Prakriti- The International Multidisciplinary Research Journal
Year 2026, Volume-3, Issue-1 (Jan-Jun)

Water Quality Indexing In Gomti River Water From Its Origin To Confluence With River Ganga: A Geospatial Based Analytical Study

[1]Mamta Shukla, [2]Pallavi Singh, [3]Dr. Sudhakar Shukla,[4]Mansa Soni

[1]Project Assistant, Remote Sensing Applications Centre – Uttar Pradesh, Lucknow,226021India
[2]Project Scientist, Remote Sensing Applications Centre – Uttar Pradesh, Lucknow,226021India
[3]Scientist SE & Head, School of Geo-Informatics, Remote Sensing Applications Centre – Uttar Pradesh, Lucknow,226021India
[4]M.Sc. IInd Year, Dr. Ram Manohar Lohia Avadh University, Ayodhya (U.P.)

ARTICLE INFO

Keywords: Water Quality Index, GIS, spatial analysis, pollution assessment, River conservation.

doi:10.48165/pimrj.2026.3.1.7

ABSTRACT

River Gomti is one of the major rivers in the northern Indian state of Uttar Pradesh. It flows through the fertile plains of Uttar Pradesh, serving as a lifeline for millions of people along its course. The river has significant cultural, historical, and ecological importance, deeply embedded in the heritage of the region. In terms of ecology, the Gomti River supports a rich ecosystem that flourishes in and around its waters recognitions to its various flora and fauna.Water Quality Indexing of the Gomti River from its origin to its confluence with the Ganga River has become increasingly crucial due to rising pollution levels and urbanization impacts. This study employs geospatial techniques and comprehensive water quality analysis to assess the river health across its entire stretch. Total 39 water samples were collected from multiple monitoring stations strategically located from the river's origin at Gomat Taal (Pilibhit) to its confluence point with the Ganga River at kaithi (Ghazipur). The analysis incorporated key physicochemical parameters including dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), pH and electrical conductivity. Geographic Information System (GIS) tools were utilized to create spatial distribution maps of water quality parameters and calculating Water Quality Index (WQI) values. Results indicated significant spatial variations in water quality, with deteriorating conditions observed in urban segments, particularly near Lucknow. The study revealed that approximately 45% of the river stretch falls under the 'poor' to 'very poor' water quality categories, primarily due to untreated sewage discharge and industrial effluents. This research provides crucial baseline data for river management authorities and highlights areas requiring immediate intervention for pollution control and ecosystem restoration.

Introduction:

Surface waters are particularly susceptible to pollution because they are easily accessible for wastewater disposal. The quality of surface water in an area is determined by a combination of anthropogenic factors, such as urban, industrial, and agricultural activities, as well as natural processes, such as precipitation inputs, erosion, and weathering of crustal materials, as well as increased exploitation of water resources (Carpenter et al., 1998; Jarvie et al., 1998).

Corresponding author
Email: :mamtashukla2202@gmail.com

Originating from Gomat Taal in the Pilibhit district, the river flows through various urban and rural landscapes for approximately 960 kilometers before merging with the Ganga River at kaithi, Ghazipur. As it passes through Uttar Pradesh densely populated regions, the river gathers a lot of industrial and anthropogenic contaminants. The Gomti environment is negatively impacted by high pollution levels in the river, endangering its aquatic life. Gomti gets garbage from the Sitapur district distillery and sugar industry before arriving in Lucknow. In recent decades, rapid urbanization, industrial growth, and agricultural intensification along its banks have posed significant challenges to maintaining the riverwater quality.River pollution must be prevented and controlled and accurate data on water quality is essential for efficient management, as rivers are the primary inland water resources used for agriculture, industry, and residential reasons. Regular monitoring procedures are essential for accurate water quality estimations because of the temporal and spatial fluctuations in river hydrochemistry.Anthropogenic stresses on the Gomti River system include runoff from agriculture, industrial effluents, untreated household sewage, and religious activities. To comprehend the distribution and intensity of pollution loads, a thorough geographical analysis is required because these pressures differ greatly throughout the river path. The decline in water quality is closely linked to human-induced changes (Haldar et al., 2014). Farmers utilise a variety of substances such as pesticides, herbicides, and fertilizers, to boost agricultural yields, which adds pollutants to the river (Rashid and Romshoo, 2013; Yang et al., 2013). Pollutants are brought into municipalities by direct garbage disposal, downpours runoff, and leachates from landfills (Tsihrintzis and Hamid, 1997).

The Water Quality Index (WQI) is a numerical tool that provides a single value expressing overall water quality at a specific location based on several water quality parameters. It transforms complex water quality data into simple and easily understandable information. Srivastava and Srivastava (2018) developed a comprehensive WQI for the Gomti River using 15 physicochemical parameters collected from 39sampling stations along the river course. Their study established that WQI values worsened significantly as the river passed through urban areas, with values ranging from 38 (good quality) at the origin to 118 (very poor quality) in downstream sections after Lucknow.This study presents a comprehensive methodological framework for integrating geospatial techniques with Water Quality Index (WQI) assessment to enhance water quality monitoring and management. A widely used technique for assessing the water quality in aquatic bodies, the WQI method is straightforward but effective, and it is becoming more and more important in the management of water resources (Abbasnia et al., 2018, 2019; Machiwal et al., 2019; Saleh et al., 2019; Wang et al., 2017; Wu et al., 2018; Yousefi et al., 2017). The study combines Geographic Information Systems (GIS), spatial statistics, and traditional water quality parameters to develop a robust spatial analysis approach for water quality assessment across various geographical scales. Advanced spatial interpolation techniques, including Inverse Distance Weighting (IDW), are employed to generate continuous surfaces of water quality parameters. Tripathi and Kumar (2019) applied spatial interpolation techniques including Inverse Distance Weighting (IDW) and Kriging to generate continuous water quality parameter surfaces from discrete sampling points. Their research demonstrated strong spatial autocorrelation for most water quality parameters, allowing for accurate estimation of water quality between sampling locations.

This study supports the Gomti River drinking water quality exclusively. Water is classified into three categories—desirable, permissible, and non-desirable—in accordance with national and international drinking water standards. GIS and Remote Sensing are essential tools for identifying and determining the chemical, physical, and biological variability in the groundwater and surface water in a given area. In addition to being time and money efficient, Remote Sensing provides wide coverage of both space and time. Establishing a connection between water quality measures and LULC changes is challenging due to the regional and temporal variability of water quality trends (Phung et al., 2015; Russell, 2015).Water quality degradation brought on by direct and indirect human involvement depletes available water supplies, endangering ecosystem services, human health, and national security (Sotomayor et al., 2018). The purpose of this study is to provide insight into how encroachment & mismanagement affects the Gomti River water quality from its origin to confluence with river Ganga.Evaluating the Gomti River encroachments effects on water quality requires an understanding of both its spatial distribution and intensity.Rai et al. (2023) documented significant seasonal variations in the Gomti River's water quality. Their two-year study revealed that WQI values deteriorated most severely during pre-monsoon periods (March-May) when river discharge is minimal, while showing relative improvement during monsoon months due to dilution effects. However, they noted that even during periods of improved water quality, most urban and downstream sections remained in the "poor" to "very poor" quality categories.

Objectives of the study

The objectives have been laid out as following –

1 Assessment of physicochemical parameters at selected locations in entire route of River Gomti.

2 Spatial distribution of different parameters.

3 Water Quality Index calculation.

4 Spatial distribution of water quality index.

Study Area:

The Gomti River is an alluvial river of the Ganga Plain and a significant tributary of the Ganga. It rises from a lake in Madhotanda called "FulharJheel" located on the 28°34'N latitude and 80°07'E longitude. At a height of 185 meters, this area is roughly 30 kilometers east of the Uttar Pradesh town of Pilibhit (approximately 55 kilometers south of the Himalayan foothills). The river travels through a valley that has been cut into it after passing through the districts of Sitapur, Lucknow, and Jaunpur on its journey south to meet the Ganga River near Kaithi*(shown in fig.1)*.From its origin, the Gomti flows in a south and south-east ward direction and plunges into the river Ganga after traversing a distance of 960 km with an average elevation of 200 m (660 ft) above the mean sea level.

The **Gomti River Basin** can be divided into three main segments based on its geographical and hydrological characteristics:

1 Upper Segment (Origin): The Gomti River originates from **Madhotanda** near **Pilibhit** in Uttar Pradesh. This segment mainly consists of small streams, wetlands, and marshes. The River in this region is shallow and narrow, with slow-moving water. The upper segment is heavily dependent on rainfall, and during the dry season, the river's flow reduces significantly.

2 Middle Segment (Main Flow through Urban Areas): The River expands as it flows through **Sitapur, Lucknow, and Barabanki** districts, receiving water from various tributaries such as **Kathina, Sai, and Reth**. This section experiences increased **urbanization and industrialization**, leading to pollution from sewage discharge and industrial effluents, especially in **Lucknow**.The river is a major source of water for irrigation, industries, and drinking purposes in the cities along its course. The middle segment is characterized by floodplains and oxbow lakes, which are important for biodiversity and groundwater recharge.

3 Lower Segment (Confluence with the Ganga): The river continues flowing eastward through **Sultanpur, Jaunpur, and Varanasi districts** before joining the **Ganga River at Kaithi (Ghazipur district)**.This segment has a **broader river channel** with increased sediment load due to soil erosion upstream.The river's water quality further deteriorates due to agricultural runoff, untreated sewage, and industrial waste. The confluence with the Ganga is ecologically significant, supporting aquatic biodiversity, including fish species that contribute to local fisheries.

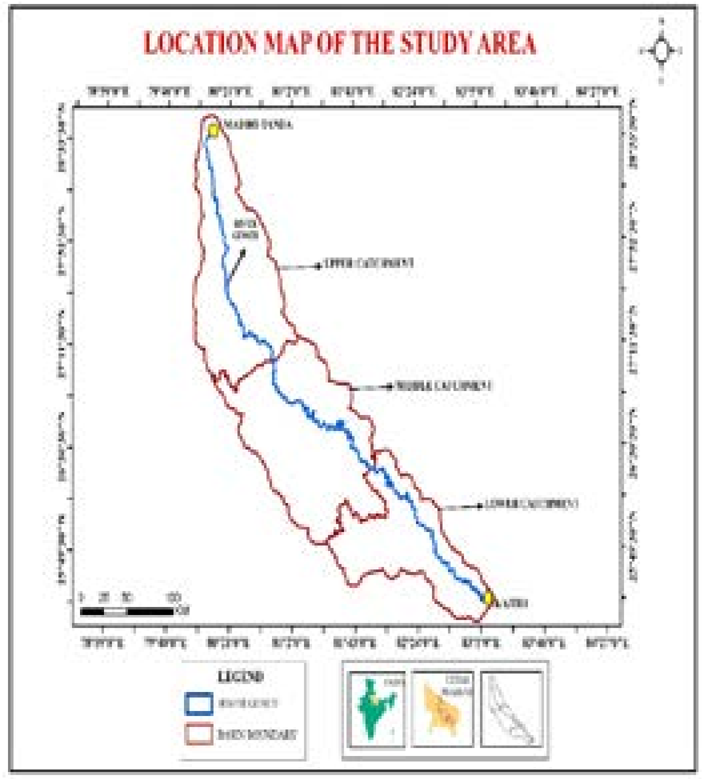


Fig 1: Location Map of the Study Area

The Gomti River basin is located in the Indian state of Uttar Pradesh, covering an area of approximately 30,437 square kilometers.The Gomti River originates from the Gomat Taal lake in the Pilibhit district of Uttar Pradesh, at an elevation of about 200 meters above mean sea level.The Gomti River basin's latitude and longitude are 25° 39' 9.36" N and 82° 48' 7.92" E, respectively.

The Gomti River flows through the districts of Pilibhit, Shahjahanpur, Farrukhabad, Hardoi, Unnao, Raebareli, and Lucknow, before merging with the Ganges River at Kaithi, near the city of Varanasi.The Gomti River has several tributaries, including *the Sarayan, the Chauka, the Sai, and the Kathina.* The Gomti River basin is a part of the Ganga-Brahmaputra river system and is characterized by a flat to gently sloping terrain, with an average elevation of about 100-150 meters above mean sea level.The Gomti River basin experiences a subtropical climate, with hot summers and cool winters. The average annual rainfall in the basin is around 800-1000 mm.The Gomti River basin is primarily an agricultural region, with crops like wheat, rice, sugarcane, and maize being majorly cultivated. The basin is also home to several urban centers, including the city of Lucknow.The Gomti River basin is underlain by a sequence of sedimentary rocks, including sand, silt, and clay, which are deposited by the river and its tributaries. The basin is also characterized by the presence of several faults and fractures, which have a significant impact on the groundwater flow and quality.

The Gomti River basin, located in the middle Ganga plain, Uttar Pradesh, North India, has several key hydrological characteristics.The basin exhibits a sub-dendritic to dendritic drainage pattern, indicating that the Gomti River follows the natural gradient of the terrain.The drainage density of the basin is relatively low, ranging from 0.39 to 0.4, which suggests that the basin has highly permeable subsoil and thick vegetative cover .The stream frequency of the basin is around 0.09, indicating a moderate density of streams.

