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Full Length Research Paper

Evaluation of ground water quality in Lucknow, Uttar Pradesh using remote sensing and geographic information systems (GIS)

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Lucknow being capital city of most poapulated state of India is facing tremendous population pressure. This has led to overexploitation of natural resources and among them water is most valuable natural resource essential for human survival and ecosystem. This study monitors ground water quality, relating it to land use/land cover and habitation mask of different water quality parameters are prepared by using geographic information systems (GIS) and remote sensing technique. Base map was prepared by Survey of India toposheets on 1:50.000 scale. The land use / land cover map was made from satellite imagery and GIS software like ERDAS Imagine and ARC GIS 9.3. The ground water samples were collected from the selected locations and were analyzed for different physico-chemical analysis and a water quality index was prepared. Water quality index (WQI) was then calculated on the basis of WHO standards to classify suitability for drinking water. The WQI map was interpolated using inverse distance weight (IDW) method on GIS for spatial variation and suitability of quality assessment.

Key words: Remote sensing, ground water, water quality index, urban sprawl, inverse distance weight (IDW) method, WHO standard.

INTRODUCTION

Urbanization is characterized by clustering of people in relatively small areas and is recognized as an inevitable historical process (UN, 2004). The urbanization leads to many changes which have adverse impacts on Environment, including ecology, especially hydro-geomorphology, water resources and vegetation. Rapid growth of urban areas has further affected the ground water quality due to over exploitation of resources and improper practices (Mohrir et al., 2002). Lucknow is the capital city of the most populous state Uttar Pradesh and is one of the fastest developing urban centers of India. Lucknow district is a part of Central Ganga Plain covering an area of 2, 528 km^2. and lies between North latitudes 26°30’ and 27°10’ and East longitudes 80°30’and 81°13’ with total population of 34 lakhs as per 2011 (Anonymous, 2011).

The city is facing a rapid change in environmental quality. Rapid urbanization leads to many problems as it places huge demand on land, water, housing, transport, health, Education etc (Gyananath et al., 2001). The city has an alarming increase in population it increased from 0.497 million in 1951 to 2.267 million in 2001 and 2.714 million in 2006 to 3.306 in 2011 increased 4.56 times (456 per cent) during the last fifty years. The growth rate of population Lucknow (UA) was at 7.12% per annum (Lucknow Master Plan, 2010). This rising population density has major impact on natural resources of the area especially on water quality and quantity.

Fresh water is most important natural resources for the life but overexploitation and unjustified use of water has led to deterioration of quality of water. In the last few decades, ground water has become an essential resource due to its use for drinking, industrial and irrigation purposes. Remote sensing and geographic information

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systems (GIS) are effective tools for land use/ land cover, water quality mapping for monitoring and detection of change in environment (Ferry et al., 2003). One of the greatest advantages of using remotely sensing data for hydrological investigations and monitoring its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction and validation (Saraf, 1999; Epstein et al., 2002). GIS can be a powerful tool for dealing with water resource problems and developing solutions (Skidmore et al., 1997). In this paper we have integrated remote sensing, GIS and field studies for evaluating impacts of land use change on water quality of Lucknow City.

METHODOLOGY

Study area

Lucknow district is a part of Central Ganga Plain in the state of Uttar Pradesh covering an area of 2,528 km^2 and lies between North latitudes 26°30' and 27°10' and East longitudes 80°30'and 81°13' (Figure 1) with total population of 34 lakhs as per 2011 (Anonymous, 2011]. General elevation of the district varies between 103 and 130 (Anonymous, 2009-10) meters above mean sea level showing southeasterly slope. Irrigation in the district takes place through Sharda Canal and Sharda Sahayak network systems and tube-wells. The Gomati River, the chief geographical feature, meanders through the city, dividing it into the Trans-Gomati and Cis-Gomati regions. The climate of Lucknow city is of subtropical type with three distinct seasons namely summer, monsoon and winter. The maximum temperature remains 45°C during month of May and minimum temperature remains 5°C during January. The average annual rainfall of the city is 1014.7 mm.

Data used

Different data products required for the study include Survey of India toposheets 63B/9, 10, 13, 14, 63F/1, 2, 63 A/ 12, 16, 63 E/ 4 on 1:50,000 scale. Besides this guide map of Lucknow on 1:20,000 scale have also been referred during interpretation as well as for base map preparation. IRS- P6 LISS III of 2005 have also been utilized for land use and urban settlement map.

The study area was demarcated using Toposheets of 1:50,000 by identifying the district boundaries by Scanning, projecting, geo-referencing and digitizing toposheets of the area manually using ERDAS. Various land use / land cover features were studied and a base map was prepared by visual interpretation using toposheets and false colour composite image of LISS III sensor. Water samples were taken from the area using random sampling techniques and with the help of GPS (Global Positioning System) the co-ordinates were noted down.

Spatial database

The spatial database is prepared by using different thematic Thematic layers like base map of the study area, land use / land cover, drainage network from SOI toposheets on 1:50,000 scale using ERDAS, Arc/Info GIS software to obtain baseline data. All maps are digitized to convert data into vector format. Landuse / land cover maps are prepared by using GIS software through supervised classification. SOI toposheets, satellite data and GPS (global Positioning data) together used with ground truth data.

