

Chapter 1

Introduction

1.1 Urbanization

Urbanization refers to the migration of individuals from rural to urban regions, leading to significant transformations in the size and structure of cities [1]. It encompasses both a temporal and a gradual process [2]. It is a form of urban growth that occurs as a response to complex economic, social, and political influences, as well as the physical characteristics that may be associated with a region [3]. It is the process through which rural regions undergo transformation and become urban spaces [4]. The degree of urbanization can be determined by calculating the percentage of the population that resides in urban areas [5]. Global trends reflect that urbanization has happened in the past, is currently happening, and has the potential to continue in almost every part of the world [6]. This shift to urban spaces is sheerly motivated by the pursuit of favorable prospects and socioeconomic prosperity.

Urbanization, in fact, also refers to the relationship between the entire population and its urban segment [1]. It is most commonly employed as a demographic indicator, indicating the increase in the proportion of urban population relative to the total population over a specific period of time and is expressed in the form of Conurbation. Conurbation refers to the disorderly, unplanned, and uneven expansion beyond the administrative limits of a town or metropolis, mostly due to growth in population [7]. The immediate consequence of such conurbation is the alteration in the utilization of land and the physical characteristics of the region. The spatial distribution and extent

of urban conurbation will reflect the nature and form of sprawl in the specific geographic region or locality where population growth is occurring.

Urbanization is influenced by factors such as quality of life, availability and access to resources, geography, socioeconomic dynamics, and many more. The growth and progress of cities greatly depend on their critical factors. In India, urbanization is a complex process that has a significant effect on society, leading to modernization, providing opportunities for innovation, and overall improvement in people's lives.

In the Indian context, the urban population has experienced significant expansion. The urban population is growing rapidly, mostly because of significant migration from rural and smaller towns to larger cities, driven by the desire for improved employment prospects and a higher quality of life. The rapid increase in population has caused unplanned expansion in urban areas.

1.2 Urban Sprawl

It is well understood that the community's socio-economic progress and associated transitions in the environmental conditions are greatly influenced by the settlements developed for its sustenance. The studies related to building sustainable communities are referred to as Sprawl [8]. Urban sprawl can be defined as low-density [8], haphazard [8], uncontrolled [9], unplanned [10], and unrestricted [11] proliferation of urban spaces into rural as well as natural landscapes to meet the increasing demand arising from escalating population growth [12][13] and their aspirations towards attainment of economic stability and prosperity. Continuous increase in population in and around urban spaces results in an increase in the requirement for infrastructure

establishments to meet up with the emerging needs arising from requirements related to academics, administration, transportation, recreation, public health, and public convenience [14][15]. Sprawl results in negative consequences such as the depletion of agricultural land, open space, and environmentally fragile habitats [16]. Furthermore, sprawl also relates to the enlargement of a municipality or urban area through radial or linear expansion. Put simply, as the population of a neighborhood or city grows, the town's boundaries expand to accommodate the growth. Sprawls typically occur on the outskirts of urban areas, either at the edge of the city or along major highways [17]. Developing countries are at the forefront of the transition process during periods of peak growth rates. Sprawl is regarded as one of the potential dangers to urban growth.

The remarkable expansion of urban agglomerations in numerous emerging countries can be attributed to a tripartite process of structural change: the shift away from agricultural employment, significant overall growth, and rising urbanization rates [18]. The primary problem for science, engineering, and technology in the 21st century is finding a solution to provide sufficient housing, sanitation, health, and transportation services in livable urban environments in emerging nations.

Understanding sprawl trends and their analysis leverages the quality of remote-sensed data and the capabilities of associated data-processing technological tools that analyze the data critically and help in deriving objective, motivated results that would help responsible agencies to make quality decisions as well as formulate effective plans. Further, value addition to the results may be performed by incorporating multifaceted data periodically published by various agencies.

1.2.1 A brief on types of Urban sprawl, its characteristics, causes, consequences and control measures

Urban sprawl can be categorized into different types, including leapfrog sprawl, ribbon sprawl, low-density single-use sprawl, exurban, and edge cities. Leapfrog sprawl involves clusters of infrastructural setups scattered over open spaces, requiring increased cost investments. Ribbon sprawl, also known as strip sprawl, involves development along linear features like transportation and river networks, causing social order issues, traffic congestion, and environmental hazards. Low-density single-use sprawl creates dedicated zones for industries, residences, health, administration, and education, but also increases costs and reliance on transportation aids. Exurban sprawl occurs along the peripheries of an urban core, encroaching upon rural spaces, and is driven by reduced costs and availability of ample spaces. Edge cities are suburban, self-reliant settlements far from the urban core, requiring investment in transportation facilities to connect them to the urban cores.

Revealing the characteristics of urban growth is critical to understanding Urban sprawl and addressing the challenges associated with it. It mandates analyzing land use change and recognizing patterns of urban growth. Urban sprawl possesses multifaceted characteristics, including density [19], continuity [20][21], concentration [22], clustering [19], centrality, nuclearity, proximity [18], and mixed uses [23].

