Impact Assessment of Urbanisation on the Groundwater Recharge of Ahmedabad District using Geospatial Techniques and Hydrological Modelling

A PhD synopsis submitted to Gujarat Technological University for the Award of

Doctor of Philosophy in Civil Engineering

By

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Abstract

This study provides insight into urban groundwater recharge of the Ahmedabad district which happens to be one of the most urbanised cities of India. Urbanisation, a dominant global trend of the 21st century, reshapes hydrological dynamics and directly influences groundwater recharge rates. Groundwater is essential to the social and economic well-being of urban populations of developing world. According to the Central Ground Water Board, India is world's largest groundwater extractor, 45–50% of urban water supply dependent on groundwater. Ahmedabad is extracting an enormous amount of available groundwater recharge. Groundwater recharge is one of the most significant hydrological processes needs thorough analysis under urbanisation. The study was carried with objectives of assessing impact of urbanisation on groundwater recharge by performing statistical analysis of existing hydrometeorological condition, land use change detection using geospatial techniques and hydrological modelling. This work integrates multi-temporal and geospatial analysis with the Soil and Water Assessment Tool (SWAT) which is a semi-distributed hydrological model. The required input data including Hydrometreological data and spatial maps have been collected from the authentic sources like SWDC, IMD and satellites. The multi-temporal satellite imagery imported in ArcGIS to prepare decadal land use maps. After performing land use change detection, it is found that the built-up area increased consistently across all decades, with the largest expansion of 7.2% between 2011 to 2020.

The analysis carried by the non-parametric Mann-Kendall (MK) test that was used to examine historical temperature and rainfall time-series for temporal trends in order to identify statistically significant changes in climatic variables over the period of 1980 to 2020. Followed by the hydrological modelling, the analysis part includes SWAT model as it is one of the most efficient models in this field. It is made to run using multiple land use/land cover scenarios with Digital Elevation Model (DEM), soil type data, and climate inputs to simulate hydrological processes. From the existing literature review, it has been observed that out of all the basins available in the study area, Vasna barrage (22.9928°N,72.5537°E) located in the heart of the city is one of the most significant hydraulic structures which contribute to the hydrology of the study area. SWAT model output i.e. groundwater recharge specifically to the shallow aquifer was visualized using a tool named SWAT output viewer which is widely used to represent outputs obtained from SWAT run.

The calibration and validation are carried out for 2014-2019 and 2020-2024 respectively by SWAT -CUP and the SUFI-2 algorithm. Observed streamflow data from Vasna barrage were

used by identifying the sensitive parameters that affects the value of groundwater recharge considerably. During the calibration and validation periods, model predictions performed well as shown by the coefficient of determination (R^2) and Nash-Sutcliffe efficiency (NSE) values that significantly exceeded 0.7. During the calibration phase, the coefficient of determination value of 0.74 indicates a highly accurate correlation between the simulated and observed daily discharge. The Nash Sutcliffe coefficients obtained were 0.79 and 0.72 for the calibration and validation period, respectively. After the successful validation, the absolute values of sensitive parameters are incorporated in the SWAT model to replicate the watershed and analyses suggest the marginal increase in groundwater recharge 0.58% during 1991-2000,1.98% increase during 2001-2010 with baseline period (1981-1990) due to relatively higher amount of rainfall and during 2011-2020 groundwater recharge declined by 5.36% relative to the baseline due to rapid urbanisation.

Future projections were carried out after calibration and validation of SWAT model where rainfall and temperature projections are derived from the Coupled Model Intercomparison Project Phase 6 (CMIP6) dataset that represents the latest generation of climatic projections. The CMIP6 provides climate projections from a large number of Global Climate Models (GCMs). In this study, EC-Earth3, one of the CMIP6 models, is used for Indian monsoon region and provides consistent daily climate variables required for hydrological modelling. Daily precipitation, maximum temperature, and minimum temperature data will be used for future periods under the SSP3-7.0. The coefficient of determination (R^2) between observed and simulated values was found to be 0.96, indicating a strong agreement of the model. The model was subsequently used to generate future climate projections up to the year 2050 which shows annual average groundwater recharge decreases up to 11.79%. This trend indicates that Ahmedabad might face groundwater extraction challenges in near future.

The study shows the significant decadal variability in groundwater recharge where recharge exhibited an increasing trend during the first two decades but declined in the most recent decade where urbanisation is dominant driver but climatic variability may also have played a secondary role.

The integrated GIS and SWAT modelling approach provides a solid framework to understand how urbanization impacts groundwater dynamics and aids in sustainable water resource management and planning in semi-arid regions like Ahmedabad. By analysing land-use change and its impact on groundwater recharge, the study contributes directly in achieving SDGs.

