Impact of Urban Sprawl/Urbanization on the City of Patna and Mitigation Measures: an Analysis of Flooding and Water logging in Recent Years

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Abstract

This study examines the impact of urban sprawl and flooding in Patna, Bihar, highlighting the socio-economic challenges posed by increased water logging in the city. Over recent decades, Patna has experienced significant urbanization, driven by population growth and economic development. However, this rapid expansion has led to inadequate drainage infrastructure and exacerbated flooding incidents, particularly during the monsoon season. The research employs a mixed-methods approach, combining qualitative interviews with local residents and officials, alongside quantitative analysis of rainfall and flood data from 2015 to 2023. Key findings reveal a direct correlation between urban development, climate change, and the increased frequency of water logging events, particularly in vulnerable areas such as Kankerbagh and Rajendra Nagar. The study emphasizes the urgent need for integrated urban planning and effective flood management strategies, including infrastructure upgrades, increased green spaces, and community awareness programs. It also calls for further research into sustainable urbanization practices that can enhance resilience to climate-related disasters, thereby contributing to more effective policy-making in flood-prone areas like Patna.

Keywords: Urban Sprawl, Urbanization, Flooding, Water logging, Patna, Mitigation Measures, Socio-economic Impact

Introduction

Patna, the capital city of Bihar with average elevation 53m (174 ft) , has undergone significant growth and urbanization over the past few decades. City is approximately 35 kms in length and approximately 17 kms in width. A characteristic feature of geography of Patna is its location at confluence of rivers. With a population increase from approximately 1.5 million in 2001 to over 2 million in 2021, the city has seen a rapid expansion of urban infrastructure and settlements (Census of India, 2021). This urban growth has been largely unplanned, leading to challenges such as inadequate drainage systems, haphazard land use, and insufficient public services. As Patna (figure 1) continues to evolve into a bustling metropolis, the consequences of this urbanization are becoming increasingly apparent, particularly in the context of flooding and water logging.Between 1991 and 2011, Patna experienced significant population growth, driven by urbanization, rural-to-urban migration, and the expansion of its municipal boundaries. According to the Census of India, Patna's population in 1991 was approximately 1.1 million. This figure rose sharply to around 1.7 million by 2001, marking a growth of about 54.5% over the decade. The upward trend continued, with the population reaching approximately 2.05 million by 2011, a further increase of 20.6%. This rapid

urban expansion was fueled by the city's development as an administrative, educational, and economic hub. However, this growth also exerted immense pressure on urban infrastructure, leading to challenges in housing, sanitation, and transportation systems.

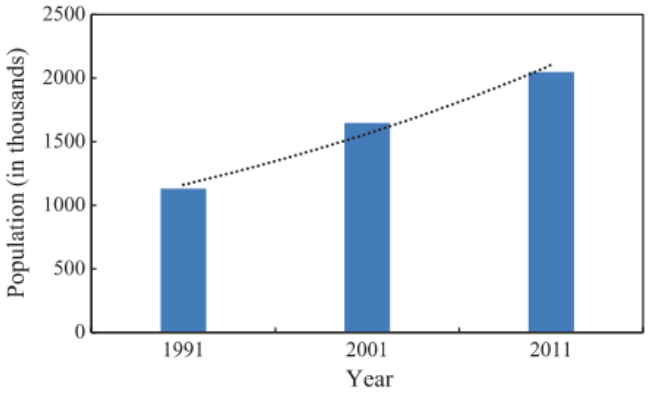


Fig 1- Population of Patna city (1991-2001) (Rashiq and Prakash,2023)

Geographically, Patna is situated along the southern bank of Ganges River and is characterized by low-lying areas that are susceptible to flooding during the monsoon season. The region experiences a humid subtropical climate, which brings heavy rainfall, particularly between June and September (Mishra & Singh, 2020). Over the years, the frequency and intensity of floods have escalated, largely attributed to climate change and erratic weather patterns, leading to significant disruptions in daily life and economic activities (IPCC, 2021). The interplay between the city's geographical features and climatic factors creates a precarious environment that is further exacerbated by anthropogenic influences.