Some of the prominent causes of urban growth and sprawl include socio-economic advancement, pursuit of enhanced quality of life, growing population, institutional requirements [24], escalating desire for affordable housing [25], availability of cheap land [24], transportation infrastructure [26][27], infrastructure initiatives, socio-

economic differentiation and lifestyle preferences [28], zoning regulations and land utilization policies [24], unsustainable urbanization planning, institutional incentives, technological advancements, and the impact of globalization [24].

Some of the consequences of urban sprawl include unregulated population growth, social pollution, scarcity of resources, social stratification, deteriorating social relationships, and limited access to essential services. Uncontrolled urban sprawl may also exert tremendous stress on public services and public infrastructure such as healthcare, education, and recreational facilities, and social security. Some prominent examples are traffic congestion, increased cost of living, increased infrastructural expenses, social security, escalating land consumption, environmental degradation, noise, air, water, and soil pollution, climate change, loss of natural resources, deteriorating water quality, elevated flood risk, degradation of arable land, reduction of forested land and waterways, and escalated reliance on non-renewable natural resources.

To mitigate these issues, strategies include promoting smart growth initiatives, implementing stringent urban growth boundaries, enforcing policies and frameworks, promoting mixed-use development projects, promoting ecologically sustainable practices, limiting development in ecologically vulnerable regions, and strengthening the urban plan framework. Mitigation strategies include promoting sustainable growth, rejuvenating existing urban spaces, enhancing public services, providing convenient and affordable public transport facilities, raising public awareness, and incentivizing sustainable growth through subsidies and tax benefits.

1.3 Study Area

Sikkim officially became part of India on May 16, 1975, as its 22nd state, as represented in Figure 1.2 a) Sikkim is a land where nature peacefully coexists in harmony with rich culture, tradition, and aspiration for development leading to economic prosperity. Sikkim initially had four districts, namely East Sikkim, North Sikkim, South Sikkim, and West Sikkim, as represented in figure 1.2 b) These four districts were further subdivided into 16 subdivisions. As per the reorganization of districts notification [29] dated 20/12/2021, Sikkim now has 6 districts, namely Mangan, Gangtok, Pakyong, Namchi, Soreng, and Gyalshing. North Sikkim District is now Mangan, South Sikkim District is now Namchi, Gangtok and Pakyong have been carved out of East Sikkim District, and Soreng and Gyalshing have been carved out of West Sikkim District for administrative ease.

The four districts of Sikkim, namely East Sikkim, North Sikkim, South Sikkim, and West Sikkim, occupy areas of size 954 sq km, 4226 sq km, 750 sq km, and 1166 sq km, respectively. Geographically, North Sikkim is the largest district as per the area, followed by West Sikkim, East Sikkim, and South Sikkim, respectively. Altitude-wise, North Sikkim lies in between 610 meters in the lower areas to over 8,585 meters at the highest peak, East Sikkim is located at an altitude of 1145 meters to 2619 meters, South Sikkim lies in between 400 meters to 2,000 meters, and finally West Sikkim lies in between 400 meters to 2500 meters.

Altitude and seasonal variation have a significant influence on the weather of the four districts. North Sikkim experiences a pleasant summer with temperatures ranging from 8°C to 20°C, a very harsh and cold winter with temperatures ranging from -5°C to -

40°C, and a moderately wet monsoon. East Sikkim experiences a pleasant summer with temperatures ranging from 5°C to 18°C, a chilly winter with temperatures ranging from 0°C to 7°C, and a wet monsoon with average rainfall of 700 mm. South Sikkim experiences a warm summer with temperatures ranging from 14°C to 23°C, a relatively warm winter with temperatures ranging from 5°C to 12°C, and heavy rainfall during monsoon. West Sikkim experiences a hot summer with temperatures ranging from 16°C to 24°C, a relatively cool winter with temperatures ranging from 4°C to 10°C, and moderate rainfall during monsoon. [30][31].

The four districts are well connected with an extensive road network among the four districts, East Sikkim is the best connected by air and land, as it is in close proximity to Pakyong Airport and has well-established interstate connectivity. Located at the farthest distance are the North and West districts.

Over the years, Sikkim has undergone tremendous transformation and has emerged as one of the focal points for study. Urban sprawl has resulted in the loss of productive agricultural lands and open green spaces, the loss of surface water bodies, and the depletion of groundwater. Therefore, there is a need to study, understand, and quantify the urban sprawl.

Considering geographical landscape, favorable weather, availability of resources, affordability, and reachability, East Sikkim stands as the most preferred of the four districts in terms of administration, business, finance, industries, tourism, education, public work, and avenues for public health. Further, the majority of East Sikkim has a

well-established water supply network, sewerage network, waste disposal provision, and well-established power network, making it an ideal choice.

