SUPTM 2026: 3rd Conference on Future Challenges in Sustainable Urban Planning & Territorial Management

Universidad Politécnica de Cartagena

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Spatio-Temporal Dynamics of Built-Up Areas in Pune City, Maharashtra, India (1992 and 2022): Implications for Groundwater Management and Urban Planning

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Abstract: Rapid land-use/land-cover (LULC) transformation in Pune is intensifying challenges for urban planning and groundwater governance. This study assesses the implications of spatio-temporal LULC dynamics for groundwater management using LANDSAT (30 m) data for 1992 and 2022 and ALOS PALSAR (12.5 m) DEM to derive the drainage density. Results revealed that built-up areas expanded from 47.7 km² to 151.5 km², while encroachment into Aquifer Recharge Zones (ARZs) increased from 12.68 km² to 25.45 km² between 1992 and 2022. Safeguarding existing undisturbed ARZs (41.71 km²) and integrating Managed Aquifer Recharge (MAR) into land-use planning are essential for long-term groundwater security and sustainable urban development.

Keywords: Land use/Land cover; Urban planning; Managed aquifer recharge (MAR) strategy; Groundwater security

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *SUPTM 2026 conference proceedings* xx. https://doi.org/ 10.31428/xxxxx

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1. Introduction

Pune, presently the largest municipal corporation by area in Maharashtra, spans approximately 516.18 km² area, following recent inclusion of new villages in the boundary limits. The historical development of city is closely associated with the banks of the Mula and Mutha rivers. Geologically, the region forms part of the Deccan Volcanic Province (DVP) and is characterized by five unconfined aquifers hosted within basaltic lava flows emplaced around 65 Ma. Census data shows population increase from 1.2 million (1981) to 3.1 million (2011), with projections of ~10 million by 2047-2050 [1]. Consequently, annual urban water demand is expected to rise from ~20.30 TMC (2022-23) to ~34-35 TMC by 2050-52 [2,3]. Rising water demand has accelerated groundwater extraction, with estimates indicating an increase from ~2 TMC in 2011 to ~8 TMC by 2023 [4,5]. Correspondingly, post-monsoon groundwater levels declined from ~2.2 m bgl in 1992 to ~4.1m in 2022 in some parts of the city, indicating localized overextraction [6]. Although ground-water extraction occurs at a large-scale citywide, the predominantly localized declines in water table may indicate that, in developing cities, leakage-driven urban recharge masks broader depletion trends, while expanding impervious built-up areas increase runoff and reduce natural recharge [5,7,8,9,10]. Urban recharge often introduces contaminants into aquifers, underscoring the need to strengthen natural recharge processes within ARZs to safeguard groundwater quantity and quality. This study documents the correlation between LULC changes, especially built-up expansion, and its encroachment onto ARZs. Considering groundwater's role as a critical supplementary source to Pune municipal water supply, this study recommends integrating MAR strategies, which have evolved globally over decades [11], into urban planning and land use management as a key response to overextraction and climate stress.

2. Study area and methodology

2.1 Study area

Figure 1 illustrates the geographical location of Pune city in western Maharashtra, India (18.52° N Latitude and 73.88° E Longitude). The present PMC boundary, with administrative wards *(Prabhags)*, is delineated in red. Major surface water bodies, including the Mula and Mutha river and their confluence, are shown in blue.