Brief description of the state of the art of research

Urbanization is one of the most significant demographic and socioeconomic trends of the twenty-first century, with over 68% of the world's population predicted to reside in cities by 2050**.** The natural water cycle is being drastically altered by the quick growth of metropolitan areas, which is putting increasing strain on freshwater resources across the globe. Particularly susceptible to these changes is groundwater, which supplies about half of the world's irrigation demands and makes up almost 97% of the planet's liquid freshwater. (Ali J,2024**)**

India has experienced remarkable urban growth in recent decades as a result of economic development and migration from rural to urban areas. One of the main effects of India's urbanization is environmental stress. In addition to changing local hydrology and increasing surface imperviousness, the transformation of natural and agricultural landscapes into urban environments can lead to groundwater depletion and water scarcity when municipal systems are unable to keep up with the increasing demand. (Shashank Shekhar,2025). Urban growth frequently involves the transformation of permeable natural surfaces into impervious artificial environments. Urbanization significantly alters patterns of land use and land cover (LULC) by replacing vegetative and permeable surfaces with impermeable surfaces such as highways, buildings, and pavements. (Bibhash Nath,2021).

The amount of rainwater that seeps into groundwater reserves may decrease as a result of this loss of natural recharge zones since there may be less natural infiltration and greater surface runoff (Sahana Goswami,2021). India's yearly groundwater recharge is estimated to be around 448.52 billion cubic meters, while total extraction is still high at about 247.22 billion cubic meters (with extraction at about 60.63% of recharge), according to the most recent Dynamic Groundwater Resources assessment (CGWB-2025). This indicates continuous pressures on the aquifer systems. Rapid urban growth, changing LULC patterns, and increasing water demand are all contributing factors to the severe strain on groundwater systems in metropolitan India. The combined effects of rapid urban expansion, changing LULC patterns, and increasing water demand have placed significant stress on groundwater systems in urban India (Dutta, 2024).

Water is a finite, vulnerable and valuable natural resource. According to the United Nations Development Program (UNDP, 2007), Asia is the most vulnerable and scarce freshwater resources area in the world More than half of the world's population lives in urban areas, a proportion that is expected to increase in the next decades (McDonald et al., 2014). Global urbanization projections indicate that by 2050, 60 to 90% of the global population will reside in cities (Ritchie, H.;2022, Wang, K.;2021). This rapid surge in urbanization driven by population growth and socioeconomic conditions has heightened the demand for water, thereby straining both surface and subsurface water resources (Nasiri, S.2020). In many cities in the world, urbanization changes the land use practice, usually by reducing the natural land area and increasing the impervious cover area (Murakami et al., 2005). Assessing the impact of land-use change on hydrological parameters is considered an important step in water resources management and a prerequisite for ecological restoration as well as for their sustainable management. Groundwater is not only the primary source of drinking water for half of the world's population but also sustains ecosystems in providing water, nutrients and a relatively stable temperature (Tharme et al., 2003). The increase of groundwater abstraction to meet the water supply demand of a growing urban population is one of the causes of groundwater depletion in megacities (Naik and Tambe, 2008). land use changes and anthropogenic activities such as surface sealing due to streets and buildings, flood control, forest management and irrigation modify the infiltration and movement of water (Baillieux et al., 2015).

Need of the study

Groundwater is a vital freshwater resource for domestic consumption, agriculture, industry, and biological systems worldwide. According to the United Nations Educational, Scientific, and Cultural Organization, groundwater provides almost half of the world's drinking water needs (UNESCO, 2022). In rapidly developing regions, dependence on groundwater has increased significantly due to urban expansion. The natural hydrological cycle is significantly altered by urbanization.

The Ahmedabad district's rapid urbanization is causing significant changes in land use and land cover patterns. These changes reduce the natural penetration of rainfall and directly affect groundwater recharge processes. At the same time, groundwater demand for domestic, industrial, and commercial purposes has increased substantially. According to the Central Ground Water Board’s (CGWB) Dynamic Ground Water Resources Report 2023, Ahmedabad’s groundwater extraction exceeds its natural recharge rates. There is a lack of comprehensive quantitative assessment that integrates hydrological modelling with geospatial analysis to estimate how urbanisation affect groundwater recharge over time. This study helps to know how Ahmedabad's groundwater dynamics are changing due to development and contribute to planning strategies for long-term water security.

Objectives

- To perform land use change detection using geospatial techniques.
- Statistical analysis of existing hydrometeorological condition.
- Impact assessment of urbanisation on groundwater recharge using hydrological modelling.
- To model the groundwater recharge using future projections.

Scope of the work

Following is the scope of the present study:

- Decadal LULC maps are prepared using satellite imagery to analyze spatial and temporal changes in urban expansion.
- The Mann–Kendall test is used to detect trends in hydro-meteorological variables.
- The SWAT model is used to simulate watershed hydrology and estimate groundwater recharge using SWAT output viewer. Input datasets such as DEM, soil maps, weather data, and LULC are integrated within a GIS environment.
- Sensitivity analysis is performed to identify the most sensitive hydrological parameters affecting groundwater recharge using the SWAT-CUP and SUFI-2 algorithm.
- SWAT model is calibrated using observed data to adjust sensitive parameters and improve simulation accuracy. Statistical indicators such as Nash-Sutcliffe Efficiency (NSE) and R^2 are used to evaluate model performance.
- Model is validated with an independent dataset to test its reliability.
- Spatial and temporal variations in groundwater recharge are estimated under existing land use conditions.
- Future climate projections from CMIP6 (Coupled Model Intercomparison Project Phase 6) using the EC-Earth3 under selected SSP scenarios are used.
- Future groundwater recharge is estimated under projected climate scenarios to assess impact of urbanization on groundwater sustainability.