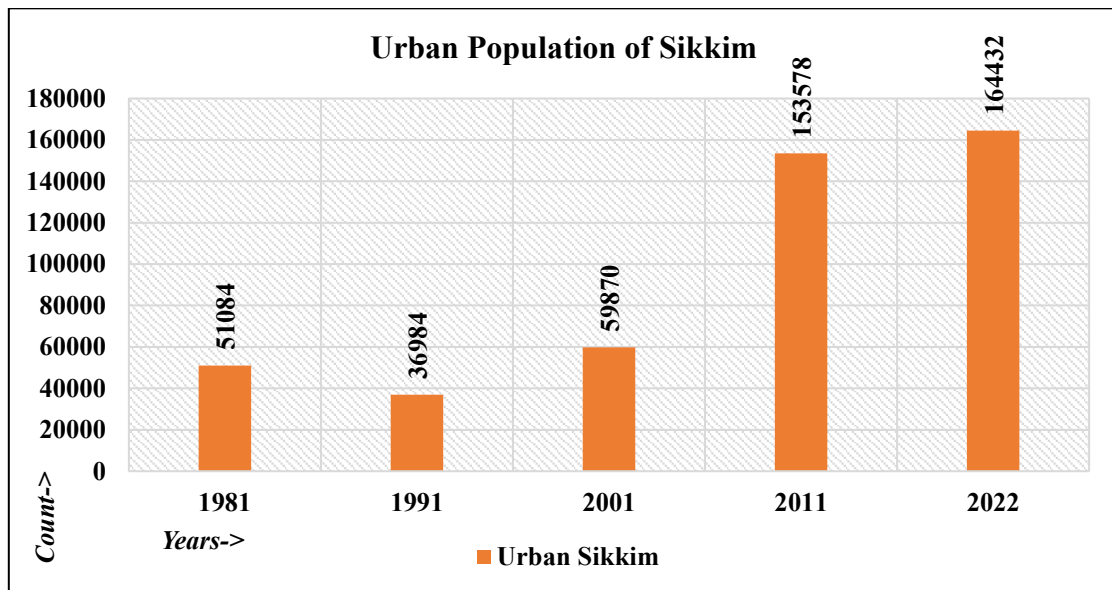


Figure 1.1: Population of East Sikkim

Since the last seven decades, East Sikkim has been experiencing tremendous transitions in population (as shown in figure 1.1) and all spheres of socio-economic growth due to the creation of opportunities in governmental institutions, industries, business enterprises, tourism, and projects of public interest. It has been observed that these opportunities for socio-economic prosperity are not uniformly distributed across the various districts of the state. It may be due to the geopolitical dynamics, ease of accessibility to resources, favorable climatic conditions, reachability, investment strengths & certainty of returns, suitability for habitation, and many more.

East Sikkim (represented in figure 1.2 c) in particular has experienced unprecedented growth; some of the influential causes could be,

- it accounts for approximately 46% of the total state's population.
- it has Gangtok, the capital of the state, as one of its prime centers.

- it has the headquarters of all the governmental offices, banking institutions, private ventures, and start-ups.
- it serves as the business capital, a hub for financial institutions, and a commercial center that caters to a wide variety of macro as well as micro businesses.
- it caters to the hospitality and tourism industry as it is one of the premier tourist destinations of the state.
- it serves as a center for academic institutions, including the majority of schools, colleges, and universities.
- it serves as a hub for the majority of health institutions, government/private.
- it hosts pharmaceutical industries, power projects, and other avenues of commerce.
- it has become an urban hotspot for infrastructural projects to cater to increasing residential needs of the population.