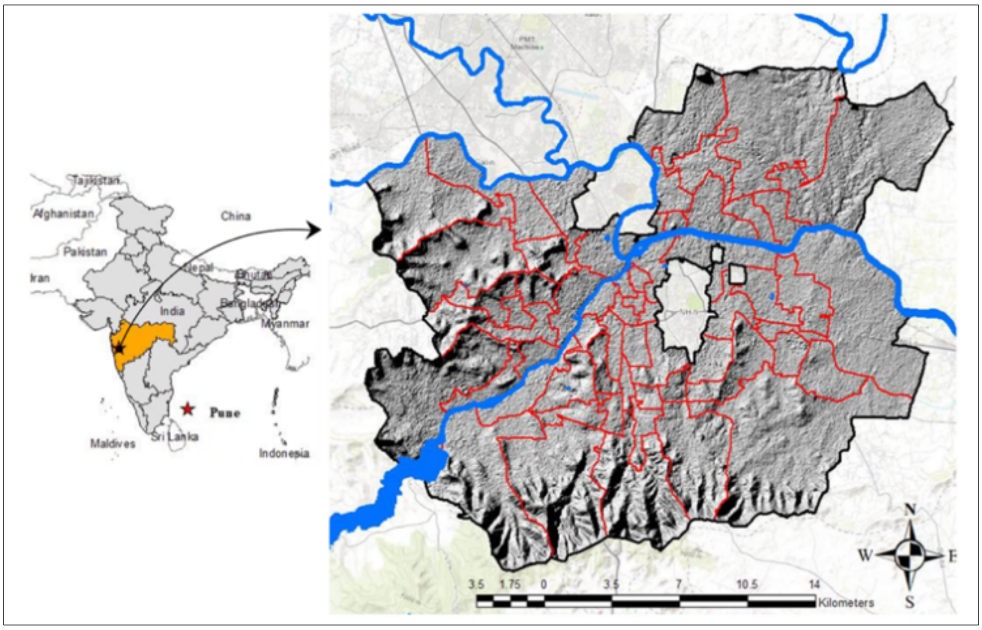


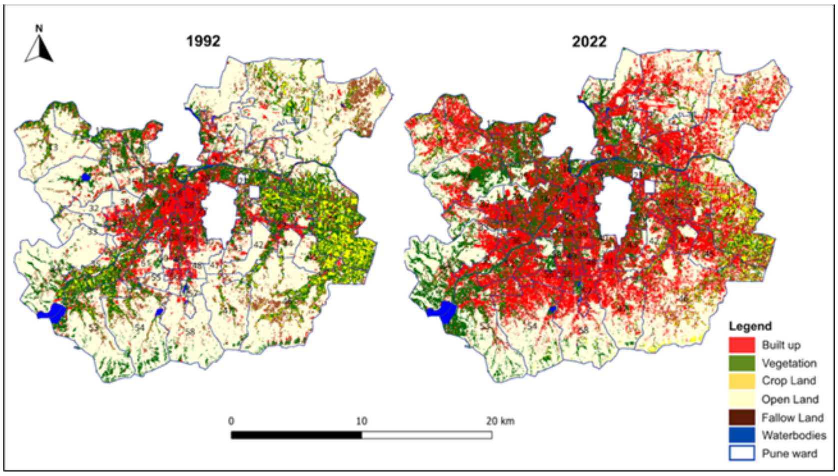
Figure 1. Geographical location of the study area

2.2. Methodology for LULC mapping and Aquifer Recharge Zones (ARZs) Delineation

To conduct LULC mapping, cloud-free satellite images of February 1992 and 2022 were obtained from USGS Earth Explorer and processed using ERDAS Imagine 2014. The PMC boundary shapefile facilitated the extraction of regions. LULC mapping employed the maximum likelihood supervised algorithm, categorizing six major classes: Built-up, Waterbodies, Vegetation, Crop land, Fallow Land, and Open Land. Built-up expansion and its implications for sustainable urban planning and groundwater management were analyzed. Accuracy assessment using random sampling points of 300 per class was conducted, yielding Kappa values >0.85. ARZs were extracted from the maps presented in the study 'Pune's Aquifers: Some Early Insights from a Strategic Hydrogeological Appraisal' [4,5]. LULC maps (30 × 30 m) quantified built-up encroachment over ARZs in 1992 and 2022 using the extract-by-mask tool embedded in ERDAS Imagine.

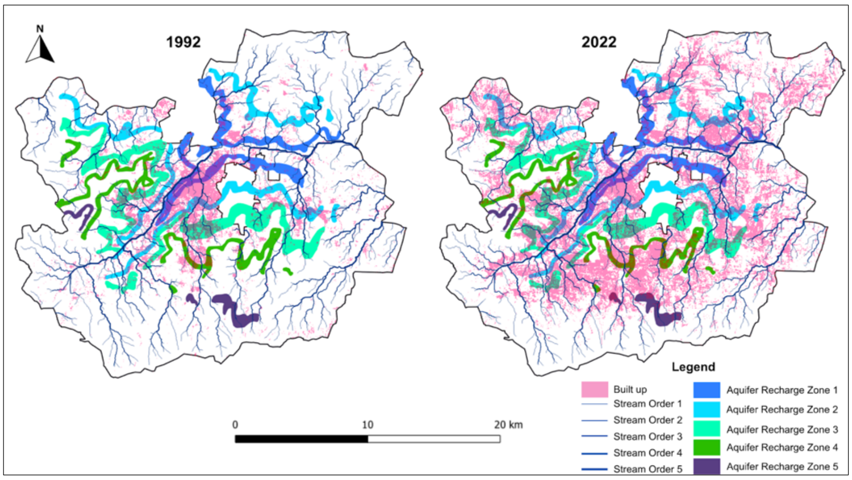
3. Results

Results show six LULC categories, with built-up area increasing from 47.7 km² (1992) to 151.5 km² (2022), highlighting accelerated, uneven urbanisation (Figure 2). Overlaying built-up extent on five central ARZs (67.81 km²) delineated within the PMC boundary indicates comparatively higher expansion in ARZs 1-3, indicating proximity to urban cores and intensified land-use transformation (Figure 3).



