Anthropogenic Parameters Regulating Urban Flood Variability-A Literature Case Study Based Parameter Identification for Urban Flood Resilient City Planning

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Abstract — Urban flooding in Kerala can no longer be understood only as the outcome of intense rainfall, it increasingly reflects the cumulative effect of human alteration of land, drainage systems, and ecological buffers and other human-induced modifications to the urban fabric. This reviewed literature case studies consistently evaluates the variability of anthropogenic variables that reduce the capacity of urban landscapes to absorb, store, and convey water safely and that regulate contemporary urban flood inundation patterns. This paper also develops a clear clarity on how these variables influence runoff, storage, and exposure. Evidence drawn from the case studies of Okitipupa, Bhopal, Bangalore, Mumbai, Hyderabad, and Surat to identify recurring anthropogenic parameters, explain how they modify urban hydrology, and consolidate them into a practical indicator framework for flood vulnerability analysis. The cases consistently show that flood severity is controlled not only by rainfall intensity but also by built-up expansion, wetland loss, less vegetation cover, surface sealing, floodplain encroachment, blocked drainage, poor land-use regulation, waste dumping, and high population exposure. The study further explains how GIS, remote sensing, census data, and field observations can be combined to quantify these drivers through normalization, weighting, and composite vulnerability indices. By synthesizing findings from the provided case study, the paper highlights the role of human-induced modifications to the urban landscape in exacerbating flood risks and by addressing these parameters through efficient planning can make urban flood resilient cities.

Keywords: Urban Flood Variability, Anthropogenic Parameters, Floodplain Encroachment, Surface Sealing, Land Use Change, Natural Environment.

I. Introduction

Urban flooding can be understood as flooding occurring in urbanized areas due to rainfall-induced surface water exceeding the capacity of drainage systems, and altered natural water cycle frequently worsened by impervious surfaces and inadequate infrastructure [1] [2]. So urban flooding is increasingly understood as a product of urbanisation processes that alter the natural balance between rainfall, infiltration, storage, and runoff. In many cities, the same rainfall event produces very different flood impacts because one area has retained wetlands, open spaces, and functioning drains while another has been sealed, encroached, and poorly serviced. Thus, study finds the strong influence of human induced factors rather than by rainfall alone which shift the planning response from a purely meteorological view to a broader land water governance perspective. Through the review of different case studies of urban areas, the paper focuses on the variables that repeatedly appear across the cities and explains how each parameter contributes to flood susceptibility, exposure, and damage.

II. Approach of Study

A qualitative comparative synthesis approach is used here. Each case is examined for its aim, method, principal findings, discussion, and summary table, and the repeated indicators are reorganized into a single analytical framework.

III. Case Study Evidence

A. *Okitipupa, Ondo State, Nigeria:*

The Okitipupa study focuses on socio-economic effects of flooding and the distinction between anthropogenic and natural causes. The survey of households recorded property damage, displacement, food-price increase, learning disruption, market access problems, and business losses, showing that floods affect both the physical and economic fabric of the town.

The findings are notable because rainfall intensity accounted for only 21.5% of flood causes, whereas dumping of waste into drainage channels contributed 21%, blockage of waterways 18.5%, construction on floodplains 16.5%, poor drainage 14%, and inadequate land-use planning 8.5%. This indicates that governance and maintenance failures were more influential than rainfall alone [3]. The parameters identified in the study, its effect, how the study is sourced and the method of analysis is explained in Table 1.

