

Remote Sensing (RS) Terrain Analysis for Mapping Water Accumulation Zones: Towards a Sustainable Rainwater Harvesting Approach for Cities

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Abstract

The objective of this work is to improve rainwater Harvesting methodology, by integrating Geographical Information System(GIS) and Remote Sensing Techniques. The focus is on identifying the most suited zones for Rainwater Harvesting(RWH). To assess the hydrological behavior and surface runoff patterns, terrain parameters such as slope, flow accumulation and flow path length were analyzed using a Digital Elevation Model within an open-source geographic information system software, QGIS (Quantum GIS). To classify RWH suitability zones, a weighted overlay model was developed, which include slope (40%), flow accumulation (35%), and Flow path length (25%). The integration of GIS based analysis with IMD rainfall data was also considered to develop a better framework for water conservation and drainage planning. The overall methodology focus on the effective urban water management and Climate-adaptive infrastructure planning.

Keyword: Remote Sensing, rain water harvesting, GIS

1. Introduction

Each year country received close to 4,000 billion cubic meters(BCM) of participation from an average rainfall of roughly 1,170 mm, but only a limited portion of this has been effectively stored, as a result being blessed with Intense precipitation of Substantial rainfall country faces a Paradoxical situation of water scarcity [2]. It looks that inefficiency of water management, planning and groundwater governance nation suffers from water scarcity, diminishing aquifers, and increasing incidents of urban flooding. Despite this vast volume, millions across rural and urban India continue to experience drinking water shortage, depleting groundwater reserves and frequent urban flooding. The issues lies not in the amount of rainfall but in the inefficiency of water management, planning and groundwater governance. India has a diversified economy, with agriculture employing a large part of the population, under which groundwater play a vital role as a lifeline and is essential for sustainable agriculture, industries and daily life. In the year 2023-24, the nation's groundwater recharge was approximately 446.9 BCM, however, it was extracted at 245.6 BCM, indicating stress in several regions, according to the Central Ground Water Board [9]. Since 85% of rural population and 45% of urban population's depends on groundwater, 78% of the country's water resources now fall under the category of critical and overexploited, according to the Central water commission (2024) [15]. It assumes that by 2030 water stress impacting the GDP growth by 6% as India water demand increased by 50% also

unpredictable monsoon also impacting the challenges of water [22]. It could become a Day Zero water crises for the metro cities like Delhi, Chennai, Bengaluru and Hyderabad if a proper strategy for water conservation and ground water recharge are not implemented in next decade. This presents an alarming situation that demands an integrated groundwater management approach. The overall pressure will build on households and national economy, as it ultimately impacts land subsidence, which decreased agricultural productivity. Delhi NCR has been particularly affected. Uncoordinated water management can be observed in example such as flooding during the monsoons and depletion of groundwater in dry month. In 2024, despite a long-term average rainfall of 774 mm, Delhi recorded 1000 mm of rainfall mm [17][19]. Recent rainfall data shows rainfall exceeding the seasonal average, making the year wetter than usual according to preliminary IMD 2025 data [2]. Negligence of waterlogging continuously impacting the highways, residential colonies, underpasses and other low lying area which ultimately causing infrastructure damage and disrupting daily life. Well planned rainwater harvesting systems will help manage excess water generated from heavy rainfall and will strengthen the city water reserving capacity, which ultimately improving ground water level. Telangana was highlighted as a good example of decentralized storm-water management. In 2024–25, the state received 32% excess rainfall, but due to early efforts, urban flooding was reduced [6]. An eye-opener example of Punjab’s 2025 floods, indicates how poor drainage and unregulated are runoff impacting the lives of common people, as over 1,400 villages were affected in this natural calamity [8]. Such incidences highlight the importance of emphasizing strong rain water harvesting (RWH) infrastructure and terrain-sensitive planning to minimize the impact of natural calamities. Interestingly, if we look at our ancestor, they were well aware of sustainable water restoration practices. For example, in Rajasthan, tradition systems like taankas, johads and kunds were implemented to collect and store rain water for year-round use. These systems not only fulfilled daily needs but also helped recharge groundwater [27]. To accumulate and recharge groundwater, Gujarat has traditionally used stepwells and vavs, which function as community reservoirs and provide sustainable solutions during droughts. These systems were developed with a deep understanding of topography and water flows, and were built in areas where water naturally gathers and seeps into the ground. They now serve as a valuable model for today’s science based system. When we look at the economic viability of implementing rainwater harvesting (RWH) systems, the cost varies significantly. A small domestic setup- such as gutters or storage tanks – typically cost between 15000 to 30000 whereas large scale RWH system for large communities can cost several lakhs [20][35]. To motivate peoples, government are providing subsidies – for example, Goa’s Water Resources department offer a benefit of 50% reimbursement or up to 1 lakh specifically for rooftop rainwater collection [13]. With the advancement of technology, we may use some advance version technology to catch natural depression, natural built drainage paths for better water restoration. The paper try to present the terrain information and geospatial strategy for water accumulation. We may use tools like GIS for elevation analysis and QGIS for slope detection. To identify the natural depression zones hydrological analysis may be used. These freely available low-lying zones can be used which ultimately the flood path can we used as a recharge station for water.

