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This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

Session HS 5.6: Impacts of land use and land cover changes on water resources management and water-related ecosystem services

Spatial variability assessment of groundwater quality dispersion with reference to land-use indices

*Shipra Tyagi and Kiranmay Sarma

*PhD Scholar (UGC Senior Research Fellow), Earth Sciences Lab (ARL-009)

UNIVERSITY SCHOOL OF ENVIRONMENT MANAGEMENT,
GURU GOBIND SINGH INDRAPRASTHA UNIVERSITY, SECTOR-16 C, DWARKA, NEW DELHI-110078, INDIA

Kindly contact for any information:
shipra.usem.900680@ipu.ac.in

26th May, 2022 **[Room 2.17]**

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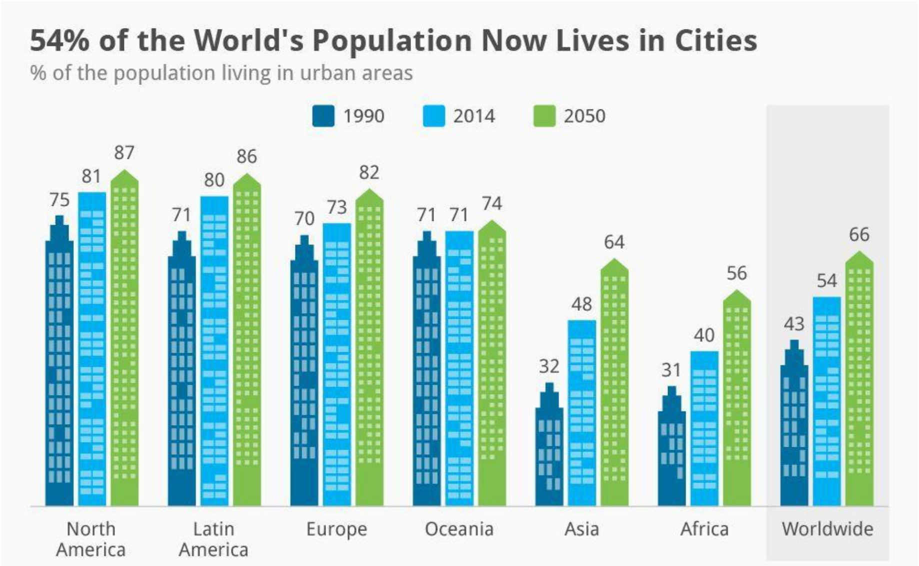
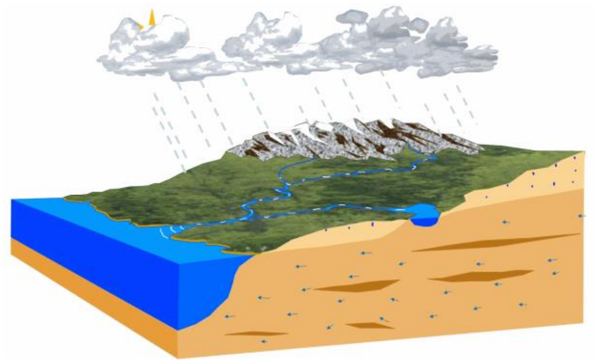
Land Use and Groundwaters

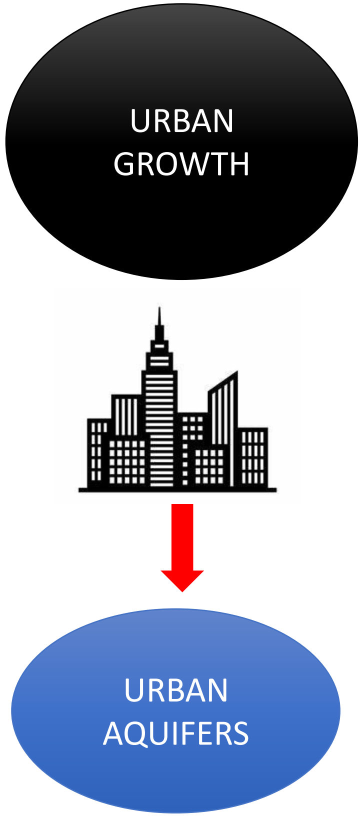
According to United Nations, about 66% of the world population projected to live in urban areas by 2050.



Source: United Nations

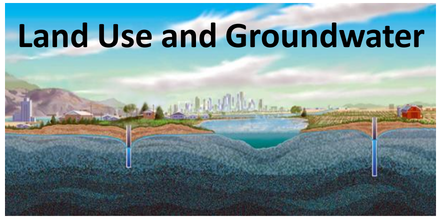


About half of the world's megacities are groundwater dependent (Wolf et al. 2006)



URBAN GROWTH

URBAN AQUIFERS



Rapid Growth of Cities & Groundwater Pollution

Effects on Natural Recharge of Aquifers due to increased pavements and concrete causing **impermeabilization and ground sealing** effect might contribute to decrease in groundwater recharge

Due to leakage from drainage and, industrial wastage and septic effluents

URBAN WATER CYCLE

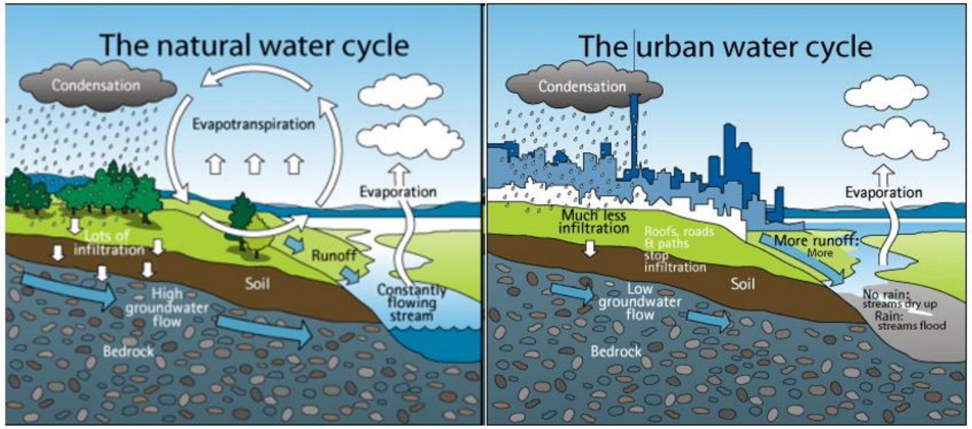


Image Source: Auckland Council

SUSTAINABLE DEVELOPMENT GOALS

6 CLEAN WATER AND SANITATION

Under Studied & Under Protected

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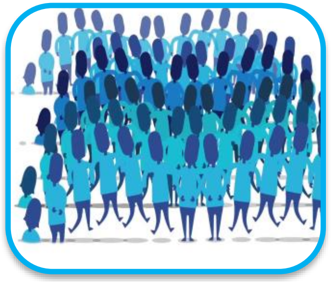
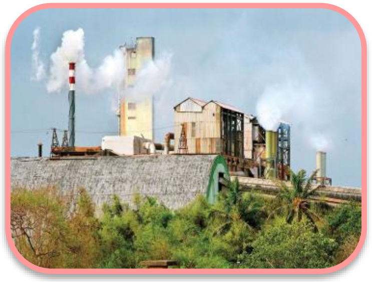
Land Use based impacts on Groundwater Quality

Link between land use and groundwater has long been recognized but has not been widely translated into integrated policies and practices…



Population growth

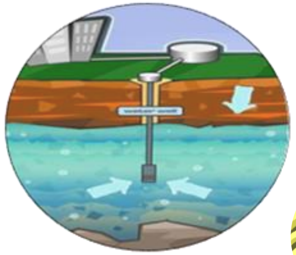
Increasing and changing food demands



Industrial use

- **Land use mismanagement leads to degradation of groundwater quality which depends on the type of land use.**
- **Overlying landscapes influence the quality of groundwater by discharging excess nutrient and toxic chemicals that influence the groundwater quality to a greater extent.**
- **Sharply focused land-use management measures can produce significant groundwater quality and quantity benefits at relatively modest cost and improving integrated governance will be crucial to ensuring an acceptable harvest of both food and groundwater from the available land.**

Potential Sources of Groundwater Contamination



NATURAL SOURCES	Geo-genic through the geological processes occurring in the earth's crust, and Rock-water interaction
ANTHROPOGENIC SOURCES	Industrial effluents discharges; Urban discharges; Landfills and Septic tanks; Agricultural pesticides and fertilizers runoff activities

Image Source: Bodrud-Doza, Md., et al. (2016)

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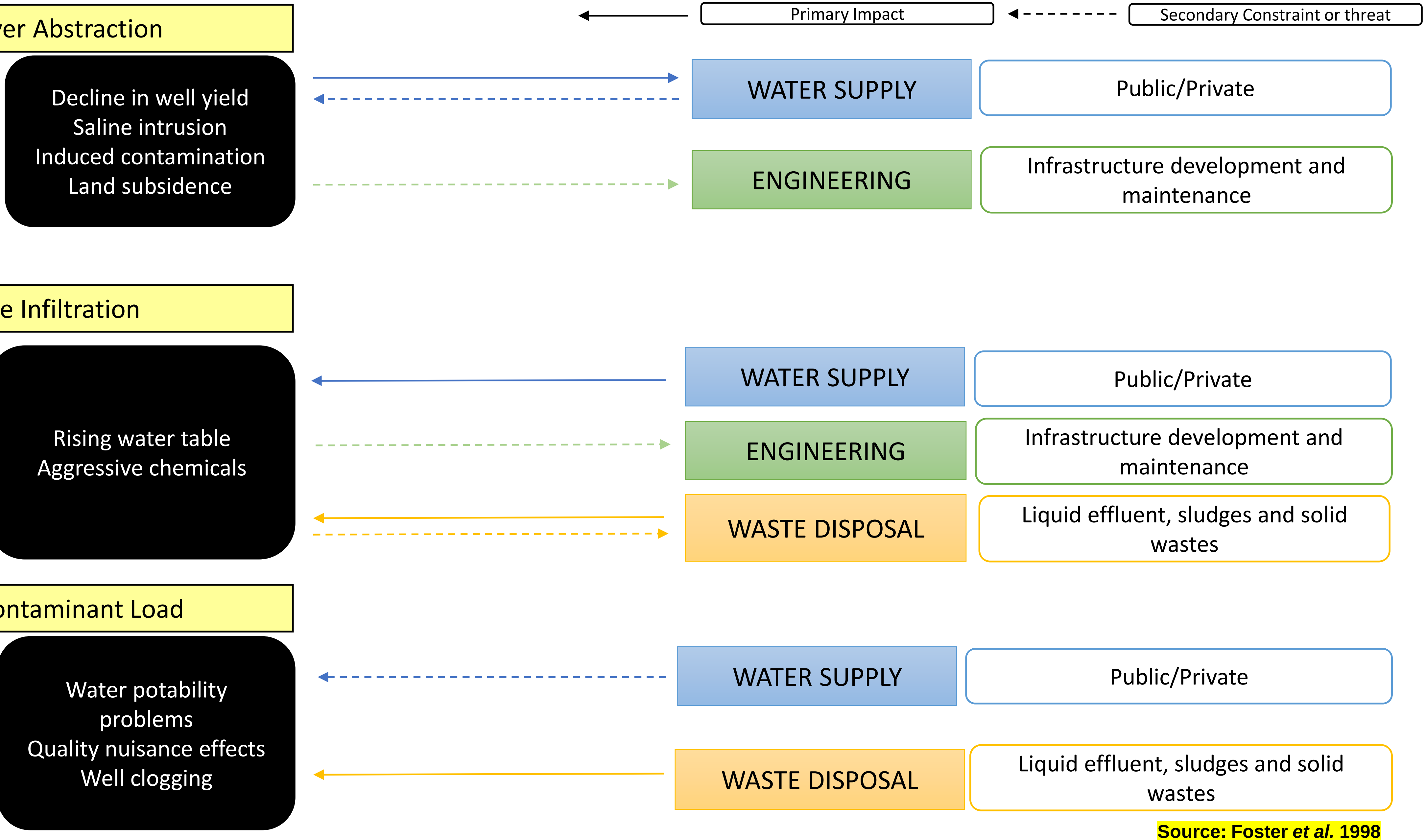
Potential Effects on Urban Groundwater System



Primary Impact

Secondary Constraint or threat

Aquifer over Abstraction

Decline in well yield
Saline intrusion
Induced contamination
Land subsidence

WATER SUPPLY	Public/Private
ENGINEERING	Infrastructure development and maintenance

Excessive Infiltration

Rising water table
Aggressive chemicals

WATER SUPPLY	Public/Private
ENGINEERING	Infrastructure development and maintenance
WASTE DISPOSAL	Liquid effluent, sludges and solid wastes

Excessive Contaminant Load

Water potability problems
Quality nuisance effects
Well clogging

WATER SUPPLY	Public/Private
WASTE DISPOSAL	Liquid effluent, sludges and solid wastes

Source: Foster *et al.* 1998

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Drivers' categories that changes the processes in Groundwater Systems

Demographic Drivers

Population Growth - - - → Increasing Water & Food Demands

Mobility - - - → Increasing loads of waste & wastewater

Urbanization - - - → Shifting land use patterns modify pressures

Science & Technological Innovation Drivers

Intensive Pumping - - - → Stresses on related environment and ecosystems of GW

Improved technologies for drilling and pumping → Systematic Aquifer Exploration

Science assisted technical innovation → Water Use, Water treatment & Water reuse systematic approach

Political, Legal & Financial Drivers

Planned Changes → Development & Management of GW resources

Socio-Economic Drivers

People's demands and behavior with respect to GW
Economic profitability of GW
- - - → Intensive Extraction of Groundwater