Attribute database

Ground water samples were collected from predetermined locations that is, Urban and Suburban areas selected from the satellite imagery (Figure 2). The water samples taken from these locations and the area were then analyzed for eight water quality physico-chemical parameters adopting standard protocols (APHA, 1998). The water quality data thus obtained is used as database for present study (Table 1).

The standards prescribed by BIS were used foe the calculation of water quality indices (BIS, 1991)

GIS based spatial modeling for pollutant distribution

GIS can act as a powerful tool for modeling water quality. Various Thematic maps which are helpful understanding and managing water resources can be prepared with the use of GIS. In this study spatial interpolation technique through inverse distance weighted (IDW) approach of GIS has been used. In this technique sample points on different locations are selected for estimating output grid value. It determines cell value using a linearly weighted combination of sample points and controls the significance of known points upon the interpolated values based upon their distance from the output point thus a surface grid is generated as thematic isolines (Asadi et al., 2007).

Calculation

Water quality index (WQI)

Water quality index is regarded as one of the most effective way to communicate water quality (Sinha et al., 2004; Srivastava et al., 1994) WQI of water collected from 52 (22 + 30) locations of urban and sub-urban areas of Lucknow district were calculated. It is very useful method for assessing water quality of drinking water. In this a rating scale is fixed on the basis of importance and incidence on the overall quality of drinking water I terms of different physic-chemical parameters (Anonymous 2009-10; Horton, 1965). For calculating WQI different formulas given below are used (Sinha et al., 2006; Singh et al., 1999).

(i) Water Quality Rating, $Q_n = [(V_a - Vi) / (Vs - Vi)] \times 100$ (1)

$Q_{n =}$ Quality rating for total water quality parameter.
$V_{a =}$ Actual value of parameter obtained from Laboratory analysis.
Vi = Ideal value of the parameter obtained from the standards. (For pH it is 7 and for others it is zero).
Vs = Value recommended by BIS India of water quality.

(ii) Unit weight (Wn) = K / Sn (2)

Sn is accepted drinking water quality standards by ISO
K = Proportionality Constant
Calculated by $K = [1 / (\Sigma^{n}_{n=i} 1/S_i]$
Sn = Standard values of the water quality.

Based on the above water quality values, the water samples quality is categorized as Excellent, Good, poor, Very Poor, Unfit for Drinking (Tiwari et al., 1985) (Table 2).

Land use land cover distribution

Land use change with time has great impacts on the environmental quality of the area. The change in land use is highly associated with ground water quality (Dasgupta et al., 2001). In the present study the land use has been classified into ten classes. In the overall

