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Research Article

Integrated geospatial database design for land use pattern analysis and its impact on local governance: A case study of Manesar Urban Complex, Gurugram, India

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Abstract

The absence of an integrated geospatial database hinders effective decision-making among various stakeholders in national projects and programs. The study aimed to create an integrated geospatial database for the Manesar tehsil, District Gurugram, Haryana. Another objective was to create a land use map to analyze the temporal change in land use patterns and its socioeconomic impact along the surrounding areas. The first stage of the study involved creating an integrated database after interviewing different stakeholders. In the second stage, the satellite imagery was georeferenced using Ground Control Points, and the land use patterns were digitized using Landsat imagery for 1987, 2011, 2014, and 2022. The study suggested that the construction area has grown up to 6% while cultivation has dropped significantly from 76% in 1987 to 50% in 2022. Likewise, the industrial area has grown up to 2% and natural vegetation dropped in coverage from 11% to 4%. The area witnessed a population growth rate of 3.2% per year and a decadal growth rate of 39.7%. Less than 50% of the land in the tehsil is used for agricultural purposes. It estimates that 4% of the tehsil's entire surface was covered by natural vegetation in 2019, down from 11% in 1987. The study recommends the creation of an integrated geospatial database that will help reduce duplication and speed up decision-making in government. This will pave the way for improving e-governance in local bodies. The framework created for developing the database system is universally applicable and can be used appropriately by other states, regions, and the entire country.

Keywords: E-governance, Geographical information system, Geospatial database, Land use, Remote sensing, Temporal analysis, Urban planning

INTRODUCTION

Rapid population increase and economic expansion have driven urbanization, one of the major challenges facing developing countries like India and is straining the entire political system. India has been fueled by a rapidly rising population, which is increasing at a rate of 1.41% per year despite occupying only 2.4% of the total world's land area (Shakeel *et al*., 2019). The economic growth, which is expected to be 6.9% for the financial year 2023 as per the world Bank (Aswin *et al*., 2023), places much strain on the entire governing system. Decentralizing the governance is the greatest approach to handling such a huge landmass and population (Shruti *et al*., 2014). Local government responsibilities were delegated to the states while the constitution was being written, and this was one of the clauses in the directive principle of state policy (Manjula *et al*., 2012; Hazra *et al*., 2013). By establishing the *Panchayati raj,* India made a tremendous contribution to decentralization. This was done after the 73rd amendment to the constitution, which resulted in a standard three-tier panchayat raj in all states. Gram panchayat is at the bottom of the three-tier structure, followed by Mandal and Zila panchayat (Hazra *et al*., 2013). The government may receive help from local experts and make quick, simple decisions through local governance. The lack of geographical and linked real-time non-spatial information that everyone can use is one of the primary causes of local governance's low effectiveness, among other issues (Tiwari *et al*., 2014; Panwar *et al*., 2016). Geospatial technology must be used locally to boost government development efforts and improve people's quality of life. It is crucial that the local decision-makers, including those in the Gram Panchayat, District Administration, and Municipal Corporations, have access to the geospatial data necessary for the development-related activities to address this issue (Kaushik *et al*., 2017).

Geographical Information System (GIS) is a computer-based system that captures, stores, analyses, and manages all kinds of spatial data (Breunig *et al*., 2001; Economou *et al*., 2018). The future of accelerating decision-making for sustainable local self-governance may lie in geospatial data with updated real-time information (Kumar *et al*., 2010; Fosu *et al*., 2015). Examples of effective systems include those used to collect local taxes and keep national land records. Following decentralization, local governments use geospatial datasets to control, monitor, and carry out various initiatives (Gabriel *et al*., 2015; Singh *et al*., 2018). The connectivity between the geodatabases that are accessible at the local, state, and federal levels is, however, far from the best. Due to this, implementing the state or center-sponsored project at the local level is not without its difficulties. Integrated geospatial datasets for all levels of governance have many advantages for decision-making. The present study outlines the layout of a standard geospatial database that can effectively supply geographic data to decision-makers at all three levels of governance. The lack of agency coordination and the officers' inability to access data on-site are two of the most prevalent issues in developing nations like India. Some of the most integrated issues are unplanned digging of roads by Jal board and telecom agencies, urban flooding of roads, road potholes maintenance, electricity thefts, clogged drains, illegal encroachments on right of way, road maintenance and periodic update of maps.

The task is to collect Geographic information through reliable sources and link it with a database that different stakeholders can use to make choices more efficiently in their daily activities. The possibility of discrimination will be eliminated because all governmental levels and municipalities will have integrated access to the data and be able to discharge their duties successfully and proficiently. A crucial factor in deciding the usability and acceptability of geographic information by end users is the availability of a standard geospatial database and an intuitive interface.

There are government agencies such as National Spatial Data Infrastructure (NSDI), National Urban Information System (NUIS) and Natural Resources Management System (NNRMS) trying to use the geographical information for various activities. However, their services domain does not include the integrated framework that all departments can use. They work in their respective domain for some specific usage only. The closest that is seen is the NUIS, which wants to prepare 10K and 2K maps but with limited use for infrastructure projects. The study aims to create a land use map to analyze the temporal change in land use patterns along the surrounding areas. Many studies have cited the visual depiction of data in vector and raster forms using GIS software as a critical element (Vathy-Fogarassy *et al*., 2017; Borrmann *et al*., 2015) and this emphasizes the visual interpretation of spatial data for decision-making. A GIS database is a collection of different attribute data kept in tabular form and structured. The database management system of various GIS software's, such as Arc GIS from ESRI, exploits the tabular relationships among data by performing several structural queries. Like other conventional databases, the geospatial database differs from them by being able to store, manipulate, retrieve, and display spatial data (NYONI *et al*., 2020).

The database management systems (DBMS) are specialized software packages that interact with users, other programs, and the database itself to collect, query, and analyze data (Thabani *et al*., 2020). GIS-based Spatial query languages were used to study the area's changing land use pattern (Borrmann et.al; Breunig *et al*., 2010). Building database models for applications like asset mapping, landslide analysis, and land use/ landcover research is the focus of the studies and literature that are now available. These databases can all be accessed individually for subject-specific research. To support decentralized administration, there has not been much research on how to build a single database that can be used by all government agencies (Breunig *et al*., 2016). The first goal of this study was to find the distinct types of geographic information needed for local governance in the Manesar region and link them with an integrated database that different stakeholders can use to make choices more efficiently in their daily activities. Various stakeholders, including experts and users, were consulted when developing a standardized geospatial database design for the present study. The second goal was to create a land use map to analyze the temporal change in land use patterns along the surrounding areas to understand the socioeconomic impact for enhanced decision-making for e-governance.

MATERIALS AND METHODS

Location of study area

The area is next to Gurugram district, covering the Manesar industrial township under tehsil Manesar at one side and Aravali ranges on the other side. The study area (Fig 1) is in the projected Gurugram-Manesar Urban Complex and covers an area of about 178 square kilometers along the Manesar tehsil in Haryana. The area's climatic conditions are very hot during summers, with the temperature rising to 45 degrees Celsius, while in winters, the temperatures dip down to 3 degrees Celsius. The average relative humidity of Manesar study area is 21% with peaking up to 70% in the month of August. The southwest monsoon is affected by El Nino, resulting in higher rainfalls in July and August (Mohan *et al*., 2011).

