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RAINWATER HARVESTING POTENTIAL ASSESSMENT USING GIS AND HYDROLOGICAL MODELS

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***Abstract*- Freshwater scarcity has emerged as one of the most pressing environmental challenges worldwide, driven by rapid urbanization, population growth, and climate variability. Rainwater harvesting (RWH) offers a sustainable and cost-effective solution to augment water availability, reduce dependence on conventional sources, and mitigate urban flooding. This study presents a comprehensive methodology for assessing rainwater harvesting potential through the integration of Geographic Information Systems (GIS) and hydrological models. GIS enables spatial analysis of topography, land use, soil characteristics, and rainfall distribution, while hydrological models such as SWAT, HEC-HMS, and SWMM simulate runoff generation, groundwater recharge, and system performance under varying scenarios.**

A detailed literature survey highlights successful applications of RWH across diverse regions, including semi-arid zones in India and Brazil, and flood-prone urban areas in Bangladesh, demonstrating its role in enhancing water security and resilience. The research area, Chikkasandra in Bangalore, was selected to evaluate RWH feasibility due to its rapid urbanization, undulating terrain, and reliance on borewells. Climatic and hydrological data were analyzed to identify suitable sites for rooftop harvesting, recharge pits, and surface runoff collection.

The findings emphasize the importance of integrating GIS-based spatial analysis with hydrological modeling to optimize site selection, system design, and performance evaluation. Key challenges identified include limited high-resolution datasets, lack of real-time rainfall integration, and uncertainties in model calibration. Despite these constraints, the study concludes that combining modern geospatial tools with traditional RWH practices can significantly improve water resource management, reduce urban flooding, and promote long-term sustainability. Future research should focus on incorporating climate change scenarios, real-time sensor data, and advanced modeling techniques to enhance predictive capacity and support dynamic RWH planning frameworks.

***Keywords*- RWH,GIS,spatial analysis,hydrological modeling**

1. INTRODUCTION

Freshwater scarcity has become one of the most critical environmental challenges of the 21st century, affecting both urban and rural communities across the globe. Rapid urbanization, population growth, and erratic climatic patterns have intensified the demand for water, placing immense pressure on conventional sources such as rivers, reservoirs, and groundwater aquifers. In many regions, overexploitation of groundwater has led to declining water tables, while surface water bodies are increasingly polluted or insufficient to meet rising needs. Against this backdrop, Rainwater Harvesting (RWH) emerges as a sustainable and cost-effective solution to augment water availability and strengthen resilience against water stress.

Rainwater harvesting involves the collection and storage of precipitation from rooftops, paved surfaces, and catchment areas, which can then be directed into storage tanks, recharge pits, or reservoirs. Historically practiced in ancient civilizations, RWH has regained importance today as a cornerstone of sustainable development and environmental conservation. Its benefits extend beyond water supply: it reduces surface runoff, mitigates urban flooding, recharges groundwater, and promotes local water self-sufficiency. In urban contexts, RWH can be integrated into stormwater management systems, while in rural areas it supports agriculture and domestic needs during dry seasons.

Assessing the potential for rainwater harvesting is a crucial first step toward designing effective catchment and storage systems. This requires a detailed understanding of topography, land use, rainfall distribution, soil characteristics, and hydrological behavior. Traditional methods of site selection and water yield estimation are often time-consuming and spatially limited. In contrast, Geographic Information Systems (GIS) and hydrological models provide powerful tools to analyze large datasets and generate spatially explicit information critical for identifying and prioritizing suitable locations for RWH interventions. GIS technology enables the integration of multiple spatial layers—such as slope, land use/land cover (LULC), soil type, drainage patterns, and rainfall distribution—while hydrological models simulate runoff generation, infiltration, and water balance under varying scenarios.
The integration of GIS and hydrological modeling offers a data-driven, scalable, and cost-effective approach to RWH planning. By combining spatial analysis with predictive simulations, planners can identify optimal sites for structures such as check dams, percolation tanks, recharge pits, and rooftop systems. Moreover, these tools allow scenario-based evaluations, helping policymakers and engineers anticipate the impacts of climate variability, land use changes, and urban expansion on water availability. This journal aims to present a comprehensive methodology for assessing rainwater harvesting potential using GIS and hydrological models, with a focus on the study area of Chikkasandra, Bangalore. Through this approach, the research seeks to provide actionable insights for enhancing water security, promoting sustainable urban development, and supporting long-term environmental resilience.