One of the most pressing challenges facing Patna is the issue of waterlogging, which has emerged as a direct consequence of rapid urban sprawl. The city’s expansion has often encroached upon natural water bodies and drainage paths, leading to inadequate water management systems that fail to cope with heavy rainfall (Jha et al., 2021). Areas like Kankerbagh and Rajendra Nagar are particularly prone to severe waterlogging, disrupting transportation, daily activities, and local economies (Sahu & Kumar, 2020).

Addressing the challenges associated with urbanization and its impact on flooding is crucial for sustainable city management. A comprehensive understanding of the relationship between urban development and environmental vulnerabilities is essential for devising effective policies and strategies that can mitigate the adverse effects of flooding and waterlogging in Patna.

The aim of this study is to analyze the impact of urban sprawl and urbanization on the city of Patna, specifically focusing on the implications of flooding and waterlogging. The study seeks to identify the underlying causes of these issues, assess their socio-economic impacts, and propose effective mitigation measures to enhance the city’s resilience to flooding events. Through a mixed-methods approach, this research will contribute valuable insights into sustainable urban management practices that can be adopted in Patna and similar urban areas facing comparable challenges.

Methodology

Research Design

This study employed a mixed-methods approach, Literature study, site visit and analysis, both qualitative and quantitative research methods to provide a comprehensive understanding of the impacts of urban sprawl and waterlogging in Patna. Qualitative interviews with key stakeholders were combined with quantitative data analysis to facilitate a deeper exploration of the socio-economic effects of flooding and the challenges posed by rapid urbanization.

Data Sources

- **Primary Data**:
  - Interviews were conducted with local residents, urban planners, and officials from the Bihar State Disaster Management Authority (BSDMA). These interviews aimed to gather firsthand insights on the challenges of urban flooding and waterlogging, as well as perspectives on current management practices and proposed solutions.
- **Secondary Data**:
  - A comprehensive review of government reports, academic literature, and media articles was undertaken to contextualize the research. Sources included studies on urbanization trends, historical flooding events, and existing policy frameworks addressing flooding and waterlogging in Patna.

Sample Selection

- The research focused on urban areas of Patna, particularly neighborhoods that are most vulnerable to flooding and waterlogging. Areas like Kankerbagh and Rajendra Nagar were prioritized due to their history of severe waterlogging.
- **Time Frame**: Data analysis covered the period from 2015 to 2023 to capture recent trends, events, and the impact of significant urban development projects on the flooding situation.

Data Collection Methods

- **Surveys**:
  - Structured surveys were administered to residents in the selected areas to assess the impact of urbanization and flooding on their daily lives, livelihoods, and coping strategies. The survey included questions on experiences of flooding, economic losses, and community preparedness.
- **Statistical Analysis**:
  - A compilation of rainfall data, flood occurrences, and waterlogging incidents was conducted using records from government and meteorological agencies. This quantitative data was analyzed to identify patterns and correlations between rainfall events and flooding incidents in Patna.

Analytical Framework

- **Descriptive Analysis**:
  - This method was used to summarize and present the findings from the surveys and interviews. Key themes and patterns were identified to highlight the socio-economic impacts of flooding and waterlogging on residents and local businesses.
- **Comparative Analysis**:
  - This approach facilitated comparisons of socio-economic impacts of flooding before and after significant urban development projects were implemented. It aimed to evaluate how urbanization has influenced flooding incidents and waterlogging in Patna over the selected time frame.

Results

Urbanization Trends in Patna

The analysis of population growth and urban sprawl in Patna over the past two decades reveals significant urbanization trends. From 2001 to 2021, Patna's population increased from approximately 1.5 million to over 2 million, reflecting a growth rate of around 33% (Census of India, 2021). Overall the entire district of Patna has shown an increase in built-up area by almost 60% between 1998 and 2013(Mishra and Rai, 2016). This rapid urbanization has led to the expansion of built-up areas, particularly in neighborhoods like Kankerbagh, Rajendra Nagar, and Patna City.

