

Impact of urbanization on urban flooding: A case study of Chandragiri Municipality, Nepal

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Abstract:

Urban flooding has become one of the most significant hazards associated with rapid urbanization in South Asian municipalities. Chandragiri Municipality, a rapidly expanding peri-urban municipality of the Kathmandu Valley, has undergone dramatic land use transformation over the past two decades, yet the link between this urbanization and urban flooding has not been systematically studied. Hence, this study was conducted with an aim to identify the major problems of urbanization related to urban flooding in Chandragiri Municipality, their causes and effects, and appropriate mitigation measures. Primary data were collected through questionnaire survey of 156 respondents determined using Slovin's formula, field observation in the downstream wards along the Balkhu River, in-depth interviews with seven key informants and three focus group discussions, whereas secondary data were collected from published literatures, hazard maps and municipal planning documents. The collected data were analyzed using the Relative Importance Index (RII). The results showed that major problem is insufficient storm-water drainage infrastructure in new settlements with the highest RII value of 0.92, followed by encroachment of rivers and natural waterways (RII 0.91) and loss of open spaces and pervious land (RII 0.89). Weak fines and penalties for illegal dumping (RII 0.92) and disposal of plastic, sand and construction debris into drains (RII 0.91) were the most significant causes, while water diversion towards neighboring houses and fields (RII 0.91), sudden flooding after moderate rain due to partial drain blockages (RII 0.90) and the desire to migrate out of high-risk neighbourhoods (RII 0.89) were the most significant effects. Built-up area now covers 51.4% of the municipality, and wards 15, 12, 11, 14 and 10 were the most affected, with 70, 60, 45, 25 and 8 houses experiencing recurrent inundation. Interviews and discussions revealed the absence of a drainage master plan, weak enforcement of river setbacks, non-functional early warning systems and a disproportionate flood burden on tenants, daily wage labourers, women and elderly residents. The study recommends flood-sensitive land use planning, a comprehensive storm-water drainage plan with regular maintenance, river corridor protection, sustainable drainage measures and community-based early warning systems.

Keywords: urbanization, urban flooding, impervious surface, storm-water management, land use change, flood risk

1. Introduction

Urban flooding has emerged as a serious environmental and development challenge in many cities of South Asia, including the rapidly growing urban centres of Nepal. Urban floods occur when storm water generated during intense rainfall exceeds the capacity of natural and artificial drainage systems, leading to waterlogging, overflow of drains and inundation of streets, houses and other infrastructure [9]. In many developing countries, this problem is closely linked with unplanned urbanization, encroachment of natural waterways, inadequate storm-water infrastructure and poor solid waste management [15]. More than half of the world's population now lives in urban areas, and nearly 70% is projected to be urban by 2050, with much of this growth occurring in Asia and Africa [22][24].

Urbanization replaces soil, vegetation and wetlands, with roofs, roads and paved areas, which reduces infiltration and increases surface runoff, so that urban catchments produce higher peak flows, larger runoff volumes and shorter lag times between rainfall and peak discharge [19][26]. Measurable hydrological changes appear when impervious cover in a catchment exceeds about 10–20%, and both the amount and the spatial distribution of impervious surfaces amplify flood peaks [7][10]. Urban drainage systems with limited design capacity, combined with blocked drains and encroached waterways, are easily overwhelmed by intense

storms, producing pluvial flooding even where rivers do not overflow [6]. Urban exposure to extreme precipitation in South Asia is projected to increase under global warming [11], and combined scenarios of higher imperviousness and more intense rainfall substantially increase flood volumes unless low-impact development and drainage upgrades are implemented [12].

Nepal has experienced strong rural–urban migration and expansion of municipal boundaries, with the share of urban population rising from 6.3% in 1981 to about 66% in 2021 according to the national census. In the Kathmandu Valley, built-up area increased by about 386% between 1990 and 2020 while forest cover declined by around 28%, and because the valley has few natural drainage outlets, intense late-monsoon rainfall on saturated ground now exceeds drainage capacity and causes widespread flooding [2]. The storage capacity of urban watersheds is decreasing as low-lying depressions and ponds are filled, and rivers are encroached [3], drainage has not kept pace with urban growth of around 6.5% per year [18], and development along riverside corridors has reduced floodplain storage and redirected floodwaters into the urban fabric [8][16]. Extreme rainfall is expected to become more intense in the Bagmati Basin [4], and during the unprecedented September 2024 floods, floodwaters in the valley expanded to more than 2.5 times the bankfull extent of rivers [9][21]. GIS-based assessments have identified unplanned urbanization, inadequate drainage and river encroachment as key drivers of flood risk in the valley [20].

Chandragiri Municipality, on the south-western fringe of the Kathmandu Valley, has undergone rapid urban expansion along transport corridors and in the flat low-lying areas near the Balkhu River and its tributaries. Multi-hazard mapping of the municipality placed 120.46 ha in high, 127.13 ha in medium and 186.49 ha in low flood-susceptible zones, with Balambu, Gurjudhara, Machhegaun, Satungal and Tinthana historically prone to inundation [14]. The municipal profile notes that flood problems are emerging alongside the conversion of agricultural land into plotted residential and commercial areas without adequate storm-water and river-training measures [1], and the Voluntary Local Review highlights the need for risk-sensitive planning as population, infrastructure and economic activities concentrate in these areas [23].

Despite this identified hazard, empirical studies that link patterns of urbanization in Chandragiri with the problems, causes and effects of urban flooding experienced at ward level are limited, and municipal decisions are often made without a clear understanding of how ongoing land use change is altering runoff and exposure. Therefore, this study was conducted with an aim to identify the major problems of urbanization related to urban flooding in Chandragiri Municipality, to identify their causes and effects, and to provide mitigation measures and recommendations for flood-resilient urban planning. The findings are expected to support the municipality, policy makers and other stakeholders in integrating flood risk into local development planning.

2. Study Area

Figure 2.1 shows the map of the study area. Chandragiri Municipality is located in the south-western part of Kathmandu District, Bagmati Province, bordering Dhading and Makwanpur districts. It shares its boundary with Nagarjun Municipality to the north, Kirtipur Municipality to the east, Dhunibeshi Municipality to the west and Dakshinkali Municipality to the south. It was established on 2nd December 2014 by merging 11 former Village Development Committees and is divided into 15 wards covering 43.9 km². The Prithvi Highway passes through the center of the municipality, which is a major reason for its rapid population growth, with population rising from 55,032 in 2001 and 85,198 in 2011 to 136,860 in 2021.