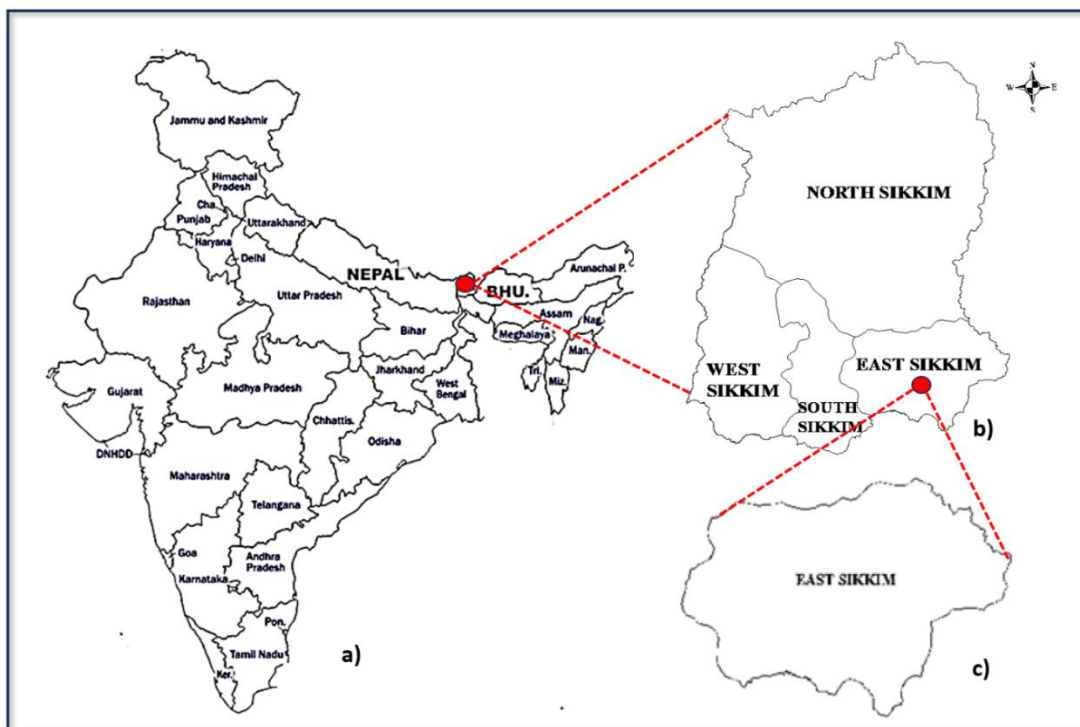


Figure 1.2: a) Map of India b) Map of Sikkim c) Map of East Sikkim

1.4 Scope of the research work

The primary scope of this study is to examine and understand the trends in urban sprawl and its extent in the East Sikkim District (Gangtok District and Pakyong District) of the State of Sikkim, India. Further, the study also aims at identifying urban hotspots for analyzing temporal changes. Eventually, the research also extends its scope to identifying and examining various demographic and developmental factors that are critical to triggering such advancements.

Attainment of the aforementioned work is strategized through

- analysis of temporal remotely sensed satellite dataset for building an understanding of trends of urban sprawl and its progression over years
- identification of hotspots for understanding growth in urban sprawl.
- exploring classified temporal demographic data and other critical factors that would explicitly or implicitly have a causal relation with the growth in urban sprawl

1.5 Problem definition

With the scope of work defined, the problem statement for the research work is

“Study of Sprawl Pattern for Deriving bases for Urban Planning”

1.6 Research Objectives

The objectives of the research initiative are

- analyze temporal satellite imageries for deriving a basis for understanding the extent of urban sprawl

- select urban hotspots for establishing a basis for understanding the growth of urban sprawl
- exploring demographic trends and other critical influential factors affecting sprawl
- forecast the growth of sprawl based on the trends identified during the study
- build suggestive measures that would help the responsible institutions build sustainable plans for effective mitigation and management of sprawl

1.7 Solution Strategy

The research initiative adheres to the following sequence of phases for attainment of the aforementioned objectives (as represented in figure 1.3):

- **Phase 1:** classification of temporal satellite imageries for deriving a basis for understanding the extent of urban sprawl.
- **Phase 2:** identification of urban hotspots for establishing a basis for understanding the growth of urban sprawl.
- **Phase 3:** exploring demographic trends and other critical influential factors
- **Phase 4:** forecast the growth of sprawl based on the trends identified during the study.
- **Phase 5:** conceive suggestive measures that would help in building sustainable plans for effective mitigation and management of sprawl. Figure 1.2 displays the schematic representation of the research initiative.