DATA USED:

A.**Topographical sheets from the Survey of India** Using the Arc GIS platform, the research area has been extracted by georeferencing the topographical sheets that were acquired from the Survey of India site. Following S.O.I. toposheets are 62D/2, 62D/3, 62D/4, 62D/8, 63A/1, 63A/5, 63A/6, 63A/7, 63A/11, 63A/12, 63A/16, 63B/13, 63F/1, 63F/2, 63F/5, 63F/6, 63F/10, 63F/11, 63F/14, 63F/15, 63J/3, 63J/4, 63J/8, 63K/5, 63K/9, 63K/10, 63K/14, 63O/2, 63O/3 used for the same.

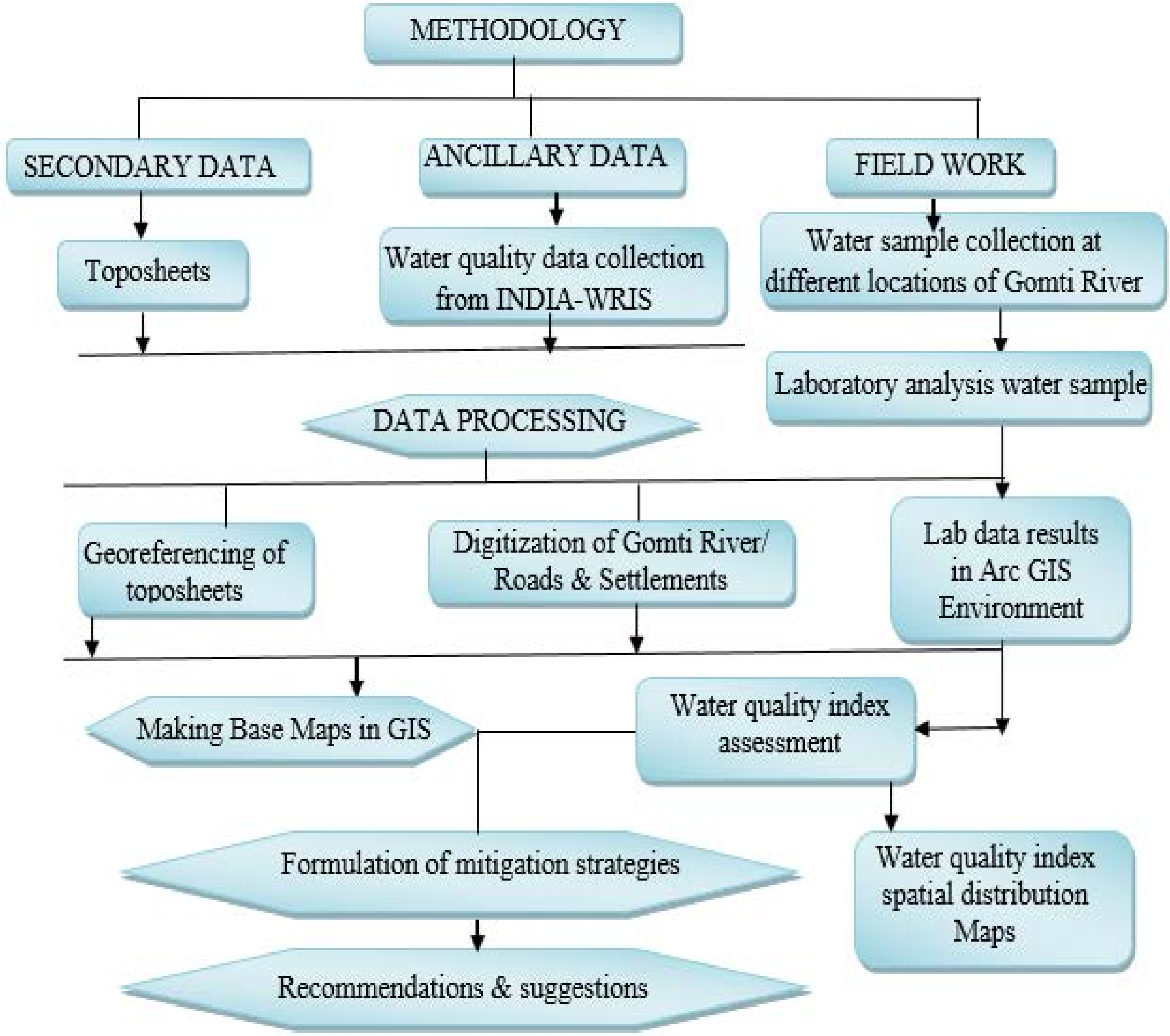
B. Ancillary Data: To assess, monitor, analyze, and prepare the dataset for the study region, a variety of auxiliary data from various sources were used. We gathered parameter-wise water quality data from **India-WRIS** (India-Water Resource Information System) along with sampling sites and locations for the years between 2020-23. It serves as a repository for data on water resources around the country, offering a centralized location for up-to-date information on water resources and related topics. Research Gate, Scholar's Data, Google, Chrome, and other sources are also used to create/collect datasets for the subject areas of investigation. Water quality parameters with their desirable and non-desirable limits are mentioned in table:1.

TABLE.1 Drinking water standards (International Standards WHO-1971, CMR, New Delhi Second Edition and ISI 10500 (1991)

S.No.	Water Quality Parameters	Desirable Limit	Permissible Limit
1	Calcium	75 (mg/L)	200 (mg/L)
2	Chloride	200 (mg/L)	600 (mg/L)
3	Electrical Conductivity	800 (μS/cm) at 25°C	2500 (μS/cm) at 25°C
4	Fluoride	0.7 (mg/L)	1.0 (mg/L)
5	Magnesium	30 (mg/L)	100 (mg/L)
6	Sulphate	200 (mg/L)	400 (mg/L)
7	pH	7.0 to 8.5	8.5 to 9.2
8	TDS	500 (mg/L)	1500 (mg/L)
9	Total Hardness	100 (mg/L)	500 (mg/L)
10	Potassium	12 (mg/L)	55 (mg/L)
11	Sodium	20 (mg/L)	200 (mg/L)
12	Bicarbonate	400 ppm	1000 ppm
13	Silicate	50 (mg/L)	100 (mg/L)
14	Total Alkalinity	30 (mg/L)	400 (mg/L)
15	Nitrate	45 (mg/L)	No relaxation
16	BOD	20 ppm	30 ppm
17	Boron	0.5 (mg/L)	1.0 (mg/L)
18	DO	4-6 (mg/L)	6-8 (mg/L)
19	Fecal Coliform	0 (mg/L)	1000 (mg/L)
20	Temperature	10 degree C	22 degree C
21	Total Coliform	0 (mg/L)	1000 (mg/L)
22	Turbidity	5 JTU	25 JTU
23	COD	200ppm	250ppm

Methodology

The methodology adopted in the execution of the aforesaid study has been discussed in given figure:



A total of 29 toposheets were obtained from the Survey of India, are shown in table no.1, in order to depict the water quality of the chosen location. Following the georeferencing process of every toposheet downloaded from the Survey of India, the region of interest was retrieved. The study region was then extracted by mosaicking all of the toposheets. The Gomti River stretch (Study region) has been created from SOI toposheets and subsequently digitized onArc/GIS platform. Various satellite data and auxiliary data have been combined for the purpose of studying and evaluating the water quality of the chosen study region using GIS software (Arc GIS 10.4).

The surface water data collected from different locations of the River Gomti & the auxiliary data taken from India Water Resource Information System (WRIS) sitehave been compiled on an Excel sheet to make a seamless data for entire length of River Gomti. Creating a shape file, the same data was superimposed onGoogle Earth in order to evaluate the Gomti River surface water quality. Using the IDW process, the spatial analyst toolon Arc/GIS platform, the water quality parameters for different Chemical & biological parameters such as(pH, temperature, turbidity, TDS,DO, BOD, COD, and nutrients like nitrogen and phosphorus, and biological parameters incorporates bacteria, viruses, and other microorganisms)have been assessed which is shown in *Table 2*.These parameters have been usedto analyze and monitor the water quality. Using these information WQI of all the three segments of the Gomti river have been estimated separately and spatial extent has been mapped using IDW techniques.

For millions of people living along the banks of the river Gomti, the samewater is essentiallyused for drinking, farming, and industry purpose. However, a number of problems including urbanization, industrial discharge, agricultural runoff, and untreated sewage at number of places, have negatively impacted the Gomti River's water quality over the time. In the Gomti River Basin, surface water quality monitoring and assessment are essential for both public health and water management.Water resources become scarcer due to the degradation of water quality brought on by direct and indirect human activity; this further jeopardizes ecosystem functions, human well-being, and national security (Sotomayor et al., 2018).

The Surface Water Quality Index (SWQI), which combines multiple water quality characteristics into a single index number to give a thorough picture of the water's health, is one of the most efficient methods of evaluating the quality of the water. Usually, these criteria consist of a measurement of alkalinity or acidity that affects water's biological activity which is termed as pH.The amount of oxygen accessible for aquatic life is indicated by dissolved oxygen (DO), the amount of organic matter in the water and its capacity to deplete oxygen are reflected in the biochemical oxygen demand, or BOD and an indicator of waters salinity or mineral makeup is termed as TDS. There are several reasons why the Gomti River Basin WQI geographical distribution can differ greatly:

a)**Urban and Industrial Areas:** Waste from nearby communities, untreated sewage, and industrial effluents all play a major role in pollution in cities like Lucknow, Sultanpur, and other towns along the river. Higher levels of BOD, TDS, and pathogens typically indicate deterioration in the water quality in these places.

b)**Agricultural Runoff:**Rice, wheat, and sugarcane are among the many crops that are widely grown in the basin's agricultural sector. Water bodies become eutrophic as a result of the runoff of excess nutrients, particularly nitrogen and phosphorus, caused by the use of chemical fertilizers and pesticides. Thisphenomenon is seen in rural river segments where fertilizer loading causes DO levels to drop and water quality to deteriorate.

c)**Land Use and Vegetation:** Water quality is often higher in forested and less developed areas of the Gomti River Basin. Because riparian vegetation serves as a buffer to lessen contamination from surface runoff, these places typically have greater natural filtration.

d)**Wastewater Treatment and Management:** Water quality is significantly impacted by the existence of wastewater treatment facilities (WWTPs) and the effectiveness of their operations. The river receives a lot of organic waste in places with poor or non-existent sewage treatment, which raises BOD and lowers DO.

e)**Monsoon and Seasonal Variations:** The water quality spatial distribution is greatly influenced by the monsoon season. Water quality may temporarily deteriorate as a result of heavy rains washing pollutants into the river, increasing the nitrogen content and sediment load. However, as the flow stabilizes and pollution sources are diffused, water quality may somewhat improve during dry spells.

Water Quality Index& its Calculation

Water Quality Indexing (WQI) is a mathematical method used to assess and communicate the quality of water in a specific location, such as a river, lake, or groundwater source. It's a way to summarize complex water quality data into a single number or rating, making it easier to understand and communicate to stakeholders. There are three main parameters which are used for calculation of WQI.**Physical parameters** such as pH, temperature, turbidity, and total dissolved solids., others is **Chemical parameters**which are dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and nutrients like nitrogen and phosphorus and third one is**Biological parameters** which incorporates presence of bacteria, viruses, and other microorganisms.

WQI provides a single, easy-to-understand value that represents the overall water quality.It allowscomparison of water quality between different locations and over time andhelps policymakers, water managers, and stakeholders make informed decisions about water management, conservation, and treatment.WQI can be used to communicate water quality information to the public, raising awareness about the importance of water quality and the need for conservation efforts.WQI can be used to identify areas that require improvement and to develop effective water management plans.

Relevant water quality parameters are selected based on the water body's characteristics and intended use.Water samples are collected and analyzed for the selected parameters.Each parameter is assigned a weight age based on its relative importance.The WQI is calculated using a mathematical formula that takes into account the weighted values of each parameter.

The WQI has been calculated using the following formula:

$$WQI = \sum (Wi \times Qi)$$

Where:

. Wi is the weight assigned to each parameter.

. Qi is the quality rating of the parameter, calculated as:

$$\mathbf{Qi = (Vi - V\ min \backslash Vi\ max - V\ min)} \times 100$$

Where:

Vi is the observed value of the parameter.

$Vmin$ and $Vmax$ are the minimum and maximum permissible limits of the parameter.

Spatial Distribution of Surface Water Quality Index in Gomti River Basin:

The Surface Water Quality Index (SWQI), which takes into account a number of water quality parameters like pH, dissolved oxygen (DO), biological oxygen demand (BOD), turbidity, and the concentration of nutrients like nitrogen and phosphorus, is a helpful tool for evaluating the general state of the water in a given area.The Gomti River Basin's Surface Water Quality Index (SWQI) spatially ranges from "Good" to "Very Poor"*(as shown in fig.2)*.As the river flows from NW to SE, the quality of the water declines, particularly in urban and industrialized areas. Rahman and Mukhopadhyay (2024) specifically examined the mixing zone where the Gomti joins the Ganga River. Their research employed hydrodynamic modelling integrated with water quality sampling to characterize pollution dilution patterns. They found that complete mixing of Gomti water with the Ganga occurred approximately 5 km downstream from the confluence point, with water quality gradually improving due to the Ganga's higher discharge and relatively better water quality.

Improving the water quality in the Gomti River Basin requires effective management techniques, such as enhanced wastewater treatment, better farming methods, and more stringent pollution control laws.

