SPATIO-TEMPORAL MAPPING AND ANALYSIS OF WATER BODIES IN KAKORI, CHINHAT, AND SAROJINI NAGAR BLOCKS OF LUCKNOW DISTRICT USING OPTICAL REMOTE SENSING TECHNIQUES

A dissertation submitted for the partial fulfillment of the requirements

for the award of M.Sc. degree in

Environmental Science

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May 2023

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CERTIFICATE

This is to certify that **Miss Ghousiya,** a bonafide student of **M.Sc. Environmental Science, 4th** Semester, Session 2021-2022 to 2022-2023 at Integral University, Lucknow has completed her three months compulsory Industrial Training (15th February, 2023 – 15th May, 2023) and Dissertation work entitled **"Spatio-temporal mapping and analysis of water bodies in Kakori, Chinhat and Sarojini Nagar blocks of Lucknow district using optical remote sensing techniques"** in partial fulfillment of the requirements for the award of degree of **Master's of Environmental Science.** The work embodied in the dissertation was conducted at **Remote Sensing Applications Centre- U.P.** under my supervision. The Internal supervisor was **Prof. (Dr.) Monowar Alam Khalid,** Professor, Department of Environmental Science, Integral University, Lucknow.

I wish her all success in her future endeavors.

26/06/2023

(Dr. Sudhakar Shukla)

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I wish her success in her future life.

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DECLARATION

I, Miss. Ghousiya do hereby declare that the dissertation entitled "**SPATIO-TEMPORAL MAPPING AND ANALYSIS OF WATER BODIES IN KAKORI, CHINHAT AND SAROJINI NAGAR BLOCKS OF LUCKNOW DISTRICT USING OPTICAL REMOTE SENSING TECHNIQUES**" has been undertaken by me for the award of degree of Masters of Environmental Science. I have completed this study under the guidance of Prof. (Dr.) Monowar Alam Khalid, DSW, HOD, Department of Environmental Science, Integral Unversity, Lucknow, and Dr. Sudhakar Shukla, Scientist SE & Head of School of Geoinformatics, Remote Sensing Applications Centre, Kursi Road, Lucknow, Uttar Pradesh.

I also declare that the contents of the report have never been published anywhere before except the quotations and references which have been duly acknowledged in the concerned places. It reflects the work done solely by me during my training (from 15th February to 15th May, 2023)

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ACKNOWLEDGEMENT

First and foremost, I express my sincere and profound feeling to my external supervisor, **Dr. Sudhakar Shukla, Scientist SE & Head, School of Geoinformatics, Remote Sensing Applications Centre, UP, Kursi Road, Lucknow,** who gave me this monumental chance to be a part of this organization. I am deeply indebted to him for his valuable guidance, technical expertise, and knowledge that he shared and bestowed upon me.

I need to specially thank **Prof. (Dr.) Monowar Alam Khalid, HOD, Department of Environmental Science, Integral University, Lucknow, U.P.** for his immense support and guidance throughout my course and my dissertation work. He has been incredibly patient and generous and giving along with his time. My time under his guidance has been pure bliss.

My special thanks to all the respected faculty members of Department of Environmental Science, Integral University for their support during the study period and providing me with all the necessary official information regarding dissertation work.

Lastly, I would like to express my gratitude towards my parents and my family members for their support, love, and guidance throughout the duration of this study.

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PREFACE

Water plays a vital role in sustaining livelihood of the people of Lucknow district, Uttar Pradesh. With ever-increasing population, the demand of water resources has increased manifold to cater the demand from agriculture, industry and domestic activities. In Lucknow city, river Gomti has been the main source for drinking water, but now 50% of the municipal water supplies are dependent on ground water, which has far exceeded the natural recharge in many parts of the city. The resources are depleting at faster pace particularly in urban sprawl. Hence, it becomes essential to manage and utilize natural resource more efficiently. Water Remote Sensing is the observation of water bodies such as lakes, oceans, and rivers from a distance in order to describe their color, state of ecosystem health, and productivity. Water remote sensing studies the color of water through the observation of the spectrum of water leaving radiance. Optical remote sensing imagery is commonly used to monitor the spatial and temporal distribution patterns of inland waters. In order to address the upcoming challenges, it has become important to look after the water bodies and formulate water resource management plan. The main objectives of the study are: Identification and mapping of water bodies, water body characterization, calculate number and area of Water bodies, to map spatio-temporal changes in the water bodies and to suggest ways to minimize the decaying of water bodies.

ABSTRACT

Lucknow is the capital and the largest city of the Indian state of Uttar Pradesh. Lucknow has continental type climate and North East Monsoon winds reach late in this area, Lucknow receives 100 to 120 cm only. Lucknow is situated at the junction of numerous roads and rail lines, and Chaudhary Charan Singh International Airport is located about 6 miles (10 km) southwest of the central city. The city is a marketplace for agricultural products, and its industries include food processing, manufacturing, handicrafts, and railroad shops. Its population, which has grown dramatically since the late 20th century, surpassed that of Kanpur in the early 21st century to become the most-populous city in Uttar Pradesh. It has 8 blocks namely: Mall, Malihabad, Chinhat, Bakhshi Ka Talab, Kakori, Gosain ganj, Sarojini Nagar and Mohanlal Ganj. Among them my study area is Chinhat, Kakori and Sarojini Nagar.

Water is an imperative part of the Earth and an essential resource in human life and production. Wetland ecosystems are one of the most important areas that provide different ecosystem services as well as habitat for plants and animal species. In spite of multipurpose, wetland ecosystems are under threats. Under the effects of climate change and human activities, the spatial and temporal distribution of water bodies has been changing, and the shortage of water resources is becoming increasingly serious worldwide. In addition, water information is widely used for many purposes (Danesh *et al.*, 2021; Dang *et al.*, 2021; Das *et al.*, 2021; Meng *et al.*, 2012) including water resource surveys, environmental protection, land classification, and flood monitoring. Therefore, the monitoring of water bodies is indispensable. Remote sensing has the advantages of real time, wide coverage, and rich information and has become a brand-new technical means to quickly obtain water information.

Spatial refers to space. Temporal refers to time. Spatiotemporal, or spatial temporal, is used in data analysis when data is collected across both space and time. It describes a phenomenon in a certain location and time. Applications for spatio-temporal data analysis include the study of biology, biology, ecology, meteorology, medicine, transportation and forestry. Spatio-temporal data visualization and analysis can be challenging because space has unlimited directions — up, down, sideways, North, South, East, West — while time can only go forward. Combining and assessing the two factors of space and time can be complex.

Besides traditional methods based on ground measurements, satellite imagery can prove useful in mapping and detailed assessment of surface water resources. The objective of this study is to determine spatial-temporal changes of water bodies in Chinhat, Kakori and Sarojini Nagar by analyzing Landsat satellite images. These data are generated using scenes from Landsat 4, 5 of 1993 and Landsat 8 of 2022 Changes in the extent of water bodies are determined.

In this study pre monsoon data of the years 1972, 1993 and 2022 were used. By superimposing the water bodies of 1972 on 1993 satellite data and then on 2022 data , the Spatio-temporal variations in water bodies of Kakori, Chinhat and Sarojini Nagar were observed. The result showed that there is a drastic decrease in the number and area of water bodies during this period. The number of water bodies in 1972 was 871, in 1993 was 309 and in the year 2022 it was 259. Overall, the number of water bodies has decreased, which is shown in Spatio-temporal maps for above period.

CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

1.1.1. Lucknow

It is the capital and the largest city of the Indian state of Uttar Pradesh and it is also the second largest urban agglomeration in Uttar Pradesh. Lucknow is a district in the Uttar Pradesh State of India. Total area of Lucknow is 2,528 km² including 2,057.29 km² rural area and 470.71 km² urban area. As per 2011 stats, Lucknow has a population of 45,89,838 peoples, out of which urban population is 30,38,996 while rural population is 15,50,842. Lucknow, the *golden city of the east'* retains an old world charm that fascinates one and all. Regarded as one of the finest cities of India, Lucknow emanates a culture that combines emotional warmth, a high degree of sophistication, courtesy and a love for gracious living. This sublime cultural richness famous as 'Lucknowi Tehzeeb' blends the cultures of two communities living side by side for centuries, sharing similar interests, speaking a common language -Urdu. There are 8 blocks in Lucknow district- Mall, Malihabad, Kakori, Bakshi ka talab, Chinhat, Gosainganj, Sarojini Nagar, and Mohanlalganj. There are 5 tehsil in lucknow district- Bakshi ka talab, Mohanlalganj, Malihabad, Sadar, and Sarojini Nagar.

1.1.1.1. Chinhat

It is a block in Lucknow City, Uttar Pradesh, India. According to 2011 Census of India the population of the village is 137,251 out of whom 71,211 are males and 66,040 are females. Lucknow serves as the block headquarters. The block is part of two tehsils, with some parts belonging to Lucknow tehsil and other parts belonging to Bakshi Ka Talab tehsil.

1.1.1.2. Kakori

It is a town and a nagar panchayat in Lucknow district in the Indian state of Uttar Pradesh, 14 km north of Lucknow. As of 2001 India census, Kakori had a population of 16,731. Males constitute 53% of the population and females 47%. (Census of India 2011)

1.1.1.3. Sarojini Nagar

It is a community development block in Lucknow district, Uttar Pradesh, India. It is part of the tehsil of Lucknow and it includes 90 villages. As of 2011, its population was 224,045. As of 2011, the sex ratio of Sarojini Nagar block is 903 females for every 1000 males. (Census of India 2011)

1.2. Water bodies

Despite playing a crucial role in preserving the ecological equilibrium, water bodies are the most vulnerable to anthropogenic activities across the world. Water bodies not only provide drinking water and agricultural needs but also protect the human population from the impact of natural disasters. Some of the developmental projects in densely populated countries have ignored the necessity of conserving the water bodies. In developing countries, the loss of water bodies, especially the smaller ones, has raised major concerns about their protection and management. Globally, concerns have been raised over the reduction in water bodies since they may lead to ecological imbalance and biodiversity loss.

1.3. Wetland

Wetlands are recognized as one of the world's most valuable natural resources (Burton & Tiner, 2009; Tiner, 2015). They provide a wide range of economic, social, environmental and cultural benefits – in recent times classified as ecosystem services (Costanza *et al*., 1997). Wetlands are ecosystems where terrestrial and aquatic regions meet and share some characteristics. Wetlands also contain water for some periods of a year and are characterized by the presence of water, hydric soil, and specific vegetation adapted to a wet environment (Mahdavi *et al*., 2018). Wetlands are invaluable natural resources that provide exceptional benefits to humans and the surrounding environment (Grenier *et al*., 2008). Due to numerous environmental services of wetlands, including carbon sequestration (Trepel, 2010), water purification (Knox *et al*., 2008), sediment filtration, soil conservation (Claassen, 2006), and other critical services, wetlands have been called the "kidneys" of nature. The term Wetlands covers a wide variety of aquatic habitats, including marshes, swamps, bogs, fens, peatlands, prairie, vernal pools, and aquatic beds, among others. Under the Ramsar international wetland conservation treaty, wetlands are defined as areas of marsh, fens, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brakish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar Convention Secretariat 2016).

Wetland ecosystems are one of the most important areas that provide different ecosystems services as well as habitat for plant and animal species. In spite of multipurpose, wetland ecosystem are under threats. Wetlands are the transition between the land and sea and thus from freshwater to marine environments (Basset *et al*., 2013; Facca, 2022). Wetlands are one of the most important habitats for various plants and animals. It provides different varieties of ecosystem services (Maltby, 1991; Zollitsch *et al*., 2019). The presence of wetlands is one of the main indicators of environmental health. Wetlands are critical resources with numerous values and uses (Shi *et al*., 2008).

Geographic Information Systems (GIS) and remote sensing satellites have become the most powerful tools for assessing and monitoring of natural resources and the environment (Das *et al*., 2022; Garg, 2015; Najar *et al*., 2017). Substantial studies highlight that GIS and remote sensing techniques are widely used to survey wetland change very quickly, at low cost, and with greater accuracy (Brooks *et al*., 2004; Haque & Basak, 2017; Liu *et al*., 2006; Mabwoga & Thukral, 2014; Schmidt & Skidmore, 2003; Tobore *et al*., 2021).

Wetlands are under threats all over the world, despite the benefits and services they provide to humans (Maltby, 1991). At global level, wetland ecosystems are destroyed by agricultural expansion, urban development, hydrological changes, pollutants input from factories, and municipalities. Wetlands are recognized as one of the world's most valuable natural resources. Wetlands provide numerous ecological and socio-economic benefits, such as providing critical habitats for fish, wildlife, and plant communities, storing floodwater and reducing peak runoff, recharging groundwater, filtering impurities in water, acting as nutrients and sediment sinks, protecting shorelines from erosion and providing a range of recreational opportunities. With the increasing world population, human demands on wetland resources for agricultural expansion and urban development continue to increase (Zedler & Kercher, 2005)

In addition, global climate change has pronounced impacts on wetland ecosystems through alterations in hydrological regimes. To better manage and conserve wetland resources, we need to know the distribution and extent of wetlands and monitor their dynamic changes. Wetland maps and inventories can provide crucial information for wetland conservation, restoration, and management. Geographic Information System (GIS) and remote sensing technologies have proven to be useful for mapping and monitoring wetland resources.

1.4. Justification

I have taken this topic because water is vital for every living being on earth and it is our duty and responsibility to conserve water for future generation or use it in a sustainable way. Water is the basic necessity for the functioning of all life forms that exist on earth. It is safe to say that water is the reason behind earth being the only planet to support life. This universal solvent is one of the major resources we have on this planet. It is impossible for life to function without water. After all, it makes for almost 71% of the earth. However, despite its vast abundance, water is very much limited. It is a non-renewable resource. In addition, we need to realize the fact that although there is an abundance of water, not all of it is safe to consume. Water is not only required for our survival but for a healthy and happy life as well.

Everyone has seen the scenario of water-deprived countries like Africa, where citizens are leading a miserable life. It is time for everyone to wake up and realize the urgency of conserving water. Firstly, the greenery will soon diminish. When earth won't get water, all the vegetation will die and turn into barren land. The occurrence of different seasons will soon cease. The earth will be caught in one big endless summer. Furthermore, the home of aquatic animals will be taken from them. That means no fishes and whales for us to see. Most importantly, all forms of living organisms will go extinct if we do not conserve water right away. So, unnecessary usage of water must be stopped at once. Every single person must work to conserve water and restore the balance. By using the remote sensing techniques it becomes easy to quickly obtain information regarding water bodies.