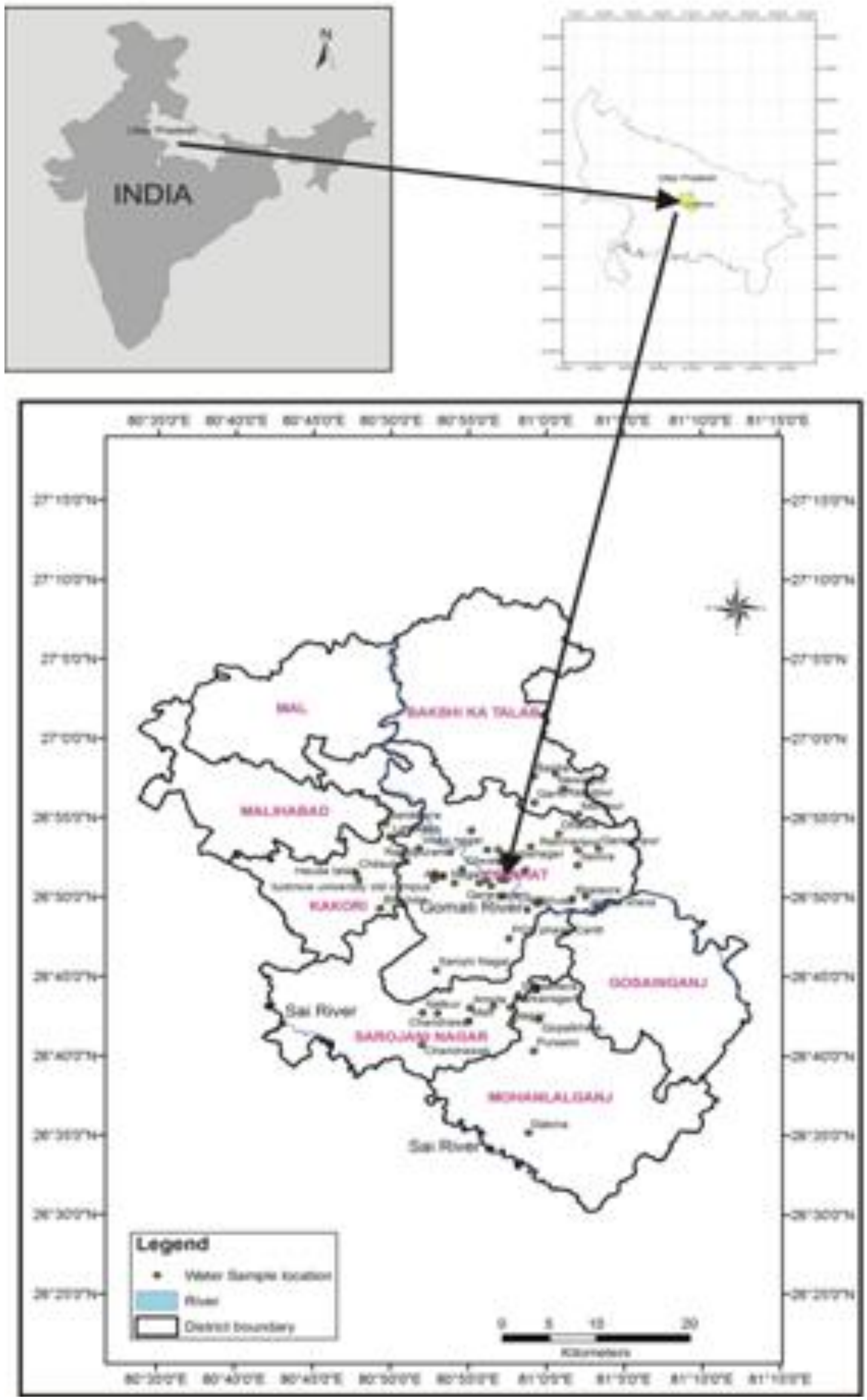

Figure 1. Location map of the study area -Lucknow city, Uttar Pradesh, India.

