EXPLORING THE IMPACTS OF SPATIAL DEVELOPMENT ON PUBLIC WATER SERVICE PROVISION: A CASE OF BENGALURU, INDIA

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August, 2021

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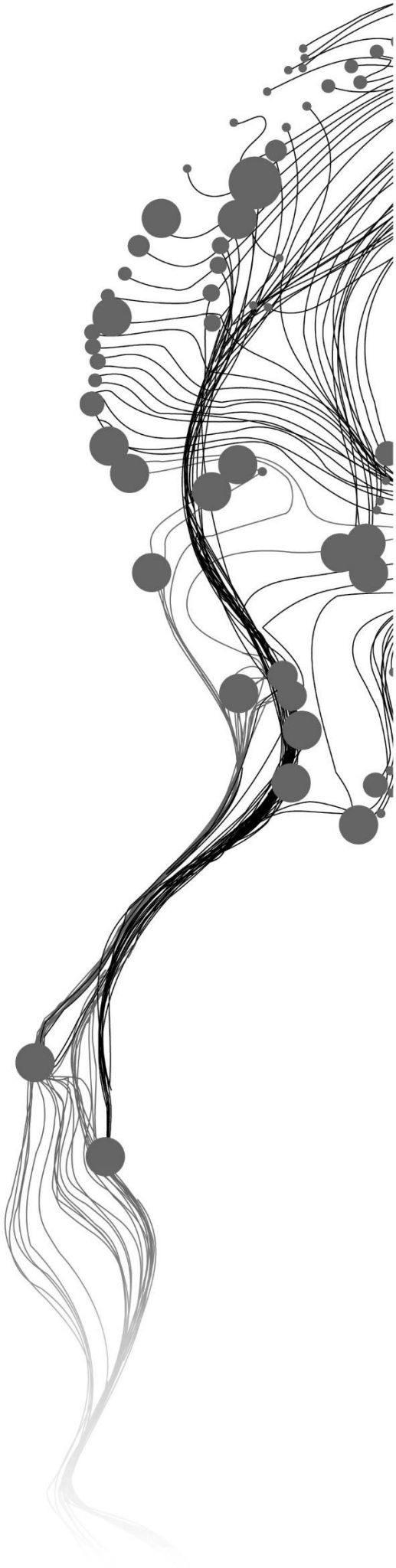

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MAHESH DUTT LINGAMGUNTA
Enschede, The Netherlands, August, 2021

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Urban Planning and Management

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DISCLAIMER

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ABSTRACT

Urbanization and associated spatial development in the global south cities exert a lot of pressure on urban infrastructure provision and management. Indian metropolitan cities such as Bengaluru are experiencing severe water-related issues due to unprecedented spatial growth and complicated spatial development patterns. The absence of territorial equalization and other unifying mechanisms amongst urban spatial development and water service planning, resulting in a sectoral approach, is escalating the issue day by day. To address this poor coordination between the spatial development and water service sectors and formulate infrastructure integrated spatial planning policies, there is a need to understand the feedbacks and interactions between spatial development and water service provision. This study explores the impacts of spatial development on public water service provision using a case study and mixed methodological approach. This study was conducted in an Indian city named Bengaluru. It used spatial, quantitative, and qualitative data analysis methods to associate spatial development patterns and policy with changes in public water service provision. The study's main findings confirm that spatial development and planning policies have a direct influence on public water service provision. Additionally, this study finds that spatial development has both positive and negative impacts on water service provision. The empirical research shows that spatial development patterns act differently on water service provision in different parts of the study due to its poor integrations with the urban water sector. In specific, the research outcome adds to the current understanding of spatial development patterns of Bengaluru by finding out that spatial development patterns such as changes in landcover and landuse diversity can also be observed in inner city areas along with the peripheral areas. This study shows that the current spatial planning policies emphasize more on regulating spatial development over sustainable development. Concerning the impact of spatial development on water service provision in the city of Bengaluru, this study demonstrates that spatial development has led to positive changes in a few aspects of public waters service provision such as accessibility, availability with the improvement of physical infrastructure along with the spatial development. However, aspects such as affordability show a neutral picture in inner and outer city areas, and adequacy shows a negative picture in the inner and outer city areas with the increased demand-supply gap as the spatial growth increases especially in the peripheral areas. Overall, this research argues that water service planning is insufficiently aligned with spatial development planning in Bengaluru. Moreover, there is a rise in water adequacy issues due to increasing urban growth and reliability on a single water supply source. This understanding of the impacts of spatial development on the water service sector can inform water-sensitive spatial development and planning policies that are context-specific.

This research adds a new understanding of the interactions between aspects of spatial development and water service dimensions in an urban setting by demonstrating the positive impacts in addition to the negative impacts. Furthermore, this study confirms the influences of inefficient spatial planning policies on spatial development and urban water service provision. Lastly, this study acts as a bridge between spatial and urban water service domains promoting integrated research in urban planning studies.

Keywords: Spatial development, spatial planning policy, water service provision, Landuse, Landcover, infrastructure-integrated development, Bengaluru.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my gratitude towards my supervisors, family, and friends, who have played an important role throughout the writing of this dissertation.

Foremost, I express my sincerest thanks to my first supervisor, Prof.dr. Karin Pfeffer for her guidance, patience, and support throughout this dissertation. I am profoundly grateful for your belief in me and for supporting me in developing a new research topic from scratch. Your insightful feedback helped me to sharpen my thinking and brought my work to a higher level.
I sincerely express my gratitude to my second supervisor, Dr. Cheryl de Boer, for her guidance, valuable feedback, and constructive criticism throughout this journey. I am sincerely grateful for your support and for helping me to think outside of the box.
I would specially thank my advisor Fenna Imara Hoefsloot for her constant support and guidance from the beginning of my thesis. I want to thank you for your continuous support and encouragement. I am very much grateful for your sincere involvement in this research.
I am greatly indebted to my chair prof.dr.ir. Jaap Zevenbergen for his critical evaluation and suggestions that contributed to the quality of this research. I extend my sincerest thanks to all the teaching and non-teaching staff who made my experience at ITC pleasurable and ITC excellence scholarship for providing financial assistance to my education.

I thank prof. Champaka Rajagopal for her insights and productive discussions which helped me to shape my research in the early stages. I want to acknowledge Mr. Murali and Mr. Girish from the Bengaluru Development authority for their valuable time and support. I want to thank all the field assistants for their assistance in collecting data.

Finally, I express my sincerest thanks to my parents, brother, and grandparents for their constant support and comfort in stressful times. I would like to thank my colleagues and friends at ITC who made this journey memorable and cheerful.

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LIST OF ABBREVIATIONS

KGIS – Karnataka Geographic Information System

BDA – Bengaluru Development Authority

LULC – Land Use Land Cover

BMA – Bengaluru Metropolitan Area

DCR – Development Control Regulations

PRR – Peripheral Ring Road

LPA – Local Planning Area

KTCP – Karnataka Town and Country planning

CPHEEO – Central Public Health and Environmental Engineering Organisation

LPCD – Litres per Capita Per Day

HH – Household

TCPA – Town and Country Planning Authority

PD – Planning District

LPA – Local Planning Area

BWSSB – Bengaluru Water Supply and Sewerage Board

1. INTRODUCTION

Urbanisation is arguably the primary driving force behind spatial development in urban areas by promoting rural to urban transformations and patterns of organization, spurring changes in landcover and landuse (Jain & Korzhenevych, 2020). In developing countries like India, urbanization has resulted in a significant increase in urban land and distinct landuse patterns (Taubenböck, Wegmann, Roth, Mehl, & Dech, 2009). Ideally, urbanization should result in developments in social, economic, and political dimensions with high concentrations of human resources coming into one place (Ellis & Roberts, 2016). However, it can be observed that the global south nations have not benefited from urbanization, as the growth rate surpasses the institutional capacity of infrastructure delivery. Ironically, the process of urbanization has resulted in 'pseudo-urbanization' in many urban centers of the global south (Jain & Korzhenevych, 2020). In the case of India, it resulted as shock urbanization, indicating uncoupling of urban growth with infrastructural provisions (Rode et al., 2008). Accommodating the rising urban populations and providing them with adequate infrastructure has become challenging for spatial development agencies in developing nations like India (Jain & Korzhenevych, 2020). However, these challenges also create strategic landuse development opportunities and innovative spatial planning policies to achieve infrastructure-integrated development (Christmann, Ibert, Jessen, & Walther, 2020).

1.1. Background and Justification

Sustainable development goal 6.1 aims to "achieve universal and equitable access to safe and affordable drinking water for all" by 2030 (United Nations, 2017, p. 7). According to the United Nations Department of Economic and Social Affairs, UNDESA (2018), 68% of the global population is estimated to move to urban areas by 2050. With the rising population in urban areas causing rapid urban growth, the increased demand for urban water services has become a challenging issue that urban societies face today (Paiva et al., 2020). Specifically, large towns and cities would need vast amounts of water for various landuse sectors such as residential, commercial, industrial, and so forth. Therefore, urbanization followed by spatial development significantly affects urban water resources and contributes to several water-related issues concerning service provision and physical infrastructure. These tensions between spatial development and water service provision can potentially be addressed by sustainable landuse development and strategic spatial planning practices (Schneider, William, et al., 1973; Verhaeghe, Zondag, & Grashoff, 2005).

In the context of developing countries, with the increasing urban growth, issues related to urban water service provision tend to incline, and several factors are responsible for these issues (Olmstead, 2004). Firstly, the economic and financial factors such as lack of ability to pay for the service and new infrastructural development are directly proportional to the service provision and delivery (Olmstead, 2004). Second, the political factors will significantly influence decisions about which areas will be served, and social factors such as community involvement play a significant role in service acquisition (Olmstead, 2004). Lastly, institutional factors such as lack of institutional integration and poor urban planning and management that focus solely on settlement characteristics are more likely to neglect service provision (Olmstead, 2004). In some cases, the combinations of these factors will also affect water resources' availability and service provision, creating severe water stress in urban communities (Olmstead, 2004). For instance, cities that neglect the integration between spatial development and water management are likely

to bring about several water issues such as unavailability, unequal distribution, reduced water quality, and water scarcity (Neto, 2016). Therefore, the study on interactions between infrastructure and spatial development plays a significant role in helping spatial policy and planning make informed decisions to facilitate infrastructure integrated development. In the Indian context, infrastructure extensions like water and sanitation networks face complications due to their poor integrations with spatial development and planning processes (Criqui, 2015). As most of the current research targets water and spatial development sectors separately, there are very limited studies available on the cross-sectoral interactions between spatial development and water service provision. Therefore, it creates a need for studies that explore the cross-sectoral relationship and possible implications of spatial development dimension on water service dimension could be beneficial in the evolution of informed and innovative spatial planning practices.

1.2. Research Problem

The emergence of complicated spatial development patterns and unprecedented spatial growth in metropolitan cities of the global south exert a lot of pressure on urban water systems (Janakarajan, Zérah, & Llorente, 2005). Specifically, public water service provision has become a challenging task in these cities with the rapid spatial growth and population due to limited supply and absence of physical infrastructures. This situation places spatial planning, which regulates spatial development patterns, in a stronger position to affect water service provision (J. Carter, 2007). However, in countries like India, the absence of territorial equalization or any other unifying mechanisms between urban development and water planning organizations results in a sectoral approach and minimal interactions (Janakarajan et al., 2005). These modes of organization reveal the weakness of the institutional environment, such as poor coordination between spatial development and water planning agencies which results in erratic planning and management (Janakarajan et al., 2005). Therefore, efficient and advanced spatial development planning of landuse and infrastructure is very important for growing cities of developing countries. With only a few studies exploring the dynamics between spatial development and water service provision, there is limited understanding regarding the interactions between spatial development and water sector dimensions (J. Carter, 2007; Criqui, 2015; Khatri & Vairavamoorthy, 2008; Verhaeghe, Zondag, & Grashoff, 2005; Woltjer & Al, 2007). In order to facilitate better integrations between spatial development and urban water services, there is a need to understand the dynamics and interactions between spatial development on water service provision in urban societies as a preliminary step. Hence, this research attempts to contribute to the gap in this aspect by exploring the possible implications of spatial development on water service provision in the Indian context. This study not only contributes to the existing literature gap with regard to interactions between spatial development and water service provision but also serves as an information source for the spatial planning authorities and water planning agencies in the formulation and integration of related policies to promote cross sectoral integration amongst spatial development and water service dimensions in other Indian cities and similar contexts.

1.3. Case study and contextual information - Bengaluru, India

Considering the population growth rate and extent of water resource depletion in India, the country likely will have the most significant number of water-deprived individuals in the world by 2025 (Khatri & Vairavamoorthy, 2008). As per the Asian Development Bank (2019), among the most Indian Megacities, Bengaluru is the second-fastest-growing city in terms of population, experiencing a population growth rate of 2.8 percent a year and most likely to be the first Indian city to experience severe water scarcity (Khatri & Vairavamoorthy, 2008). Bengaluru is located in Karnataka state and is a highly complex city because of

its diverse character. For instance, on the one hand, the city experiences considerable economic expansion. On the other hand, it has to face challenges posed by population increase, such as inadequate infrastructure, traffic congestion, and inequalities in resource distribution (Lane, 2007). As the city grew spatially, it led to implementing various spatial planning strategies and policies with a vision to develop the city sustainably (Lane, 2007). However, the implemented spatial planning practices allowed the city to build and grow outwards, leading to urban sprawl and complicated landuse patterns (Menezes, 2019). The addition of newly developed urban areas to the city eventually resulted in the increased demand for urban services (Lane, 2007) (Table 1). Specifically, the city of Bengaluru has been facing a decline in drinking water availability for over a decade due to the increased demand-supply gap (Raj, 2015). As a result, various policy proposals related to spatial planning, such as a moratorium on the new constructions in case of no water availability in the vicinity, are under consideration (Hindu, 2019). Increasing water service-related issues in a globalized metropolitan area with strategic spatial planning policies in place highlights the need and importance of integration between two sectors. The inadequate water service provision and the aging of existing water infrastructures with the continuous spatial growth leading to issues with respect to public water provision. These issues are becoming more critical due to the lack of an intersectoral approach and communication amongst spatial development and water service sectors (Report, 2015).

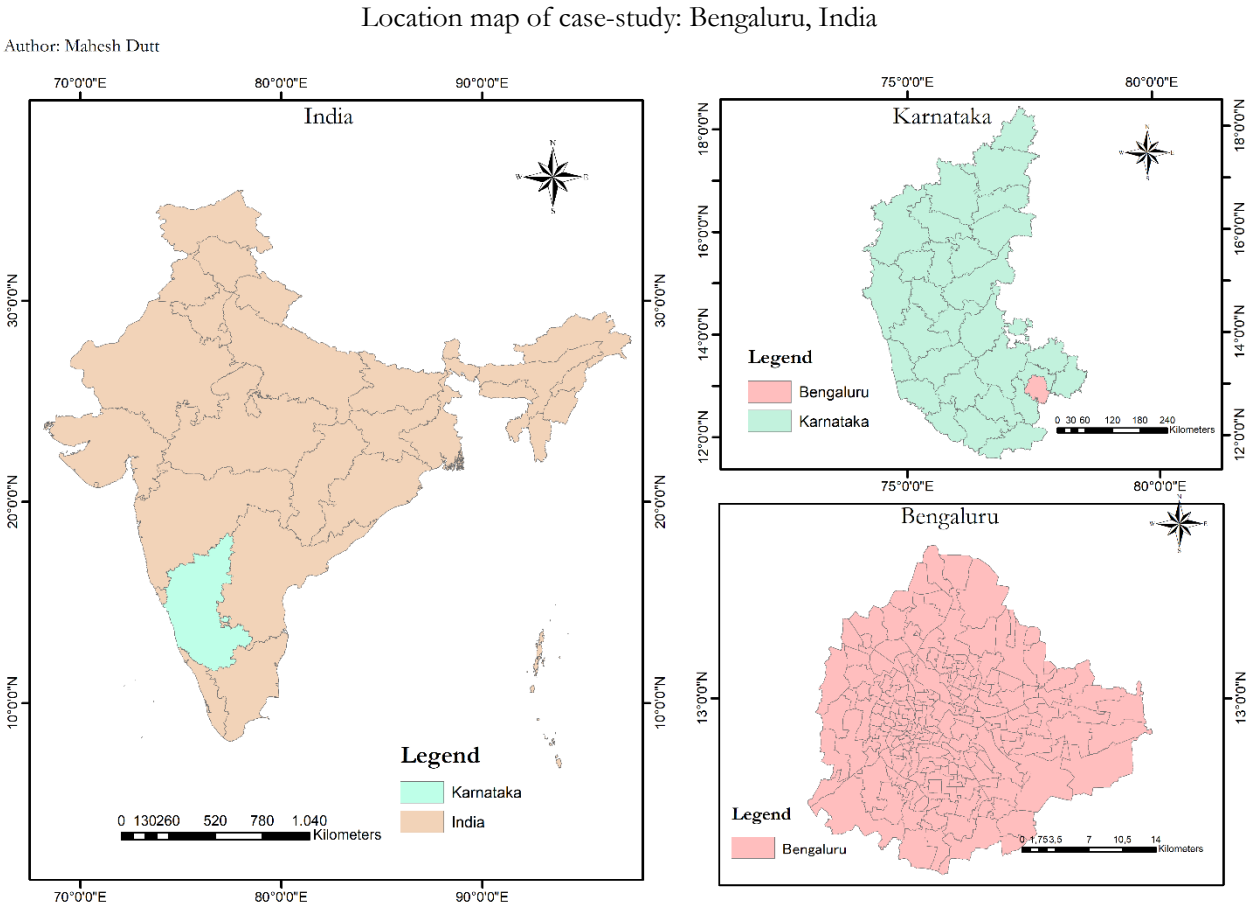


Figure 1: Location map showing India, Karnataka, and Bengaluru

Source: Statsilk, KGIS

1.4. Spatial planning in Bengaluru

Spatial planning is a newly emerging practice in Bengaluru that has started to see progress in its processes by adopting new ideology and upgrading its old practices (Mahendra, Harikrishnan, & Krishne, 2010). Currently, spatial planning in Bengaluru is implemented with the help of its master planning process under the 'Karnataka Town and Country Planning Act 1961', which ensures valuable powers to the local authorities on spatial development and planning. In Bengaluru, BDA (Bengaluru Development Authority) is the local planning authority and is responsible for preparing the master plan, which serves as a base for developing strategic plans, local area plans, and neighborhood designs. The past master plans and the current RMP 2015 (Revised Master plan) emphasize landuse and zonal regulations and ensure its implementation (Mahendra et al., 2010). Due to its focus on development regulations over integrated development, the master planning process resulted in less spatial and more landuse planning practice. Ideally, the spatial planning process aligns spatial development with social, environmental, and ecological dimensions and promotes sustainable development, and landuse planning primarily focuses on regulating and controlling development (Shaw & Lord, 2017). In the case of Bengaluru, it is alarming to observe that the past and current master plan, RMP-2015 of Bengaluru, do not seem to adopt the spatial planning practice but rather a non-integrated and top-down development approach with a focus on regulating and controlling the spatial development. However, it is relaxing to learn that the proposed master plan 2031 of Bengaluru incorporates sustainability, making it a complete spatial plan in theory (Mahendra et al., 2010). In total, the current spatial planning of Bengaluru is in its initial stages of evolution. Spatial plans of Bengaluru have influenced its spatial growth over the years, and the following Table 1 will give a general idea of the timeline and the major actions such as the addition of new administrative areas in the respective plans, which will support the study in further sections.

Table 1: Timeline of spatial development plans of Bengaluru

Period	Event
1952	Bengaluru development committee Responsible for planning and developing the extension areas of Bengaluru.
1961	Karnataka Town and Country Planning Act drafted
1965	Karnataka Town and Country Planning Act enforced Planning authority was constituted, and LPA was declared 218 villages were included in Bengaluru city
1972	Outline Development Plan adopted under KTCP Act
1984 - 1995	Comprehensive development plan 1
1996 - 2005	Comprehensive development plan 2
2006 - 2015	Comprehensive development plan 3 (Revised Master plan 2015) 538 villages were covered in this Masterplan (Addition of new villages in the local planning area)
2016 – 2031	Comprehensive development plan 4

Source: BDA

1.5. Research objectives

1.5.1. General objective

To explore the impacts of spatial development on public water service provision in the Indian context.

1.5.2. Research question

What is the influence of spatial planning policies on prevalent spatial development patterns? How are spatial development patterns and policies affecting public water service provision in Bengaluru?

1.5.3. Sub-objectives

1. To understand the prevalent patterns of spatial development in the city of Bengaluru.
    - What are the observable changes in land cover patterns?
    - How does landuse mix composition look like in different parts of the city?
    - How have spatial planning policies shaped spatial development patterns?
2. To reveal the changes in public water service provision in different parts of the city.
    - What are the relevant indicators to measure public water service provision?
    - How does the water service provision look like, and how has it changed over the years in different parts of the city?
3. To explore the impacts of spatial planning policies and spatial development patterns on public water service provision.
    - How are changes in spatial development patterns regarding landcover and landuse patterns affecting water service provision?
    - How do spatial planning policies and spatial development patterns together affect public water service provision?

1.6. Thesis structure

This study is consolidated into seven chapters. Chapter 1 provides the introduction, background and justification, research problem, case study and contextual information, research objective, and questions. Chapter 2 describes the literature review with emphasis on key concepts of the study from existing literature on spatial development, spatial planning, landuse patterns, and water service provision, followed by a conceptual framework. Chapter 3 focuses on research design, methods and methodology, techniques for data collection, and ethical considerations, followed by chapter 4 with study areas selection based on a preliminary analysis. Chapter 5 focuses on analysis and presents the study results based on the defined objectives and questions. Chapter 6 discusses and attempts to explain the findings of the study in line with the literature review. Lastly, chapter 7 presents the conclusions and recommendations concerning the existing and future scope of research.

2. LITERATURE REVIEW

This chapter reviews key concepts and related terms concerning the effects of spatial development on water service provision based on current literature.

2.1. Spatial development and planning

Spatial development is the spatial arrangement of different landuses and urban activities (Weith et al., 2020). It is associated with several factors such as economic development, urban-rural migrations, and increasing population growth rates (Weith et al., 2020). Inefficient spatial development could result in rapid urban expansion, leading to changes in landcover, landuse patterns, and infrastructure needs (Arif & Gupta, 2020). For instance, the increasing urban growth rates have resulted in disintegrated spatial growth and complicated landuse patterns in developing nations like India (Alsharif & Pradhan, 2014). Additionally, challenges such as traffic congestion, landuse conflicts, social segregation, and lack of running piped water affect urban areas' spatial development process (Fung-Loy, Van Rompaey, & Hemerijckx, 2019). In total, the increase in urban activities and population growth rates exerts a lot of pressure on urban infrastructures, the economy, and the environment challenging the spatial development processes and planning systems (Lane, 2007).

Concerning spatial planning, it provides a framework for regulating spatial development and landuse based on the context, political aspirations, social goals, and requirements (J. Carter, 2007). Spatial planning follows a separate decision-making system at national, regional, and local scales (Woltjer & Al, 2007). The national government is responsible for strategy making and major planning decisions. Regions further translate these strategies into regional plans. At the local level, spatial planning is responsible for shaping places and delivering social, economic, and environmental infrastructures for fulfilling the current and future needs of urban communities (Morphet, 2010; Woltjer & Al, 2007). Spatial planning at the local level plays a crucial role in fulfilling communities' requirements by facilitating the synergies between multiple agencies in an urban area. To facilitate this process, planning officials work in integrative ways with the other agencies to achieve the desired outcomes (Morphet, 2010). For instance, in the case of the geographical area investigated in this thesis, spatial development decisions in coordination with the water infrastructure development at a local scale should aim at equitable and safe water supply delivery among all the urban communities.

2.2. Spatial development and water service provision

Spatial development affects water service provision by influencing the distribution of population densities and physical assets that determine the demand for water and related infrastructure services (Weith et al., 2020). For example, building a new transport corridor will eventually attract new developments that influence the population densities that, in turn, affect the demand for several urban utilities such as water supply. To study the interactions between spatial development and water service provision in an urban context, there is a need to have a set of variables and indicators for both sectors to measure and evaluate the effects of one on another (Kayser, Moriarty, Fonseca, & Bartram, 2013; Storch & Schmidt, 2008). The

relevant water service variables and spatial development variables are explained in detail in the below sections and can be related as follows.

Assessment of water services in urban communities inform about the effects of policy and planning decisions on the water. In urban domestic water supply and delivery assessment, the use of multiple indicators can be a practical step in capturing water service provision (Kayser et al., 2013). For example, Howard & Bartram (2003), demonstrates that with the increase of distance from the piped water source, i.e., accessibility, the level of health concerns among the households has been compromised significantly. This case advocates the importance of accessibility in the spatial distribution of high-quality water facilities, such as piped water within premises. Concerning spatial development, studies such as Paiva et al. (2020), found that the development decisions influence urban services such as water provision and concluded that the way we manage our cities, population distribution, and urban growth would affect water service provision in one way or another.

