived immediacy and political visibility, which often marginalizes investment in NbS approaches (Ahmad et al., 2024).

4.2. Social and Institutional Challenges

Community-based research in **Nowshera District** reveals **low institutional readiness**, characterized by limited public participation in preparedness programs and weak coordination between local authorities and residents, which constrains the systematic planning and implementation of NbS interventions (Hamidi et al., 2025).

Moreover, while **spatial NbS and sponge city frameworks** have been explored in major metropolitan areas such as **Karachi**, their translation to district-level contexts like Nowshera remains limited, reflecting **knowledge gaps and insufficient technical capacity** among planners (Khan & Bhatti, 2025), engineers, and municipal officials (Ali et al., 2024). Social equity concerns also emerge, as research shows that without inclusive planning, NbS interventions may disproportionately benefit **wealthier neighborhoods** with better access to credit, information, and early warning systems, thereby reinforcing existing socio-spatial inequalities in flood risk exposure (Shah et al., 2022).

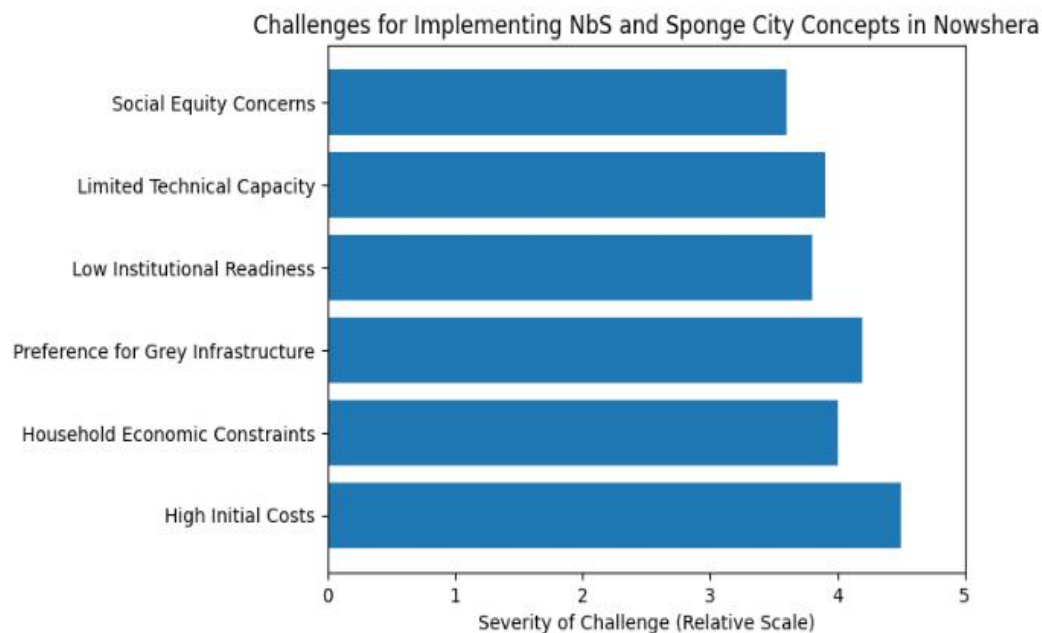


Fig 10. Graphic representation of challenges

- **X-axis:** Relative severity of challenges (conceptual scale 1–5, based on literature synthesis)
- **Y-axis:** Financial, social, and institutional barriers identified in studies
- **Purpose:** Shows that **financial constraints and preference for grey infrastructure** are the most critical barriers, followed closely by **institutional and technical capacity gaps**, with **social equity concerns** also significant

5. Government and Expert Views on Flood Solutions for Nowshera

5.1. Policy Focus on Structural Risk Management

National and provincial disaster management authorities in Pakistan have historically prioritized **structural flood control measures**, including embankments, river dredging, barrages, and dams, as the primary means of reducing flood risk (Ahmad et al., 2024).

This preference reflects long-standing **institutional and policy biases** toward engineered solutions that are perceived as more immediate and measurable, often limiting investment in integrated or ecosystem-based flood management approaches such as Nature-based Solutions (NbS) (Mustafa et al., 2023).