Table 2. Water Quality Index Calculation with Status

LOCATION	WATER QUALITY INDEX	STATUS
Fulhar Lake, Madho Tanda	13.1702	Excellent
Puranpur	13.1706	Excellent
Puranpur	13.1705	Excellent
Paliakalan	28.7767	Good
River Gomti At Mohmeak D/s	1.7867	Excellent
River Gomti At Mohmeak U/s	1.8318	Excellent
River Gomti At Bhatpur D/s	2.011	Excellent
River Gomti At Bhatpur U/s	2.1116	Excellent
Gomti At Sitapur U/s At Water Intake	79.1712	Very poor
Neemsar	85.41155	Very poor
Sitapur	86.4999	Very poor
Chandrika Devi	57.36	Poor
Gomti At Lucknow D/s	139.15	Unfit
Gomti At Lucknow U/s	100.55	Very poor
Gomti Nagar	96.97	Very poor
Lucknow (Hanuman Setu)	36.21	Good
Gaughat	50.407	Good
KudiaGhat	40.801	Good
Bairrage	41.802	Good
River Front	50.04	Good
Pipraghat	1.902	Excellent
Mohan Meakins	1.637	Excellent
River Gomti At Gangaganj U/s	165.82	Unfit
River Gomti At Sultanpur D/s	1.7001	Excellent
River Gomti At Sultanpur D/s	171.04	Unfit
River Gomti At Sultanpur U/s	41.26	Good
Sultanpur	168.41	Unfit
Kurwar	158.07	Unfit
Golaghat	147.96	Unfit
Shmashan-Ghat	163.17	Unfit
Paperghat	148.96	Unfit

Dhopapghat	165.76	Unfit
Gomti At Jaunpur D/s	26.96	Good
Jaunpur (MG Marg Bridge)	28.46	Good
Maighat	91.01	Very poor
River Gomti At Jaunpur U/s	1.946	Excellent
River Gomti At Pipraghat D/s	3.36	Excellent
River Gomti At Pipraghat U/s	96.58	Very poor
River Sai At Jalalpur	45.96	Good

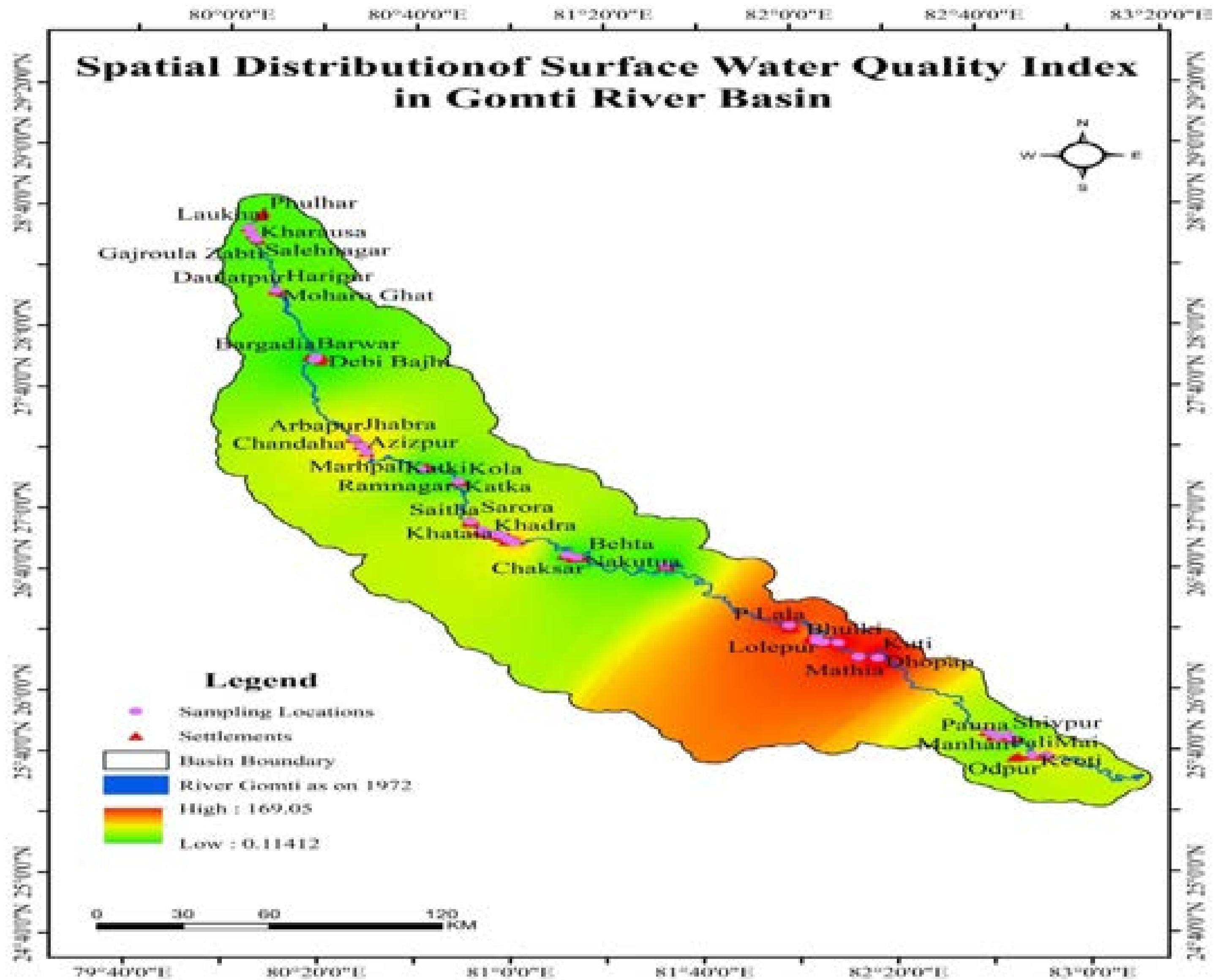


Fig 2: Spatial distribution of surface water quality in Gomti River Basin

Spatial Distribution of Surface Water Quality Index in Upper Catchment:

The upper stages of the river, which are close to the Himalayan foothills, have a somewhat excellent water quality index. Pollution levels are low to moderate in these areas. Upper part of the Gomti River basin i.e. *Fulhar Jheel* to *DebiBajhi* areas often have *lower pollution concentrations and better water quality because thereisless industrial and pollution activity*.Since the river absorbs less pollutant before passing through metropolitan areas, the SWQI often shows **"Good"** to **"Fair"** quality in these places. In *Biharipurm. Rampur fakir* village of Pilibhit district, the Gomti river experiences almost 370m of dry patch. Further downstream at *Suhela* village in Lakhimpur district, a dry patch has been observed.

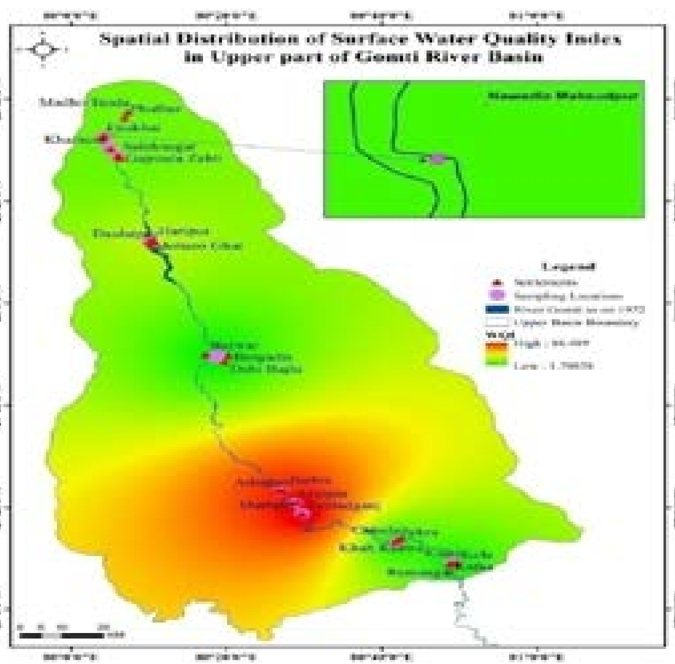
There are different levels of water contamination in the upper part of the basin of the Gomti River, as indicated by the spatial distribution of the surface water quality index. Based on factors like pH, turbidity, total dissolved solids,the water quality index indicates a downward tendency from upstream to downstream regions. Between *Arbapur to Fauladganj* areas very high values of WQI have been observed, which are attributed to the range of **80-86 WQI**. This part of the river is experiencing anthropogenic activities in terms of encroachment.

Fig. 3-13 show the varying water quality index in upper part of the Gomti River basin at different locations. *Moharoghat, Barawar, Bargadia* are the places where agricultural encroachment in the river bed has been started.

Places like *Chandaha, Azizpur &Fauladganj* are experiencing lot of anthropogenic activities on/ near river bed and making the river water more and more polluted whereas agricultural encroachment in areas like *Pakra, Katki, Kharausa Navadia Maksudpur& Saleh nagar* has been started, which may turn river water more polluted in near future.

Some of the workers like Verma and Singh (2021) investigated the relationship between land use patterns and seasonal water quality variations using geospatial analysis. It was found that agricultural runoff contributed significantly to elevated nitrate and phosphate levels during monsoon periods, while industrial and municipal wastewater dominated pollution sources during non-monsoon periods.

Sharma et al. (2018) developed a modified Water Quality Index (WQI) specifically calibrated for the upper Gomti River, incorporating 12 physicochemical parameters collected from 14 sampling stations along the first 250 km of the river course. Their study established that the WQI values in the uppermost reaches (first 50 km) typically ranged from 34-48, indicating "good" water quality.



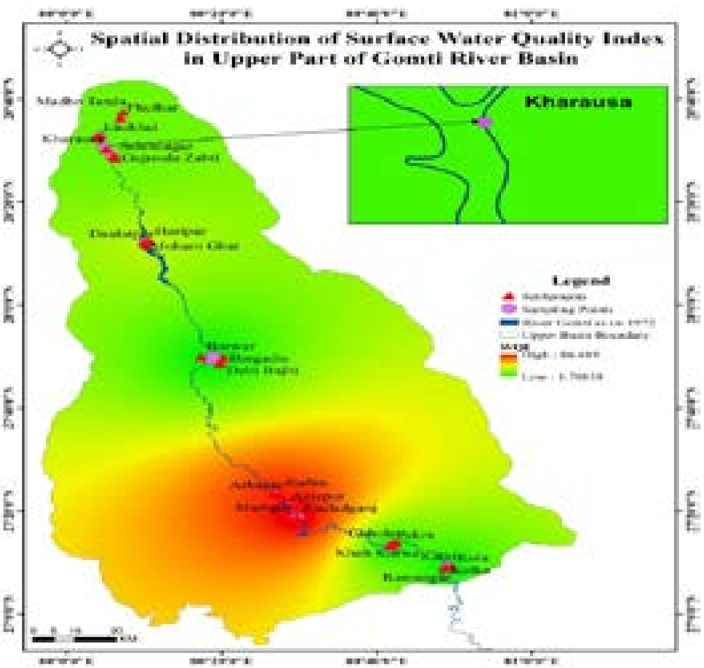
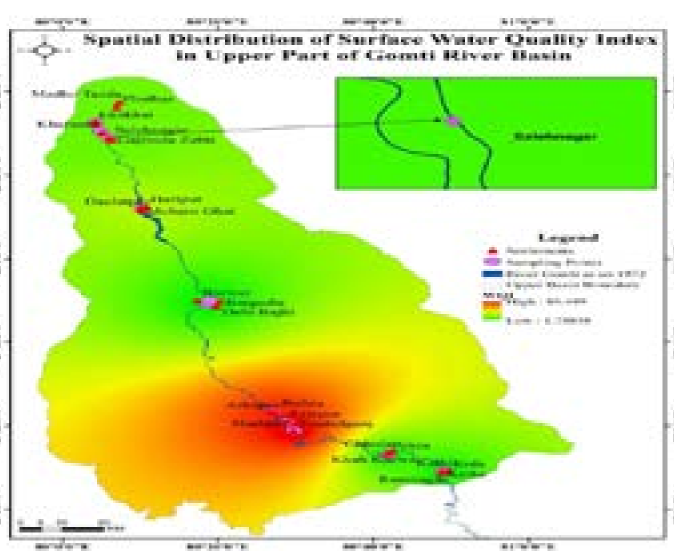