The following table summarizes the population growth and urbanization patterns in key areas of Patna:

Area	Population Growth (2001-2021)	Key Developments	Implications for Flood Management
Kankerbagh	40%	Increased residential and commercial construction	Strain on existing drainage systems
Rajendra Nagar	35%	Development of new housing projects	Inadequate infrastructure leading to waterlogging
Patna City	30%	Expansion of urban services	High vulnerability to flooding due to impervious surfaces

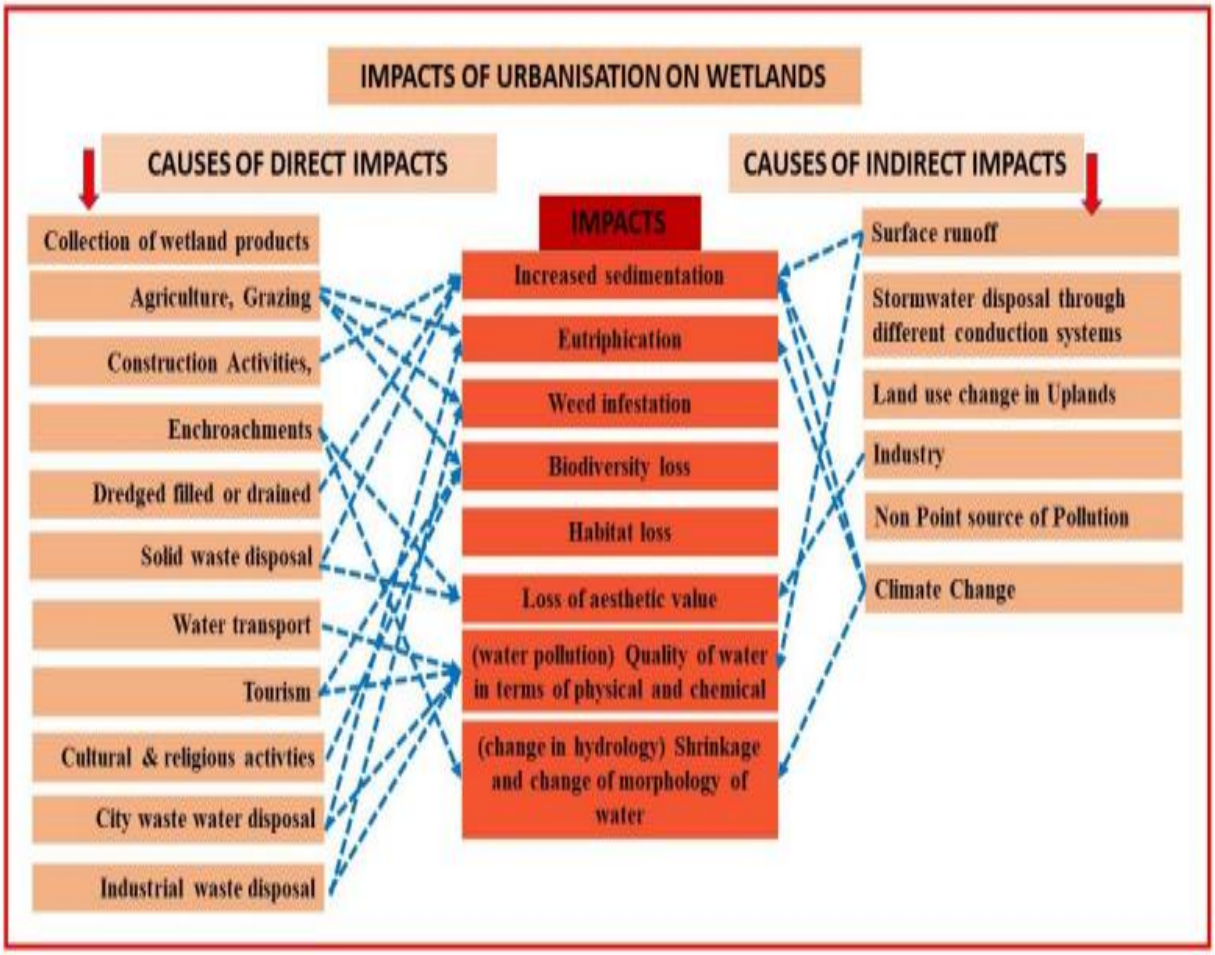


Fig 2 Impacts of urbanization on urban wetlands (Barman et al.,2021)

Urban wetlands, which play a critical role in ecological balance, are increasingly under threat due to rapid urbanization. According to Barman (2020), (figure 2) urbanization exerts profound and often detrimental impacts on these ecosystems. As cities expand, wetlands are frequently encroached upon for infrastructure development, industrial projects, and housing schemes. This leads to habitat loss, degradation of water quality, and disruption of wetland biodiversity.