1.5. Past and present status of water bodies

Earlier in 1972 there were 871 water bodies in Chinhat, Kakori and Sarojini Nagar. The total area covered by them was 1052 hectare. Due to many anthropogenic activities the number of water bodies started declining and there were only 309 water bodies left in 1993. The total area covered by them was 416 hectare. The number kept on decreasing and now only 269 water bodies were left in 2022. The total area covered by the water bodies is about 307 hectare.

LUCKNOW DISTRICT AT A GLANCE

1. General Information	
i. Geographical Area (sq km.)	:2565 (including Urban area of 310 sq km)
ii. Administrative Divisions Number of Block Number of Tehsil Number of Villages	 :08 :05 :811 803 (inhabited villages) , 8 (uninhabited villages)
iii. Population (2011 census)	: 4589000 Male-2394000, Female-2195000
iv. Population Density (2011)	: 735 persons per Sq. Km
v. Average Annual Rainfall (mm)	: 779.7
2. Geomorphology	: Alluvium
Major Physiographic Units	: Older and younger Alluvium, Palaeochannel, Flood Plains, ox-bow lakes, Piedmont slope, Channel bar
Major Drainages	: Gomti and Sai river
3. Land Use (Sq. Km.)	
Forest area	: 66.41
Net area sown	: 1308.19
Gross area sown	: 1945.26
4. Major Soil Types	: Bhur, Matiyaar and Dumat
5. Area under Principal crops (Sq. Km)	: Rabi 937.57 : Kharif 670.11 : Zaid 382.04

Table 1: Lucknow at a glance

CHAPTER 2: OBJECTIVES OF THE STUDY

The major objectives of the study are as here under:

i. To identify and map water bodies for 1972, 1993 and 2022.

ii. To characterize the types of water bodies.

iii. To calculate the number of water bodies in 1972, 1993 and 2022.

iv. To calculate the area of water bodies.

v. To map the Spatio-temporal changes in the water bodies from 1972 to 2022.

vi. To give suggestions to minimize the decaying of water bodies.

CHAPTER 3: LITERATURE REVIEW

Remote sensing technology offers effective ways to observe surface water dynamics. Compared to traditional in situ measurements, remote sensing is much more efficient, because of its ability to continuously monitor Earth's surface at multiple scales. Remote sensing data sets provide spatially explicit and temporally frequent observational data of a number of physical attributes about the Earth's surface that can be appropriately leveraged to map the extent of water bodies at regional or even global scale, and to monitor their dynamics at regular and frequent time intervals. (Donchyts *et al*., 2016)

One of the most vital natural resources is water, these water resources are becoming increasingly strained throughout the world. This is due to several causes including larger populations; increasing agricultural irrigation that often results in overuse or salinization; populations increasing in sunny dry climates that have limited water, to begin with; more pollution from cities, agriculture, and industry; increased human and industrial consumption; and climate change. Surface water resources in some humid regions are characterized by inconsistency, shortage, unequal distribution, and inadequate development (Ahirwar *et al*., 2021; Taloor *et al.*, 2021; Guha *et al*., 2022).

The wetlands are considered as the natural water storage body as well as water reservoir on the earth and they also act as a transition zone between permanently flooded and the strictly terrestrial areas is the presence of hydromorphic soils and hydrophytic vegetation. Wetlands are one of the most threatened habitats of the world (Prasad *et al*., 2002). Wetlands in India, as elsewhere are increasingly facing several anthropogenic pressures.

Human activities cause wetland degradation and loss by changing water quality, quantity and flow rates; increasing pollutant inputs; and changing species composition as a result of disturbance and the introduction of non-native species. The current loss rates of wetlands in India can lead to serious consequences, where 74% population is rural (Anon, 1994). At present in India, only 50percent of wetlands remain. They are disappearing at a rate of 2% to 3% every year.

Remote Sensing techniques have been used effectively in integrated development and management of water resources of India (Balakrishnan, 1986). Physical characteristics of water quality can be ascertained through satellite imagery (Moore, 1977).

A vast diversity of research has been done by remote sensing technology for water resource management. The use of GIS and remote sensing is a rapidly developing area in which data from a number of sources is being utilized. A temporal pattern of shore line changes has been identified using Land sat Multi Spectral Scanner and a GIS package (Frihy *et al*., 1994).

Using visible and infrared remote sensing images, the snow melt-runoff modeling has been applied to the Italian Alps (Swamy & Brivio, 1996). An integrated package of GIS has been proposed to upgrade the Hong Kong water supply scheme (Plante *et al.*, 1999).

Ground water salinity has been mapped using Indian Remote Sensing-IB Linear Imaging Self-Scanning Sensor II data and a GIS package in Uttar Pradesh India (Srivastava *et al*., 1997). The extent of water vapor transformation over Calcutta has been studied using radiometric studies and a GIS system (Karmakar *et al*., 1994).

Satellite data provide quick and useful base line information about the factors controlling the occurrence and movement of groundwater like geology, lithology, geomorphology, soils, land use/cover, drainage patterns, lineaments, etc. Structural features such as faults, fracture traces and other such linear or curvilinear features can indicate the possible presence of groundwater.

CHAPTER 4: STUDY AREA

4.1. LUCKNOW

Lucknow city, the capital of the State of Uttar Pradesh, covers an area of 315.63 km^2 and its latitudes ranging between 26°44'08"N and 26°57'57"N and longitude ranging between 80°49'50"E and 81°03'14"E, is chosen as study area. The city is drained by the Gomti River on its central part in which this river flowing North-West to South-East. The location of the city above mean sea level is near 123.000 m. The climate of the city is sub-humid where average annual rainfall is 904 mm and temperature ranges 40-45 ºC (maximum) and 5-15 ºC (minimum) (Singh *et al.*, 2017).

It is surrounded on the eastern side by Barabanki district, on the western side by district Unnao, on the southern side by Raebareli and on the northern side by Sitapur and Hardoi districts, Lucknow sits on the northwestern shore of the Gomti River. The shape of the district is like an irregular quadrilateral.

4.1.1. Geology

The district forms a part of Ganga basin with flat alluvial terrain which is underlain by sands of various grades, silt and clay with kankar of Quaternary age. The general slope of the district is south-east. The alluvium is broadly divided into:

I. Older Alluvium comprised of grey to brown coloured silt clay and sand with or without Kankar of middle to late Pleistocene age. Older alluvium occupies large part of the district.

II. Newer/Younger Alluvium overlies the older alluvium and has been sub divided into terrace alluvium and channel alluvium and belongs to Holocene age. Newer alluvium occupies the tract along the river course forming present and old flood plain.

The geological succession is as follows:

Age	Formation	Lithology
recent	**Newer**	Light Khaki grey silt, clay and fine to medium and coarse grained

	Alluvium	grey sand of micaceous in nature.
	Older Alluvium	Fine sand, silt, Clay admixed with or without Kankar

Table 2: Geological Succession

4.1.2. Soil

The district is mostly covered by Loamy soil. Soil in the district exhibits a wide variation in composition, texture and appearance. The ridges are occupied by soils locally known as "Bhur" or "Silty Sand". "Matiyar" or "Clay Soils" occurs along topographic lows and "Dumat or Loamy soils" in the level lands. Clay is dominant in the areas where "Reh" (Usar) prevails. Along the river valleys, a very fertile soil called "Dumat" is prevalent which is youngest. Generally the soil is fertile in nature. Soil may be divided into following types depending on the physiography of the region:

Coarse Loamy: Coarse textured poor water holding capacity, low in organic matter, good aeration, poor nutrients retaining capacity.