High levels of Socio-economic developments → Adaptation with changing conditions

Physical Drivers

Climate Change & resulted variability - - - → Change in the rate GW renewal, alterations in availability of freshwater sources, and changing water demands

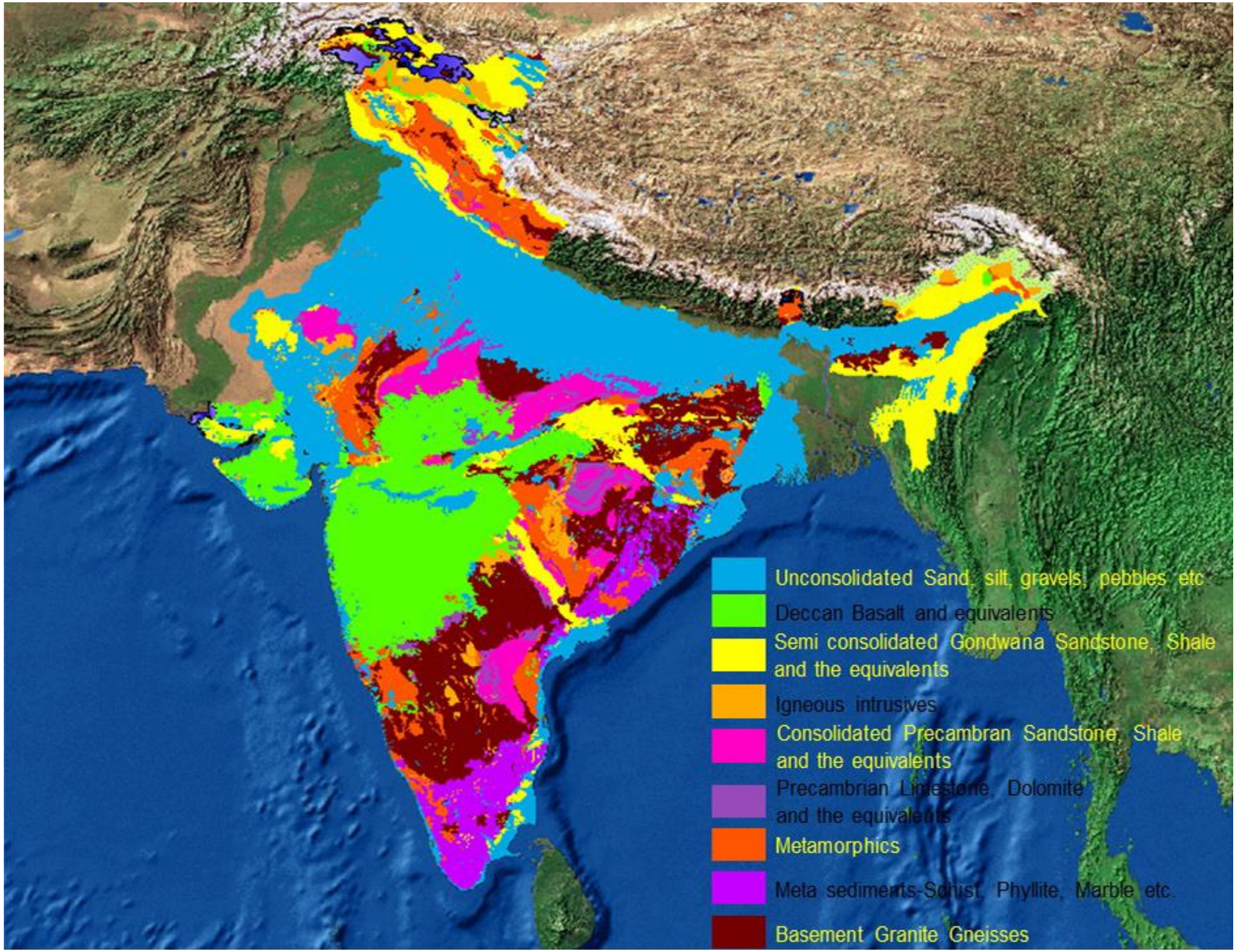
Natural & anthropogenic hazards - - - → Sea level rise affecting low level coastal zones, intrusion of saline water in aquifers and sudden probabilistic in nature

- - - → Negative Impacts

→ Positive Impacts

Data Source: Margat and Gun (2013)

Groundwater Scenario in India



By 2025, India's annual water demand will be **1050 km^3** which would be mainly for the production of food grains for the increased volume of population (Singhal, 2002).

More than **60% of irrigated agriculture and 85% of drinking water** supplies are dependent on groundwater.

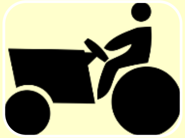
Among 15 nations, India is the largest user of groundwater in the world and has largest annual groundwater extraction estimated (2010) of about **251 km^3/year** (Margat, J. et al., 2013).

Extraction rate of groundwater in **Delhi, Haryana, Punjab and Rajasthan** is greater than the rate of replenishment, i.e., groundwater development is more than 100 percent.

Groundwater Availability in India

PARAMETER	Unit (Billion cubic meter/year)
Annual Water Availability	1869
Usable Water	1123
Surface Water	690
Ground Water	**433**

Annual Groundwater Extraction in India



AGRICULTURE (Irrigation) : 89%

DOMESTIC USE : 9%

INDUSTRY : 2%

50% of urban water and 85% of rural domestic water requirements are fulfilled by ground water.

Sources: Water and Related Statistics, April 2015, Central Water Commission; PRS.

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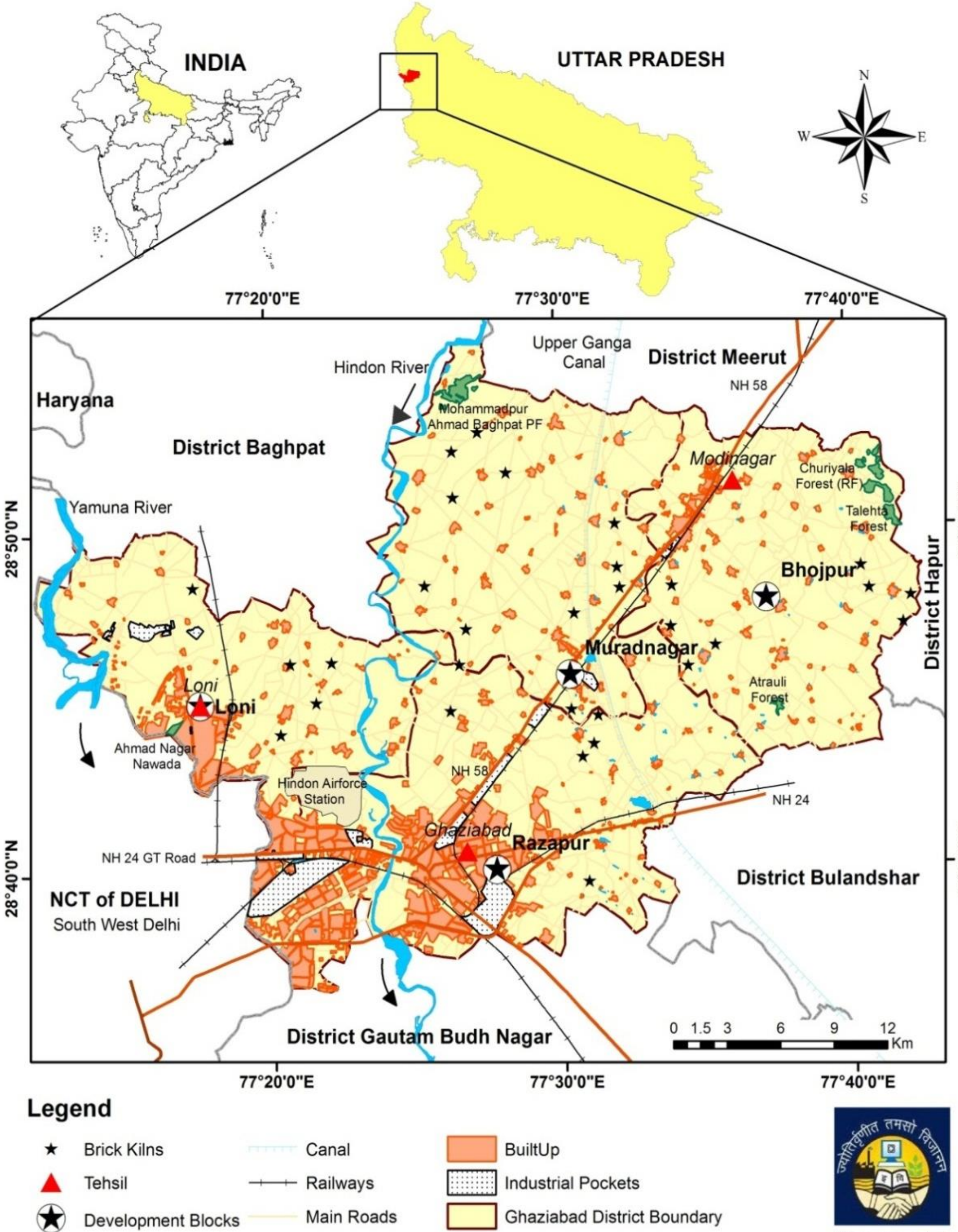
STUDY AREA



Map prepared at:
University School of Environment Management,
GGS Indraprastha University, 2021

Source: Survey of India (SOI), GoI (Toposheet No. H43X1/X5/X6/X9/X10)

Ghaziabad: GATEWAY OF UTTAR PRADESH, INDIA

One of the fastest growing suburban districts of western Uttar Pradesh situated in the middle of the Ganga-Yamuna doab

Landuse scenario in Ghaziabad district, western Uttar Pradesh

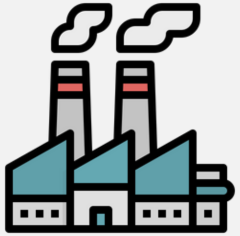
- Densely populated due to which residential and commercial projects have been constructed the building societies and multi-storied apartments into manifolds such as **Indirapuram, Vaishali, Kaushambi, Vasundhara, Raj Nagar Extension, Crossing Republik, and Rajendra Nagar.**

Residential

- **Farming cultivations** are still practiced predominantly in northern and northeastern parts. About **56.8% of the population is still engaged in agricultural practices for varied cropping seasons such as kharif, rabi and zaid, with major crops productivity of sugarcane, wheat and rice.**
- Net cultivated area accounts for 53129 hectares with 92 percent of irrigation potential and 159 percent of cropping intensity (Krishi Vigyan Kendra, Ghaziabad).

Agriculture

- Major industrial pockets are **Sahibabad industrial estate, Kavi Nagar industrial area, Bulandshahr and Meerut industrial road etc. and small units are located in Loni blocks.**
- Besides 14,160 small scale industries, 145 are medium and heavy scale production industries.
- About 73% of the heavy based industries includes: Food, sugar and jiggery, soft drinks and tobacco, cotton textiles, Paper and paper products & printings, Rubber plastic and petroleum, chemicals and chemical products, Metal products, machinery tools and parts, electric & transport equipment etc.



Industrial

Groundwater Resource Availability and Extraction

(in Uttar Pradesh state and Ghaziabad district, 2017)

	Ground Water Recharge							Current Annual Ground Water Extraction					
	Monsoon Season		Non-monsoon Season		Total Annual Ground Water Recharge	Total Natural Discharges	Annual Extractable Ground Water Resources	Irrigation	Domestic & Industrial	Total	Annual GW Allocation for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)
	Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources									
UP Total (Ham)	3772717.56	1167315.33	159010.82	1892952.69	6991996.40	459916.69	6532079.71	4089209.58	494837.81	4584047.39	596453.20	2036249.37	70.18
UP Total (Bcm)	37.72	11.67	1.59	18.93	69.92	4.60	65.32	40.89	4.95	45.84	5.96	20.36	70.18
Gzb. (Ham)	15248.13	9630.54	1078.71	15185.9	41143.30	4114.33	37028.97	35693.32	11837.44	47530.76	17469.88	1339.60	128.36
Gzb. (Bcm) (Mcm)	0.15 (152.48)	0.096 (96.31)	0.017 (10.78)	0.15 (151.85)	0.41 (411.43)	0.041 (41.14)	0.37 **(370.28)**	0.35 **(356.93)**	0.118 **(118.37)**	0.475 (475.30)	0.174 (174.69)	0.013 (13.39)	0.00128 (1.28)

Ham: Hectare meter; **Bcm:** Billion cubic meters; **Mcm:** Million cubic meters; 1 Ham = 100000; 1 cubic meter is equal to 0.0001 hectare; 1 Bcm = 100000 hectare meter; 1 Mcm = 100 hectare meters

Source: Dynamic Ground Water Resources of India, 2017

Past study analysis of groundwater chemistry within the Ghaziabad district

Study location in Ghaziabad district	Season (Year); No. of Samples	pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{2-}	F^{-}	NO_3^{-}	Cl^{-}	PO_4^{3-}	Reference
In the village of Lutfullapur Nawada, Loni	August (2010); n=15	7.74	**2,167.6**	**1,434.33**	307.87	138.27	13.19	442.20	129.99	394.00	152.94	0.35	2.94	451.77	0.002	Singh et al. 2012
Region of Indo-Gangetic plain	PRM May (2011); n=250	7.3	**1,803.4**	**1,198.8**	406.6	36.9	75.4	368.1	9.8	264.1	100.6	**0.82**	5.9	275.4	0.03	Singh et al. 2014
Bulandshahar road industrial area and Meerut road industrial area	PRM, May; n=30	7.09	**2270**	**1452**	-	158.50	120.50	1033.41	87.48	-	-	-	-	-	-	Kumari et al. 2014
Peri-urban and urban-industrial clusters	PRM, May (2010); n=22	7.4	920	771	335	-	-	-	-	370	38.2	0.5	25.2	327	-	Chabukdhara et al. 2017