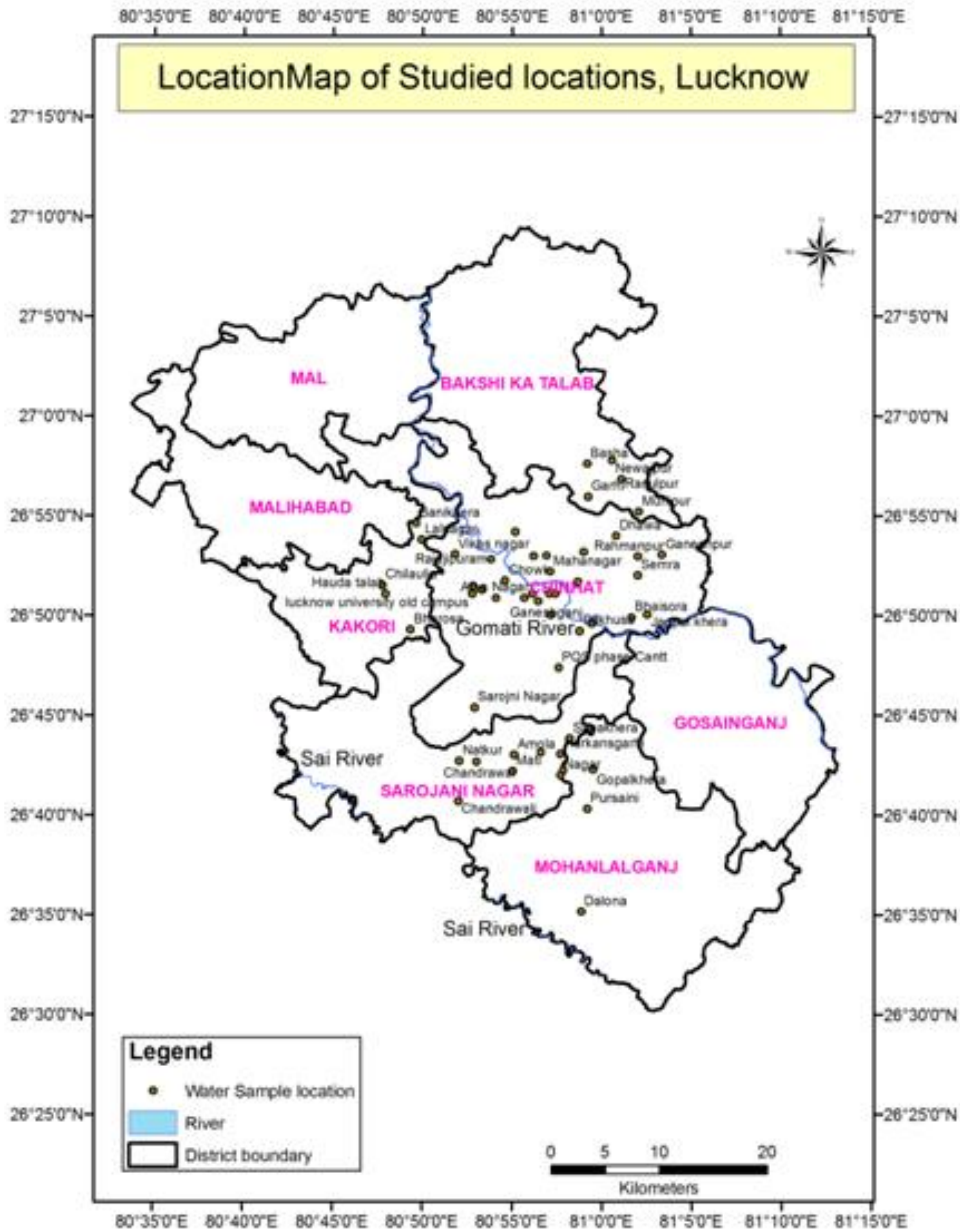

Figure 2. Sample location of studied water samples.