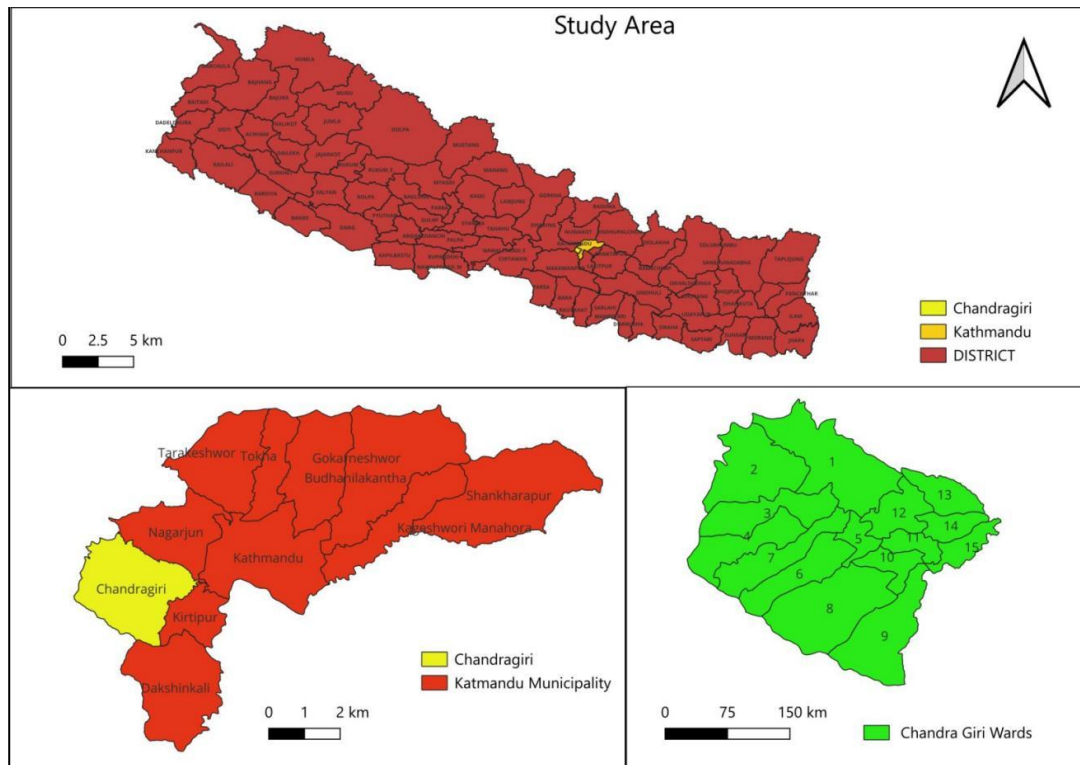


Figure 2.1 Map of the study area

The most flood-prone areas are the low-lying plains and settlements along the Balkhu River and its tributaries. The Balkhu River, a tributary of the Bagmati River about 14 km long, originates from the Chandragiri Hill/Nagdhunga area and flows south-east through wards 1, 2, 3, 11, 12, 14 and 15 before entering Kathmandu Metropolitan City. The Ghatte Khola (wards 8, 10 and 15) and the Daudadi Khola (wards 12, 13, 14 and 15), together with several smaller streams and traditional irrigation canals (Rajkulos), discharge into the Balkhu River. According to the municipal by-laws, the upstream section of the river has a drift area of 4 m and a setback of 6 m, while the downstream section has a drift area of 10 m and a setback of 10 m on both sides, the two zones meeting at Tribeni Ghat. This study focuses on the downstream section of the Balkhu River, covering wards 5, 10, 11, 12, 14 and 15, which are among the most densely populated and rapidly urbanizing parts of the municipality and receive runoff from the upstream catchment and tributaries (Figure 2.2).

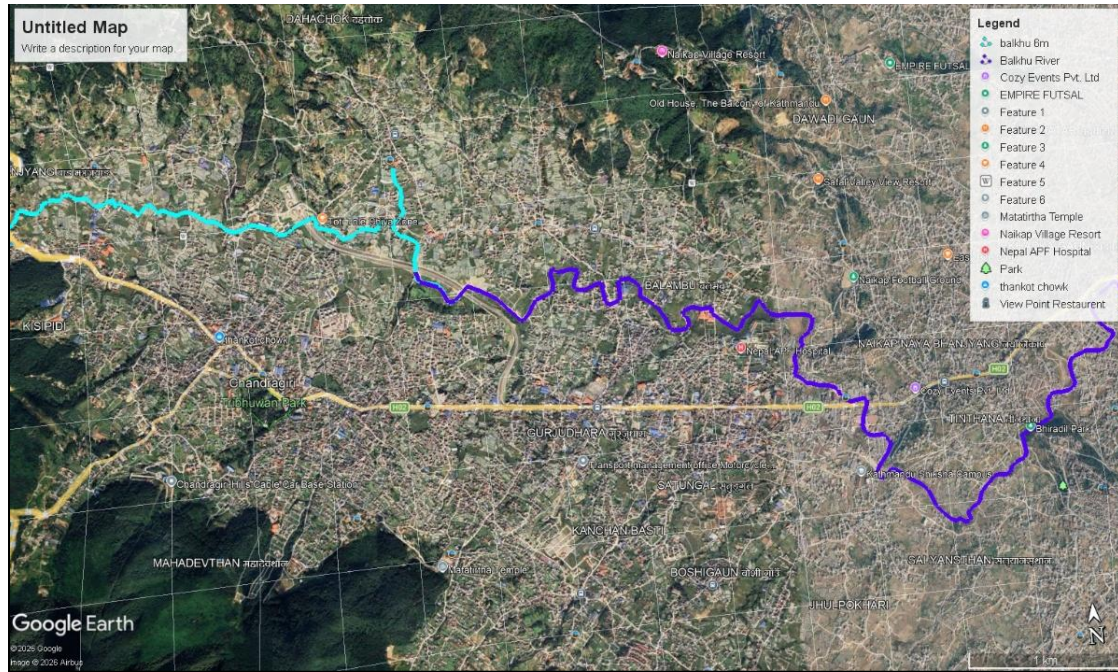


Figure 2.2 Balkhu River flowing through Chandragiri Municipality (Source: Google Earth)

3. Material and methods

3.1 Data collection methods

In this study, information was collected in four main ways. First, field observation was done, by visiting site to collect information directly, so there is less chance of wrong data. Wards 5, 10, 11, 12, 14 and 15 were observed before and after the monsoon. During these visits, hard surfaces that do not let water soak in, encroachment of river areas, drainage conditions, flood marks and flood damage were noted, and photos were taken as a record. Second, in-depth interviews were held. These are face-to-face talks where open questions are asked to learn a person's information, opinions and beliefs. Seven key informants were interviewed for 30 to 45 minutes each. They included the ward chairpersons of wards 10, 11 and 12, an engineer from the Infrastructure and Development Section, an officer from the Disaster Management Committee and community representatives.

Third, three focus group discussions were held in Balambu (Ward 12), Satungal (Wards 10 and 11) and Tinthana (Ward 15). In these group talks, people were asked open questions and shared their views. Each group had 8 to 10 people, chosen so that there was a mix of gender, age, job and how long they had lived in the area. They talked about the history, causes and effects of flooding, how people cope with floods and what role the municipality plays. Fourth, a questionnaire survey was done using a set of questions made by the researcher based on earlier studies. The people answering gave each statement a score from 1 to 5 to show how much they agreed with it. This is called a Likert five-point scale.

3.2 Sample size

A purposive sampling method was adopted to gather the views and opinions of respondents appropriate for the research objective. Slovin's formula, which is used for determining the sample size for categorical types of data, was used to fix the sample size:

$$\text{Sample size (n)} = N / (1 + Ne^2) \quad \text{Equation (1)}$$

Where,

N = total population of Chandragiri Municipality (National Population and Housing Census, 2021) = 136,860

e = permissible error = 8%

Here,

Sample size (n) = $136,860 / (1 + 136,860 \times 0.08^2) = 156$

Hence, 156 respondents participated in the questionnaire survey and presented their responses. Secondary data were collected through published journals, articles, government and project reports, hazard maps, municipal planning documents, media reports and other published and unpublished literature.