GHAZIABAD DISTRICT

Developmental Blocks

LONI

RAZAPUR

BHOJPUR

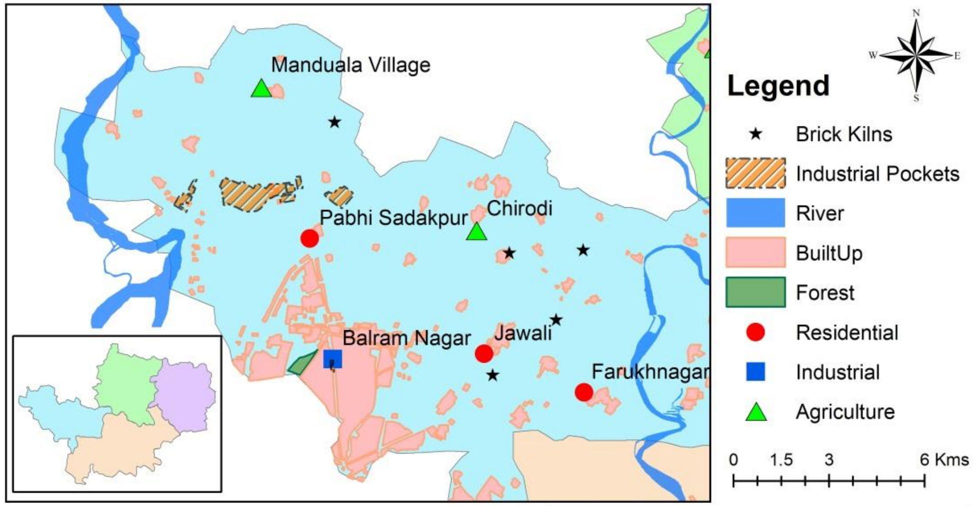
MURADNAGAR

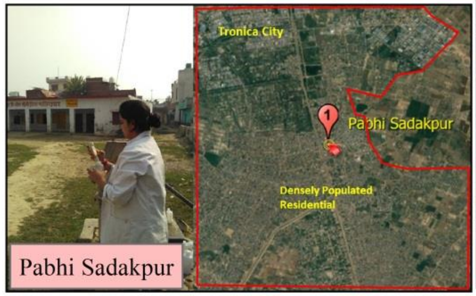
Land Use based Groundwater Sampling Sites

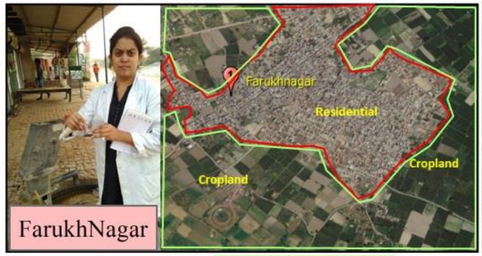
Residential

Industrial

Agriculture







Builtup

Agriculture/Cropland

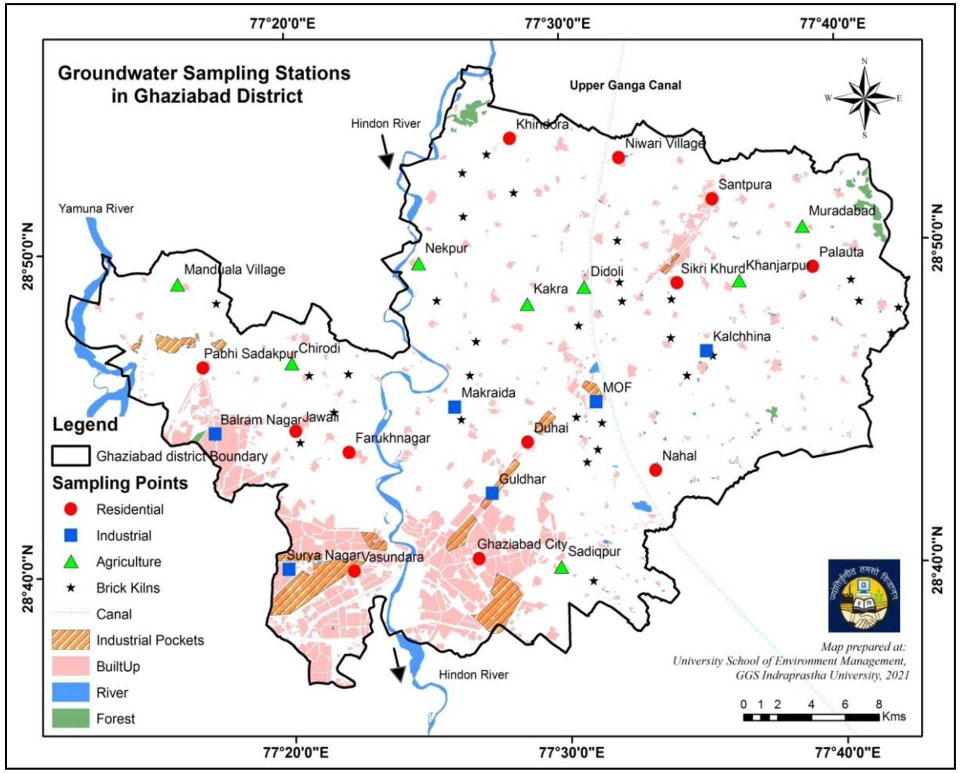
Industrial

Brick Kilns

Water Body

Methodology Involved

Groundwater Sampling Stations
(26 Sites)



Groundwater Chemistry

Pre-Monsoon (May, 2017, 2018)	Post-Monsoon (October, 2017, 2018)

Parameters (16):
pH, EC, TDS, Hardness, Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride, Sulphate, Fluoride, Nitrate, Iron, Zinc and Manganese

Spot-Specific Apportionment

$$\mathrm{NDDI} = \frac{C\ (post\text{-}monsoon - pre\text{-}monsoon)}{C\ (post\text{-}monsoon + pre\text{-}monsoon)}$$

$$-1 \leq \mathrm{NDDI} \geq 1$$

NDDI = -1 ; Absolute Dilution

NDDI = 1 ; Absolute Accretion

Geo-statistical mapping (Ordinary Kriging)

Spatial Auto-correlation
Moran's I

Land Use Spectral Indices

Indices:
NDVI, NDSI, NDBI and MNDWI

Relationship of Groundwater Chemistry with Land Use Spectral Indices

Technique:
Pearson's Correlation Analysis (SPSS v21):

Groundwater Quality Assessment based on multiple spectral land use indices

Groundwater Quality Index

Normalized Difference Dispersal Index (NDDI)

Spot-specific apportion of parameters will be normalized and quantified with the NDDI

Accretion/Attrition

Dilution

Geostatistical Interpolation Mapping

$$\text{NDDI} = \frac{C\ (\textit{post-monsoon} - \textit{pre-monsoon})}{C\ (\textit{post-monsoon} + \textit{pre-monsoon})}$$

$$\mathbf{-1 \leq NDDI \geq 1}$$

NDDI = -1 ; Absolute Dilution

NDDI = 1 ; Absolute Accretion

Multiple Land Use Spectral Indices

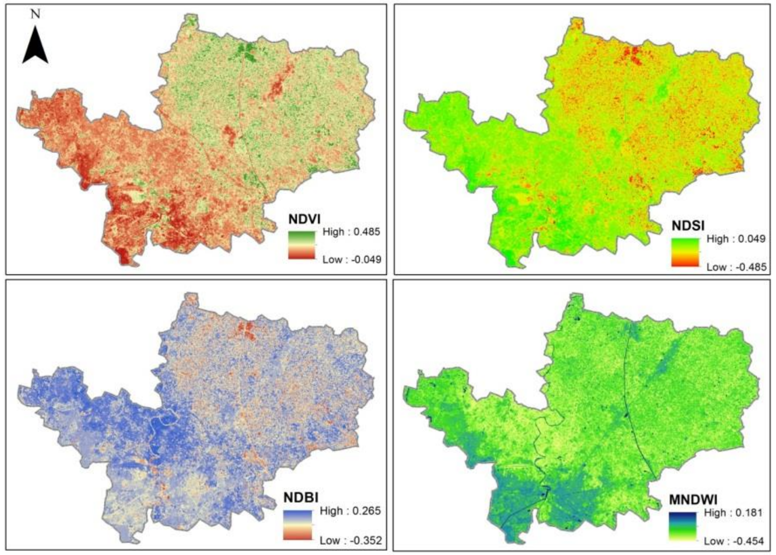
Normalized Difference Vegetation Index (NDVI)

Normalized Difference Built-Up Index (NDBI)

Normalized Difference Salinity Index (NDSI)

Modified Normalized Difference Water Index (MNDWI)

LAND USE SPECTRAL INDICES



Correlating the groundwater chemistry with landuse spectral indices

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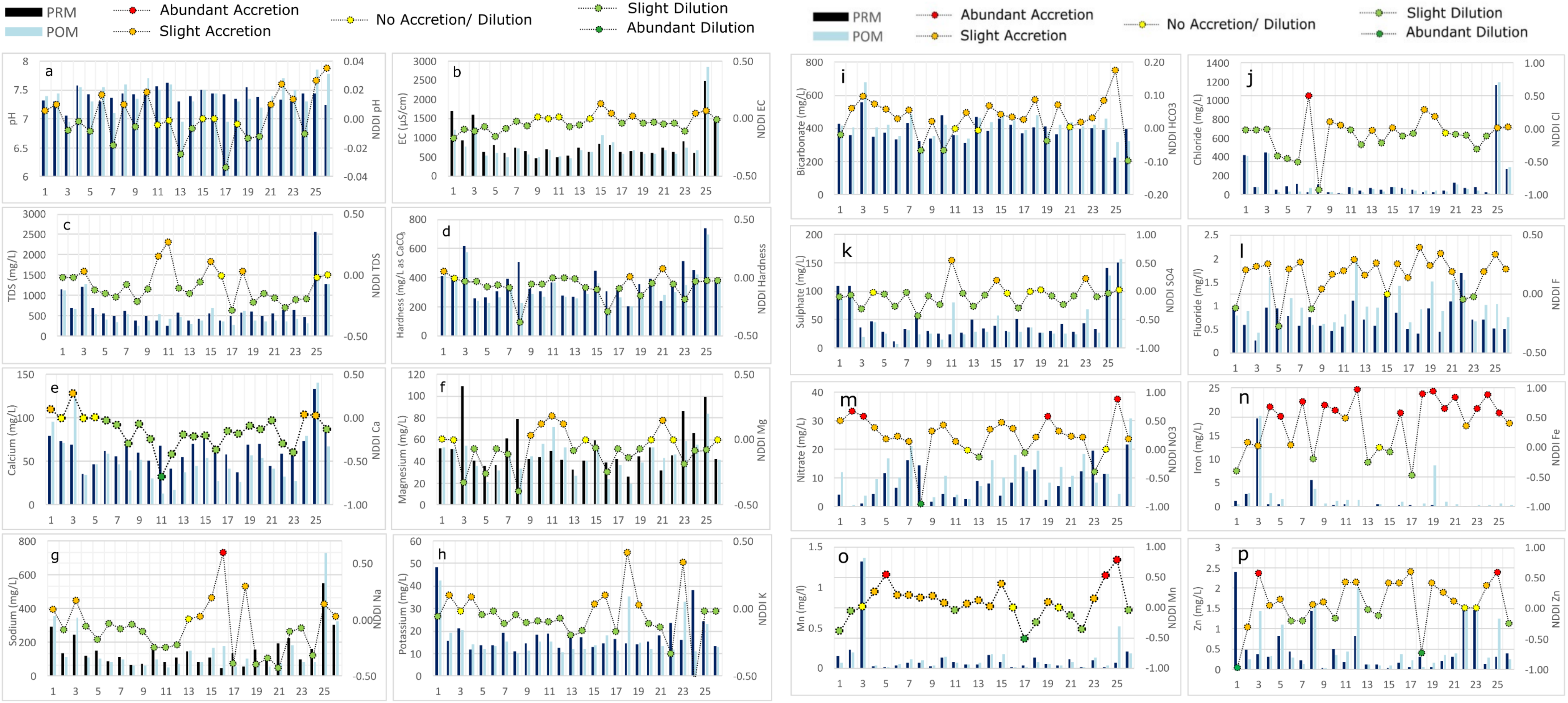
NDDI based Groundwater Quality Assessment

Spot-Specific Apportionment



a) pH; b) EC; c) TDS; d) Hardness; e) Calcium; f) Magnesium; g) Sodium; h) Potassium; i) Bicarbonate; j) Chloride; k) Sulphate; l) Fluoride; m) Nitrate; n) Iron; o) Manganese; p) Zinc

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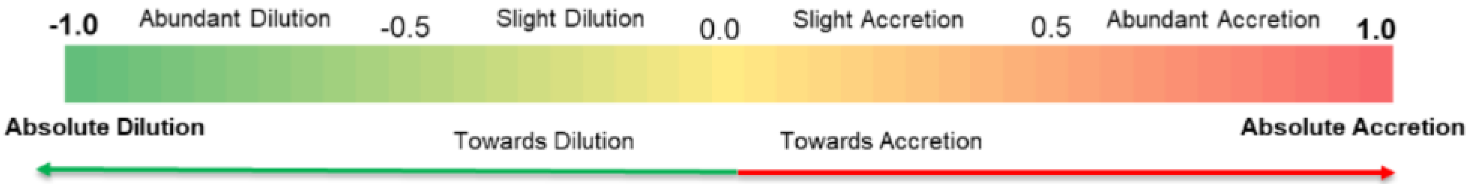
NDDI Groundwater Quality Heatmap