view of Lucknow district, the land use represents very few classes and hence the area is well suited for development projects. The expansion of the city's spatial limit has lead to a surmounting pressure on both natural and built drainage systems (Krishna et al., 2001). A measurable amount of settlement can be observed in most of the regions showing that the agricultural region has been converted into residential or urban purposes. In the overall view of Lucknow district, the land use represents very few classes and hence the area is well suited for development projects (RSACUP, 2000). The expansion of the city's spatial limit has lead to a surmounting pressure on both natural and built drainage systems. Drainage modifications and land use changes have lead to alterations in the regional hydrology, that is, the natural pattern of drainage has been modified by the changed land use. The build up area has increased at a faster rate and most categories are getting converted in buildup area. Table 3 shows that different categories of land have been transformed into build up area. The total land use change in the district has been shown in Figure 3.

Table 1. Physico-chemical analysis of water of Lucknow district.

S. No	Locations	pH	HCO_3	Cl	NO_3	SO_4	F	Ca	Mg	Na	Ec	WQI	Category of water
Physico-chemical analysis of urban area of Lucknow district													
1	Bhujal Bhawan	8	183	7	3	Nil	0.6	16	22	9	325	30.54	Good
2	Indira Nagar	8.2	317	71	118	29	0.4	24	75	53	1000	70.17	Very poor
3	Gomti Nagar	8.1	403	28	19	43	0.3	40	68	26	900	62.32	poor
4	Narahi	8.2	51	78	2	29	0.4	24	63	115	1160	52.3	poor
5	Gulistan Colony	8.2	500	35	19	24	1.2	40	54	83	1040	70.11	Very poor
6	PQS Phase Catt.	8	310	21	3	10	1.1	32	46	12	600	51.47	Poor
7	Cariappa Road Catt.	8	290	14	3	Nil	0.7	32	19	42	550	38.63	Good
8	Dilkusha	8.1	409	35	2	14	0.7	48	34	64	840	101	UBD
9	Sarojini Nagar	8	177	57	12	10	0.3	40	15	35	530	35.28	Good
10	Mahanagar	8.2	366	185	155	43	0.6	96	78	80	1500	118.3	UFD
11	Vikas Nagar	8	293	57	12	38	0.1	56	32	46	785	48.84	poor
12	Lucknow University(New Campus)	8	232	28	13	10	0.8	16	29	42	530	39.26	Good
13	Lucknow University(Old Campus)	8.2	457	142	23	65	0.5	56	63	400	1360	88.49	Very poor
14	Aminabad	8.2	427	142	56	38	0.7	38	51	113	1300	82.05	Very Poor
15	River Bank Colony	8.2	457	57	10	14	0.4	48	49	67	1000	63.21	Poor
16	Chowk	8.1	256	71	10	24	0.4	40	39	37	714	49.94	Good
17	Campbell Road	8.2	275	99	70	28	0.8	80	49	16	926	59.20	Poor
18	Rajajipuram	8	171	28	12	10	0.6	32	15	18	400	33.86	Good
19	Arya Nagar	8	226	71	12	24	1.1	48	20	40	658	48	Good
20	Ganesh Ganj	8.1	409	99	4	24	0.4	64	34	90	996	59.86	Poor
21	New Hyderabad	8.2	659	64	2	67	0.3	8	141	51	1440	98.75	Very Poor
22	Nirala Nagar	8.2	494	64	50	48	0.5	8	88	92	1200	86.27	Very Poor
Physico-Chemical analysis of Sub-urban area of Lucknow district													
1	Ahirankhera,Thakur ganj	7.85	329	14	2.4	20	0.78	25	42	23	320	46.91	Good
2	Lalnagar, Kakori	7.5	214	11	4	10	0.25	30	26	22	480	30.65	Good
3	Baniyakhera,Malihabad, Kakori	7.7	207	14	3	8	0.26	24	20	25	490	28.77	Good
4	Hauda Talab, Kakori	7.9	244	14	2.7	4	0.27	27	15	20	350	29.81	Good
5	Chilauli,kakori	7.9	245	15	2.1	5	0.58	26	25	17	440	35.42	Good
6	Bharosa,Kakori	8	216	7.1	2.7	5	0.52	20	30	25	350	35.82	Good
7	Chandraval, Sarojini nagar.	8.1	366	18	4.8	12	0.42	30	24	8	550	41.08	Good
8	Chandraval	8	299	14	2.8	14	0.62	32	28	10	410	40.66	Good
9	Natkur, SN	7.8	287	28	3.5	10	0.48	31	23	8	480	35.74	Good
10	Bhaisora, GN	8.1	159	14	2.1	8	0.22	24	15	12	260	26.93	Good
11	Jagpalkhera,GN	8	178	14	2.5	8	0.24	27	17	14	270	28.38	Good
12	Semra, Chinhat	8.1	189	7.1	1.2	2	0.25	22	20	24	280	29.63	Good
13	Rehmanpur, Chinhat	8	175	8	2.5	1	0.29	25	22	25	240	30.21	Good
14	Ganashpur, Chinhat	8.05	287	7.5	0.7	4	0.29	22	24	23	230	34.64	Good
15	Dhawa, Chinhat	7.8	195	10	2.5	4	0.25	24	24	22	250	29.84	Good
16	Murlipur, Chinhat	7.7	232	9	1.3	2	0.16	25	21	24	260	28.48	Good
17	Rasoolpur ,Chinhat	8	145	7.1	2.7	5	0.65	26	25	26	240	29.54	Good
18	Gadahi, Chinhat	8.1	234	7.5	2.1	2	0.46	22	21	25	230	33.47	Good
19	Basha, Kursi road	8.1	268	11	0.9	7	0.43	44	30	5	410	40.18	Good
20	Newajpur, Kursi road	8	287	14	1.2	5	0.79	30	35	3.5	420	42.49	Good
21	Sabhakhera, Mohanlalganj	7.8	366	18	2.7	5	0.69	20	30	35	580	42.24	Good
22	Kalli Pachim, Mohanlalganj	7.9	305	11	2.5	2	0.32	25	28	32	570	37.32	Good
23	Gareniankhera, Mohanlalganj	7.7	217	14	1.1	4	0.44	20	24	30	460	31	Good
24	Amola,Mohanlalganj	7.9	220	11	3.2	5	0.55	22	20	28	380	32.53	Good
25	Matee, Mohanlalganj	7.8	240	12	2.1	4	0.52	28	25	30	460	31.21	Good
26	Harkansgadhi, Mohanlalganj	7.6	250	14	2.3	5	0.44	20	20	33	450	30.55	Good