Methodology

The method was explored and adopted based on the goal of the study (Fig.2).

Datasets

To facilitate the study, we used the temporal Landsat-5, 8 satellite imagery from USGS to understand the spatio-temporal dynamics of surface changes. The satellite imagery was used as the background layer and the data was digitized in the CAD environment. Apart from the satellite imagery, multiple datasets such as road network with multiple attribute data, water distribution network etc. collected from various organizations was used.

Design of Database

The present study was able to gain insight into the viewpoints of individuals most strongly associated with the problems by researching through unstructured interviews (Jain *et al*., 2016; Kaushik *et al*., 2017) with members of panchayats, municipal councils, and local government officials. The discussion's goal was to learn how GIS technology is presently used in operational and decision-making contexts. The discussion with several government agencies influenced the database's design (Strauch *et al*., 2000). There were also brainstorming sessions with several government entities. The following agencies were contacted to prepare the database.

- Department of Town and Country Planning, Government of Haryana
- Haryana Urban Development Authority now renamed as Haryana Shehri Vikas Pradhikaran
- Haryana State Industrial & Infrastructure Development Corporation Ltd.
- National Highway Authority of India
- Dakshin Haryana Bijli Vitran Nigam
- Horticulture Department, Government of Haryana
- Excise and Taxation Department, Government of Haryana
- Below issues are highlighted during the discussion:
- Maintenance and repair of Road assets such as Road kerb, Traffic Island, Manhole, Ditch, Electric Poles
- Drainage
- Water logging
- Encroachment on Right of Way
- Plantation along the road
- Unauthorised construction

One of the major challenges faced by the authorities included the requirement for repairing and keeping road assets, such as kerbs, traffic islands, maintenance pits, ditches, electric poles, etc. Encroachment, poor design, waterlogging, and drainage presented significant issues to engineers (Amini *et al*., 2016; Daqian *et al*., 2022). Government organizations were using diverse types of spatial data to analyze a problem that calls for cooperation between them. Since many parties rely on their own data to meet their demands, there has been truly little cooperation among

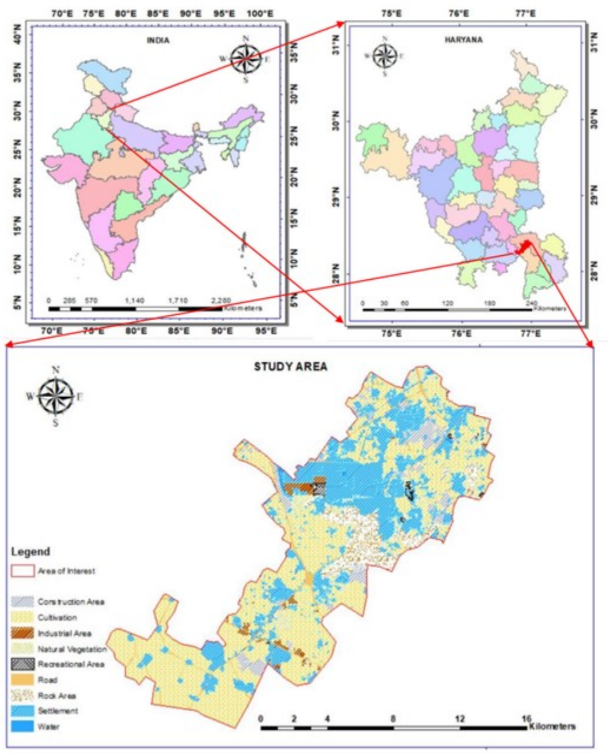

Fig. 1. *Location of study area*

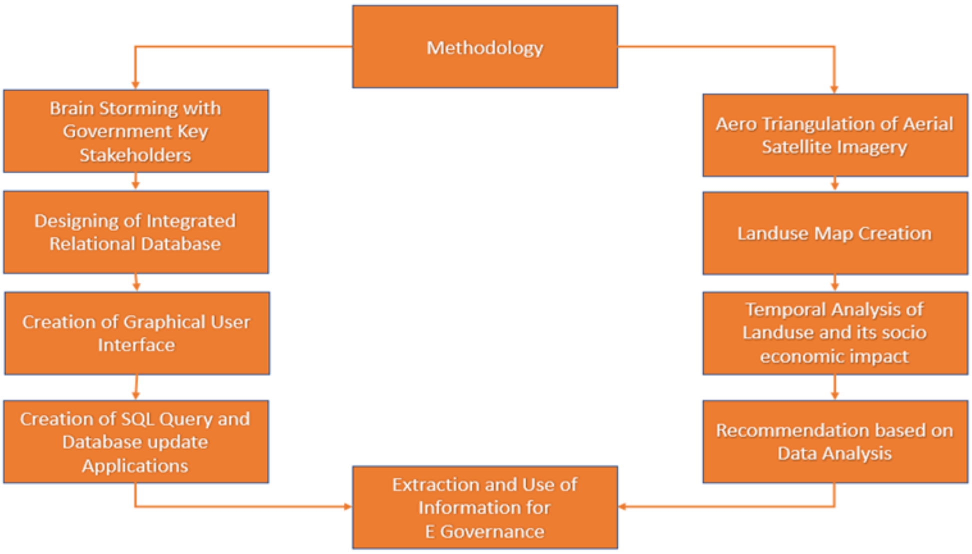

Fig. 2. *Methodology for designing relational database and temporal analysis for e- governance*

agencies (Khovrichev *et al*., 2019; Masmoudi *et al*., 2021). The decision-making process to deal with the issues discovered was delayed as a result. At the end of the brainstorming sessions, the most often occurring features with issues were found and categorized according to their attributes and Sub attributes as depicted in Table 1.

Identification of data types

After compiling all the data, the identified features were classified into their Categories and Groups, as shown in Table 2. The structure of the Feature was decided based on its location and usage and accorded the Point, Line and Polygon attribute. Attribute information requirements were later set for each field, including integer, Boolean, text, Date (Carrion *et al*., 2009; Kumar M *et al*., 2010; Suzanchi and Kaur *et al*., 2011; Le *et al*., 2013). The columns having Feature names have been given unique primary keys.

Conceptualization of Relational Database Management System (RDBMS)

Design of database model is a process of conceptual representation of the data structures in a database where data structures form objects of data, relationships between data objects and rules which regulate

Table 1. Table for creation of relational database for Manesar Tehsil, District Gurugram, Haryana

Geography Markup Language Name	Manesar Feature Name	Category Name
Building	a101_Building	Buildings
Road Center Line	a301_RoadCentreLine	Traffic
Railway	a303_Railway	Traffic
Parking Area	a306_ParkingArea	Traffic
Settlement Village	a205_SettlementVillage	Built-up Area
Under_Construction Area	a207_Under_ConstructionArea	Built-up Area
Urban Area	a201_UrbanArea	Built-up Area
Industrial Area	a202_IndustrialArea	Built-up Area
Lake	a601_Lake	Water
Water Way	a602_WaterWay	Water
Rocky Area	a505_RockyArea	Vegetation
High Tension Wire	a405_HighTensionWire	Technical Installations
Water Treatment Plant	a408_WaterTreatmentPlant	Technical Installations
Electric Substation	a415_ElectricSubstation	Technical Installations
Electric Pole	a403_Electric_Pole	Technical Installations