Spot-specific apportion for accretion/dilution effects

Site ID	pH	EC	TDS	Hardness	Ca	Mg	Na	K	HCO3	Cl	SO4	F	NO3	Fe	Mn	Zn
Mean	0.00	-0.03	-0.08	-0.07	-0.15	-0.07	-0.07	-0.05	0.03	-0.10	-0.08	0.15	0.22	0.39	0.08	0.08

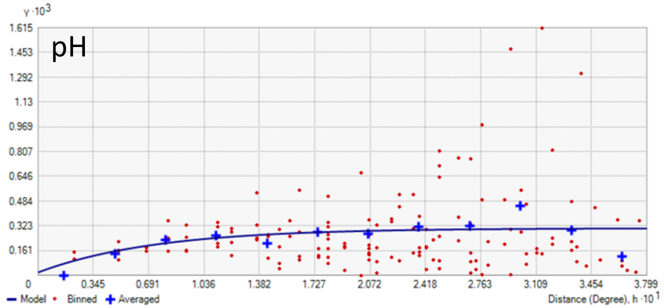


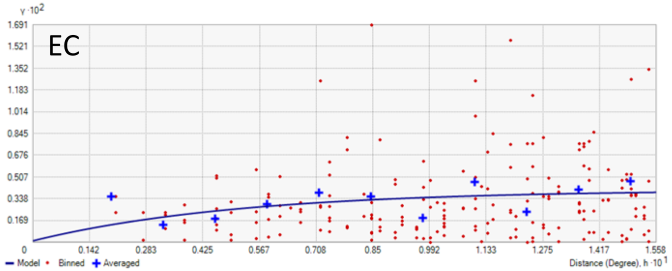
NDDI based best fitted semivariogram models in kriging interpolation and spatial autocorrelation for groundwater quality

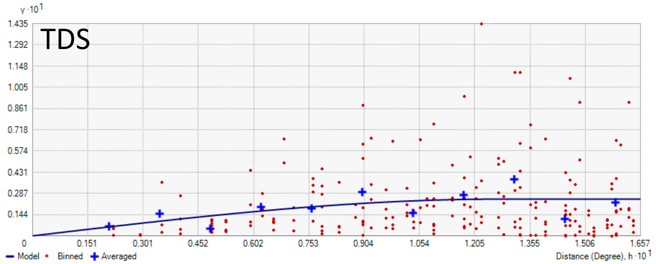
Parameter	Model	Nugget	Major Range	Sill	Nugget/ Sill	Lag Size	ME	RMSE	MSE	RMSSE	ASE	Moran's I	Variance	Z Score	pValue
pH	Exponential	0.000	0.220	0.000	0.062	0.032	-0.001	0.013	-0.041	0.961	0.013	0.444	0.033	2.655	0.008
EC	Exponential	0.000	0.156	0.004	0.026	0.013	-0.002	0.056	-0.032	1.037	0.054	0.495	0.031	3.064	0.002
TDS	Spherical	0.000	0.127	0.025	0.000	0.014	-0.001	0.113	-0.014	0.974	0.121	0.494	0.030	3.068	0.002
Hardness	Exponential	0.005	0.095	0.009	0.536	0.012	0.005	0.103	0.050	1.060	0.097	-0.06	0.026	-0.126	0.900
Ca^{2+}	Exponential	0.011	0.320	0.047	0.246	0.030	-0.001	0.177	-0.006	1.057	0.169	0.279	0.029	1.865	0.062
Mg^{2+}	Exponential	0.014	0.247	0.023	0.582	0.021	0.003	0.148	0.017	1.032	0.143	-0.072	0.030	-0.183	0.855
Na^{+}	Exponential	0.024	0.434	0.073	0.333	0.036	-0.009	0.189	-0.035	0.909	0.212	0.390	0.029	2.505	0.012
K^{+}	Circular	0.035	0.444	0.035	1.000	0.037	-0.001	0.193	-0.002	0.998	0.193	-0.157	0.028	-0.702	0.483
HCO_3^-	Exponential	0.002	0.196	0.004	0.399	0.018	0.000	0.064	-0.010	1.121	0.056	-0.254	0.030	-1.240	0.215
Cl^-	Exponential	0.000	0.125	0.108	0.000	0.010	-0.005	0.313	-0.014	1.038	0.293	-0.083	0.028	-0.260	0.795
SO_4^{2-}	Exponential	0.000	0.139	0.058	0.000	0.012	-0.001	0.204	-0.005	0.986	0.209	-0.134	0.027	-0.567	0.571
F^-	Stable	0.025	0.444	0.026	0.970	0.037	0.010	0.171	0.059	1.030	0.166	0.193	0.030	1.345	0.179
NO_3^-	Circular	0.000	0.118	0.125	0.000	0.015	0.000	0.310	-0.002	1.112	0.257	0.168	0.027	1.277	0.202
Fe	Exponential	0.098	0.304	0.237	0.415	0.025	0.006	0.393	0.019	0.945	0.420	0.208	0.032	1.384	0.166
Mn	Exponential	0.026	0.095	0.095	0.276	0.012	-0.015	0.316	-0.041	1.026	0.307	-0.023	0.030	0.101	0.920
Zn	Stable	0.135	0.444	0.177	0.761	0.037	0.003	0.420	0.008	1.079	0.387	-0.339	0.030	-1.731	0.083

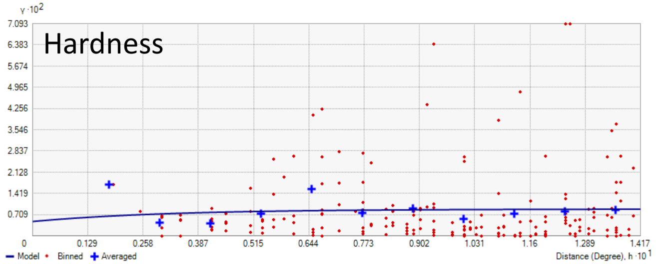
Groundwater Quality Dispersion (NDDI)