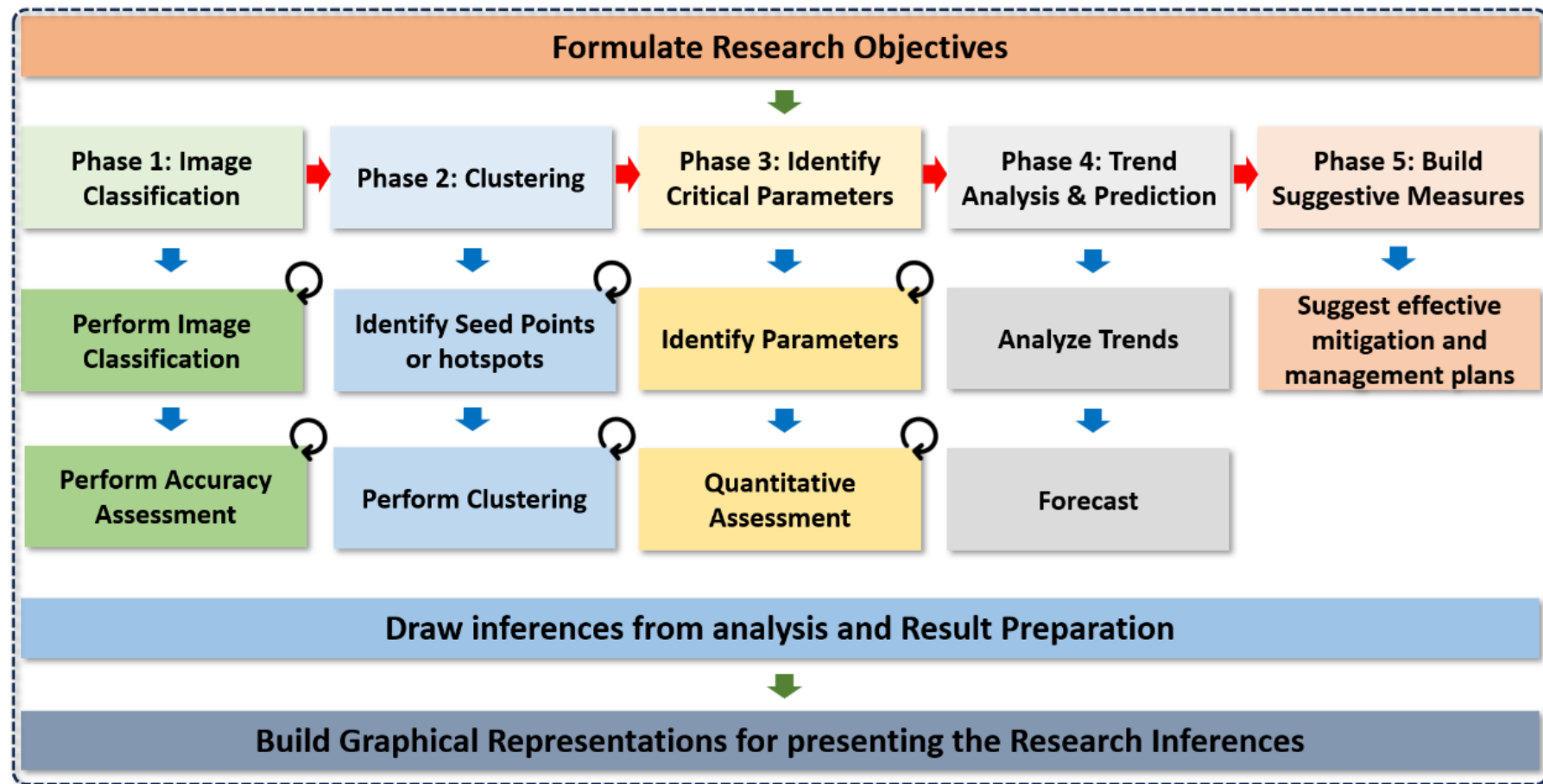


Figure 1.3: Schematic representation of research work

The research initiative leverages the capabilities of Remote Sensing (RS) and Geographic Information System (GIS).

1.8 Remote Sensing

Remote sensing (RS), as defined by National Aeronautics and Space Administration (NASA), is the process of collecting and analyzing data about a phenomenon, object, or material without direct physical contact. This is done using various recording devices such as cameras, radiometers, scanners, lasers, radio frequency receivers, radar systems, sonar thermal devices, seismographs, magnetometers, gravimeters, scintillometers, and other instruments. The techniques used in remote sensing involve measuring force fields, electromagnetic radiation, or acoustic energy to gather information about the environment [32][33].

Major Components of Remote Sensing Technology (as represented in figure 1.4):

- **Radiation by energy source (A):** The primary prerequisite for remote sensing is the presence of an energy source that emits or supplies electromagnetic radiation to the desired target.
- **Interaction with the earth's atmosphere (B):** As the energy propagates from its origin to the destination. It will make contact with and engage with the atmosphere it traverses.
- **Interaction with the target (C):** Once the energy reaches the target after passing through the atmosphere, it interacts with the target based on the characteristics of both the target and the radiation.

- **Recording of energy by the sensor (D):** After the energy has been dispersed or released from the target, we need a sensor (not in physical touch with the target) to gather and document the electromagnetic radiation.
- **Transmission, Reception, and Processing (E):** The sensor must transfer the energy it records, typically in electronic format, to a receiving and processing station. At this station, the data is processed and transformed into an image, which can be either a hard copy or a digital version.

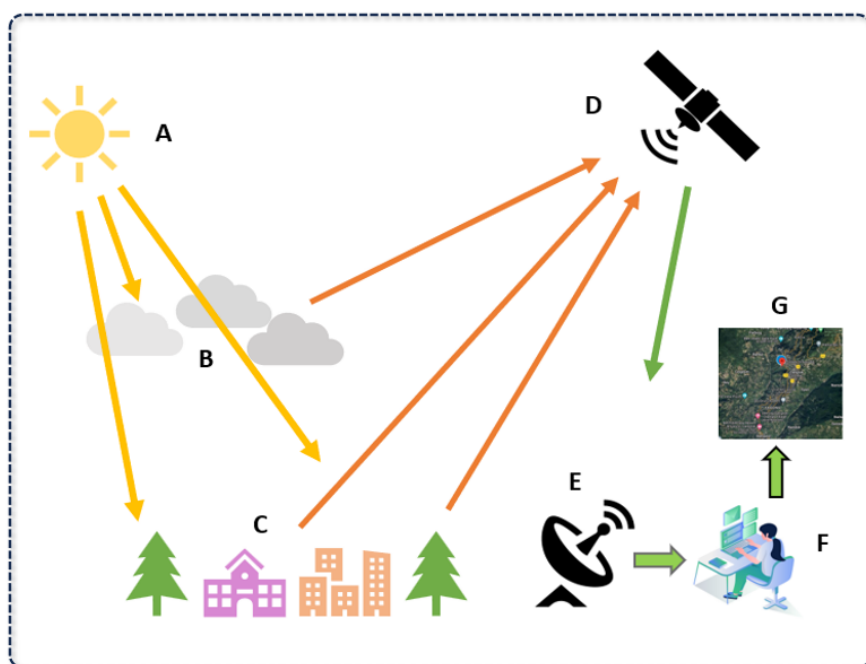


Figure 1.4: Working of Remote Sensing

- **Interpretation and analysis (F):** The processed image is analyzed, either visually or digitally, to obtain information about the target.
- **Application (G):** The remote sensing process is completed when we utilize the extracted information from imagery to gain a deeper understanding of the target, uncover new insights, or aid in resolving a specific issue.