Variable / Parameter	Effect	Data Source / Method	Analysis
Poor urban planning / land-use management	Raises flood risk	Planning documents; field checks	Qualitative comparison with land-use plans
Socio-economic indicators	Captures flood impacts on people and assets	Questionnaires (n=200n=200n=200); pie charts	Descriptive statistics; weighted responses
Rainfall intensity	Flood trigger	Rain-gauge data; meteorological records	Frequency and intensity analysis
Waste dumping in drainage	Causes blockage and flooding	Field surveys; questionnaires	Qualitative scoring; frequency counts

Drainage condition	Indicates infrastructure efficiency	Field observations; municipal records	Qualitative ranking
Waterway blockage	Lowers flow capacity	Field surveys; satellite imagery	Frequency and severity ranking
Building on floodplain	Reduces flood storage space	GIS maps; land-use maps	Spatial overlay for encroachment

Table 1: Parameter Impact Analysis-Okitipupa, Ondo State, Nigeria

B. *Bhopal, Madhya Pradesh, India:*

The Bhopal case study shows how rapid urbanisation transforms hydrological function. The study identifies increases in paved area, loss of agricultural percolation zones, encroachment of natural drainage, poorly maintained stormwater drains, and solid waste mismanagement as the main causes of recurrent flooding [4].

The study also links vulnerability to built environment quality and social conditions. House condition, land use, elevation, proximity to inundation, soil porosity, groundwater level, drainage pattern, population density, gender ratio, literacy, and household size were all used in a weighted vulnerability framework, showing that the urban flood problem is simultaneously physical and social [4].

The parameters identified, its effect, how the study is sourced and the method of analysis is explained in Table 2.

Parameter	Effect	Source	Method
Green space	Improves infiltration	DP 2005; GIS	Weighted overlay
Elevation	Low areas flood more	DEM; GIS	AHP
Inundation proximity	Closer = higher risk	Flood maps	Distance weighting
Soil porosity	Low porosity increases runoff	Soil map; texture data	Weighted penalty
Groundwater prospects	High water table increases risk	Groundwater map	GIS overlay
Drainage pattern	Better drainage lowers risk	Bhuvan DEM	Weighted overlay
Population density	More exposure	Census 2011	Z-score
Under-6 population	Demographic vulnerability	Census 2011	Percent weighted
House condition	Structural fragility	Census housing data	Rank weighting
Land use (built-up/open)	Less infiltration with built-up growth	DP 2005; GIS	Min-max

Table 2: Parameter Impact Analysis- Bhopal, Madhya Pradesh

The Bhopal study confirms that while rainfall intensity is a factor, it is the embedded anthropogenic changes and infrastructural deficits that dominate flood vulnerability. It recommends more stringent land use and development controls, stormwater infrastructure upgrades, and integration of community-based adaptation [4].

C. *Bangalore:*

The Bangalore case documents dramatic ecological change, especially the reduction of wetlands and lakes from 51 in 1973 to 17 in 2007. It also reports that traditional drainage channels, locally known as Rajakaluves, were lost or obstructed by new development, resulting in higher runoff, sudden waterlogging, and repeated inundation in former wetland zones [5]. The parameters identified, its effect, how the study is sourced and the method of analysis is explained in Table 3.

Parameter group	Key effect	Main data / method
Rainfall, slope, soil	Drives runoff, accumulation, and infiltration	IMD rainfall, DEM, soil data; weighted overlay/AHP
Land use, built-up area, wetlands	Controls imperviousness and flood storage	RS classification, GIS maps, field data; min-max/AHP
Drainage condition and blockage	Indicates drainage efficiency or obstruction	BWSSB maps, field scoring; expert weighting
Population and housing vulnerability	Reflects exposure and social fragility	Census 2011, housing data; percent normalization, rank weights

Table 3: Parameter Impact Analysis- Bangalore

D. *Mumbai:*

Mumbai is described as a dense coastal metropolis located on reclaimed land and influenced by tidal conditions. The 26 July 2005 event, with 944 mm of rain in 24 hours, caused flash floods, landslides, more than 419 deaths, and widespread failure of transport and services. The study stresses that low-lying reclaimed ground, encroachment of floodplains and drains, insufficient drainage capacity, and high tide conditions together intensified the disaster [6]. The parameters identified, its effect, how the study is sourced and the method of analysis is explained in Table 4.