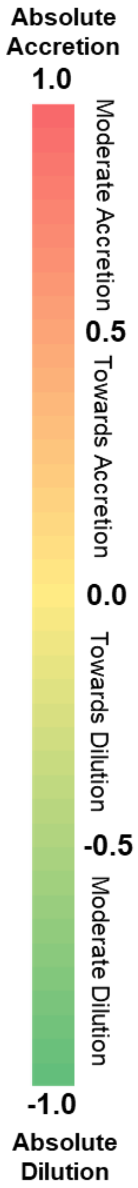
spatial variability assessment

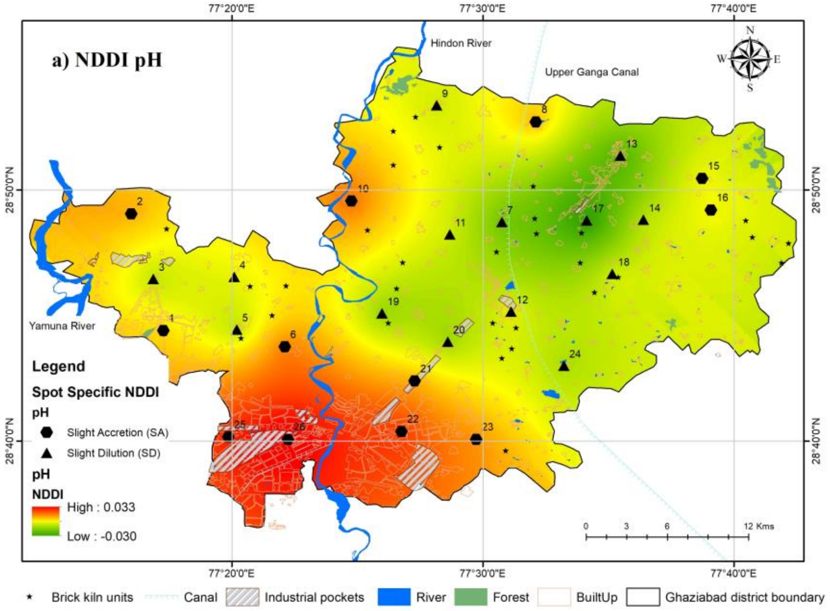


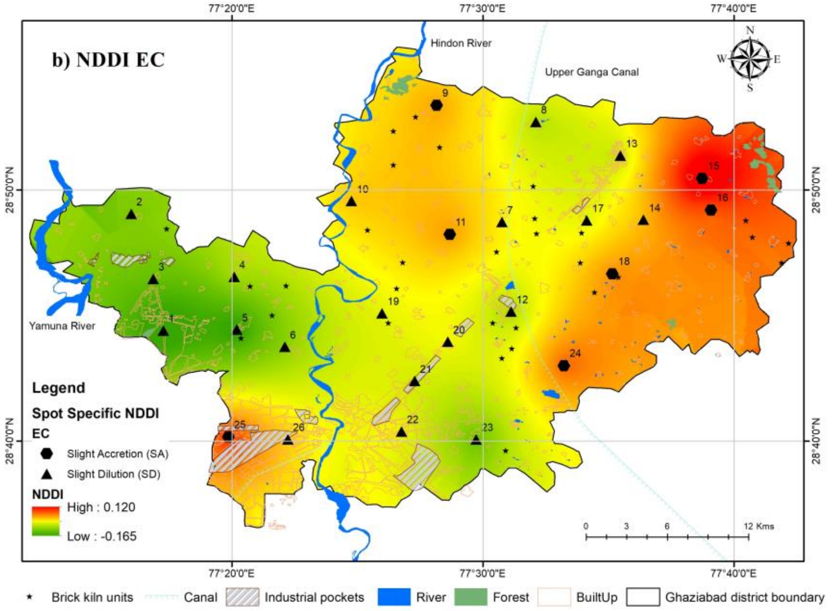


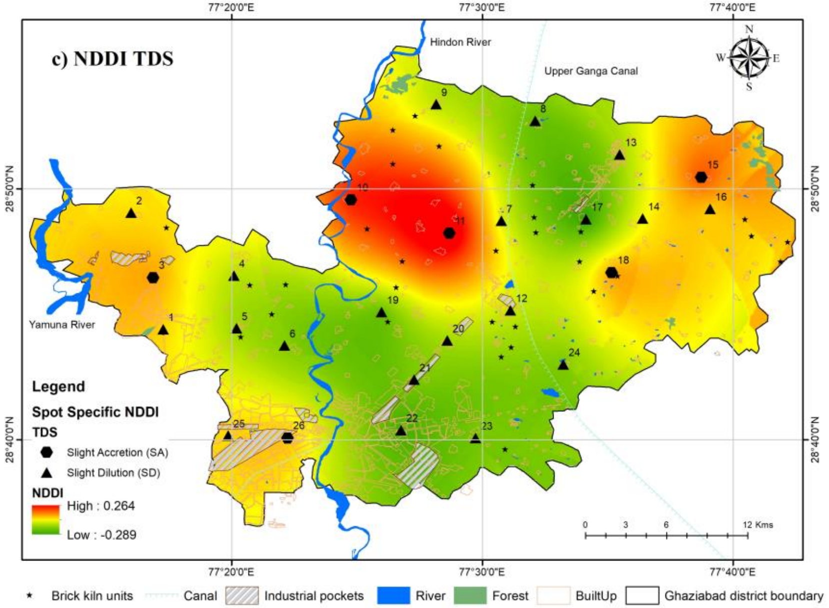


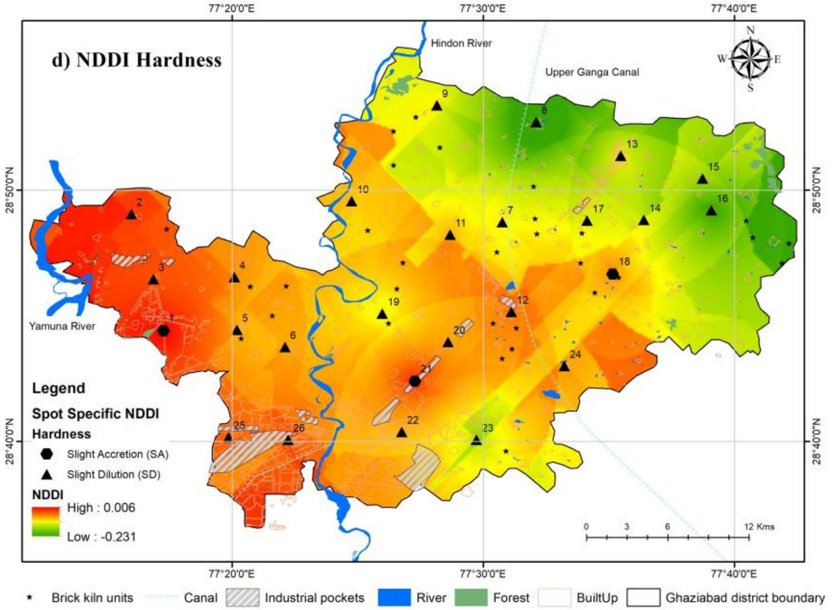




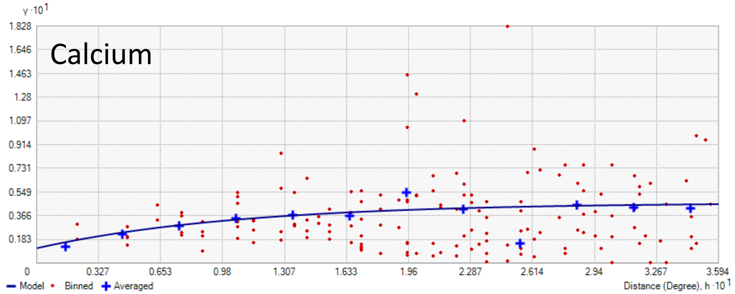


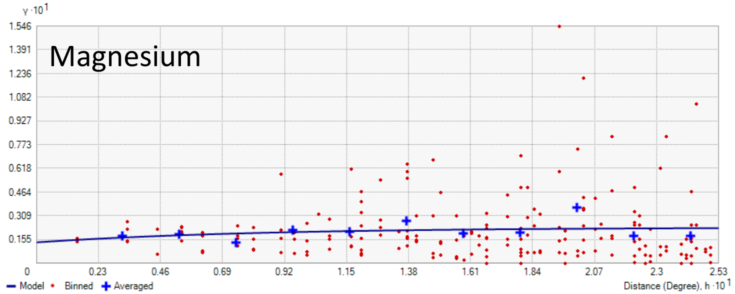


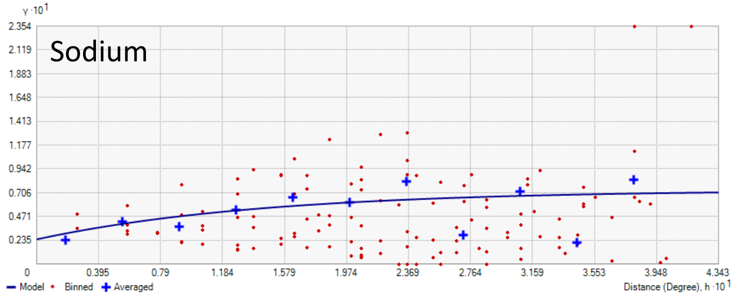


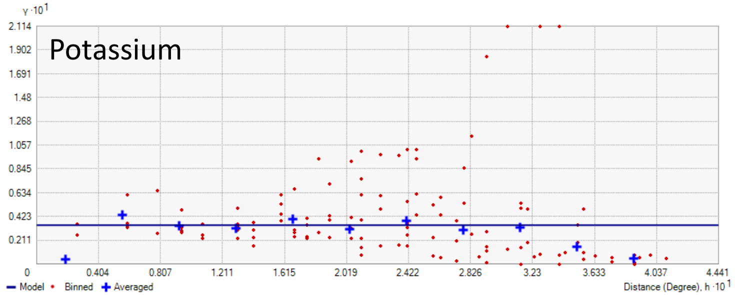


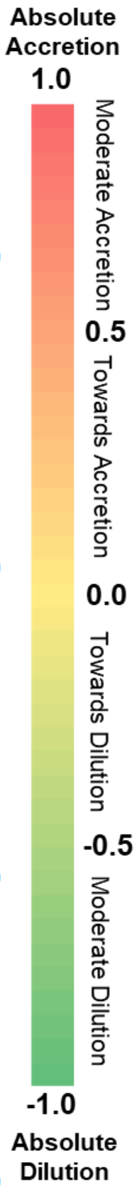
Groundwater Quality Dispersion (NDDI)
spatial variability assessment

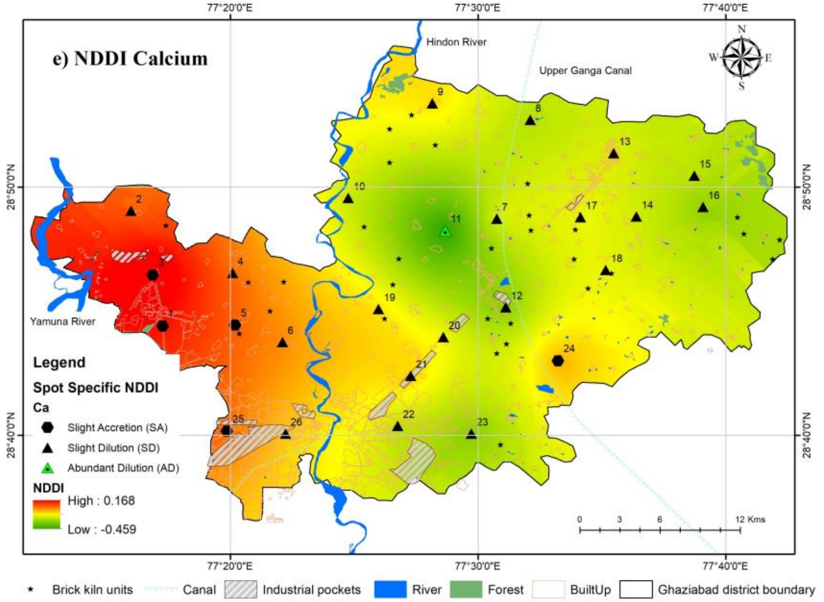


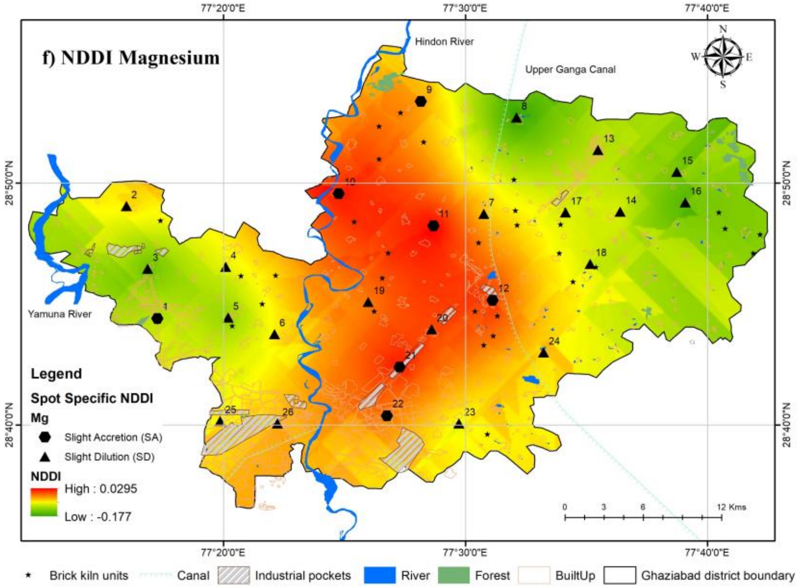


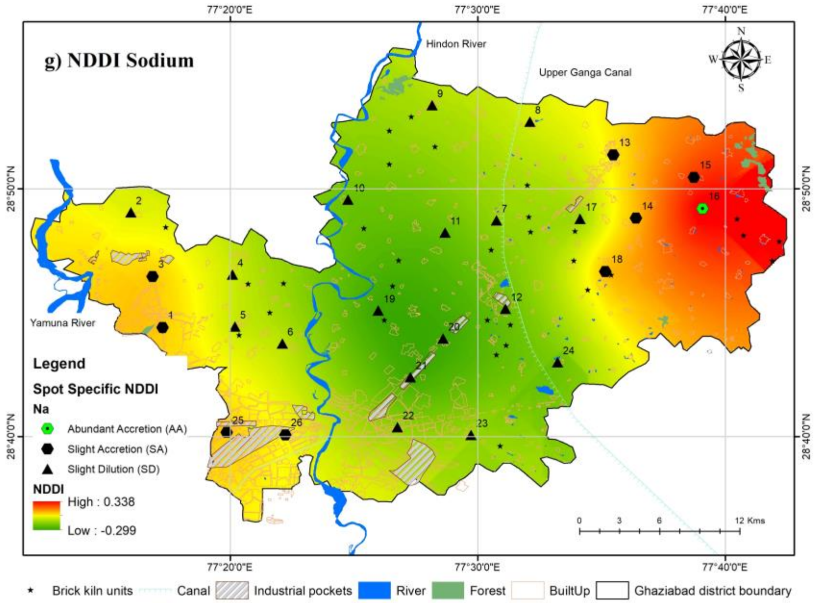


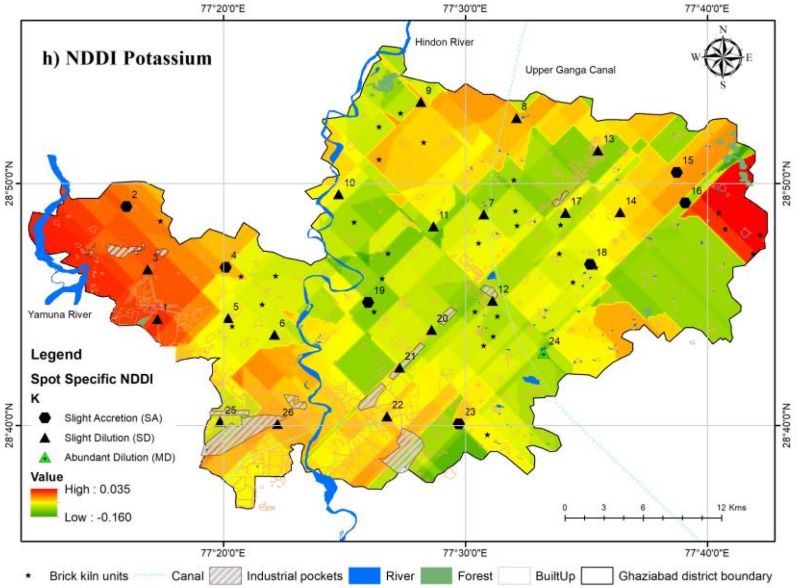






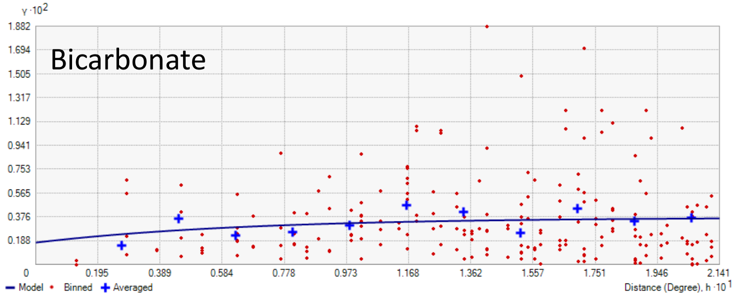


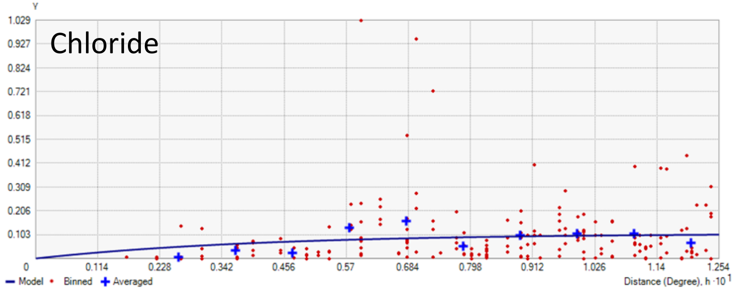


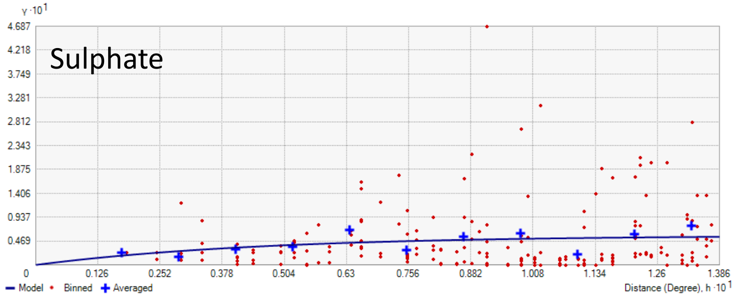


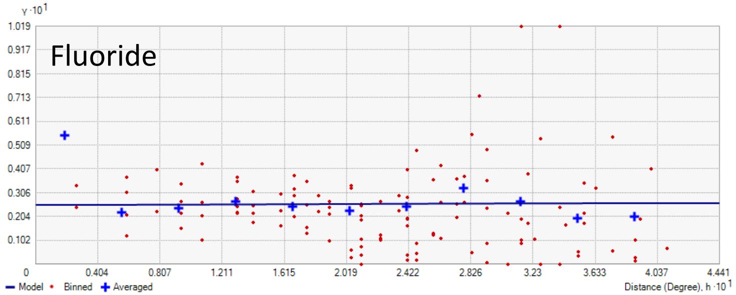
EGU General Assembly 2022

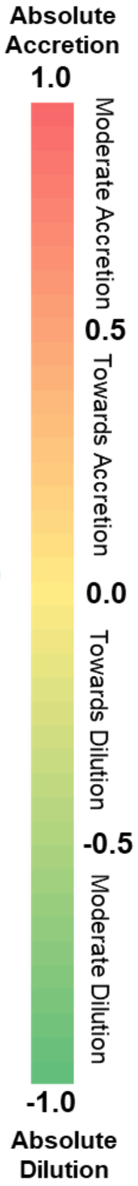
Groundwater Quality Dispersion (NDDI)
spatial variability assessment