2.3. Spatial development patterns with respect to landuse landcover changes

Urban landuse and landcover changes have diverse impacts on environmental and social systems (Nuissl & Siedentop, 2021). For instance, the development of residential areas on former agricultural land may result in considerably less damage to other natural habitats in comparison to industrial development on a wetland site. Therefore, it is necessary to consider aspects such as former landuse and landcover, the purpose of landuse, location, and efficiency in land conversions that provide an understanding of the social and environmental effects and acts as a basis for infrastructure developments, urban planning, and management. Significant improvements in digital landuse and landcover data in terms of resolution and quality have opened up new possibilities for monitoring landuse change dynamics and patterns that measure the differences in land cover, landuse, and landuse intensity to study its impacts on other urban elements (Nuissl & Siedentop, 2021). To comprehend urban landuse change and the observations and measurements of urban landuse change phenomenon, it is necessary to consider the driving factors responsible for this change. Broadly, these factors are classified into biophysical factors such as slope, social factors like population growth, income level and location preferences, economic factors such as market access, neighborhood interactions, and spatial policy and planning, which includes distinguishing the land parcel usability and protection of specific landuse (Storch & Schmidt, 2008).

2.4. Spatial development variables

To understand the spatial development patterns in different parts of the city, landcover change and landuse mix diversity have been observed and interrogated.

Land cover change

Land cover change can be described as the new land consumption where the land is converted from non-urban to urban. Urban land cover change is closely associated with urban sprawl as it is considered a process of landuse change over time (Galster et al., 2001). Generally, land cover change can be characterized by its change of landuse composition. It can be described as the conversion of agricultural or natural/semi-natural surfaces to built-up areas (Siedentop & Fina, 2010). Besides the effects on ecological systems, land cover changes in the long-term pose challenges such as complicated landuse types, increased urban densities, high infrastructure demands. As this study deals with the impact on existing infrastructure, built up and non-built-up percentage has been selected as an indicator to measure

the landcover change over a period to interrogate its contribution or effect on water service provision (Table 2)

Landuse mix diversity

Landuse mix can be defined as the degree to which different urban landuse exist in close vicinity to each other (Nuissl & Siedentop, 2021). According to Song & Knaap (2004), lack of landuse mix leads to urban sprawl and results in unsustainable urban development. Also, an increase in the greater mix of landuse facilitates enhanced urban aesthetics, reduces vehicular dependency, and improves public health by promoting walking and biking (Song & Knaap, 2004). This study investigates the effects of diverse landuse mix composition on public water service provision by studying the possible impact of the differences in the degree of the mix.

2.5. Water service provision

Water service provision has become a rising challenge where urban areas sprawl rapidly and are unplanned (Romano & Akhmouch, 2019). Water services provision involves various steps starting from abstraction, treatment, storage, and delivery of water to the households and multiple institutions (European Union, 2000). Internationally, there are various institutions to support the water service sector in these steps. Yet, water services in most underdeveloped and developing countries are provided by public sector organizations and are often responsible for inadequate water service provision (Schwartz, 2006). According to the UN-HABITAT (2016), many cities and urban centers in the developing world are still unable to receive adequate freshwater supplies for at least half of its population. The increased demand for freshwater and the outgrowth of urban areas led to increased consumption of surface and underground water resources faster than the natural recharge rate. In addition, issues like infrastructure expansion with spatial development to meet the demand, financial, and management decisions also affecting the water service provision in urban areas (Criqui, 2015).

2.6. Public water service provision variables

To reveal the public water service provision, here we review four relevant indicators based on studies conducted on infrastructure service delivery indicator identification from a variety of national and international frameworks on water service provision (García-Valiñas, Martínez-Espiñeira, & González-Gómez, 2010; Kallidaikurichi & Rao, 2010; Mahama, Anaman, & Osei-Akoto, 2014; McDonald et al., 2011).

Accessibility

Accessibility in this study refers to physical access to water ranging from household access to service delivery points outside of the household. Water accessibility takes into account the travel distance and collection time to investigate the reliability factor (Kayser et al., 2013). Usually, an inverse relation between collection time and distance to water facility has been demonstrated as an important barrier to access.

Availability

Water availability in this context refers to the quantity of water available for all household usage purposes. The availability of water can be answered simply by stating a yes or a no. With time, the notion of water

availability has been changing in different societies based on factors such as the economic capacity of the social class, political influences, and infrastructural development (Kayser et al., 2013). In this study, water availability is measured with the help of indicators such as water quantity per person in the household and household connectivity to the main water supply line.

Adequacy

In addition to accessibility and availability of water services, it is essential to consider the satisfaction levels on quantity, continuity, and frequency of public water supply. According to Kallidaikurichi & Rao (2010), the rate of dependencies on alternative water sources and illegal water connections tends to rise due to inadequate public water service provision. This study aims to measure the adequacy using qualitative indicators and user's opinions at two different time periods to capture the differences and relate with spatial developments in the time.

Affordability

Affordability or financial accessibility is highly dependent on the financing mechanisms and sources of financing public services in low-income and developing countries (Peters et al., 2008). Lack of affordability to water services may result in infectious diseases and compromises in public health. Water affordability is always a great concern to the public authorities regarding aging infrastructures, limited supply, and increasing demands. Affordability of water service can be distinguished into the ability to pay, which applies to lower-income households, and willingness to pay which is concerned to any water consumer who believes that water supply costs justify the quantity and quality of water service. The latter has been considered to learn about the overall water affordability dynamics from a general water consumer in this study.

2.7. Spatial development and urban infrastructure in Bengaluru, India.

Spatial development is a permanent form of land transformation, which is arguably, a result of urbanization, as described earlier. Though urbanization is a global phenomenon, it is very prevalent in India, with unprecedented urban growth rates in the last 30 years (Taubenböck et al., 2009). Urbanization in India appears to experience constant growth, yet broad transition due to its rural sector dominancy (Nagendra, Sudhira, Katti, Tengö, & Schewenius, 2014). According to Chanmal & Tg (2016), there is a strong link between human development and urbanization levels as cities lead and enrich their nation's economic development, transforming societies and liberating them from poverty and disease. However, the rapid growth of cities could lead to increasing unemployment, lack of access to land and environmental degradation, and poor urban services.

In the case of Bengaluru, which is one of India's fastest-growing metropolitan cities, the study by Sudhira, Ramachandra, Raj, & Jagadish (2003), demonstrates that overall spatial growth in Bengaluru increased by 194%, especially in the peripheral areas, and the smaller settlements that are closer to Bengaluru. With the increase in spatial growth and population increase, the city of Bengaluru is experiencing challenges in upgrading the infrastructure facilities like water, sanitation, housing, transport, and power due to the supply and demand gap (Chanmal & Tg, 2016). This gap, combined with non-integrated spatial development, puts Bengaluru at high risk, especially concerning its water service provision.

2.8. Conceptual framework

The scope of the study is to explore the one-way relationship of how spatial development impacts public water service provision. Therefore, this study deals with two concepts, spatial development, and water service provision. Spatial development is further classified into two dimensions: spatial planning and spatial development patterns (Figure 2). First, this study tries to understand the spatial development patterns using landuse and landcover changes, followed by interrogating the influence of spatial planning policy on the prevalent spatial development patterns. Second, it explores the combined influence of spatial planning policy and development patterns on public water service provision. To summarize, the concepts in this study include spatial development, landuse mix, landcover change, spatial planning policy, and public water service provision. There is a compelling influence of spatial planning policies on spatial development patterns in the case of Bengaluru, thereby affecting infrastructure facilities and delivery of basic services (Sudhira & Ramachandra, 2009).

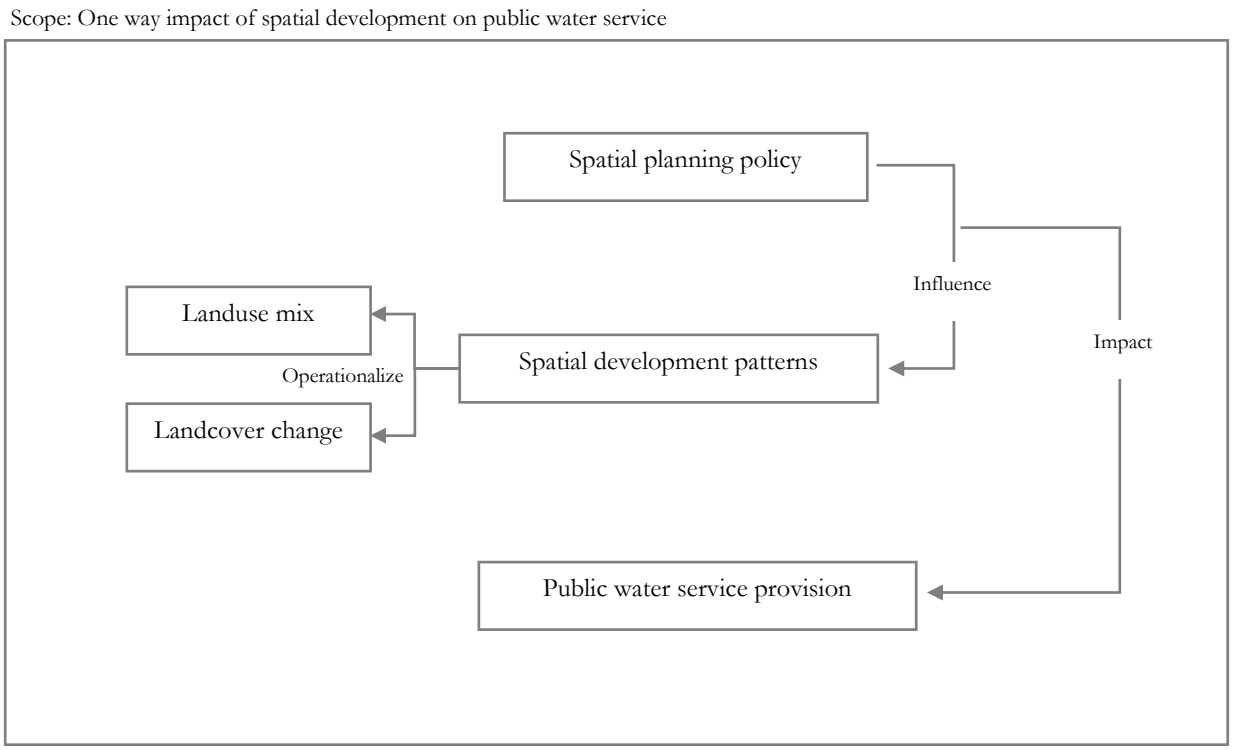


Figure 2: Conceptual diagram

3. METHODS AND DATA

3.1. Research design and approach

This research explores the impacts of spatial development on public water service provision in the Indian context. To investigate this impact in a contemporary context, this study adopts the case study approach, which is suitable for answering 'how,' 'who,' and 'why' questions (Farquhar, 2014). The case study approach ensures an in-depth investigation into a specific phenomenon in a real-world context (Yin, 2013). At the same time, it can be experimental, explorative, or descriptive. Furthermore, this research employs a mixed-methodological approach for data collection and analysis by combining quantitative, qualitative, and spatial analysis methods (Creswell & Pioano Clark, 2007). As the study focuses on exploring the complex phenomenon, which is understanding the influences of spatial development on water service provision, triangulation design is considered the appropriate research design where the spatial, qualitative, and quantitative data are used to support and complement each other. Specifically, the mixed-method approach is used for data triangulation and methodological triangulation (N. Carter, Bryant-Lukosius, DiCenso, Blythe, & Neville, 2014). With regard to data triangulation, this study inspects the spatial data, quantitative data in the same period of time and in similar administrative contexts to understand the prevalent spatial development patterns. Concerning methodological triangulation, this study uses structured interviews from the users and semi-structured interviews from key informants to make conclusions on similar aspects of water service provision.

Firstly, to investigate the spatial development patterns with respect to landuse and landcover, time series analysis was performed for three years, 2009, 2013, and 2018, which covers the span of ten years. The rationale behind the 'ten years' time span is to capture the significant spatial changes in Bengaluru's master plan implementation period, i.e., 2005 to 2015. As the current master plan of Bengaluru is valid until 2015, the years 2009 and 2018 have been selected to capture the spatial changes in the respective study areas. The detailed landcover analysis and landuse mix mapping for each study area which covers both inner-city and outer city areas is demonstrated and explained with supporting maps in chapter 5. Concerning landcover, the study areas have been classified into three categories: built-up, non-built-up, and water, for better understanding, and the landuse mix mapping has been done based on the secondary information collected from the case study area.

Concerning public water service provision, the changes in public water service provision have been studied with the help of residents' perceptions/experiences on the changes in water service indicators from the past 'eight years' in relation to observable changes in spatial development patterns from the past ten years. Now, the rationale behind eight years for water service provision is to collect the most appropriate responses from users as more than eight years could lead to mis representation of opinion. This data has been captured using a structured questionnaire survey (Appendix 3). To avoid confusion for the respondents, minimal open-ended questions and a majority of Likert scale questions were preferred with six possible answers: strongly agree, agree, neutral, disagree, strongly disagree, and do not know.

The selection of relevant variables and indicators in this study to measure the changes in spatial development patterns and the changes in public water service provision was made through literature study and performance indicators of the case study area (Kayser et al., 2013; Raj, 2015). This has resulted in the identification and selection of two variables for measuring spatial development patterns and four variables to operationalize the public water service provision (Table 1).

Table 2: Dimensions, variables, and indicators to measure spatial development patterns and status of public water service provision in the context of Bengaluru, India.

Dimension	Variables	Indicators	Relevant Publications
Spatial development	Landcover	Share of Built-up vs. Non-Built-up	(Storch & Schmidt, 2008)
	Landuse mix	Share of different landuse types such as (Residential, commercial, industrial, Mixed, parks, etc.)	(Storch & Schmidt, 2008) (Torrens, 2008)
Public water service provision	Accessibility	Type of water supply (Individual/shared) Distance to primary water sources such as tap, public water tanker, public water pump. (Ntozini et al., 2015)	(Candelieri, Soldi, & Archetti, 2015)
	Availability	Water availability per person (Liters per capita per day LPCD) Availability of public water supply connections. Location of public water connection (CPHEEO Handbook of service level benchmarking)	(Kayser et al., 2013) (Ntozini et al., 2015)
	Adequacy	Quantity of public water supply Satisfaction on the quantity of water supplied Continuity/Duration of public water supply (Hours per day) Frequency of public water supply	(Kallidaikurichi & Rao, 2010) CPHEEO, (Ministry of Urban Development, 2014)
	Affordability	Monthly costs of water bills as a percentage of median HH income Satisfaction costs (Satisfied with service compared to the amount paid for service)	(Rubin, 2001)

3.2. Data sources and analysis methods

This study uses both primary and secondary data (Table 3). Secondary data consists of remote sensing data such as Landsat imagery, population data from the census 2011 which is currently available, ward-level geo data from the open city data website, and planning documents such as city master plan, action plan for water service provision, and grey literature. The Landsat imageries were used to do preliminary analysis and selection of study areas to investigate land cover change patterns. Primary data includes interviews with key informants from the concerned departments such as the water supply board, spatial development authority, and structured questionnaire survey with residents of the study areas. The structured questionnaire surveys aim to collect residents' perspectives on the changes in public water service provision, and the key informants' interviews served to understand the professional perspectives on both spatial development and water service provision.

Spatial Analysis of landcover landuse patterns

Landcover patterns have been calculated using a supervised classification technique for the study areas using LANDSAT 8 and 5 data. The satellite imagery has been acquired for the years 2009, 2013, and 2018 to understand the landcover change dynamics over ten years in the respective study areas as described earlier. Supervised classification has been performed using ArcGIS software with a classification accuracy of approximately 75 % (Appendix 5). Upon Image classification, the area under each landcover has been calculated using the Fragstats Application to extract the area under different classes using class metrics. The landuse mix mapping for the study areas is also done in ArcGIS using manual digitisation from the landuse data collected from the development authority of Bengaluru. Upon mapping the landuse, the area under each landuse category has been calculated using the ArcMap field calculator.

Analysing the Status of public water service provision based on residents perception

As explained briefly in the previous section, the field data on residents' opinions regarding the changes in public water service provision which has been collected using a structured questionnaire survey and analysed with the help of descriptive statistics such as mean and standard deviation. Detailed analysis of each indicator has been presented under specifically selected variables to showcase a clear understanding of the existing status and changes in water services. Mean values for each indicator were calculated to understand how the majority of the respondents experienced the changes in specific indicators. The standard deviation has also been calculated for each indicator to know whether the indicator needs closer observation upon high standard deviation. Regarding sample size, due to the qualitative nature of the study, 60 samples from each administrative has been considered appropriate (Boddy, 2016).

Table 3: Summary of data types and their sources

Data Types	Source
Population data	Census 2011
The boundary of wards, Local planning area	Bengaluru Development Authority (BDA)

Landuse information	Bengaluru Development Authority (BDA), Existing Landuse maps
Landcover data	Landsat imagery (2009, 2013, 2018)
Influence of spatial planning policy on spatial development	Key informants, spatial policy documents
Status of public water service provision variables	Questionnaire
Impact of planning policies on water service provision	Key informant interviews, Spatial planning policy documents

3.3. Selection of study areas

This research adopts the case study approach (Farquhar, 2014) to investigate and understand the dynamics between spatial development and water service provision in the context of Bengaluru. As the synergy between spatial development and water services is different in different geographical contexts, study areas selection has been made in two spatial settings based on the below-mentioned criteria, which is expected to give an understanding of the dynamics between spatial development and water service provision. With respect to selection criteria of study areas, settlement density, built-up change rate, and total ward population have been used to select four study areas under the two spatial settings that cover the central/inner city and outer/peripheral areas of Bengaluru. The queries with the combination of selection criteria that have been used to select study areas can be found in the below queries.

Query 1: Category 1 - Inner-city areas: high settlement density and high built-up change areas, and above-average population

Query 2: Category 2 - Outer city areas: low settlement density and high built-up change areas, and above-average population.

The high-density settlement areas are defined as the areas greater than or equal to mean settlement density. The low-density areas are the areas with less than the mean settlement density. The selection for one high-density settlement and one low-density settlement with both experiencing new developments and high rate of change in built-up is to understand how changes in landcover intensity and different landuse mix influence water service provision in diverse spatial settings. The detailed analysis and procedure of study area selection are demonstrated in chapter 4.

3.4. Pre-fieldwork stage

The pre-fieldwork stage involved a thorough review of existing literature on spatial development, water service provision, and the dynamics between spatial development and water service provision in developing nations. During this stage, preliminary analysis has been done to select four study areas to investigate further the impact of spatial planning on water service provision in the context of Bengaluru. It also includes preparing questionnaires for residents and an interview guide for key informants based on the research objectives and questions. The sampling method used in the study is purposive sampling as the study relies on a specific category of resident's perceptions to capture the water service provision for a period of time. Purposive sampling is time and cost-effective for this research by resulting in a range of responses which is helpful for qualitative research. Care has been taken to avoid judgement errors as this sampling method is potentially broad.

3.5. Fieldwork stage

3.5.1. Sampling strategy

The study uses mainly purposive, snowball, and stratified sampling techniques. Purposive sampling has been used to select study areas to understand the research question in high and low-dense administrative units. The selection of key informants was made using purposive and snowball sampling techniques to identify experienced and informative individuals in the spatial planning and water service sectors. The selection of respondents for the questionnaire survey in the case study areas uses both purposive and stratified sampling techniques for two purposes. First, to select residents who live in the same area for more than eight years who have experienced changes in spatial development and water service provision. Second, to ensure the spatial distribution of samples and avoid clustering of responses.

3.5.2. Key informants

The interviews were collected from key informants to gain insight into local spatial planning and policy and changes in water service provision regarding accessibility, availability, adequacy, and affordability due to changes in spatial development interventions and changes. Key informant interviews use a semi-structured questionnaire and are recorded upon the consent of key informants. Three key informants were selected from the development authority, town and country planning, and water supply board to understand the dynamics between spatial development and public water service sectors.

Table 4: Particulars of key informants

Key informants	1	Additional director, Bangalore Development Authority
	2	Joint Director, Town and Country Planning Authority (TCPA)
	3	Public Relations Officer, Bangalore water supply and Sewerage Board

3.5.3. Recruitment, training of field assistants, and piloting the questionnaire

Four field assistants, one person per study area, have been recruited and trained to perform the field survey. The selection of assistants was based on their ability to perform social surveys on e-platform and previous experience in data collection. The field assistants were given strict instructions on the ethics of data collection. They were also given explicit instructions on the use of Maptionnaire software for data collection. The training involves explaining and going through the complete questionnaire with all the field assistants to ensure the understanding of each question by the field assistants. After training the field assistants, a pilot survey was carried out in all the selected study areas. This pilot survey is instrumental in adjusting the questionnaire based on the local understanding. It also gives the researcher a basic understanding of the study areas, which helps structure the research strategy.

3.6. Ethical considerations

As the study involves individuals of diverse social classes, economic backgrounds, and different locations in the city, research ethics has been viewed strictly to protect the participants' rights, avoid any kind of risk or threat to the participants, and ensure the authenticity of research. A detailed consent form has been prepared, which informs the participants about the background and aim of this study, along with the type and usage of the information that shall be collected. As the survey takes place during the pandemic and involves direct contact, a digital survey tool called Maptionnaire, which is in compliance with GDPR policy, had been used to collect the information in a safe and secure manner. The possible risks associated with the study, such as the identification of respondents based on their location data, have been dealt with by absolute restriction of locational data from sharing to the second party. Also, personal information such as income data has been anonymized to ensure the response cannot be traced back to the individuals. Concerning key informant interviews, all the informants were provided with necessary information related to the study and asked for consent before the interviews. All the spatial and non-spatial data generated and collected will be saved in the ITC repository, and only limited material will be allowed to share upon proper justification.

The flowchart below explains the overall workflow in a detailed manner

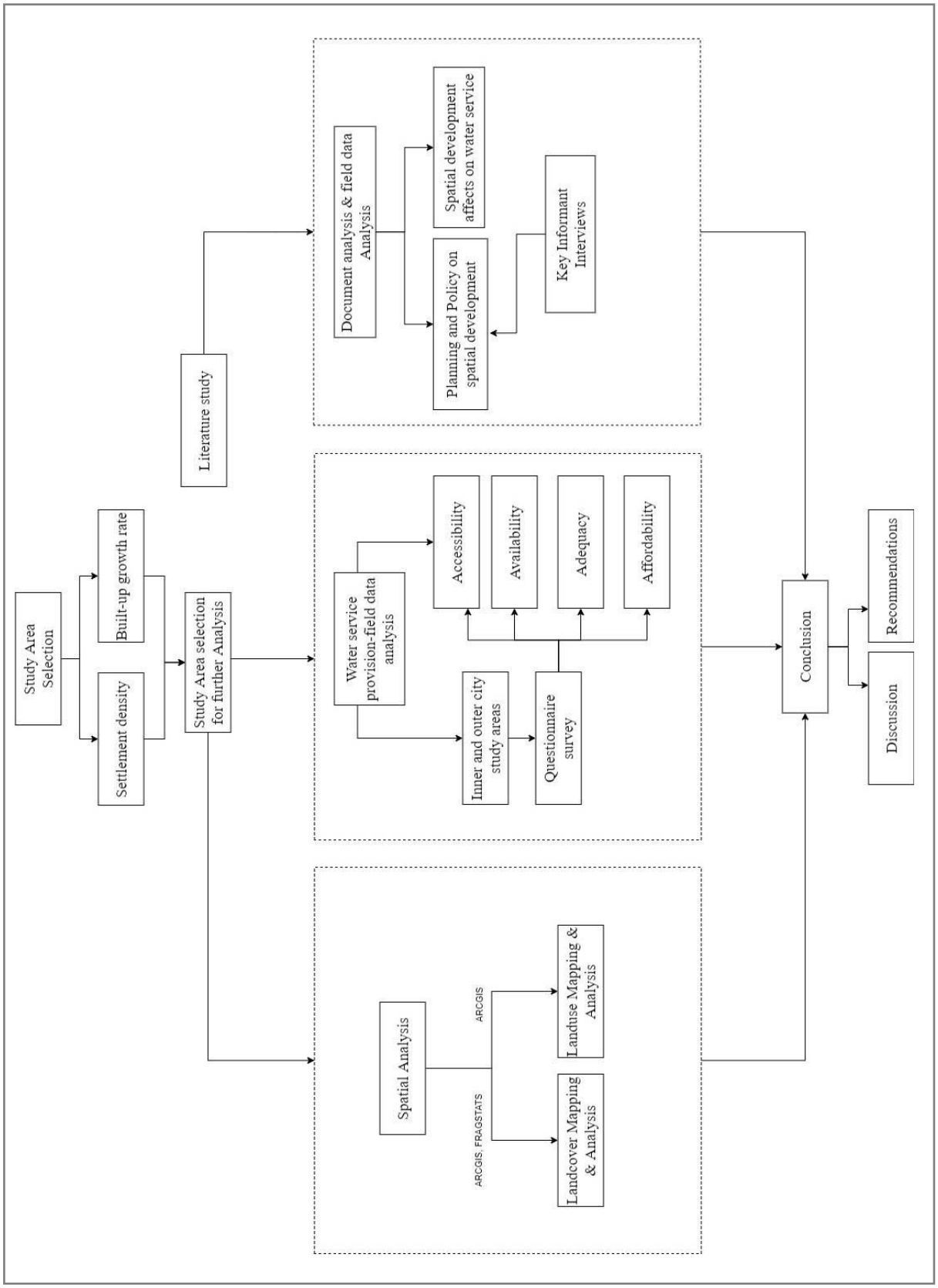


Figure 3: Methodology

4. STUDY AREAS SELECTION

4.1. Preliminary results

A preliminary analysis has been done to select the study areas, namely settlement density mapping and built-up change mapping. This spatial mapping has been used as a screen to identify and choose the wards/study areas with observable changes in the landuse patterns.