Fine Loamy: Fine textured, moderate aeration, high moisture and nutrients retaining capacity, soil particles sticky when wet, dries out slowly and moderate aeration.

Fine Silty: Fine textured, moderate aeration, high moisture and nutrients retaining capacity, soil particles sticky when wet, dries out slowly and moderate aeration.

4.1.3. Geomorphology

Geomorphologically the district can be classified into two geomorphological units (i) Older flood plains and (ii) Active flood plain.

(i) Older flood Plain: Older flood plains are represented by two level of terraces viz Erosional terrace (Te) occupying at higher level and Depositional terrace (Td) at lower depressions. Older flood plain exists between elevation of 103 and 110 mamsl. Both the terraces are developed on the either side of Gomti River. Erosional Terrace is also developed along Sai Nadi.

(ii) Active flood Plain: Active flood plains are restricted to present day bank line of the rivers. These are represented by land forms like point bars, channel bars and lateral bars.

Administratively, Lucknow district has been divided into 5 tehsils and 8 Community Development blocks viz., Bakshi Ka Talab, Chinhat, Gosainganj, Kakori, Mall, Malihabad, Mohanlalganj and Sarojini Nagar. The district being the capital of Uttar Pradesh is well connected by railways, roads and airway. My study area includes the following blocks:

4.2. KAKORI

4.2.1. Latitude/Longitude

It is located at 26.88°N and 80.8°E.

4.2.2. Location

Kakori block lies in W of Lucknow district, shares border with Chinhat block in east, Sarojini Nagar block district in south, Unnao district in west and Mall block in north.

4.2.3. Geology

Kakori block constitutes a part of Ganga basin with flat alluvial terrain which is underlain by sands of various grades with sand, silt and clay with kankar of Quaternary age.

4.2.4. Drainage

Kakori Block mainly drained by tributaries of Gomti River.

4.2.5. Soil

The block is mainly covered with fine silt with varying grades of loamy soil.

4.2.6. Geomorphology

The block is mainly covered with older/upper alluvial plain and younger/lower alluvial plain. Ravines feature of younger alluvium while palaeo channels can be seen in older/upper alluvial plain.

4.3. CHINHAT

4.3.1. Latitude/Longitude

It is located at 26.8799° N and 80.9741° E.

4.3.2. Location

Chinhat block lies in E of Lucknow district, shares border with Barabanki district in east, Gosainganj block in south, Kakori and Malihabad block in west and Bakshi ka Talab in north.

4.3.3. Geology

Chinhat block constitutes a part of Ganga basin with flat alluvial terrain which is underlain by sands of various grades with sand, silt and clay with kankar of Quaternary age.

4.3.4. Drainage

Chinhat Block mainly drained by tributaries of Gomti River. Gomti River is forming a boundary between Chinhat block and Kakori, Sarojini Nagar Blocks together.

4.3.5. Soil

The block is mainly covered with fine silt with varying grades of loamy soil.

4.3.6. Geomorphology

The block is mainly covered with older/upper alluvial plain and younger/lower alluvial plain. There are several oxbow lakes which are the results of meandering rivers and which contain water except in the summer. Palaeo Channels can be seen in older/upper alluvial plain.

4.4. SAROJINI NAGAR

4.4.1. Latitude/Longitude

It is located at 26.81826° N and Longitude is 80.92506° E.

4.4.2. Location

Sarojini Nagar block lies in SW of Lucknow district, shares border with Chinhat and Gosainganj block in east, Mohanlalganj block in south, Unnao district in west and Kakori block in north.

4.4.3. Geology

Sarojini Nagar block constitutes a part of Ganga basin with flat alluvial terrain which is underlain by sands of various grades with sand, silt and clay with kankar of Quaternary age.

4.4.4. Drainage

Sarojini Nagar Block mainly drained by tributaries of Gomti River in east and tributaries of Sai River in west.

4.4.5. Soil

The block is mainly covered with silty soil with varying grades of loamy soil.

4.4.6. Geomorphology

The block is mainly covered with older/upper alluvial plain and younger/lower alluvial plain. Ravines feature in younger alluvium and palaeo channels in older/upper alluvial plain can be seen.