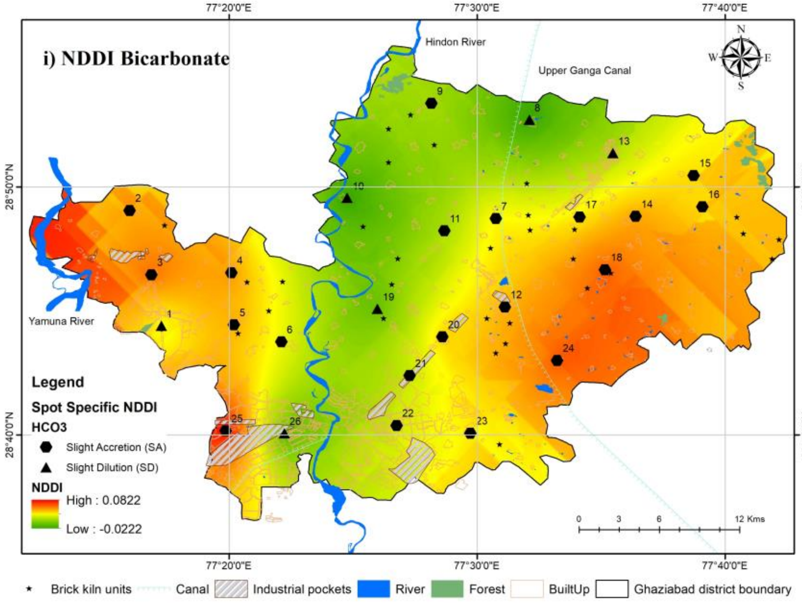


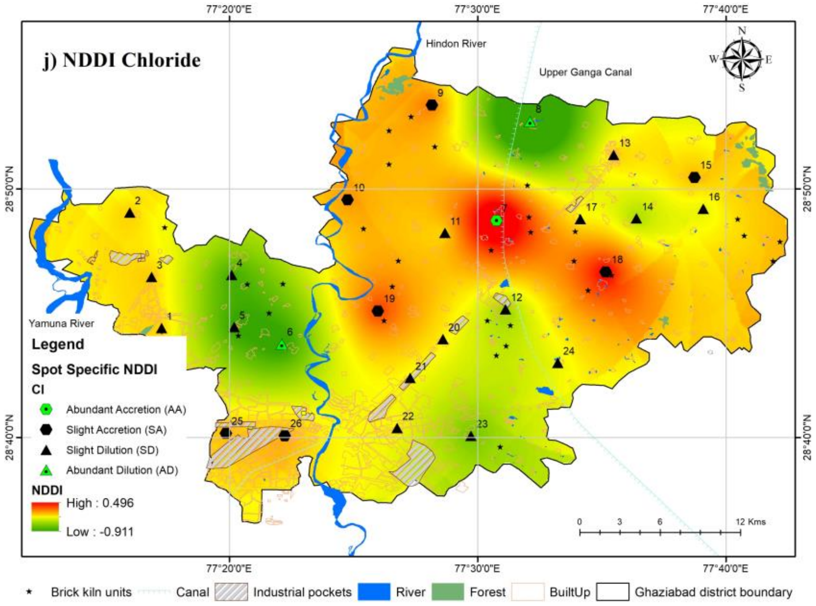


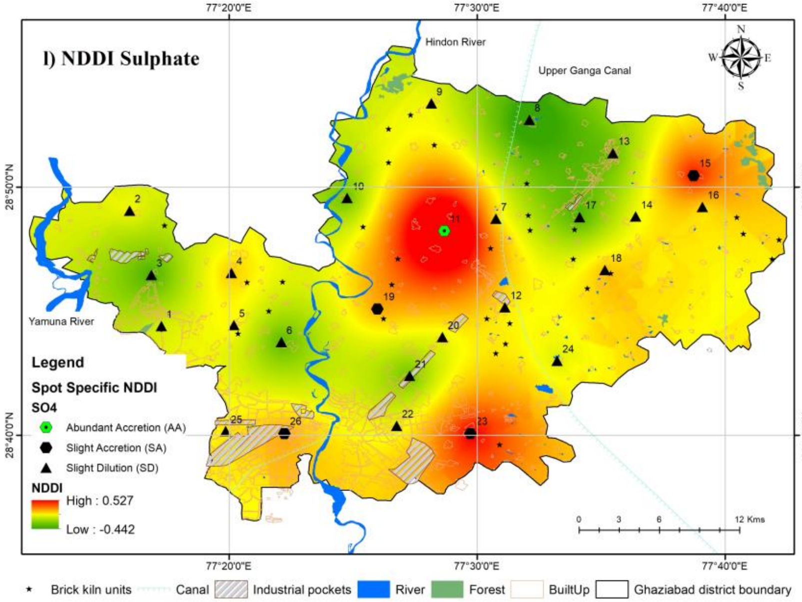


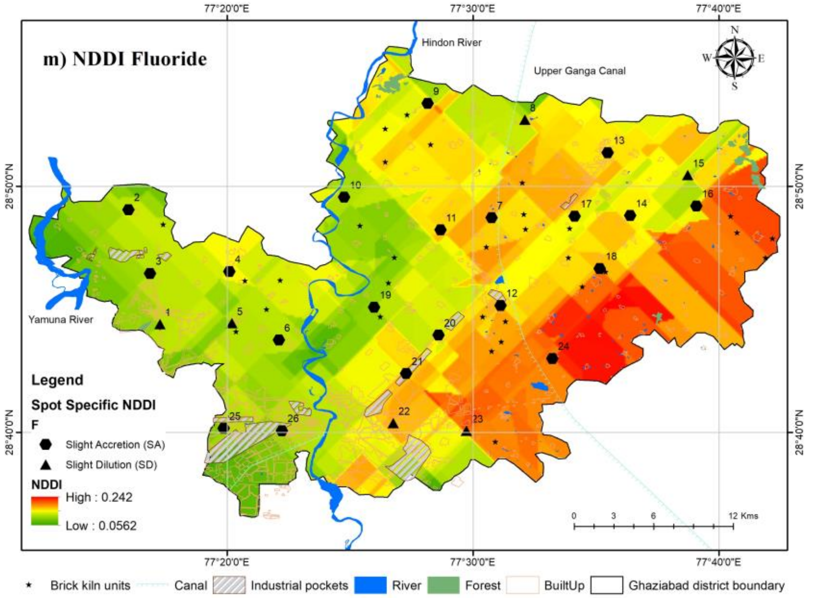






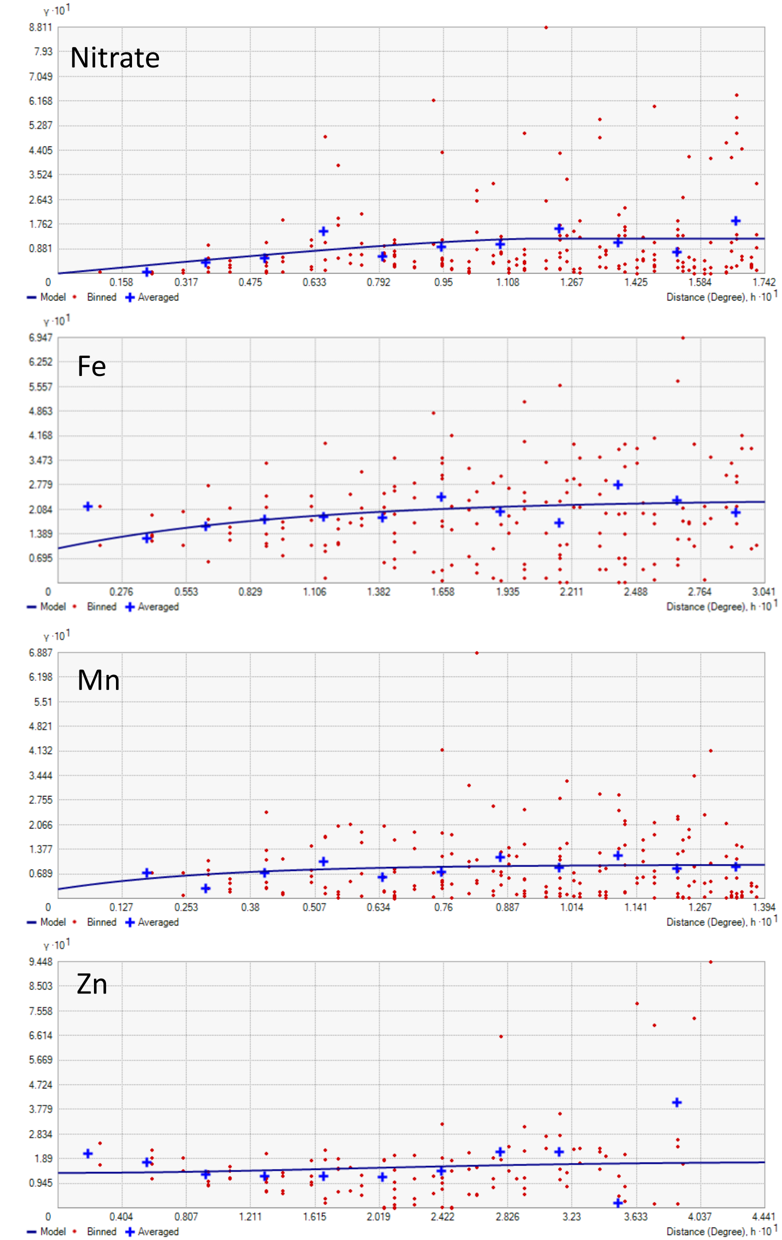


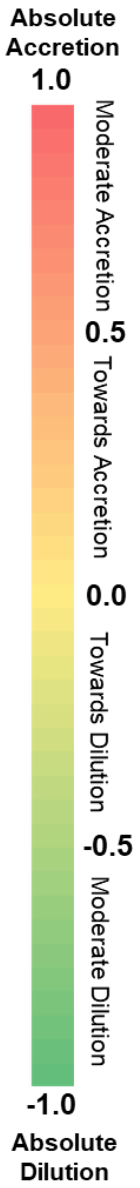


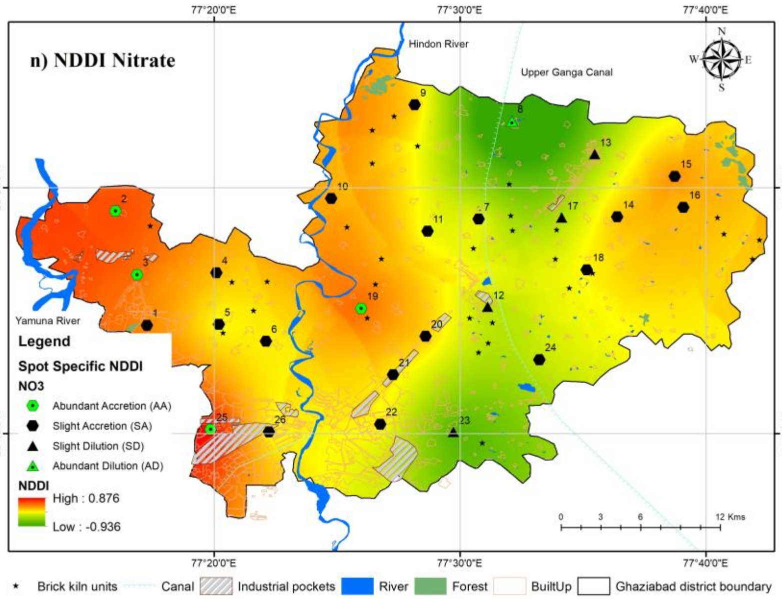


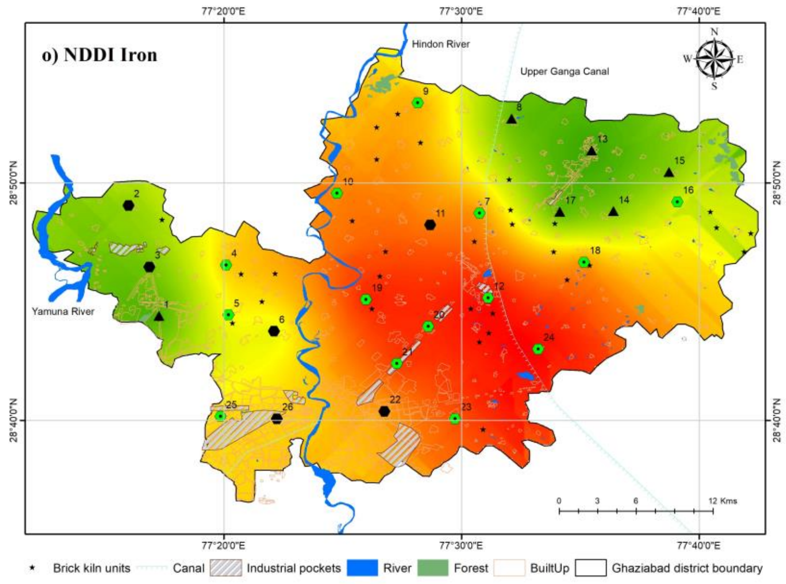
Groundwater Quality Dispersion (NDDI)