4.1.1. Settlement density mapping

Settlement density provides information regarding land consumption by calculating the number of inhabitants versus habitable or settlement space. An increase in settlement density denotes population growth, thereby exerting pressure on available resources. The aim of the settlement density map in this study is to identify the high-density wards since wards are the lowest administrative unit where the management of public services and utilities can be measurable. The first step involved in the settlement density mapping is collecting population data from the census 2011 as the recent census 2021 is not available due to the corona pandemic. The second set of information required for calculating settlement density per ward in the habitable area of the respective wards. This information has been derived from the global built-up dataset from the Global Human Settlement website and verified with the local records collected from the city government. The population data per ward has been divided with the available habitable area of the ward, including roads, green and open spaces to calculate the settlement density per ward. Upon computing the settlement density, the classification of wards has been done and visualized to identify the high, moderate, and low-density wards. High-density wards are defined as wards with settlement density greater than mean settlement density, and low-density wards as areas with a settlement density less than mean settlement density. The settlement density mapping can be seen in Figure 5.

4.1.2. Built-up change mapping

As the current master plan is valid until the year 2015, mapping of built-up change over eight years (2008-2018) has been done to identify the areas that have spatially developed and grown in this period to understand the association with the master plan 2015. To do the same, Landsat imagery acquired in April for the years 2008 and 2018 has been used with less than 10% cloud cover has been preferred to do this analysis. The first step involves supervised classification of 2008 and 2018 imagery with three landcover categories: water, built, and non-built. After the classification of the map into built, non-built, and water for both the years with an overall accuracy of above 80% (see Appendix 2), the two data layers have been subtracted using the image difference tool, which performs the layer-wise raster to raster subtraction which gives the result of a subtracted map showing the change from non-built to built-up areas. The next step involves calculating this change per ward to identify the wards that changed from built-up to non-built and with what rate. To do the same, zonal statistics have been used to calculate the change percentage that each ward has undergone during eight years. The percentage change in the area has been derived using the range operation, which can be found in the functions of zonal statistics. The built-up change map that has been generated can be found in Figure 4, and the classified maps, landcover difference map used to produce the change map can be found in Appendix 1.

4.1.3. Categorization of study areas

Based on the settlement density, built-up growth rate, and total population, four study areas have been selected in two spatial settings, as explained earlier. The first category consists of two areas with greater than mean settlement density, greater than mean population, and built-up change ranges from (40%-50%). The second category has two study areas with low, dense settlement areas and high built-up change. The rationale behind this categorization is to study the two diverse settlements with both low and high settlement densities and have undergone or undergoing rapid spatial growth over the past ten years along with a significant amount of population. Studying these two categories would give insight into how spatial development patterns impact public water service provision in two spatial settings in the same city and how well the spatial planning policies are integrated with water service planning. The segregation of areas with categories and their characteristics is explained in the below section 4.1.4. Interestingly, category one areas with high settlement densities are inner-city areas, and category 2 study areas are outer city areas.

4.1.4. Query used for study area selection

Category 1: Inner-city study areas

Case study Areas (1a & 1b) : high-density areas with high built-up change (see Table 5, Table 6)

Settlement density > mean AND total population >= mean AND built-up change = (40% - 50%)

Category 2: Outer city study areas

Case study Areas (2a & 2b): low-density areas with high built up to change (see Table 7, Table 8)

Settlement density < mean AND total population < mean AND built-up change = (50% - 60%)

Built-up change mapping

The below Figure 4 shows the ward-wise built-up change, i.e., the area that has changed from non-built to built-up in the respective wards. The areas have been categorised into 4 classes ranging from 0% - 30%, 30%-40%, 40%-50% and Above 50%. The built-up change is used as one of the key determinants for case study selection. This study considers only the wards with a built-up growth rate greater than 40% to select the areas undergoing rapid change in recent times.

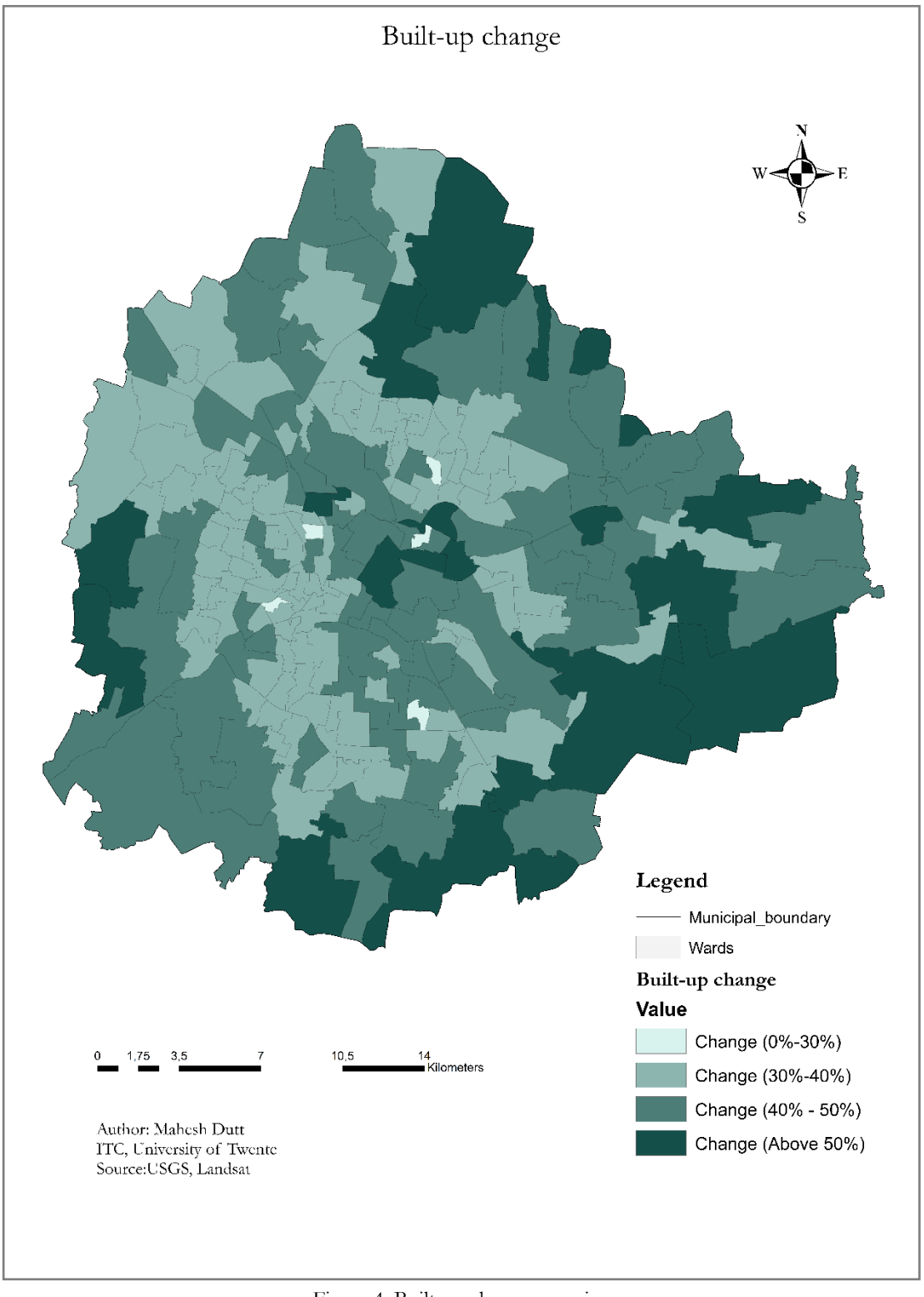
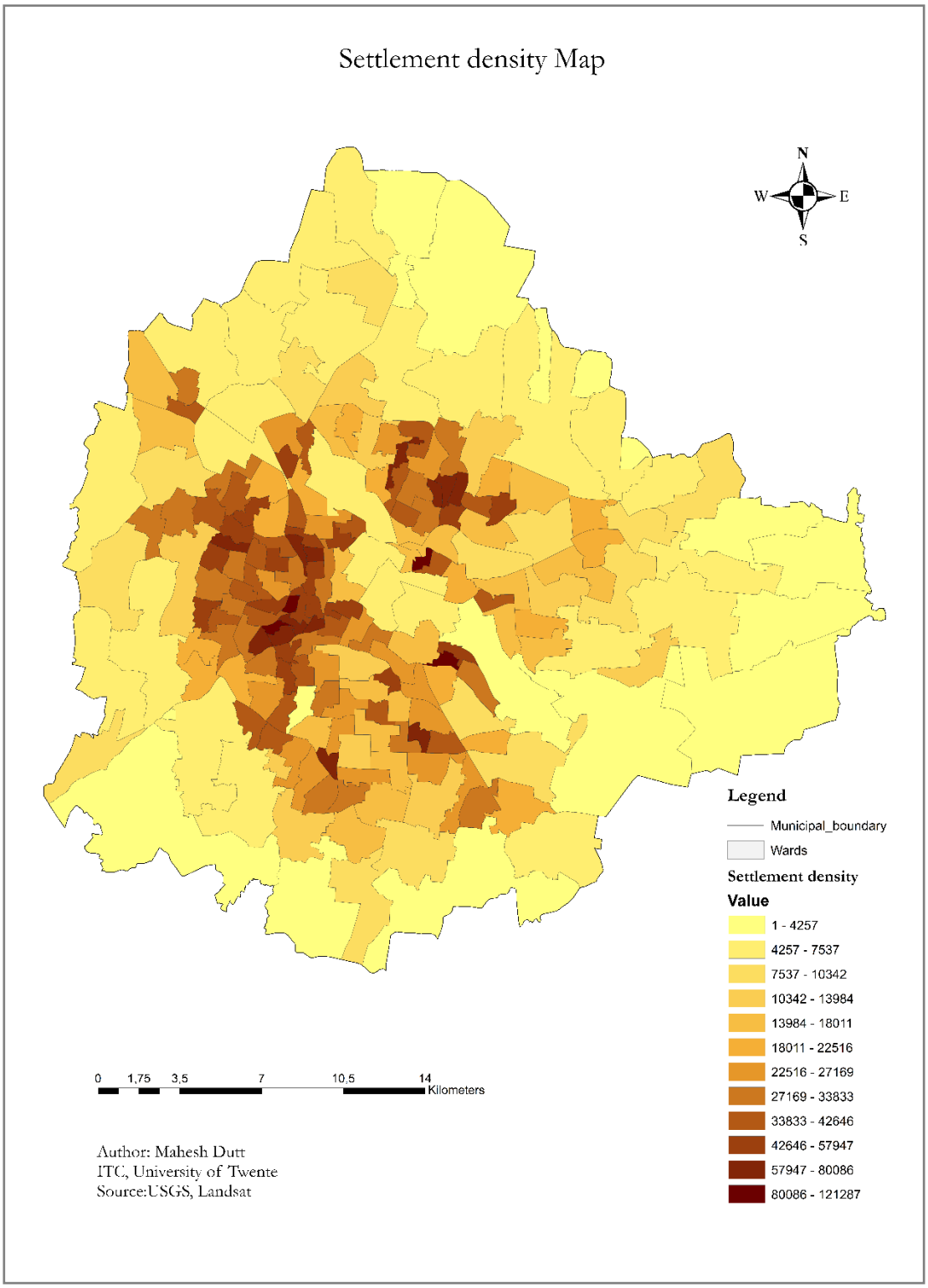


Figure 4: Built-up change mapping

Settlement density mapping

Settlement density is one of the key determinants in the selection of case study areas. The below Figure 5 shows the settlement density of each ward in the city of Bengaluru. The areas with below mean settlement density and above mean settlement have been included to maintain the variability in study areas. The map has been categorised into 12 classes to observe the distribution of settlement density at the city scale, and it is interesting to see the increase in settlement densities as we move to the periphery.



Source: Census 2011

Figure 5: Settlement density mapping

4.2. Overview of the Study Areas

Wards are the lowest administrative units where the provision and management of public utilities and services take place. In total, there are 198 wards in Bengaluru. Based on the proposed Master plan 2031, Bengaluru is divided into 42 planning districts (PD). The planning district is the lowest spatial unit where the implementation of physical planning takes place. All the wards are divided based on their location and character among the 47 planning districts.

Study Area 1a: Jayanagar East

Table 5: Geographic and demographic information of Jayanagar East

Source: BDA

Ward Number	Ward Name	Population	Area (sq.km)	Settlement density	Built-up change
170	Jayanagar East	33927	1,01	33591	(40%-50%)

Description

Jayanagar East is located in the core area of the Bangalore Metropolitan Area (BMA). As this area is geographically located in the southern part of Bengaluru, it comes under the Bengaluru south zone, one among the eight administrative zones of BMA. This ward comes under planning district 14, characterized by planned residential development, education and health institutions, industries, water bodies, and open spaces. Although this planning district is planned for residential development, it is currently transformed into mixed-use zones with high commercial development and many heritage sites. According to planning district reports, almost 48% of households in the planning district are connected to the public water supply regarding water service provision (Bengaluru Development Authority, 2017).

Study Area 1b: Hampi Nagar

Table 6: Geographical and Demographical details of Hampi Nagar

Source: BDA

Ward Number	Ward Name	Population	Area (sq.km)	Settlement density	Built-up change
133	Hampi Nagar	35113	1.11	31633	(40%-50%)

Description

Hampi Nagar is located in the core area of the BMA. This ward comes under planning district five and is in the western part of Bengaluru. The predominant landuse in this planning district is dense residential and mixed-use settlements and industrial estates. However, this planning district is experiencing increased commercialization due to increased commercial activity along the major roads. As per the master plan, this planning district aims to stabilize the transformation by limiting commercial activities on specific roads. Concerning water service provision, around 42% of the planning district households are connected to the public water supply (Bengaluru Development Authority, 2017).

Study Area 2a: Ullalu (130)

Table 7: Geographic and Demographic information of Ullalu

Source: BDA

Ward Number	Ward Name	Population	Area (sq.km)	Settlement density	Built-up change
130	Ullalu	58199	8.92	6524	(50%-60%)

Description

Ullalu is located southwest of the BMA. This ward comes under planning district 32 and is in the peripheral area of Bengaluru. The predominant landuse in this planning district is under vacant land. However, the master plan aims to make this area predominantly residential along with increased road infrastructure up-gradation due to its proximity to express highway. Being a peripheral and newly introduced area in the BMA, there is a significant amount of agricultural land in this planning district. According to the Bangalore water service board, approximately 42% of households have access to public water service provision in this planning district (Bengaluru Development Authority, 2017).

Study Area 2b : Anjanapura

Table 8: Geographic and Demographic details of Anjanapura

Source: BDA

Ward Number	Ward Name	Population	Area (sq.km)	Settlement density	Built-up change
196	Anjanapura	45608	11.92	3826	(50%-60%)

Description

Anjanapura is located in the southern part of the BMA. This ward comes under planning district 16 and is in the peripheral area of Bengaluru. Like Ullalu, the predominant landuse in this planning district is under vacant land. Due to huge amounts of vacant land, it is envisioned to make this area a dense residential development with a focus on public transit-oriented development. Being a peripheral and newly introduced area in LPA, there is a significant amount of agricultural land in this planning district. As per the water service board, only 16% of households are connected to public water service provision in this planning district (Bengaluru Development Authority, 2017).

The below Figure 6 shows the location of study areas that have been selected in inner and outer city areas.

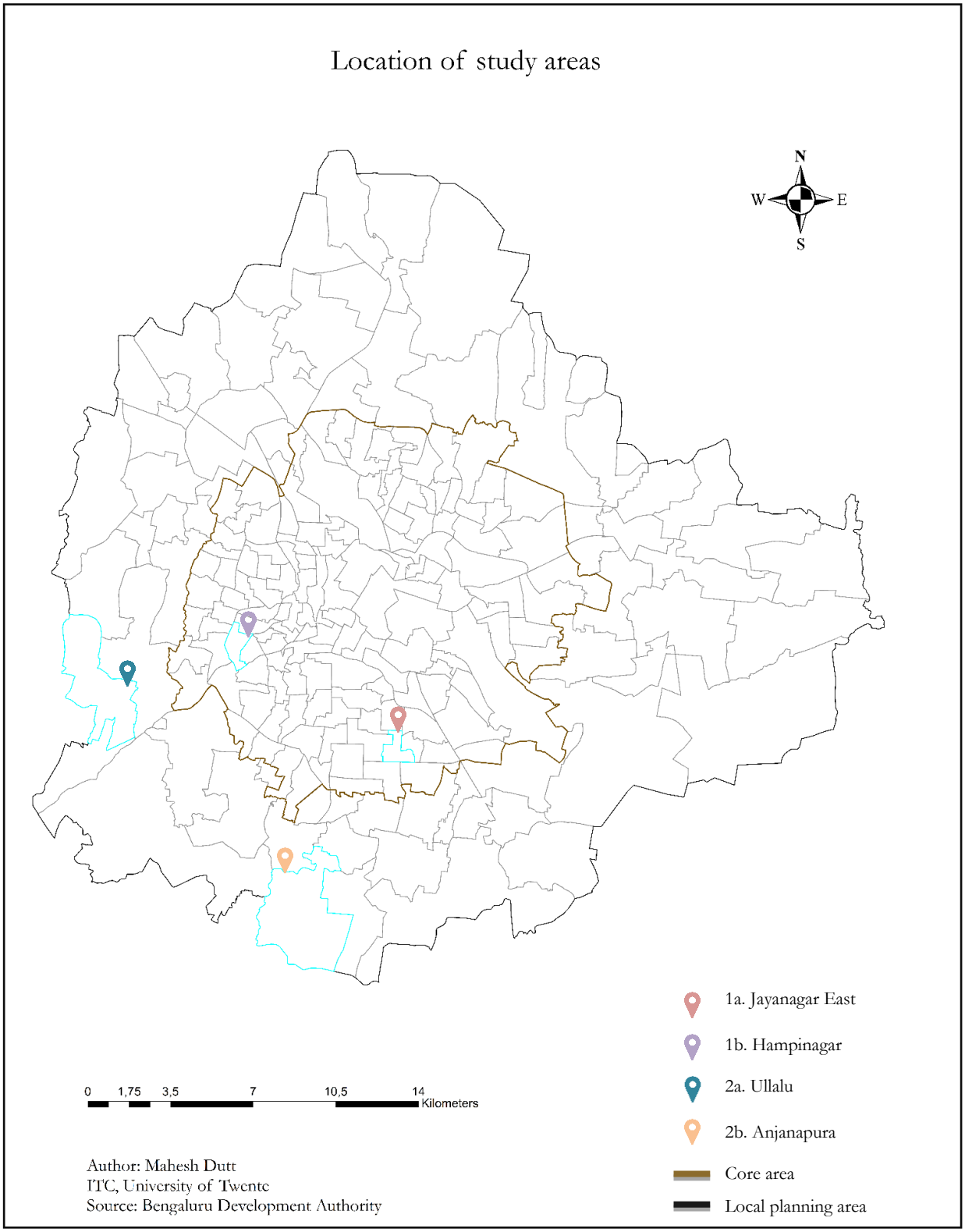


Figure 6: Location of study areas

5. RESULTS

This chapter presents the prevailing spatial development patterns by measuring the changes in landcover and composition of existing landuse in four study areas categorized into the inner city and outer city areas of Bengaluru. It also presents the association between existing spatial planning policies and spatial development patterns using policy document analysis and key informant interviews. Furthermore, this chapter also presents the results from the field survey on the perceived status of public water service provision using indicators and their changes over the past eight years. In the end, it presents the association between changes in spatial development patterns and changes in the public water service provision using a specific period while highlighting the possible implications of the existing spatial planning policies and patterns on public water service provision.

5.1. Mapping the changes in land cover and landuse composition to understand the prevalent patterns of spatial development in the study areas of Bengaluru.

This section studies the changes in landcover patterns over the past ten years to understand the built-up growth scenario over time and also visualizes the existing landuse mix in the respective study areas to learn about the landuse composition in different parts of the city to further understand its impact on public water service provision.

Spatial development patterns have been observed for the span of ten years, as described in the research method. Mapping landcover for three years that covers the span of ten years helps us understand the type of spatial growth, such as slow or rapid growth in respective study areas. Secondly, landuse mix mapping allows learning about the existing patterns of landuse mix diversity in inner and outer city areas. In the end, mapping of land cover patterns and landuse mix composition in all the study areas will be used to associate the spatial development patterns and spatial planning policies.

5.1.1. Changes in the landcover patterns of the study areas in Bengaluru

Category 1: Inner-city areas

1a: Jayanagar East

Jayanagar is a predominantly residential ward which is located in the inner parts of Bengaluru. From Figure 7, it can be observed that there is an overall increase of 10 percent in the built-up land cover from 2009 to 2018. Interestingly, there are no noticeable changes in the built-up or non-built areas from 2009 until 2013, which confirms the increased developmental activity, especially after 2013, the period close to the expiration of the Bengaluru master plan 2015. It is also worth noticing that the built-up area in the recent year, i.e., 2018, has reached 92 percent of the total area, leaving only 8 percent under open space and vacant land. Figure 11 shows the land cover maps, highlighting the spatial allocation of land cover types in 2009, 2013, 2018. The maps demonstrate the movement of built-up and non-built-up patches over the period of 10 years. Interestingly, the non-built patches were clustered until 2013 and started to show dispersed patterns confirming the spatial development on a smaller scale. The water patches in the landcover map of 2013 are due to heavy rainfall and flashfloods in 2013 (Deccan Herald, 2013). In total,

Jayanagar East is undergoing slow and steady changes in its non-built land, although there is limited availability of open space.

1b: Hampinagar

Hampinagar is an inner-city ward that is a planned predominantly residential development. The landcover graph in Figure 8 shows that Hampinagar is experiencing significant landcover changes for the past ten years. Similar to Jayanagar, the landcover changes in Hampinagar can only be seen after 2013, which confirms the increased developmental activities in the inner city areas in recent years. From Figure 8, the built land cover category is almost constant until 2013, whereas the non-built area is under continuous pressure, with a significant reduction in its area over the ten years from 2009 to 2018. It is worth noticing that almost 95% of the land in the Hampinagar is under the built-up category, whereas only 5 percent is left under the non-built category, which could adversely impact the ward in terms of resource distribution.

Category 2: Outer city areas

2a. Ullalu

The landcover maps in Figure 9 display the land cover categories in the outer city ward Ullalu. From Figure 9, it can be observed that the maximum percentage of land in Ullalu was under the non-built category until 2013. Whereas, the same Figure 9 shows that the majority of the land is under the built category in the year 2018, which confirms the rapid spatial growth within the ward in a short span. This demonstrates the increased spatial development interventions in the outer city areas such as Ullalu. The noticeable fact is that Ullalu spatial development has grown rapidly after its inclusion in the local planning area in the year 2007 (Table 1). Figure 9 also shows that the built land cover increased three times from the past ten years. According to the landcover maps in Figure 14 show that the natural water bodies in 2009 and 2013 have been converted into other landcover categories by the year 2018. Unlike the inner city areas, the Ullalu ward is experiencing rapid land cover conversions from non-built to build in a very short time.

2b. Anjanapura

Figure 10 shows a rapid increase in the built-up area of Anjanapura landcover from 2009 to 2018. From the same Figure 10, it can also be seen that the built land cover increased almost twice from the past ten years. Landcover maps from the Figure 14 shows that the natural water bodies in 2009 and 2013 have been reduced drastically and are on the verge of disappearing. These landcover maps also show that similar to Ullalu, Anjanapura ward is also experiencing rapid land cover conversions from non-built to built in a very short time. Although the majority of land in Anjanapura is still under the non-built category, the built-up land has been growing significantly over the last ten years and spreading evenly all over the ward.