The process involves:

- Natural depressions and low-lying zones can be mapped using elevation profiles.
- Water accumulation pattern can be identify using analyzed slopes and flow directions.

- Based on the slopes and other parameter, different types of RWH structure can be designed such as recharge pits, ponds, tailored to soil and hydrological conditions.
- Identify the proximity to existing water treatment facilities to redirect the rainwater runoff.

To provide major hydrological and infrastructure benefits, this GIS based, topography-driven method is eco-friendly and cost effective and that too require minimal equipment. By embracing this decentralized approach, local bodies can curb stormwater runoff, which ultimately recharge groundwater and help mitigate flooding. Further, this broader objective aligns with government initiative such as Jal Shakti Abhiyan, Catch the Rain campaign and the Master plan for Artificial recharge to Groundwater. This study aims to turns rainfall-related challenges into opportunities by transforming monsoon flood zones into model for sustainable water management, contributing to ground water rejuvenation in the future.

2. Literature Review

Rainwater harvesting (RWH) has steadily become a crucial part of India's efforts toward sustainable water management, especially amid rapid urban growth, groundwater depletion, and recurring water shortages. India receives an average annual rainfall of about 1,170 mm, yet, much of this water is lost as surface runoff due to poor collection infrastructure and the expansion of paved urban areas [2]. Traditional and modern methods are being adopted by government after recognizing this paradox of abundant rainfall alongside various limitation in promoting rainwater harvesting. To enforce the implementation of these systems, some governments have adopted legal measures requiring the installations of RWH in new buildings that exceed specific plot size. One such example where Delhi Jal Board (DJB) in early 2000s made rooftop RWH mandatory under the Delhi Building Bye-Laws [28]. Tamil Nadu, Karnataka, and Rajasthan are on the same track of introduces penalty clauses for non-compliance with integrating RWH in buildings. The good part is that these legislative measures collectively support localized water conservation and improve water restoration [28][24]. Rainwater collection from rooftops and open surfaces is supported and promoted through government initiative and the "Catching the Rain, where it falls, when it falls" campaign, under the flagship of Jal Shakti Abhiyan (JSA) [14]. Around 23 lakh rural and 8.8 lakh urban recharge structures have been proposed across the country under Ministry of Jal Shakti's Master Plan [4]. Restoring heritage water bodies and strengthening urban water security are key goals supported by the Amrit Sarovar Mission, whose aims is to revive 75 water bodies in each district. Meanwhile the programmes like Jal Sanchay Jan Bhagidari focus on encouraging local ownership and community participation [4][21]. With the advancements in technological, innovation approaches are gaining greater attention in redefining the RWH structure. Urban cities have adopted modular recharge well combined with eco-friendly modular blocks that filter and recharge storm water, enabling both infiltration and purification. Another notable example is from New Delhi Municipal Council (NDMC), which implemented an infiltration-based system by constructing 60- meter deep recharge well using polymer filter boxes[15]. Coimbatore's eco-bloc setups, made from recycled polyethylene, offer durable and low-maintenance options for public areas. These innovations mark a clear shift from traditional pit-based systems to modular, scalable, and environmentally engineered infrastructure. Simultaneously, traditional systems such as taankas, johads, and baoris-long used in Rajasthan and other arid regions-are being revived under integrated conservation programs. By Combining age-old practices with modern urban design, efficient rainwater infiltration is

supported by initiatives like Jal Yukt Shivar Abhiyan and the Amrit Sarovar mission [30]. In the long term, these initiatives emphasize a heritage based model that integrate both technology and community. The use of geospatial technologies has added a new layer of precision to RWH planning and monitoring. Research by Preeti et al., Nanteza et al., and Du et al. demonstrates that GIS and Remote Sensing tools improve site selection accuracy by analyzing slope, elevation, soil, and runoff dynamics [31][32][12]. Similarly, Bera et al. used geospatial analysis to locate suitable RWH sites in Jharkhand, showing that terrain and catchment mapping directly increase recharge potential [25]. Ahmad et al. Focus on cost-effective model by optimizing the capability of GIS framework in combination with Water systems, geological, and societal-environmental components [11]. His study shown that urban flooding and water restoration can be improve using better RWH design pattern. Even with strong support, most national projects focus more on building infrastructure than on water management or recharge[4]. Only few studies track water capture and small areas like dips, which could store water are often overlooked. In conclusion, the evolution of rainwater harvesting in India represents a convergence of policy, technology, and traditional knowledge. The next stage lies in terrain-based planning-where digital mapping, community involvement, and sustainable engineering come together to make RWH not just a policy obligation but a climate-resilient pathway toward securing India's water future.