Urbanization also contributes to increased pollution levels in wetlands. The discharge of untreated sewage, industrial effluents, and solid waste into these water bodies contaminates them with heavy metals, chemicals, and nutrients, resulting in eutrophication and reduced oxygen levels. Additionally, the replacement of natural wetland buffers with impervious surfaces exacerbates stormwater runoff, causing flooding and sedimentation in wetland areas.

Furthermore, Barman highlights the socio-economic implications of urban wetland degradation. Wetlands provide essential services such as groundwater recharge, flood regulation, and livelihoods for local communities. Urban encroachment compromises these benefits, affecting both urban resilience and community welfare.

The study underscores the need for sustainable urban planning and stringent regulatory measures to conserve urban wetlands and ensure their integration into urban landscapes. This includes promoting awareness, restoring degraded wetlands, and implementing policies that balance urban growth with ecological preservation.

Flooding and Water-logging Incidents

Urban flooding can be defined as inundation of urban area as a result of meterological and hydrological factors exacerbated by anthropogenic activities. Urban floods build up in very quick time due to impervious nature of surface. Historical data analysis indicates a marked increase in the frequency and intensity of flooding in Patna, particularly during the monsoon season. Notable flooding events occurred in 2017,2019 and 2020, which resulted in widespread water logging across the city. Last week of September 2019 saw city receive much more rainfall than 21 mm predicted by IMD. This triggered flooding in urban regions on September 29, low lying areas like Rajendra Nagar, Kankarbagh, Gandhi maidan were most affected areas. Entire state was receiving heavy rainfall, the situation was coupled by four rivers near patna son,Ganga, Gandak and Punpun rises above danger mark. Release of 2.75 lakh cusecs of water from Indrapuri barrage across sone river has worsened the situation in river ganga affecting patna flood **situation.**