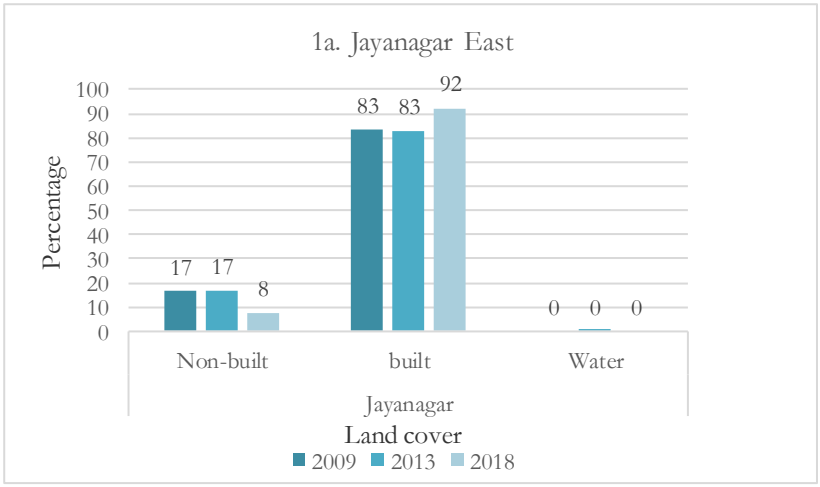


Figure 7: Jayanagar East

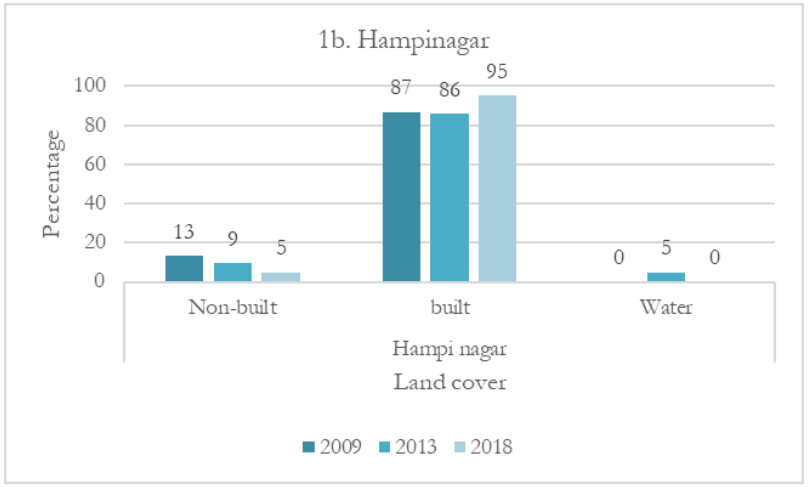


Figure 8: Hampinagar

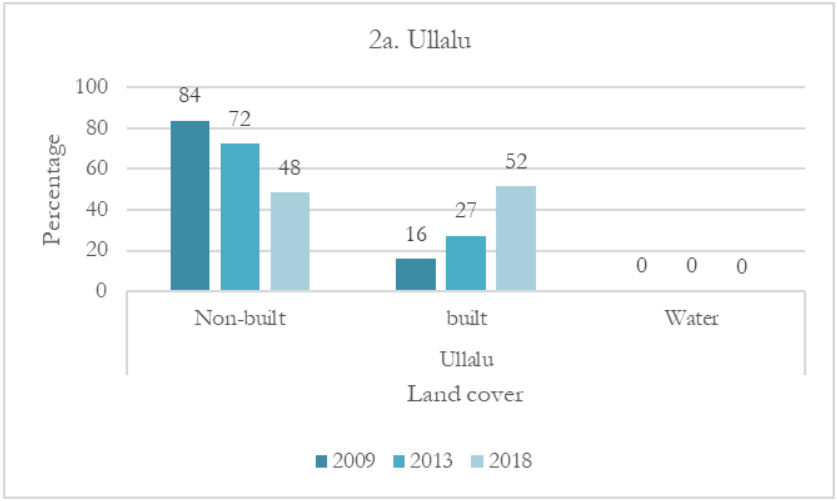


Figure 9: Ullalu

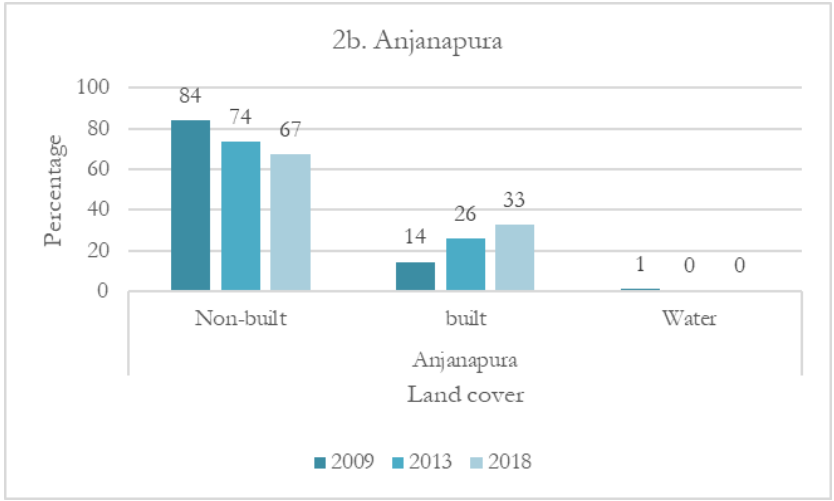


Figure 10: Anjanapura

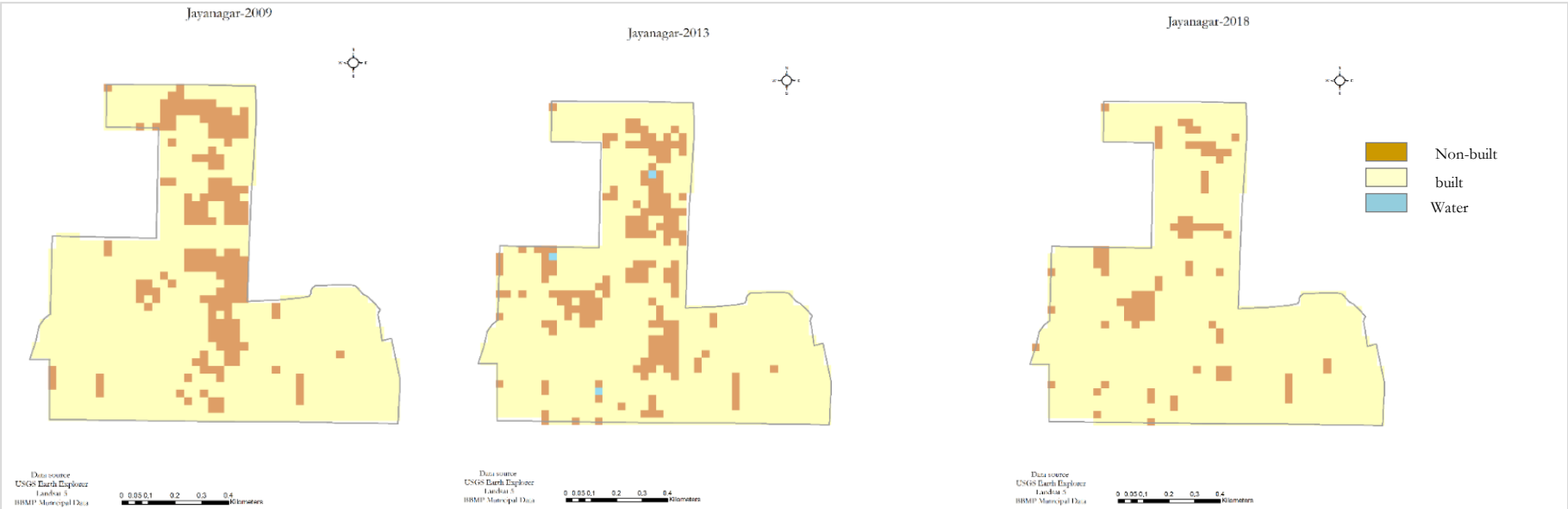


Figure 11: Landcover maps for the years 2009, 2013, 2018 – Jayanagar East

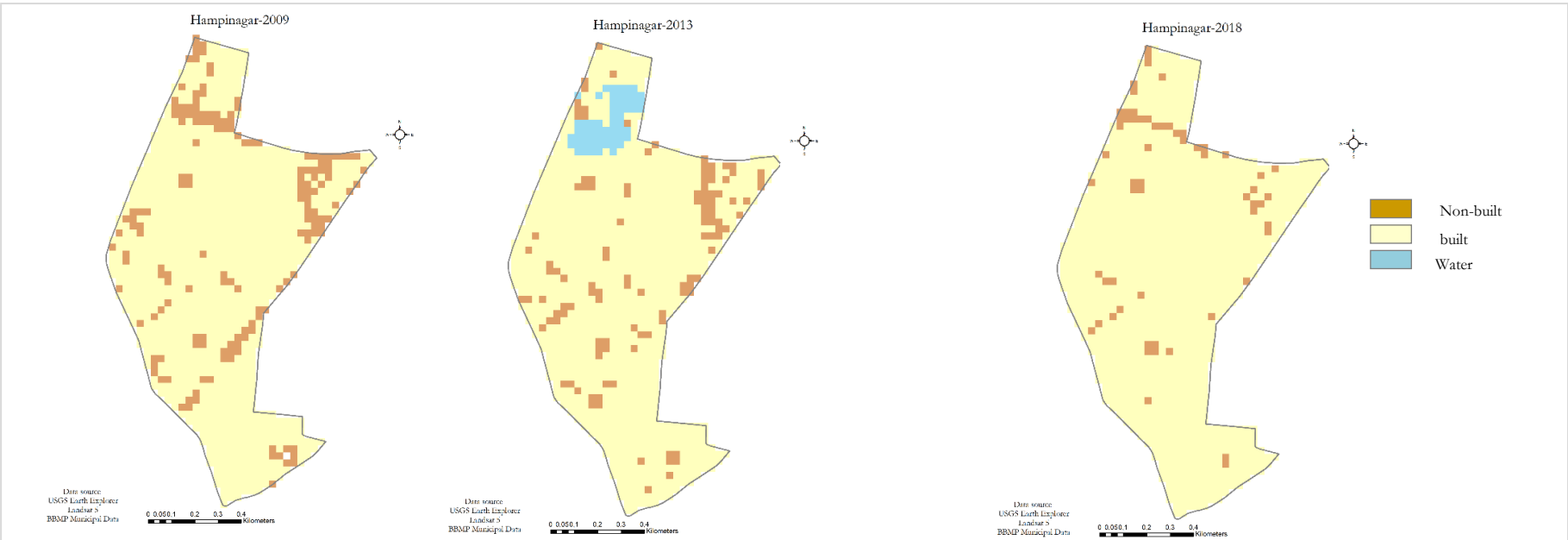


Figure 12: Landcover maps for the years 2009, 2013, 2018 – Hampinagar

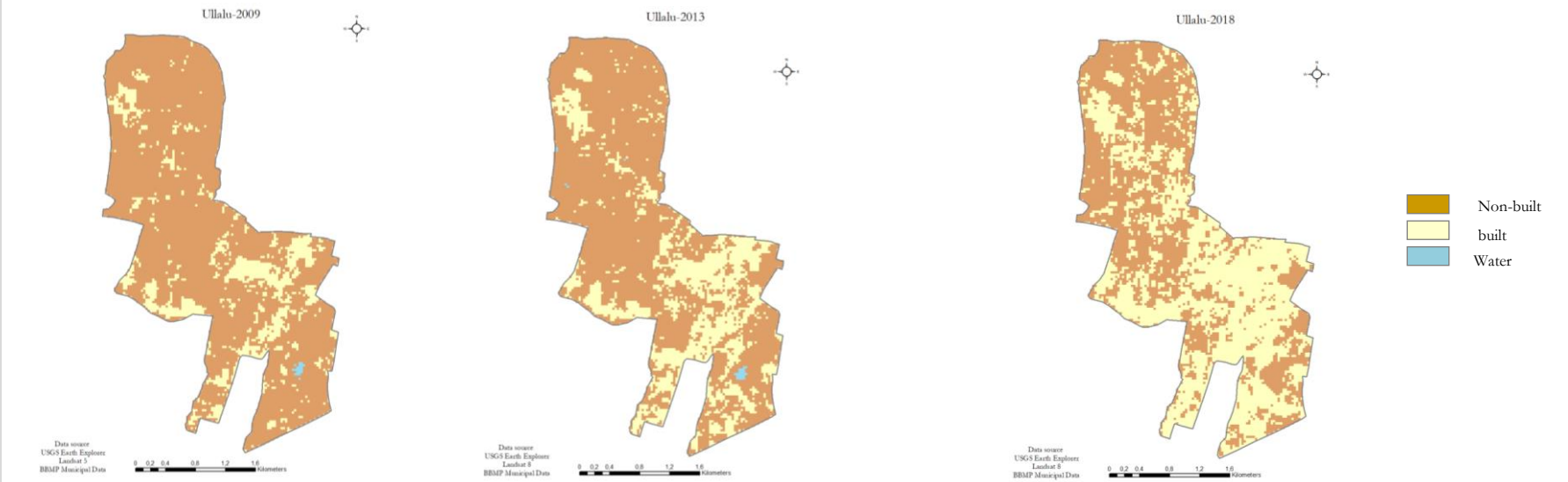


Figure 13: Landcover maps for the years 2009, 2013, 2018 - Ullalu

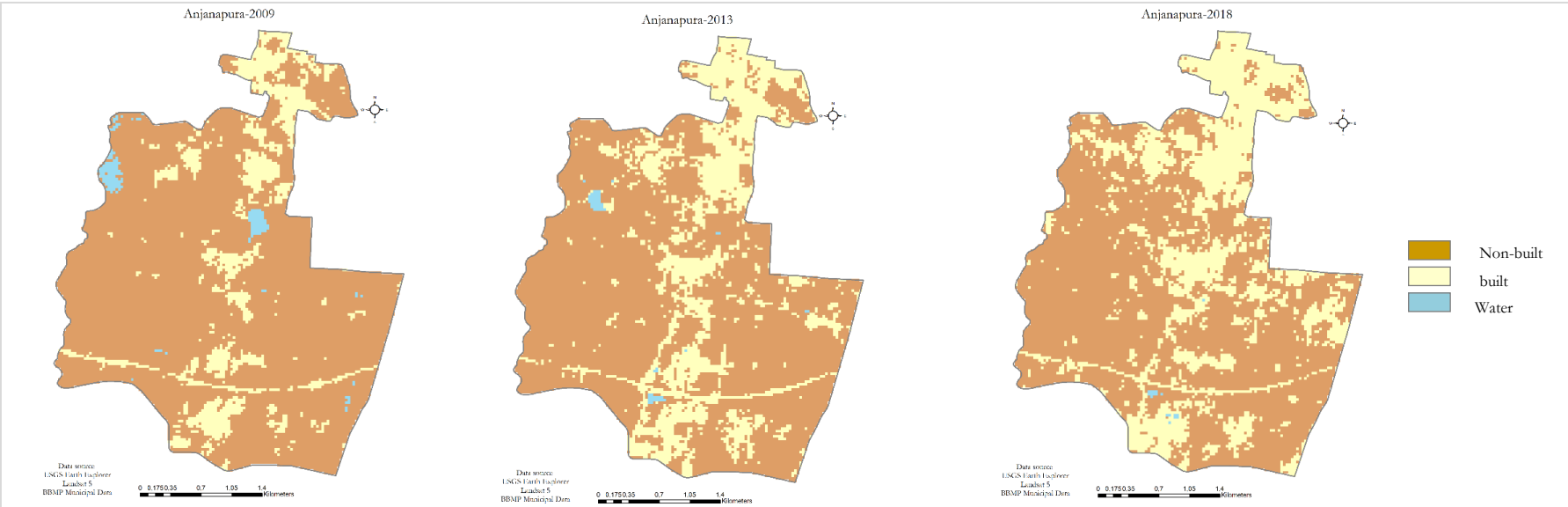


Figure 14: Landcover maps for the years 2009, 2013, 2018 - Anjanapura

5.2. Mapping the landuse mix composition in the study areas of Bengaluru

Category 1: Inner-city areas

1a. Jayanagar East: As mentioned earlier, Jayanagar East is a predominantly residential ward. Table 9 shows the overall landuses existing in the ward. From Table 9, it also can be observed that the main landuse in this ward are residential, public and semi-public, commercial, parks, and recreation, with a significant amount of area under roads and open areas. Concerning main landuses, Jayanagar East shows a majority of land under residential with a 24% of the overall built-up area followed by commercial development and public & semi-public sharing 4% and 7% of total built-up land. From Figure 16, Jayanagar's landuse map shows that the roads and open areas are already parts of demarcated landuse, narrowing the scope for new landuse categories or extension of existing landuse in the respective ward.

Table 9: Area with percentages under all the existing landuse types in Jayanagar East

Source: BDA

Jayanagar		
Landuse	Area(ha)	Percentage
Residential	24.7	24
Public and Semi-public	7.7	7
Parks and Recreation	0.5	1
Industrial	0.1	0
Commercial	4.2	4
Others(Roads and Open areas)	66	64
Total Area	103.3	100

1b. Hampi nagar: Hampi nagar consists of six major landuse categories. Table 10 shows that residential is the dominant landuse in Hampi nagar with 42% of total area, followed by parks and recreation with 5%, commercial with 4%, industrial and public & semi-public with 3%. According to the master plan, the area should be developed as a dense residential and mixed-use settlement and industrial development. However, with the increased roads and transportation network, the commercial landuse along the roads has been increased over the years, according to the key informant 2 (Appendix 8). Similar to the Jayanagar East, most of the area, 41%, is under the roads and open spaces category (Table 10). Interestingly, the open areas mapped are a part of the existing landuse, unlike a dedicated portion of the open area or reserved land, leaving less scope for the new landuses and expansion of existing landuse categories. This can be seen in the landuse map of Hampi Nagar from Figure 15.

Table 10: Area under different landuse in Hampi Nagar

Source: BDA

Hampi Nagar		
Landuse	Area(ha)	Percentage
Residential	46.8	42
Public and Semi-public	3.1	3
Parks and Recreation	6.0	5
Industrial	3.7	3
Commercial	4.3	4
Water bodies	1.0	1
Others(Roads and Open areas)	45.9	41
Total Area	111	100

Category 2: Outer city areas

2a. Ullalu: Ullalu is located in the peripheral area of Bengaluru west. As mentioned in 5.1.1, only 52% of the total area is under built-up land in Ullalu. From Table 11, the major landuse categories found in this outer city ward are residential, public & semi-public, parks & recreational, commercial, agriculture, and water bodies contributing to increased diversity of landuse mix. As most landuse share less than or equal to 10 percent of the total area, currently, this area is predominantly under vacant landuse, which has been merged with roads and open area classification. The high percentage of vacant land makes the ward highly potential for innovative landuse mix strategies and vulnerable to complicated landuse patterns.

Table 11: Area under different landuse in Ullalu

Source: BDA

Ullalu		
Landuse	Area(ha)	Percentage
Residential	89.7	10
Public and Semi-public	51.6	6
Parks and Recreation	41.3	5
Industrial	1.44	0
Commercial	17.58	2
Agriculture	16.9	2
Water bodies	15.5	2
Public Utility	0.51	0
Others (Roads and Open Areas)	662	74
Total Area	896.68	100

2b. Anjanapura: Anjanapura is the peripheral ward added within the local planning area in 2007 similar to Ullalu. Therefore, most of the land in this study area is under the vacant category. As mentioned in 5.1.1, it can be observed that only 33 % of the total land is under built-up area and has been categorized under eight main landuse categories making it a high diverse landuse mix area. Table 12 shows that the residential landuse holds the majority of built-up land with 5% of the total built area, followed by agriculture, parks & recreation, industrial and public utility. Anjanapura is predominantly under vacant landuse, making the ward a high potential area for new development and vulnerable to complicated landuse mix patterns similar to Ullau.

Table 12: Area under different landuse (Anjanapura)

Source: BDA

Anjanapura		
Landuse	Area(ha)	Percentage
Residential	61.5	5
Public and Semi-public	7.5	1
Parks and Recreation	20.2	2
Industrial	17.5	1
Commercial	2.1	0
Agriculture	41	3
Water bodies	9.3	1
Public Utility	14.2	1
Others(Roads& Open areas)	166	14
Vacant	688	57
Total Area	1208	100