Table 2. Data base structure for Manesar tehsil, district Gurugram, Haryana

Category Table	Attribute Table	SubAttribute Table	Indexing	Value Definition	Text Description	Boolean Table
A101_Building	Type of Building ID	PL_101_TypeOfBuilding	MSLink	Value		1
A000_Default	Metadata ID	Metadata	MSLink	MSLink		0
A301_RoadCenter Line	Type of Traffic ID	PL_301_TypeOfTraffic	MSLink	Value		1
A301_RoadCenter Line	Surface ID	PL_301_Surface	MSLink	Value		1
A301_RoadCenter Line	Roundabout ID	PL_000_Boolean	MSLink	Value	Description	1
A303_Railway	Metadata ID	Metadata	MSLink	MSLink		0
A303_Railway	Type of Track ID	PL_303_TypeOFTrack	MSLink	Value		1
A303_Railway	Level ID	PL_303_Level	MSLink	Value		1
A304_RoadEdge	TypeID	PL_304_Type	MSLink	Value		1
A304_RoadEdge	SurfaceID	PL_304_Surface	MSLink	Value		1
A307_TrafficFence	TypeOfFenceID	PL_307_TypeOfFence	MSLink	Value		1
A401_TechnicalArea	TypeOFAreaID	PL_401_TypeOfArea	MSLink	Value		1
A402_BasinReservoir	TypeOFBasinID	PL_402_TypeOfBasin	MSLink	Value		1
A405_HighTension Line	TensionID	PL_405_Tension	MSLink	Value		1
A410_Pole	TypeOfMediumid	PL_410_TypeOFMedium	MSLink	Value		1
A602_Waterways	Network ID	PL_602_Network	MSLink	Value	Description	1
A602_Waterways	Visible ID	PL_602_Visible	MSLink	Value	Description	1
A801_AreaPolygon	Type ID	PL_801_Type	MSLink	Value	Description	1
A510_LanduseBoundary	Type of Landuse Boundary ID	PL_510_TypeOfLanduseBoundary	MSLink	Value		1
A511_Slope	Type of Slope ID	PL_511_TypeOfSlope	MSLink	Value		1
A203_IndustrialHigh Density	Metadata ID	PL_203_Metadata	MSLink	MSLink		0
A201_UrbanHighDensity	Metadata ID	PL_201_Metadata	MSLink	MSLink		0
A202_IndustrialLow Density	Metadata ID	PL_202_Metadata	MSLink	MSLink		0
A415_ElectricSubstation	Metadata ID	PL_415_Metadata	MSLink	MSLink		0

operations on the objects (Chen *et al*., 1976; Egenhofer *et al*., 1991; Bradley *et al*., 2010; Le *et al*., 2014). The Relational model is simple to implement and efficient in its results. It enables the use of a high-level query language, also known as Structured Query Language (SQL). It can be used to avoid time-consuming manual database browsing. A relational database's entries, rows, and columns can easily be increased or decreased without affecting any of the relevant applications (Al-Saffar *et al*., 2018; Hu, *et al.,* 2018). The foundation of every GIS is its data models, which provide a framework for selecting and characterizing elements of the actual world in a digital environment. RDBMS guarantees the correctness and integrity of its data by preventing data storage in many places (Amirebrahimi *et al*., 2016; Arroyo *et al*., 2018; Li *et al*.,2022). Fig.3 shows the general procedure for creating RDBMS.

Creation of relationships among tables

Relationships between tables are the most important aspect of the architecture, as this is where the power of a relational database is realized (Le *et al*., 2013; Boguslawski *et al*., 2015; Breunig *et al*., 2020; Mekala *et al*., 2020; Daraio *et al*.,2022). The present study compiled a set of metadata describing each Feature, attribute, and sub-attributes used to ease the development of a unified database. Most of the time, the simplest one-to-one relationships were kept, but based on some specific requirements, there are also many-to-many database relationships (L. Dalla Valle *et al*., 2018; Hor et al., 2018). Fig.4 shows some of the most important connections in the present data set.

Refinement and normalization of design

There were several iterations in the standardization process for the design. Features have been broken down into distinct tables by categories and feature types. All normalization principles were followed for a database to be considered well-structured (Le *et al*., 2014; Khovrichev *et al*., 2014). In the first normal form, each cell contained a single value. A second normal form, a third normal form and a higher order normal

forms were introduced. By using consistency standards to examine the schema tables, data integrity, and consistency, the database was put to the test.
This included the following checks:
The primary key has no NULL values.
The primary key value and each foreign key value were matched.
Column indexing was done to make it easier to search for and retrieve data. Different queries were developed to support data retrieval and linking.

Creation of Graphical user interface

Bentley's MicroStation (MSTN) and the database Microsoft Access were combined to supply a graphical user interface that enabled real-time viewing and changing of feature attributes (Lenzerini *et al*., 2002; Wiedau *et al*., 2019; Masmoudi *et al*., 2021). Bentley micro-Station API (application protocol interfaces) and Solution Development Kits (SDKs) were used to create Graphical user interface for use in the Microstation environment. The Bentley API consists of rules and CAD (Computer Aided Design) tools to aid the digitization of line, point and areas plus linking it to the SQL database. Microstation can host and interface with a variety of programming languages. Various Libraries for MicroStation Development (MDL) are available to develop CAD products and the most stable and feature rich MicroStation programming environment available by MDL

