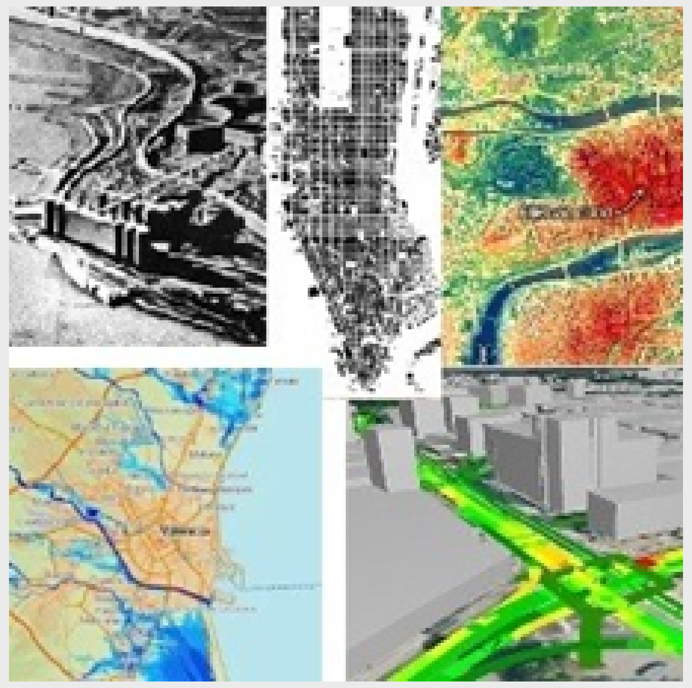

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Spatio-Temporal Dynamics of Built-Up Areas in Pune City, Maharashtra, India (1992 and 2022): Implications for Groundwater Management and Urban Planning

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Abstract

Pune city (~516.18 km²) in western Maharashtra, India developed along the Mula–Mutha rivers, and lies in the Deccan Volcanic Province with five unconfined basalt aquifers. 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 sustainable groundwater security and urban development.