3.3 Data analysis

The data collected from the questionnaire survey were analyzed using the Relative Importance Index (RII), which converts the qualitative responses of the respondents into quantitative values that can be ranked. In this research, a Likert five-point scale was used to determine the RII of the problems of urbanization related to urban flooding and their causes and effects. The value of RII is given by the equation:

$$\text{Relative Importance Index (RII)} = (\sum W)/AN = (5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1)/5N \quad \text{Equation (2)}$$

Where, W = weight given to each factor by the respondent, ranging from 1 to 5

n_1 = number of respondents who least agree

n_2 = number of respondents who slightly agree

n_3 = number of respondents who moderately agree

n_4 = number of respondents who mostly agree

n_5 = number of respondents who strongly agree

A = highest weight, i.e. 5 in this study

N = total number of respondents

The relative importance index (RII) ranges from 0 to 1. The qualitative information from field observation, focus group discussions and in-depth interviews was analyzed descriptively. The personal information of the respondents was kept anonymous to maintain their privacy.

4. Results and discussion

4.1 Relative importance index analysis

The weightage was marked from one to five. For the RII analysis, 156 respondents were involved and, according to their views, they marked each statement on a scale ranging from least agree to strongly agree. Of the respondents, 72% were male and 28% were female. The largest share of respondents belonged to the age group of 31–40 years (37%), followed by 20–30 years and 41–50 years (27% each), while 10% were above 50 years. By profession, 26% were engaged in private business, 21% in agriculture, 20% in the non-government sector, 17% in government service and 16% in the health sector. Regarding education, 41% held a bachelor's degree, 33% a master's degree, 22% had intermediate level education and 4% held a PhD. The data were analyzed by computing the RII of each statement and are expressed in bar graphs as shown below.

4.2 Major problems of urbanization related to urban flooding

There were thirteen problems for ranking. Figure 4.1 shows the main problems of urbanization related to urban flooding in Chandragiri Municipality. The major problem of urbanization related to urban flooding in Chandragiri Municipality is "Insufficient storm-water drainage infrastructure in new settlements" with the highest RII value of 0.92, followed by "Encroachment of rivers, kholas and natural waterways" (0.91) and "Loss of open spaces and pervious land due to urban expansion" (0.89). Similarly, "Lack of regular maintenance and cleaning of existing drains" and "Frequent waterlogging of roads and streets" have the RII value of 0.88, followed by "Damage to private property" (0.87), "Poorly planned land plotting and housing colonies" and "Flooding of houses and courtyards during heavy rain" (0.86). The least significant problems were "Psychological stress and livelihood insecurity", "Disruption and contamination of drinking-water supply", "Overloaded and blocked drainage systems", "Increased water-borne and vector-borne diseases" and "Solid waste dumping in drains, rivers and low-lying areas" with RII values ranging from 0.84 to 0.82 (Figure 3.1).

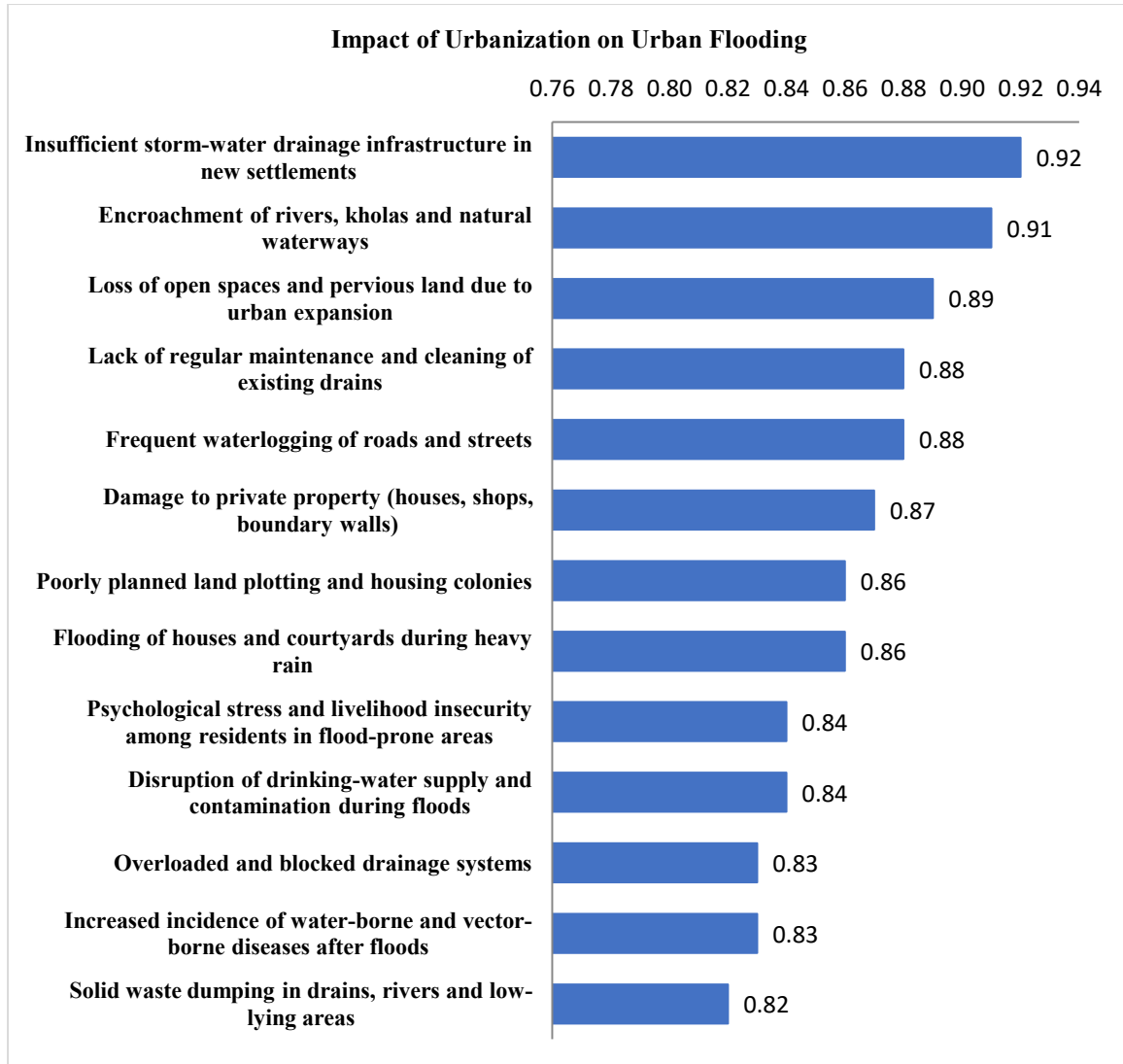


Figure 4.1 Major problems of urbanization related to urban flooding in Chandragiri Municipality

4.3 Causes and effects of the problems

The causes and effects of each problem are presented in figures 4.2 to 4.14. The most significant cause of insufficient storm-water drainage in new settlements was “Delays in municipal planning and investment” (RII 0.88), which resulted mainly in “New areas experiencing repeated waterlogging from the start” (RII 0.87). Encroachment of rivers was mainly caused by “Settlement expansion along riverbanks and corridors” (RII 0.89) and led to “Water diversion toward neighboring houses/fields” (RII 0.91), while loss of open spaces resulted in “Reduced infiltration and higher surface runoff peaks” (RII 0.89). Lack of drain maintenance, attributed to the “Absence of fixed cleaning schedules before monsoon” (RII 0.86), caused “Sudden flooding after moderate rain due to partial blockages” (RII 0.90). Among all causes, “Weak fines/penalties for illegal dumping” received the highest RII of 0.92, followed by “Disposal of plastic, sand and construction debris into drains” (RII 0.91), and “Absence of contour-based planning and storm-water design” and “Houses built at low levels relative to road/drain” (RII 0.90) were the main causes of poorly planned colonies and flooded houses.