Research Gap: While the initiative of the government for rainwater harvesting on a large scale are appreciable, a number of key gaps persist. The majority of national and state level reports concentrate on achievement of targets example how many buildings were constructed or money spent instead of measuring real recharge volumes or the operational effectiveness of these systems. Integrated data on the amount of water actually being collected or replenished each year is still scarce. Terrain analysis through GIS is an essential parameter to be taken into account while installing RWH system. Weak framework selection can influence system performance and another factor like sedimentation, choking and poor maintenance tends to premature system failure. Urban areas contain smaller micro-depressions like roadside basins, natural dips in parks or vacant land which are immensely underutilized even though they can be used as localized water storage sites. In addition, there is little utilization of real time monitoring and remote sensing technologies in the evaluation of performance or efficiency of recharge. The research proposed in this study aims to overcome these research and application gaps by applying slope and depression mapping for the determination of natural collection points and the construction of low cost, sustainable reservoirs. This approach complements such national initiatives as Jal Shakti Abhiyan and Catch the Rain, adding a data aware, terrain specific outlook to India's rainwater harvesting strategy.

3. Methodology

This section discusses the methodological approach applied to determine appropriate Rainwater Harvesting (RWH) locations in South-East Delhi by geospatial technology. The method integrates freely accessible remote sensing data and open source GIS software to quantify terrain characteristics, drainage characteristics and land use patterns that determines water runoff and accumulation. The process mainly consists of data collection, terrain analysis and spatial interpretation using Digital Elevation Model (DEM), state GIS portal and QGIS software.

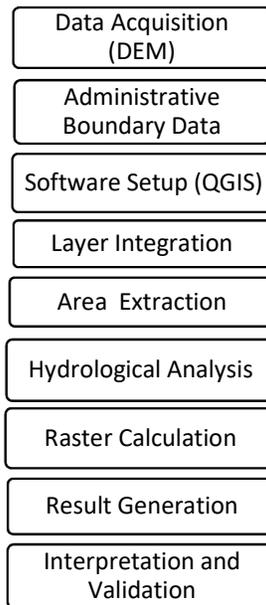


Table 1. Methodological Process

3.1 Study Area:

The selected study area, South-East Delhi falls with approximately 28.5531° N latitude and 77.2599° E longitude covering an area of approximately 102 km^2 (39 sq mi). The region consists of highly populated residential, institutional and industrial areas. The ground is typically flat to gently sloping with slight elevation variations affecting drainage and patterns water stagnation. As per IMD, cumulative rainfall during 2025 had already passed 963.4 mm as on August-September. Because of Spurt in urbanization, impervious surfaces have grown significantly, which leads to constant waterlogging and low infiltration capacity. So, mapping terrain based RWH potential become necessary for sustain stormwater management.



Figure 1: Location map of the study area – South-East Delhi

3.2. Data sources and Database preparation:

The data used in this research were gathered from a combination of government and open-source geospatial datasets to provide both authenticity and analysis compatibility in the QGIS environment. The main data used in the study are the Digital Elevation Model (DEM), elevation profile, land use/Land cover (LULC) images, and administrative boundaries of South-East Delhi. The Digital Elevation Model (DEM) was retrieved from Bhoonidhi based on CartoDEM data, which is required for the detailed elevation and terrain analysis. This DEM was the reference datasets for the hydrological processing that involved slope, flow accumulation and flow path length analysis. The elevation profile data was obtained through the Delhi state GIS portal in the form of elevation graphs and point-specific relief information. This data was utilized for the validation and cross-verification of the elevation graphs from the DEM, establishing topographic variation in South-East Delhi. Land use/Land cover (LULC) information was collected from Bhuvan using IRS Resourcesat-2 LISS III data. This data was especially useful for differentiating between built-up land, vegetation, open land and water bodies major determining factors of infiltration capacity, surface runoff and overall rainwater harvesting potential. The boundary shapefile for South-East Delhi was generated through the application of QGIS and augmented with Opencity and other open-source geospatial data. The boundary layer was utilized to clip every thematic dataset so that all analysis remained geographically bounded within the study area. IMD data was utilized to also consider the average rainfall in Delhi for the year. The LULC map developed from Bhuvan's IRS Resourcesat-2 LISS III data gave a snapshot of surface properties in South-East Delhi. It divided the area into four broad classes built up areas, vegetation, open areas and water bodies assisting in the evaluation of surface permeability and runoff capacity. The map shows that most of the area is urbanized and how low natural infiltration, but open and vegetated areas are potential sites for groundwater recharge and sustainable rainwater harvesting schemes.