Hampi

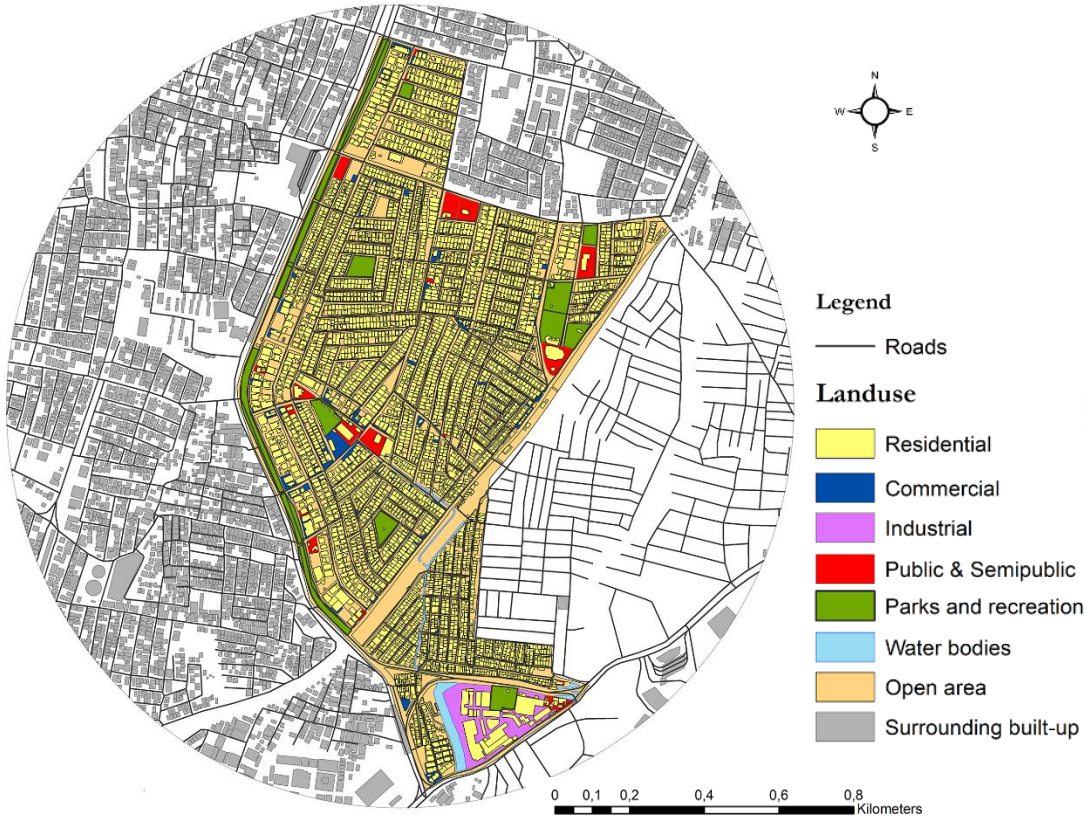


Figure 15: Landuse map, Hampinagar

Jayanagar East

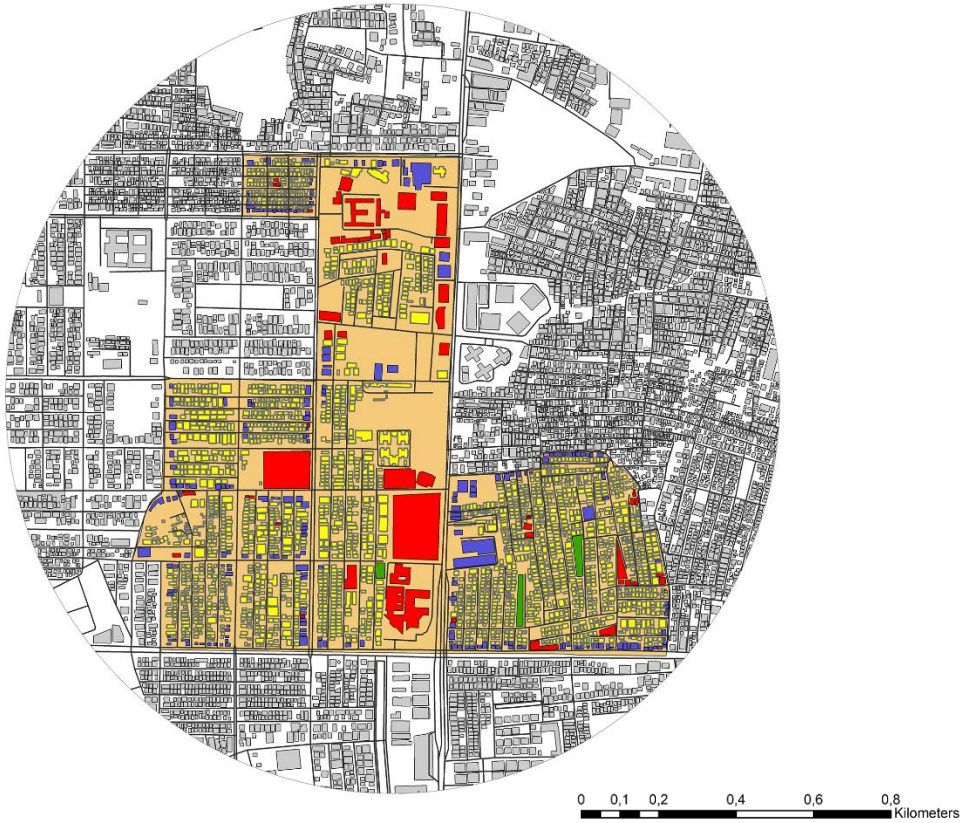


Figure 16: Landuse map, Jayanagar

Data source: Bengaluru Development Authority
Author: Mahesh Dutt

Ullalu

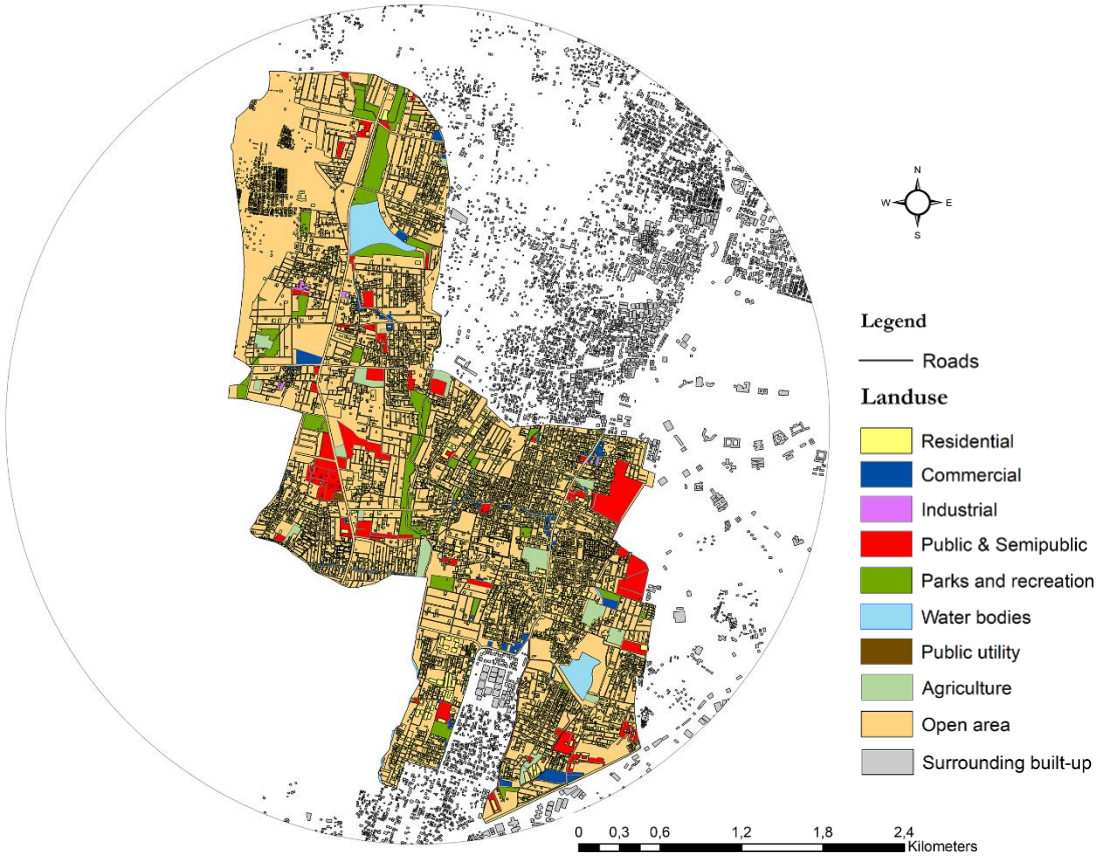


Figure 17: Landuse map, Ullalu

Anjanapura

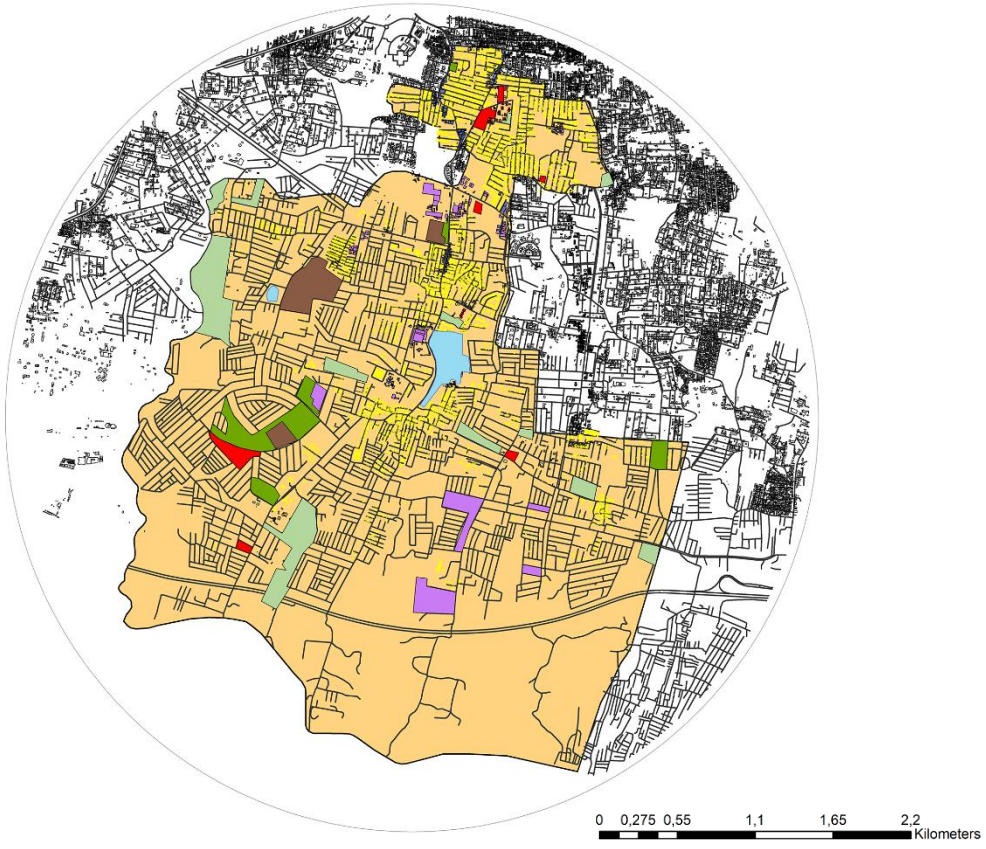


Figure 18: Landuse maps, Anjanapura

Data source: Bengaluru Development Authority
Author: Mahesh Dutt

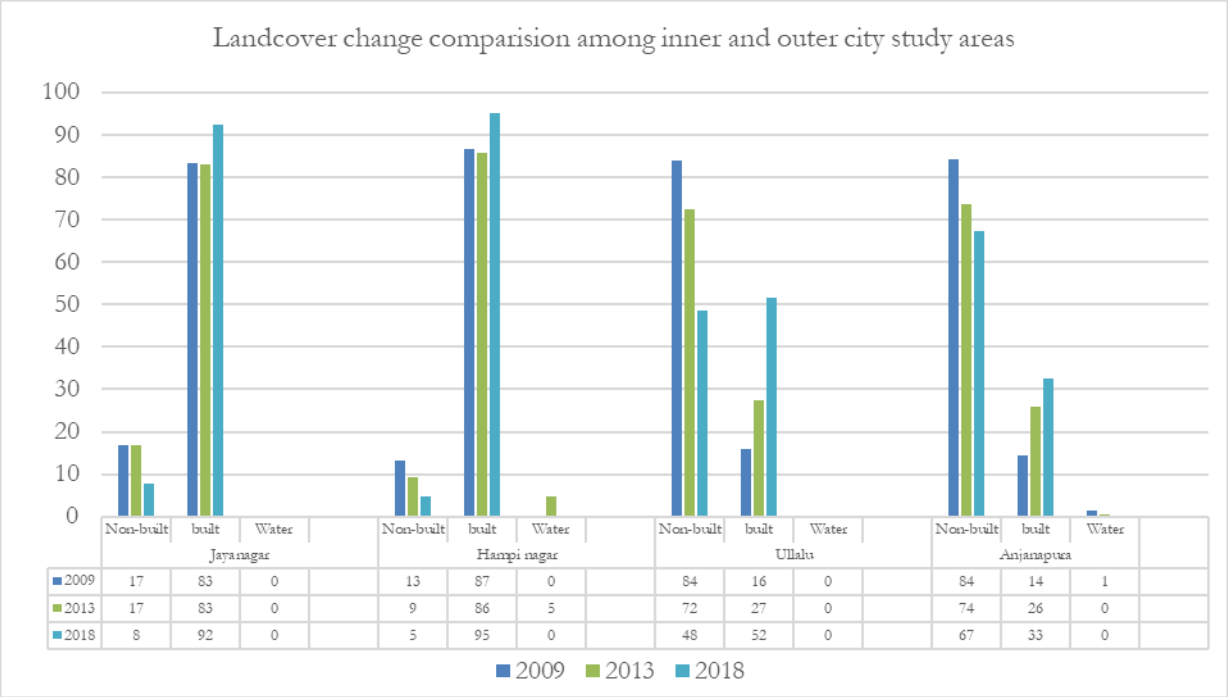
5.3. Overview of Spatial development patterns of inner and outer city study areas of Bengaluru

This section presents the consolidated findings on landuse and land cover patterns in inner and outer city study areas based on the observations from specific study areas. The comparison of landcover, landuse statistics have been presented below in Figure 19 and Figure 20 for consolidated understanding.

Landcover patterns

Landcover changes can be observed in both inner city and outer city areas. Firstly, inner-city areas show no shift in land cover until 2013. But, later to 2013, inner-city areas shows a sudden increase in their built-up land. According to key informant 2, infrastructure up-gradation such as road widening and new road constructions associated with poor development control regulations and monitoring has been one of the primary reasons for increased built-up within the ward. Secondly, outer city study areas show constant changes in land cover over the past ten years. While the non-built areas cover the maximum percentage of the total area, the built-up growth rate has been rapid in outer city areas. The built-up in the outer city study areas has grown from almost 15 to 50 percent, nearly half of the total ward area within the last ten years. The inclusion of these wards in the local planning area and transport infrastructure development contributed to increased built-up up to 3 times from the past ten years.

"After Bengaluru's local planning area was reconstituted in 2007, new villages within the Bengaluru municipal area limits have been added in which Ullalu and Anjanapura were also part of this local planning area reconstitution. Upon notification of these areas under city limits, spatial development started increasing in these areas, and the proximity to the peripheral ring road with the absence of development control regulations in these newly formed areas have contributed to the rapid spatial development in peripheral regions of the city" – Key informant 1 (Appendix 8)



	Jayanagar			Hampi nagar			Ullalu			Anjanapura		
	Non-built	built	Water	Non-built	built	Water	Non-built	built	Water	Non-built	built	Water
2009	17	83	0	13	87	0	84	16	0	84	14	1
2013	17	83	0	9	86	5	72	27	0	74	26	0
2018	8	92	0	5	95	0	48	52	0	67	33	0

Figure 19: Consolidated landcover graph - Inner and Outer city areas

Landuse patterns

Concerning landuse composition, the predominant landuse in the inner city study areas are residential. The ancillary landuses are public & semi-public, parks & recreation, commercial and industrial. Although the predominant landuse of inner-city study areas is residential, these areas face the transformation to mixed residential due to increased small-scale commercial and industrial activities as per key informant 1 (Appendix 8). Lack of regulations on landuse on either side of the main roads has become an attraction to small-scale commercial activities and started to grow in the last five years. Now, the inner city areas like Jayanagar and Hampi nagar see a transformation to predominantly mixed residential, which is not the envisioned development for these areas (Source: Key informant 1, Appendix 8).

Concerning outer city areas, the predominant landuse in these areas is vacant land. The other landuse categories seen in the outer city areas are residential, public and semi-public, parks & recreation, industrial, commercial, public utility, agriculture, and water bodies. Figure 20 shows landuse diversity seen in the outer city study areas is high compared to inner-city areas. According to the vision plan, these outer city wards are envisioned as predominantly residential areas with ancillary landuse of less than 20% of the total area. However, with vast amounts of vacant land, the outer city areas could experience demand-led development in the future with the existing spatial development practices (source: Key informant 2, Appendix 8)

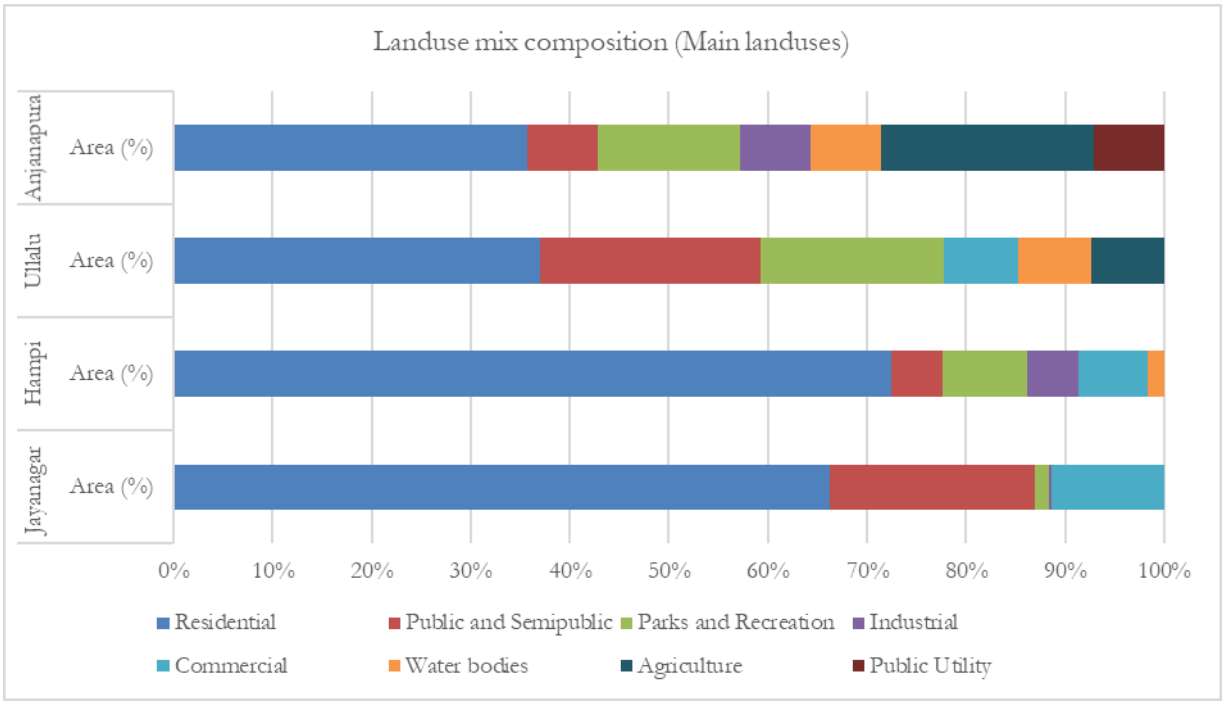


Figure 20: Landuse composition - Inner and Outer city study areas

Source: BDA

In conclusion, from Figure 19, it can be understood that there are significant changes in land cover, although minimal in the inner-city areas. However, the outer city areas show continuous changes in their landcover patterns. It is interesting to observe significant changes in inner-city built-up areas, although they are minimal due to less available non-built land. Interestingly, although the built-up land is increasing rapidly, non-built-up land still holds the majority of land in the outer city study areas, which demonstrates that these areas are going to be the future growth areas for any large scale spatial developments due to factors such as land availability and its exposure to express highways which increases the connectivity to the nearby urban centers. With respect to landuse, from Figure 20, inner-city study areas show less complicated landuse patterns while the outer-city study areas exhibit more diversity in landuse composition. Based on interviews of key informants, it has been observed that the landuse composition in the inner city areas is under transformation from purely residential to mixed residential. However, the outer city study areas have their dominant landuse under the vacant category despite the presence of a variety of landuse categories.

5.4. Spatial planning policy influence on spatial development patterns

This section analyses the existing spatial planning policies based on two themes: Development Control Regulations (DCR) and infrastructure development guidelines. It then compares with the spatial development patterns observed in the study areas to learn the possible implications of spatial planning policies on the existing spatial development patterns. Along with the cross-comparison between the actual policies and ground reality, key informant interviews have been collected to understand the deviations in policies, if any, exist. The information on current spatial planning policies and their possible deviations is majorly from two sources. First, existing spatial planning documents like city master plan 2015 and second key informant interviews from the developmental agencies. This understanding of spatial planning policy influence on spatial development patterns could help devise strategies that could positively impact and promote sustainable spatial development.

Based on the master plan 2015, the division of policies under two themes has been done based on their influence on spatial development. As development control regulations and infrastructure development guidelines are direct influencers of spatial growth and development, they have been selected to further elaborate its effect on spatial planning patterns by associating the existing policy and observations of spatial development patterns from the study areas, which can be seen in Table 13. To elaborate, the first theme - developmental control regulations states: 1) when an area is predominantly residential, the ancillary land should not exceed more than 20% of the total area; 2) a minimum of 10% of land should be under parks and open space; 3) a minimum of 5% area should be provided under civic amenities; and 4) limitation of landuse composition based on the natural character of the area should be followed. Coming to the on-ground scenario or the existing spatial development patterns, the proportion of landuse mix follows development regulations in both inner city and outer city areas. The sum of ancillary landuse is not more than 20% of the total area. However, none of the areas maintain 10 % of the total area under parks and open spaces. The suggested areas for civic amenities such as water supply, sanitation, public transport, and electricity are absent in inner-city areas and present very minimal in outer city study areas. Due to liberations in permissible landuse, the inner city areas experience adverse effects in their current landuse, transforming from purely residential to mixed residential due to increased small-scale commercial activity (Key informant 2, Appendix 8). Regarding the outer city areas, the increased landuse mix, and spatial growth, especially after their inclusion in the local planning area (Table 13), contributed to the incidences

such as reduction of water bodies, leading to increased stress on public water service provision (Nagendra et al., 2014).

"Spatial plans of Bengaluru face difficulties in its implementation and monitoring procedures. For instance, allowing small-scale commercial activity in a predominantly residential neighborhood has resulted in mixed residential development in the inner city areas like Jayanagar East though, it has been classified under residential in the landuse maps of Jayanagar, which is a total deviation from the original plan. Although spatial plans are made, when it comes to the implementation, the development is driven by the demand of the settlement, irrespective of what is envisioned in the master plan. The absence of a monitoring agency to keep track of the spatial development in accordance with spatial planning has resulted in haphazard landuse and landcover patterns" – Key informant 2 (See Appendix 8)

Concerning the second theme, infrastructure development guidelines, a peripheral ring road proposal has initiated the land acquisition and landcover change process in the peripheral areas. Regarding other civic infrastructure, there is a mandate to prepare the sectoral plans relating to public water supply, sewerage, transport, power supply, and other municipal services. However, on the ground, due to the proposal and construction of peripheral ring road and absence of guidelines on permissible development on either side of the roads has eventually resulted in rapid urban growth and sprawl in outer parts of Bengaluru city (Table 13). On the same note, due to the absence of sectoral plans and lack of communication among developmental institutions and line departments, there are no clear directions on civic infrastructural development in the master plan of Bengaluru.

"Spatial plans of Bengaluru influence spatial development patterns in the form of regulations. The current infrastructure projects with a primary focus on economic benefits have resulted in increased urban activity and spatial growth in and around the peripheral areas. For example, the small scale commercial development strategy aiming to improve employment opportunities have resulted in severe landuse changes due to a lack of clarity and restrictions in development policies" – Key informant 2 (See Appendix 8)

Table 13 presents the association between spatial planning policy and the prevalent patterns of spatial development patterns that have been captured in the study areas as elaborated above. The aim of this association is to understand the reflection of spatial planning policies on spatial development.

Table 13: Spatial planning policy reflections on spatial development patterns in the study areas.

Spatial policy	Spatial development (Landuse, Landcover)	Spatial development patterns (Landcover, Landuse) Observations
Themes	Master plan 2015	
Development control regulations (Landuse, Landcover)	• If the area is predominant Residential, ancillary land uses such as commercial, Industrial, Utility and are allowed only 20% of the total built-up area.	Both of the inner city study areas, which are planned predominantly residential, show that the total percentage of ancillary land uses less than 20%, which is in line with the DCR. Outer city study areas also do not violate landuse norms and maintain ancillary land use percentages under 20%.
	• 10% of the total land shall be reserved under parks and open space	The area under parks and recreation in the inner city areas ranges from 1% to 5% of the total area, which is less than the prescribed. However, parks and recreation in outer city areas also do not satisfy the required 10% as prescribed in development control regulations.
	• A minimum of 5% of the total area shall be provided for Civic amenities.	Inner-city study areas do not have a reserved space for public utility inside the ward as the ward area is quite small and shares the public utility with the neighboring wards. However, outer city study areas with large ward areas have less than 1% of the total area for public utility.

	• Development of commercial space in mainly residential areas is permissible.	Increased commercial activity has resulted in the conversion of residential land use along the major roads to mixed residential land use.
	• Protection of water bodies by limiting the permissible land uses	Inner-city areas do not show the presence of water bodies from the past ten years. However, outer city areas tend to lose the water bodies and exhibit more variety of land uses compared to inner-city areas.
Infrastructure development guidelines (transport and other infrastructure)	• Proposed Peripheral Ring Road (PPRR): Land acquisition has been notified in the peripheral/outer city areas	The absence of guidelines on permissible development on either side of the roads resulted in rapid urban growth and sprawl in outer parts of Bengaluru (Appendix 8)
	• Mandate to prepare the sectoral plans relating to water supply, sewerage, transport, power supply, and municipal services.	Absence of land for Bangalore water supply and sewerage board to extend water supply and sewerage services to serviced areas (Report, 2015). Lack of knowledge on developmental activities to other urban sectors (Appendix 8) The absence of sectoral plans needs to be included in the master plan to promote infrastructure integrated development (Report, 2015).

Source: Revised Masterplan 2015, BDA

5.5. Studying the changes in public water service provision in the inner and outer city areas of Bengaluru

This section analyses the status of public water service provision for four aspects, namely, accessibility, availability, adequacy, and affordability in all the study areas. To do the same, residents' perceptions have been collected using a questionnaire survey. To capture the changes in public water service provision, responses were collected from the residents who have been staying in the same locality or neighborhood for more than eight years to further study its associations with changes in spatial development during this period.

The results are presented separately for both the categories and for each study area, followed by an overview of public water service provision status on the selected indicators, highlighting the differences in outer and inner-city study areas.

Category 1: Inner-city areas

1a. Jayanagar East

Accessibility

From Figure 21 and Table 15, with regard to water accessibility, it can be inferred that most of the respondents feel the distance to water service has been decreased over the past years, and the majority of the respondents indicated that public water service has become accessible within the household compound.

Availability

Regarding water availability in the Jayanagar ward, Figure 21 shows that household/domestic public water connections have increased compared to the past, and there is a reduction in reliability on alternative water supply sources such as private and underground water. However, it can be observed 1/4th of respondents still rely on alternative water sources to fulfill their daily water needs.

Adequacy

Figure 21 displays that respondents of Jayanagar feel there is a constant decrease in the water quantity of public water supply compared to the past eight years. However, almost all the respondents feel that the public water is almost sufficient as of now. It is worth noticing that, with the decrease in water quantity, the frequency of public water service provision has been changed drastically. This change can be seen in almost half of the responses, stating their frequency has been reduced compared to the past.

Affordability

3/4th of the sample size from Figure 21 shows an increase in tariff for public water supply and indicates that they feel satisfied with the amount and quantity of the water supplied. However, a considerable number of respondents feel there is not much change in water tariff, and they are not satisfied with the tariff in proportion to the quantity of water they use. The field observations show that 1/4th of respondents who are not satisfied with the water tariff in proportion to water use are small family size households or single-person households.

Table 14 and Table 15 show the existing and changes in public water service provision in Jayanagar East. According to Table 14, the majority of the households in this study area rely on only public water service provision. Also, nearly all respondents state that they avail water within 200 meters distance. The frequency of water supply is alternate days for the majority of the households. However, the duration of the water supply is greater than four hours, satisfying the overall water requirements. All the households in this study area stated that the water costs are less than three percent of the monthly family income, making the public water service affordable to the users.

Table 14: Indicators explaining existing water service provision, Jayanagar East

Indicators	Responses (in percentage)		
The primary source of water supply	Public only	Both Public and Private	
	93	7	
Distance to a public water source	< 200 meters	200-600	>600 meters
	99	1	-
Duration of public water supply	< 2 hours	2-4 hours	>4 hours
		28	72
Frequency of water supply	Daily	Alternate days	Twice a week
	1	88	10
Percentage of family income spent on public water supply	(<3)%	(3-5)%	(5-10)%
	96	4	

Source: Field data, Jayanagar East

Table 15: Status of public water service provision, Jayanagar East

Status of Public water service provision	Jayanagar East		
	Mean		Standard Deviation
Accessibility	Observation	Range	
Increased distance to public water source	2.7	(2.6-3.4) Disagree	2.2
Availability			
Increase in public water connections	5.4	(5.0-5.8) Strongly agree	4.9
Increased use of alternative sources of water	3.1	(2.6-3.4) Disagree	2.8
Adequacy			
Quantity of public water supply has decreased	3.3	(2.6-3.4) Disagree	2.9
Water quantity is quite sufficient for the Household	5.2	(5.0-5.8) Strongly agree	4.8
Frequency of water supply has decreased	3.5	(3.4-4.2) Neutral	3.2
Affordability			
Increase in water tariff over the time	4.9	(4.2-5.0) Agree	4.4
Satisfied with the water tariff in proportion to the supplied quantity	5.1	(5.0-5.8) Strongly agree	4.6

Figure 21: Bargraphs showing the changes in water service provision variables and indicators, Jayanagar East

1b. Hampinagar

Accessibility

From Figure 22, concerning public water accessibility in Hampinagar, the majority of the households responded or feel the accessibility to water service has been improved with respect to distance to public water sources over the past years. Also, from Table 16, it can be observed the location of public water source for almost 99 percent of the respondents has become accessible within the household compound.