1.9 Geographic Information System

Geographic Information System (GIS), is an advanced system that allows for the input, storage, retrieval, manipulation, analysis, and output of data that is related to specific geographic locations. Its purpose is to aid in decision making for various purposes such as land use planning, natural resource management, environmental analysis, transportation planning, urban facility management, and administrative record keeping. The typical tasks performed using a GIS involve the spatial measurement of both natural and human-made events and processes. These metrics highlight three categories of features typically linked to these systems: elements, attributes, and relationships. GIS is a methodical approach to organizing and coordinating hardware, software, personnel, and procedures to gather, modify, analyze, model, and present data with geographical references. Its purpose is to facilitate comprehension, planning, management, and resolution of intricate issues in many fields [32][33].

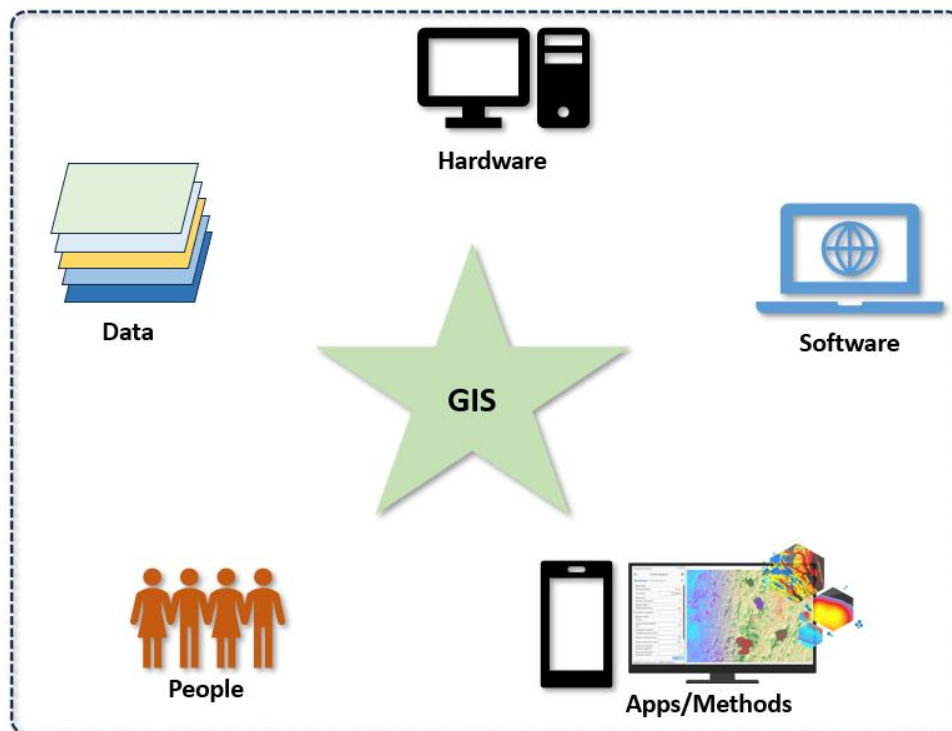


Figure 1.5: The major components of GIS

- **Hardware:** It refers to the physical components that enable users to capture, store, process, and visualize geographic information. The system comprises of high-performance computers capable of running GIS software, ample storage capacity for seamless software operation, as well as input and output devices such as digitizers, scanners, printers, and plotters.
- **Software:** The GIS program enables users to input, save, manipulate, analyze, and generate desired outputs in the form of maps and reports. Today, the GIS software in use falls into one of two categories: proprietary or open source.
- **Proprietary GIS software includes ArcGIS, MapInfo, Microstation, Geomedia etc.** However, opensource (freely available) GIS software include QGIS, gVSIG, SAGA GIS, GRASSGIS, MapWindow, ILWIS, Open Jump etc.
- **Data:** The GIS relies heavily on this component, as it is of utmost significance. Data can be acquired or gathered from diverse sources. For instance, methods such as cartography, on-site data collection, photography, and satellite images can be used. GIS data is kept in two formats: spatial data, which represents geographic information, and non-spatial data, which is in tabular form. It is imperative to gather data from a dependable source and ensure that it accurately reflects reality. Ensuring universal access to geo-spatial data is crucial, particularly in developing nations where data availability is a major issue.
- **Methods:** These encompass a range of methods for modifying, retrieving, organizing, storing, and examining data in order to attain the desired results for a certain application and study, such as change detection analysis.
- **People:** GIS professionals are those with technical expertise who are capable of managing data, devising methodologies, processing, and analyzing geo-spatial data to address real-world issues. Therefore, GIS professionals encompass those

with expertise in technical specialties, GIS management, database administration, programming, scientific research, and planning, among others.