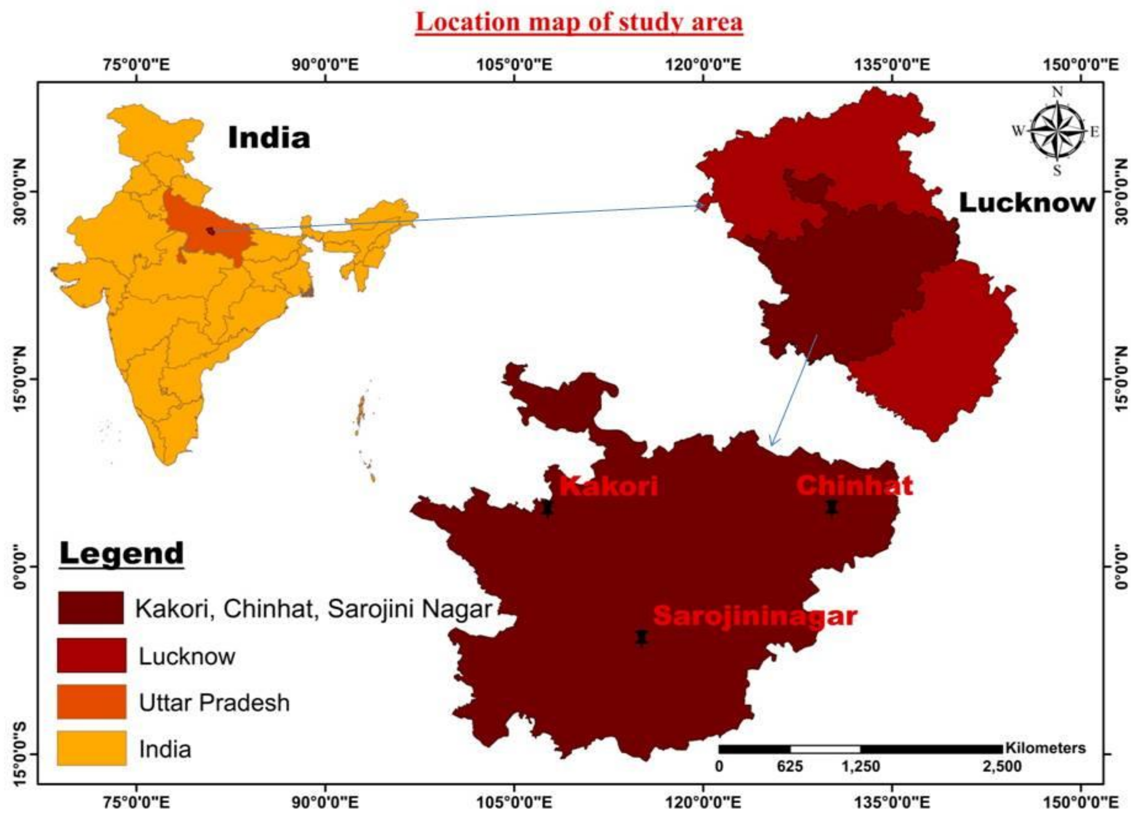

Fig 1: Location map of the study area

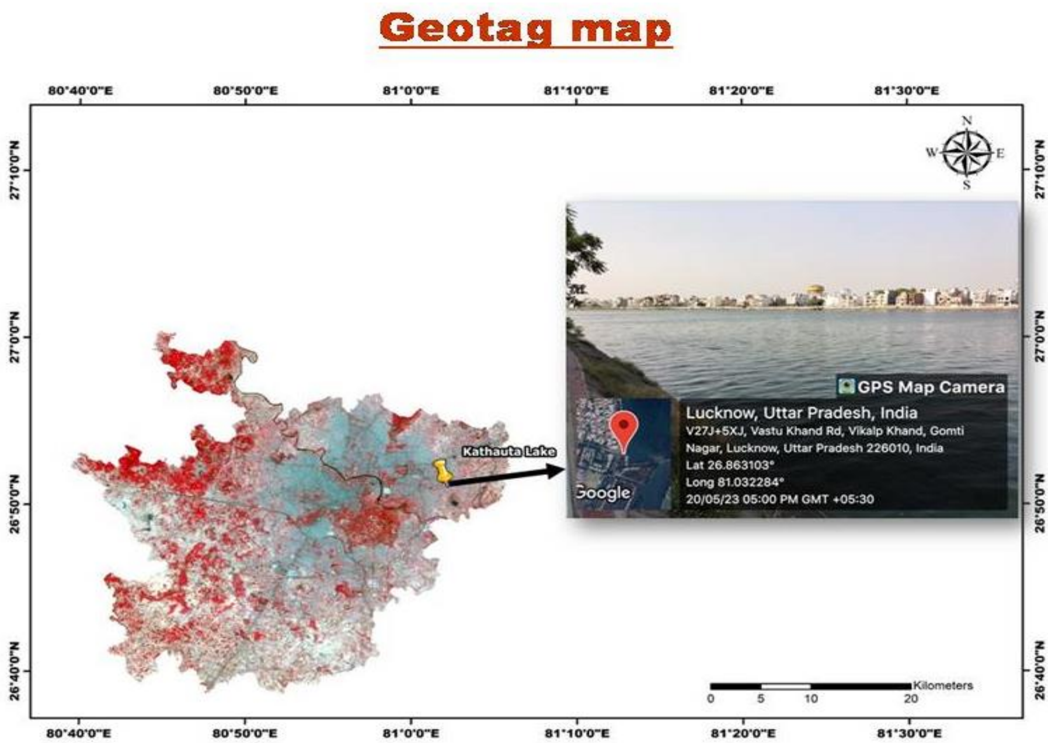

Fig 2: Geotag map of Kathauta Jheel

CHAPTER 5: DATA AND MATERIAL

5.1. Software

In this study the software used was provided by Remote sensing application centre. The version of the software used is ArcMap 10.8.

5.2. Toposheet

Then the toposheet were downloaded from the Survey of India on 1:50,000 scale

1. G44C12_63A/12
2. G44C16_63A/16
3. G44I13_63B/13
4. G44I14_63B/14
5. G44J1_63F/1
6. G44J2_63F/2
7. G44I9_63B/9
8. G44I10_63B/10

5.3. Satellite data

Landsat images obtained from the portal of United States of Geological Survey (USGS) (https://earthexplorer.usgs.gov/) were used. Remote sensing data from Google Earth was used to identify wetlands at the present time.

5.4. Field survey

Ground photograph of Kathauta Jheel was used to link the image to the satellite data.

Fig 3: Field photograph

CHAPTER 6: METHODOLOGY

For the above study, the following methodology has been followed:

Firstly I have downloaded ArcMap 10.8 software. Then I downloaded toposheets from Survey of India. After that, I georeferenced all the toposheets followed by the mosaic. After merging or mosaicking all the toposheets together I have marked the boundary of my study area. Then there are several tools available in the software so with the help of those tools I clipped my study area. Apart from marking the boundary, I have also marked the water bodies lying in my area.

Next, I downloaded the satellite data of 1993, followed by a mosaic, and then I superimposed the shapefile of the study area and shapefile of water bodies of 1972 on 1993 data. After this, I clipped my area and started marking the water bodies present in the 1993 data.

Next, I downloaded satellite data for 2022, superimposed the shapefile of the study area, and clipped my area. Then taking the shapefile of water bodies of 1972 as base and marking the avalaible water bodies. At last compared the difference between 1972, 1993, and 2022 and made different types of maps.

Figure no. 4 shows the schematic representation of the methodology used in the study.