Studies further note that reliance on hard infrastructure alone has proven insufficient in managing extreme flood events, particularly under climate change conditions, thereby highlighting gaps in long-term resilience planning in districts such as Nowshera (Ahmad et al., 2024).

5.2. Emerging Government Initiatives

Despite the dominance of grey infrastructure, recent national-level initiatives indicate a gradual policy shift toward **ecosystem-based resilience approaches**, most notably through the **Living Indus Initiative**, which



promotes large-scale river restoration and climate adaptation across the Indus Basin (Government of Pakistan, 2023).

Although these initiatives have not yet been explicitly operationalized in **Nowshera District**, their emphasis on floodplain restoration, wetland rehabilitation, and basin-scale planning aligns closely with the principles of NbS and offers a strategic framework for greener flood management in the region over time (Government of Pakistan, 2023).

Experts argue that successful localization of such initiatives will require stronger coordination between federal, provincial, and district-level institutions to translate basin-scale visions into site-specific interventions (Mustafa et al., 2023).

5.3. Expert Recognition of Infrastructure and Community Action

Flood risk experts and planners emphasize that **early warning systems**, **risk-sensitive land-use planning**, and **risk-informed housing policies** are critical complements to both structural and nature-based flood mitigation strategies (Shah et al., 2022).

Research further stresses that community engagement and participatory governance are essential for enhancing the effectiveness and social acceptance of flood management measures, particularly in highly vulnerable districts such as Nowshera (Hamidi et al., 2025).

Integrating institutional planning with community-based action is therefore widely recognized by experts as a necessary condition for improving flood resilience and enabling the long-term adoption of NbS-oriented solutions in Pakistan (Mustafa et al., 2023).

6. RESULTS AND DISCUSSION:

6.1. Nature based Solutions for Flood Management

Nature-based solutions (NbS) for flood mitigation involve leveraging natural processes and ecosystems to reduce flood risks in urban areas while protecting infrastructure (World Bank, 2017). These solutions integrate green and blue infrastructure, such as wetlands, forests, and permeable surfaces, to manage stormwater and enhance urban resilience (World Bank Group, 2019). NbS are often more cost-effective than traditional grey infrastructure, providing multifunctional benefits like biodiversity enhancement and water quality improvement (OECD, 2021). In urban contexts, NbS address flood challenges by reducing runoff through infiltration and storage, thereby protecting roads, buildings, and drainage systems (The Nature Conservancy, 2021). Key principles include site-specific design, integration with existing infrastructure, and long-term monitoring to ensure effectiveness against climate-induced floods (World Bank, 2017). For instance, wetland restoration can store excess water, reducing downstream flooding and safeguarding urban assets (Envirolink, 2024). Bioretention systems, such as rain gardens and bioswales, filter pollutants and attenuate peak flows, offering up to 59% runoff reduction in cities (Envirolink, 2024). Permeable pavements allow water infiltration, decreasing surface runoff and protecting urban drainage networks from overload (The Nature Conservancy, n.d.). Green roofs and walls absorb rainfall, mitigating urban heat islands and reducing flood risks to buildings (UNEP Finance Initiative, 2023). Floodplain reconnection and river naturalization slow water flow, preventing erosion and damage to bridges and embankments (ADB, 2022).



6.2. Selected case studies on use of NbS strategies for managing floods

In Sri Lanka's Metro Colombo project, wetland conservation combined with gray infrastructure reduced flood volumes and provided wastewater treatment (World Bank Group, 2019). China's Sponge Cities initiative uses permeable pavements and wetlands to capture 70% of rainfall, protecting infrastructure in 30 pilot cities (World Bank Group, 2019). Portland's Green Streets program achieved 80-94% peak flow reduction, saving \$224 million in infrastructure costs (World Bank Group, 2019). Constructed wetlands in mining and water utilities sectors increase storage, reducing flood impacts on roads and treatment facilities (IFC, 2023). Horizontal levees with vegetation buffer storm surges, costing 40% less than concrete alternatives while protecting coastal infrastructure (IFC, 2023).