1. Insufficient storm-water drainage in new settlements

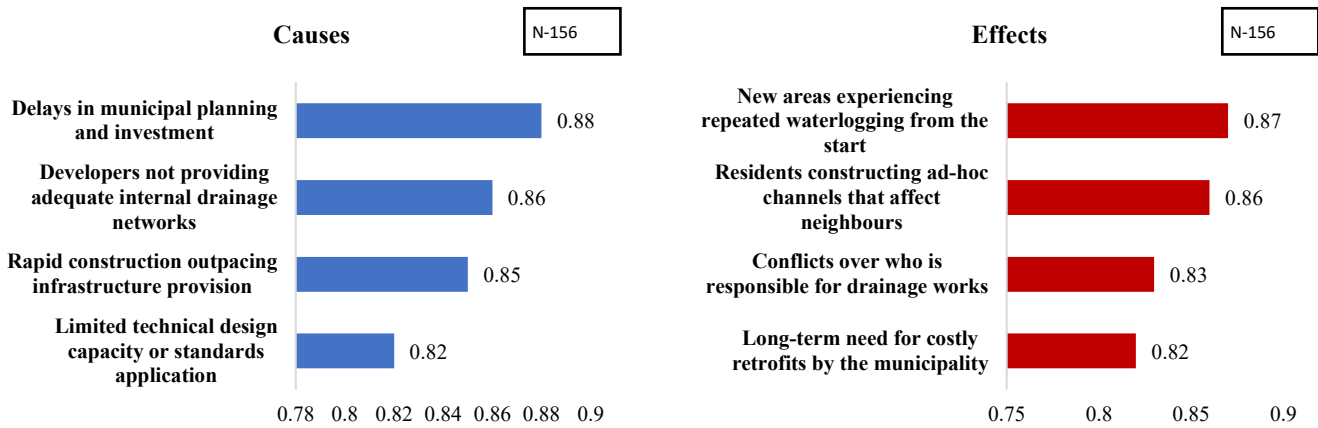


Figure 4.2. Causes and effects of insufficient storm-water drainage in new settlements