Availability

Regarding water availability, Figure 22, water availability indicators show that there is a significant increase in household public water connections. Also, a considerable number of households, i.e. (34%), stated that there is an increase in usage of alternate sources of water supply and 21 % said neutral, and 46% confirmed no increase in alternate use of water sources.

Adequacy

According to Figure 22, water quantity has been compromised over the years, resulting in reduced frequency of public water supply. From the adequacy indicators in Figure 22, there has been a significant disagreement with the sufficiency in the quantity of public water supply. This could confirm the possibility of inadequate water supply as per the population demand or unequal share of water supply within the ward area.

Affordability

The majority of respondents experience an increase in water tariff and indicate that they feel satisfied with the amount and quantity of the water supplied based on Figure 22. However, a significant number of respondents sit in the neutral category in terms of their satisfaction levels with the tariff in proportion to the quantity of water they use.

Table 16 and Table 17 show the existing and changes in the public water service provision in Hampinagar. Table 16 shows that around 30% of responses in Hampinagar depend on private water supply as an additional source. However, 67% of respondents stated that public water supply is sufficient for household needs as the water supply is more than 4 hours and is available every alternate day. The majority of respondents also stated that the water supply tariff is quite reasonable for the quantity of water received. From Table 17, higher standard deviations in adequacy and affordability indicators reveal higher differences in these indicators within the ward.

Table 16: Indicators explaining existing water service provision, Hampi Nagar

Indicators	Responses (in percentage)		
The primary source of water supply	Public only	Both Public and Private	
	67	33	
Distance to a public water source	< 200 meters	200-600	>600 meters
	100	0	-
Duration of public water supply	< 2 hours	2-4 hours	>4 hours
	2	8	91
Frequency of water supply	Daily	Alternate days	Twice a week
	5	92	3
Percentage of family income spent on public water supply	(<3)%	(3-5)%	(5-10)%
	97	3	

Source: Field data, Hampi Nagar

Table 17: Status of public water service provision, Hampi Nagar

Status of Public water service provision	Hampi Nagar		
	Mean		Standard Deviation
Accessibility	Observation	Range	
Increased distance to a public water source	2.5	(1.8-2.6)Strongly disagree	2.0
Availability			
Increase in public water connections	5.4	(5.0-5.8)Strongly agree	4.9
Increased use of alternative sources of water	3.8	(3.4-4.2)Neutral	3.5
Adequacy			
Quantity of public water supply has decreased	4.0	(3.4-4.2)Neutral	3.6
Water quantity is quite sufficient for the Household	5.3	(5.0-5.8)Strongly agree	4.8
Frequency of water supply has decreased	4.2	(4.2-5.0) Agree	3.8
Affordability			
Increase in water tariff over the time	5.1	(5.0-5.8)Strongly agree	4.7
Satisfied with the water tariff in proportion to supplied quantity	5.4	(5.0-5.8)Strongly agree	4.9

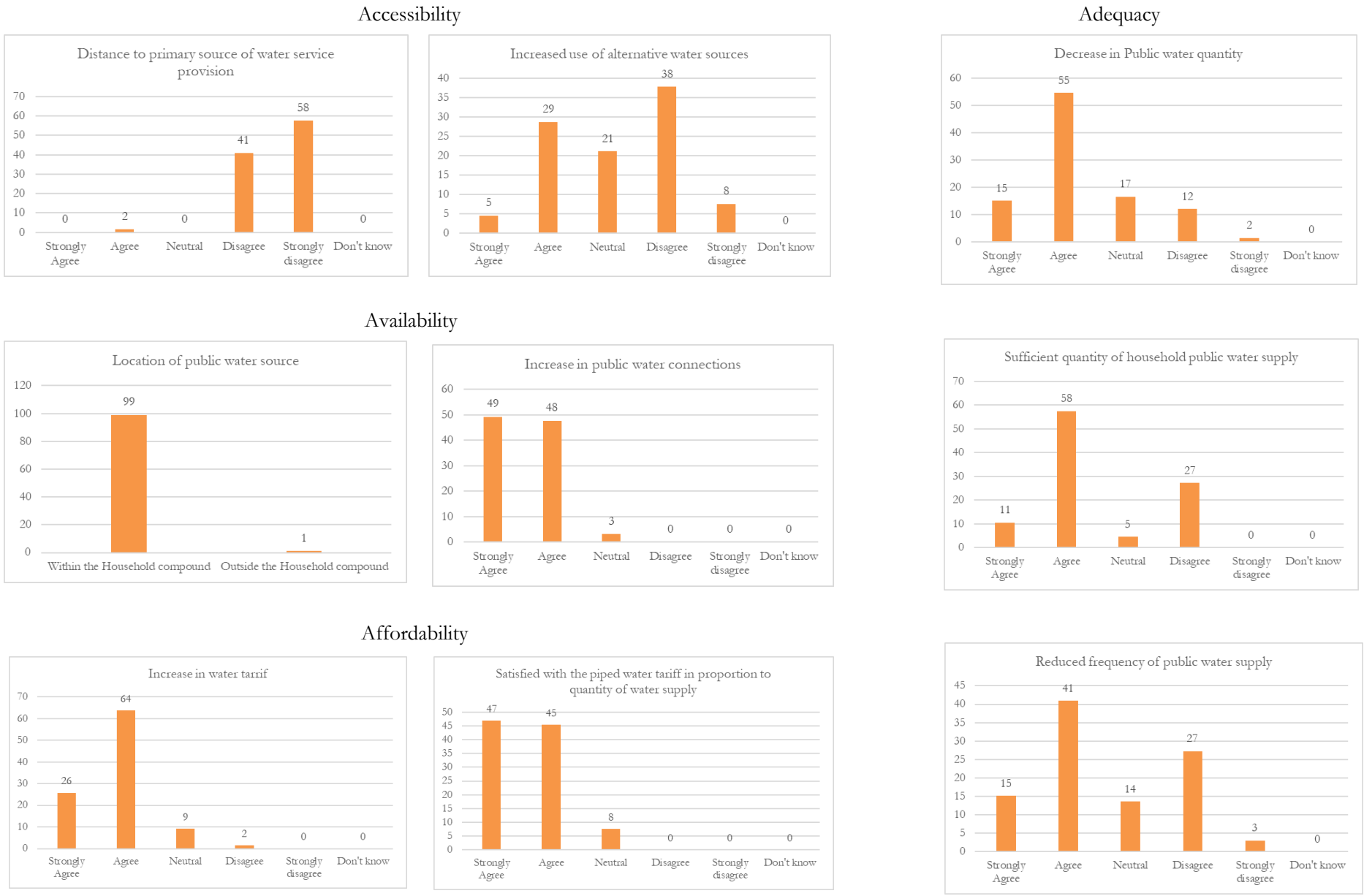


Figure 22: Bargraphs showing the changes in water service provision variables and indicators, Hampinagar

Category 2: Outer city areas

2a. Ullalu

Accessibility

According to Figure 23, public water accessibility in Ullalu has seen a positive trend compared to the past eight years. The majority of the respondents stated that distance to the primary source of public water facility decreased compared to the past. However, few respondents feel the distance to the source of public water facility has increased or not changed, which highlights an outdated water service network in some of the newly or rapidly changing areas. It is interesting to notice from Figure 23 and Table 18 that those respondents whose distance to public water service provision has improved are having their water supply within the household compound.

Availability

Water availability in Ullalu also shows a positive trend in general, with all the respondents stating there is a significant increase in public water connections. However, as per Figure 23, the use of alternate water sources other than public water supply is very high compared to inner-city wards. This is supported by Table 18, where 87 percent of the population uses private and public water sources for their daily use. These figures clearly illustrate that although there is water service available in the area, respondents face adequacy issues in the public water supply.

Adequacy

With respect to adequacy, the majority of the respondents agree to a decrease in public water quantity compared to the past, which highlights the insufficient public water supply. As per Figure 23, almost 50 percent of the households state that they feel insufficiency in public water supply with significantly reduced frequency compared to the past. This confirms the above-mentioned inadequate water supply as per the population demand and up to date with newly built areas in the ward. Unlike inner city areas, with an overall improvement in water service provision, with respect to increased domestic/household water connections and increased water accessibility, outer city areas such as Ullalu experience reduced water quantity and degraded frequency of public water supply.

Affordability

Almost 74% of the respondents agree to the increased water tariff in Ullalu. It is worth noticing that a significant number of the population express neutrality when asked about the satisfaction on water tariff in relation to water supply, according to Figure 23.

Table 18 highlights that most respondents, i.e., 87%, depend on private water supply as an additional source of their overall water supply, unlike the inner-city wards. Moreover, all of the respondents stated that they could collect water within 200 meters from their household with a duration of more than 4 hours of public water. However, the frequency of water supply is just twice a week to the majority of households. As the majority of the households feel insufficient amounts of water quantity, most of them are forced to move towards alternate water sources, which is increasing the private water share in the ward.

Table 18: Indicators explaining existing public water service provision, Ullalu

Indicators	Responses (in percentage)			
The primary source of water supply	Public only	Both Public and Private		
	13	87		
Distance to a public water source	< 200 meters	200-600	>600 meters	
	100		-	
Duration of public water supply	< 2 hours	2-4 hours	>4 hours	
	2		98	
Frequency of water supply	Daily	Alternate days	Twice a week	Once a week
	2	5	92	2
Percentage of family income spent on public water supply	(<3)%	(3-5)%	(5-10)%	
	100	0	0	

Source: Field data

Table 19: Status of public water service provision, Ullalu

Status of Public water service provision	Ullalu		
	Mean		Standard Deviation
Accessibility	Observation	Range	
Increased distance to public water source	2.6	(2.6-3.4) Disagree	2.3
Availability			
Increase in public water connections	5.0	(5.0-5.8) Strongly agree	4.5
Increased use of alternative sources of water	4.8	(4.2-5.0)Agree	4.3
Adequacy			
Quantity of public water supply has decreased	5.0	(5.0-5.8) Strongly Agree	4.5
Water quantity is quite sufficient for the Household	3.8	(3.4-4.2) Neutral	3.4
Frequency of water supply has decreased	4.8	(4.2-5.0)Agree	4.4
Affordability			
Increase in water tariff over the time	4.8	(4.2-5.0)Agree	4.3
Satisfied with the water tariff in proportion to supplied quantity	4.9	(4.2-5.0)Agree	4.4

Figure 23: Bargraphs showing the changes in water service provision variables and indicators, Ullalu

2b. Anjanapura

Accessibility

According to Figure 24, Anjanapura shows an improvement in public water accessibility. Almost 93 percent of respondents stated their distance to public water service provision has decreased compared to the past and are able to access public water within their household compound. However, few respondents, i.e., 6%, state that their distance to the public water source has increased, highlighting the absence of an updated water service network in newly or rapidly changing areas within the ward.

Availability

Water availability in Anjanapura shows overall improvement, with 96% of the respondents stating a significant increase in public water connections compared to the past eight years. However, as per Figure 24, alternate water sources other than public water supply are currently very high compared to inner-city wards. This can be supported by Table 20, where 79 percent of the population uses private and public water sources for their daily use. Figure 24 clearly illustrates that although water service is available in the area, respondents face adequacy issues regarding the public water supply.

Adequacy

Regarding public water adequacy, most of the respondents in Anjanapura agree that there has been a significant decrease in public water quantity compared to the past, highlighting the insufficient public water supply. According to Figure 24, only 52 percent of the households feel sufficiency in public water supply with significantly reduced frequency compared to the past. This confirms the above-mentioned inadequate water supply in the newly developed or built areas in the ward. Unlike the inner city areas, although overall water service provision has improved, concerning an increase in the number of household water connections and increased water accessibility at the household level. The outer city areas, such as Anjanapura, are experiencing reduced water quantity and degraded frequency of public water supply, possibly due to delay in infrastructure update or non-integrated spatial development with water service provision.

Affordability

Almost all of the respondents agree that there has been an increase in public water tariffs in Anjanapura. However, from the affordability bar graphs in Figure 24, it can be noticed that there are still 3/4th of respondents who expressed their dissatisfaction with the current water tariff in proportion to the public water supply.

Table 20 highlights that 79% of the respondents are dependent on private water supply as an additional source of their overall water supply. This is similar to the Ullalu ward, a newly developing ward, and outer city ward. However, all the respondents stated that they are able to collect water within 200 meters from their household with a duration of more than 4 hours of public water. However, the frequency of water supply is just twice a week to the majority of households. I believe this insufficiency in water quantity felt by the residents forces them to move towards alternative water sources such as private water supply and groundwater. Table 21 shows higher standard deviations for adequacy and affordability indicators, which confirms a high difference of perceptions in the respective indicators in this study area.

Table 20: Indicators explaining existing public water service provision, Anjanapura

Indicators	Responses (in percentages)			
	Public only	Both Public and Private		
The primary source of water supply	21	79		
	< 200 meters	200-600	>600 meters	
Distance to a public water source	100		-	
	< 2 hours	2-4 hours	>4 hours	
Duration of public water supply	2	18	40	
	Daily	Alternate days	Twice a week	Once a week
Frequency of water supply	0	2	98	0
	(<3)%	(3-5)%	(5-10)%	
Percentage of family income spent on public water supply	100			

Source: Field Data

Table 21: Status of public water service provision, Anjanapura

Status of Public water service provision	Anjanapura		
	Mean		Standard Deviation
Accessibility	Observation	Range	
Increased distance to a public water source	2.8	(2.6-3.4) Disagree	2.4
Availability			
Increase in public water connections	5.1	(5.0-5.8) Strongly agree	4.6
Increased use of alternative sources of water	5.0	(5.0-5.8) Strongly agree	4.5
Adequacy			
Quantity of public water supply has decreased	5.3	(5.0-5.8) Strongly Agree	4.8
Water quantity is quite sufficient for the Household	3.9	(3.4-4.2)Neutral	3.5
Frequency of water supply has decreased	5.0	(5.0-5.8) Strongly Agree	4.5
Affordability			
Increase in water tariff over the time	5.1	(5.0-5.8) Strongly agree	4.6
Satisfied with the water tariff in proportion to the supplied quantity	4.6	(4.2-5.0) Agree	4.2

Figure 24: Bargraphs showing the changes in water service provision variables and indicators, Anjanapura

5.6. Overview of the status of public water service provision in inner and outer city study areas

This section briefly explains the status of public water service provision in inner and outer city study areas. To give an overview, the overall status of public water service provision improved in all the areas compared to the past. However, the closer observation of water service indicators reveals interesting insights in inner and outer city study areas.

Inner-city study areas: Jayanagar East, Hampinagar

Being inner-city areas, Jayanagar East and Hampinagar exhibit a well-developed water-related infrastructure from the past. According to the Bengaluru water supply and sewerage board (BWSSB), almost 50% of the residents possess public water connections in these study areas. The above results show that access and availability of public water supply have improved in terms of distance to nearest water facility and number of household water connections compared to past. Regarding adequacy, the inner city areas show adequate water supply most times of the year. However, areas such as Hampinagar tend to show a decrease in public water quantity in recent years. Concerning public water affordability, inner-city areas show high satisfaction about costs as the users feel that existing water quantity is reasonably proportionate to water tax.

Outer city study areas: Ullalu, Anjanapura

Most of the outer city study areas were added to the local planning area in 2007. Although the areas have been added recently, the spatial development has been happening for a long time, and related infrastructure developments also started before the inclusion of these areas in the local planning area (Appendix 8). According to the BWSSB, the public water connections in these areas range from 16% to 40%. The above results show that access and availability of public water services in outer city areas have improved significantly compared to the past. However, total water connections with respect to the scale of the neighborhoods are very low, which is quite in contrast to inner-city areas. Also, it is interesting to notice that majority of the population relies on both public and private water supply for their daily purpose despite increased access and availability to public water infrastructure. This highlights the issues with water adequacy in the outer city areas. The increase in population densities and urban activities with limited water quantity has resulted in inadequacy issues in the outer city areas of Bengaluru. This has eventually led to lower satisfaction levels in the outer city areas with respect to affordability.

5.7. Influence of spatial development patterns on public water service provision

This section explores the impacts of spatial development patterns on public water service provision in the study areas of Bengaluru. As described earlier, the selected study areas represent the inner and outer city contexts of Bengaluru. The spatial development patterns and status of public water service provision have been studied in these two contexts and associated to understand the relationship between the two sectors using spatial data analysis and field data analysis. The results have been compiled for the two study area categories with respect to spatial planning and water service provision and have been presented in Table 22. A detailed overview of the association between spatial development patterns and public water service provision status for each study area has been provided in the table format in Appendix 1.

From Table 22, inner-city study areas such as Jayanagar East and Hampinagar witnessed a significant built-up change in the past ten years. This has resulted in an increase in 1) settlement densities in inner-city study areas and 2) the emergence of various land uses. At the same time, the study of water service provision in the inner city study areas clearly shows that 1) there is an improvement in water accessibility with a decreased distance to a public water source; 2) overall, water availability has also been improved in the inner city areas with increase in public water connections; however, 3) the households in inner city areas started to face adequacy issues in terms of shortage in water quantity during certain times and starting to rely on alternate water sources when necessary. This can be observed mainly in the Hampinagar, in which the land use mix is quite diverse compared to Jayanagar East, although both the areas are planned predominantly residential.

Table 22 shows that spatial development patterns seem to have a significant impact on public water service indicators such as accessibility, availability, adequacy, and affordability. Firstly, in the inner city, the study areas in this part of the city are densely populated and predominantly residential. Therefore, water service provision has been facilitated with ease in the past; however, with the increase in built-up density to almost 90% of the total ward area and increased land-use diversity in wards like Hampinagar; the households started to face issues with the water service provision in terms of adequacy although the accessibility and availability have improved compared to past. From the above results, it can be interpreted that although the increased built-up and classification of land use in the inner city areas has helped in bringing the water infrastructure, thereby improving the accessibility and availability aspects of public water, the increased spatial growth and diverse development patterns have started to show adverse effects on water adequacy, although minimal for now.

Concerning peripheral areas of Bengaluru, outer city study areas such as Ullalu and Anjanapura demonstrate that the built-up density has been increased very rapidly in the past ten years after their inclusion in the administrative boundary in the year 2007(Figure 19, Table 1). From Table 22, on the one hand, it can be observed that the built-up density in the outer city areas is showing an inclined trend with high diversity in land use mix. On the other hand, from the water service provision analysis, it can be observed that access and availability to water have improved over the years along with the built-up growth with an increase in household water connections and decreased distance to water sources. However, the share of 'only public water service' users is significantly less than in inner-city areas, which means an increased dependency on private and alternate water sources. Although the water accessibility in terms of household water connections has improved compared to the past, most residents still rely on private water sources and public water supply to fulfil their daily water demands. This highlights the poor water adequacy and the shortage of water service infrastructure in proportion to the existing and future population of the study area. In total, it can be confirmed that the outer city areas face severe adequacy issues despite improved accessibility and availability of water supply, and the majority of the population still relies on alternate water sources, which also increases the water costs for certain groups of residents.

In summary, water service provision with respect to accessibility and availability has improved in all the study areas. However, due to rapid built-up growth, public water service provision in the outer city areas does not seem to develop with the same speed as the built-up growth but showing a positive trend with improved accessibility and availability aspects. Being in the administrative boundary from the beginning and incremental built-up change, water service provision with respect to accessibility and availability is quite satisfactory in inner city study areas. Concerning water adequacy, both the inner and outer city study

areas face challenges with different intensities. First, inner city areas that show comparatively less diversity in their land use positively affect water adequacy. In areas with a more diverse land use mix such as Hampinagar, water adequacy started becoming an issue in recent times. Second, as the outer parts of the city contain diverse landuse composition shows severe water adequacy issues. It seems diverse landuse mix appears to have a significant effect on water distribution among different sectors such as residential, commercial, industrial, and so on, which exist within a common boundary.

Table 22: Association of spatial development and public water service provision

Study areas	Spatial development patterns	Water service provision
Inner-city Areas (Jayanagar East , Hampi Nagar)	• Significant increase in built-up density from 2013 to 2018. • The increased built-up density has resulted in a reduction of open spaces and limits the scope for necessary land uses, such as reserved spaces for civic amenities, which is absent in inner-city study areas • Two types of land-use composition can be seen in inner-city areas. One with a less complicated land-use mix and the other with a diverse land-use mix. • In spite of the presence of a more land-use mix diversity, both of the inner city areas are predominantly residential. • There is no vacant land in the inner city study areas. All the land is classified under the existing land uses. Addition of new landuse is a challenging task in the inner city areas	• Access to public water service has become better • Water availability stands in a better position compared to outer city areas • Water quantity is quite sufficient in inner-city areas. However, usage of alternate sources has started to increase in recent years due to insufficient quantity • Affordability of public water is not an issue in the inner city areas as the households are satisfied with the tariff in proportion to supplied quantity.
Outer city Areas (Ullalu, Anjanapura)	• The outer city areas or peripheral areas have experienced rapid built-up growth over the past ten years. • The outer city areas have experienced an increase in built-up densities almost twice or three times in the last ten years. • Outer city areas shows diverse and complex landuse mix composition. • Predominant landuse in outer	• Overall access to public water supply has improved in the outer city study areas compared to the past. • Water availability in the outer city areas is debatable. Water connections have been improved in these areas compared to the past. However, majority of the residents rely upon alternate water sources till date due to insufficient public water quantity.

	city study areas is vacant land followed by residential land. • Outer city areas show a positive trend with respect to built-up growth.	• Regarding water adequacy, outer city study areas experience severe shortages in public water quantity along with reduced frequency in public water service provision. • Majority of the households expressed their satisfaction towards water tariff in proportion to water quantity supplied. Whereas, a significant amount of households are still not satisfied with the tariff in proportionate to water quantity.

5.8. Impacts of spatial planning policy on public water service provision

This section explores the impacts of spatial planning policies on public water service provision to understand how the spatial planning policies resulted in different spatial development patterns and hence their possible implications on public water service provision. The observations from the previous section on possible deviations in spatial planning policies will be used to compare them with the variables of public water service provision. This comparison is amongst two main themes of spatial planning policies and four public water service provision variables as described in previous sections.

To begin with, in terms of development control regulations, the existing developmental practices and policies on spatial development allow physical development of new areas upon confirmation of the availability of necessary basic infrastructures such as water, electricity, and transportation. However, they ignore the continuity of these services for longer periods hindering the sustainable development and management of urban communities. Moreover, past developmental decisions of Bengaluru solely focused on economic development with no regard to the then existing spatial development plans. Eventually, it has resulted in rapid changes in land cover that can be observed in outer city and inner-city areas. These changes are still continuing with much more complexity since the existing planning policies and practices are unable to tackle or address these challenges (source: key informant 1, Appendix 8). There are also clear deviations in land use mix patterns in inner and outer city areas, mainly due to misuse of ancillary land-use permissions in the respective neighborhoods. This has also resulted in the transformation of neighborhoods' character (Appendix 8). For infrastructure development guidelines, the absence of guidelines on permissible development on either side of the roads upon the proposal of Peripheral Ring Road (PRR) resulted in rapid urban growth and sprawl in the outer city/peripheral areas. Construction of new roads in outer city areas and widening existing roads in the inner city study areas without guidelines on permissible development on either side of the roads has resulted in small-scale commercial development along the major roads creating complexity in the proposed land use mix (Appendix 8). And lastly, the absence of detailed sectoral plans with space requirements and their inclusion in spatial development plans have resulted in insufficient infrastructures (Report, 2015).

"Past development plans primarily focused on economical up-gradation. As a result, commercial and industrial sectors developments resulted in housing development around the industrial establishments irrespective of proposed land use plans.

With the neglect of other urban sectors by the developmental agencies, housing and related infrastructure were developed without proper integration. In total, the sectoral and institutional coordination is still a missing entity in the spatial development process of Bengaluru" – key informant 1(See Appendix 8)

From Table 22, upon observing the possible implications of spatial planning policies and development patterns on water service indicators, increased built-up density as a result of poor spatial development regulations in outer city areas and demand-led developmental approach in inner and outer city areas have possibly contributed to improved accessibility and availability to water service provision in both inner and outer parts of the city. However, the alternate water supply usage has increased in diverse land use mix areas than in the areas with less diverse land use mix. According to key informants, land use mix diversity can act negatively and positively on water service provision. A less diverse land-use mix strategy helps the organization of water services based on activity and demand and helps to maintain consistency in quality. However, more diverse land uses could attract water-related infrastructure due to high economic benefits. In the case study areas with high land use mix, the possible reason behind the improvement in water availability is due to the attraction of water infrastructure by the ancillary land uses such as industrial and commercial.