Fig.3Fig.4



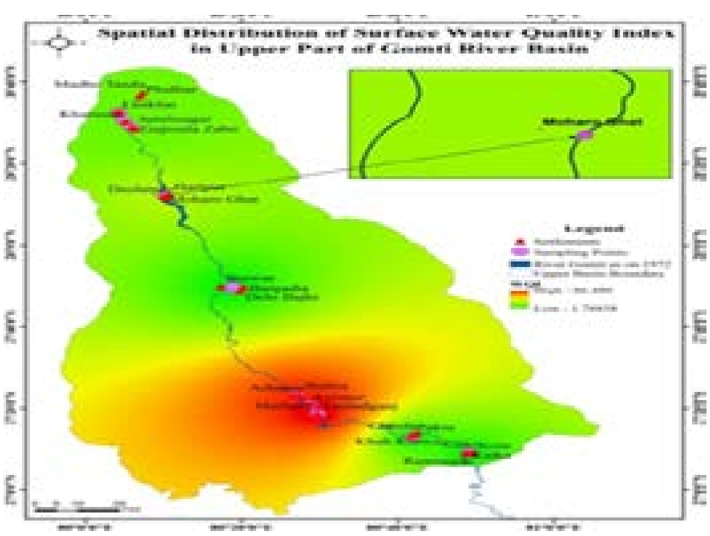
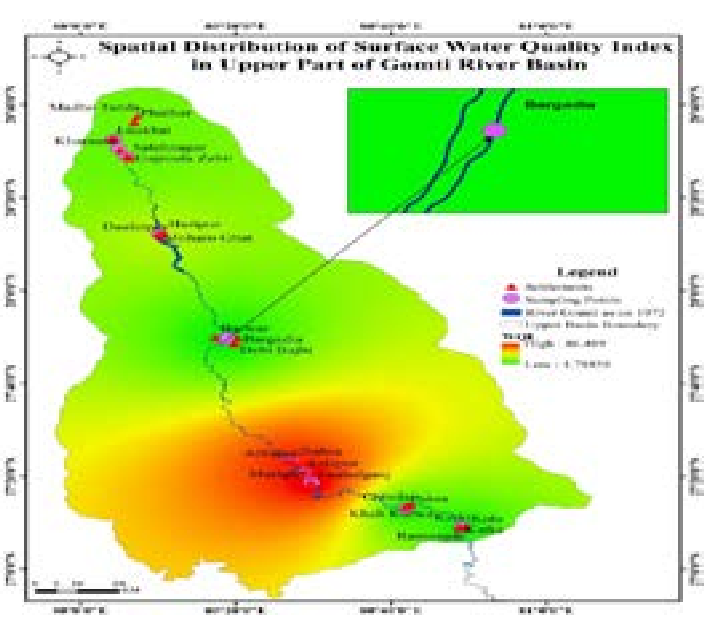


Fig.5Fig.6



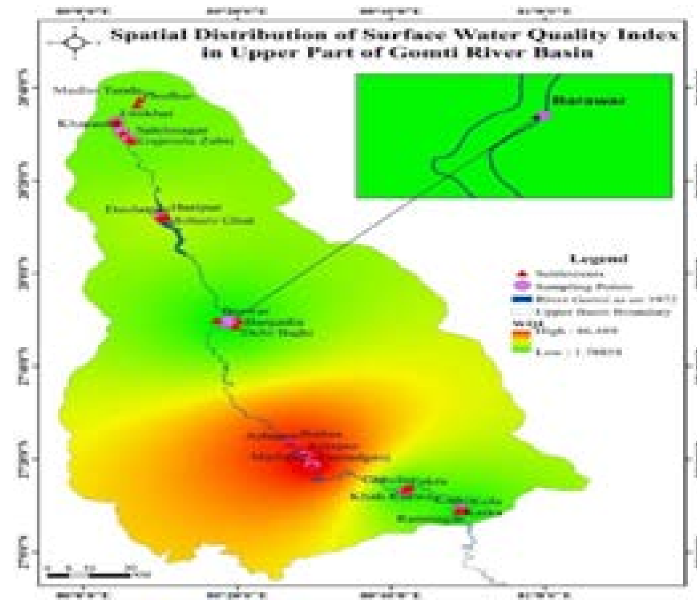
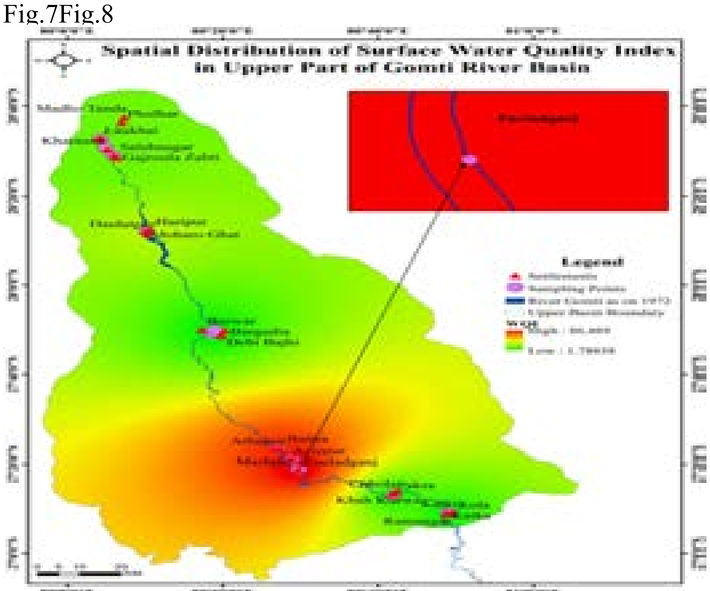


Fig.7Fig.8



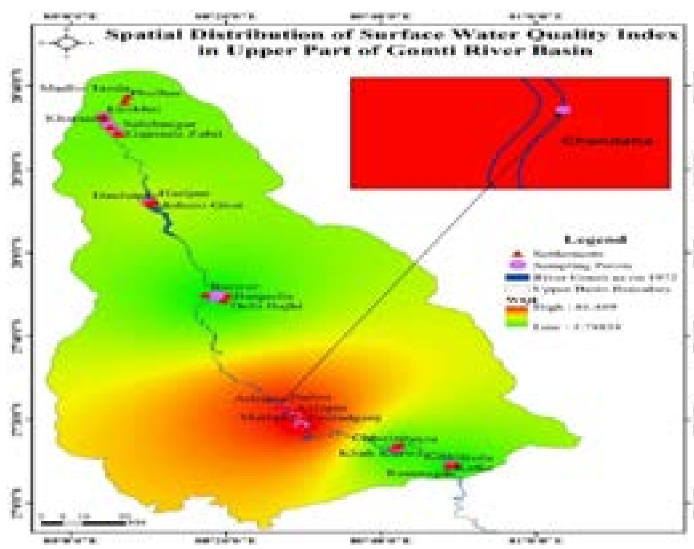


Fig.9Fig.10

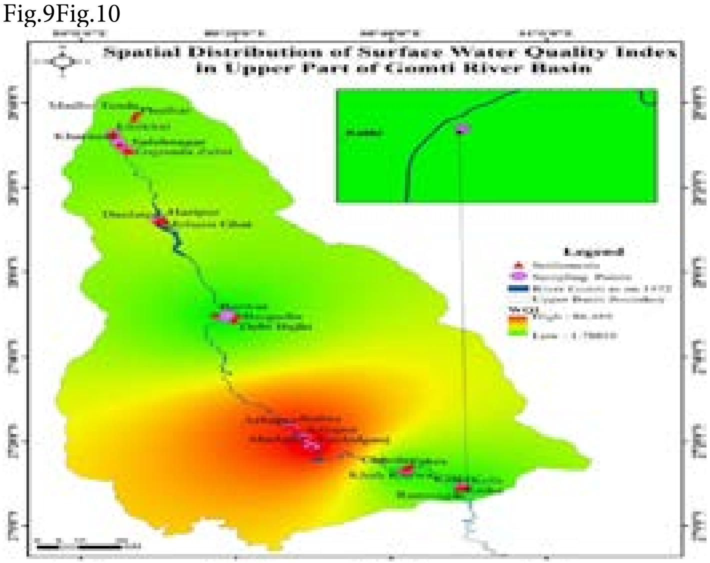


Fig 12

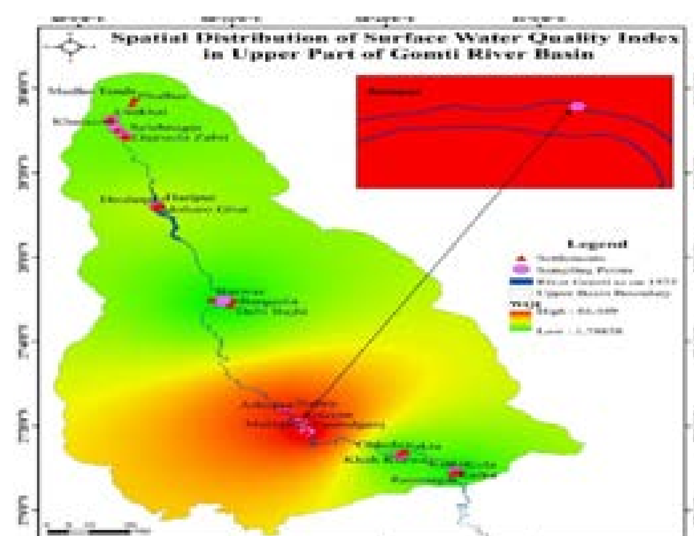


Fig 13

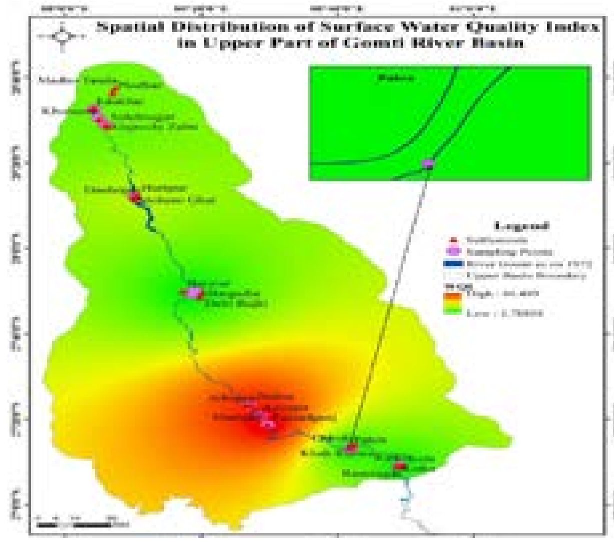


Fig.11

Spatial Distribution of Surface Water Quality Index in Middle Part of the Gomti River Basin:

The Gomti River's middle part (mainly Lucknow & Unnao District) shows a severe decline in water quality based on the spatial distribution of the surface water quality index. Due to the regions of 7[th]high population density, industrial activity, and agricultural runoff, the pollutant loading has significantly increased. This area has a high amount of pollution, as shown by the water quality index readings, which range from .002 to 137. The spatial distribution reveals that there are large quantities of bacteria, extreme utilisation of fertilizers, and other pollutants in the water, which is especially close to metropolitan centres. The wastewater from multiple industrial estates is also received by the middle catchment, which exacerbates the issue of water contamination. Kumar et al. (2019) identified critical pollution hotspots along the Gomti River course using spatial cluster analysis techniques. Their research pinpointed major drains in Lucknow including Sarkata, Patanala, and Gaughat as contributing over 60% of the total pollution load to the river. The Gomti River middle catchment water pollution problems require immediate action, as indicated by the spatial distribution of the water quality index.**Fig.14 to 25** show spatial distribution of Water Quality Index values.The spatial distribution pattern of water pollution in this area demonstrates that the water quality is especially bad in urban areas. Due to their high nutrient, bacterial, and other pollutant concentrations.The cities of Lucknow and Unnao are significant contributors to water pollution. The issue of water contamination is made worse by the effluent that the river receives from multiple industrial estates which are located on either banks of the river Gomti.