2. Encroachment of rivers and natural waterways

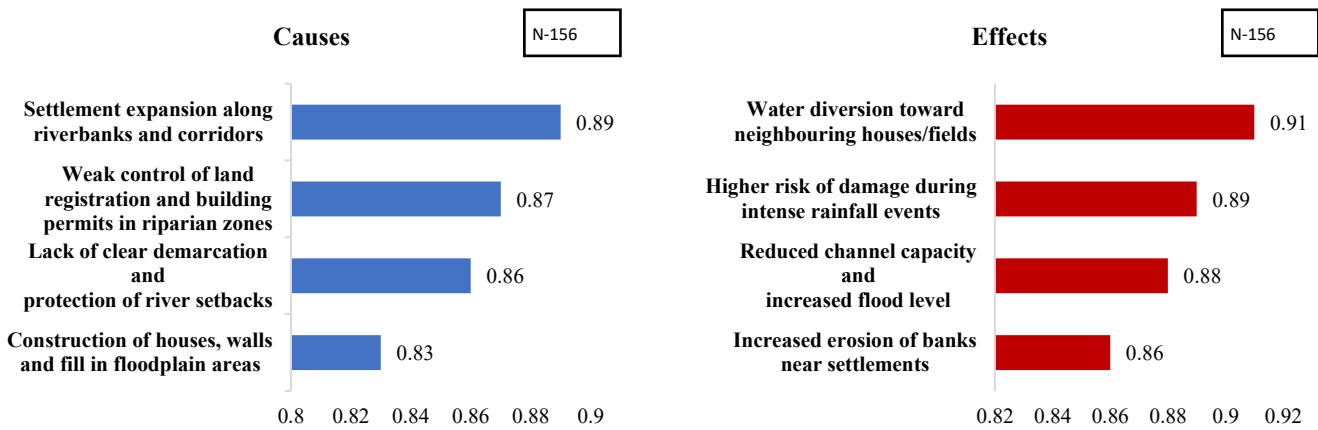


Figure 4.3. Causes and effects of encroachment of rivers and natural waterways

3. Loss of open spaces and pervious land

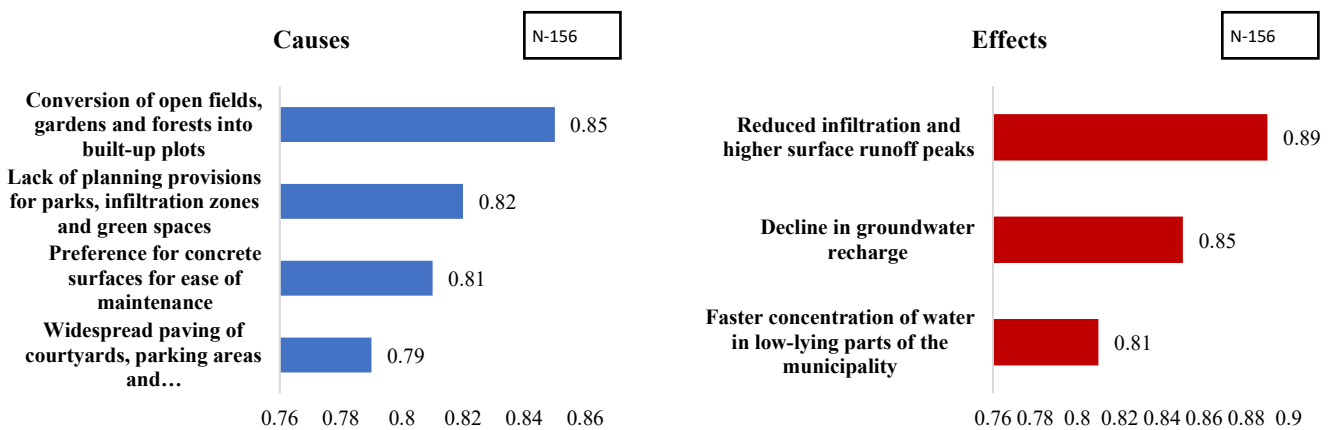


Figure 4.4. Causes and effects of loss of open spaces and pervious land

4. Lack of regular maintenance and cleaning of drains

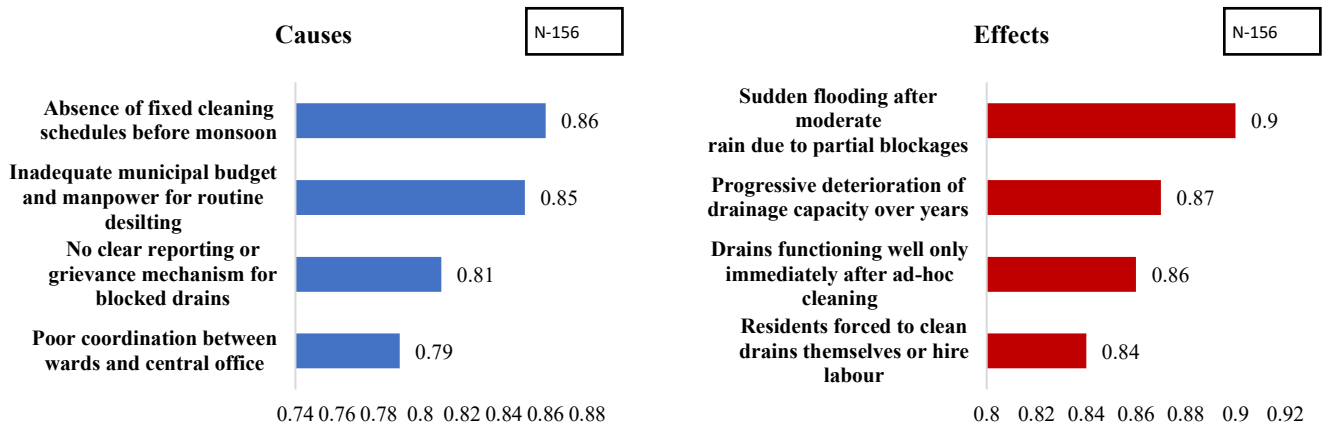


Figure 4.5. Causes and effects of lack of regular maintenance and cleaning of drains

5. Frequent waterlogging of roads and streets

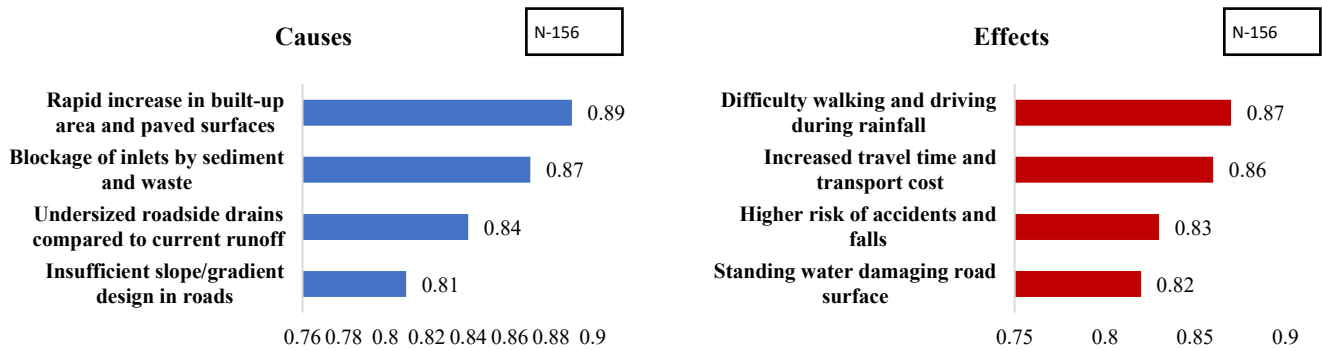


Figure 4.6. Causes and effects of frequent waterlogging of roads and streets

6. Damage to private property

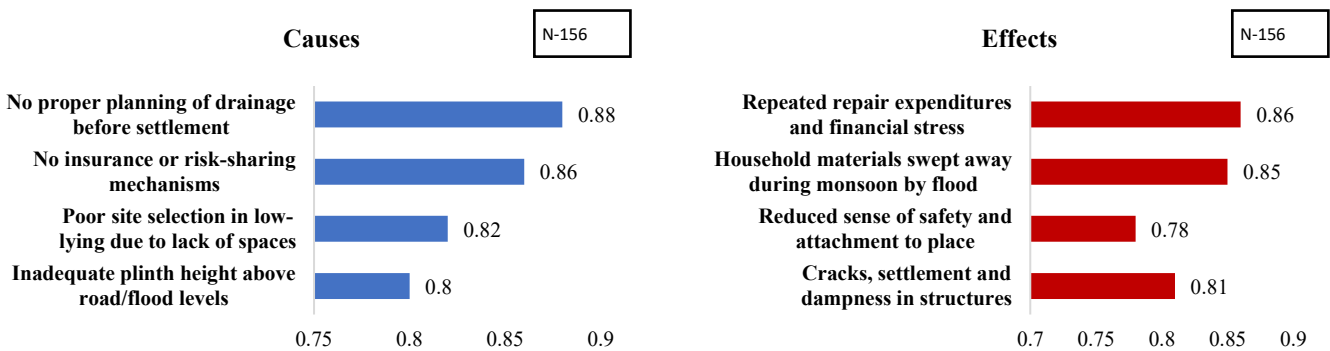


Figure 4.7. Causes and effects of damage to private property

7. Poorly planned land plotting and housing colonies

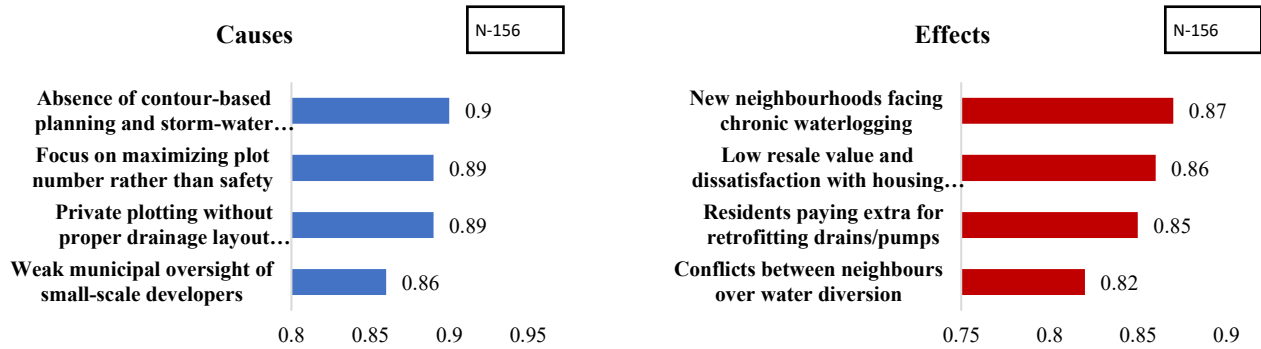


Figure 4.8. Causes and effects of poorly planned land plotting and housing colonies

8. Flooding of houses and courtyards during heavy rain

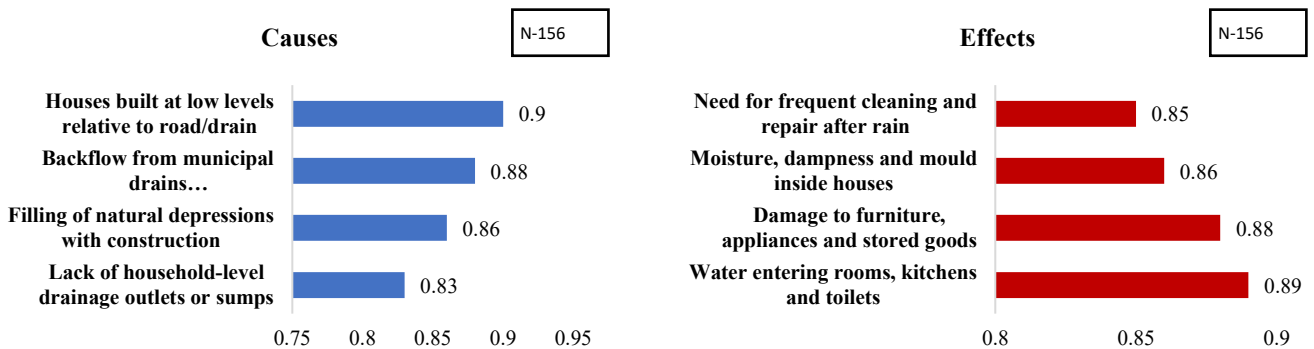


Figure 4.9. Causes and effects of flooding of houses and courtyards during heavy rain