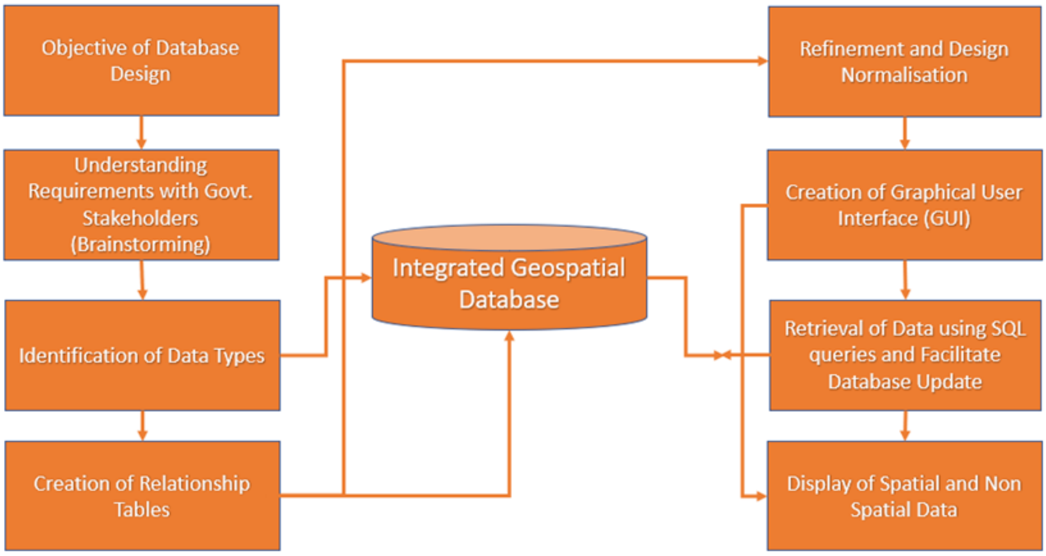

Fig. 3. *Approach for Geo-database creation*

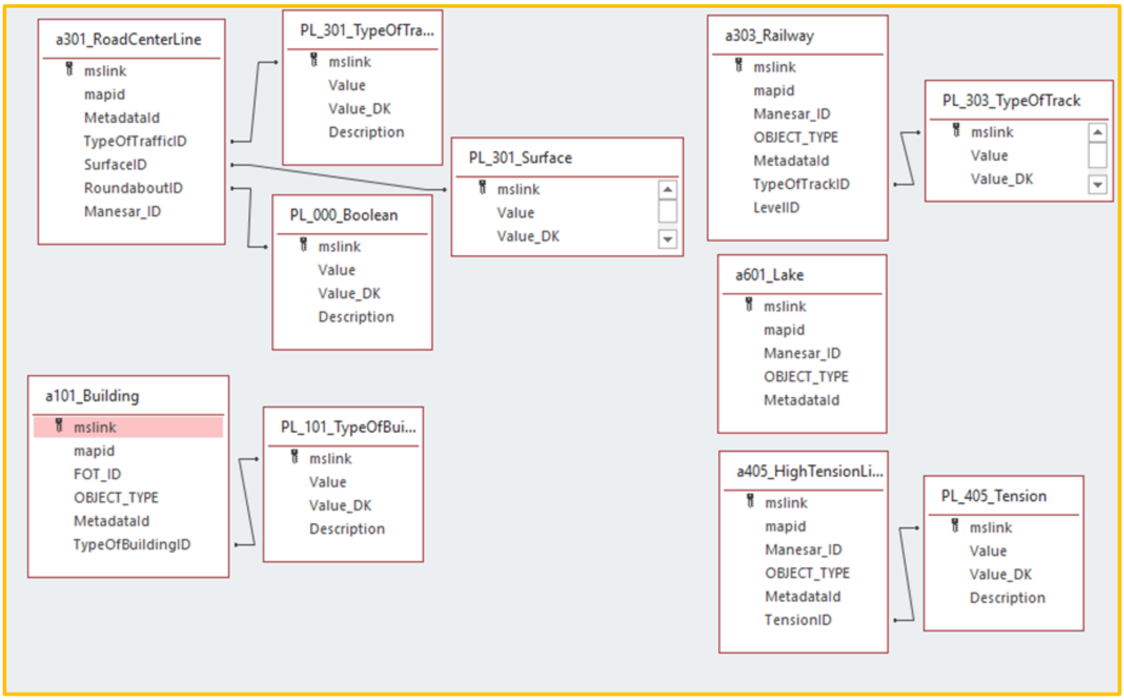

Fig. 4. *Relationship table for database design of Manesar Tehsil, District Gurugram, Haryana*

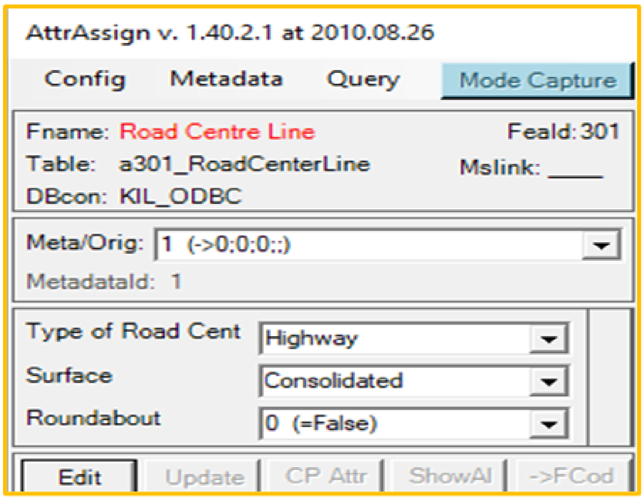

Fig. 5. *Graphical user interface*

to intermediate and advanced programmers. It offers managed (Microsoft.NET) and native (C++ and C) APIs (Application Protocol Interfaces) that provide complete access to the MicroStation environment and output format (DGN) design data. DOT.NET framework 3.5 using C# programming language was used for development initiatives. Bentley Project wise SDK (Solution Development Kits) was used to create custom utilities and enhancements. “C” libraries were used to design the windows and console application which is called the “Attribute Assign” tool. The tool offers typical attribute assignment capability for element capture and attribute manipulation.

The attribute assign tool has the following functionalities (Fig.5):

- Feature digitization
- Selection of attribute for multiple features
- Query based selection using fence mode.
- Database update
- Database validation

Retrieval of Data through SQL queries

Various lines and colour styles were applied to make the traits and attributes easier to discern. As part of the testing process, a variety of SQL-based queries were run to decide how well the database design followed the requirements (Michael *et al*., 1990; Rajagopalan *et al*., 2014; Tan *et al*., 2017; Wu *et al*., 2017; Goyal *et al*., 2017; Vathy-Fogarassy *et al*., 2017).

The routes surrounding the intersection of the KMP motorway and the NH48 are shown in Fig 6. The NH48 is in cyan, and the KMP Motorway is in yellow colour (Manoj Panwar *et al*., 2016). The above, however, is primarily intended to find other "All traffic" types of roads and those with "unconsolidated" or unpaved road surfaces. Green dotted lines represent the unpaved roads. Query as below.

Select *from a301_roadcenterline where surfaceid = 2 and mslink =

Where surfaceid = 2 denotes the roads as “unconsolidated” or unpaved

Land use Map

Satellite data used.

For the study's goals, the USGS (United States Geological Survey) site was used to download the available Landsat Satellite Imagery of the study region. USGS Explorer has images for 1987, 2011, 2014, and 2022; these images were downloaded and used after the necessary processing. The imagery's specifications are listed below.

The satellite imagery of Year 1987 belongs to Landsat - 5 with 28-meter resolution.

The satellite imagery of Year 2011 belongs to Landsat - 5 with 30-meter resolution.

The satellite imagery of Year 2014 belongs to Landsat - 8 with 30-meter resolution.

The satellite imagery of Year 2022 belongs to Landsat - 5 with 30-meter resolution.

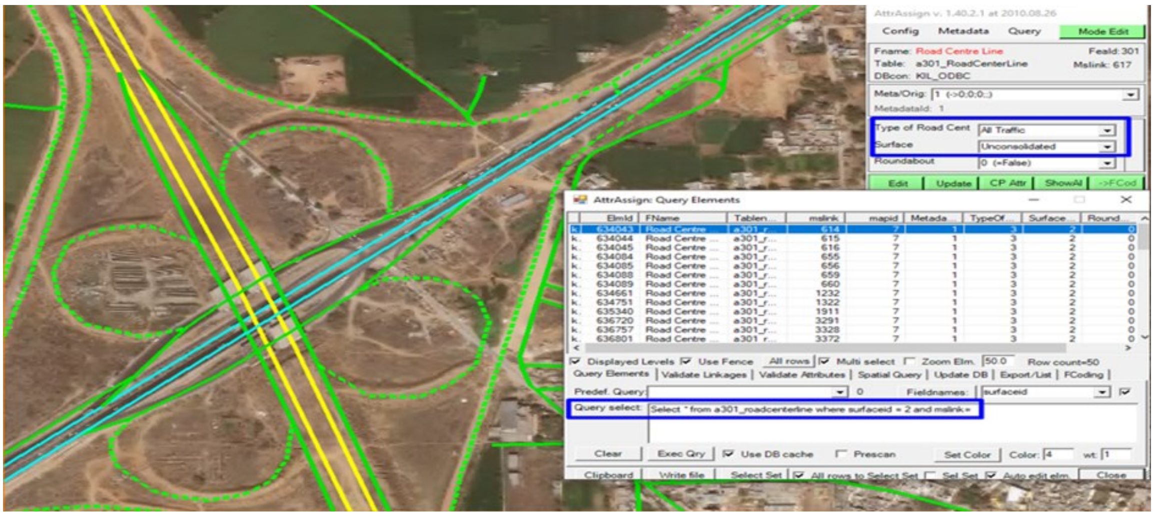

Fig.6. *Result of attribute query for line feature – kundli manesar palwal (KMP) expressway*