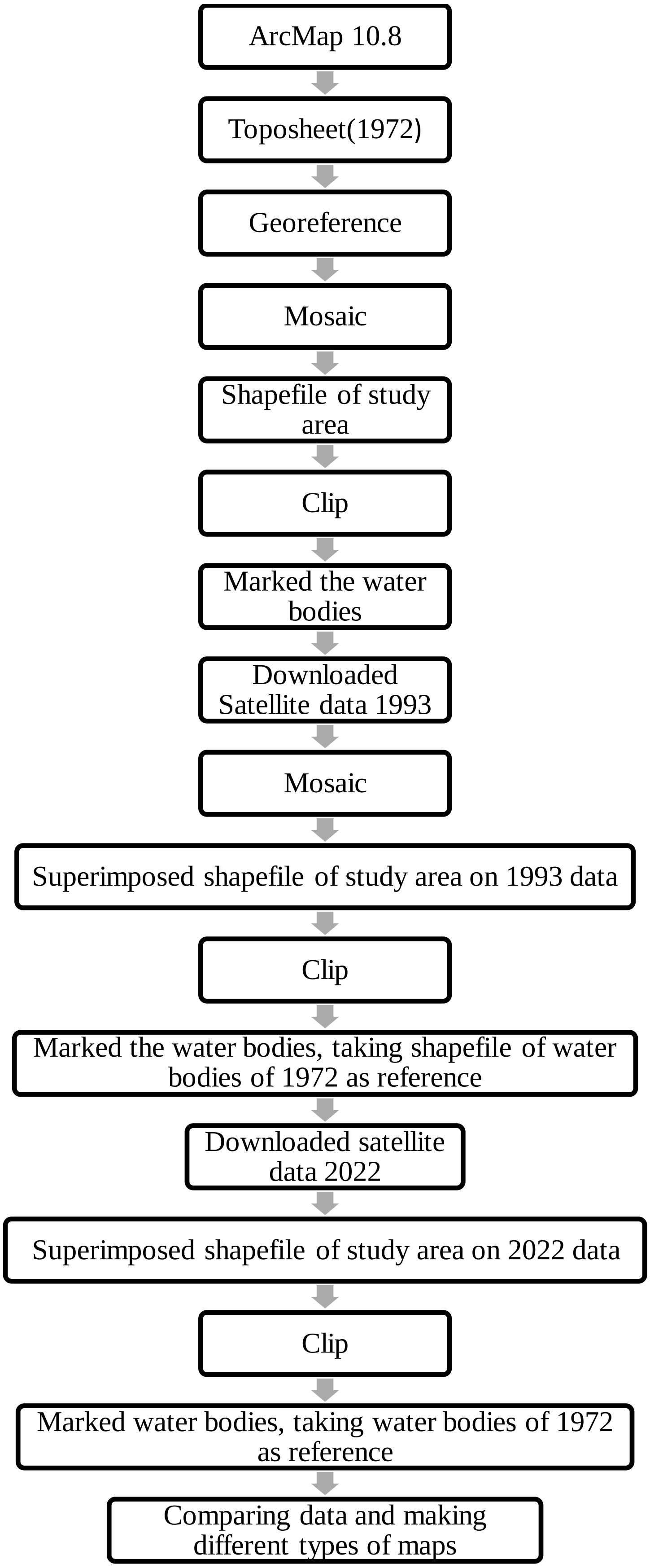

Fig 4: Schematic representation of the methodology

CHAPTER 7: GEOSPATIAL TECHNIQUES FOR WETLAND MAPPING

Geospatial technology (also known as geomatics) is a multidisciplinary field that includes disciplines such as surveying, photogrammetry, remote sensing, mapping, geographic information systems (GIS), geodesy and global navigation satellite system (GNSS) (Pun-cheng, 2001). According to the U.S. Department of Labour "Geospatial industry can be regarded as "an information technology field of practise that acquires, manages, interprets, integrates, displays, analyzes, or otherwise uses data focusing on the geographic, temporal, and spatial context" (Klinkenberg, 2007). It is a new integrated academic field that has a diverse range of applications (Konecny, 2002). The applications of geomatics are in the fields of precision farming, urban planning, facilities management, business geographics, security and intelligence, automated mapping, real estate management, environmental management, land administration, telecommunication, automated machine control, civil engineering and so on.

Geospatial technologies are spatial/mapping technologies that utilize data related to place and space. Geospatial Technology is an emerging field of study that includes Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS). Geospatial technology enables us to acquire data that is referenced to the earth and use it for analysis, modeling, simulations, and visualization. Geospatial technology allows us to make informed decisions based on the importance and priority of resources most of which are limited in nature.

7.1. Geospatial Technology Types

Geospatial technology has become an essential part of everyday life. It's used to track everything from personal fitness to transportation to changes on the surface of the earth. "Geospatial technology" is an umbrella term for a collection of technology types. Let's study some of the geospatial technology types that are commonly used today. Some of the major types of geospatial technologies are: remote sensing systems, Geographic Information Systems (GIS), and Global Positioning Systems (GPS).

7.1.1. Remote Sensing

Remote Sensing is the process of sensing, identification, delineation, measurement of surface features and their processes from a distance without directly coming into physical contact. Remote Sensing measures Electro Magnetic Energy (EME) from the sun or emitted by the sensor itself (microwave sensor) which is reflected, scattered or emitted by different surface features on the earth. It employs passive and/or active sensors. Passive sensors are those, which sense natural radiations, either reflected or emitted from the earth. On the other hand, the sensors, which produce their own electromagnetic radiation, are called active sensors (e.g. LIDAR, RADAR). The radiation from the scene or a particular area that a remote sensor detects is measured as radiance not reflectance. Remote Sensing provides multi-spectral, multi-sensor and multi-temporal data which help in the generation of accurate, timely and cost effective information on natural resources. Remote sensing offers the capability to observe and collect data for large areas relatively rapidly, and is a non-destructive and important source of information can be used for further analysis and interpretation in various disciplines (Campbell *et al*., 2011).

7.1.2. GIS (Geographic Information System)

G: Geographic: *Implies an interest in the spatial identity or locality of certain entities on, under or above the surface of the earth.*

I: Information: *Implies the need to be informed in order to make decisions. Data or raw facts are interpreted to create information that is useful for decision-making.*

S: System: *Implies the need for staff, computer hardware and procedures, which can produce the information required for decision-making that is data collection, processing, and presentation.*

GIS is defined as a computerized system for capture, storage, retrieval, analysis and display of spatial data describing the land attributes and environmental features for a given geographic region, by using modem information technology (Thurgood, 1995). According to this definition, a GIS includes not only computing capability and data, but also managers and users, the organization in which they function and institutional relationships that govern their management and use of information.

GIS stands for Geographic Information System. GIS can collect, store, display, and analyze geospatial data about the Earth. GIS is a computer based system which can handle large volumes of spatial data derived from a variety of sources such as field surveys, aerial surveys and space remote sensing, in addition to the already existing maps and reports. GIS is a crucial means of understanding spatial data that can be related to people (such as urban sprawl), the environment (such as forest-cover data), or both (deforestation, for example). GIS data include cartographic data (i.e., maps), photographs (from aerial photography), and other forms of digitized data (from satellites).

GIS can display various forms of data and relate them spatially. When data are layered into GIS, lots of different pieces of collected data can be extracted to create a map. These layers can be turned on or off. This means one single map could show an area, and include data such as average age, voting preferences, or religion, all on one map.

Major components of GIS are: Data inputting, Data encoding, Data management, Data analysis and manipulation, Data presentation or output

7.1.3. GPS (Global Positioning System)

You might have heard of GPS before, especially when thinking about driving somewhere. GPS stands for Global Positioning System and is a navigation system based on location. GPS uses satellites orbiting the earth to provide spatial and locational information. These satellites send radio signals to receivers on the ground at control stations, and to those who are using GPS navigation data, such as airplanes, submarines, and land-based vehicles such as your car. A GPS device can read those signals and work out an exact location, as long as the GPS device is able to read the signals from four of those satellites.

GPS being an all weather, real time, continuously available, economic and very precise positioning technique; with the well established high accuracy achievable with GPS in positioning of points separated by a few hundred of meters to a few thousand of kilometers, this unique surveying technique has wide range of applications in various fields . Some of the important applications are as under:

i) Geodetic control surveys i.e. location of precise control points
ii) Geodynamics surveys i.e. determination of recent crustal movements
iii) Setting out local network for the control of engineering projects
iv) Monitoring mass movements i.e. ground subsidence and landslides

CHAPTER 8: ANALYSIS AND RESULT

I have taken the data of 1972, 1992 and 2022 from Survey of India and USGS respectively. There is a huge difference between the numbers of water bodies from 1972 to 2022. Here the water bodies are characterized as wet and dry. Earlier in 1972 there were 871 water bodies in Chinhat, Kakori and Sarojini Nagar. Among them 608 were wet and 263 were dry. The total area covered by them was 1052 hectare. Due to many anthropogenic activities the number of water bodies started declining and there were only 309 water bodies left in 1993. Among them 236 were wet and 73 were dry. The total area covered by them was 416 hectare. The number kept on decreasing and now only 269 water bodies were left in 2022. Among the 215 were wet and 54 were dry and covers area of about 307 hectare (Table 3). From the visual inspection, there is an apparent loss of water bodies between 1972, 1993 and 2022.