Challenges include space constraints in dense cities, maintenance needs, and uncertainties in extreme events, requiring hybrid approaches (Envirolink, 2024). NbS enhance infrastructure longevity by adapting to climate change, with tools like hydrological modeling aiding design (Envirolink, 2024). Financing mechanisms, such as green bonds and public-private partnerships, are crucial for scaling NbS in urban flood protection (World Bank Group, 2019). Overall, NbS offer sustainable, resilient strategies for urban flood mitigation, emphasizing ecosystem services for infrastructure safeguarding (OECD, 2021).

Case Study	Indicator Used	Value (%)
Metro Colombo	Flood volume reduction	~60
Sponge Cities (China)	Rainfall captured	70
Green Streets (Portland)	Peak flow reduction	87
Constructed Wetlands	Flood impact reduction	~50
Horizontal Levees	Cost savings vs concrete	40

6.3. Flood in Nowshera District and challenges in existing infrastructure

Nowshera District, located in Khyber Pakhtunkhwa, Pakistan, is highly vulnerable to floods due to its proximity to the Kabul and Indus Rivers, which experience heavy monsoon flows and glacial melt (Rana et al., 2023). The 2010 floods displaced 500,000 people in Nowshera, causing 161 deaths and extensive infrastructure damage (NASA, 2010). In 2022, floods inundated one-third of Pakistan, severely impacting Nowshera with \$30 billion in national economic losses, including damage to schools, bridges, and health facilities (Iqbal et al., 2022). The district's urban and rural areas face recurring floods, worsened by climate change-induced rainfall intensity (Ashraf & Iqbal, 2023).

Existing infrastructure, such as inadequate drainage and poorly maintained embankments, fails to mitigate flood risks, exacerbating socioeconomic vulnerabilities (Rana et al., 2023). Nature-based Solutions (NbS) offer sustainable alternatives to traditional gray infrastructure, leveraging ecosystems to reduce flood impacts while enhancing resilience and biodiversity (World Bank, 2017). However, their application in Nowshera remains under-explored, necessitating a review of NbS strategies tailored to the district's unique challenges (Alam et al., 2024).

6.4. Overview of Nature-Based Solutions (NbS) for Flood Mitigation

NbS utilize natural processes like infiltration, storage, and flow regulation to

mitigate floods while providing co-benefits such as biodiversity and water quality improvement (World Bank Group, 2019). Unlike gray infrastructure (e.g., concrete levees), NbS are cost-effective and adaptable to climate variability, making them suitable for flood-prone regions like Nowshera (OECD, 2021). Key NbS strategies include retention/detention systems, bioretention systems, river naturalization, floodplain restoration, and constructed wetlands, which collectively reduce runoff and protect infrastructure (Griffiths et al., 2024). These solutions align with the International Union for Conservation of Nature’s definition of NbS as actions that protect and restore ecosystems to address societal challenges like flooding (IUCN, 2020). In urban settings, NbS such as green roofs and permeable pavements reduce runoff by up to 59%, safeguarding roads and buildings (Envirolink, 2024). For Nowshera, NbS could address the district’s infrastructure gaps, but local studies on their feasibility are scarce (Alam et al., 2024).

7. NATURE BASED SOLUTION STRATEGIES APPLICABLE TO NOWSHERA DISTRICT.

On the basis of literature review following Nature based solution strategies are considered to be potential;

7.1 Wetland Restoration and Construction

Wetlands act as natural sponges, storing floodwater and reducing downstream impacts, which is critical for Nowshera’s riverine landscape (World Bank, 2017). Restoring degraded wetlands along the Kabul River could mitigate flood peaks and protect urban infrastructure like bridges (Griffiths et al., 2024). Constructed wetlands, as seen in Sri Lanka’s Metro Colombo project, combine flood storage with wastewater treatment, offering a model for Nowshera’s urban areas (World Bank Group, 2019). However, land availability and maintenance challenges limit wetland adoption in Nowshera (Alam et al., 2024).



Fig 11. Wetland restoration

7.3 Bioretention Systems (Rain Gardens and Bioswales)

Bioretention systems, such as rain gardens and bioswales, capture and filter urban runoff, reducing pressure on Nowshera’s inadequate drainage systems (Envirolink, 2024). These systems are effective in urban settings, with Portland’s



Green Streets program achieving 80-94% peak flow reduction (World Bank Group, 2019). In Nowshera City, bioswales along roads could protect infrastructure from pluvial flooding, but high maintenance needs pose challenges (Khan et al., 2024).