Original contribution of the study

The original contribution lies in the integration of decadal Land Use Land Cover (LULC) analysis with hydrological modelling to quantify the influence of urban expansion on groundwater recharge. The study applies the Mann–Kendall test to detect long-term trends in hydro-meteorological variables, thereby strengthening the understanding of climatic variability in the region. Decadal Land Use Land Cover (LULC) maps using supervised classification techniques, which provide a detailed representation of urban growth patterns over time.

The application of the Soil and Water Assessment Tool (SWAT) facilitates the simulation of hydrological processes and estimation of groundwater recharge under varying land use and climatic conditions. A key contribution of this research is model performance enhances through integrated parameter sensitivity analysis, calibration, and validation, wherein sensitive parameters identified through iterative sensitivity analysis are systematically optimized using observed streamflow data to minimize discrepancies between simulated and observed outputs, and model performance is quantitatively evaluated using statistical indicators such as Nash–Sutcliffe Efficiency (NSE), coefficient of determination (R^2).

Future climate projections obtained from the Coupled Model Intercomparison Project Phase 6 (CMIP6) using the EC-Earth3. These projections, combined with LULC scenarios, enable the assessment of the combined impacts of climate change and urbanisation on groundwater recharge.

Study area description

Ahmedabad is located in the central part of Gujarat State, western India, situated between latitudes 22°55'00" N and 23 °07'30" N and longitudes 72°22'30" E and 72°47'30" E. The area, which covers 8,087 km^2 in the state of Gujarat, and includes Ahmedabad city, one of the fastest growing urban centers in India. The climate of Ahmedabad is semi-arid, characterized by hot summers, mild winters and a distinct monsoon season. Historically, recharge to the shallow aquifer has been primarily rainfall-driven, supplemented locally by river seepage and irrigation return flow. Ahmedabad is located 30 km from Gandhinagar, the state capital, on the banks of the Sabarmati River.

Apart from the rainy season, Ahmedabad receives hot, dry tropical monsoon weather. Summer days are hot, with an average maximum temperature of 41.3°C, while nights are cold, with an average minimum temperature of 26.3°C. The average maximum temperature in winter is 30°C, and the average minimum is 15.4°C.

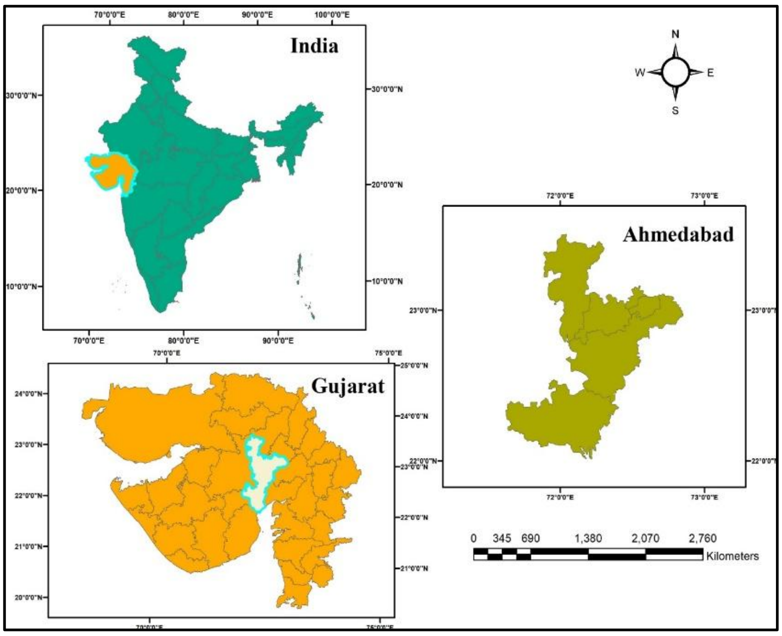

Figure 1: Location map of Ahmedabad District in Gujarat, India.

Methodology:

This research work involves following modules:

1) Data collection

1. Satellite Data for LULC Mapping

Landsat 5 TM / Landsat 7 ETM+ / Landsat 8 OLI (30 m resolution) for selected decadal years will be obtained from the United States Geological Survey.

2. Meteorological Data

Daily rainfall and temperature data from the India Meteorological Department, CWC and SWDC for period of 1980-2020.

3. Digital Elevation Model (DEM)

DEM – Spatial resolution: 30 m; from ISRO-BHUVAN used for watershed delineation, slope analysis, and drainage extraction in SWAT model setup.

4. Soil Data

Soil maps are prepared from FAO.

2) LULC classification

Multi-temporal Land Use/Land Cover (LULC) classification for the years 1985, 1995, 2005, and 2017 is carried out using supervised classification techniques to quantify urbanisation trends in Ahmedabad. Landsat satellite imagery (30 m spatial resolution) corresponding to each study year was pre-processed. Supervised classification is adopted to achieve higher thematic accuracy by defining representative training samples for major classes- built-up, waterbodies, fallow land, cropland, shrubland, waste land and grass-land. Accuracy assessment is conducted using confusion matrix analysis to compute overall accuracy, producer's accuracy, user's accuracy, and Kappa coefficient, ensuring classification reliability above acceptable thresholds (≥85% overall accuracy).