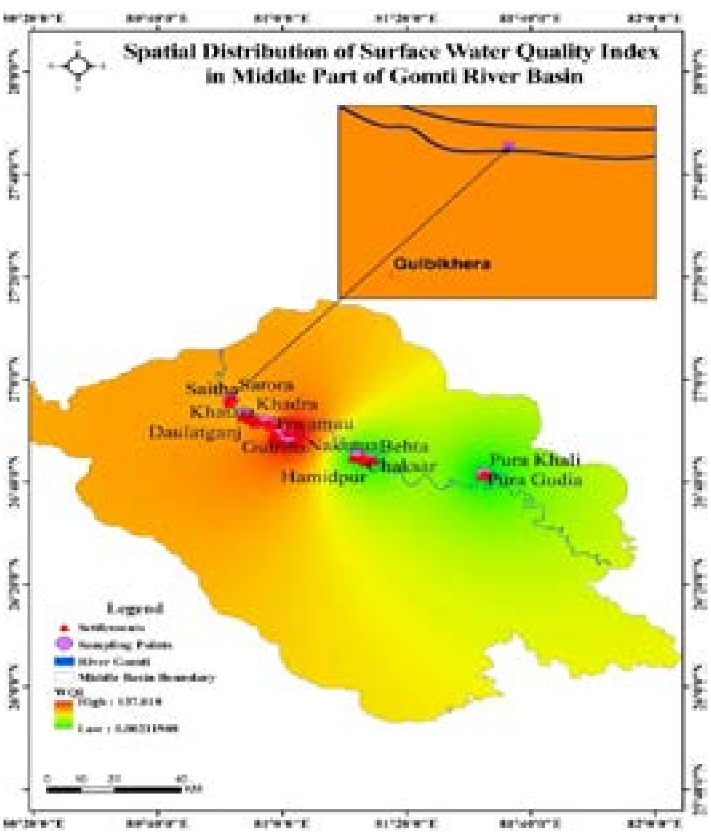


Fig.14

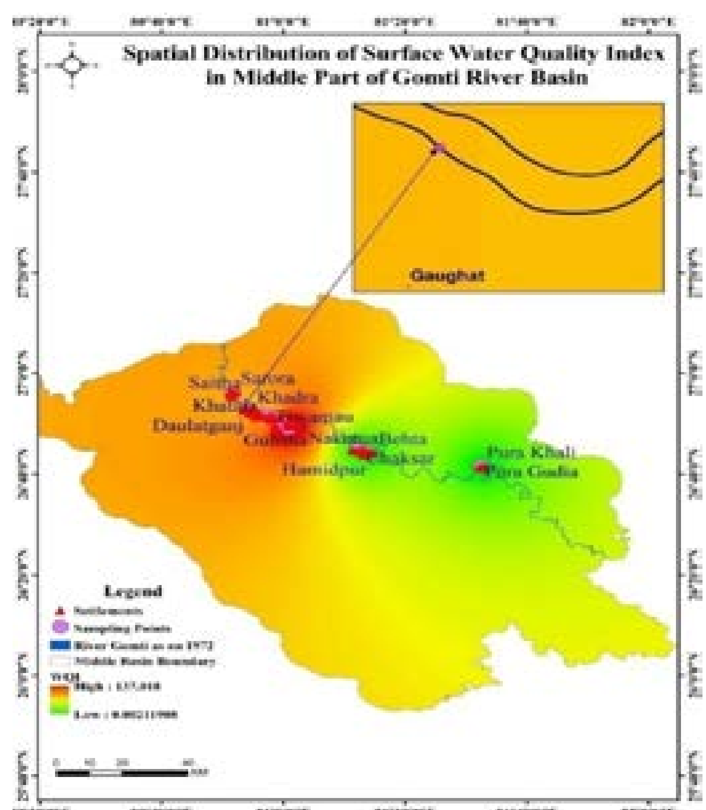


Fig.15

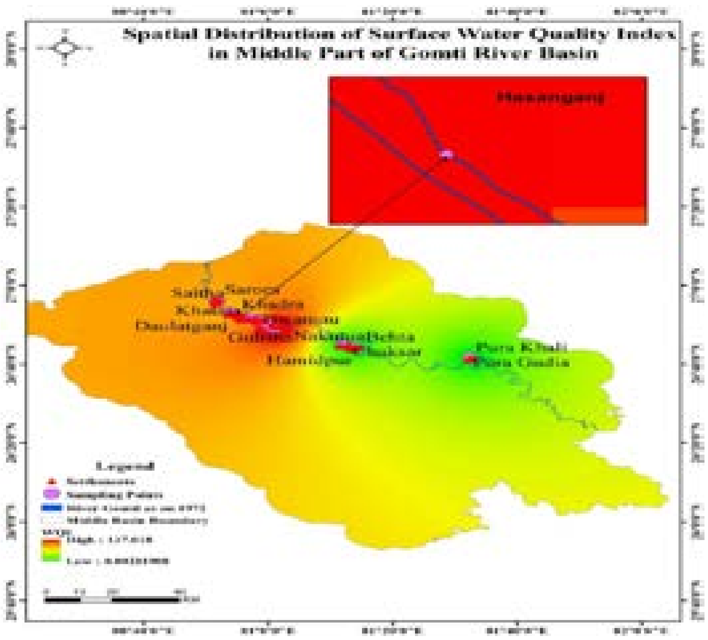


Fig.16

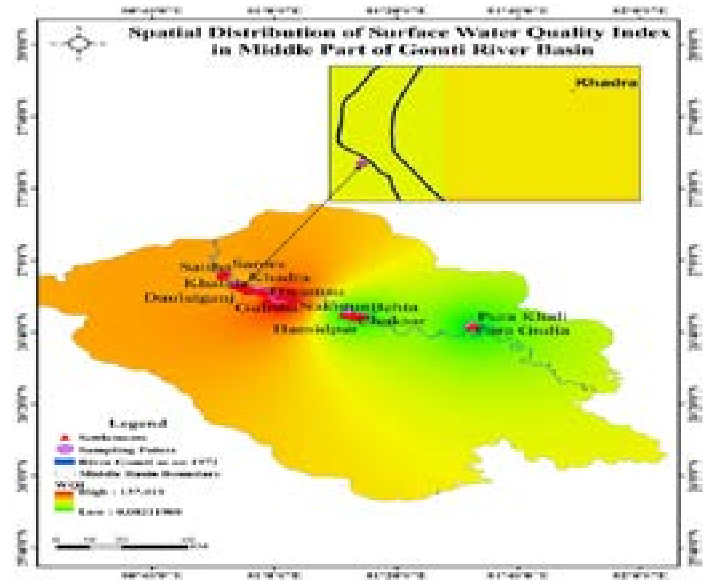


Fig.17

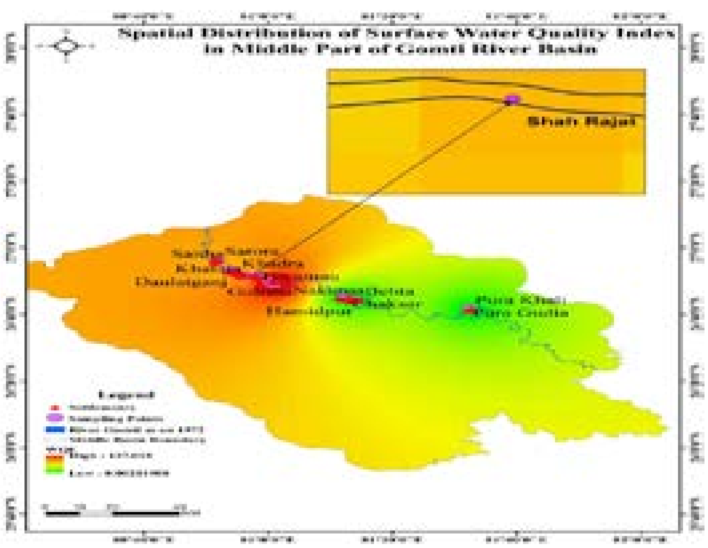


Fig.18

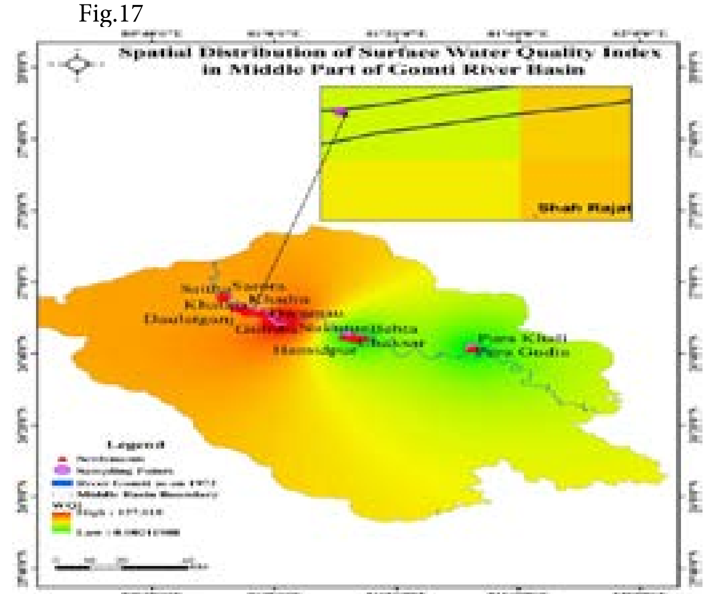


Fig.19

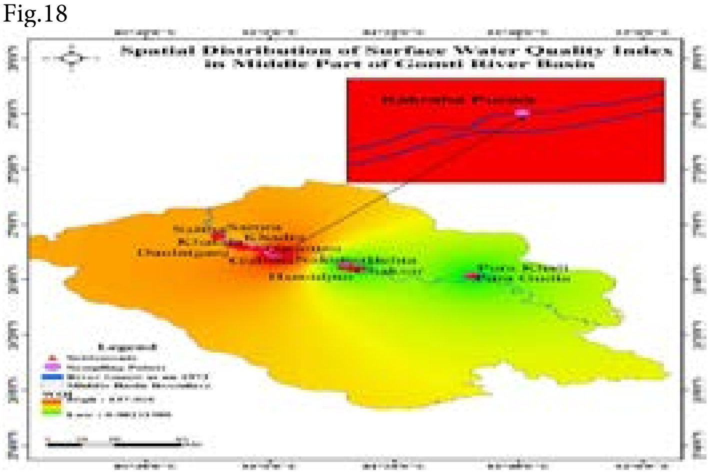


Fig. 21

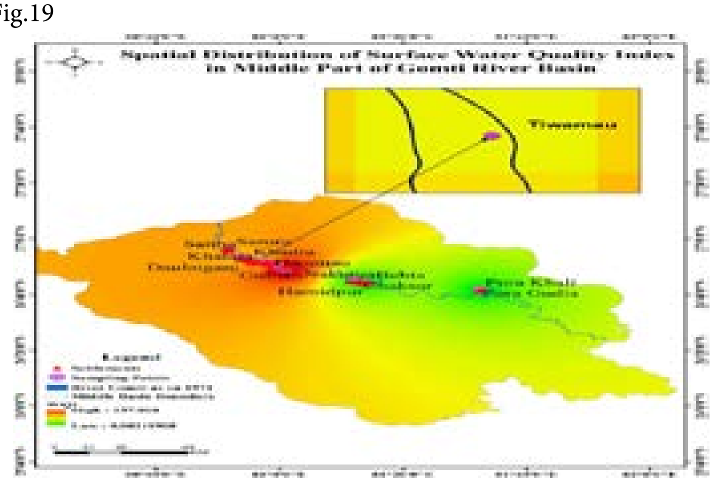


Fig.20

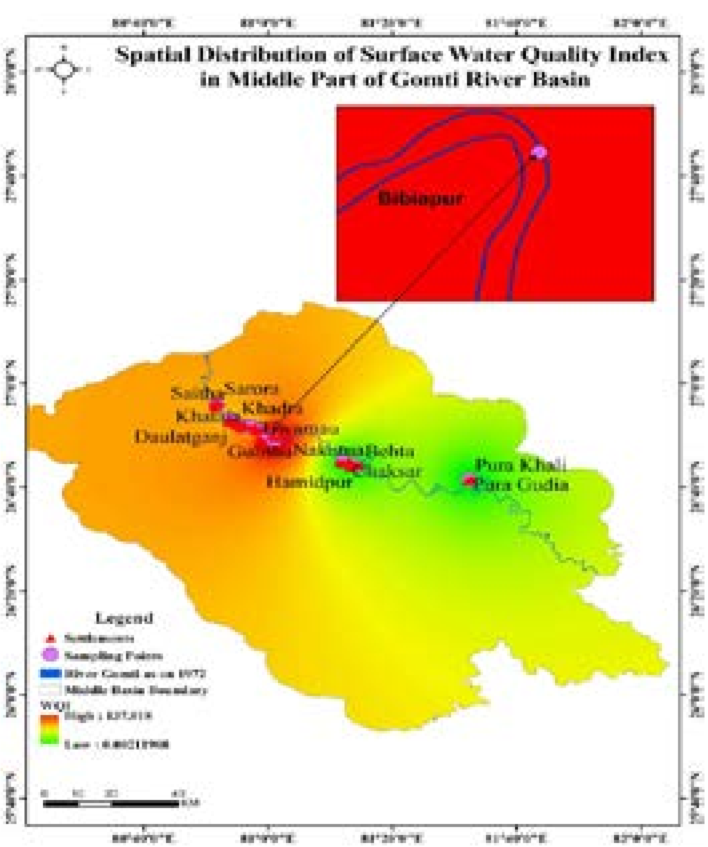


Fig.22

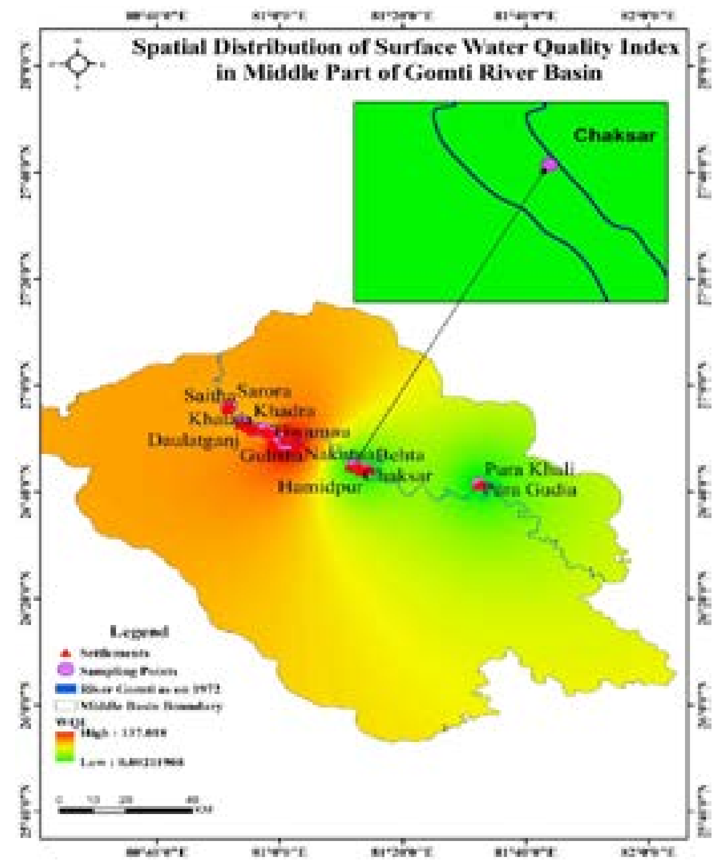


Fig.23

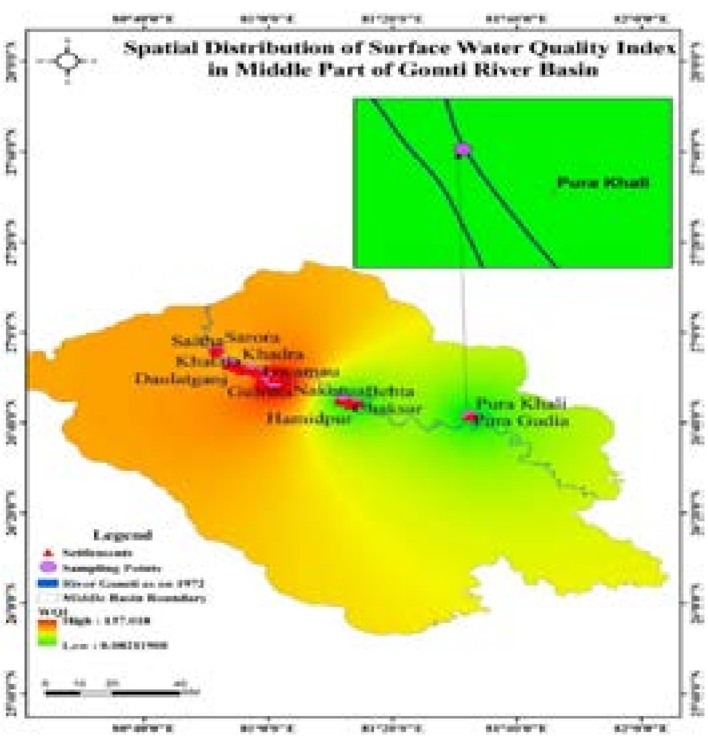


Fig.24

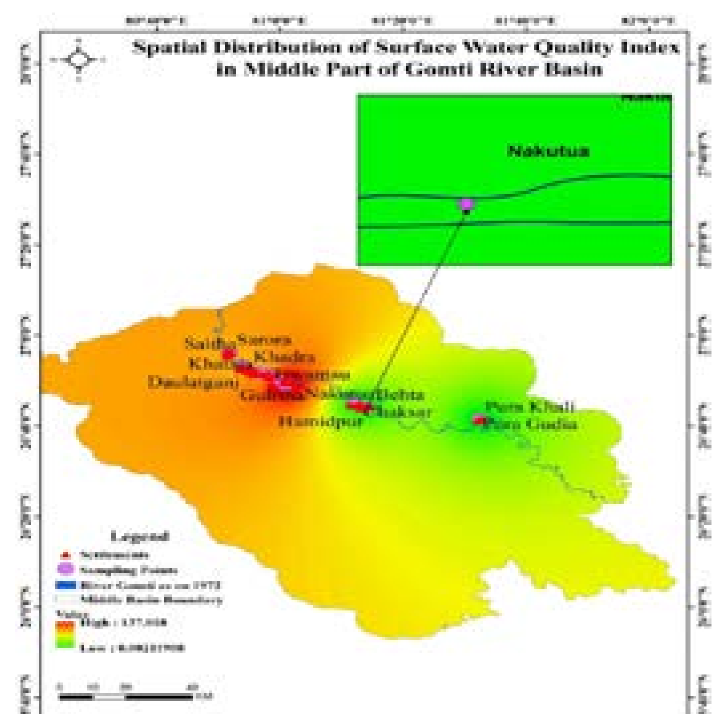


Fig.25

Khadra is an area where moderate level of Water Quality index has been observed. On the other hand further downstream near *Hasanganj, Krkahapurwa*&*nearBibiapur* extremely high values of the WQI are noticed which are as high as 137. Such type of values of WQI gives clear cut idea of poor quality of water. A plume of high WQI have been noticed in this stretch of River Gomti. This could be attributed to small drains, emanating from various locations and meeting river Gomti at this juncture & a lot of anthropogenic activities in terms of encroachment.

Near*Khataia ,Shahrajat, Tiwamau*moderate values of WQI have been noticed. Further downstream, interestingly the WQI values show very good quality of water, particularly near *Chaksar, Nakutua, Pura Khali*.

Overall out skirt areas of an Urban agglomerations, the WQI conditions are in Low to moderate range.

Spatial Distribution of Surface Water Quality Index in Lower Segment of Gomti River Basin:

In the lower part of basin of the Gomti River, the spatial distribution of the surface water quality index show a mixed tendency, with some regions experiencing an improvement in water quality while others are still plagued by pollution. The middle catchment, which is very contaminated, supplies water to the lower catchment, which comprises the districts of Sultanpur, Jaunpur, and Ghazipur. But the river also gets water from a number of tributaries, such as the Sai River, which contributes water that is comparatively cleaner. Consequently, the lower catchment's water quality index scores fall between 2 to 171, signifying a moderate degree of contamination. While