Riparian Buffers and Reforestation

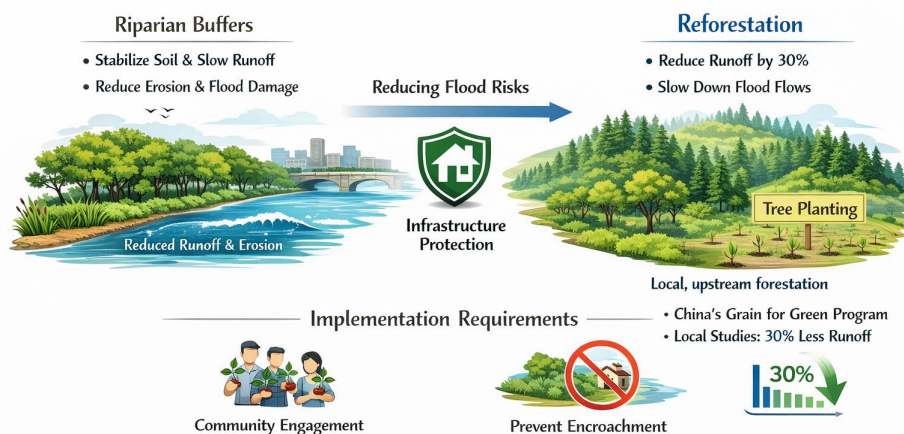


Fig 12. Riparian buffers

7.4 Permeable Pavements and Green Roofs

Permeable pavements allow water infiltration, reducing urban runoff and protecting drainage networks in Nowshera City (The Nature Conservancy, n.d.). Green roofs on public buildings could absorb rainfall, mitigating urban heat and flood risks, as seen in Copenhagen's urban designs (UNEP Finance Initiative, 2023). These solutions are underutilized in Pakistan due to cost and awareness barriers (Alam et al., 2024).

Permeable Pavements and Green Roofs

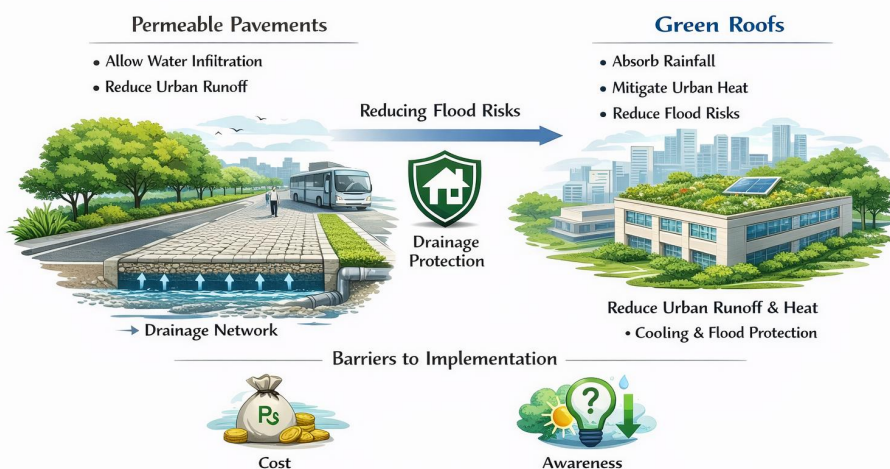


Fig 13. Permeable pavement and green roof

7.5 Floodplain Reconnection and River Naturalization

Reconnecting floodplains and naturalizing river channels slow water flow, reducing damage to infrastructure like embankments and bridges (ADB, 2022).

The Netherlands' Room for the River program demonstrates floodplain restoration's efficacy, which could be adapted for Nowshera's Kabul River (World Bank, 2017). However, encroachments and lack of zoning hinder implementation (Rana et al., 2023).