*"In terms of water infrastructure, water service provision gets complicated when several landuse exist in the common boundary. The water supply board works on a self-financing model. As a result, it tries to provide more water for land uses such as industrial, commercial, for economic generation, and subsidies residential water service. So, the presence of commercial and industrial land uses could be able to bring the water infrastructure to the respective areas. However, eventually, it could result in adverse effects such as reduced quality" – Key informant 2. (*Appendix 8*)*

The above-mentioned phenomenon could also lead to uneven distribution of water quantity and severe quality issues, which can be clearly observed by the increase in alternate water supply use in outer city areas and in inner-city areas occasionally. The field data shows that the outer city areas are facing severe adequacy issues compared to inner-city areas, with the increase in built-up density and diverse land use mix due to Megha road infrastructure projects and the absence of spatial growth regulations. Overall, the affordability aspect in inner and outer study areas shows a positive trend as the higher densities and segregated land uses result in larger user groups and sufficient quantity. However, in the outer city areas, poor satisfaction costs can be witnessed amongst significant individuals due to increased water tariffs and insufficient water quantity.

Table 23: Implications of spatial planning policies on public water service provision

Spatial planning policies		Public water service provision	
Themes	Observations	Indicators	Observations
Development control regulations	• Past developmental decisions focused on economic development with no regard to proposed spatial development plans. This has resulted in rapid changes in landcover and land uses both in the peripheral and the inner city areas (although minor) and are still continuing with much more complexity that the current planning policies and practices unable to address. • Allowing the demand-led development has resulted in deviations in landuse mix patterns in both inner and outer city areas (Appendix 8) • Existing spatial development practices lack in ensuring sustainable water infrastructure development while allowing area development or physical development (Appendix 7)	Accessibility	It can be observed that, Increase in overall built-up shows a positive contribution on water accessibility with a decreased distance to public water sources compared to the past when the built-up area is significantly less. This can be well understood from the outer city study areas where access to water within the ward has improved very much in the recent years compared to the past eight years with significantly less built up.
		Availability	From the key informant interviews (Appendix 8) and the field data, it can be observed that landuse mix seems to have a positive effect on water availability by attracting the water-related infrastructure with a variety of land uses
Infrastructure development guidelines	• Absence of guidelines on permissible development on either side of the roads upon the proposal of Peripheral Ring Road (PPRR) resulted in rapid urban growth and sprawl in the outer city/peripheral areas. • Construction of new roads in outer city areas and widening of existing roads in the inner city study areas without guidelines on permissible development on either side of the roads has resulted in the development of small-scale commercial development along the major roads creating complexity in the proposed landuse mix. • Absence of detailed sectoral plans with space requirements and their inclusion in spatial developmnet plans.	Adequacy	As mentioned earlier, various land uses could have impacted the water availability positively. However, we can observe that the water quantity has been compromised in high landuse mix areas. This can be clearly observed in both inner city (Hampinagar) and outer city areas where landuse mix composition is complex.
		Affordability	Increased built-up and mixed landuse resulted in increased water users in both inner and outer city areas, which explains the improved satisfaction about costs.

6. DISCUSSION

This chapter discusses prevalent spatial planning patterns of Bengaluru and the role of spatial planning policies in influencing existing spatial development patterns followed by changes in the status of public water service in the city of Bengaluru and the possible impacts of spatial development on public water service provision.

6.1. Spatial development patterns in inner and outer city areas of Bengaluru.

The current study shows that Bengaluru is experiencing rapid spatial development with respect to its landcover change and land-use diversity over the recent decade. Firstly, with respect to land cover changes, outer city areas show up to 50% increase of built-up, and inner-city areas show an increase of almost 10% built-up growth. Therefore, it can be understood from this study that both inner and outer city areas are undergoing built-up changes. However, the outer city areas of Bengaluru show rapid spatial growth rates compared to inner-city areas with an overall built-up growth of 190% in the late 20th century (Sudhira et al., 2003; Taubenböck et al., 2009). Secondly, the study also found that spatial development with respect to land-use mix shows less diversity in inner-city areas compared to outer city areas. From the key informants and policy document analysis, it can be inferred that the poor spatial development guidelines in the newly developed areas have resulted in unexpected land use compositions. Furthermore, this study shows an increase in landuse diversity with the changes in landcover patterns confirming the association between landcover changes and landuse mix (Siedentop & Fina, 2010). Additionally, Proposals such as special economic zones and highway construction in the peripheral areas of Bengaluru with poor urban development guidelines had led to drastic and unrealistic land-use changes (Nagendra & Ashok, 2019).

In total, the findings of the study confirm that spatial development patterns such as rapid landcover changes result in increased built-up densities and complicated landuse patterns while promoting the urban sprawl in peripheral areas just like Bengaluru (Siedentop & Fina, 2010; Verma, Chatterjee, & Mandal, 2017).

6.2. Influence of spatial planning policies on spatial development patterns

The heavy influx of population and implementation of large-scale urban development projects such as industrial development and road constructions are contributing to changes in urban areas with regard to spatial development and infrastructural needs (Arif & Gupta, 2020). In this research, from the policy document analysis and key informant interviews, the large scale infrastructural proposals such as the construction of peripheral ring road have resulted in rapid spatial growth in outer parts of the city, while road widening activities in the inner city areas has spurred the spatial growth on either side of the roads. This study also argues that the existing spatial planning and implementation practices lack sufficient knowledge on spatial development dynamics and proper integrations with other urban sectors, which makes the regulation of spatial growth difficult. In specific, the lack of development control regulations in the newly developing areas on the type of allowable development and permissible land uses has resulted in urban sprawl and non-integrated infrastructure development as per the key informants. This phenomenon shows a contradiction with the framework on which the local spatial planning process should work by facilitating synergies between multiple agencies in an urban area (Morphet, 2010).

The current study reveals a strong influence of past spatial planning policies on the current ones. It has been understood from the key informants that the past spatial planning decisions are more inclined towards economic development and less focused on service provision and balanced spatial growth. As a result, most of the spatial development in the mid-20th century is the resultant of demand-led development (Chanmal & Tg, 2016). Based on policy document analysis and key informant interviews, the study found that the existing spatial planning policies still encourage demand-led development as they face difficulties in controlling or regulating past developmental decisions. In total, the inefficient spatial planning policies led to the urban sprawl in peripheral areas and diverse land use mix patterns in the case of Bengaluru. However, urban sprawl can be witnessed in other Indian cities such as Pune due to factors such as limited land availability in the center and increased fragmentation in the suburbs as the city grows towards the outside (Taubenböck et al., 2009).

Overall, two themes of spatial planning policies have been highlighted in this study that significantly impacts spatial development patterns. Firstly, deviations in land-use regulations under Development Control Regulations (DCR) have resulted in complex land use mix patterns. Secondly, the absence of development guidelines under infrastructure development has resulted in increased built-up densities. Additionally, as explained earlier, urban sprawl in peripheral areas and poor development guidelines have resulted in land use conversions and diverse land use mix patterns in inner and outer city areas (Siedentop & Fina, 2010). Proposal and implementation of huge infrastructure projects without proper impact studies and non-integration of the implemented projects into the spatial planning policies have resulted in rapid spatial growth in Bengaluru. This understanding confirms the issue of Bengaluru's urban sprawl due to inefficient planning, policies, and poor governance (Sudhira & Ramachandra, 2009).

6.3. Status of public water service provision over the years

Bengaluru city faces a growing demand and supply gap of water due to limited surface water availability (Raj, 2015). The current study explores the other aspects of water service provision, including the demand and supply gap in different parts of the city. From the field data analysis, it has been understood that overall water service provision with respect to accessibility and availability of public water service has gotten better in all the areas compared to the past. However, this study shows that aspects such as water adequacy and affordability are showing differences across various study areas.

Access to public water service in terms of decreased distance to public water source and location of public water source has improved in inner and outer city areas. Additionally, water availability with respect to domestic/household water connections has also improved in inner and outer city areas. However, this study reveals that the dependency on private water sources has increased in outer city areas compared to inner-city areas. This shows that water service provision in terms of availability and accessibility indicators shows a positive picture in Bengaluru (Raj, 2015). From the field data observations, water adequacy is showing a negative picture with a reduced quantity of public water supply in both inner and outer city areas. It has been found that, despite reduced water quantity, the frequency of the public water supply had been unchanged in inner-city areas, which is in contrast to outer city areas where the frequency of public water supply has reduced drastically. Also, it is worth noticing that, despite reduced water quantity, the inner city respondents stated that the water quantity is quite sufficient for their daily use, which is not the situation in outer city study areas. This confirms that water service provision is experiencing differences in different parts of the city (Raj, 2015). From the spatial data analysis, it can be interpreted that outer city areas experience inadequacy in public water supply in comparison to inner-city areas. Concerning

affordability, water tariff in all the study areas has been increased compared to past charges. However, inner-city residents feel satisfied with the tariff as they feel proportion to water quantity is equivalent to water tariff. In contrast, the outer city residents feel comparatively less satisfied by considering their reduced water quantity and frequency of public water supply. This highlights the negative trend of satisfaction costs in outer city areas despite the positive picture on revenue collection as portrayed by Raj (2015).

6.4. Impact of Spatial planning policies and development patterns on public water service provision

Firstly, as described in the earlier section, the overall status of public water service provision in Bengaluru is showing a positive trend by showing an improvement when compared to the past. According to Raj (2015), the Bengaluru water supply, regarding water accessibility, availability of physical infrastructure, and revenue collection, shows a 'positive picture.' However, the current study found that indicators such as water adequacy and affordability show a 'negative picture' by a reduction in per capita water quantity reduction in both inner and outer city areas as the current water quantity available in Bengaluru stands at 74 LPCD, which is far less than the CPHEEO standard of 150 LPCD. The demand-supply gap in Bengaluru will increase from 116 million liters per day to 514 million liters per day by the year 2025 (Raj, 2015). The current study argues that Bengaluru is undergoing rapid spatial development with increasing built-up densities from the spatial data analysis. This parallel phenomenon of increased spatial growth and increased demand and supply gap in Bengaluru city during the same period establishes a clear connection between the two sectors.

Secondly, this research studies the changes in landcover patterns and land-use composition in different parts of Bengaluru and its association with spatial planning policies. Based on the observations, it has been found that water service aspects such as accessibility and availability of water service have improved with the increased built-up densities and land-use diversity. In contrast, water adequacy and affordability indicators show a 'negative picture' with the increased land-use diversity and high built-up growth areas, which are predominantly outer city areas. From the field data analysis, one of the key findings of this study is that differences in landcover and landuse compositions have contributed to differences in water demand based on the levels of spatial growth.

Lastly, this study establishes a clear link between spatial development patterns and policies with public water service provision in the context of Bengaluru and confirms that the spatial planning factors have a considerable impact on the public water service provision (Olmstead, 2004). It also argues that spatial planning policies have a strong influence on shaping the spatial development patterns in an urban area such as Bengaluru (Sudhira & Ramachandra, 2009). According to key informants, it has been observed that the current spatial planning policies of Bengaluru have resulted in increased spatial growth and complex land-use patterns, especially in the peripheral parts of the city. Furthermore, by demonstrating the Impact of spatial planning policies on water service provision in Bengaluru, this study confirms the fact that spatial planning practices that focus solely on settlement characteristics are more likely to negatively impact water service provision by creating water stress in urban communities (Olmstead, 2004). Additionally, the study found that the increased spatial growth with increased densities and complex land use mix patterns has likely contributed to or influenced certain aspects of water service providers such as accessibility and availability 'positively' while the other aspects such as adequacy, i.e., quantity and affordability 'negatively'. This understanding of the relationships and impacts of spatial development and spatial planning policy on water service provision in inner and outer city areas could help devise strategies

that are specific to Bengaluru and could reduce the resistance between the two sectors and contribute to innovative policies that encourage infrastructure integrated development, especially with respect to water infrastructure as Bengaluru is experiencing severe water related issues.

6.5. Uncertainties that might affect the research results

This section discusses the aspects that this research has not considered that could probably affect the research findings.

The first uncertainty arises with the reduced scope to spatial development while other urban dimensions could also impact water service provision. As the primary interest of this research lies in understanding the dynamics of water service provision due to changes in spatial development and planning, other dimensions such as political and socio-economic have been neglected that could also have a considerable impact on public water service provision in the case study. The second uncertainty could be the neglect of public participation that could have played a significant role in public water service provision. Thirdly, the current research only considers the spatial planning policies while other urban policies could have an impact on spatial development patterns and public water service provision. Lastly, the study areas selected mostly lie in the southern parts of Bengaluru, although they cover both inner and outer city areas. Therefore, the areas in the northern parts of Bengaluru, which are less dense in terms of population, built-up, and quite far from the water source, i.e., the Cauvery river water extraction point, could experience the water service provision differently.

7. CONCLUSION AND RECOMMENDATIONS

The main objective of this research was to explore the impacts of spatial development on public water service provision in the Indian context. This study drew on empirical data of four administrative districts in two different spatial settings, the inner and outer city areas of Bengaluru. Based on the spatial, quantitative, and qualitative analysis, it can be concluded that spatial development patterns and policies show both positive and negative impacts on the variables of public water service provision in different parts of Bengaluru.

In response to the first objective, which was to understand the prevalent patterns of spatial development in Bengaluru, this study found that landcover changes in the inner city areas show slow and steady growth. In contrast, the outer city areas exhibit increased spatial growth with a rapid increase in built-up area over the years. Concerning the landuse mix, inner-city areas started to experience deviations in their landuse composition. Outer city areas on the other hand, with less than 50% of total built-up shows high diversity in their landuse mix. In other words, landuse mix diversity is increasing as we move from the inner city to outer city areas. This phenomenon highlights the role of spatial planning policies in the sustainable spatial development of Bengaluru. The analysis of existing spatial planning policies and regulations reveals that poor spatial planning implementation mechanisms and the lack of intersectoral approach in the spatial development process have resulted in demand-led development and complicated landuse patterns irrespective of vision plans. It has been found that the extension of city boundaries with poor development guidelines has resulted in haphazard spatial development patterns such as rapid urban growth, urban sprawl, and diverse landuse patterns, especially in the outer city areas. Overall, the spatial planning policies of Bengaluru do not show a positive influence on spatial development patterns due to its narrow focus on regulating instead of promoting sustainable growth.

The second objective was to reveal the changes in public water service provision in different parts of the city with the help of user experience. This study found changes in water service provision status using nine indicators classified under four relevant variables, namely, accessibility, availability, adequacy, and affordability. The study revealed that overall water service provision has improved in both inner and outer city areas over the years. However, few aspects, such as accessibility and availability, show a positive picture in all the parts of the city. In contrast, aspects such as adequacy and affordability show a neutral picture in inner-city areas and a negative picture in outer city areas. The results indicate that, although inner and outer city areas show positive progress in overall water service provision, outer city areas are experiencing high demand and supply gap and inner city areas started to experience adequacy issues in the recent period.

The third objective was concerned with exploring the impacts of spatial development patterns and policies on public water service provision. The study found that the haphazard spatial development patterns encouraged by spatial planning policies as described earlier show a positive influence on public water service provision with an improvement in water accessibility and availability in the same period where the city is experiencing increased built-up densities and landuse mix diversity. With respect to water affordability, satisfaction with costs has improved in many parts of the city as the increased spatial growth resulted in higher user groups. Furthermore, the study results show a perceived decline in water quantity in

both inner and outer city areas as the spatial growth and landuse mix diversity tend to incline. In total, the results suggest that spatial development patterns and policies positively affect water accessibility and availability both in the inner and peripheral areas of the city. At the same time, they impact water affordability neutrally and water adequacy in a negative way.

In summary, this research confirms that, out of many possible dimensions that could impact urban water service provision, spatial development holds a strong position in affecting and urban water service provision, and inefficient spatial planning decisions could affect urban water service provision negatively by creating severe water stress in urban communities. As the current start of the art in the Indian context focuses on spatial development issues or infrastructure issues such as water service provision separately, this study adds a new perspective by presenting evidence on the possible interactions that could facilitate strategic/integrated planning practices in urban areas. This study also confirms the importance of strategic planning in promoting infrastructure integrated spatial development by presenting the influence of spatial planning policies on spatial development and water service provision. This study adds to the current knowledge by providing insights on interactions between spatial development and water service dimensions that spatial development shows not only negative impacts but also positive impacts on urban water service provision. Therefore, this study sees spatial development as an opportunity to promote sustainable spatial planning practices with informed development policies in place. Lastly, this study encourages future researches to study the cities in systems approach rather than individual elements.

Research question: Answered

What are the impacts of spatial planning policies on prevalent spatial development patterns? How are spatial development patterns and policies affecting public water service provision in Bengaluru?

The current spatial planning policies do not show a positive influence on prevalent spatial development patterns. Poor spatial planning strategies, lack of implementation mechanisms, and its narrow focus on regulating over sustainable development have resulted in complex landuse compositions and rapid landcover changes, especially in the peripheral areas. The combined effect of the inefficient spatial planning strategies and the prevailing spatial development patterns on water service provision shows a dynamic effect on water service provision by affecting differently in different parts of the city.

7.1. Limitations

This study sought to understand and explore the relationship between spatial development and public water service sectors in an urban setting. It is essential to consider that the empirical findings are case-specific and cannot be generalized to all urban areas as such areas have different spatial patterns and may affect differently on public water service provision. Therefore, the findings of this study should only be aligned with other similar contexts to obtain logical conclusions. One of the major limitations of this research is the cancellation of study area visits due to the covid pandemic, as a significant part of the research involves field data analysis. Other limitations include limited key informants and a lack of focus group discussions to understand the character of the communities due to raising covid cases in the study area. As a result, the study had to completely rely on survey data to understand the status of water service provision. Cancellation of study area visits limited the scope for meeting the development agencies and decision-makers. Due to limited time, the scope of the research is limited to one way impact of spatial development on public water service provision and not the other way, i.e., impact of public water service provision on spatial development.

7.2. Recommendations

The current study's findings sought to lay a foundation for understanding the tensions between spatial and water sector dimensions in India's highly urbanized city, Bengaluru. Further studies in this regard would provide rational conclusions for formulating integrated development policies of the city. It is clearly evident in this study that the existing planning policies influence spatial development patterns and water service provision. However, it has been observed that the past spatial planning policies and decisions are still showing a significant effect on the current spatial development. Therefore, this study recommends the rectification of the policies that are adversely affecting spatial growth and development. This study also suggests conducting an impact study on previous and existing policies to avoid further conflicts between spatial planning and other urban sectors such as water service and promote sustainable and infrastructure-integrated development. Regarding policy recommendations, decisions related to the extension of administrative boundaries, which has resulted adversely in this case, need to be made informatively. This study recommends improving the area development strategies to follow sustainable development practices such as ensuring the provision of basic services and amenities for longer periods along with the area development. Lastly, policy innovations to promote infrastructure integrated development are highly essential and recommended in Bengaluru.

Concerning recommendations for future research, as this study limits its scope to one way understanding of spatial planning impacts on public water service provision, learning the other way relationship, which is the impact of water service provision on spatial development, is highly recommended. The selection of variables of spatial planning and water service provision in this study comes from well-established literature and field data availability. However, experimentation with more relevant indicators is recommended that could increase the depth of understanding between spatial development and water service provision.

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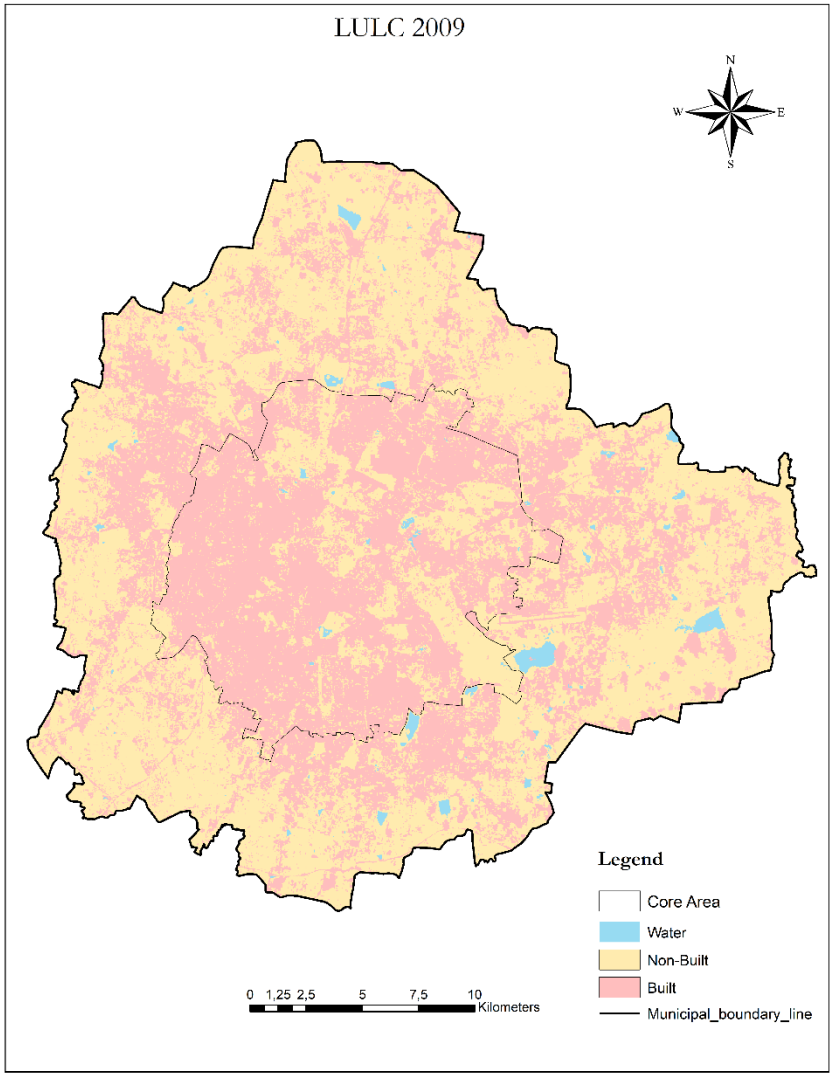
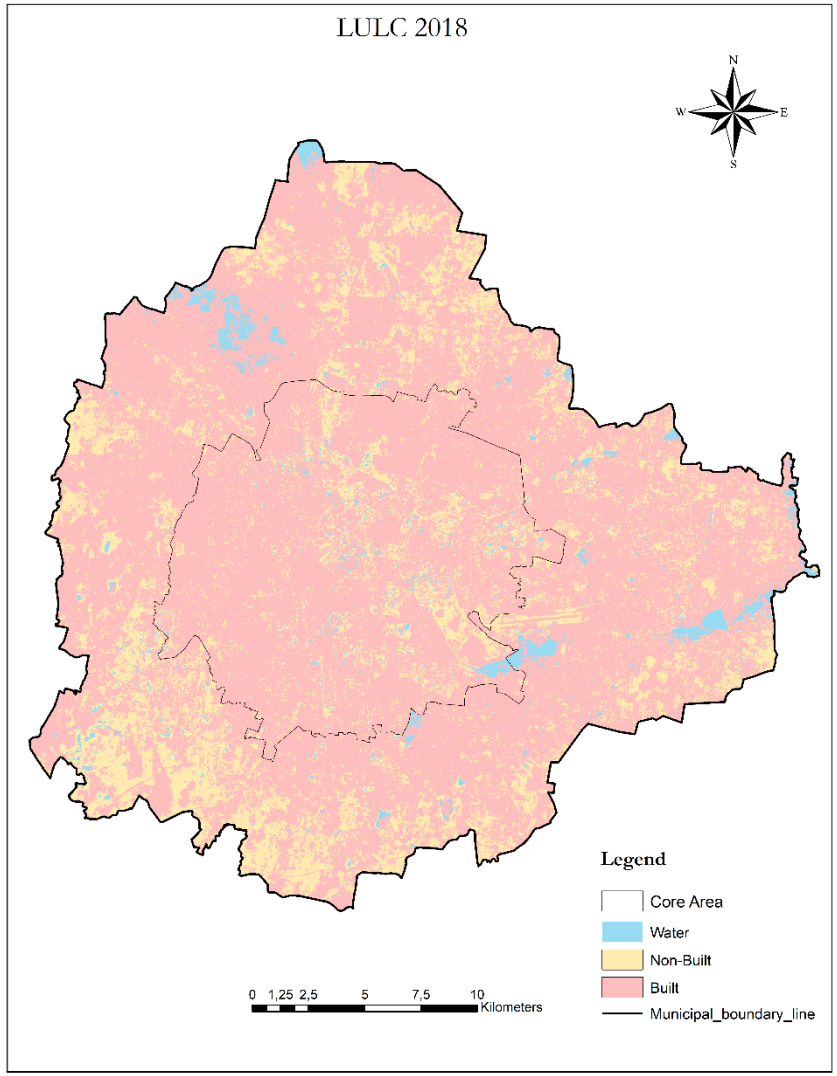
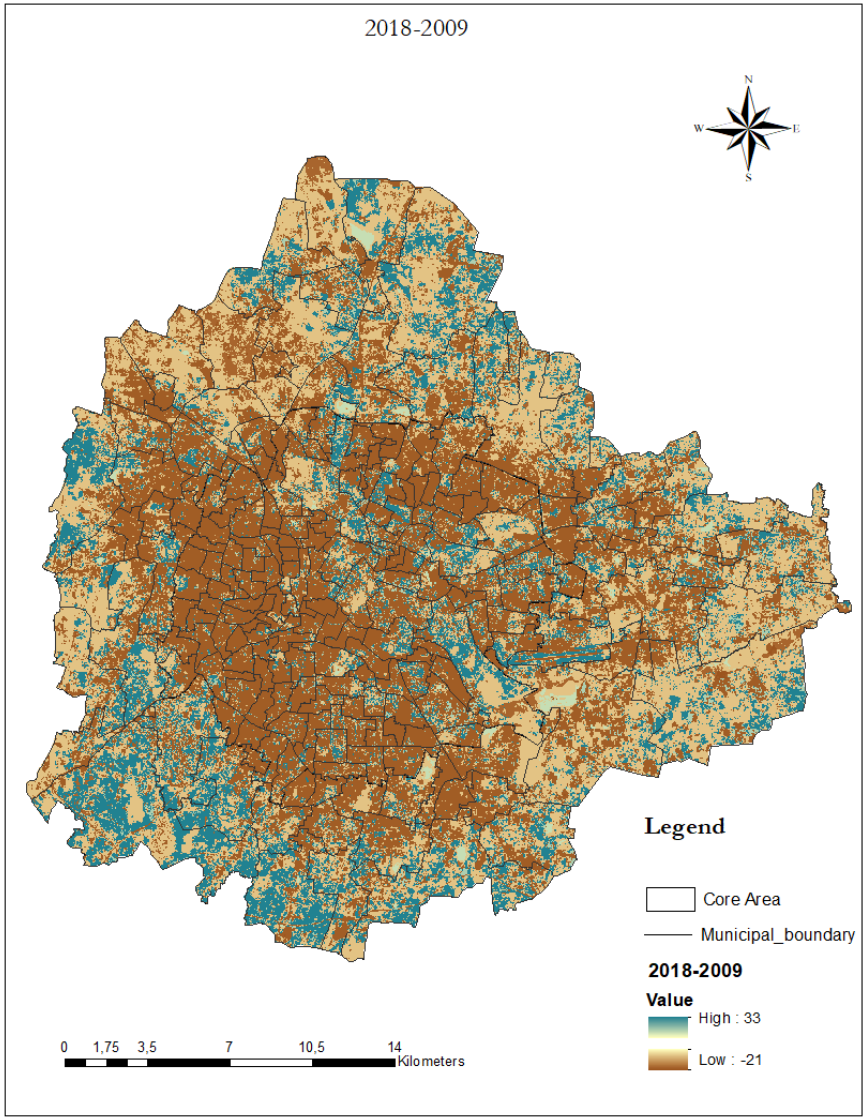
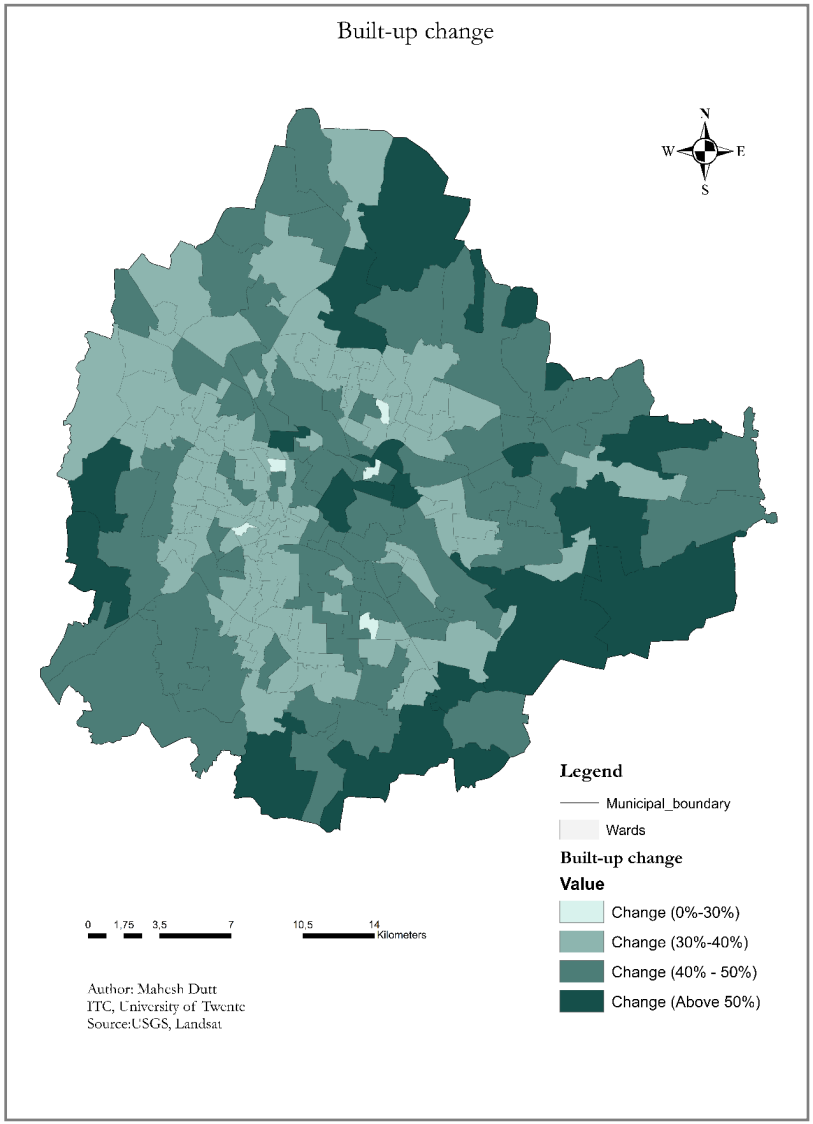
APPENDICES