some regions, like the areas close to Sultanpur, exhibit better water quality, others, like the area next to Ghazipur, still face significant pollution problems. The overall regional distribution of the Gomti River lower catchment surface water quality index emphasizes the necessity of ongoing initiatives to cut pollution and enhance water quality.

Spatial Distribution of Water Pollution: In the Gomti River lower basin, the geographical distribution of water contamination reveals that certain regions are more polluted than others. With high levels of bacteria, nutrients, and other pollutants, the section of the river close to Ghazipur is severely contaminated. This is because untreated household and industrial effluent is being dumped into the river. On the other hand, the river section close to Sultanpur exhibits better water quality due to reduced pollution levels. The Sai River, one of the many tributaries that contribute comparatively cleaner water, is the cause of this. Fig. 26 to 40 at different locations show changing pattern in spatial distribution of WQI. Areas near to *P.lala,Bahadurpur, Gharahakhu,Pyaepatti, PaparGhat, Karaumi, Puramallan* exhibit very high values (171) of WQI which covers almost 50 percent of the Lower part of Gomti river basin. On the other hand south eastern part of lower segment exhibits good quality of WQI, where values are as low as 2. Places like *Karoudiya, Baluaghat, Shivpur, Bhawanipur, Uttargawan, Odpur, Mai-ghat* experience very low WQI values and water quality is very good before meeting to river Ganga near Village *Kaithi*.

In the Gomti River's lower watershed, the primary causes of water pollution are:
1. Industrial Effluents: Untreated effluents with high amounts of pollutants are released into the river by industrial estates in the area.
2. Residential Sewage: One of the main causes of water contamination is untreated residential sewage from the cities of Sultanpur, Jaunpur, and Ghazipur.
3. Agricultural Runoff: The river receives fertilizers, pesticides, and other contaminants from nearby agricultural runoff. Water contamination is a result of improper solid waste disposal, which includes the improper handling of plastic and other non-biodegradable materials.