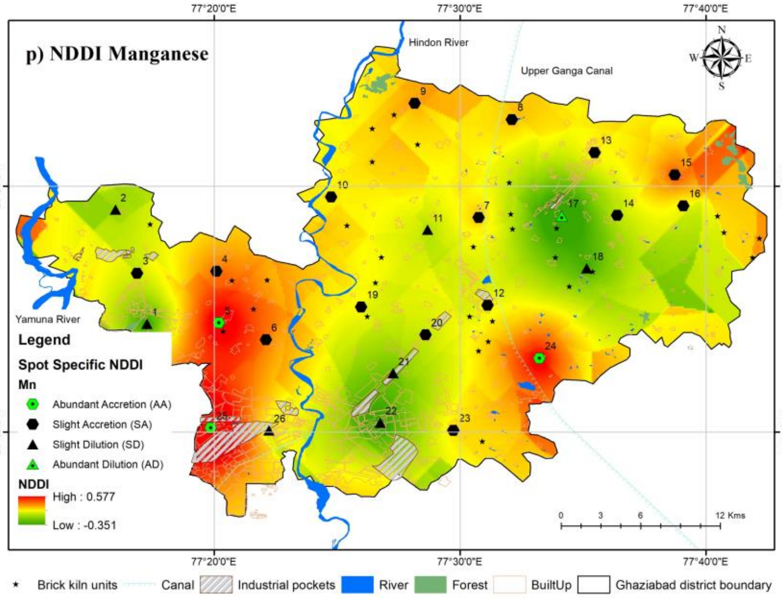
spatial variability assessment

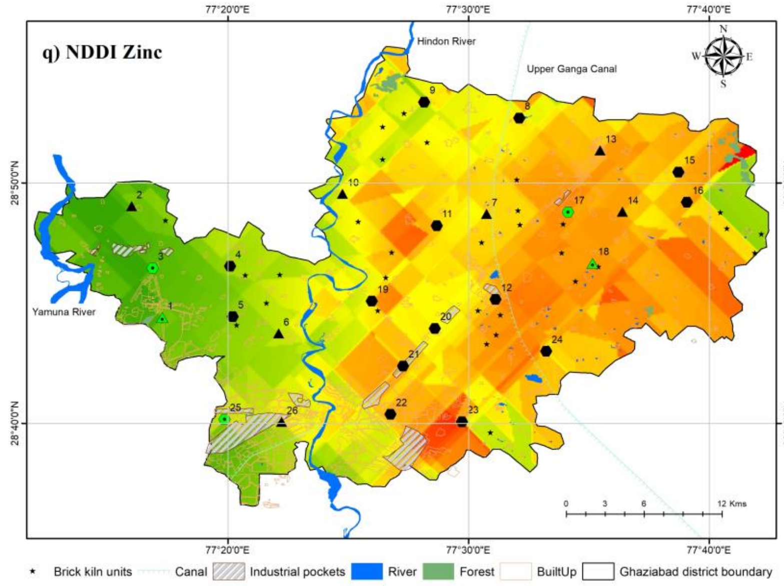




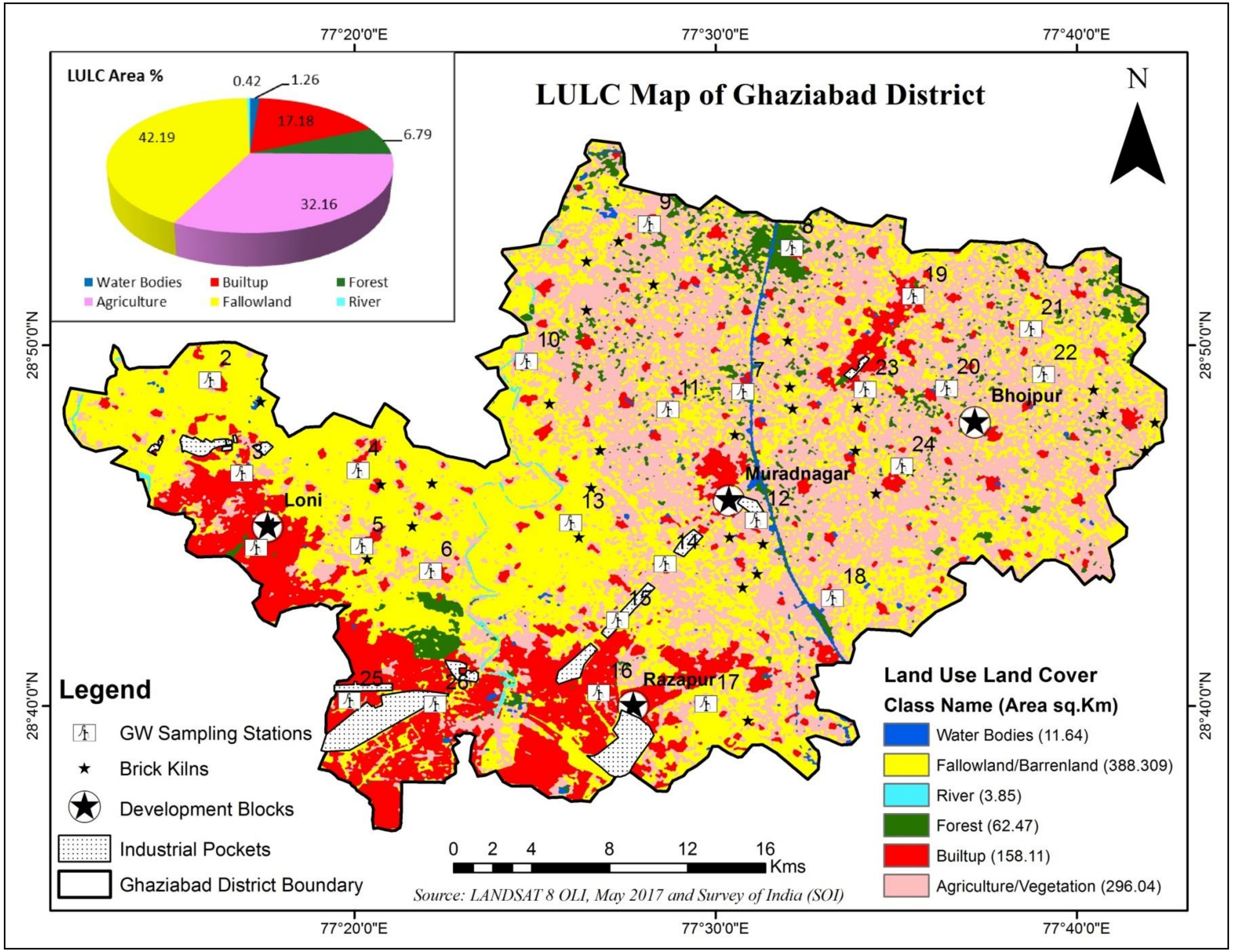




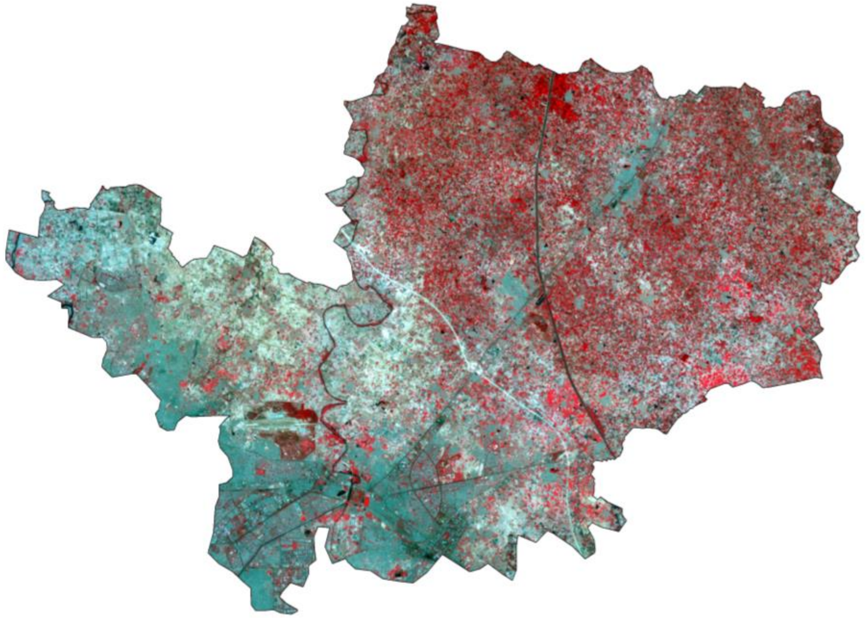




Land Use Land Cover Mapping (2017)



Source: LANDSAT 8 OLI, May 2017 and Survey of India (SOI)



Path/Row	146/40
Date of Image Acquisition	2017/05/24 **(May 2017)**
Image Classification Method	Supervised (Maximum Likelihood Classification)
Overall Accuracy Assessment	89%
Kappa statistics Coefficient	0.835

Spot-specific NDDI values for groundwater parameters and land use spectral indices

	NDDI values of Groundwater Parameters																Land Use Spectral Indices			
Location Name	**pH**	**EC**	**TDS**	**Hardness**	**Ca**	**Mg**	**Na**	**K**	**HCO3**	**Cl**	**SO4**	**F**	**NO3**	**Fe**	**Mn**	**Zn**	**NDBI**	**NDVI**	**NDSI**	**MNDWI**
Balram Nagar	-0.023	-0.133	0.055	0.182	0.101	0.281	0.028	-0.174	-0.059	-0.042	-0.168	-0.331	0.707	-0.139	-0.341	-0.960	-0.036	0.146	-0.146	-0.125
Mandaula Village	-0.020	-0.073	-0.040	0.055	-0.053	0.169	-0.149	-0.079	0.063	-0.163	-0.150	0.209	-1.000	-0.100	-0.038	-0.200	0.026	0.105	-0.105	-0.161
Pabhi Sadakpur	-0.023	-0.122	-0.026	0.025	0.097	-0.067	0.154	-0.075	0.169	-0.010	-0.696	0.293	0.812	0.057	0.063	0.671	0.015	0.085	-0.085	-0.132
Chirodi	-0.010	-0.043	-0.426	0.028	-0.045	0.077	-0.104	-0.049	0.101	-0.724	-0.092	0.582	0.728	0.711	0.226	0.045	0.026	0.109	-0.109	-0.167
Jawali	-0.010	-0.171	-0.121	-0.019	0.017	-0.067	-0.164	-0.091	0.093	-0.695	-0.118	-0.254	0.614	0.641	0.053	0.132	-0.001	0.132	-0.132	-0.167
Farukhnagar	-0.007	-0.056	-0.220	0.039	-0.041	0.148	-0.147	-0.088	0.061	-0.563	1.000	0.341	0.637	0.024	-0.026	-0.176	0.020	0.108	-0.108	-0.164
Didoli	-0.002	-0.002	-0.065	-0.012	-0.086	0.041	-0.126	-0.102	0.068	-0.080	-0.007	0.418	0.601	0.685	0.025	-0.412	0.000	0.151	-0.151	-0.176
Niwari Village	-0.006	-0.020	-0.077	-0.009	-0.125	0.082	0.511	-0.151	0.073	-0.400	-0.119	-0.091	-1.000	-0.364	0.129	0.056	-0.005	0.127	-0.127	-0.140
Khindora	-0.011	-0.013	-0.210	0.022	-0.261	0.270	-0.243	-0.125	0.072	-0.778	-0.094	0.126	0.434	0.741	0.097	0.000	0.015	0.117	-0.117	-0.155
Nekpur	0.031	0.004	0.155	0.022	-0.583	0.356	-0.197	-0.133	0.056	-0.152	-0.165	0.548	0.805	0.533	0.052	0.079	0.027	0.108	-0.108	-0.169
Kakra	-0.002	-0.013	0.221	0.006	-0.714	0.298	-0.288	-0.103	0.057	-0.429	0.532	0.796	0.606	0.452	0.029	0.356	-0.031	0.171	-0.171	-0.148
MOF	0.035	-0.054	-0.094	0.040	-0.474	0.264	-0.390	-0.210	0.045	-0.385	-0.090	0.434	0.415	0.963	0.030	0.406	0.012	0.137	-0.137	-0.169
Santpura	0.000	-0.033	0.517	-0.055	-0.250	0.217	-0.031	-0.220	-0.020	-0.250	-0.343	0.194	-1.000	-0.848	0.127	-0.048	-0.035	0.145	-0.145	-0.122
Khanjarpur	-0.007	-0.008	-0.171	0.000	-0.178	0.188	-0.083	-0.165	0.070	-0.167	-0.136	0.618	0.637	0.145	0.000	-0.048	-0.064	0.218	-0.218	-0.150
Muradabad	0.013	0.000	0.028	0.021	-0.167	0.170	0.080	0.038	0.059	0.024	0.020	0.082	0.638	0.021	0.135	0.200	0.011	0.146	-0.146	-0.181
Palauta	0.007	-0.085	0.047	-0.386	-0.443	-0.035	0.763	0.086	0.019	-0.174	-0.091	0.361	0.532	0.677	-0.200	0.377	-0.001	0.171	-0.171	-0.190
Sikri Khurd	-0.017	0.006	0.024	0.039	-0.169	0.250	-0.486	-0.104	0.048	-0.250	-0.035	0.532	0.797	-0.439	-0.564	0.467	-0.001	0.131	-0.131	-0.155
Kalchhina	-0.026	0.062	0.043	-0.088	-0.122	-0.037	0.328	0.446	0.091	0.409	-0.052	0.774	0.620	0.901	-0.185	-0.667	0.002	0.151	-0.151	-0.175
Makraida	-0.020	-0.036	-0.523	0.209	0.077	0.344	-0.493	-0.054	0.000	0.000	0.017	-0.035	0.562	0.945	0.164	0.333	0.018	0.129	-0.129	-0.191
Duhai	0.030	-0.010	-0.211	0.017	-0.154	0.158	-0.452	-0.110	0.089	-0.200	-0.074	0.342	0.620	0.672	0.000	0.379	0.025	0.080	-0.080	-0.137
Guldhar	0.044	-0.069	0.150	0.203	-0.071	0.452	-0.512	-0.284	0.000	-0.111	-0.074	0.212	0.581	0.755	-0.036	0.121	-0.009	0.101	-0.101	-0.118
Ghaziabad City	0.022	-0.011	-0.434	0.007	-0.354	0.316	-0.141	-0.476	0.057	0.067	-0.135	0.085	0.696	0.358	-0.590	0.008	-0.040	0.111	-0.111	-0.082
Sadiqpur	0.020	-0.219	-0.370	-0.279	-0.400	-0.233	0.000	0.417	-0.087	-0.453	0.094	0.384	-0.573	0.627	0.043	0.006	0.004	0.123	-0.123	-0.150
Nahal	-0.014	0.035	-0.165	0.043	0.021	0.063	-0.329	-0.592	0.095	-0.200	-0.084	0.738	0.410	0.905	0.348	0.391	0.009	0.100	-0.100	-0.139
Surya Nagar	0.008	0.085	-0.052	0.059	0.005	0.129	0.137	-0.039	0.087	0.013	-0.066	0.456	0.657	0.641	0.702	0.759	0.011	0.074	-0.074	-0.108
Vasundara	0.036	-0.026	-0.056	-0.018	-0.231	0.333	0.019	-0.089	0.013	-0.037	0.018	0.544	0.558	0.397	-0.056	-0.111	0.000	0.102	-0.102	-0.123

Land Use Spectral Indices

Normalized Difference Vegetation Index (NDVI)