9. Psychological Stress and Livelihood Insecurity

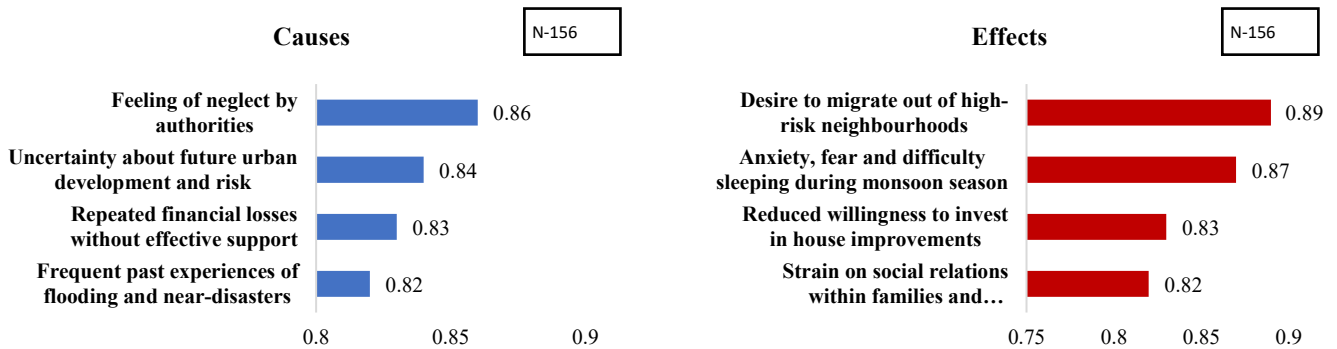


Figure 4.10. Causes and effects of Psychological Stress and Livelihood Insecurity

10. Disruption and contamination of drinking-water supply

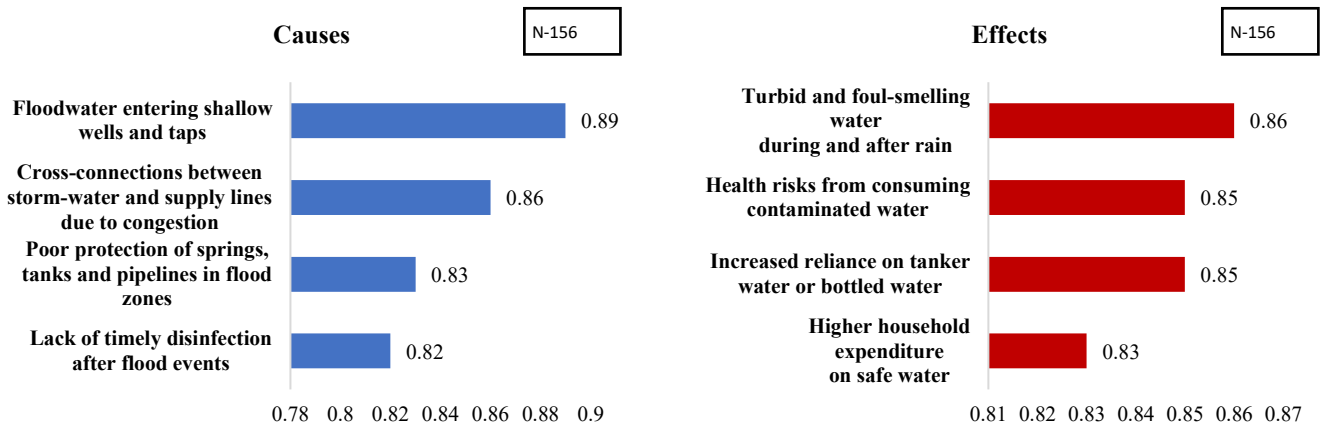


Figure 4.11. Causes and effects of disruption and contamination of drinking-water supply

11. Overloaded and blocked drainage systems

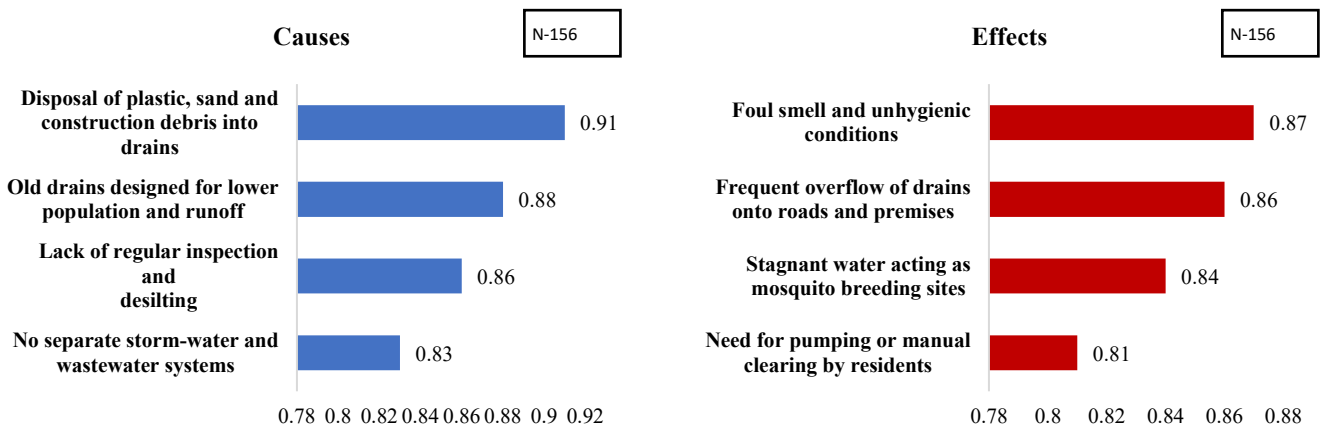


Figure 4.12. Causes and effects of overloaded and blocked drainage systems

12. Increased water-borne and vector-borne diseases

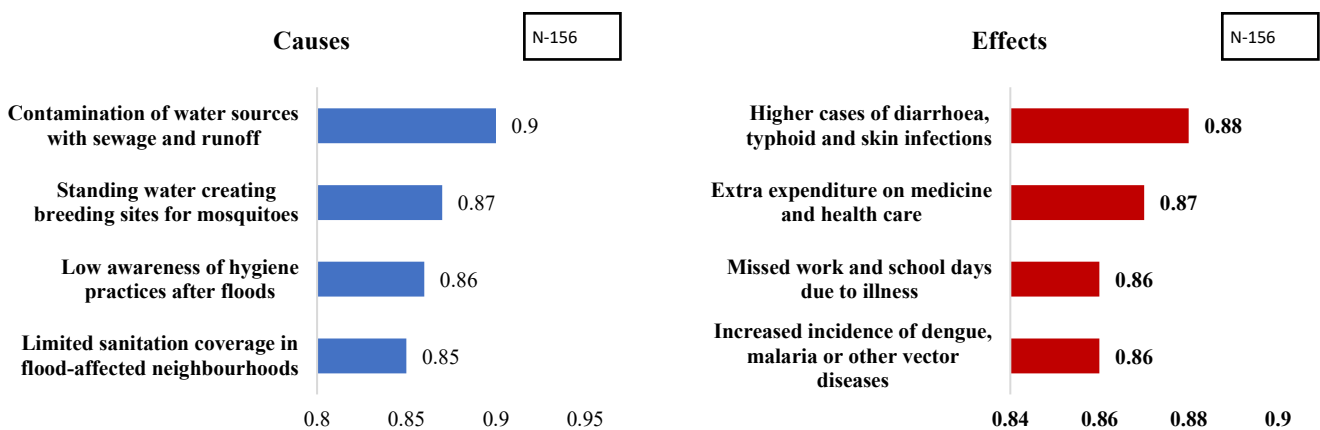


Figure 4.13. Causes and effects of increased water-borne and vector-borne diseases