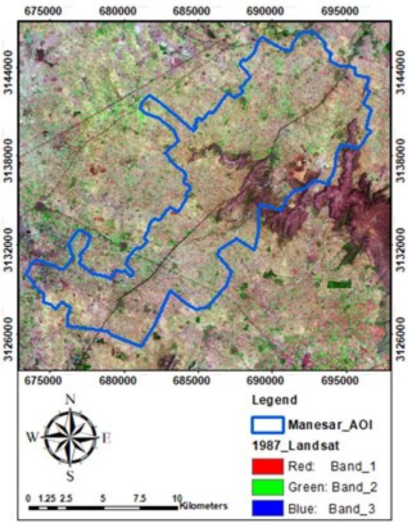

Fig.7. *Land use map of year 1987*

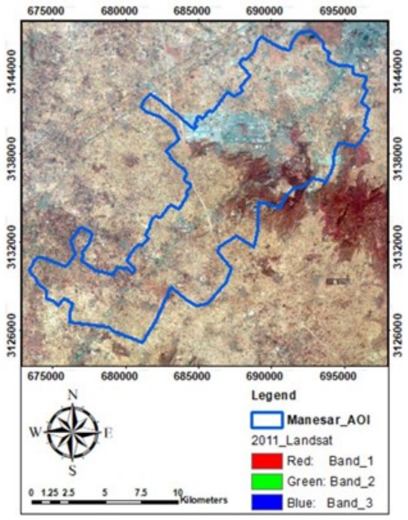

Fig. 8. *Land use map of year 2011*

The downloaded image was made up of several bands of pan imaging, thus, all the bands were combined using the ERDAS-imagine program to create a multispectral image. For this, the RGB (Red, Green, and Blue) bands 1, 2, and 3 were used (Fig 7-10).

Preparation of land use land cover

Arc GIS version 10.2.1 land cover map was used to prepare the land use. The following elements on satellite imagery were digitized based on manual interpretation to decide how land use patterns have changed over time (Fig.11).

RESULTS AND DISCUSSION

The Manesar region's municipal, electrical, and transportation departments can now access integrated geographical data. A database-first approach was taken to handling shared geographic data, which is a crucial part of any GIS. A solid database architecture was built using MicroStation and the Microsoft database, and a base map with topographical elements was produced (Jyothi *et al*., 2013; Zhang *et al*., 2014; Azzalini *et al*., 2021). These three GIS components allow structural attribute searches to be developed for requirement analysis (Hardware, software, and Geospatial data). The entire area is mapped with a connection to buildings, traffic, populated regions, technical infrastructure, water, vegetation, and other factors. Using its distinguishing type IDs and surface IDs, 27 significant properties were mapped. Each feature type and attribute have a unique colour to represent them. It is simple to discern between joint surfaces (solid) and unconsolidated ones (dotted) due to the visual cues used to depict them. The topology, data editing, and attribute searches of the GIS database are all fully operational, enabling reliable daily decision-making (Ozel *et al*., 2000; Zhu *et al*., 2018; Fikri *et al*., 2019). The database was highlighted, and carefully created SQL queries were used to confirm it. Field engineers, town planners, and

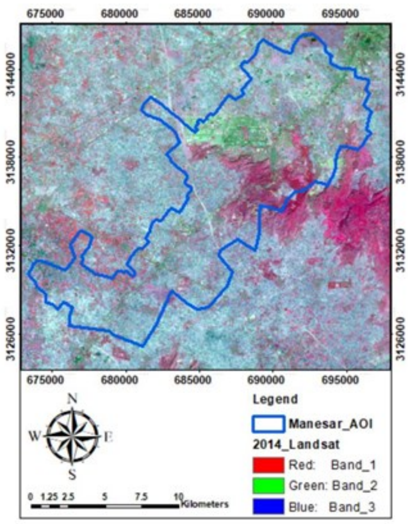

Fig. 9. *Land use map of year 2014*

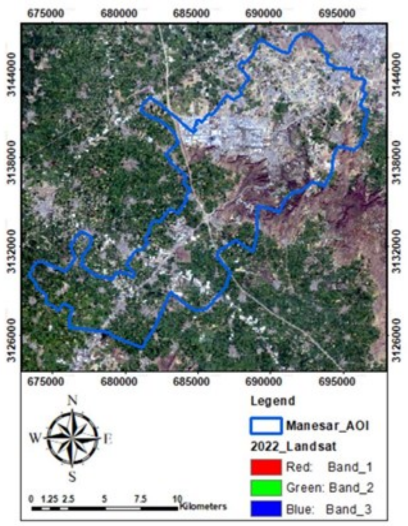

Fig. 10. *Land use map of year 2022*

S.NO	Category (Features)	Remarks
1	Urban Area	Clustered, uncluttered building across the towns in study area
2	Area Under_Construction	Site where development work was found in progress across the years
3	Farmland	Agricultural farmland
4	Forest Area	Forest
5	Industrial Area	Defined location as industries by Government across the study area
6	Rocky Area	Mountainous region
7	Recreational Area	Tourist place and public/restricted area identified for recreational purposes
8	Road Center Line	All transportation network covered under road category
9	Water Way	All identified water body across the study area

Fig. 11. *Land use classification*

related offices used data for attribute-based enquiry during testing and deployment. This dataset is unique because it provides a distinct place for all data that may be updated at any time during a specified period. Geographic information on buildings, traffic, populated areas, technological infrastructure, water, and vegetation can all be viewed graphically and in tabular format using a single SQL query.

The database developed will open a lot of avenues in streamlining e-governance. It will decide the ownership of the land, which is one of the biggest problems in India. Almost 70% of the cases in Indian courts are related to land ownership (prsindia.org). The data can be sold to banks, insurance companies, and other agencies for property registration. The model will be self-sustainable and can even be used as a profit center. Banks spend around INR 25,000 (US$ 300) to collect all the relevant documents before disbursing the Loans. This can be done at the click of a button at 10 times cheaper cost. Online Property registration is already in use by Banks and legal authorities in Canada (titleserachers.ca/registries).

Web GIS

An online web based intelligent geospatial database that links the smallest unit of governance in India, panchayats to blocks and to districts was identified as a necessary improvement. Fig.12 illustrates the approach's three separate components. The first segment (temporal data) constitutes the usage in GIS based analysis, all pertinent historical data that can be gathered into a database. This could include orthophotos, historical vector data, information from census records, weather records, crop patterns, etc. The second part can help with the database's real-time insertion of spatial and non-spatial data. At predetermined intervals, the map and its attributes may be updated to reflect current affairs (Tan, Z *et al*., 2017; Wu *et al*., 2017). The Field surveyor can act as a moderator in case of discrepancies, approving data and altering the dataset in response to requests from the end user or a third party. In Third Segment, users who want to gather information relevant to their interests could access this section of the website. One might have the option to select real-time updates in this situation, such as the most recent crop pattern in each village's panchayat. This information can be used to decide the types of grains and veggies available in the area.