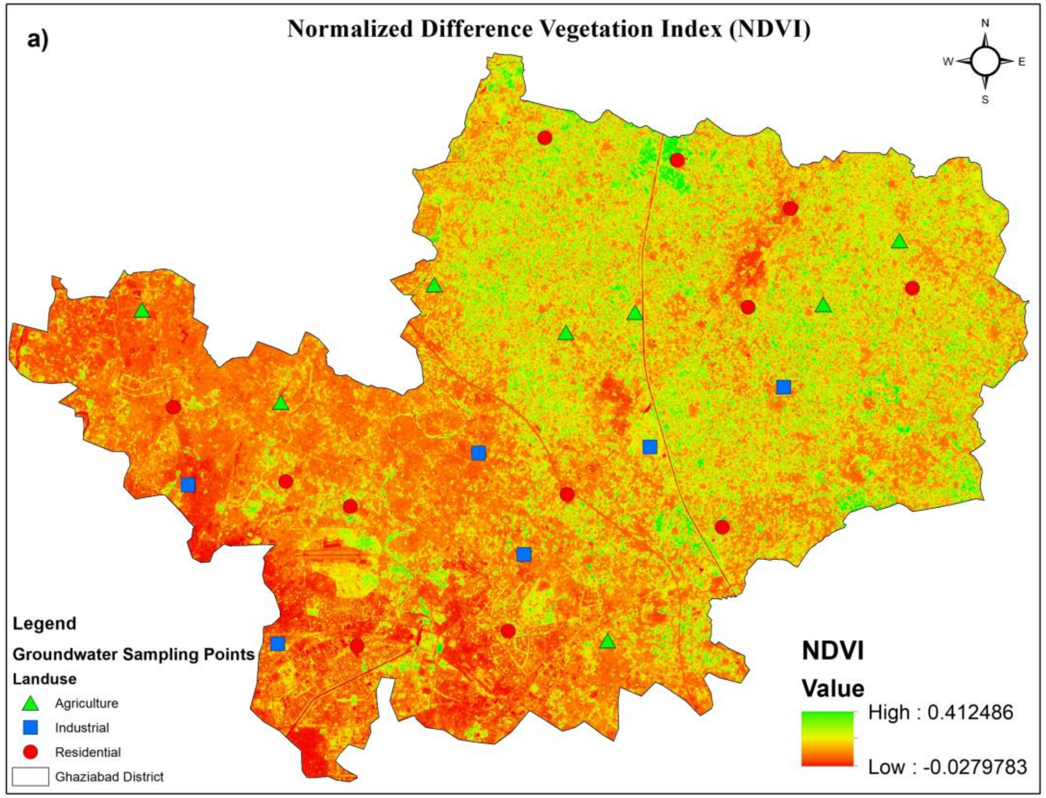
- NDVI measures green vegetation by employing bands that record highest reflectance and absorption regions of chlorophyll (Rouse et al., 1973).
- NDVI ranges from -1 to +1 and vegetation is typically seen in **0.2 to 0.8 µm.**

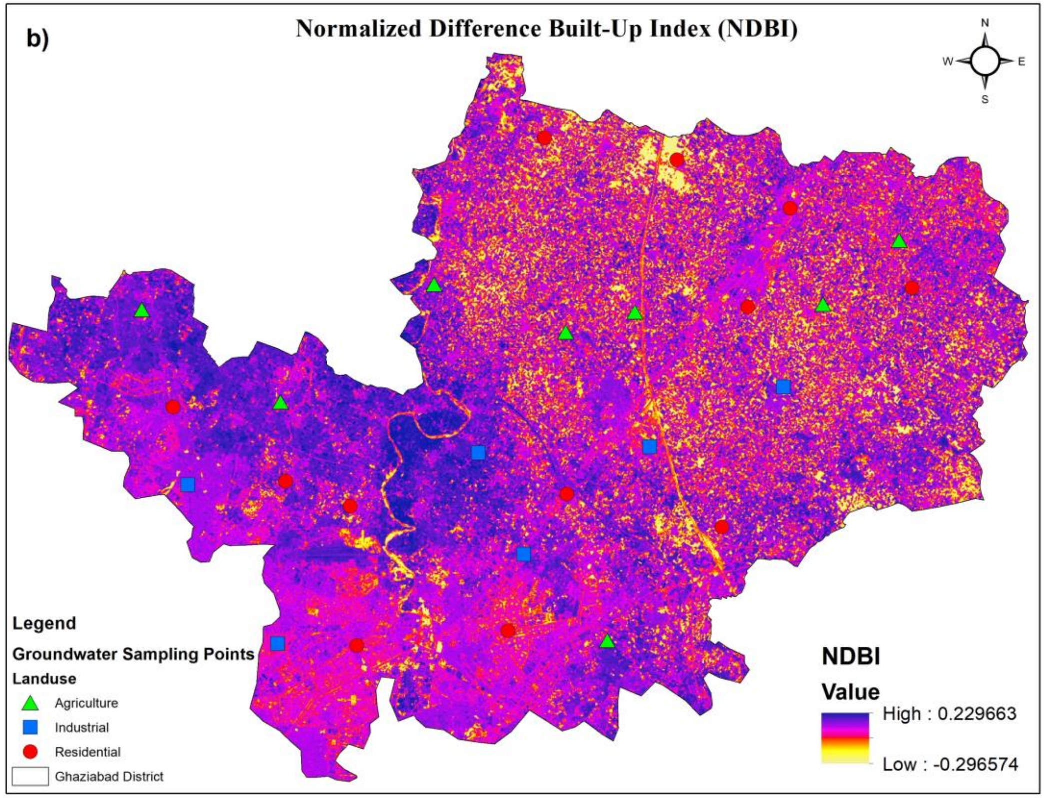
$$\mathrm{NDVI} = \frac{NIR - Red}{NIR + Red} = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$$

Normalized Difference Built-Up Index (NDBI)

- NDBI highlights urban regions where higher reflectance in SWIR wavelength compared to NIR wavelength and generally utilized in watershed runoff predictions and land use planning (Zha et al., 2003).
- NIR band ranging from **0.76-0.9 µm** and SWIR ranging from **1.55-1.75 µm.**

$$\mathrm{NDBI} = \frac{SWIR - NIR}{SWIR + NIR} = \frac{Band\ 6 - Band\ 5}{Band\ 6 + Band\ 5}$$





All the Spectral Bands acquired from ***Landsat 8 OLI (earthexplorer.usgs.gov) (***Level 2) were calculated in ArcGIS Environment; **NIR:** Near Infrared; **SWIR:** Short-wave Infrared

Land Use Spectral Indices

Normalized Difference Salinity Index (NDSI)

- **NDSI is opposite of NDVI** (Tuker, 1979) and preferably used to estimate the salinization hazards in the northern part of China (Jabbar and Xiaoling, 2008).

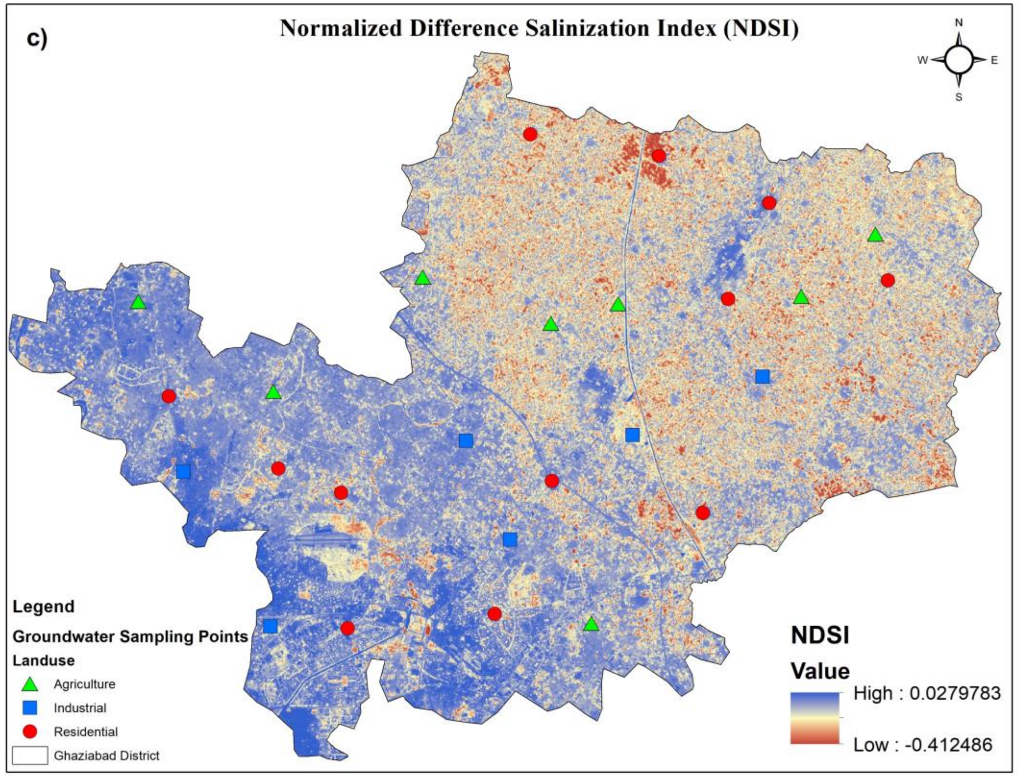
$$\mathrm{NDSI} = \frac{Red - NIR}{Red + NIR} = \frac{Band\ 4\ - Band\ 5}{Band\ 4 + Band\ 5}$$

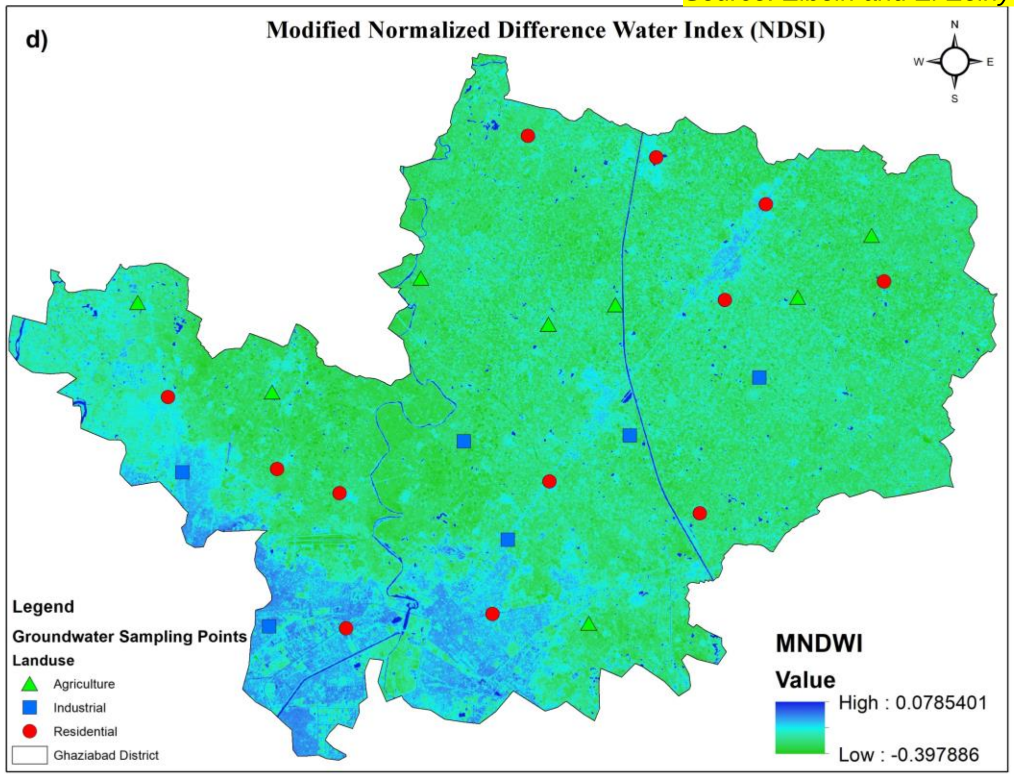
Modified Normalized Difference Water Index (MNDWI)

- MNDWI highlights open water signatures while suppressing noise from urban, green vegetation, and soil. MNDWI ranges from -1.0 to +1.0 and -1.0 to +0.4 µm is the usual range for green vegetation.
- Green band ranging from **0.5-0.6 µm** and SWIR ranging from **1.55-1.75 µm.**

$$\mathrm{MNDWI} = \frac{Green\ - SWIR}{Green + SWIR} = \frac{Band\ 3\ - Band\ 6}{Band\ 3 + Band\ 6}$$

Source: Elbeih and El-Zeiny (2018)





All the Spectral Bands acquired from ***Landsat 8 OLI (earthexplorer.usgs.gov) (***Level 2) were calculated in ArcGIS Environment; **NIR:** Near Infrared; **SWIR:** Short-wave Infrared

Conclusions and Recommendations

- Land use mismanagement is an important factor that must be considered in the degradation of groundwater quality.

- The absolute to moderate accretion was apparent for the parameters like nitrate, fluoride, iron, and zinc in the vicinity of the densely populated residential areas and industrial pockets. Similarly, dilution within the rest of the parameters showed a recharging effects of the groundwater.

- Site specific NDDI values were correlated with the site specific land use spectral indices in order to register the influence within the chemistry of groundwater. However, a significant low correlation (> 0.2) has been found and inter-relationships of the land use with groundwater quality is found to be moderately affected.

- Furthermore, a strong assessment can be drawn out with more concrete spectral basis in order to track the discharges of nutrient and toxic chemicals that influence the groundwater quality to a greater extent with respect to anthropogenic impacts.

- Land-use management measures can produce significant groundwater quality and quantity benefits at relatively modest cost and improving integrated governance towards sustainable abstraction and protection of groundwater.

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Directorate of Students’ Welfare (DSW), GGSIPU, India (Travel Support)

&

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