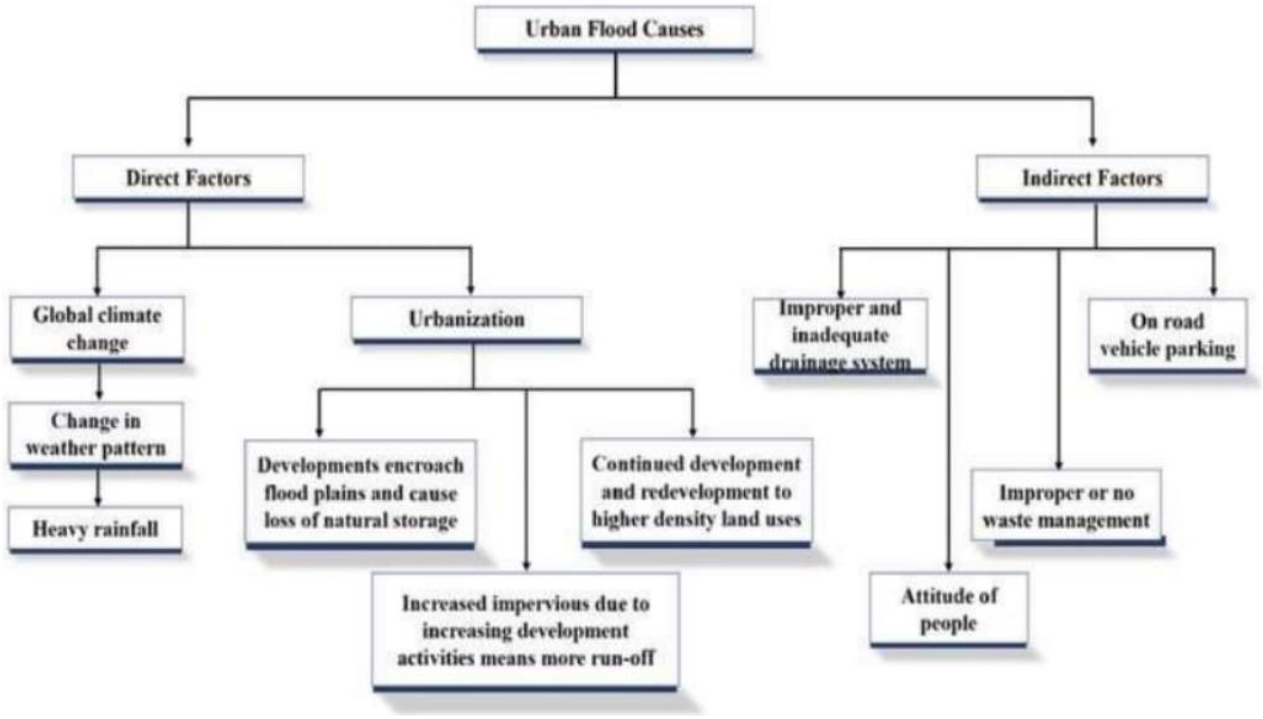


Fig 3 Causes of urban floods(Rashiq, Ahmad & Prakash, Om. (2023)

The following table provides an overview of significant flooding incidents in Patna during recent years:

Year	Rainfall (mm)	Areas Affected	Severity of Waterlogging
2017	600	Kankerbagh, Rajendra Nagar	Severe
2019	910	Kankerbagh, Rajendra Nagar, Gandhi Maidan, Patliputra colony	Severe
2020	550	Patna City, Kankerbagh	Moderate

Key areas in Patna most severely affected by waterlogging include Kankerbagh, Rajendra Nagar, and various parts of Patna City. The persistent waterlogging in these areas disrupts transportation, daily activities, and local economies, leading to increased public dissatisfaction and health risks.