1.1 AIM OF THE PROJECT

The study aims to evaluate rainwater harvesting (RWH) potential in Chikkasandra, Bangalore using GIS and hydrological models. The key objectives are:

1. Spatial Analysis – Use GIS to identify suitable sites based on slope, soil, land use, and rainfall.
2. Runoff Estimation – Apply hydrological models (SWAT, HEC-HMS, SWMM) to calculate harvestable rainwater.
3. Impact Assessment – Examine how topography, land use, and urbanization affect runoff and recharge.
4. Integration – Combine GIS datasets with hydrological simulations for accurate planning.
5. System Optimization – Design and test RWH structures (tanks, recharge pits, trenches) under different scenarios.
6. Urban Stormwater Management – Use SWMM to reduce flooding and integrate green infrastructure.
7. Policy Recommendations – Provide insights for planners and policymakers to incorporate RWH in urban codes.
8. Future Scope – Highlight data gaps, real-time integration needs, and climate change considerations.

2. LITERATURE REVIEW

Literature review on different aspects of the present work not only provided a deep insight of the problem under consideration but also helped in finalising the methodology of the work. Availability of water resource is a serious problem and is faced by almost all the countries in the world with varying intensity. As a result the available literature as a subject is inexhaustible. Hence, only selected works have been included in the present chapter.
S.S.S.Kumar et al.(2020) , - "Rainwater harvesting Potential 2020 ,assessment using GIS and Hydrological Models:A case study of Bangalore."Geographic Information Systems (GIS) have revolutionized the planning and design of RWH by enabling spatially explicit analysis of site suitability. Researchers have developed frameworks that combine multiple layers—rainfall distribution, land use, soil type, slope, and

drainage density—to identify zones with high potential for harvesting. These spatial overlays allow planners to pinpoint optimal locations for tanks, recharge pits, and conveyance routes, ensuring that investments are both effective and cost-efficient. Management Model) are frequently integrated with GIS to simulate runoff volumes and predict system performance under varying scenarios. For instance, studies in African urban centers have used GIS- SWAT coupling to estimate potential water yields from different catchments, while research in European cities has employed SWMM to evaluate how distributed cisterns influence hydrographs during storm events. The strength of GIS-driven approaches lies in their ability to capture heterogeneity across urban landscapes. Rather than applying uniform assumptions, spatial analysis accounts for variations in slope, infiltration capacity, and rainfall intensity, thereby producing more reliable and site- specific recommendations. Moreover, GIS facilitates participatory planning by visualizing results in maps that are easily interpretable by policymakers and communities.

Low-impact development (LID) performance practices represent a broader category of interventions that overlap with Literature on LID consistently highlights its effectiveness in reducing both peak discharge and total runoff volume in urban watersheds. Techniques such as green roofs, bioretention cells, permeable pavements, and cisterns mimic natural hydrological processes by promoting infiltration, evapotranspiration, and on-site storage.

Aroujo, M.C., Leao, A.S., Jesus, T.B., & Cohim, E. (2021) – The ole of Rainwater Harvesting in Urban Stormwater Runoff in Brazil's Semiarid Region Aroujo and colleagues (2021) explored the role of rainwater harvesting (RWH) in managing stormwater runoff in Brazil's semiarid regions, where rainfall is scarce but often intense. Their study emphasized that conventional drainage systems are insufficient to handle sudden downpours, leading to localized flooding and water scarcity during dry seasons.