The inability of several government entities to collaborate productively results in added expenses for the general population (Winter *et al*., 2000; Park *et al*., 2017; Zadeh *et al*., 2019). Some examples of this include multiple organizations excavating the same road twice, mistaken taxing, and encroachments that have not been notified (Zope *et al*., 2013; Jain *et al*., 2017; Desai *et al*., 2018). The study revealed that a GIS-based solution can be made accessible in the form of a common geographic database that many government organizations can use simultaneously. A web-based shared intelligent geospatial database that can link panchayats to blocks and then those blocks to districts was found to be necessary. As a result of the research, a Geodatabase have been created to helps all local governing bodies cooperate to reach rational decisions. A vector map of the study area can be produced because of the research to design a web-based user interface.

End users can use this interface at all levels of a three-tier Panchayat system. By analyzing and gaining access to the most recent information will be of assis-

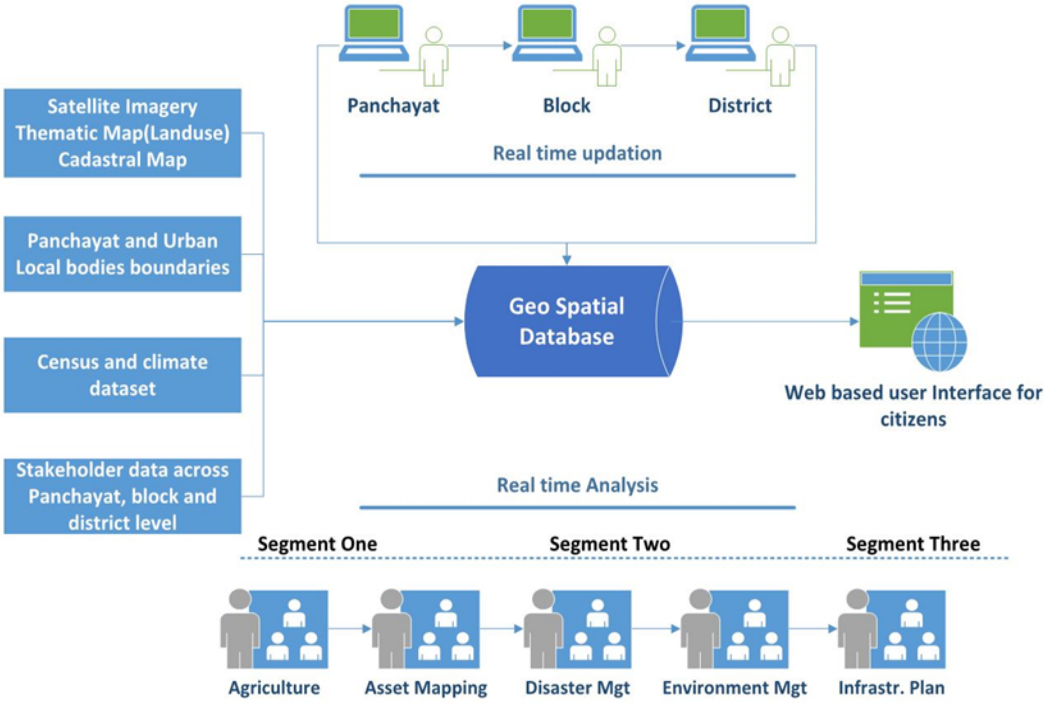

Fig. 12. *Web based integrated geospatial database management system*

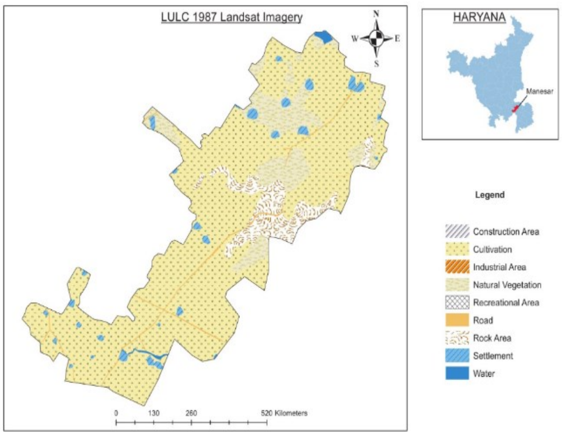

Fig. 13. *Landuse map for year 1987*

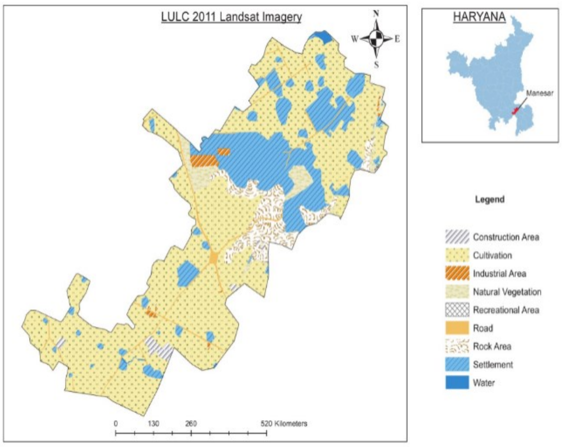

Fig. 14. *Landuse map for year 2011*

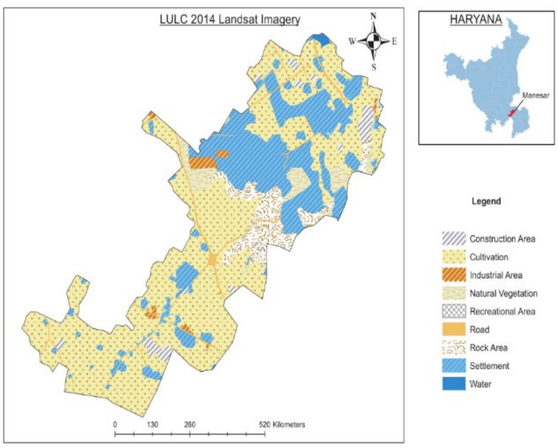

Fig. 15. *Landuse map for year 2014*

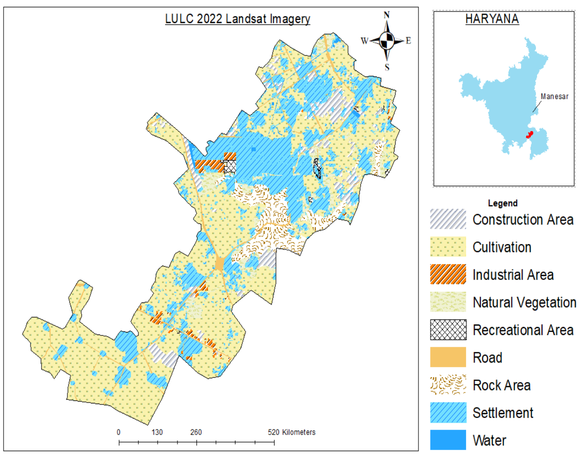

Fig. 16. *Landuse map for year 2022*

tance to the relevant stakeholders in the process of making day-to-day decisions (Lienhardt *et al*., 1994; Irizarry *et al*., 2013; Valle *et al*., 2018) This will also help in effective functioning and speedy decision making, eliminating the lag time, and saving both time and money in the process.