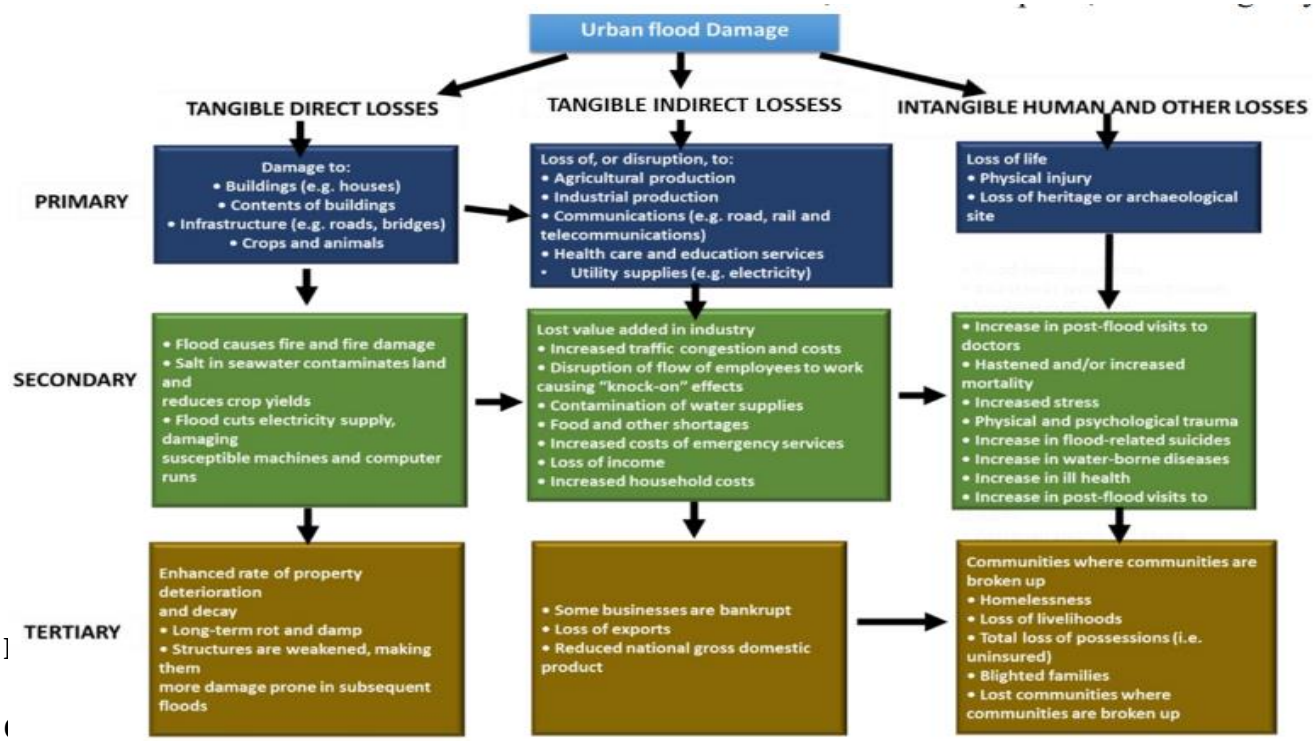
Socio-economic Impacts

The assessment of economic losses due to flooding and waterlogging indicates significant negative impacts on various sectors, including agriculture, businesses, and public health. Agricultural losses were particularly pronounced, as flooding affected crop yields and livelihoods in surrounding rural areas.

Survey findings further highlight the perceived impacts of urbanization on residents' quality of life and vulnerability to flooding. The results indicate that:

- **Economic Losses**: Approximately 60% of respondents reported economic losses due to flooding, with many citing damage to property and disruption of local businesses.

- **Quality of Life**: Over 70% of residents expressed concerns about the declining quality of life due to increased flooding incidents, emphasizing stress and health risks associated with waterlogging.



Flood losses can be broadly categorized into direct, indirect, and intangible losses, based on their nature and the extent of their impact. Each category encompasses a variety of social, economic, and environmental dimensions, highlighting the multifaceted repercussions of flood events.

Direct Losses:

These are immediate and physical damages caused by floodwaters. They include:

Property Damage: Destruction of residential buildings, commercial properties, and public infrastructure such as roads, bridges, and schools.

Agricultural Losses: Submersion of farmlands leading to crop destruction, loss of livestock, and soil erosion.

Human Casualties: Injuries and fatalities resulting directly from the flood event.

Environmental Impact: Alteration of riverbanks, erosion, and loss of biodiversity in flooded areas.

Indirect Losses:

These refer to secondary effects that emerge after the flood has subsided, often impacting the broader economy and community:

Economic Disruptions: Loss of income due to halted industrial production, disrupted trade, and closed businesses.

Health-Related Issues: Outbreaks of waterborne diseases, malnutrition due to food scarcity, and mental health challenges from displacement.

Infrastructure Downtime: Extended repair periods for damaged utilities such as electricity, water supply, and transportation networks.

Intangible Losses:

These are losses that are challenging to quantify but have profound social and psychological implications:

Cultural Heritage: Damage to historical sites, monuments, and places of religious importance.

Social Displacement: Long-term displacement of communities leading to loss of social cohesion.

Emotional Trauma: Psychological distress experienced by flood victims, including anxiety, depression, and loss of a sense of security.

Importance of Categorization

Categorizing flood losses helps policymakers, researchers, and disaster management authorities develop targeted strategies for mitigation, relief, and recovery. It ensures that all dimensions of flood impacts, including the less tangible but equally significant psychological and cultural losses, are acknowledged and addressed in comprehensive flood management plans.

The results illustrate the interconnectedness of urbanization, flooding, and socio-economic challenges faced by the residents of Patna, underscoring the urgent need for effective flood management strategies.

Discussion

Causes of Increased Waterlogging

The rising incidence of waterlogging in Patna can largely be attributed to rapid urbanization, which has significantly increased the amount of impervious surfaces, such as roads and buildings. This expansion reduces the natural absorption of rainwater, leading to overwhelmed drainage systems that cannot cope with heavy rainfall (Choudhary et al., 2020). Additionally, the city's drainage infrastructure, designed for a much smaller population and less intensive urban development, is inadequate for the current demands placed on it.