TABLE SHOWING THE DIFFERENCES IN THE NUMBER AND AREA OF WATER BODIES-

Water bodies in 1972		Water bodies in 1993		Water bodies in 2022	
Dry	wet	Dry	Wet	Dry	Wet
263	608	73	236	54	215
Total number of water bodies- 871		Total number of water bodies-309		Total number of water bodies-269	
Total area covered in hectare- 1052		Total area covered in hectare-416		Total area covered in hectare-307	

Table 3: Showing the differences in the number and area of water bodies

Below are the maps showing the differences in the number of water bodies in 1972, 1993 and 2022-

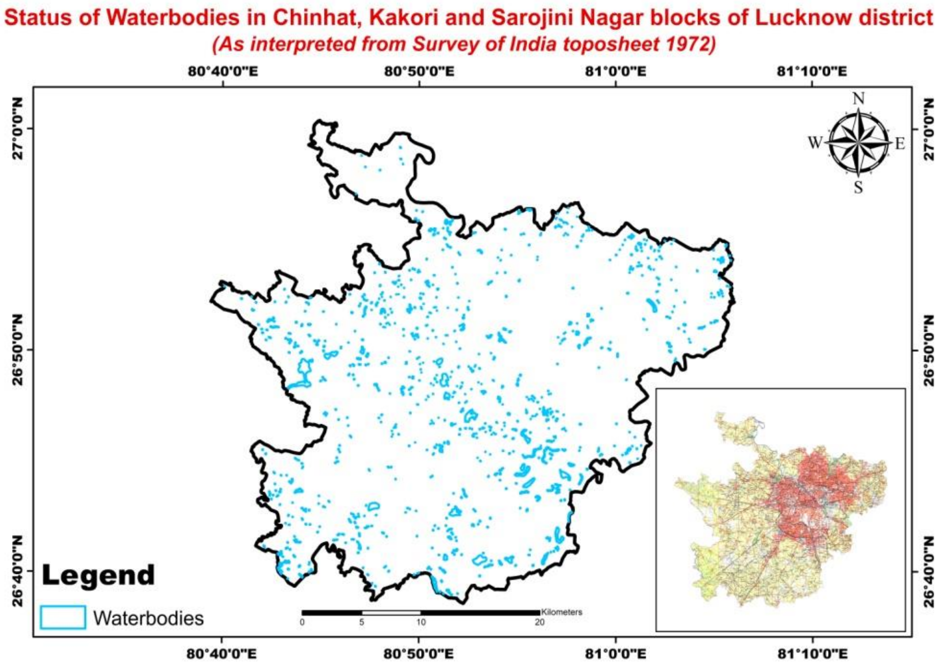

Fig 5: Status of water bodies in Chinhat, Kakori and Sarojini Nagar blocks of Lucknow district (1972)

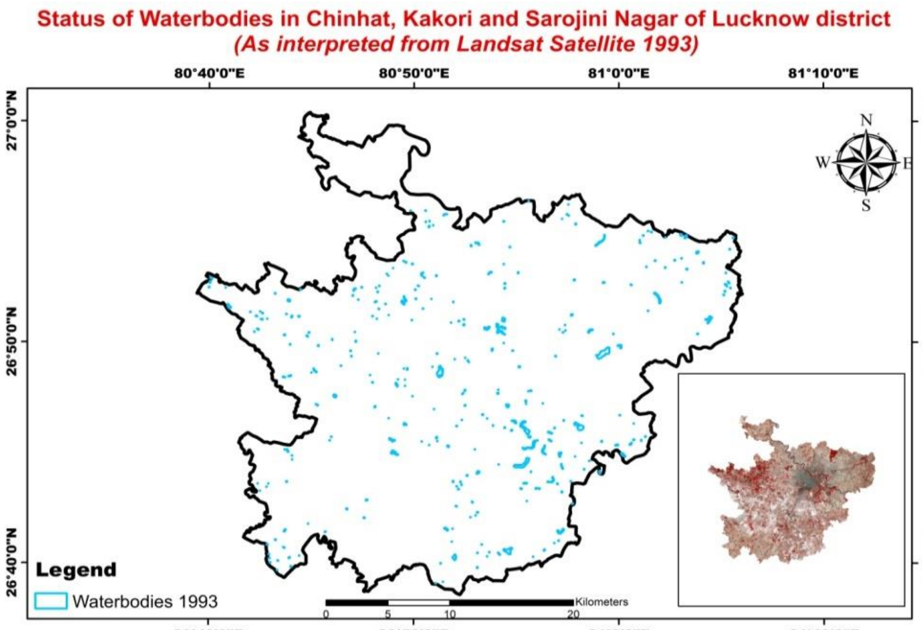

Fig 6: Status of water bodies in Chinhat, Kakori and Sarojini Nagar blocks of Lucknow district (1993)

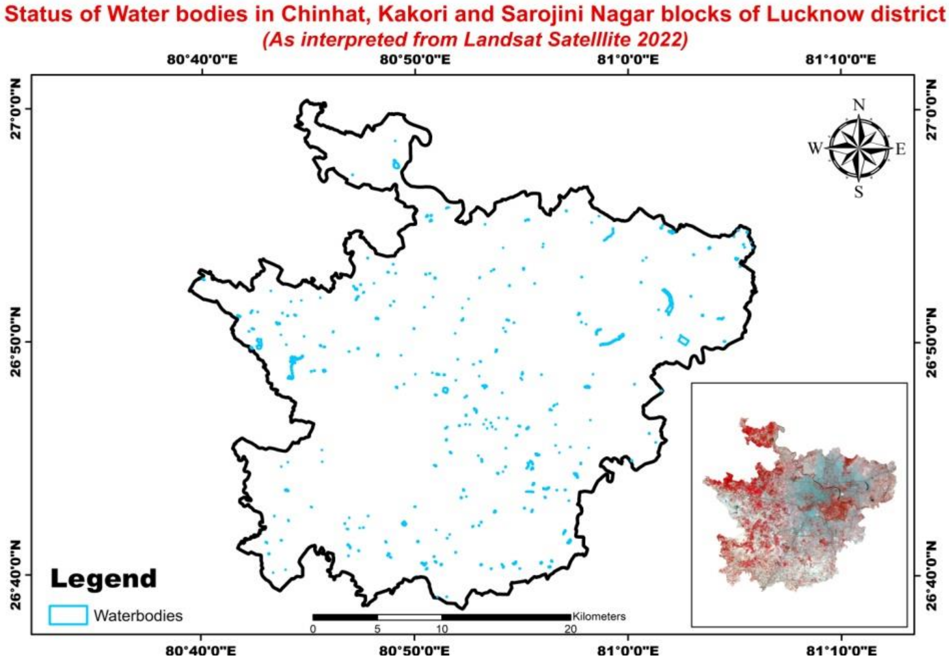

Fig 7: Status of water bodies in Chinhat, Kakori and Sarojini Nagar blocks of Lucknow district (2022)