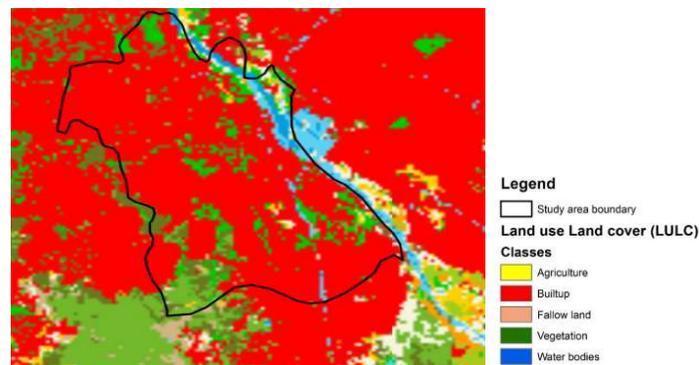


Figure 2: LULC map of South-East Delhi

3.3. Step-wise process:

Step 1. DEM Extraction and Preparation

South-East Delhi DEM was downloaded from Bhoonidhi and clipped against the study area administrative boundary using QGIS. This elevation data was used as a base layer for the derivation of hydrological parameters such as slope, flow accumulation and flow length.

Previously, the DEM was also screened for anomalies like depressions or voids and filled using the fill sink tool in QGIS to provide a continuous hydrological flow network.



Figure 3: DEM of South-East Delhi

Step 2. Elevation Profiling

Elevation profiling was performed with the state GIS portal in order to represent vertical elevation variation in various transects through the study area. The profiles were cross-checked with Google Earth Pro's Elevation graph tool. The analysis revealed how terrain slope are related to runoff sensitive areas. Three elevation profile plots were plotted to evaluate directional variation in ground elevation form the outside edges in the direction of the central and outer portions of the study area. The analysis was carried out in order to know the natural slope gradient and surface morphology, assisting in determining probable flow directions and natural runoff accumulation areas during rainfall along transects A-B, C-D and E-D.



Figure 4 (i)



Figure 4 (ii)

Figure 4 (i, ii): Map and Elevation profile graph of South-East Delhi from point A to B.

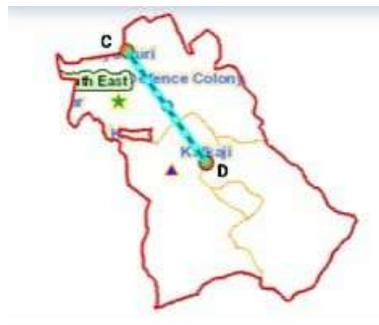


Figure 4 (iii)

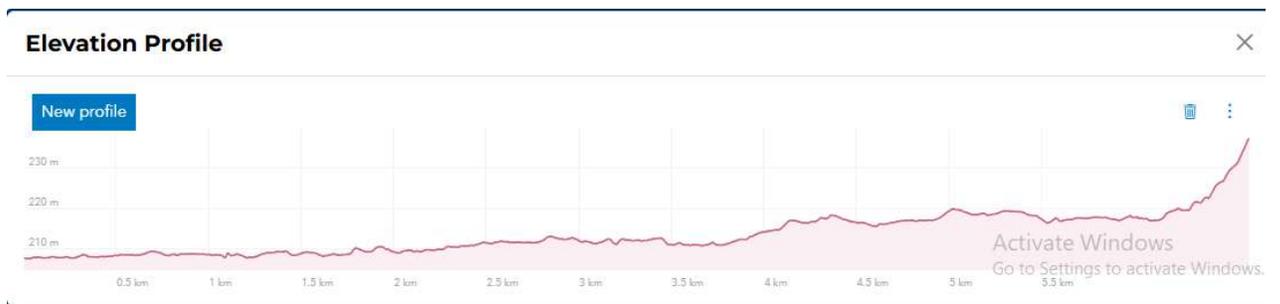


Figure 4 (iv)

Figure 4 (iii, iv): Map and Elevation profile graph of South-East Delhi from point C to D.

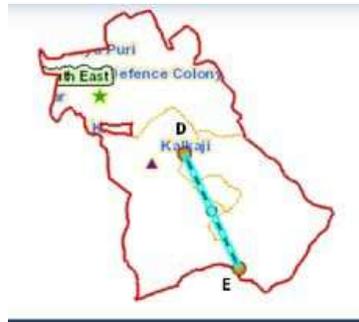


Figure 4 (v)



Figure 4 (vi)

Figure 4 (v, vi): Map and Elevation profile graph of South-East Delhi from point E to D.