3) Trend analysis

Trend analysis of long-term temperature and rainfall data is conducted using the non-parametric Mann–Kendall (MK) test to identify statistically significant monotonic trends in climatic variables influencing groundwater recharge in Ahmedabad.

The Mann-Kendall test statistics (Mann, 1945; Kendall, 1975) is calculated as:

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} \operatorname{sgn}(xj-xk)$$

where n denotes the number of data points, xj and xk denote the data values in time series j and k (k>i), respectively and sgn (xj−xk) denotes the sign function as:

$$\begin{aligned}\operatorname{sgn}(xj-xk) &= 1 \quad \text{if } xj-xk>0\\ &=0 \quad \text{if } xj-xk=0\\ &=-1 \quad \text{if } xj-xk<0\end{aligned}$$

S is an indicator of trend where very high positive value of S indicates an increasing trend and a very low negative value indicates a decreasing trend. The Variance computed as,

$$\operatorname{var}(S)=\frac{1}{18}\left[n(n-1)(2n+5)-\sum_{p=1}^{q} f_p(f_p-1)(2f_p+5)\right]$$

where n denotes the number of data points, q the number of tied groups and fp the number of ties of extent p. A tied class is a set of sample data that all have the same meaning. When the sample size n>10, the regular normal test statistic Z is computed using following equation.

$$Z=\begin{cases}(S-1)/\mathrm{sr}, & \text{if } S>0\\ 0, & \text{if } S=0\\ (S+1)/\mathrm{sr}, & \text{if } S<0\end{cases}$$

where sr is the square root of var (*S*).

The Mann–Kendall statistic (S) and standardized Z-value are computed to determine the presence and direction of trends, where a positive Z-value indicates an increasing trend and a negative Z-value indicates a decreasing trend. Seasons are defined in the following manner: Winter: December, January and February; Pre Monsoon: March, April and May; Monsoon: June, July, August and September and Post Monsoon: October and November.

4) SWAT Modelling

The Soil and Water Assessment Tool (SWAT) model is employed to simulate hydrological processes and estimate groundwater recharge under varying land use conditions in Ahmedabad. SWAT is a physically based, semi-distributed, continuous-time hydrological model designed to predict the impact of land use, soil properties, and climate variability on water balance components at the watershed scale. In the present study, the model setup involved watershed delineation using a Digital Elevation Model (DEM), followed by subdivision into sub-basins and Hydrological Response Units (HRUs) based on unique combinations of land use/land cover, soil type, and slope classes.

Multi-temporal LULC maps (1985, 1995, 2005, and 2017), soil data, and daily climate inputs were incorporated into the model.

5) Calibration & Validation

Calibration and validation of the SWAT model were carried out to ensure reliable simulation of hydrological processes and groundwater recharge in Ahmedabad. Calibration involves systematic adjustment of sensitive parameters which are selected from extensive literature review. In this study, the model is calibrated using observed streamflow data collected from Vasna barrage. Sensitivity analysis is carried out using SWAT-CUP interface using SUFI-2 algorithm. Model performance is evaluated using statistical indicators such as Nash–Sutcliffe Efficiency (NSE), coefficient of determination (R^2) with acceptable performance criteria of NSE > 0.5, R^2 > 0.6. To evaluate the reliability and stability of the simulated outputs by examining the extent to which observed data were encompassed within the model's prediction range Uncertainty analysis is performed using the 95% Prediction Uncertainty (95PPU) band.

6) Simulation using forecasting scenarios

Simulation under forecasting scenarios is performed to evaluate the potential future impacts of urbanisation and climate variability on groundwater recharge in Ahmedabad. Climate projections are derived from the Coupled Model Intercomparison Project Phase 6 (CMIP6) framework, which provides state-of-the-art global climate model outputs for different greenhouse gas concentration pathways. In this study, outputs from the EC-Earth climate model, specifically the EC-Earth3 General Circulation Model (GCM), are utilised due to its demonstrated reliability in simulating South Asian monsoon dynamics. Future climate scenarios are selected under Shared Socioeconomic Pathways (SSPs), SSP3-7.0 to represent future conditions up-to 2050. The projected daily temperature and precipitation downscaled and bias corrected datasets are used from EC-Earth3. This integrated CMIP6–SWAT modelling framework provides a robust scientific basis for understanding climate-driven hydrological responses and supports long-term adaptive groundwater management planning in semi-arid urban environments.