1. Study Area & Methodology

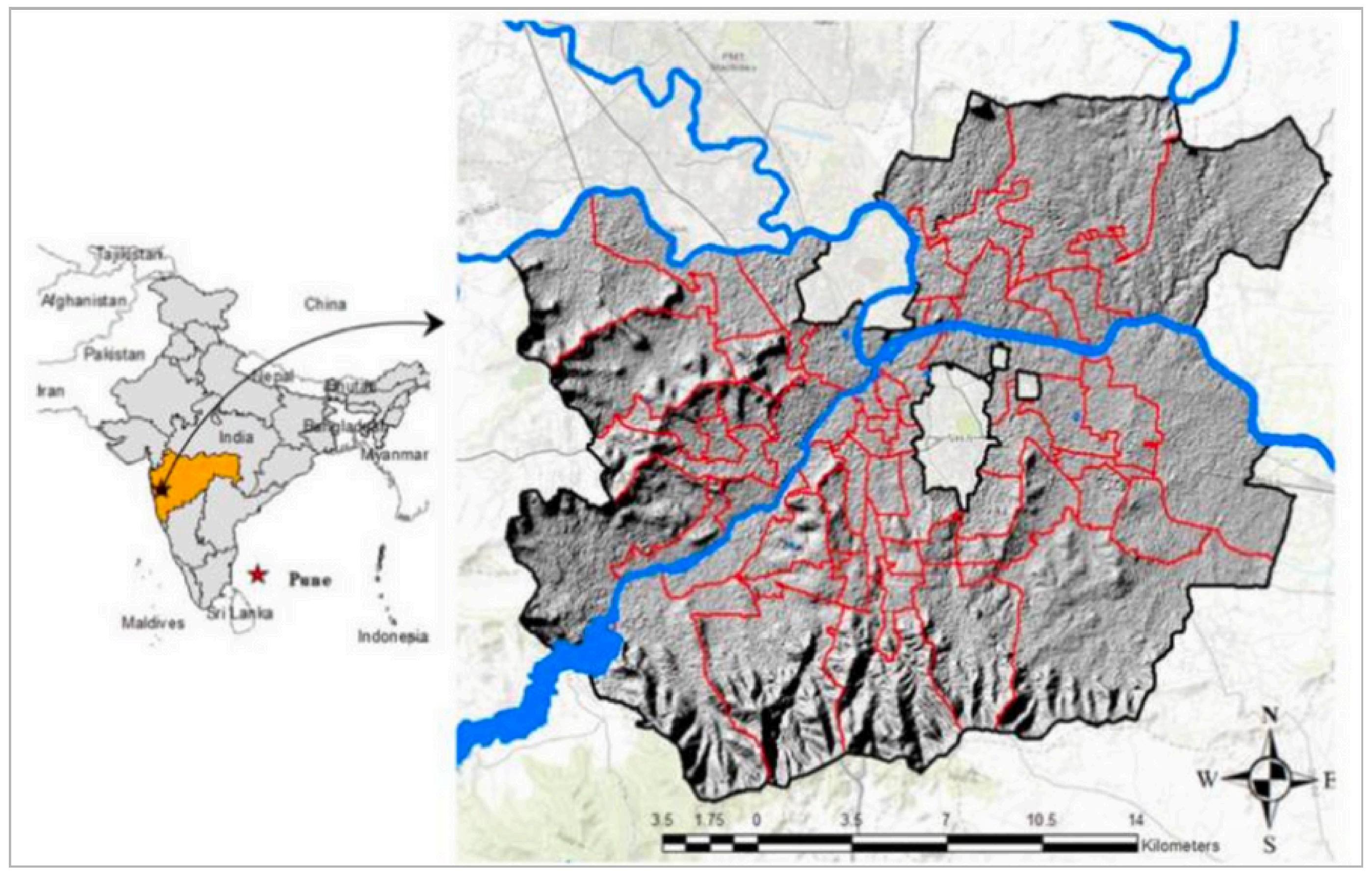

Figure 1: Pune city in western Maharashtra, India (18.52° N Latitude and 73.88° E Longitude)

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 Pune Municipal Corporation (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' [1,2]. 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.

2. 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).

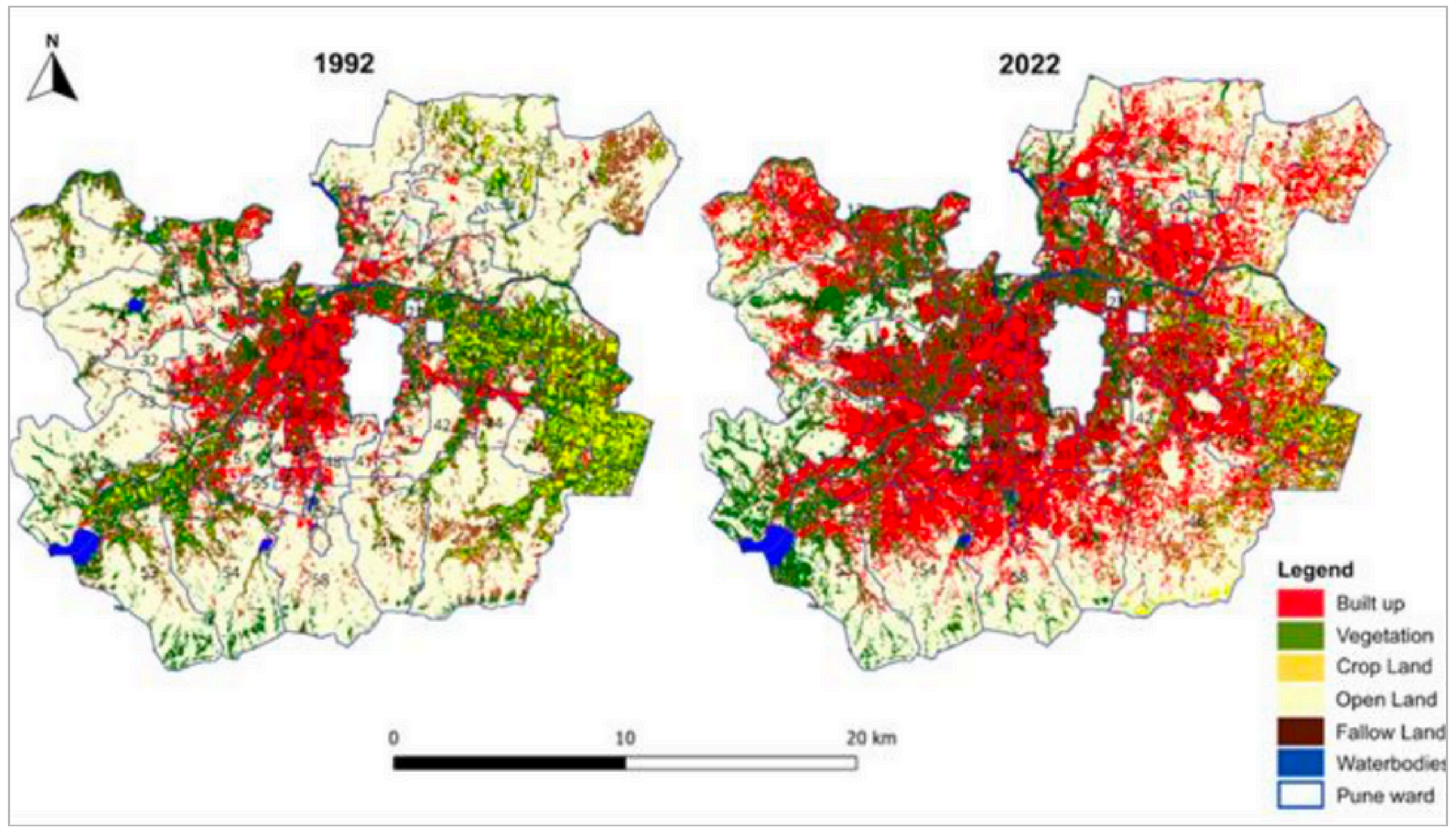

Figure 2: Landuse/ Land cover classification (1992 and 2022)