Table 1. Contd.

27	Dalona, Mohanlalganj	7.5	230	11	2.5	4	0.78	25	22	35	370	34.45	Good
28	Nagar, Mohanlalganj	7.6	219	13	1.4	2	0.05	28	30	34	430	31.06	Good
29	Gopalkhera, Mohanlalganj	7.8	250	14	2.7	3	0.45	30	25	36	520	31.86	Good
30	Pursaini, Mohanlalganj	7.8	230	11	2.3	2	0.69	28	26	31	490	36.11	Good

Table 2. Water quality index categories.

Water quality Index	Category
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
> 100	Unfit for Drinking (UFD)

Table 3. Parameter wise standards and their assigned weight.

S. No. (Wn)	Parameter	BIS standard	Assigned unit Wt.
1	pH Value	8.5	0.09818
2	Hardness	300.00	0.0027818
3	Chloride	200.00	0.0041727
4	Nitrates	50.00	0.00441347
5	Sulfate	250.00	0.0033381
6	Fluoride	1.00	0.8345365
7	Calcium	100.00	0.0083454
8	Magnesium	30.00	0.02738179
9	Sodium	200.00	0.0041727

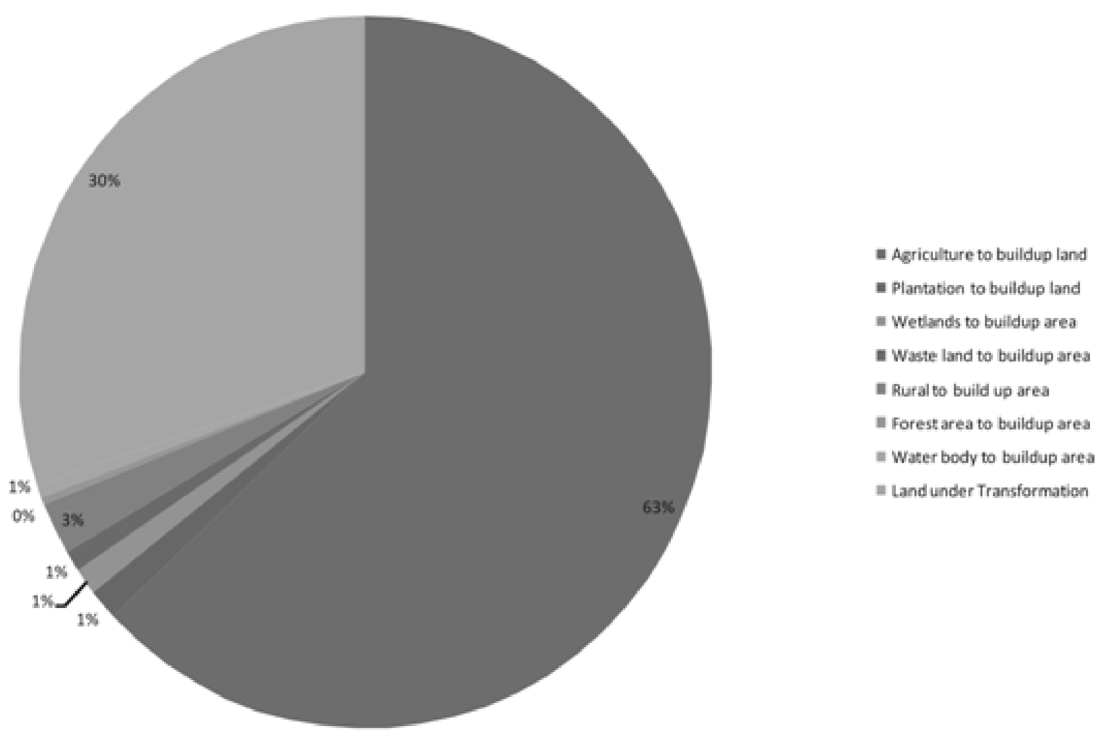

Figure 3. Pie diagram of Land transformation of Lucknow in the last 25 years.

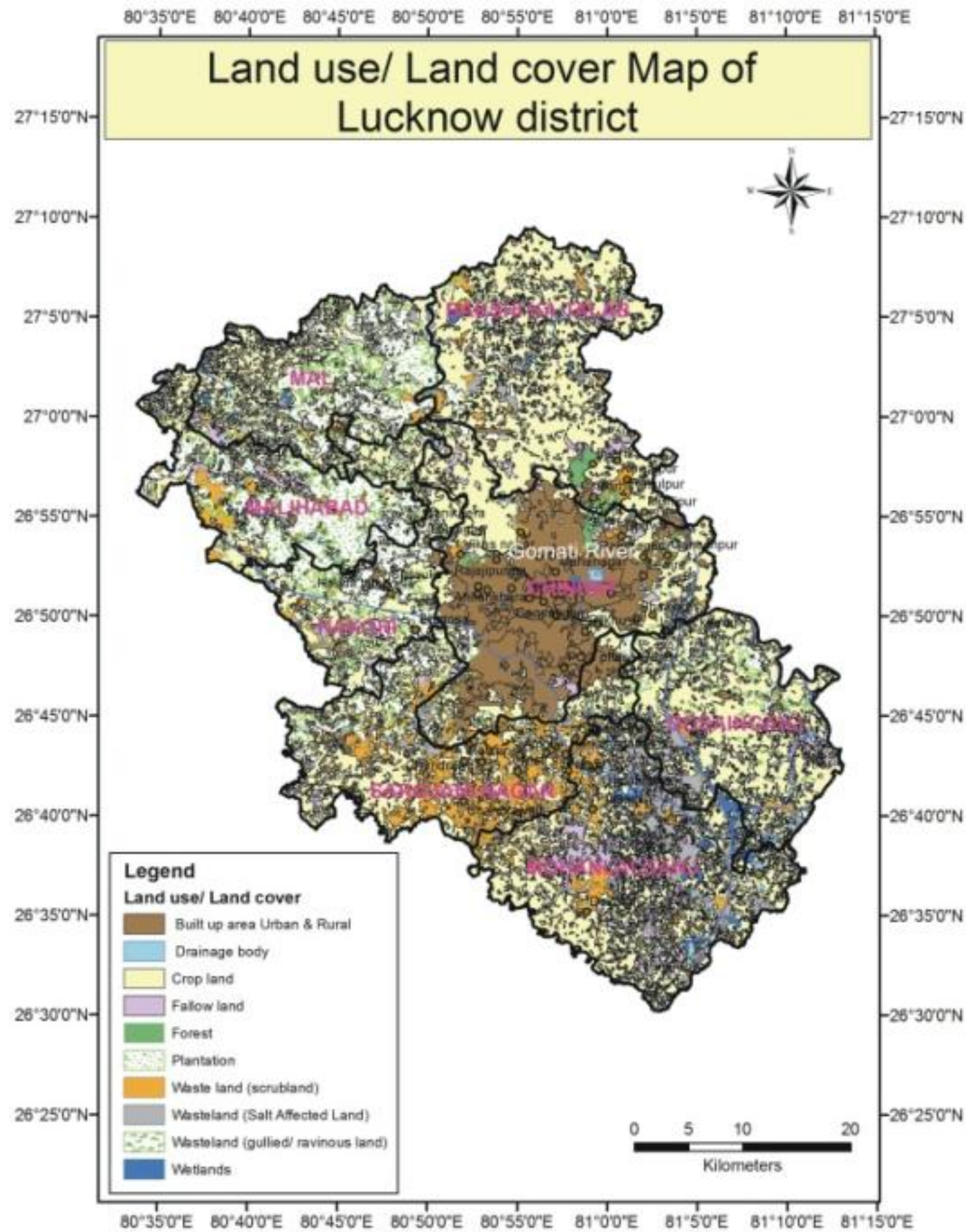

Figure 4. Landuse / Land cover map of luck now district.