The components mentioned above are crucial elements of a GIS system. All components are crucial to the GIS process. If even one individual is absent, it becomes exceedingly challenging to progress any further. It is recommended to have a comprehensive GIS system that includes all components necessary for the creation and analysis of geo-spatial data.

Five M's of Applied GIS

- **Mapping** is an analytical procedure that uses software to create maps, handle spatial data, and apply analytical techniques to terrestrial or geographic datasets.
- **Measurement** is employed to ascertain the precise positions of objects, the function f , and the procedures utilized to derive interpolated positions.
- **Monitoring** is an influential managerial tool that can enhance the effectiveness of governments and organizations in achieving desired outcomes.
- **Modelling** is a mathematical framework used to describe geographic objects or surfaces as data.
- **Management** encompasses various aspects such as customer support, operations, data management, application development and support.

The various applications of GIS

- Anticipating the location of administrative borders.
- Geographical placement of essential physical structures and systems.
- Vehicle routing, Natural resource management.

- Surveillance of the progress of development projects, Inventory of Assets, Urban mobility strategy
- Cadastral refers to the system of recording and managing land ownership and property boundaries.
- Management of natural resources
- Planning and managing utilities, Disaster mitigation and Environmental impact assessment

1.10 Importance of RS & GIS in study of Urban Sprawl

If we define local economic development as the enhancement of land and infrastructure for the overall benefit of the community, it becomes evident that GIS have a crucial role to fulfil. GIS are now widely utilized in government, business, and research for a diverse array of purposes. These include environmental resource analysis, land use planning, locational analysis, tax appraisal, utility and infrastructure planning, real estate analysis, marketing and demographic analysis, habitat studies, and archaeological analysis [34][35].

GIS and spatial planning: GIS enables comprehensive analysis of one-way traffic data, facilitating optimal decision-making for urban traffic management. Additionally, it enables the updating of dynamic information regarding urban areas as new developments are automatically incorporated into the information system. This includes the mapping of various networks such as urban transport, water, sanitation, and electricity. It also facilitates the monitoring of urban expansion and the creation of zoning regulations to accommodate the potential growth of the city along with the

necessary services. Furthermore, it allows for the monitoring of potential nuisances such as noise and pollution.

While traffic safety is a significant concern for urban dwellers, the impact of urban design on the occurrence of accidents is often overlooked in transportation planning and design. In order to more accurately consider the impact of urban planning on the occurrence of accidents, the authors recently endeavored to create a GIS. This method will aid planners and urban designers in methodically assessing the impact of community design on traffic safety.

GIS and urban dynamics: GIS is a powerful spatial analytic tool that provides exceptional and unmatched insights into both natural and manufactured surroundings. It achieves this by effectively connecting generic information with specific locations. GIS is a robust tool that can analyze both current and future environmental conditions. It may be efficiently utilized for studying the environment in the past, present, and future, ensuring its protection for future generations.

GIS can be effectively utilized in various areas such as environmental planning, groundwater contamination, freshwater and saltwater interface, water quality, solid waste and wastewater management, air and water pollution, and natural hazards and their mitigation.

GIS has the capability to track and analyze land use patterns, combine the obtained data with input from other stakeholders (such as political, agricultural, and public

entities), identify the special requirements of certain operations and enable the implementation of environmentally friendly agricultural practices (precision farming).

Urbanization in most poor countries is typically marked by informality, illegality, and unplanned settlements in cities. The proliferation of slums in emerging nations can be attributed to the expansion of metropolitan areas over the 20th and 21st centuries. There is a global agreement on poverty that recognizes slums and the living circumstances of slum residents as a significant challenge faced by humanity.

Urbanization is the process by which the influence of urban growth poles spreads into rural areas. Urbanization is a process in which the focus shifts from rural areas to towns, leading to the transformation of primary activities into secondary, tertiary, and quaternary activities in urban areas. Prior to 1961, there was only one town, Gangtok. However, by 1981, the number of towns had increased to eight. The significant increase in population density in 2011, with 86 individuals per sq km compared to 45 individuals per sq km in 1981, indicates that land resources are expensive. Urbanization has become a prevalent characteristic of all areas. The growth of this phenomenon is indicative of its impact on social and economic aspects of life. The growth of industry and transportation has facilitated the rise of cities. The exponential increase in population and the influx of people migrating from nearby states and countries are directly causing a rise in pressure.

The need for more efficient urban planning arises, which can be achieved through the use of GIS and RS. Without access to remote sensing data, it would be difficult to accurately track and predict the growth of the urban area during a specific time period.

This technology is economically efficient in managing phenomena such as conurbation, as other traditional methods of data collection and surveying are both time-consuming and costly.