Santos, V.C. dos, Neves, M.G.F.P. das, & Souza, V.C.B. de. (2023) Assessment of Rainwater Harvesting Systems Through Continuous Simulation with Sub-Daily Santos and colleagues (2023) evaluated rainwater harvesting systems using continuous simulation with sub-daily rainfall data, offering a more realistic view of system performance. Unlike traditional

3. METHODOLOGY

This study integrates GIS analysis with hydrological modeling to assess rainwater harvesting (RWH) potential in Chikkasandra, Bangalore. The approach is summarized below:

1. Data Collection – Gather spatial data (DEM, LULC, soil maps), rainfall records, and water demand statistics.
2. GIS Analysis – Delineate watersheds, analyze slope/aspect, classify land use, and identify soil infiltration zones.
3. Hydrological Modeling – Use SWAT, HEC-HMS, and SWMM to estimate runoff, simulate recharge, and test scenarios.
4. Integration – Combine GIS layers with model outputs to map runoff, recharge zones, and suitable RWH sites.
5. SWMM Application – Model urban catchments, size storage tanks, predict overflow, and integrate green infrastructure.
6. Validation – Conduct field surveys, calibrate models with observed data, and perform sensitivity analysis. Performance Evaluation – Assess efficiency, reliability, **Fig. 2 location: rrit r.r layout, chikkasandra, t.dasarahalli, bangalore**
7. environmental benefits, and economic feasibility. , and uncertainties in calibration.

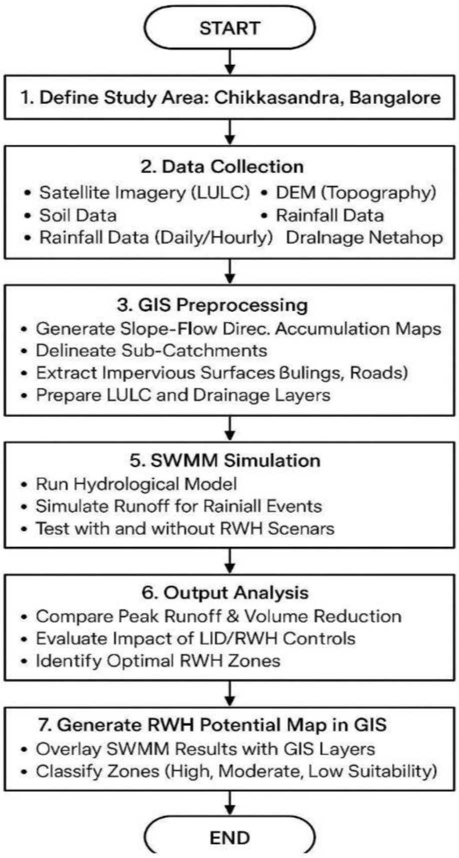


Fig 1. Flow chart of Methodology

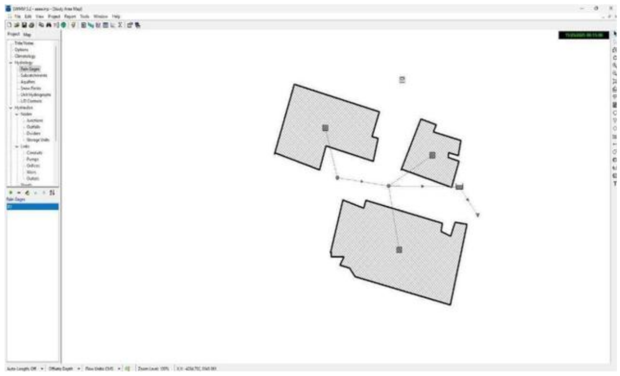
4. STUDY AREA

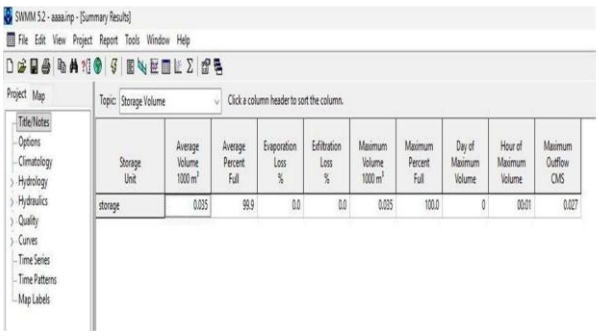
The research was carried out in Chikkasandra, located in the north-western part of Bangalore, Karnataka (13.05° N, 77.51° E), under the jurisdiction of the Bruhat Bengaluru Mahanagara Palike (BBMP).