Adding more characteristics and qualities relevant to the research topic to the database is possible. The study concluded that the Government of India should form a high-level team with professionals from many sectors to investigate and create a standard geospatial database definition for the entire country. All facets of the public and commercial sectors of governance should adhere to this specification.

Landuse Mapping

The feature-wise area statistics were examined to understand the temporal changes in land usage, pattern, and their effects on the 36 villages scattered throughout the Manesar tehsil (Fig 13 – 16). The increasing tendency of the industrial and construction areas had a corresponding impact on settlements, which have also been growing in recent years. The transportation network has grown significantly over the years and nearly doubled in the last ten years. The shift in crop patterns where less land is being used for cultivation has been linked to increased man-made features (Tiwari *et al*., 2014). The easy connectivity of the local markets is made possible by the developed transportation network, which shifts agriculture from cereals to vegetables. Yet, the study predicts that because of government land purchases and the growth of urban complexes, agricultural products will decline even more soon.

Population and habitation

Infrastructure improvements in the studied region attract immigrants, which causes the population of metropolitan areas to grow quickly. According to Census 2011, the Manesar Tehsil is made up of 34 Villages, which together have a total population of 116,606 people and 440,74 homes. The estimated population of the 34 villages along the Manesar tehsil by the end of 2023 will be around 152064 and by 2025 be around 198304 if the increasing past population is computed using the "Geometric Growth Technique" (Fig 17). This technique predicted a population growth rate of 3.2% per year and a decadal growth rate of 39.7%.

The settlement area has risen from 2% (1987) to 15% (2011) and 21% (2014) of the total Manesar tehsil area due to infrastructure upgrades and an increase in the immigrant population and is now occupied by 26% of the area. The area with growing settlements (Figs 18–19) directly affects the number of households, which has risen from 13817 in 2001 to 44074 in 2011 and is projected to reach 80000 by 2025.

Changes over the past 20 years

Over the past two decades, the study region has experienced accelerated growth in terms of the development of industries and the attraction of further forthcoming IT (Information Technology) park developments. It increases the Gurugram district's export potential and creates jobs for the local villagers. There are several industrial production facilities for vehicles, pharmaceuticals, software, telecommunications, food processing, insecticides, pesticides, and other products in the Gurugram-Manesar-Bawal belt. The government also intends to use the Metro train network to link Manesar and Gurugram. The study region has also seen chaotic real estate development (Construction area). A well-developed transportation network, which makes up 4% of the total area, has speeded up the construction of infrastructure projects, drawing in many real estate players in the area. 6% of the overall study area is currently under construction for ongoing projects (as

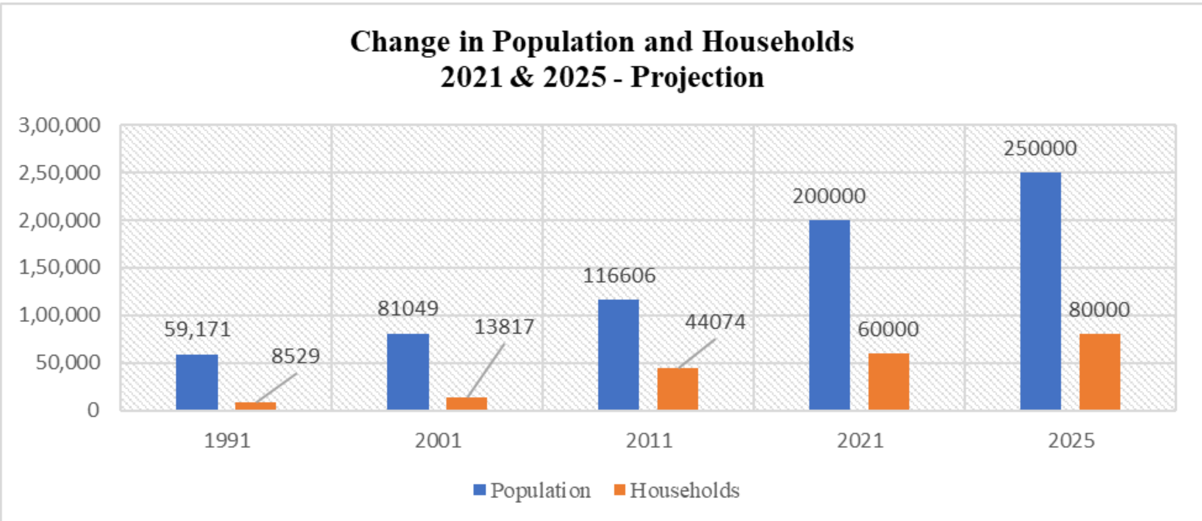

Fig.17. *Census data of population and households (1991, 2001 and 2011) and forecasted population for 2023 and 2025 of Manesar Tehsil, District Gurugram, Haryana*

opposed to the area that has previously been set up).

Agriculture

According to the study, the loose, sandy-to sandy-loam soil in the Manesar tehsil area is productive and excellent for farming. The two primary categories of crops grown in the research region are *kharif* and *rabi*, also known as *sawani* (Kharif - during the summer) and *sadhi* locally (Rabi - during Winter). The study area's principal kharif crops include paddy, sorghum, and millets, while its minor kharif crops include oilseeds, pulses like *masoor (Lens culinaris)*, and vegetables such as Pumpkin *(Cucurbita pepo),* bitter gourd *(Momordica charantia),* okra *(Abelmoschus esculentus)*, cucumber *(Cucumis sativus)*, chillies *(Capsicum annuum L)*, tomato *(Lycopersicon esculentum)*, brinjal *(Solanum melongena L),* onion *(Allium cepa).* The primary *rabi* crops include wheat, barley, rapeseed, and mustard oil seeds. *Rabi* pulses, fodder crops, and rabi vegetables are the minor rabi crops, radish *(Raphanus sativus),* carrot *(Daucus carota subsp. Sativus),* turnip *(Brassica rapa*), brinjal *(Solanum melongena L),* cauliflower *(Brassica oleracea var. botrytis),* potato *(Solanum tuberosum),* pea *(Pisum sativum),* tomato *(Lycopersicon esculentum),* Cabbage *(Brassica oleracea),* palak *(Spinacia oleracea),* methi *(Trigonella foenum-graecum)* while the primary cash crops for villagers are vegetables.