(a) **(b)**

Figure 2. (**a**) 1992 LULC; (**b**) 2022 LULC



(a) **(b)**

Figure 3. (**a**) 1992 Built-up over the ARZs (**b**) 2022 Built-up over the ARZs [ARZs are extracted from 4,5]

Table 1. Area of built-up, aquifer recharge zones and area available for MAR interventions

ARZs	Total area (km²)	Built-up in 1992		Built-up in 2022		% change in built-up	Area available for MAR intervention (km²)	% area available for MAR intervention
		area (km²)	% area	area (km²)	% area			
ARZ 1	13.35	3.92	29.36	5.72	42.85	13.48	7.63	57.15
ARZ 2	16.52	2.82	17.07	6.50	39.35	22.28	10.02	60.65
ARZ 3	24.61	5.06	20.56	9.63	39.13	18.57	14.98	60.87
ARZ 4	9.30	0.87	9.35	3.06	32.90	23.55	6.24	67.10
ARZ 5	3.40	0.01	0.26	0.54	15.88	15.62	2.86	84.12

4. Discussion and conclusion

Table 1 provides a comprehensive comparison of built-up area changes between 1992 and 2022 across five ARZs (ARZ 1-5) and evaluates the remaining land available for Managed Aquifer Recharge (MAR) interventions. ARZ 1 shows a 42.85% rise in built-up area, leaving 57.15% (7.63 km²) available for MAR. ARZ 2 records a 39.35% increase, retaining 60.65% (10.02 km²) for recharge. ARZ 3 shows a 39.13% rise, with 60.87% (14.98 km²) still available. ARZ 4 shows comparatively lower growth (32.90%), maintaining 67.10% (6.24 km²) for MAR. ARZ 5 is the least urbanized, with 84.12% (2.86 km²) MAR potential. Overall, despite urban expansion and neglect of the natural drainage systems and recharge zones, substantial recharge opportunities remain, especially in ARZs 4 and 5. Pune city, despite extensive urbanisation, offers significant potential for MAR, with 41.71 km² of the 67.81 km² recharge zone area remaining suitable. Highly built-up zones require engineered MAR integrated into infrastructure (e.g., recharge wells, percolation tanks, rainwater harvesting), whereas less urbanised zones provide opportunities for large-scale interventions (e.g., spreading basins, check dams, and protection of open and fallow lands). Alongside demand management and surface storage alternatives, this study recommends detailed ward-wise, zone-specific MAR strategies integrated with land-use planning to mitigate urbanization impacts and ensure long-term groundwater security

Funding: This research received no external funding

Acknowledgments: The authors gratefully acknowledge FLAME University, particularly the Centre for Sustainability, Environment, and Climate Change, and researchers from the Advanced Center for Water Resources Development and Management (ACWADAM), Pune.

Conflicts of Interest: The authors declare no conflict of interest.

Data availability statement: All data files produced by this study will be published on FLAME University's Map Lab portal: https://themaplab.org/

References

1. Pune Municipal Corporation. *Water Supply System for Pune City: Detailed Project Report, Vols. I–IV*; 2014. Available online: https://www.scribd.com/document/526024065/Pune-DPR (accessed on 12 October 2025).
2. Pune Municipal Corporation. *Water Budget (पाणी बजेट) 2022–23*; 2022. Available online: https://rb.gy/ndz4dr (accessed on 24 September 2025).
3. Inamdar, N. PMC Estimates 27.17 TMC Water Requirement for 1.07 Crore Population in 2027. *Hindustan Times*, 2025. Available online: https://hosturl.link/RGQmsm (accessed on 30 October 2025).
4. Kulkarni, H.; Bhagwat, M.; Kale, V.; Aslekar, U. *Pune's Aquifers: Some Early Insights from a Strategic Hydrogeological Appraisal*; Technical Report; Advanced Centre for Water Resources Development and Management (ACWADAM): Pune, India, 2019. DOI: https://doi.org/10.13140/RG.2.2.11362.48326
5. Kulkarni, H.; Rajguru, J.; Korde, P. *Unravelling Pune's Aquifers: Framework for Groundwater Management and Governance*. ACWA/Hydro/2023/H142; Advanced Center for Water Resources Development and Management: Pune, India, 2023. DOI: https://doi.org/10.13140/RG.2.2.34683.18724
6. Central Ground Water Board. *Ground Water Yearbook of Maharashtra, 2022–23*; 2023. Available online: https://cgwb.gov.in/cgwbpnm/public/uploads/documents/17032373003420914 79file.pdf (accessed on 12 September 2025).
7. Foster, S. Global Policy Overview of Groundwater in Urban Development: A Tale of 10 Cities! *Water*. 2020, 12(2), 456. DOI: https://doi.org/10.3390/w12020456
8. Dutta, J.; Choudhury, R.; Nath, B. Quantification of Urban Groundwater Recharge: A Case Study of Rapidly Urbanizing Guwahati City, India. *Urban Sci.* 2024, 8(4). 187. DOI: https://doi.org/10.3390/urbansci8040187
9. Pasquier, U.; Vahmani, P.; Jones, A. D. Quantifying the CityScale Impacts of Impervious Surfaces on Groundwater Recharge Potential: An Urban Application of WRF–Hydro. *Water*. 2022, 14(19). 3143. DOI: https://doi.org/10.3390/w14193143
10. Zhou, W.; Hao, L. Impact of rapid urbanization on groundwater storage variation amid climate change in the Yangtze River Basin. *J. Hydrol. Reg. Stud*. 2025, 59. 102360. DOI: https://doi.org/10.1016/j.ejrh.2025.102360
11. Dillon, P.; Stuyfzand, P.; Grischek, T. et al. Sixty years of global progress in managed aquifer recharge. *Hydrogeol. J.* 2019, 27 (1), 1–30. DOI: https://doi.org/10.1007/s10040-018-1841-z