Fig. 2 location: rrit r.r layout, chikkasandra, t.dasarahalli,

5. RESULT AND DISCUSSION

Climate: Tropical savanna with average annual rainfall of 850–970 mm, mainly during the southwest monsoon (June–September).
Hydrology: No perennial water bodies; heavy reliance on borewells and rain-fed sources.
Topography: Undulating terrain with gentle slopes, contributing to moderate runoff. Urbanization has increased impervious surfaces, raising flood risks but reducing natural recharge.
Soil: Moderately permeable, suitable for recharge pits and infiltration structures.
Urbanization: Rapid growth of residential and institutional areas has heightened water demand and stormwater challenges.





Storage Unit	Average Volume 1000 m³	Average Percent Full	Evaporation Loss %	Exfiltration Loss %	Maximum Volume 1000 m³	Maximum Percent Full	Day of Maximum Volume	Hour of Maximum Volume	Maximum Outflow CMS
storage	0.035	99.9	0.0	0.0	0.035	100.0	0	00:01	0.027

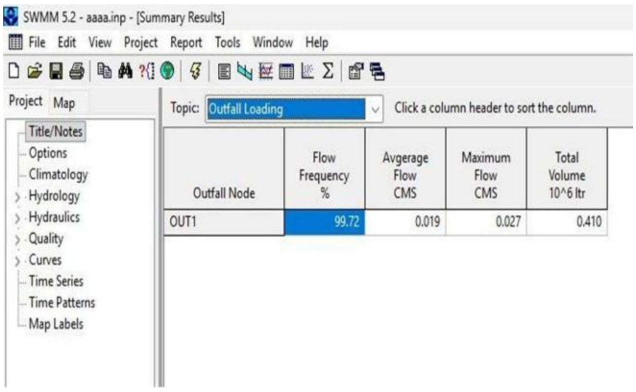


Table 1 : overall rain water harvesting potential

SL no	Typesof roof	Area(m^2)	Run off coefficients	Annual Rainfallin mm	(S=R*A*Cr) Runoff (cu. m)	(S=R*A*CR) Runoff (liters)
1	Concrete Roof	4598.369326	0.85	820	3204806.00	3204806000.00

A. POTENTIAL BENEFITS

Stormwater Management: Reduced surface runoff and lower load on drainage systems.

Groundwater Recharge: Surplus water during monsoon can be directed into recharge pits and trenches.

Economic Savings: Harvested water reduces reliance on purchased supply, leading to cost savings.

Environmental Impact: Promotes sustainability, reduces flooding risk, and enhances resilience against drought conditions.

6. CONCLUSION

➢The amount of water that can be collected from the rooftop and the total potential runoff which is high and good to establish rainwater harvesting systems to mitigate the drinking water scarcity.

➢By the study, it is evident that the rooftop rainwater harvesting technique can be effectively used to meet the complete domestic water demands.

➢The present study has been carried out to assess the rainwater potential that can be harvested from the rooftop and through runoff.

➢The geospatial techniques and domains like the Google earth maps and software's like QGIS and SWMM are helping tools in the works where the entities of varied characteristics and tedious field works are involved.

➢It is evident that from table 1 that the amount of water that can be harvested from rooftop is sufficient
enough to overcome water scarcity in the study area.

➢The total quantity of rainwater can be collected in the study area is around 3204806000.00 litres. Rainwater harvesting is the best alternative to address ever-growing water demand issues and concerns in study region.

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