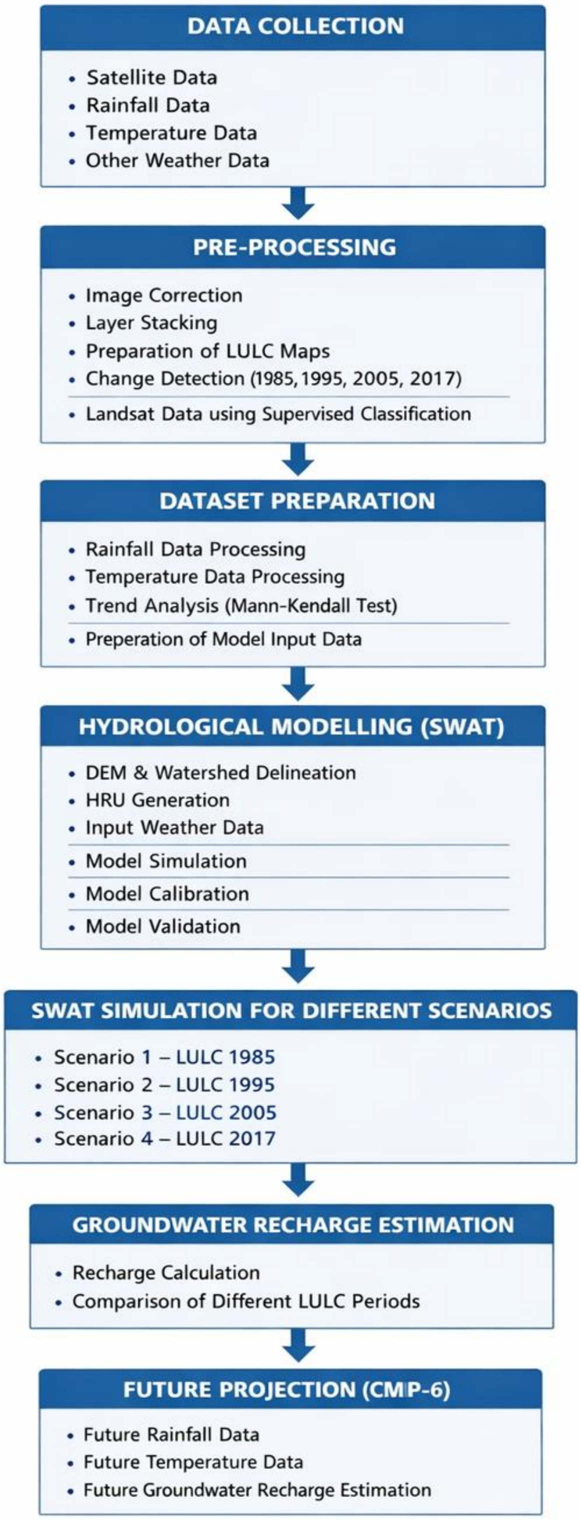

Figure 2: Methodology

Results

1) **Trend analysis:** Table 1 and Table 2 presents the results of trend analysis for rainfall and temperature.

Table:1 Summary of trend analysis (Rainfall)

Month (1980-2020)	**Z**	**trend**
January	-1.06	-Ve
February	-0.43	-Ve
March	0.31	+Ve
April	0.13	+Ve
May	-0.54	-Ve
June	0.36	+Ve
July	0.15	+Ve
August	0.71	+Ve
September	1.60	+Ve
October	-0.34	-Ve
November	-0.38	-Ve
December	0.81	+Ve
Annual	0.73	+Ve
Monsoon	0.87	+Ve
Premonsoon	0.22	+Ve
Post Monsoon	-0.44	-Ve

Table:2 Summary of trend analysis (Temperature)

Month (1980-2020)	**significance value Z for maximum temperature**	**significance value Z for minimum temperature**
January	-1.73	0.07
February	0.79	0.44
March	0.74	0.08
April	1.21	2.56
May	0.16	2.46
June	-0.73	0.92
July	-1.34	1.14
August	-0.34	0.43
September	-2.34	-1.41
October	-1.97	-1.10
November	-1.97	1.89
December	-1.64	-0.50

2) **LULC change results**

The multi-temporal Land Use/Land Cover (LULC) classification is carried out for the years 1985, 1995, 2005, and 2017 to quantify spatial and temporal changes in land transformation**.** LULC classes are defined based on standard classification systems such as USGS guidelines. Cropland: Areas used for agricultural activities; these lands are actively cultivated during the growing season. Fallow Land: Agricultural land left uncultivated for a specific period to restore soil fertility. Built-up Area: Areas covered by urban infrastructure such as residential, commercial, industrial structures, roads, and other impervious surfaces. Water Bodies: Includes rivers, lakes, reservoirs, ponds, and other surface water features. Wasteland: Degraded or barren land with little or no vegetation cover, often unsuitable for cultivation. Shrubland: Areas dominated by shrubs and small woody vegetation, typically less dense than forests.

Grassland: Areas covered predominantly by grasses and herbaceous vegetation, with minimal tree or shrub cover.

The classified maps were used to compute area statistics for each land cover category, and the results are summarised in Table 3

Table 3 Areal Extent of LULC

	Area (km^2)				% of Total Area			
LULC Classes	1985	1995	2005	2017	1985	1995	2005	2017
Cropland	6060	3441	4828	5763	77.0	43.7	61.3	73.2
Fallow land	175	178	169	402	2.2	2.3	2.1	5.1
Waterbodies	469	456	496	506	6.0	5.8	6.3	6.4
Waste land	916	3413	1933	610	11.6	43.4	24.6	7.7
Built-up	129	252	261	569	1.6	3.2	3.3	7.2
Shrubland	80	89	141	10	1.0	1.1	1.8	0.1
Grassland	43	43	44	12	0.5	0.5	0.6	0.2