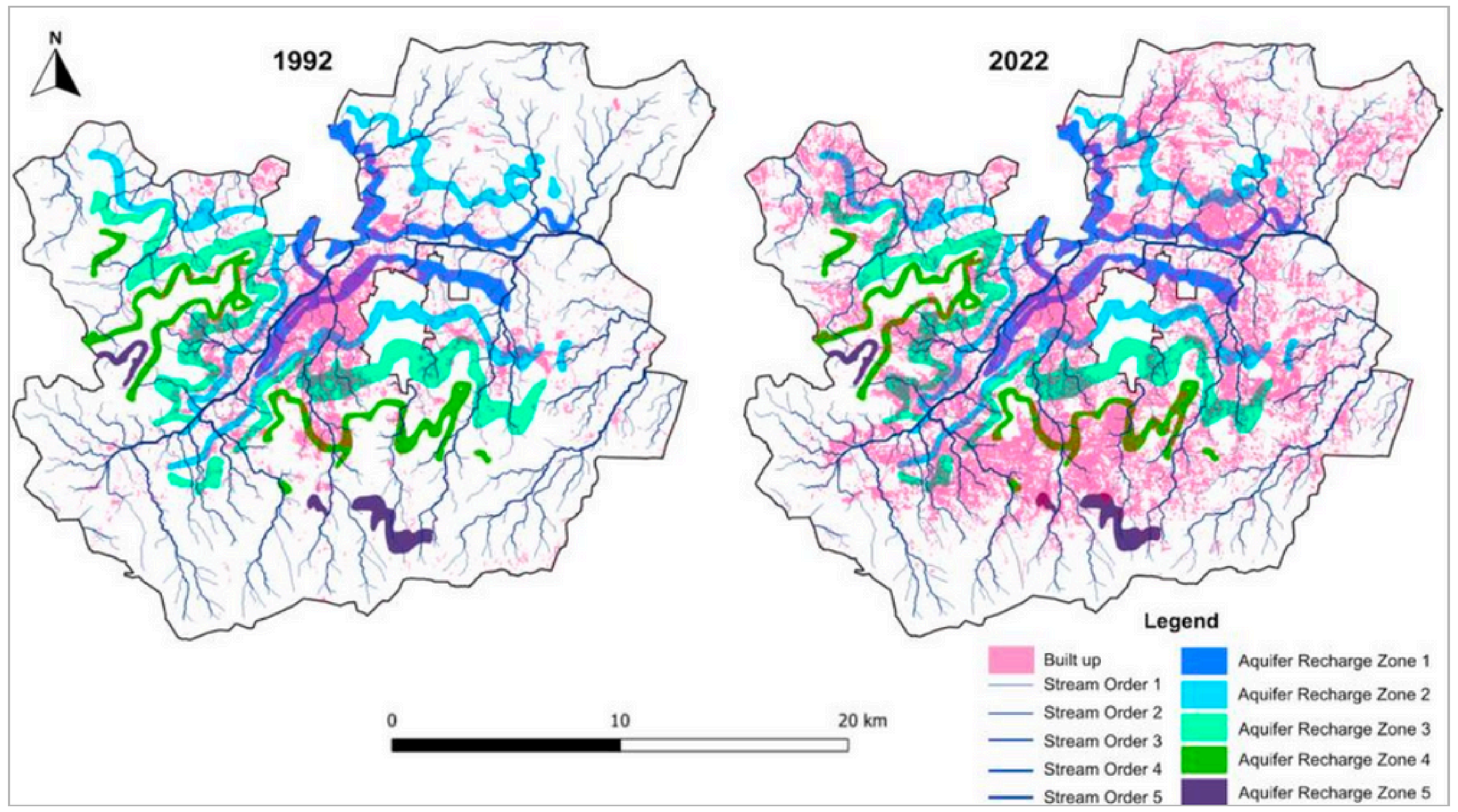

Figure 3: Aquifer recharge zone and built-up overlay (1992 and 2022) [1,2]

Table 1.Area of built-up, aquifer recharge zones & 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

3. Discussion & 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

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2. 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