RESULTS AND DISCUSSION

The land use/land cover data of the study area is showing rapid urbanization. Table 3 data shows that in last 25 years most of the land categories have changed in to buildup area. The water quality Index calculated for drinking purpose. Water quality index values shows that ground water in urban areas (Table 1) Like Dilkusha and Mahanagar is unfit for drinking, while areas like Indira Nagar, Gomti Nagar, Narhi, Gulistan colony, PQSphase cantt, Lucknow University old campus, Aminabad, New Hyderabad, Nirala Nagar, Campbell Road, Ganeshganj have very poor water quality and it is not good for human consumption. The rest of the sampling locations have comparatively good quality of water. WQI map is shown in (Figure 4) since water samples were collected from urban and sub urban areas, the water quality of the samples from urban areas was very poor but away from

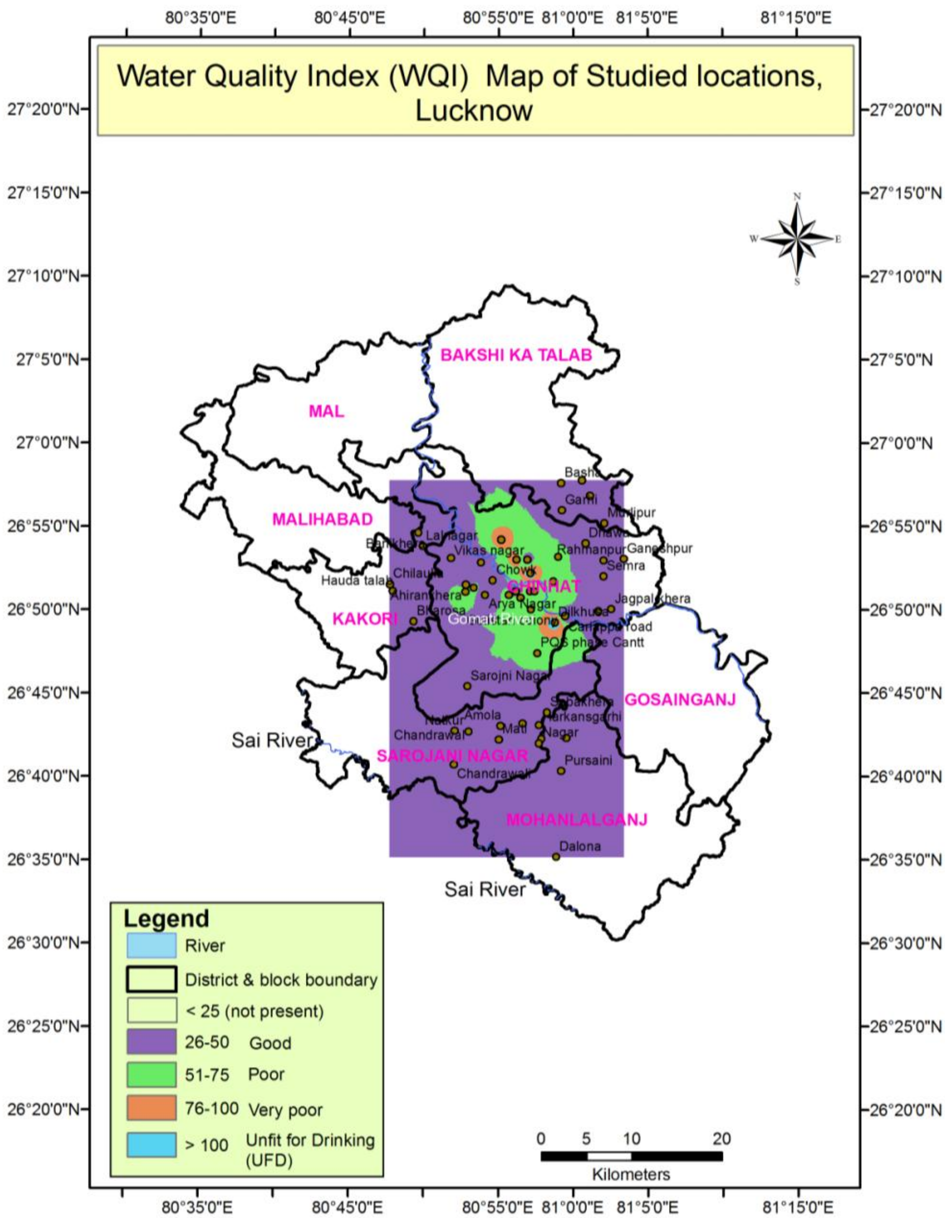

Figure 5. Water Quality Index (WQI) map.

the urban center water quality was only fairly good. The areas like Thakurganj, Newajpur and Sabha khera which are in close contact with the city areas are also showing deterioration in water quality.

The correlation of land use and water quality is depicted in Table 4. Figure 5 indicates that the extent of water quality deterioration has a linear correlation with urbanization. The water quality zones can be identified on the basis of water quality and land use. The old areas like Mahanagar, Dilkusha etc need special attention so that ground water quality can be improved. The analysis of the results drawn at various stages of work has integrated remote sensing and GIS as effective tools for the preparation of various thematic layers and final water quality zonation map and correlating it with land use map of the study area. The WQI contour map in the studied sections (Figure 6) shows that the severity of the quality deterioration is in city vicinity that is, areas like Mahanagar, Indira nagar and Dilkusha region. The close compactness of the contour shows the intense deterioration increasing at an alarming rate in the city vicinity.