Step 3. Terrain and Hydrological Analysis in QGIS

Three of the most important terrain parameters were extracted from the processed DEM through the use of the Hydrology toolbox in QGIS:

1. Slope Analysis- Slope (in degrees) was calculated to identify steepness and areas with possible infiltration.

- Flat slopes ($0-2^\circ$) – high infiltration, perfect for RWH structures.
- Gentle slopes ($10-15^\circ$) – show well balanced runoff for diversion based RWH.
- Steep slopes ($>15^\circ$)- low in-filtration, only fit for runoff collection.

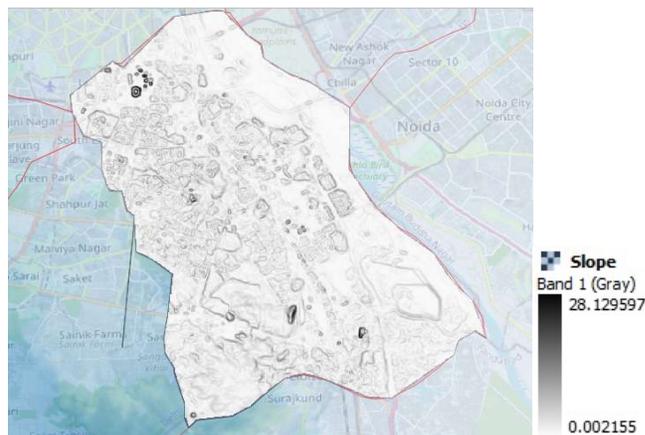


Figure 5: Slope map of South-East Delhi

QGIS obtained Values	Terrain Type	Dominant Area	RWH Suitability
0.0021546	Flat	Urban lowlands	Excellent
3.6587221	Gentle	Transitional zones	Good
7.3152896	Gentle	Transitional zones	Good
10.9718571	Gentle	Transitional zones	Good
14.6284245	Moderate	Upper urban slopes	Moderate
18.284992	Steep	Ridge areas	Poor
21.9415595	Steep	Ridge areas	Poor
25.3168525	Steep	Ridge areas	Poor
28.1295967	Steep	Ridge areas	Poor

Table 2: Average data taken from DEM Slope

2. Flow Accumulation- Flow accumulation is the number of cells that drains into a single grid cell and reflect possible zones of runoff collection. High accumulation areas reflective of natural depressions and drainage confluences prime signifiers for the placement of recharge pits or storage tanks.

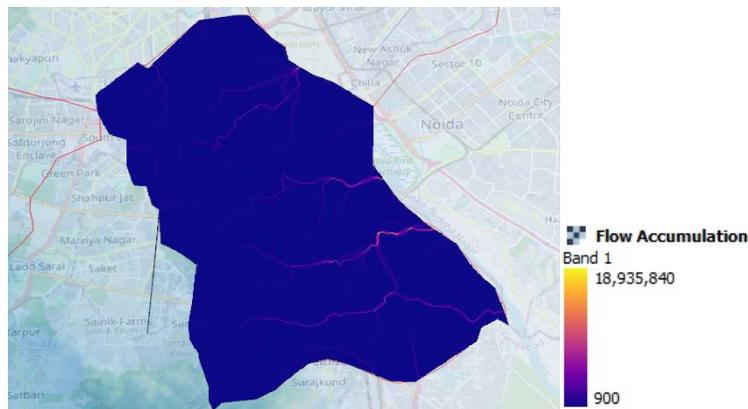


Figure 6: Flow accumulation map

Flow Accumulation (cells)	Hydrological Zone	Characteristics	RWH Suitability
900 – 2,462,442	Upper Catchment / Hilltop	Represents initial runoff cells at higher elevations with minimal contributing area. Water quickly disperses; infiltration is higher due to limited surface flow.	Low – Not suitable for major RWH structures; only small rooftop or percolation pit systems feasible.
2,462,442 – 4,923,984	Gentle Slope / Headwater Zone	Moderate runoff generation begins; small surface flow	Moderate – Suitable for recharge pits, contour bunds, or small check dams.

		paths are visible; partial infiltration possible.	
4,923,984 – 7,385,526	Transition / Flow Convergence Zone	Runoff starts to accumulate; drainage paths are identifiable; moderate surface water collection areas form.	Moderate to High – Ideal for trench-type RWH, recharge shafts, and small ponds.
7,385,526 – 9,847,068	Secondary Drainage Zone	Noticeable flow channels; medium to large contributing area; runoff volume increases significantly.	High – Suitable for constructing recharge wells or small detention ponds along channels.
9,847,068 – 12,308,611	Drainage Confluence Zone	Major flow accumulation areas; well-defined drainage paths with concentrated surface runoff.	Very High – Excellent for community-scale RWH systems or stormwater collection structures.
12,308,611 – 14,770,153	Stream Network / Lowland Zone	Surface water merges into stream-like formations; limited infiltration due to compacted soil and built-up regions.	High – Suitable for check dams, recharge trenches, or urban stormwater harvesting.
14,770,153 – 17,042,346	Flood-Prone Zone	Large accumulation area; potential for seasonal flooding; requires managed drainage.	Very High (with design controls) – Appropriate for large retention ponds, recharge parks, or bio-swales.
17,042,346 – 18,935,840	Terminal Basin / Waterlogging Zone	Represents natural depressions or end points of drainage; highest runoff concentration.	Extremely High – Prime sites for RWH structures, recharge basins, and wetland-based water storage.