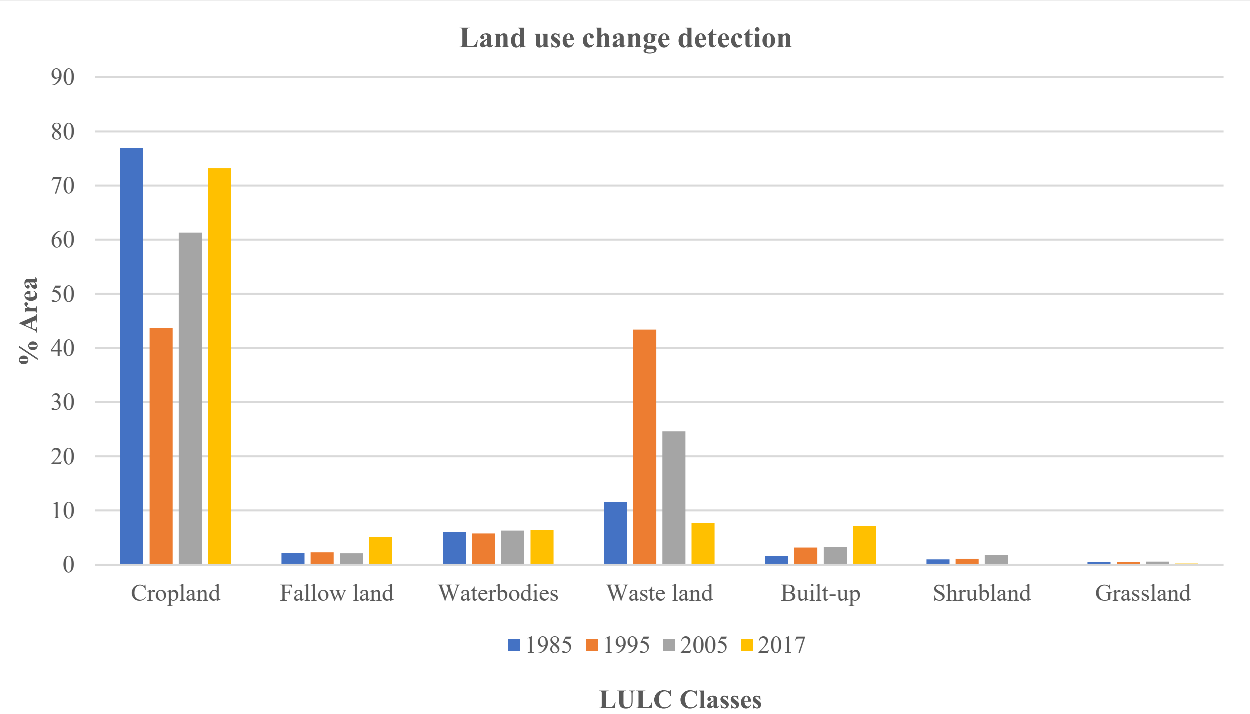

Figure 3: Decadal LULC change

3) Accuracy Assessment

The results of the accuracy assessment are presented in Table 4.

Table 4 Accuracy Assessment Results of Supervised LULC Classification

Year	Overall Accuracy	Kappa Coefficient
2017	92.93%	0.89

4) Hydrological Modelling

- **Sensitivity Analysis**

Sensitivity analysis is conducted to identify the most influential parameters affecting groundwater recharge. The ranking of sensitive parameters based on statistical significance and relative sensitivity values is presented in Table 5.

Table 5 Absolute values of sensitive parameters

Sensitivity Rank	Swat Parameter Name	Swat Parameter Description	Unit	Range	Absolute Value
1	CN2.mgt	SCS Curve Number	------	35-98	53.27
2	ALPHA_BF.gw	Baseflow recession constant	Day^{-1}	0-10	4.30
3	GW_DELAY.gw	Time lag (days) between water exiting the root zone and entering the shallow aquifer.	days	0 - 500	375.00
4	GWQMN.gw	Threshold water depth in the shallow aquifer (mm) required before groundwater flow to the stream occurs.	mm H_2O	0 - 5000	150.00
5	RCHRG_DP.gw	Fraction of percolation from the root zone that enters the deep aquifer.	---	0-1.30	0.897
6	SURLAG.bsn	Surface runoff lag time coefficient.		0-24	15.61
7	ESCO.hru	Soil evaporation compensation coefficient	--------	0-1	0.01
8	GW_SPYLD.gw	Specific yield of the shallow aquifer	------	0-600	390.00

9	REVAPMN.gw	Minimum depth of water in the shallow aquifer (mm) for revap to occur.	mm H_2O	0 - 800	280
10	SOL_AWC(..).sol	Available water capacity of the soil layer	mm H_2O / mm soil	0 - 1	0.45

The performance of the hydrological model is evaluated through calibration and validation using observed data. The performance statistics are summarised in Table 6.