Parameter	Effect	Source	Method
Population density	Exposure proxy	Census 2011	Weighted normalized index
Floodplain encroachment	Less flood buffering	Floodplain zoning; GIS	Composite vulnerability index

Coastal vulnerability	Storm surge/tidal impact	Tidal gauge; NOAA records	Higher coastal weights
Infrastructure quality	Drainage resilience	Municipal reports; field checks	Expert weighting
Rainfall intensity	Flood trigger	IMD daily rainfall	Weighted sum
Land use / land cover	More impervious runoff	RS classification; Landsat; Sentinel-2	Min-max normalization
Drainage system condition	Capacity/blockage issues	Drainage maps; surveys	Equal weighting

Table 4: Parameter Impact Analysis-Mumbai

E. Hyderabad:

Hyderabad's flood vulnerability is linked to rapid metropolitan growth, expansion into peripheral municipalities, impervious surface growth, and deterioration of natural watershed functions. During the 2008 floods, stormwater drains and tanks overflowed, more than 50 residential areas were inundated, and urban traffic and housing were heavily disrupted. The study highlights weak drainage capacity and poor coordination among agencies [7]. The parameters identified in the study, its effect, how the study is sourced and the method of analysis is explained in Table 5.

Parameter	Effect	Source	Method
LULC change	Less infiltration	IRS/Resourcesat; LISS; Google Earth	Min-max 0–1
Drainage network	Flood blockage/efficiency	Municipal GIS; field survey	Weighted overlay
Population density	Exposure/resilience	Census 2011	Z-score
Rainfall intensity	Flood severity	IMD rain data	Weighted overlay
Waste/sediment dumping	Drain blockage	Municipal waste data; reports	Expert weighting
Topography	Runoff/ flood accumulation	SRTM DEM; SOI maps	Weighted-sum model

Table 5: Parameter Impact Analysis - Hyderabad

F. Surat:

Surat is a low-lying estuarine city at the mouth of the Tapi system and is vulnerable to fluvial and tidal effects. The chapter explains that while a flood-protection scheme was developed after the 1968 floods, delays, incomplete drainage coverage, siltation, encroachment, and sewage mixing in storm drains continued to produce urban flooding, especially in the expanding peripheral areas [8]. The parameters identified in the study, its effect, how the study is sourced and the method of analysis is explained in Table 6.

Parameter	Effect	Source	Method
LULC	More impervious runoff	Sentinel-2; Landsat 8	Expert weighting
Floodplain encroachment	Less flood buffering	Zoning maps; GIS overlays	Composite vulnerability index
Population density	Higher exposure	Census 2011	Weighted-sum index
Drainage condition	More flood risk	Municipal drainage GIS	Min-max normalization
Wetland/natural area loss	Less retention	NRSC data; wetland maps	Weighted overlay
Rainfall pattern	Flood triggering	IMD station data	Weighted overlay

Table 6: Parameter Impact Analysis-Surat

IV. INFERENCE

On the basis of the above case studies, urban flood vulnerability is primarily governed by a cluster of anthropogenic variables that can be mapped using different data sets. These include land use and land cover change (especially built-up v/s green and open areas), wetland and floodplain loss, and population density, combined with physical factors such as elevation, soil/groundwater conditions, and rainfall intensity patterns. Together, these variables capture how surface sealing, encroachment, inadequate drainage, and concentrated exposure transform rainfall into damaging urban floods, and therefore form the core indicator set for spatial analysis in this study.

V. CONCLUSION

The study also confirms that rainfall intensity alone cannot explain the observed flood patterns. Flood severity becomes much higher when intense rain coincides with impervious surfaces, blocked channels, reduced infiltration, reduced storage, and dense settlement in vulnerable locations. The most transferable anthropogenic parameters of urban flood variability are land use and land cover change, built-up expansion, green-space loss, wetland and water-body loss, drainage condition, waste dumping, floodplain encroachment, and poor planning or governance. These are the variables most consistently associated with flood amplification across the reviewed cases. Below are the listed parameters identified through the study.