13. Solid waste dumping in drains, rivers and low-lying areas

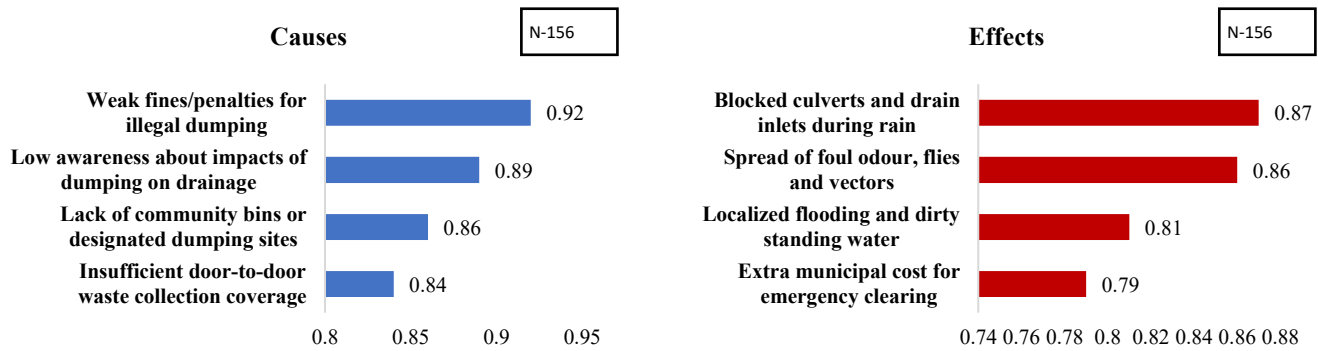


Figure 4.14. Causes and effects of solid waste dumping in drains, rivers and low-lying areas

5 Discussions

Field observation was carried out in Wards 5, 10, 11, 12, 14 and 15 to document the physical evidence of urbanization-induced flooding. Built-up area covers 51.4% of the municipality, followed by agriculture (21.6%) and bush (19.2%), while forest covers only 7.2% (Figure 5.1). The population increased from 55,032 in 2001 to 136,860 in 2021, with population density rising from 1,253 to 3,116 persons per km² and about 1,500 new households added every year (Table 5.1). Ward 5 recorded the highest annual growth rate (8.6%) during 2011–2021, followed by Wards 10, 1 and 6.

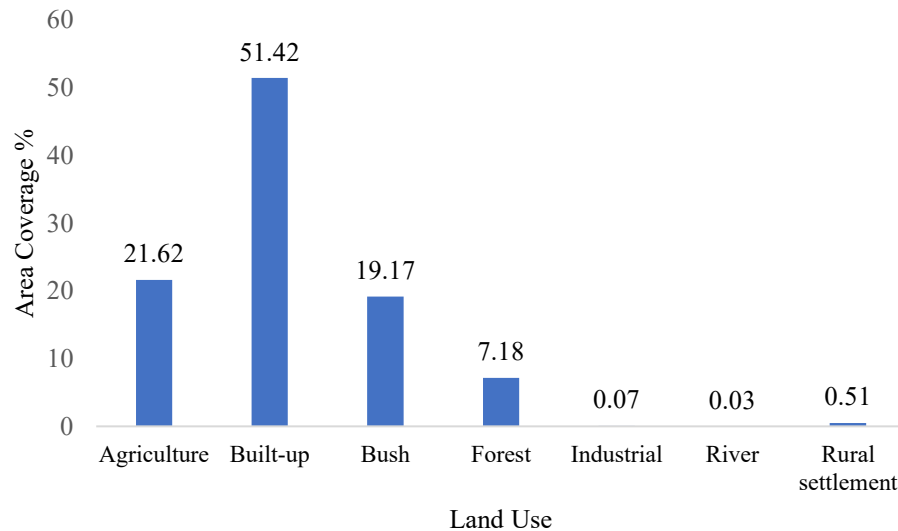


Figure 5.1 Land use of Chandragiri Municipality (Source: Municipal profile)

Table 5.1. Population growth of Chandragiri Municipality (Source: National census)

Year	Population	Density (per km ²)	Households
2001	55,032	1,253	—
2011	85,198	1,940	20,532
2021	136,860	3,116	35,994

The field visit revealed a dramatic increase in impervious surfaces: new roads, concrete pavements, tiled courtyards and flat-roofed structures cover nearly all available surface in denser clusters, and open soil, green spaces and wetland pockets that once served as natural retention features have been filled and converted into building plots. Planned green buffers or parks were almost absent in new residential clusters, although the municipality has recently made soak pits mandatory for new buildings, which is a positive step. Former agricultural fields, forest patches and drainage corridors in Thankot, Balambu, Kisipidi and Satungal have been converted into residential and commercial structures, retaining walls and even permanent structures

extend into the riparian buffer of the Balkhu Khola, and traditional stone-lined Rajkulos have been blocked, partially filled or encased in concrete.

In Bishnu Devi Housing (Ward 11), a colony of 108 houses along the Balkhu River, 18 houses have been built within the municipality-designated setback and 38 houses along the setback line are affected by frequent flooding and road inundation. In Khwoyal Sadak, Dhungeadda (Ward 15), a low-lying area adjacent to the river dominated by warehouses, factories and commercial buildings, 69 buildings lie within the affected zone. Balkumari, at the junction of Wards 11, 12 and 14, is inundated when the Rajkulos crossing it overflow during heavy rainfall. Overall, ward 15 recorded the highest number of affected houses, followed by wards 12, 11, 14 and 10 (Figure 3.16), whereas the upstream wards 1, 2, 9 and 13 experienced mainly agricultural land damage, road inundation, bridge damage and localized landslides. These flood-prone wards correspond to those assigned high flood priority in the municipality's ward-wise disaster ranking, in which flooding ranks third after earthquake and landslide.