Table 6 Performance indices

Statistical criteria	Calibration	Validation
NSE	0.74	0.70
R^2	0.79	0.72

Table 7 Water balance components from SWAT

Year	Precipitation (mm)	Groundwater recharge (mm)
1981-1990	682.9	99.65
1991-2000	724.4	109.86
2001-2010	820.8	136.04
2011-2020	789.9	72.95

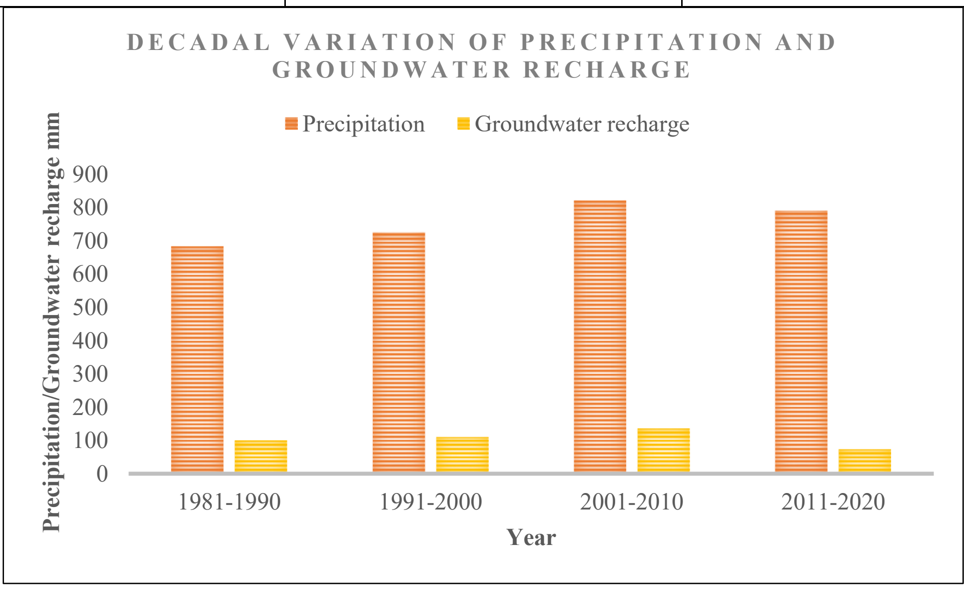

Figure 4: Decadal variation of Precipitation and Groundwater recharge

Groundwater recharge estimated from the water balance components is further analysed to understand its temporal variation over the study period. Trend analysis is performed using the

Mann–Kendall test to determine the presence and significance of monotonic changes in recharge. The statistical results of groundwater recharge trends are presented in Table 8.

Table 8 Mann-Kendall trend values for groundwater recharge

	1981-1990		1991-2000		2001-2010		2010-2020	
Month	**Z**	**trend**	**Z**	**trend**	**Z**	**trend**	**Z**	**trend**
January	0.27	+ve	1.43	+ve	1.18	+ve	0.89	+ve
February	0.09	+ve	1.35	+ve	1.18	+ve	0.27	+ve
March	0.27	+ve	1.35	+ve	1.18	+ve	-0.27	-ve
April	0.27	+ve	1.35	+ve	1.18	+ve	-0.27	-ve
May	0.27	+ve	1.35	+ve	1.18	+ve	0.18	+ve
June	0.27	+ve	1.43	+ve	1.18	+ve	-0.27	-ve
July	0.27	+ve	-0.09	-ve	-0.36	-ve	-0.81	-ve
August	-0.89	-ve	-1.25	-ve	0.54	+ve	-0.36	-ve
September	0.54	+ve	-0.36	-ve	1.43	+ve	-1.07	-ve
October	0.72	+ve	-0.18	-ve	1.25	+ve	-0.89	-ve
November	0.54	+ve	0.72	+ve	1.25	+ve	-0.89	-ve
December	0.27	+ve	0.72	+ve	1.25	+ve	-0.89	-ve
Monsoon	-0.36	-ve	-0.72	-ve	1.25	+ve	-0.72	-ve
Premonsoon	0.27	+ve	1.35	+ve	1.18	+ve	-0.89	-ve
Post Monsoon	0.54	+ve	-0.18	-ve	1.25	+ve	-0.89	-ve
Winter	0.54	+ve	0.54	+ve	1.25	+ve	-0.72	-ve