PARAMETERS

1) Rainfall Intensity & Pattern
2) Land Use / Land Cover
3) Built-up Area ratio
4) Vegetation / Green Space Coverage
5) Wetlands and Water Bodies
6) Topography (Elevation and Slope)
7) Proximity to Inundation Areas
8) Soil Porosity and Permeability
9) Groundwater Levels
10) Drainage Network Condition & Pattern
11) Population Density
12) Floodplain Encroachment
13) Urban Heat Island Effect

14) Runoff Volume / Yield

VI. DETAILED PARAMETER EXPLANATION

1) Rainfall intensity and pattern: This is the trigger variable, but in the reviewed cases it becomes damaging mainly when the city surface cannot absorb or convey water quickly. The studies use IMD rain-gauge data, historical storm records, and event-based rainfall comparison to show how short-duration high-intensity storms create flash flooding when combined with blocked drains or impervious cover.
2) Land use and land cover: This is the most repeatedly cited anthropogenic driver. Supervised classification and multi-temporal satellite analysis show that when agriculture, wetlands, or vegetated land are replaced by roofs, roads, and paved areas, infiltration falls and runoff rises sharply.
3) Built-up area ratio: The chapter uses built-up percentage as a measurable proxy for surface sealing. Higher built-up ratios are associated with increased runoff volume, lower groundwater recharge, and greater flood peaks, especially in Bhopal, Bangalore, Hyderabad, and Surat.
4) Vegetation and green space coverage: Vegetation slows runoff, supports infiltration, and temporarily stores rainfall. NDVI-based analysis and land-use maps are used in the source chapter to demonstrate that shrinking green space correlates with increasing flood susceptibility.
5) Wetlands and water bodies: Wetlands and lakes function as natural retention and attenuation systems. Their loss in Bangalore and conversion in other cities shows how urban development removes natural flood buffers and leads to sudden waterlogging and reduced storage capacity.
6) Topography: Elevation and slope govern where water accumulates and how quickly it moves. Low-lying reclaimed land, coastal tracts, and concave basins such as parts of Mumbai and Surat experience longer inundation because drainage is slowed by site conditions and tidal backwater effects.
7) Proximity to inundation areas: Settlements located near flood channels, floodplains, drains, or recurrent inundation zones are directly exposed to repeated flood impacts. This variable is measured through GIS distance analysis and flood-overlay mapping in the source chapter.
8) Soil porosity and permeability: Where soils are compacted or already sealed by development, infiltration is reduced and water rapidly becomes surface runoff. The chapter treats this as a land-cover dependent factor because built-up conversion indirectly degrades soil function.
9) Groundwater level: A high groundwater table reduces the capacity of soil and subsurface storage to accept additional rainfall. This matters especially during prolonged or repeated rainfall, when surface water cannot drain quickly and local saturation persists.
10) Drainage network condition and pattern: This is one of the most important controllable parameters. The reviewed studies repeatedly identify blocked, undersized, silted, disconnected, or poorly maintained drains as a direct cause of waterlogging, overflow, and slow recession after floods.
11) Population density: Population density does not create floodwater, but it strongly increases exposure and potential losses. Dense urban areas experience greater human impact because more people, buildings, roads, and services are located within the inundation footprint.
12) Floodplain encroachment: Construction on floodplains reduces natural storage and blocks flow paths. In the case studies, encroachment is consistently linked with prolonged inundation, channel narrowing, and repeated damage in low-lying settlements.
13) Urban heat island effect: The chapter includes this as an indirect urban climatic parameter. High surface temperatures from concrete and built-up expansion can contribute to local convective effects and also signal intense urban sealing and loss of vegetation.
14) Runoff volume and yield: This is the integrated response variable estimated through the rational method, $Q = C \times i \times A$. It summarizes how land cover, rainfall intensity, and catchment size combine to produce surface runoff and therefore acts as a compact indicator of flood potential.

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