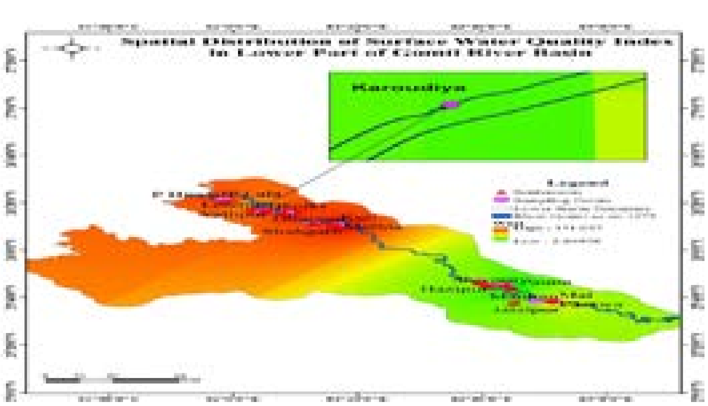


Fig.26

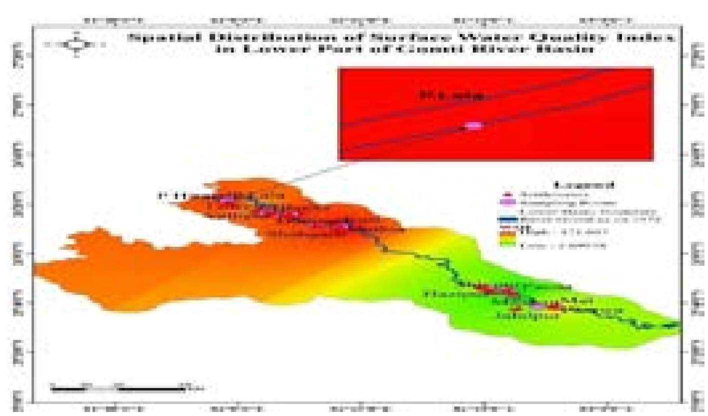


Fig.27

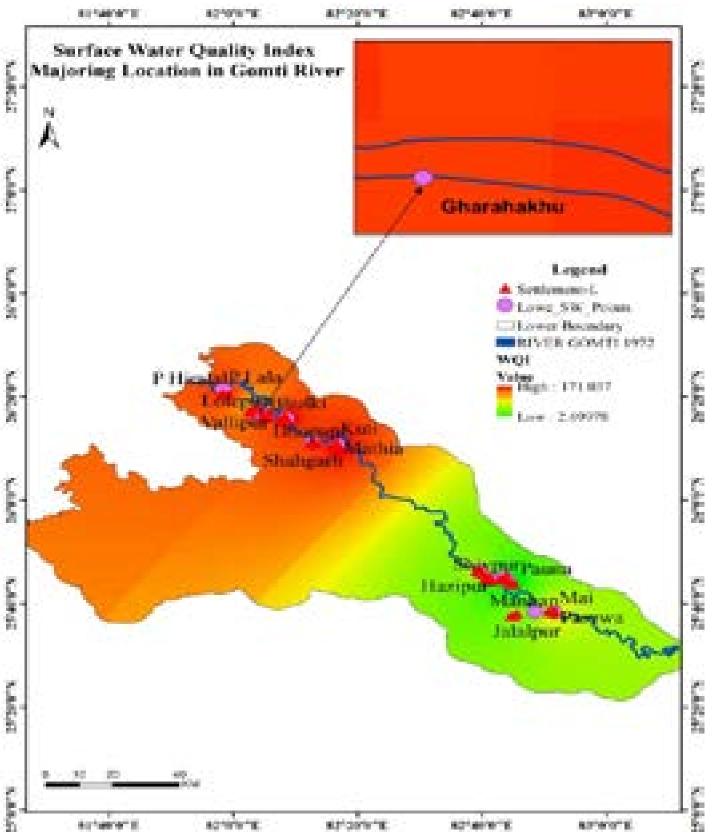


Fig.29

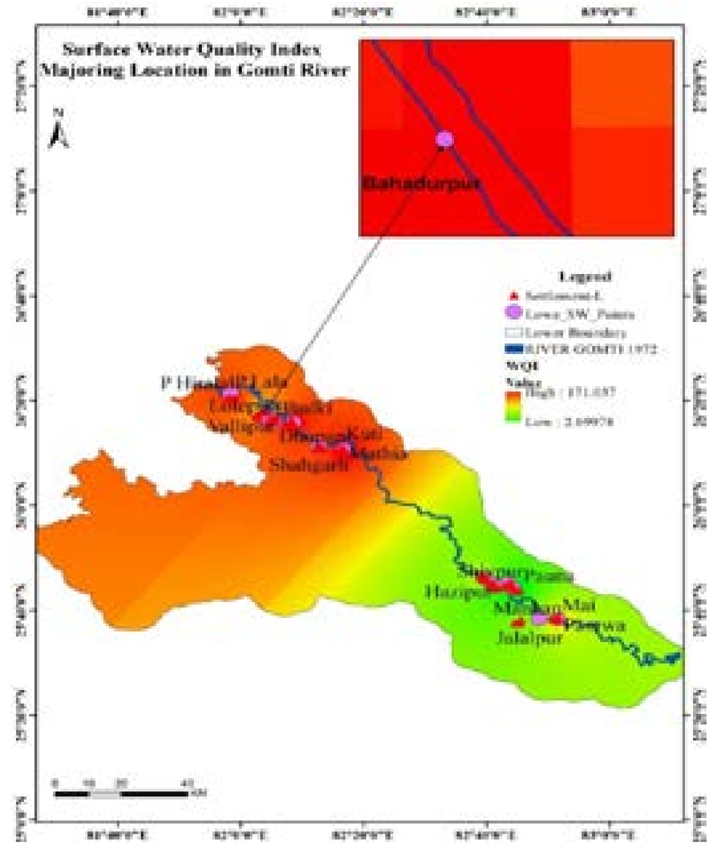


Fig.28

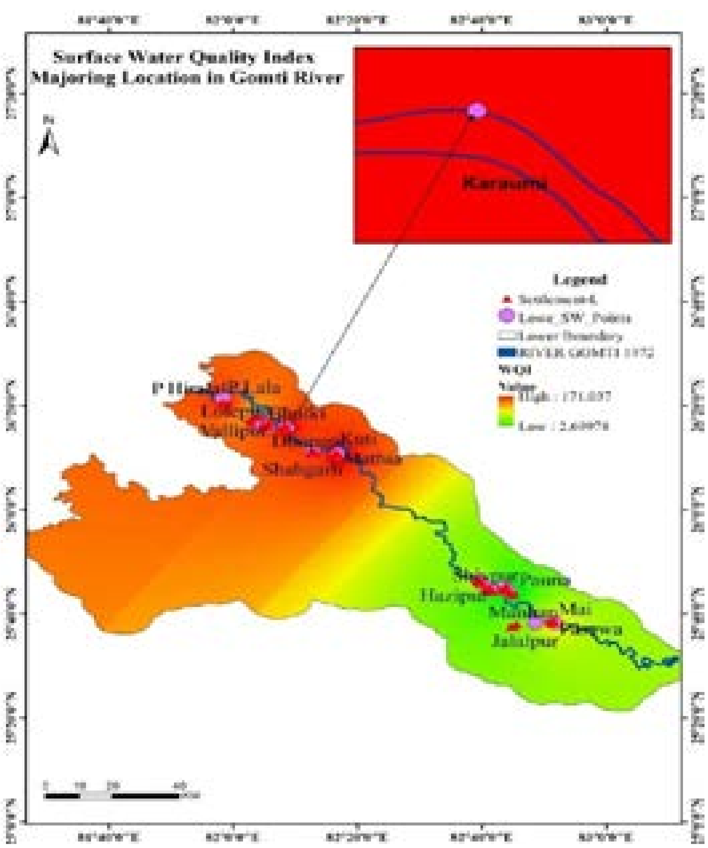


Fig.30

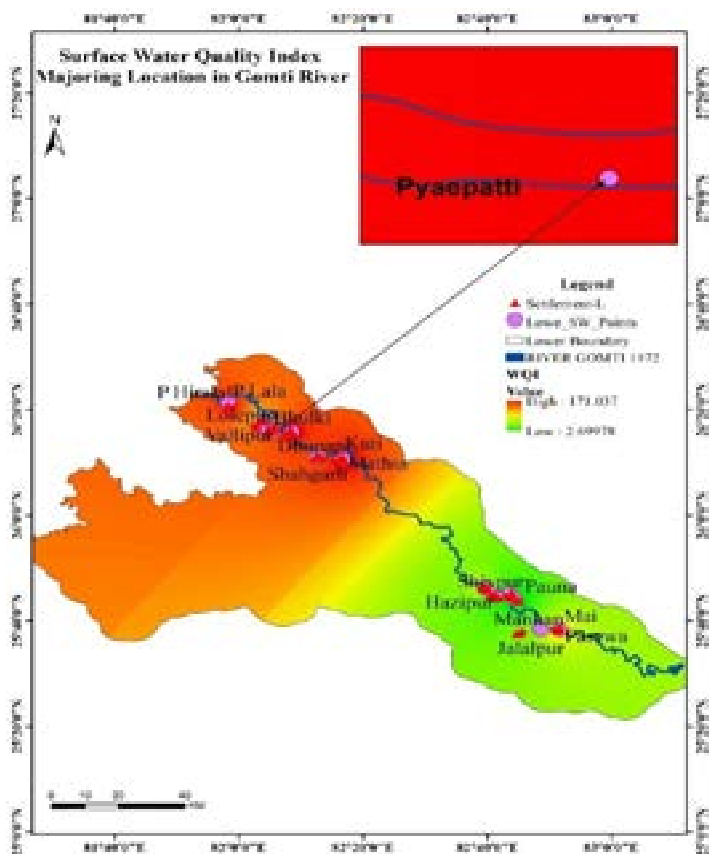


Fig.31

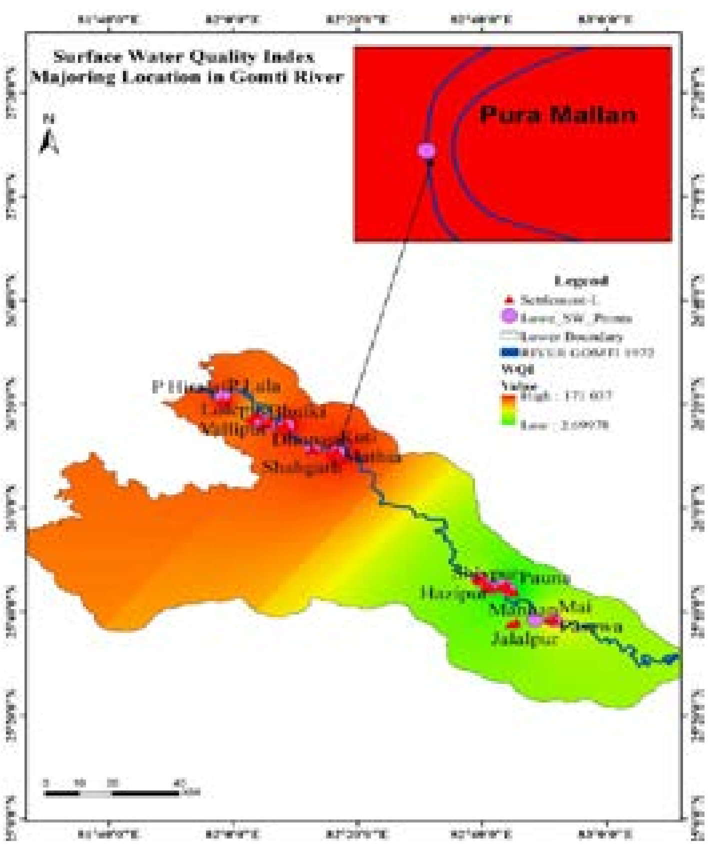


Fig.33

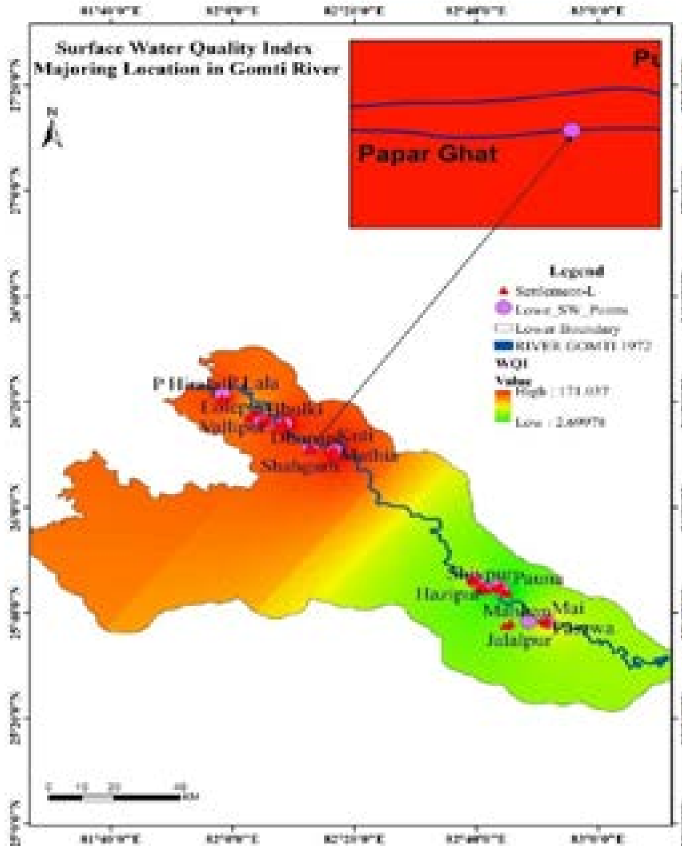


Fig.32

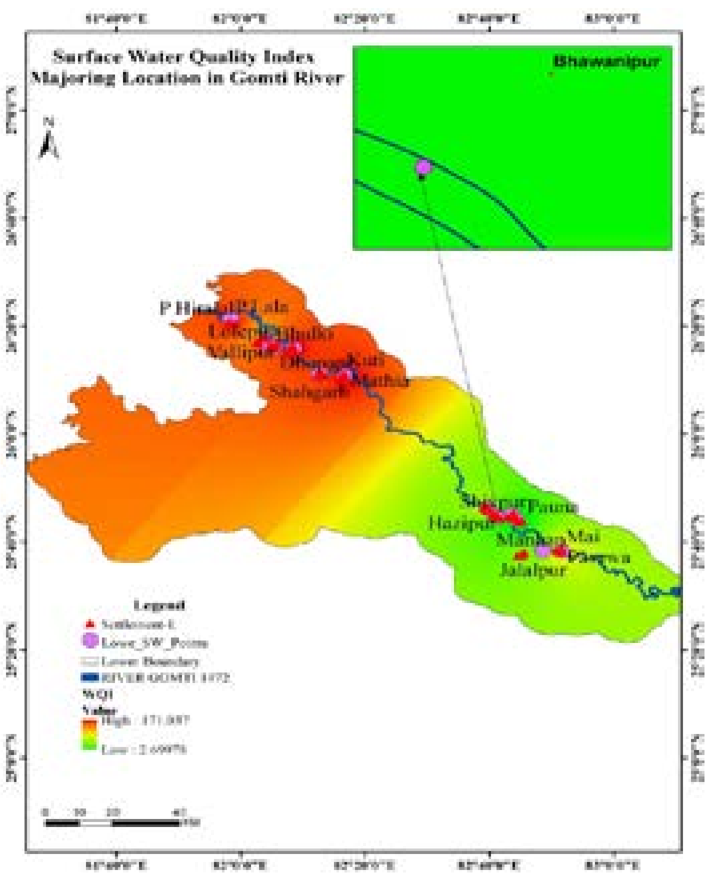


Fig.34

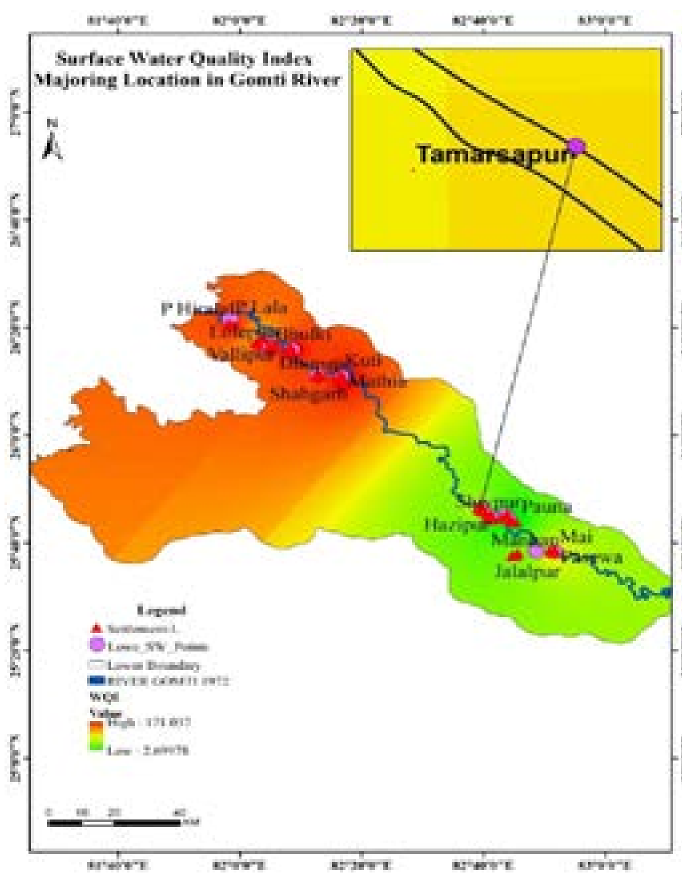


Fig.35

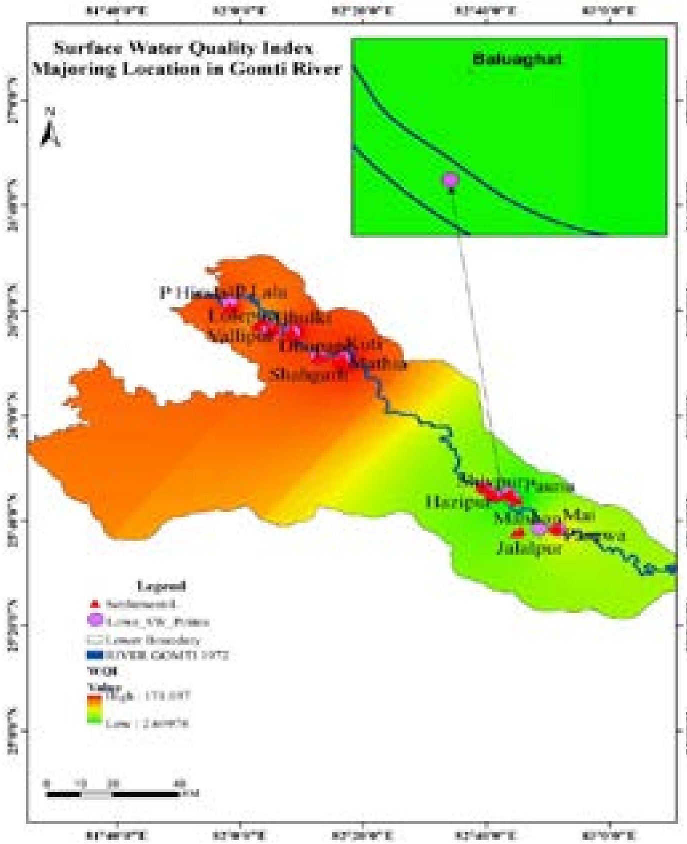


Fig.36

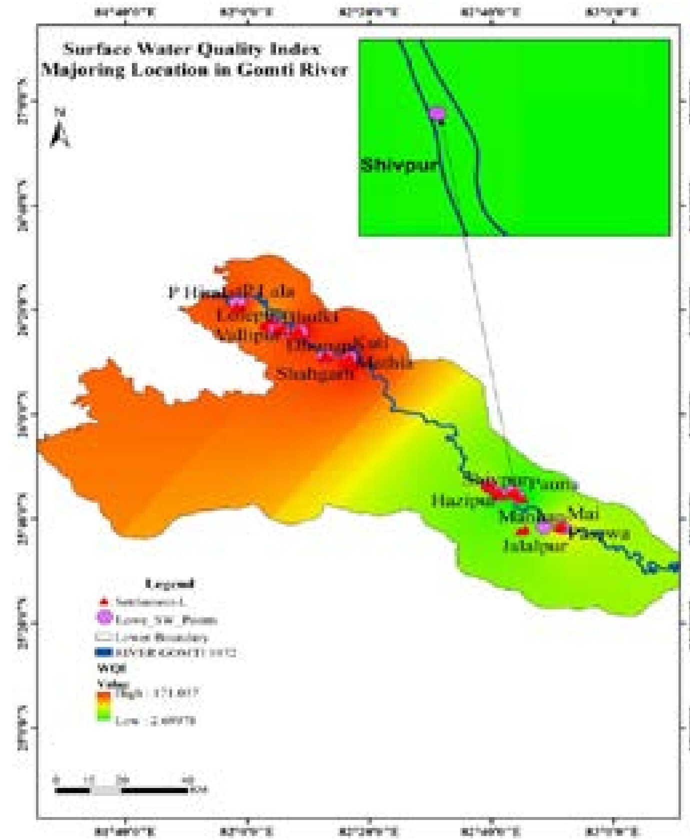


Fig.37

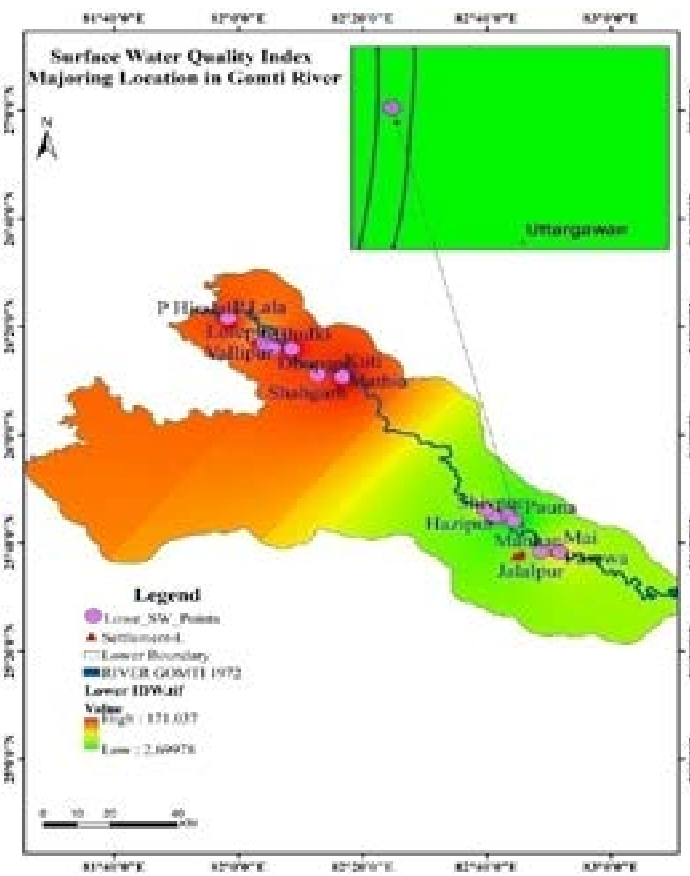


Fig.38

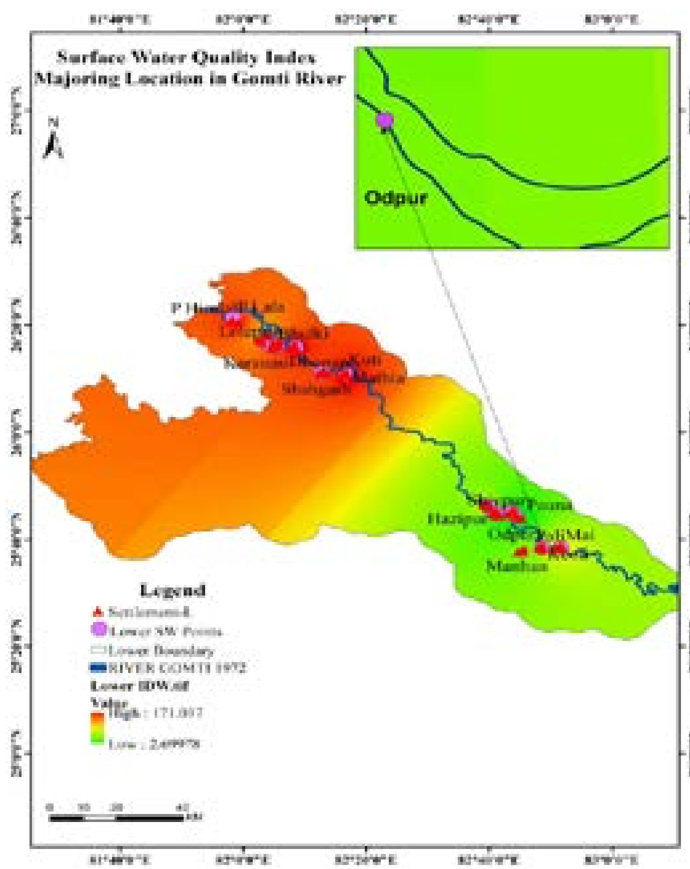


Fig.39

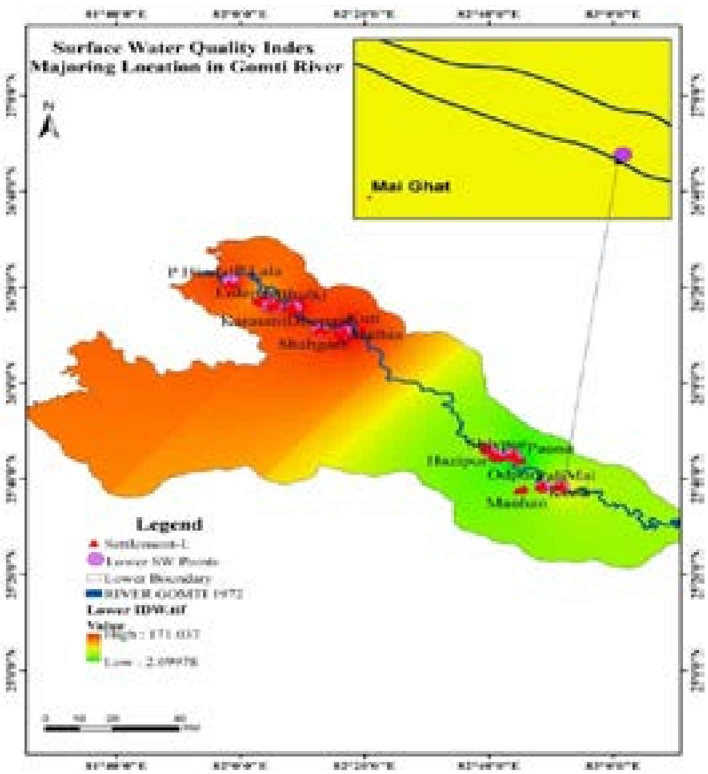


Fig. 40

Conclusion:

An alarming pattern of water pollution is revealed by the geospatial-based analytical investigation on surface water quality indices in the Gomti River from its source to its confluence with the Ganga. Without adequate treatment, the river water is unfit for drinking or other household uses, according to the study's spatial distribution of water quality index values. The water quality index analysis revealed significant spatial variations in water quality across the upper, middle and lower catchments. In Upper Catchment water quality is generally good with low pollutant level and high dissolved oxygen concentrations. This is attributed to the pristine nature of the catchment with minimal pollution source. Middle catchment water quality is moderate with increased pollutant levels and decreased dissolved oxygen concentrations due to industrial effluents and agricultural runoff. And in Lower catchment water quality is varying poor to very poor with high pollutant levels. This is attributed to the cumulative impact of pollution sources from the upper and middle catchments as well as the presence of industrial and urban areas, whereas the upper, middle, and lower catchments show differing degrees of pollution.

The study highlights the urgent need to address the Gomti River water contamination problems. To lessen the effects of pollution on the environment and human health, it is essential to install efficient wastewater treatment systems, boost environmental legislation, andimprove solid waste management.

The analytical method used in this study, which is geographical in nature, offers a useful framework for tracking and evaluating the Gomti River water quality. Monitoring changes in water quality over time and identifying pollution hotspots are made possible by the combination of remote sensing and GIS tools.

All things considered, this work adds to the corpus of knowledge already available on water quality indexing and emphasizes the significance of using a geospatial-based strategy to water resource management and monitoring. The Gomti River and other comparable river systems' water quality can be improved by using the study findings to guide policy choices and create practical solutions.

Suggestions:

1. Consistent use of geospatial-based methods for monitoring water quality parameters.
2. The application of better solid waste management techniques and efficient wastewater treatment systems.
3. Tighter enforcement of environmental laws to stop pollution.
4. Education and public awareness campaigns to encourage pollution avoidance and water conservation.
5. Combining traditional water quality monitoring techniques with geospatial-based methodologies to provide more thorough and accurate evaluations.

References:

Abbasnia, A., Alimohammadi, M., Mahvi, A.H., Nabizadeh, R., Yousefi, M., Mohammadi, A.A., Pasalari, H., Mirzabeigi, M., 2018. Assessment of groundwater quality and evaluation of scaling and corrosiveness potential of drinking water samples in villages of Chabahr city, Sistan and Baluchistan province in Iran. Data In Brief 16, 182–192. https://doi.org/10.1016/j.dib.2017.11.003.