Conclusion

On the basis of above discussion, it may be concluded that underground water quality in the study area is

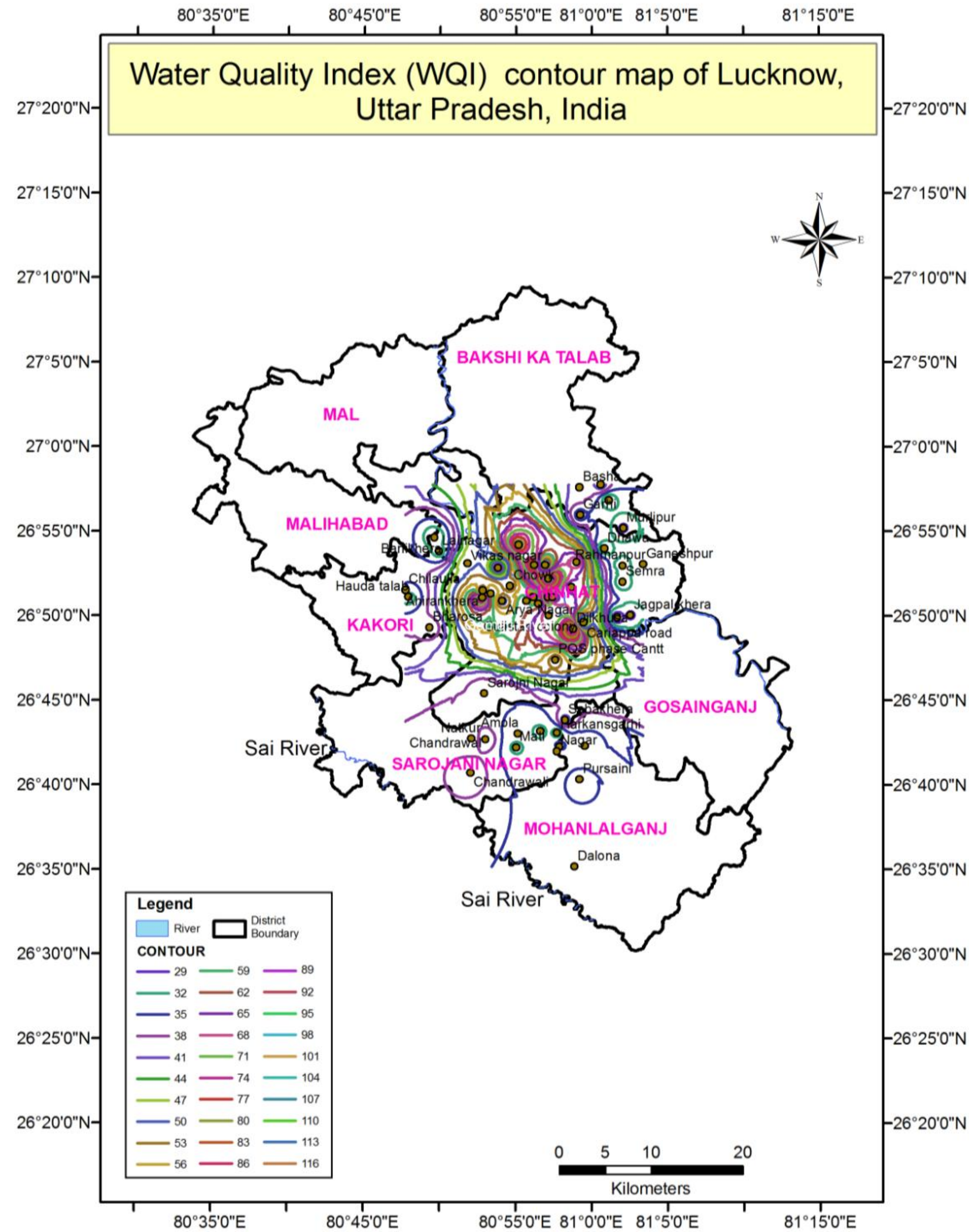

Figure 6. Contour map of the Water Quality Index (WQI) of studied location.

showing high correlation with the land use. The drinking water is highly polluted in the residential areas with high population density. The water quality of Sub urban areas having less population density and build up area are having comparatively better quality of water. Samples of suburban areas which are in close vicinity of the city like Thakurganj, Newajpur, Sabahpur are showing poor quality of water. Therefore, some effective measures are urgently required to enhance the drinking water quality by an effective management plan. the domain of the study focuses that if proper planning and measures are not taken then in the near future this will engulf the outskirts

Table 4. Land transformation of Lucknow in the last 25 years.

Categories of land transformation	Area (%)	
	(Km Sq)	%
Agriculture to buildup land	76.73	62.98
Plantation to buildup land	1.69	1.4
Wetlands to buildup area	1.45	1.19
Waste land to buildup area	1.17	0.96
Rural to build up area	2.93	2.42
Forest area to buildup area	0.39	0.32
Water body to buildup area	0.74	0.61
Land under Transformation	36.52	30.12
Total	**121.26**	**100.00**

of the city where at present the water quality is still good.

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