Table 3: Flow Accumulation Classification and RWH Suitability for South-East Delhi

3. Flow Path Length- It indicates the average distance traveled by water before it exits the system. Increased path lengths represent increased surface runoff possibilities and shorter paths represents local depressions or pond areas. Every layer was classified as low, medium or high based on ranges from standard hydrological interpretation.

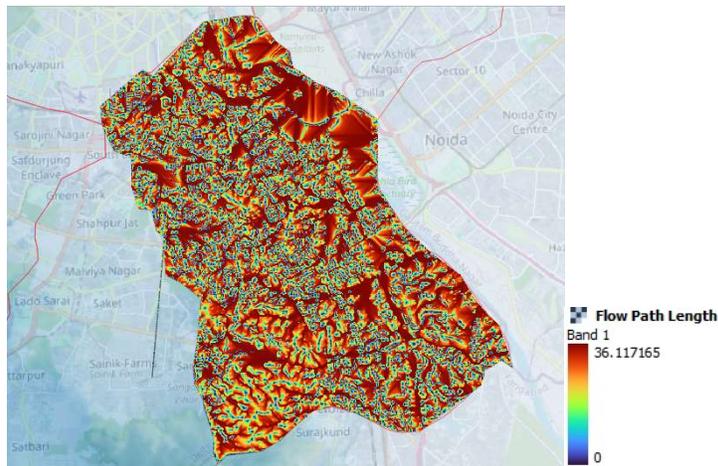


Figure 7: Flow path length map

Flow Path (m)	Surface Behavior	RWH Potential
0 – 10	Water stagnation zones	Very High
10 – 30	Moderate flow transfer	High
> 30	Rapid runoff along channels	Medium

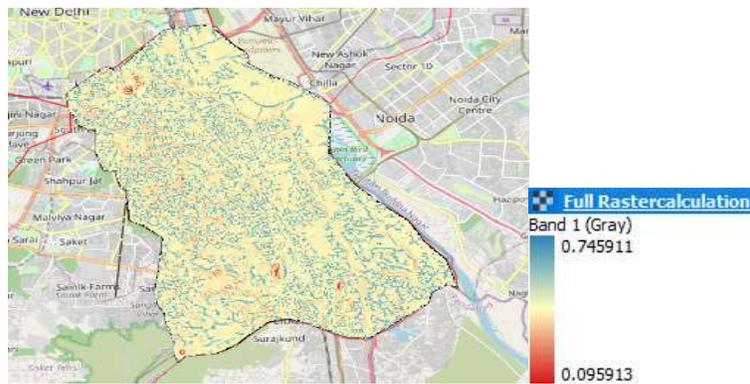
Step 4. Integrated Spatial Analysis

The three raster layer – slope, flow accumulation and flow path length were integrated within QGIS utilizing a weighted overlay model. Weights were assigned depending on their relative impact on RWH potential: Slope (40%), Flow accumulation (35%) and Flow Path length (25%).

The output resulted in the demarcation of the study area into three RWH potential zones:

- High suitability- low slope, high accumulation, short path length
- Moderate suitability- Moderate slope, intermediate accumulation.
- Low suitability- Steep slope, low accumulation.

Color code: Low suitability (red) and High suitability (blue).



- STATISTICS_MINIMUM=0.095912680029869
- STATISTICS_MAXIMUM=0.74591118097305
- STATISTICS_MEAN=0.45461918167728
- STATISTICS_STDDEV=0.077359832183448
- STATISTICS_VALID_PERCENT=53.18

Figure 8: Final RWH suitability map of South-East Delhi

Step 5: IMD data-

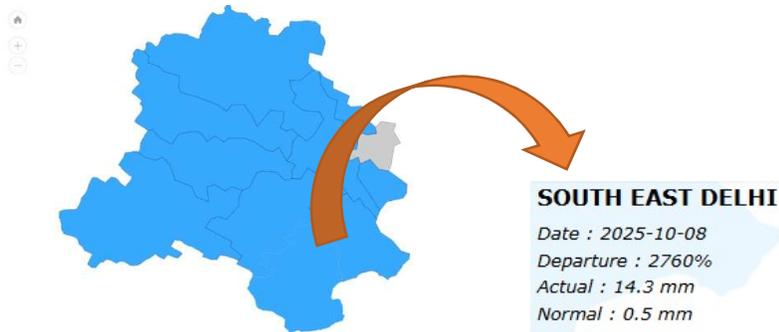


Figure 9: Showing rainfall recorded-Excess 20-90% (latest).