Moreover, climate change has exacerbated these challenges, resulting in more intense and unpredictable rainfall patterns. According to the India Meteorological Department (IMD, 2021), rainfall intensity during monsoon seasons has increased, contributing to flooding events. These changing weather patterns, coupled with urbanization, create a compounded effect that leads to increased waterlogging and poses significant risks to residents' livelihoods and health.

Policy and Infrastructure Challenges

A review of Patna's existing infrastructure reveals several inadequacies in managing flooding and waterlogging. Current urban planning policies have not adequately addressed the growing challenges posed by urban sprawl. Many of the city's drainage systems are outdated and poorly maintained, which hinders

their effectiveness during heavy rain events (Sinha & Sharma, 2021). There is a severe problem of drainage in city. There are closed drains along the main aterial road of city while there are open drains in internal roads. This open drain gets clogged during monsoon season mainly because of encroachment on road sides. This results in water logging in adjoining areas.

Construction of Ganga expressway is creating most distructive impact on riparian wetland. Huge sedimentation of construction activities has divided the main stream and its loosing the character of wetland. Ganga is considered a holy river in hindu religion. Disposal of religious offerings and gathering are also causing degradation of wetland. Thus shrinkage of wetland above bank is observed and river ganga is swiftly moving northward from the society.

Government responses to flooding have included temporary measures such as sandbagging and the construction of flood barriers. However, these measures often prove insufficient in the long term. Evaluations of past government interventions suggest that while some initiatives have been implemented, they lack a cohesive strategy that integrates disaster management with urban planning (Kumar et al., 2020). The absence of a comprehensive flood management plan highlights the need for more effective policy responses that prioritize sustainable urban development.

Mitigation Measures

To address the ongoing challenges of flooding and waterlogging in Patna, several mitigation measures should be considered:

1. **Upgrading Drainage Systems**: Investing in the improvement of existing drainage infrastructure is crucial. This includes not only expanding the capacity of drainage systems but also incorporating sustainable practices, such as the use of permeable materials for pavements and roads, which can enhance water absorption (Ranjan et al., 2021).
2. **Increasing Green Spaces**: The incorporation of green spaces, such as parks and urban forests, can help manage stormwater runoff. Green roofs, rain gardens, and bioswales are examples of urban design features that can mitigate flooding by allowing rainwater to be absorbed naturally.
3. **Community Awareness Programs**: Enhancing community awareness regarding flood preparedness and response is vital. Educational campaigns can equip residents with knowledge about evacuation routes, emergency contacts, and flood risk management strategies, thereby improving overall community resilience (Jha et al., 2021).
4. **Collaboration with NGOs and Local Communities**: Establishing partnerships with non-governmental organizations and local communities can foster sustainable urban development practices. Engaging community members in planning and decision-making processes can ensure that local knowledge is utilized in developing effective flood management strategies.

Addressing the root causes of flooding and waterlogging in Patna requires a multifaceted approach that encompasses urban planning, infrastructure improvements, community engagement, and policy reforms. By implementing these measures, Patna can enhance its resilience to flooding and create a safer environment for its residents.

Conclusion

This study has highlighted the significant impact of urban sprawl and flooding in Patna, emphasizing the

interconnectedness between rapid urbanization, inadequate infrastructure, and increased waterlogging incidents. Key findings indicate that the city's ongoing urban development has exacerbated drainage issues, leading to frequent flooding and substantial socio-economic losses for residents. The analysis underscores that existing infrastructure is insufficient to manage the growing challenges posed by both urbanization and climate change, as evidenced by the increased frequency and intensity of rainfall events.

To address the persistent challenges of waterlogging, there is a critical need for integrated urban planning and effective flood management strategies. This includes upgrading drainage systems, expanding green spaces, and implementing community awareness programs to prepare residents for flood risks. Moreover, collaboration with NGOs and local communities is essential to develop sustainable urbanization practices that not only mitigate flooding but also enhance overall resilience to climate-related disasters.

Finally, this study calls for further research into sustainable urbanization practices that can inform policy decisions and urban planning initiatives. Continued exploration of innovative solutions and best practices will be crucial in equipping cities like Patna to navigate the complexities of climate change and urban growth effectively.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

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