Nonetheless, the government's land acquisition for several current and planned projects has altered the region's agricultural landscape. According to a temporal analysis of satellite imagery, less than 50% of the land

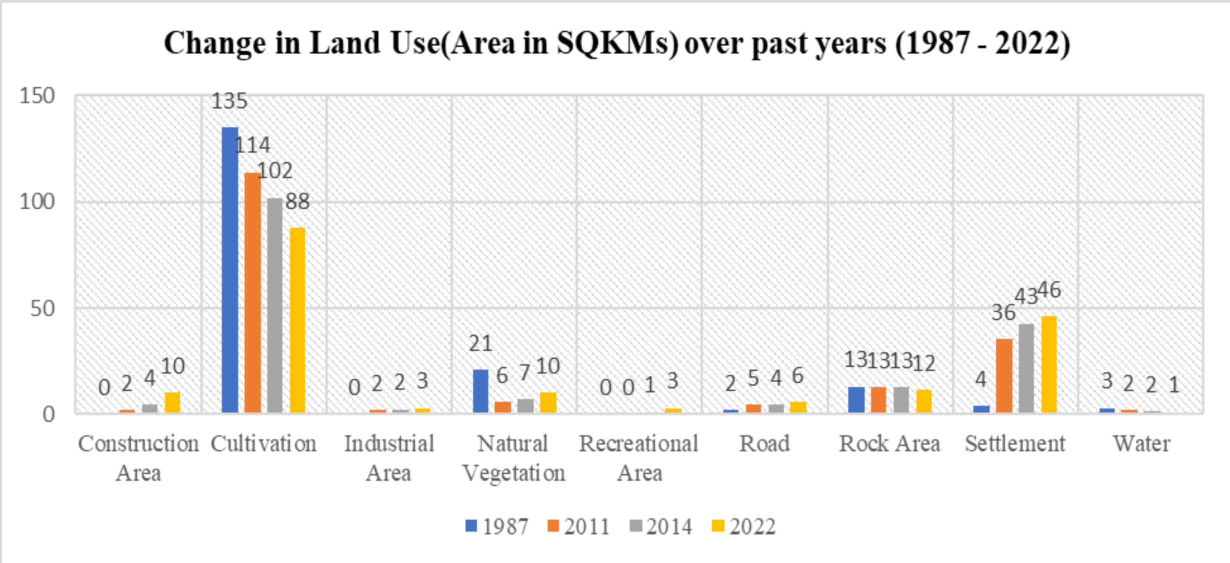

Fig.18. *Change in land use area of Manesar Tehsil, District Gurugram, Haryana*

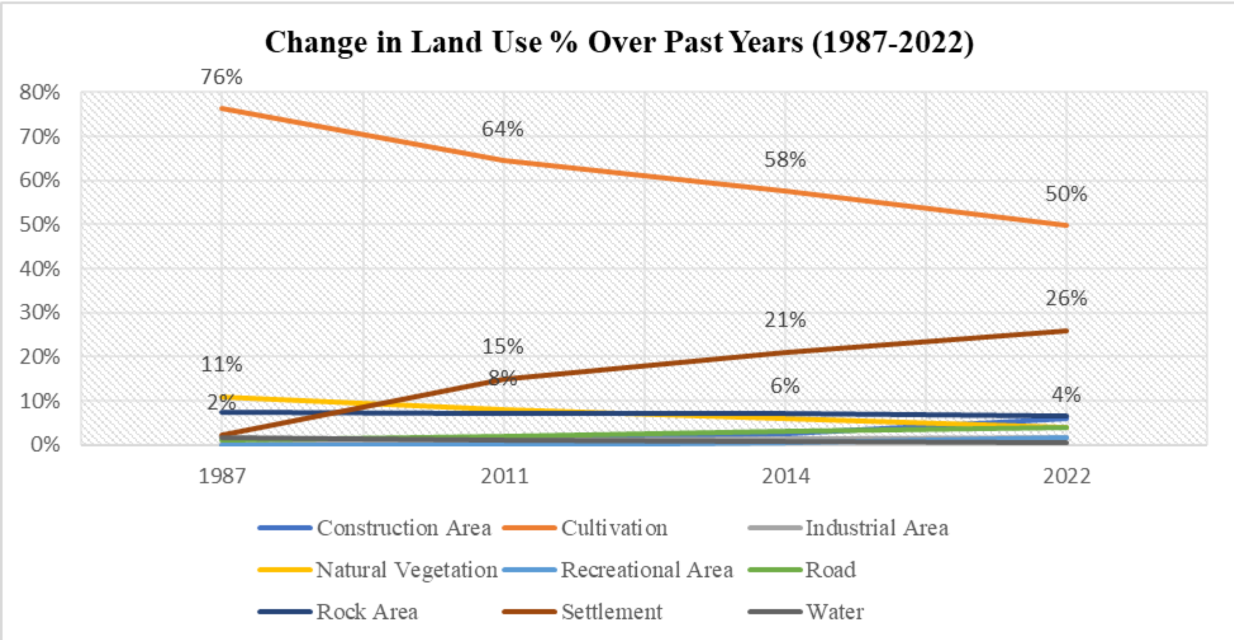

Fig.19. *Change in % area of Manesar Tehsil, District Gurugram, Haryana*

in the tehsil area appears to be used for agricultural purposes. Moreover, it estimates that 4% of the tehsil's entire surface was covered by natural vegetation in 2019, down from 11% in 1987. The way of life of the farmers has also been affected. Several farmers in the study region had to choose alternate forms of income since they lost their farming land due to land acquisition. This covers both the money received by the government and the rental income from the homes built on the agricultural land.

Sources of water

A perennial river does not cross the study area in Manesar tehsil. Several inland seasonal streams are smaller in size and do not significantly contribute to meeting rising water demand. Less rain falls on average in the region, and it does so from July to September. According to data released by the Metrological Department, the Gurugram district experienced an average rainfall of 118.3mm (about 4.66 in) in July, 116mm (about 4.57 in) in August, and 112.2mm (about 4.42 in) in September 2018. The study area's average annual rainfall falls short of what is needed for a thriving agricultural sector and long-term development.

The Manesar region relies on groundwater for both everyday necessities and agriculture. According to an analysis of historical satellite images, natural water sources (canals) have been reduced to 0.6% of the total area because of drying natural ponds, canal encroachment, and rapid building. According to the report, the area's unsustainable expansion has raised water demand, and a decline in rainfall has led to an overuse of groundwater for agriculture and daily household needs. Manesar's water supply sources are groundwater and surface water from the Gurugram Water Supply (GWS) canal. The groundwater is also used for agriculture across from the Manesar tehsil. The Central Ground Water Board reported that the water table in the Gurugram district is declining by 1.1 to 1.2 meters annually. Due to uncontrolled construction, high population density, and thus rising water demand, this may get worse in the studied area by 2030.

Conclusion

The study was necessitated considering the lack of GIS -based decision support system for e-governance. This resulted in creating a unique geospatial database for monitoring and controlling rapid changes in demographic and land use patterns. The study offers a workable solution for stakeholders in local government to build an integrated geospatial database. It was developed considering the inputs from various stakeholders. During the study, a web-based application prototype with implementation suggestions was delivered. It connects to the integrated geographic database for geographic searches. The research requires project-oriented development and customization of spatially responsive SQL. The most innovative spatial analysis tools were previously only available on desktop GIS. The unified data management, change analysis and stored data through a single online browser interface were unified. For apps and development, this can also work well. A web-based GUI (Graphical User Interface) is designed based on DOT.NET and C# platform which interacts with geospatial database. The GUI also facilitates the extraction of results in a user-friendly manner using SQL queries. Several applications in design have been given to make it user-friendly, including predefined queries on non-spatial data, database update and validation, auto zoom and multiple feature selection on maps, selection of vector data using the window, and multiple edits on the vector data. The stakeholders in the government can readily get the information in their offices without visiting the site. The database and its design can be replicated at pan India level. Many Ministries such as urban development, railways, road, and transport etc. can be invited to prepare a common database, which the Government of India can then use for planning and execution purposes.

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Conflict of interest

The authors declare that they have no conflict of interest.

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