DISTRICTWISE RAINFALL DISTRIBUTION

S.No.	MET. SUBDIVISION/ UT STATE/DISTRICT (NAME)	DAY : 14.09.2025 TO 14.09.2025				PERIOD : 01.06.2025 TO 14.09.2025			
		ACTUAL (mm)	NORMAL (mm)	% DEP.	CAT.	ACTUAL (mm)	NORMAL (mm)	% DEP.	CAT.
1	CENTRAL DELHI	0.0	5.0	-100%	NR	945.3	625.2	51%	E
2	EAST DELHI	0.0	5.0	-100%	NR	851.4	625.2	36%	E
3	NEW DELHI	0.0	3.2	-100%	NR	609.4	601.2	1%	N
4	NORTH DELHI		2.5		*		518.4		*
5	NORTH EAST DELHI	0.0	5.0	-100%	NR	880.7	625.2	41%	E
6	NORTH WEST DELHI		0.4		*		382.5		*
7	SOUTH DELHI	0.0	5.0	-100%	NR	543.3	625.2	-13%	N
8	SOUTH EAST DELHI	0.0	5.0	-100%	NR	792.4	625.2	27%	E
9	SOUTH WEST DELHI	0.0	3.3	-100%	NR	787.1	518.8	52%	E
10	WEST DELHI	0.0	2.7	-100%	NR	617.8	563.1	10%	N

Figure 10: Showing District wise rainfall distribution

The approach successfully blends DEM based hydrological modeling and remote sensing data sets to detect terrain driven RWH potential in South-East Delhi. Combination of QGIS analytical capabilities and State GIS elevation profiles ensures scientific accuracy and real world applicability for urban RWH planning. The geospatial approach provides a sound framework for enabling sustainable urban stormwater management as well as priority locations of RWH in water scarce regions of South-East Delhi.

4. Result

South-East Delhi geospatial analysis reveals that the area's topography is primarily flat to gently sloping with values of slope from 0.002° to 28.12° . The evidence suggests a low-relief area where the movement of water is guided more by gradual gradient variations than by step geomorphological features. The slope (Figure 5) indicates that the majority of the area belongs to the flat to gentle slopes ($0-10^\circ$), which implies good rainwater infiltration and storage conditions, especially within residential, institutional and open spaces in the study area. Less than a quarter of ridge zones is characterized by steep slopes ($>15\%$) in which infiltration is low and surface runoff prevails. This interpretation is corroborated by the flow accumulation pattern (Figure 6). Depending on the values of flow accumulation (900-18,935,840), the landscape has a step by step hydrological convergence starting from higher elevation catchment cells and terminating in terminal basins or natural depressions that receive high runoff. The middle and southwestern regions of South-East Delhi have extremely high accumulation areas, reflecting natural drainage convergence and RWH hotspots possibilities. On the other hand, the high ridge areas in the north and east show very little accumulation, serving to initiate runoff mainly. Distribution of flow path length (Figure 7) again explains the dynamics of runoff. Short flow paths (0-10 m) occur densely in the stagnation zones or natural depression, usually in the built up region where water pooling is actually seen during a heavy monsoon. Increased path lengths (>30 m) are reflected in large flow corridors routing towards the Yamuna floodplain, from where water leaves the local drainage systems. This spatial supports the hydrological modeling performed in QGIS. For combining terrain parameters, the weighted overlay analysis combined three raster layers- Slope (40%), Flow Accumulation (35%) and Flow Path Length (25%) to produce an integrated RWH suitability index. The composite map produced (Figure 8) separated the area into three zones of suitability. Blue color represents high suitability zones, primarily low lying land with flat slopes ($>5\%$), high flow accumulation and short path lengths. These are portions of Okhla Industrial Area, Johri Farm, Noor Nagar and surrounding institutional clusters, where surface water tends to accumulate during rainfall events. Moderate suitability zones exist over gently sloping transitional areas ($5-10^\circ$) that have runoff and infiltration in balance. they are ideal for diversion based or decentralized recharge structures, particularly in areas surrounding urban settlements and minor road networks. Low suitability zones, indicated in red, are the steep slopes and rides along the southeastern boundary. these areas have high runoff velocities and are therefore less suited for infiltration based RWH but well-suited for runoff collection and conveyance systems. The last spatial grouping reveals that almost two-thirds of South-East Delhi is classified under moderate to high suitability for RWH development. This identifies great promise for decentralized rainwater harvesting systems, particularly in institutional rooftops, open spaces and roadside medians.