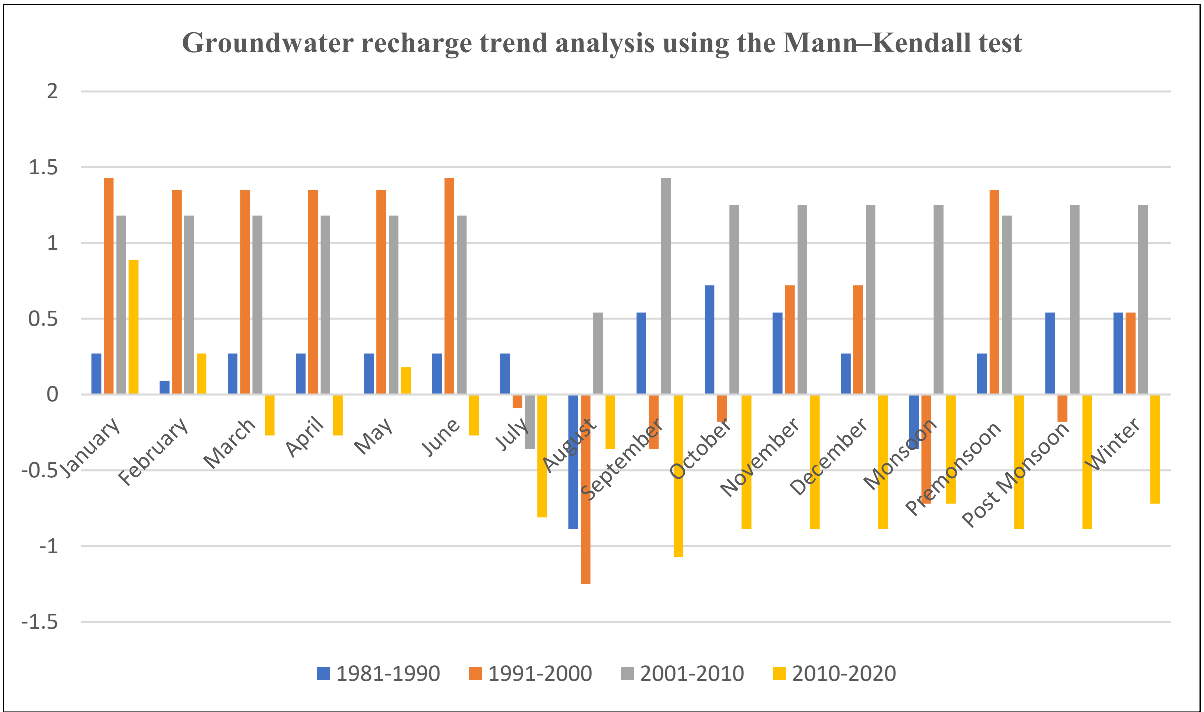

Figure 5: Decadal variation of Precipitation and Groundwater recharge

The decadal analysis of built-up area and groundwater recharge in Ahmedabad as shown in figure 6 indicates a non-linear trend in recharge response to urbanisation. The results show that during the initial two decades, groundwater recharge exhibits a moderate increasing trend and in latest decade, a significant decline in groundwater recharge is observed, corresponding with a rapid increase in built-up area.

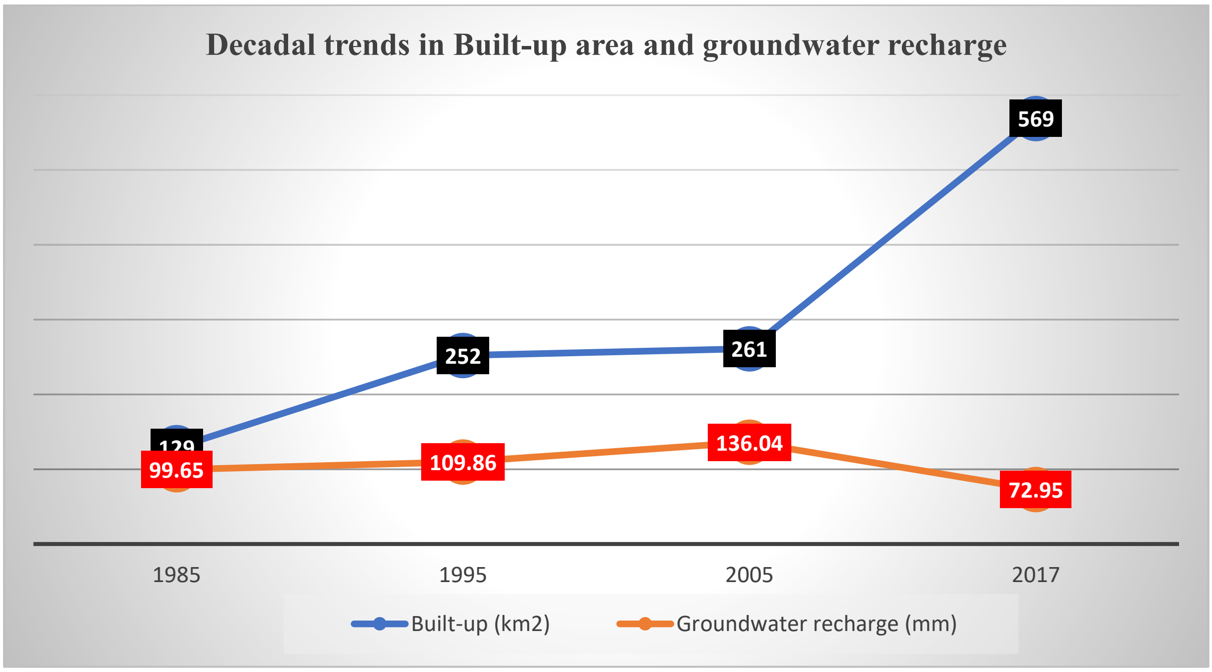

Figure 6: Decadal trends in Built-up area and groundwater recharge

Conclusion

- The results reveal substantial land use transformation, particularly the expansion of built-up areas, which has significantly altered natural infiltration processes and reduced groundwater recharge potential in the study area.
- Trend analysis of climatic variables indicates noticeable variability in rainfall and temperature pattern, influencing the overall hydrological balance of the watershed.
- Hydrological simulations demonstrate land use changes play a critical role in determining groundwater recharge dynamics.
- Scenario-based assessments highlight the potential risk of declining recharge under continued urban expansion and changing climate conditions.
- The outcomes of this research provide valuable insights for sustainable groundwater management and urban planning strategies in rapidly developing regions.

Publications

- Groundwater Infiltration Trends in the Major Basin of Ahmedabad District, Gujarat, India by Chaitali Bhavsar; Dr. Mahendra Sinh Gadhavi inInternational Journal of Innovative Science and Research Technology, Volume 10, Issue 11, November – 2025, ISSN No: -2456-2165, https://doi.org/10.38124/ijisrt/25nov102

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