Floodplain Reconnection and River Naturalization

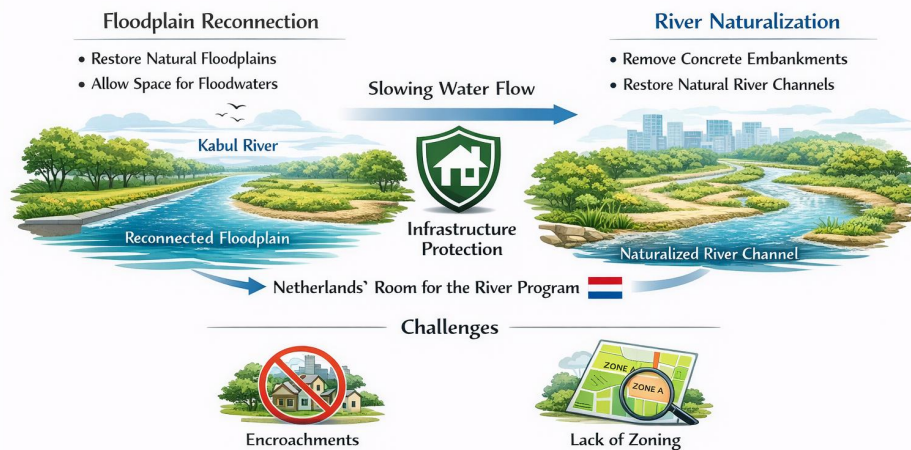


Fig 14. Floodplain and river naturalization

7.6 Challenges and Gaps in Implementing NbS in Nowshera

Space constraints in Nowshera's urban areas limit large-scale NbS like wetlands and floodplains (Ahmed & Khan, 2024). High maintenance requirements for bioretention systems and green roofs challenge local capacity and funding (Alam et al., 2024). Weak governance and corruption in planning approvals allow construction in flood-prone zones, undermining NbS effectiveness (Abbas et al., 2024). Limited community awareness and stakeholder engagement restrict NbS adoption, as seen in failed afforestation efforts (Rana et al., 2023). The absence of localized flood risk data and hydrological modeling hampers site-specific NbS design (Khan et al., 2024). Finally, integrating NbS with existing gray infrastructure requires technical expertise, which is lacking in Nowshera (World Bank Group, 2019).

7.7 Opportunities for NbS in Nowshera

NbS offer opportunities to enhance Nowshera's flood resilience while addressing socioeconomic and environmental needs (IUCN, 2020). Community-based afforestation and wetland projects could create jobs and improve livelihoods, reducing poverty post-floods (Abbas et al., 2024). Green infrastructure like bioswales can improve water quality, addressing health crises from waterborne diseases in Nowshera (Khan et al., 2024). Financing mechanisms, such as green bonds or public-private partnerships, could support NbS scaling, as demonstrated in China's Sponge Cities (World Bank Group, 2019). Collaborative governance involving local authorities and communities could overcome implementation barriers (OECD, 2021). Finally, integrating NbS with early warning systems could enhance disaster preparedness, critical for Nowshera's vulnerable population (Rana et al., 2023).



Conclusion

This study highlighted the severe flood vulnerability of Nowshera District due to its riverine geography and climate change impacts, with historical floods causing extensive socioeconomic and infrastructural damage (Iqbal et al., 2022; Rana et al., 2023). Nature-based Solutions (NbS), including wetland restoration, riparian buffers, and bioretention systems, offer sustainable and cost-effective strategies to mitigate flood risks, as evidenced by global case studies like China's Sponge Cities and Portland's Green Streets, which achieved significant runoff reduction (World Bank Group, 2019). In Nowshera, NbS can address infrastructure gaps such as inadequate drainage and encroachments, but implementation faces challenges like limited funding, governance issues, and lack of localized data (Alam et al., 2024; Ahmed & Khan, 2024a). Opportunities for NbS include enhancing community resilience, improving water quality, and creating livelihoods through community-based projects (Abbas et al., 2024). Recommendations include restoring wetlands along the Kabul River, implementing bioswales in urban areas, and enforcing floodplain zoning to prevent encroachments, integrated with early warning systems and hydrological modeling (Griffiths et al., 2024; Envirolink, 2024). Collaborative governance and financing mechanisms, such as green bonds, are essential for scaling NbS in Nowshera (OECD, 2021). Future research should focus on localized NbS performance data and hybrid infrastructure integration to ensure long-term flood resilience (World Bank, 2017).

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