1.11 Input Data

The research aims to ascertain temporal variations in land use and land cover changes in the East Sikkim District of the State of Sikkim, for which Landsat TM data is considered appropriate. The research endeavour utilized Landsat 7 data from 2000, Landsat 8 data from 2013, 2015, and 2018, as well as Landsat 8-9 data from 2023 for temporal analysis. (Source: Earth Explorer (United States Geological Survey (USGS))). The Landsat sensor encompasses a broad swath, enabling it to capture an extensive metropolitan area and its vicinity. Landsat is the longest-operating Earth Observation Satellite (EOS), launched in 1972 and collectively administered by the NASA and the USGS, facilitating the provision of continuous data for long-term analysis of changes in the Earth's surface.

The details of the imageries are given below:

Table 1.1: Landsat images utilized for land use and land cover change analysis

Year	Path/Row	Acquisition date	Satellite	Sensor	Resolution(m)
2000	139/041	2000-12-26	LANDSAT_7	ETM	30*30
2013	139/041	2013-11-20	LANDSAT_8	OLI_TIRS	30*30
2015	139/041	2015-12-02	LANDSAT_8	OLI_TIRS	30*30
2018	139/041	2018-01-02	LANDSAT_8	OLI_TIRS	30*30
2023	139/041	2023-11-16	LANDSAT_8	OLI_TIRS	30*30

Other data includes: Ancillary data; geo-registered vector layer of district and towns boundary, land use base maps and topographic map. Demographic data was drawn from Census of India and other critical parameters were referred from the departmental publications and web portal from respective government departments.

Working Environment

Software: ERDAS Imagine 14, Arc GIS 10.8

Hardware: 11th Gen Intel(R) Core(TM) i5-1135G7 @ 2.40GHz 2.42 GHz, 16.0 GB (RAM)

Operating System: Windows 11 Pro, 64-bit operating system

1.12 Organization of the Thesis

a) Chapter 1: Introduction

It introduces urbanization and urban sprawl. A brief overview of urban sprawl has also been provided here. It highlights the study area and the reason for selection along with the scope of the proposed work. The research motivation, problem definition, and the research objectives have been categorically expressed along with the description of the associated components. The methodological framework adopted for the proposed research initiative has been highlighted in this section.

b) Chapter 2: Literature Survey

This chapter provides a detailed description of urban sprawl along with types, characteristics, causes, and consequences. The different techniques and methodologies adopted by researchers and scholars for understanding sprawls have been critically reviewed in regard to methodology used and results obtained. This chapter provides a detailed parameterized comparison of various classification and clustering measures

that has critically helped in framing the solution strategy. It also discusses the various demographic parameters that potentially influence the growth in urban sprawl in the study area under consideration.

c) Chapter 3: Satellite Image Classification

In this chapter, methods from the supervised, unsupervised, and hybrid classification approaches were selected and applied to the sample satellite images. Thereafter, user accuracy, producer accuracy, error of omission, error of commission, kappa, and overall accuracy were evaluated for determining the performance. Based on the performance, Maximum likelihood classifier was found to be the best candidate. Thereafter the same was applied to the temporal satellite images for identifying the various classes. The results obtained have been suitably discussed and represented.

d) Chapter 4: Seed Based Clustering

In this chapter on the temporal class representing urban sprawl obtained from chapter 3, a seed-based clustering approach has been conceived to determine the extent of the sprawl and its trends. The seed points are the coordinates on the map where sprawl has been observed. The selection of a seed point has been done based on the density of the population expressed by the seed point as well as the inter-coordinate distance for building sizeable clusters. The clusters were then analysed to determine the growth trends.

e) Chapter 5: Identification of Few Influential Parameters

In this chapter, all the critical parameters that either explicitly or implicitly influence sprawl were identified, and statistical evidence was determined to understand their influences. The parameters that were taken into account included demographic features such as population and household, whereas developmental parameters that

were considered included administrative establishments, educational establishments, health establishments, tourism infrastructures, companies, industries, and projects.

f) Chapter 6: Data Prediction and a few Suggestive Measures

This chapter tries to use prediction tools based on needs to understand the results from satellite image classification, seed-based clustering, and important factors to learn about future trends and expected developments. It also presents some suggestive measures to contain the influence of urban sprawl in the East Sikkim District, Sikkim, India.

g) Chapter 7: Summary and Conclusion

This chapter presents the findings from the various sections of the research initiative, and it's the scope for use in GIS based applications. It also presents some of the the pertinent challenges encountered and possible directions for future research initiatives.

1.13 Conclusion

This chapter of the thesis describes urbanization and urban sprawl. It also discusses characteristics, causes, consequences of urban sprawl, and potential control measures. The chapter also highlights the study area considered for investigation and analysis along with the conceived strategy and the pertinent reasons for selecting the study area. Here, the problem definition, research objective, and detailed solution strategy have also been proposed with the detailed description of all the associated components. Further, the chapter provides a detailed description of the input dataset. The chapter concludes with a brief description of the organization of the thesis.