Appendix 1: Preparation of landuse landcover maps and built-up change map for the study area selection






2018-2009
N
W
E
S
Legend
Core Area
Municipal_boundary
2018-2009
Value
High : 33
Low : -21
0 1,75 3,5 7 10,5 14
Kilometers


Built-up change
N
W
E
S
Legend
Municipal_boundary
Wards
Built-up change
Value
Change (0%-30%)
Change (30%-40%)
Change (40% - 50%)
Change (Above 50%)
0 1,75 3,5 7 10,5 14
Kilometers
Author: Mahesh Datt
ITC, University of Twente
Source:USGS, Landsat

Appendix 2: Spatial metrics

Class metrics - Total Area			
Jayanagar			
Area (ha)	2009	2013	2018
Non-built	17.2	17.4	8
Built	85.8	86.2	96
Water		0.2	

Class metrics - Total Area			
Hampinagar			
Area (ha)	2009	2013	2018
Non-built	14.6	10.4	5.3
Built	95.5	95.2	105.6
Water		5.3	

Class metrics - Total Area			
Ullalu			
Area (ha)	2009	2013	2018
Non-built	752.7	647.4	434
Built	142.2	245.2	460.9
Water	1.8	2.4	

Class metrics - Total Area			
Anjanapura			
Area (ha)	2009	2013	2018
Non-built	1016	889.9	812,8
Built	174.9	312.14	393.4
Water	16.3	5.7	1.6

Appendix 3: Questionnaires

1. Questionnaire on existing water service provision

General Questions	**Level of Assessment**			
Ward Number				
Years of stay in the same ward				
What is your Household size				
Type of Household	Individual House	Mixed residential	Multistorey	
What is the primary source of water supply	Public	Private	Both	
Accessibility	**1**	**2**	**3**	**4**
What is the type of your water connection	Individual	Shared		
What is the location of your water source	Within the Household compound		Outside the Household compound	
How far is the primary water source that you use	<200 m	< 200 m – 600 m	600 m - 1000 m	>1000m
What is the duration of your water collection time?	<30 min	30-60 min	1 -2 hours	>2 hours
Availability				
What is the category of your public water connection	Domestic	Partial Domestic	Non-Domestic	
What is the quantity of water supplied for your Household approximately (in liters)	Enter the value:			
Adequacy				
What do you think about the water quantity per person per day	Very less	less	Sufficient	Adequate
What is the duration of water supply in the ward?	<60 min	1-2 hours	2-3 hours	> 3 hours
What will be the frequency of public water supply	Daily	Alternate days	Twice in a week	Once in a week
Affordability				
The income category the HH belongs to	Poor	Lower Middle income	Middle income	Above middle income & rich
What percentage of your family income do you spend on your overall water supply?	<3	3-5	5-10	Others: -------
What percentage of your family monthly income do you spend in public water supply?	<3	3-5	5-10	Others: -------

2. Residents Perception survey

Attribute of Assessment	**Level of Assessment**					
	1	2	3	4	5	6
The land cover change (no.of buildings) has increased significantly over the past 8 years	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
The landuse mix (residential, commercial, industrial, recreational, etc.) has increased significantly over the past 8 years	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
The landuse intensity (height of the buildings) has increased significantly over the past 8 years	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
Explain your choice for the following questions with respect to changes in land use patterns (land cover change, change in landuse mix, change is landuse intensity)in your ward/area (2008 - 2018)						
Attribute of Assessment	**Level of Assessment**					
Accessibility	**1**	**2**	**3**	**4**	**5**	**6**
Distance to primary source of public water service has increased compared to past eight years?	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't know
Time consumption for fetching water has increased in the last eight years	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
Availability						
Public water connections (Domestic, partial-domestic, non-domestic) in the locality have increased from the past eight years?	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't know
The quantity of public water supply has decreased compared to 8 years ago	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
I use alternate sources of water supply in case of insufficient water quantity	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
Adequacy						
Water quantity is quite sufficient for the Household compared to past 8 years?	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
The duration of the water supply has increased compared to the past 8 years ?	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
The frequency of water supply has decreased compared to past?	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
Affordability						
Water tariff has been increased over the eight years.	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know
I am satisfied with the piped water tariff in proportion to the quantity of water supply?	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know

3. Questionnaire for municipal and water sector authorities

Questions for Municipal authority/water department	**2008**	**2018**
Accessibility		
How many households in the ward have metered public water connections?		
Water connections for Domestic, Partial domestic, Non-domestic		
How many households have individual vs shared water connections		
Availability (Jayanagar east)		
What is the quantity of water supplied for the study Area?		
What is the current amount of water supply for the study ward or per person in the study area		
Availability (Jayanagar east)		
What is the quantity of water supplied for the study Area?		
What is the current amount of water supply for the study ward or per person in the study area		
Affordability		
Does the water tariff varies with income group and quantity of usage (collect all the details)		
Water tariffs for all categories(Domestic, partial domestic, non-domestic) (if any incentives)		
Floor Area Ratio for both study areas		
Area 1 : Jayanagar East		
Area 2 : Hampi nagar		
Area 3 : Ullalu		
Area 4 : Anjanapura		
Landuse Change information	Using Maps	

Appendix 4: Key informants interview guide

Questions for key informants
Spatial Planning department (informants: Town planner/assistant town planner)
What are the main causes for changes in land-use patterns such as land cover change, land use mix, and land-use intensity with respect to Bangalore city? Do you think that the changes in land use patterns are in line with the spatial plans or master plan? And how effective are the spatial planning policies in influencing land-use patterns? Can you comment on the types of spatial development (Landuse types) and its significance with respect to water service provision? Can you comment on the dynamics/effects (Positive and negative) of spatial development on public water service provision? What do you think about the integration between spatial development and water service planning (city scale & Ward level) What do you think about the institutional coordination between the two organizations? (Spatial development authority(BDA) and water supply board (BWSSB)) What are the opportunities do you see to strengthen the coordination between spatial development authority (BDA) and the water service board (BWSSB) Do you think, spatial development has the capacity to improve public water service provision? How? How well spatial development plans considers public water service provision in plan preparation and implementation? Is there any missing link which I haven't asked yet and could be considered for better understanding the relationship ? is there anything would you like to add ?
Water supply board (BWSSB Authority)
Can you briefly explain the functioning of BWSSB in Bangalore city? What are the current water-related issues that BWSSB is trying to solve with respect to overall water service provision both at the city level as well as municipal level? How is the current status of water service provision in terms of 1. accessibility, 2. availability, 3. adequacy, and 4. affordability? What do you think is the influence of land use mix on public water service provision w.r.t accessibility, availability, adequacy, and affordability. What are the most influencing factors of public water service provision in the city of Bangalore? What do you think about the relationship between spatial development and water service provision? What is your professional opinion on the synergy between water infrastructure development and spatial development? Can you explain in detail? How to improve the public water service provision in all the areas of Bengaluru regarding accessibility, availability, adequacy, and affordability? What can be done to strengthen the coordination between spatial development authority (BDA) and water supply board (BWSSB)?

Appendix 5: Accuracy reports for the supervised classification of LULC Analysis

	Waterbody	Built-up	Non-Built	Total (User)
Water body	8	0	2	10
Built-up	0	9	1	10
Non-Built	1	2	7	10
Total(Producer)	9	11	10	30

Accuracy report for classified Image 2018

Year – 2018: **Overall Accuracy** = (Total number of correctly classified pixels /Total number of reference pixels)*100 = (24/30)*100 = **80** %

User Accuracy
Water body = (8/10)*100 = 80%
Built-up = (9/10)*100 = 90%
Non-Built = (7/10)*100 = 70%
Producer's Accuracy
Water body = (8/9)*100 = 88%
Built-up = (9/11)*100 =81%
Non-Built = (7/10)*100 = 70%
Kappa coefficient (T) = [(TS*TCS) – SUM(column total *row total)/(TS*TS) – SUM(column total*row total)]*100
= [(30*24) – {(9*10)+(11*10)+(10*10)}/(30*30) – {(9*10)+(11*10)+(10*10)}]*100
= [(720 – 300)/(900 – 300)]*100
= **70**%
TS = Total samples
TCS = Total corrected samples

	Water body	Built-up	Non-Built	Total (User)
Water body	6	0	4	10
Built-up	0	10	0	10
Non-Built	0	1	9	10
Total(Producer)	6	11	13	30

Accuracy report for classified Image 2009

Year – 2009: **Overall Accuracy** = (Total number of correctly classified pixels /Total number of reference pixels)*100 = (25/30)*100 = **83** %
User Accuracy
Water body = (6/10)*100 = 60%
Built-up = (10/10)*100 = 100%
Non-Built = (9/10)*100 = 90%
Producer's Accuracy
Water body = (6/6)*100 = 100%
Built-up = (10/11)*100 =90%

Non-Built = (9/13)*100 = 69%

Kappa coefficient (T) = [(TS*TCS) – SUM(column total *row total)/(TS*TS) – SUM(column total*row total)]*100

= [(30*25) – {(6*10)+(11*10)+(13*10)}/(30*30) – {(6*10)+(11*10)+(13*10)}]*100

= [(750 – 300)/(900 – 300)]*100

= **75**%

TS = Total samples

TCS = Total corrected samples

Appendix 6: Overview of the study of public water service provision.

Status of Public water service provision	Jayanagar		Hampi Nagar		Ullalu		Anjanapura	
	Mean		Mean		Mean		Mean	
Accessibility								
Increased distance to public water source	2.7	Disagree	2.5	Strongly disagree	2.6	Disagree	2.8	Disagree
Availability								
Increase in public water connections	5.4	Strongly agree	5.4	Strongly agree	5.0	Strongly agree	5.1	Strongly agree
Increased time consumption for fetching public water	2.6	Disagree	2.7	Disagree	2.8	Disagree	2.7	Disagree
Increased use of alternative sources of water	3.1	Neutral	3.8	Neutral	4.8	Agree	5.0	Strongly Agree
Adequacy								
Quantity of public water supply has decreased	3.3	Disagree	4.0	Neutral	5.0	Strongly Agree	5.3	Strongly Agree
Water quantity is quite sufficient for the Household	5.2	Strongly agree	5.3	Strongly agree	3.8	Neutral	3.9	Neutral
Duration of water supply has increased	5.1	Strongly agree	5.0	Strongly agree	5.1	Strongly agree	5.3	Strongly agree
Frequency of water supply has decreased	3.5	Neutral	4.2	Agree	4.8	Agree	5.0	Strongly Agree
Affordability								
Water tariff has been increased	4.9	agree	5.1	agree	4.8	agree	5.1	Strongly agree
Satisfied with the water tariff in proportion to supplied quantity	5.1	Strongly agree	5.4	Strongly agree	4.9	Agree	4.6	Agree

Appendix 7: Association between spatial development patterns and public water service provision, tables by area

Inner city study areas

1a: Jayanagar East

Spatial development patterns		Public water service provision	
Landcover changes	• Significant built-up change from the year 2013 • Almost 92 percent of the study area is developed	Accessibility	• Access to public water source in terms of distance and location compared to past has improved significantly
		Availability	• Household public water connections which ensures equal opportunity to public water has increased • However, usage of alternate sources such as private water can also be witnessed in the study area.
Landuse mix	• Predominantly residential area • The landuse mix completely follows the building control regulations • The other landuse categories are public and semi-public which is second largest shareholder of built up area, commercial and recreational which do not demand higher water share	Adequacy	• There is a clear decrease in public water quantity • Although there is sufficient quantity as of now, the residents experience reduced frequency in public water supply in the recent years.
		Affordability	• Although there is increase in public water tariff, residents are satisfied with the tariff in proportion to supplied water quantity. • Majority of the residents feel the water tariff is affordable and satisfied with the water tariff in proportion to water quantity supplied.

1b: Hampinagar

Spatial development patterns		Public water service provision	
Landcover changes	• Built-up change is clearly evident from the year 2009 to 2018. However, this study area has experienced significant change between the period 2013 to 2018. • 95 % of the total area is under built up area which leaves less scope for future development	Accessibility	• Overall, access to public water has increased w.r.t to distance and location of public water source has improved compared to past
		Availability	• Water availability in this study area has increased in terms of public water connections. However, private water connections also increased due to increased demand over the past years.
Landuse mix	• The study area is predominantly residential with 42% of total area under residential • The other land uses comprises of public and semi-public, commercial, recreation and industrial.	Adequacy	• There is clearly, decrease in public water quantity which is affecting frequency of the public water supply. • Majority of the households feel satisfied with the current water supply quantity, However, significant number of households also feel insufficiency in public water quantity and depends on alternate water sources to substitute reduced quantity in the recent years.
		Affordability	• Most of the households in this study area feels the public water supply is affordable and satisfied with the water tariff in proportionate to supplied water quantity.

Outer city study Areas

2a. Ullalu

Spatial development patterns		Public water service provision	
Landcover changes	• Built up area has changed very rapidly from the year 2009 to 2018 from 15% of built area in the year 2009 to 52 % of built up area in 2018. • It is interesting to notice the rapid change in the period 2013 to 2018. • Currently, built up and non-built areas share almost equal percentage of total area and according to the trend built-up area is expected to grow very rapidly in the near future according to the proposed masterplan.	Accessibility	• Water accessibility in this study area increased in terms of distance and location of public water source despite its location in peripheral/outer city area.
		Availability	• There is clearly, increase in public water connections in this area compared to past. Whereas, majority of households in this area also rely upon alternative sources of water other than public water supply.
Landuse mix	• The major landuse categories exists in this study area are residential, public and semi-public, recreation, commercial, waterbodies and agricultural. • As the study area is predominantly residential, being an outer city area, the other land uses such as agriculture, commercial, recreation, public and semi-public share a significant percentage of total area making the area as a mixed development area. (This may cause disruptions to landuse mix in the coming years)	Adequacy	• Households in this study area experience reduced frequency of public water supply and insufficiency with respect to public water quantity.
		Affordability	• Due to increased water tariff and reduced water quantity, significant number of households in the study area feel not completely satisfied with water tariff in proportion to supplied water quantity

Study area 2b. Anjanapura

Spatial development patterns		Public water service provision	
Landcover changes	• Landcover change in this study area shows positive trend from the year 2009 to 2018. • The built-up growth has increased double in past 10 years. However, being an extreme city area, this ward has got 67% of total area under non-built landcover which makes this area highly potential for future development.	Accessibility	• Access to public water in this outer city study area has improved with respect to distance and location of water source when compared to past.
		Availability	• Water availability in this study area has improved in terms of public water connections. Whereas, the majority of the households rely on alternative water sources.
Landuse mix	• This landuse mix is high in this study area with eight different landuse categories. Having an abundant non-built area and being an outer city area, land uses such as agriculture, industrial, public utility, recreation share significant amount of land along with residential landuse. • As 3/4th of the study area is under vacant land, the development of the ward completely depends on spatial development strategy and planning	Adequacy	• Majority of households in this study area experience reduction in quantity and frequency of public water supply. • Regarding the sufficiency, half of the households experience insufficient water quantity whereas the other half expressed their satisfaction towards water sufficiency.
		Affordability	• Majority of the households feels satisfied with the water tariff in proportion to water quantity. Whereas, a significant percentage of households also feel not satisfactory with respect to tariff in proportionate to water quantity.

Appendix 8: Coding of key informant interviews

S.no	Code	Quotation	Source (Table 3)
1	(Landuse Landcover) LULC changes	'Due to increased economic activity and sudden influx of population in a considerably short span increased the need for housing and basic infrastructure development in a small amount of time. This unexpected demand for housing and infrastructure has resulted in island developments which have caused the landuse landcover changes in many parts of the city.'	Key informant 1
		'Small scale commercial sector developments is the result of demand-led development in Bengaluru city. In turn, this increased commercial activity has resulted in landuse diversification in and around it'	Key informant 1
		'Small scale commercial activities in the inner city areas has become a huge issue transforming the area into mixed residential. In the case of Hampinagar, this area has a planned minor portion of industrial, public and semi-public, commercial land uses. It is also facing the same issue as Jayanagar east with a transformation of purely residential to mixed residential development'	Key informant 2
		'In the master plan, the outer city areas, Ullalu and Anjanapura have been envisioned as predominantly residential with ancillary land uses not more than 20% of the total area. However, due to the vast amount of vacant land, currently, these areas have not been completely planned yet. This could result in either haphazard development or demand-led development'	Key informant 1
2	Spatial planning policy after effects	'Spatial development decisions in the past are inclined towards economic development. Therefore, the city of Bengaluru has envisioned as a global city and economic hub of state and nation. As a result of economic development and increased populations, spatial decisions such as IT sector development, Industrial and Mega road infrastructure projects and township developments have contributed to increased urban sprawl, deviated landuse patterns that they have become a challenge to the current spatial planning practices and decisions.'	Key informant 2

		'Lack of development regulations in the newly developed areas and poor practices such as absence of growth monitoring and no impact studies on the current spatial planning decisions is contributing the haphazard spatial growth'	Key informant 1
3	Effectiveness of Spatial planning	'There are several developmental agencies responsible for different types of developmental activities in Bengaluru. Although, the BDA is responsible for overall spatial development, it can only provide the vision and directions to spatial development. In case of Bengaluru, large scale industrial developments and infrastructure developments are always undertaken by different development agencies backed by political systems. As a results, some policies and decisions needs to be compromised and dealt in later stages '	Key informant 1
		'Current spatial plans face difficulties in implementation procedures'	Key informant 1
4	Overall water infrastructure	'In practice, the development authority is responsible for ensuring all the basic amenities before permitting development on a parcel of land. The current practices follows the same process. However, as it check the availability, it missies to ensure and maintenance of these provided amenities for longer periods. With respect to water service provision, the area development is done by showing short term water resources such as underground. However, with the time, the depleted water service is becoming a challenging issue for many neighborhoods making them vulnerable to water supply. With the increase in such areas or neighborhoods, the water planning authority is experiencing the sudden need of water service infrastructure in different parts of the city at the same time. With limited resources, public water supply board is trying to address these challenges in the best way possible'	Key informant 1 Key informant 2
		'The layouts with respect to water planning and spatial planning works at different levels. As a result, water service board is unaware of the proposed development or the expected demand in the service areas. This has resulted in irregular water supply provisions and inequal distribution patterns of overall water supply'	Key informant 3
5	Water Quantity	'Quantity of public water supply has been reducing over the years. From the lens of spatial development, the increased diversity of landuse mix has resulted in unequal share and lead to competition between different landuse sectors. Therefore, BDA always aims to main the less landuse mix to avoid the complexities caused by this landuse mix diversity'	Key informant 2

6	Water accessibility and availability	'Definitely, with the continuous water infrastructure development in different phases which aims to provide water to all the parts of the city had contributed to development of physical infrastructure resulting in increased public water connections overall'	Key informant 3
7	Affordability and economics of public water supply	As water supply board works on self-financing model. It has to recover its costs from one way or other. As a result, to provide subsidized water to residential sector, it actively provides water for other land uses such as commercial, industrial and other water based industries to recover its infrastructure investment costs and management costs.	Key informant 2
8	Association between spatial and water planning	'The increased spatial development is exerting a lot of pressure on public water service board which is responsible for development of water infrastructure and provision of water supply'	Key informant 2, 3
		'Lack of communication between spatial development and water sector agency has resulted in challenges for both the sectors. Firstly, lack of water supply in the newly developed areas and degradation in already developed areas. Secondly, increased scope with limited resources in a surprisingly small time for water infrastructure development'	Key informant 1