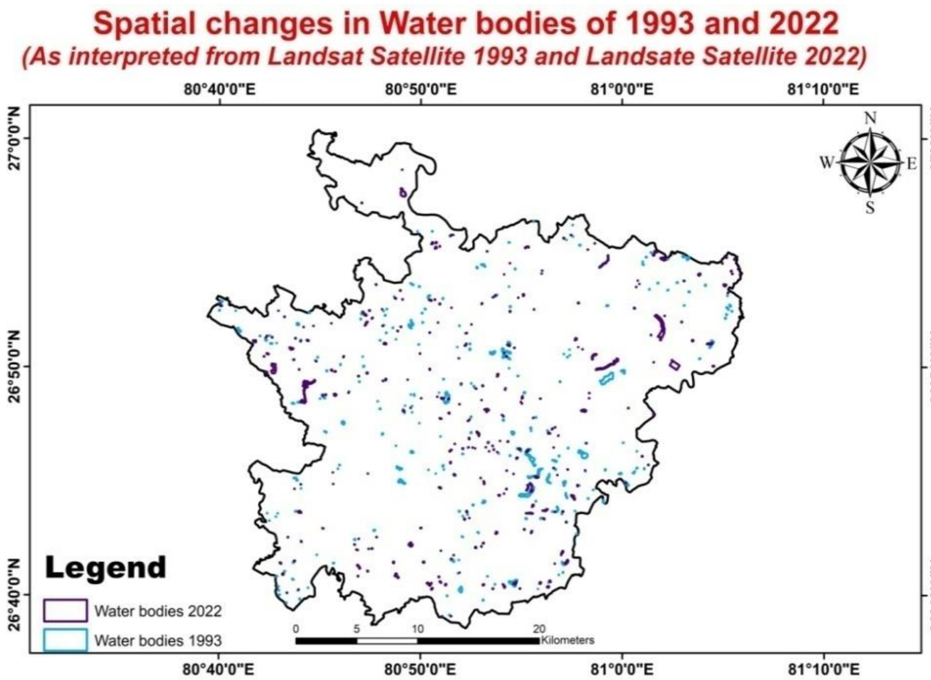

Fig 8: Spatial changes in water bodies of 1993 and 2022

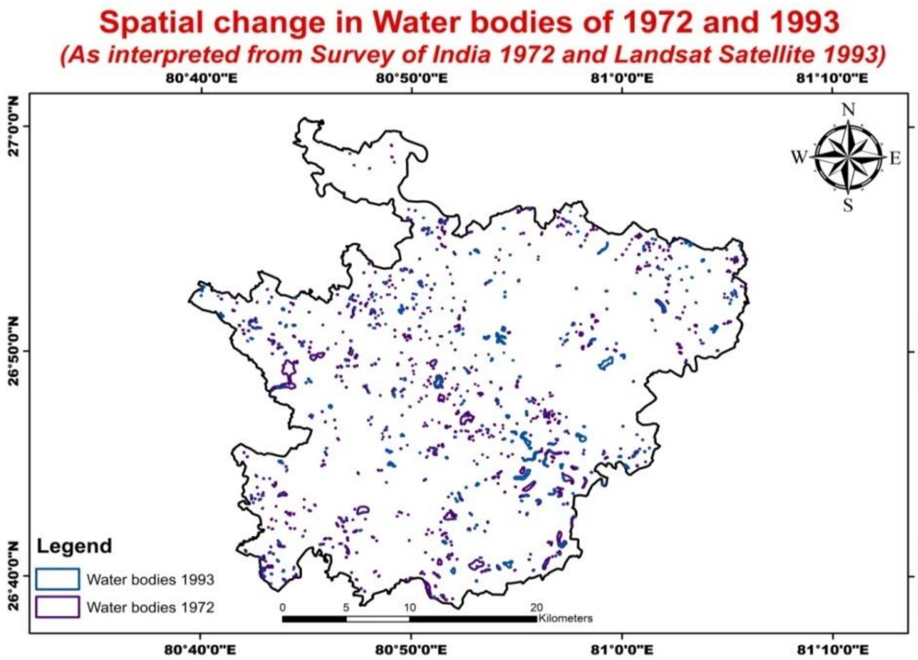

Fig 9: Spatial changes in water bodies of 1972 and 1993

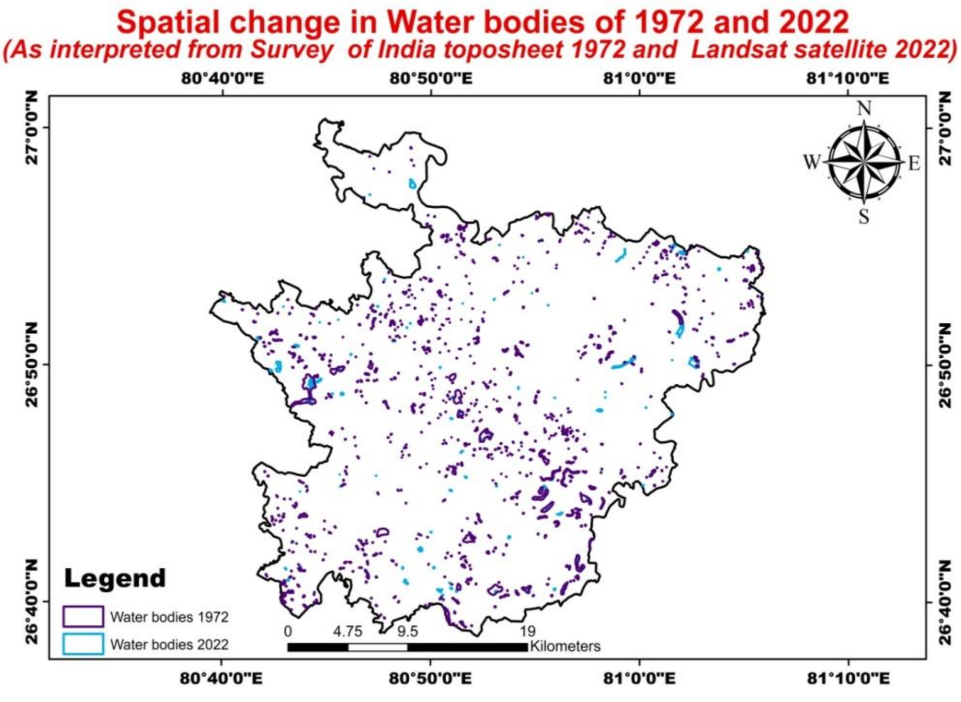

Fig 10: Spatial changes in water bodies of 1972 and 2022

CHAPTER 9: CONCLUSION

Water is an essential resource for life on earth. Water provides variety of purposes such as a source of water supply for domestic and industrial use, irrigated agriculture, livestock, mining activities, transportation and recreation (Kudesia, 1990). However by the increasing of the industrial development and anthropogenic activities the quality and quantity of water has decreased dramatically. Therefore, the monitoring programs using remote sensing and GIS are needed to maintain the quality and quantity of water. The GIS software can handle large amounts of satellite data sets in a user friendly window-based environment interface, as there is continuous improvement in software and computer technology.

Wetland mapping capabilities have been greatly improved over the past decades. Initial wetland mapping efforts were primarily based on manual photo interpretation of aerial photographs in conjunction with field data collection and verification, which are time-consuming and labor-intensive. The technological advances of GIS and remote sensing technologies have provided wetland mapping science with improved GIS tools and remotely sensed imagery with ever increasing spatial, temporal, and spectral resolution. Though the use and GIS and remote sensing has resulted in improved wetland mapping capabilities. The findings demonstrated that the total extent has been reduced between 1972-2022 in the Kakori, Chinhat and Sarojini Nagar blocks of Lucknow district. A significant portion of water bodies have perished during the last five decades as a result of development pressure, necessitating rigorous policy measures and a transparent monitoring system to prevent unauthorized use.

The numbers of water bodies are decreasing drastically due to urbanization, globalization, overpopulation, industrialization, overconsumption and mismanagement of water. Various steps can be taken to manage the water bodies of the area: the most important step is to educate the citizens of the area the importance of the water bodies. They should be protected and fenced by any kind of encroachments. Untreated sewage should not be discharged in the water bodies. Desilting, de-weeding, aeration, reduction of nutrient, removal of floating and other invasive aquatic plant-species etc should be processed in regular pattern. Buffer areas should be developed near the water bodies where no one should be allowed. Water quality of the area should be monitored in a regular manner.

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