Figure 11: Elevation from one point to another

The elevation profiling of the three transects (A-B, C-D and E-D) gives information about the internal terrain structure. The profiles reveal a gradual rise in level towards the central area of South-East Delhi and then a decline towards the peripheries. This trend reveals rainwater drains outwards from the central ridges to lower margins, filling depressions parallel to defined drainage channels. As a result, water naturally flows in the direction of the western and southern sides where waterlogging has been reported on a regular basis. This topographic interpretation matches the flow accumulation analysis, verifying terrain morphology as a controlling factor in water stagnation and runoff patterns in South-East Delhi. In 2024-25 monsoon, South-East Delhi witnessed more than average rains around 963.4 mm higher than the city's long term average of 790 mm according to IMD 2025. Yet the drainage system in the area continues to bear the brunt of the situation with numerous instances of waterlogging and flooding reported by India today 2024. The combined GIS based RWH mapping provides scientific support for such on ground observations. Regions marked as very suitable for RWH overlap with regions that are likely to experience severe waterlogging, indicating that adopting rainwater harvesting systems in the areas may deliver twin advantage of mitigating urban flooding as well as augmenting groundwater recharge. On the other hand, low suitability areas are high elevations that require proper stormwater drainage maintenance to manage rapid runoff. The combined method bridges the gap between urban water management and hydrologic modeling by demonstrating that RWH planning should be integrated into residential drainage improvement projects. By defining both runoff dominant and accumulation prone areas, the research provides a geo-hydrological basis for adaptive stormwater management in an urbanizing district. Overall, the incorporation of terrain parameters using GIS not only provides a scientific base for the sustainable management of water resources management but also supports urban climate adaptation and resiliency. By integrating hydrological model output with on-site flooding and drainage on the ground, this research shows how geospatial

technology is used to bridge environmental planning and policy relevant water management practices in data limited urban settings like South-East Delhi. As a result, the findings verify that GIS based spatial analysis is a viable method for identifying RWH potential zones, maximizing the use of resources, conserving water and enhancing the long term sustainability of urban hydrological systems.

5. Conclusion

The Hydrological and terrain parameter spatial analysis of slope, flow accumulation and flow path length in QGIS identified district runoff concentration areas in South-East Delhi, particularly in the Okhla, Sarita Vihar and Badarpur regions. The slope was analyzed and it was observed that almost 58% of the area of the study area comes under gentle slope classes (0-5°) that are extremely favorable for surface water storage and recharge systems. Conversely, sites with adequate with higher slope (15%), primarily along the ridge and high peripheral patches had low infiltration capacity and were categorized as run-off dominated areas. As per the India Meteorological Department (IMD) throughout the 2024 monsoon season (June-September), South-East Delhi received an average rainfall of 1,126 mm approximately 32% more than the long term average of 850 mm. The greatest 24 hr rainfall (187 mm) was on July 28, 2024 that caused intense flooding in various low-lying colonies in the area. The intense rain followed by inadequate drainage facilities and very high impervious surface cover (more than 70%) resulted in waterlogging depth of 20-40 cm lasting for a number of hours. By combining rainfall depth with surface runoff coefficients (0.75 for urban areas and 0.40 for open space or green belts), the harvestable water for the season was estimated at 17.3 million cubic meters (MCM). But because of poor recharge systems and clogged drainage less than 25% of this runoff was captured or infiltrated effectively. This result in almost 13 MCM of available freshwater lost annually by uncontrolled runoff water which might otherwise sustain residential use, landscaping and groundwater recharge. There existed a direct association between the intensity of rainfall (>100 mm/day) and waterlogging occurrences as confirmed by municipal fold reports and Sential-2 temporal imagery. Impervious surfaces had zero percolation capacity with resultant high runoff and localized flooding. GIS based drainage mapping established that flow accumulation converges at very same low-lying junctions where waterlogging occurred repeatedly, supporting the accuracy and predictive value of the model. The research points to the extent to which terrain modeling, delineation of flow paths and runoff mapping can contribute greatly to site specific planning for rainwater harvesting (RWH). Through the identification of natural depressions and connecting these with favorable recharge areas. This GIS approach provides double advantage minimizing flooding in urban areas by regulated runoff diversion and enhancing groundwater levels by controlled infiltration. If only 40% of the excess runoff produces during monsoon rainfall events were harvested with the help of GIS based measures, South-East Delhi would be able to recharge 6-7 MCM of groundwater annually. This would minimize reliance on external water sources and ease pressure on over-exploited aquifers. Finally, this study fills the knowledge gap between water conservation and flood management. Through combining IMD rainfall data with terrain based GIS modeling, it covert heavy rainfalls events which are previously urban risks into a valuable opportunity for sustainable recovery of water resources. The findings present a replicable model for other conurbation Indian cities grappling with the same hydrological issues in the context of climate change.

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