Abbasnia, A., Yousefi, N., Mahvi, A.H., Nabizadeh, R., Radfard, M., Yousefi, M., Alimohammadi, M., 2019. Evaluation of groundwater quality using water quality index and its suitability for assessing water for drinking and irrigation purposes: case study of Sistan and Baluchistan province (Iran). Hum. Ecol. Risk Assess. 25 (4), 988–1005. https://doi.org/10.1080/10807039.2018.1458596.

Gonzalo Sotomayor, Henrietta Hampel, Raúl F. Vázquez, Water quality assessment with emphasis in parameter optimisation using pattern recognition methods and genetic algorithm,Water Research, Volume 130,2018,Pages 353-362,ISSN 0043-1354,https://doi.org/10.1016/j.watres.2017.12.010.

Kumar, A., Singh, P. K., & Mishra, S. (2019). Spatial analysis of point and non-point source pollution in Gomti River, Uttar Pradesh, India. Environmental Science and Pollution Research, 26(18), 18863-18878.

Machiwal, D., Islam, A., Kamble, T., 2019. Trends and probabilistic stability index for evaluating groundwater quality: the case of quaternary alluvial and quartzite aquifer system of India. J. Environ. Manag. 237, 457–475. https://doi.org/10.1016/j. jenvman.2019.02.071.

Rahman, M., & Mukhopadhyay, S. (2024). Mixing zone dynamics at Gomti-Ganga confluence: Implications for downstream water quality. Journal of Hydrology, 617, 129246.

Rai, P. K., Mishra, A., & Tripathi, B. D. (2023). Seasonal variations in water quality index of Gomti River: A two-year assessment study. Environmental Monitoring and Assessment, 195(2), 156.

Saleh, H.N., Valipoor, S., Zarei, A., Yousefi, M., Asghari, F.B., Mohammadi, A.A., Amiri, F., Ghalehaskar, S., Khaneghah, A.M., 2019. Assessment of groundwater quality around municipal solid waste landfill by using Water Quality Index for groundwater resources and multivariate statistical technique: a case study of the landfill site, Qaem Shahr City, Iran. Environ. Geochem. Health. https://doi.org/ 10.1007/s10653-019-00417-0.

Sharma, D., Kumar, A., & Pandey, K. (2018). Assessment of surface water quality using modified water quality index: A case study of upper Gomti River, India. Environmental Monitoring and Assessment, 190(11), 652.

Sotomayor, G., Hampel, H., V ́ azquez, R.F., 2018. Water quality assessment with emphasis in parameter optimisation using pattern recognition methods and genetic algorithm. Water Res. 130, 353–362. https://doi.org/10.1016/j. watres.2017.12.010.

Srivastava, P. K., & Srivastava, S. (2018). Water quality assessment of Gomti River using WQI in the district of Sultanpur, Uttar Pradesh. Journal of Environmental Biology, 39(5), 749-757.

Tripathi, M., & Kumar, A. (2019). Spatial interpolation and validation of water quality parameters for Gomti River using GIS techniques. International Journal of Environmental Science and Technology, 16(1), 345-356.

Verma, P., & Singh, P. (2021). Land use influence on seasonal water quality variations in Gomti River basin: A geospatial assessment. Land Use Policy, 102, 105229.

Wang, J., Liu, G., Liu, H., Lam, P.K.S., 2017. Multivariate statistical evaluation of dissolved trace elements and a water quality assessment in the middle reaches of Huaihe River, Anhui, China. Sci. Total Environ. 583, 421–431. https://doi.org/ 10.1016/j. scitotenv.2017.01.088.

Wu, Z., Wang, X., Chen, Y., Cai, Y., Deng, J., 2018. Assessing river water quality using water quality index in Lake Taihu Basin, China. Sci. Total Environ. 612, 914–922. https://doi.org/10.1016/j.scitotenv.2017.08.293.

Yousefi, M., Saleh, H.N., Mohammadi, A.A., Mahvi, A.H., Ghadrpoori, M., Suleimani, H., 2017. Data on water quality index for the groundwater in rural area Neyshabur County, Razavi province, Iran. Data In Brief 15, 901–907. https://doi.org/10.1016/j. dib.2017.10.052.