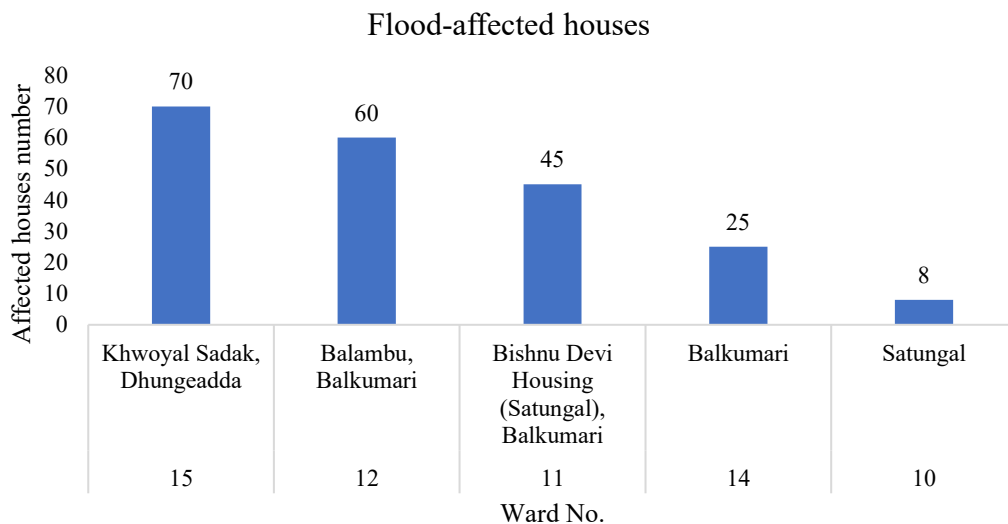


Figure 5.2. Flood-affected houses in the most affected wards

The drainage infrastructure was found to be grossly inadequate relative to the built-up density. In older settlements such as Thankot and Satungal, small brick-lined drains overflowed even during minor rainfall, while in new areas road culverts had been built without outfall channels. A primary drain of about 300 m in Satungal (Ward 11) was completely choked with plastic and household refuse, and storm drain inlets were often too small or misaligned with the road camber. High-water marks on compound walls and plinths indicated flood depths of 0.5–1.5 m in parts of Balambu and Tinthana during the 2024 and 2025 monsoons, bank erosion had partially collapsed access roads near Wards 1, 2 and 13, and households in low-lying wards had built earthen bunds and sandbag barriers and raised their water tanks on iron frames as informal adaptation.

Municipal officials and technical staff identified rapid and unregulated urbanization as the primary driver of escalating flood risk. Land sub-division approvals increased sharply after the 2015 earthquake, often in marginal flood-prone areas, and engineers acknowledged that there is no drainage master plan for Chandragiri and that drainage budgets are far below the requirement. Building permits were routinely issued without a site-level drainage assessment, the prescribed riparian setback was not effectively enforced, and overlapping jurisdictions of the municipality, the Department of Roads and the Department of Water Induced Disaster Management left critical drainage unattended.

A community representative from Balambu described how floodwaters entered the ground floors of more than 40 households within two hours during the 2024 flood, destroying household goods, livestock and grain stores, and noted that the most affected were recent in-migrants who had settled in low-lying areas because of lower land prices. Informants from Ward 11 reported that once-perennial streams have turned into episodic,

high-velocity torrents during the monsoon. The disaster management officer noted that early warning systems are non-functional at the local level, evacuation routes have not been designated in high-risk wards, relief stockpiles are minimal, and ward-level disaster management committees remain inactive between flood events.

Participants in all three focus group discussions reported a marked increase in the frequency and severity of flooding over the past 10–15 years, which they attributed to expanding construction and the loss of open land; elderly participants in Balambu recalled that nearby streams rarely flooded residential areas before the early 2000s. The blocking and narrowing of natural drainage channels by construction debris and illegal structures, and the loss of tree cover on the hillslopes, were identified as the main causes. Tenants, daily wage labourers and elderly residents bear the heaviest burden, women in Tinthana described managing children, salvaging goods and cleaning silt while men were away at work, and each significant flood was estimated to cost several months of household income, with relief described as inconsistent and insufficient.

Participants recommended retaining walls along the riverbanks, regular scheduled cleaning and widening of drains, strict enforcement of construction rules near stream banks, a halt to building permits in flood-risk zones until adequate drainage is in place, a community-based early warning network using mobile phone alerts and water-level markers, and open green spaces and soak pits within residential areas.

The findings of the present study correspond closely with existing research on urbanization-induced flooding. The rapid increase in built-up area and paved surfaces was the leading cause of frequent waterlogging of roads and streets (RII 0.89), and the field observation confirmed the near-complete replacement of open soil and recharge zones by sealed surfaces, which is consistent with Jacobson [7] and Yao et al. [26], who showed that expanding imperviousness reduces infiltration, increases runoff volume and shortens the time of concentration, and with Mejia and Moglen [10], who showed that the spatial distribution of imperviousness amplifies flood peaks. The transformation of perennial streams into episodic monsoon torrents reported by informants mirrors the hydrological changes described by Soulis et al. [19] and the USGS [25].

At the valley scale, the encroachment of the Balkhu Khola and its tributaries, the infilling of drainage corridors and the blocking of Rajkulos align with Talchabhadel et al. [20] and Lamichhane et al. [9], who identified river encroachment, loss of natural storage and unplanned settlement expansion as the principal drivers of escalating flood disasters in the Kathmandu Valley. The finding that weak fines and penalties for illegal dumping was the highest-ranked cause (RII 0.92), together with the choked drain in Satungal, supports Pervin et al. [15] and ICIMOD [6] on the decisive role of poor solid waste management, and similar patterns have been reported in Dhaka [5], Bangalore [17] and Accra [13]. The flood-affected settlements identified in this study correspond to the high and medium flood-susceptibility zones mapped by Paudel and Shrestha [14], providing ground-level validation of that assessment, and the governance gaps revealed in the interviews echo the institutional weaknesses highlighted by Shrestha [18] and the Voluntary Local Review [23]. This study extends past research by quantifying stakeholder-perceived causes and effects through RII analysis and by identifying psychological stress and the desire to migrate out of high-risk neighborhoods (RII 0.89) as significant but under-reported consequences of recurrent urban flooding.

4. Conclusions

The overall analysis of primary data collected through a mixed-method approach, including a questionnaire survey of 156 respondents, field observation, in-depth interviews and focus group discussions, reveals that rapid, largely unplanned urban growth is the primary driver of escalating flood hazard in Chandragiri Municipality. Insufficient storm-water drainage in new settlements is the most significant problem with the highest RII of 0.92, followed by encroachment of rivers and natural waterways (RII 0.91) and loss of open spaces and pervious land (RII 0.89). The conversion of agricultural land, wetlands, drainage channels and open spaces into impervious built-up areas, which now cover more than half of the municipality, has reduced infiltration and increased runoff beyond the capacity of the drainage system, while weak penalties for illegal dumping and the disposal of debris into drains further reduce its capacity. The downstream wards along the Balkhu River, particularly wards 15, 12, 11 and 14, are the most affected because of their low-lying terrain, dense development and encroachment on watercourses. The absence of a drainage master plan, weak

enforcement of river setbacks, limited inter-agency coordination and non-functional early warning systems compound this physical vulnerability, and the flood burden falls disproportionately on tenants, recent in-migrants, daily wage laborers, women and elderly residents.

To reduce flood risk, Chandragiri Municipality should adopt flood-sensitive land use planning that ensures proper drainage before settlement, planned urban development and protection of river buffer zones, and should halt building permits in flood-risk zones until adequate drainage is in place. A comprehensive storm-water drainage plan should be prepared to upgrade drainage infrastructure, separate storm-water and wastewater systems and ensure regular pre-monsoon cleaning, supported by stronger penalties for illegal dumping and better waste collection. River training, channel improvement and riverbank protection works should be prioritized, and sustainable drainage measures such as permeable pavements, retention ponds, recharge pits and soak pits should be encouraged. Finally, the municipality should prepare urban flood risk and hazard zoning maps, update disaster preparedness and evacuation plans, preserve open spaces as emergency shelters, and establish community-based early warning systems.

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