

**Accessibility of Urban Green Infrastructure in Koye Feche Sub City, Sheger City,
Ethiopia**



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A thesis submitted to the Department of Architecture
College of Civil Engineering and Architecture

Office of Graduate Studies

Adama Science and Technology University

June, 2025

Adama, Ethiopia

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DECLARATION

I declare here by this research thesis entitled “Accessibility of urban green infrastructure in Koye Feche Sub City, Sheger city, Ethiopia” is my own work and has not been submitted to any university for similar purpose. The reference used in this proposal are dully recognized by proper citations.

Name of student

Signature

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RECOMMENDATION OF ADVISORS

I, the major advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Accessibility of urban green infrastructure in Koye Feche Sub City, Sheger City, Ethiopia” prepared under my guidance by Hayu Ararsa. Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures.

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I/we, here by certify that the recommendation and suggestion given by the proposal review committee are appropriately incorporated into final thesis/dissertation proposal entitled “Accessibility of urban green infrastructure in Koye Feche Sub City, Sheger City, Ethiopia” by Hayu Ararsa.

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We, the undersigned, members of the Board of Examiners of the thesis by Hayu Ararsa have read and evaluated the thesis entitled “Accessibility of urban green infrastructure in Koye Feche Sub City, Sheger City, Ethiopia” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in Urban Planning.

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LIST OF ABBREVIATIONS

CSA	Central statistical authority
DEM	Digital Elevation Model
ERDAS	Environmental Resource Data Analysis System
FGD	Focused Group Discussion
GIS	Geographical information system
IBM	International Business Machines Corporation
LULC	Land use/land cover
MLC	Maximum Likelihood Classification
NDBI	Normalized Difference Built-up Index
NDVI	Normalized Difference vegetation Index
NIR	Near-Infrared
SPSS	Statistical Package for the Social Sciences
SWIR	Shortwave-Infrared Region
UGI	Urban green Infrastructure
UGS	Urban green space
USGS	United States Geological Survey

ABSTRACT

Urban green infrastructure (UGI) plays a vital role in enhancing the resilience of cities by addressing challenges such as the urban heat island effect, flooding, and air pollution. However, in Koye Feche Sub-City, rapid urbanization and increasing population density have significantly reduced the availability and accessibility of green spaces. This study aimed to evaluate the spatial accessibility and distribution of UGI using Geographic Information Systems (GIS), remote sensing techniques, and social surveys. Using Landsat 9 sentinel-2 satellite imagery, UGI was mapped through Normalized Difference Vegetation Index (NDVI) analysis, with vegetation classified into three levels: Level-1 (NDVI 0.2–0.4) indicating sparse vegetation, Level-2 (0.4–0.6) for moderate vegetation, and Level-3 (0.6–0.8+) representing dense and healthy vegetation. Results revealed that green infrastructure covers only about 10% of the area, predominantly in agricultural zones, with higher vegetation levels located on the periphery and limited dense vegetation within urban centers. Survey findings indicated that the lack of green space options, long distances, and personal physical limitations were major barriers to UGI access. Social and economic factors such as income, ethnicity, and gender further restricted usage, with over half of respondents reporting inequality in green space distribution. Additionally, while 35.4% of residents found information about UGI readily accessible, 45.1% indicated it was only somewhat accessible, pointing to communication gaps. Transportation challenges and mixed perceptions of public policy effectiveness also emerged as key issues. Although 28.3% respondents acknowledged positive government actions, 49.6% a significant number felt that policies had not improved green space availability. While these results emphasize the importance of greening and developing UGI in a sustainable and equitable manner. Findings indicate that environmentally friendly and fair urban green infrastructure (UGI) growth in Koye Feche Sub-city requires coordinated land use, improved policies, improved means of transport, and effective provision of information. The research can serve as a basis source for future studies.

Key words: Urban Green infrastructure, Green space, Accessibility, GIS, Koye Feche

CHAPTER 1: INTRODUCTION

1.1. Background of the Study

The expected growth of cities has led to a decline in green space almost to the residents (Apud et al., 2020). according to (Apud et al., 2020) research this has many negative consequences for health and humanity. As the Urban area comforting zone for living the greenery area provides many values for human health like physical, mental and good for public health.

Globally, many studies have shown that due to lack of greenery, many cities face challenges such as population growth, climate change, resource scarcity, environmental degradation, pollution and increased risks to human health (Apud et al., 2020). Another evidence indicated The rapid urbanization process has sharply decreased the urban green spaces and the high population density concentrated in cities has led to various urban diseases, such as climate change heat island effect, high risk of flood hazard, and air pollution (Hou & Li, 2024).

According to (Hou & Li, 2024) Understanding UGI and UGS in order to increase urban resilience in terms of greening has been brought up and the ecosystem services that it provides are considered important to be integrated in urban planning. Spatial distribution of UGI is a critical part for urban structure, and it is particularly true for the densely populated urban areas. A balanced and well-distributed UGI will benefit both residents and wildlife in and around cities (Hou & Li, 2024).

Urban green infrastructure (UGI), including parks, green roofs, urban forests, and community gardens, plays a great role in mitigating these negative effects. The application of green infrastructure in urban planning provides the opportunity to design cities and urban areas as living systems that are more connected and smarted with nature, creating healthier, resilient and sustainable urban environments (Aryal & Sitaula, 2022). Green Infrastructure and its application in spatial planning is recognized as a successful strategy to support resilience in many cities around the world (Apud et al., 2020).

In context of Ethiopia the capital Addis Ababa being the capital of the nation is facing numerous challenges in trying to meet the demands aroused by the ever-increase population and high rate of urbanization (Desta & Takele, 2008). Consequently, the need for an increase in quantity and quality of shelter, infrastructure, employment and various social services

become crucial to sustain the metropolitan life. Even with, the current planning laws and regulations of nearby city also do not specifically refer to green infrastructure (Desta & Takele, 2008).

According to various studies, while the promotion of nature-based solutions and conservation of natural resources is gaining popularity in major urban areas of the country, UGI is yet to be used as an integrated approach in urban design. The study conducted by (Azagew & Worku, 2020) show that the city residents have no sufficient recreational UGI this means the city also lacks accessibility of UGI for all residential.

However, the accessibility and distribution of UGI are often uneven, creating disparities in access and benefits across different communities. This research aims to contribute to a more equitable and sustainable urban environment by evaluating the accessibility of UGI using GIS and remote sensing additionally which integrated with socio economic data.

1.2. Statement of the Problem

Urban Green Infrastructure (UGI) is more than just an environmental asset; it is essential to the development of cities' social cohesion. Urban green infrastructure comprising Parks, green spaces, and recreational area make up UGI, which provides urban residents with a haven from the bustle of the city (Marrone, 2013) cited in (Jimenez et al., 2021).

There's a lack of comprehensive and spatially explicit assessments of UGI accessibility in urban areas, particularly considering factors beyond mere distance, such as Social equity which Access for diverse populations, including vulnerable groups. Transportation infrastructure like Accessibility via public transportation, walkability area, and cycling road. The another one is Environmental factors which include barriers like busy roads, Air pollution, and safety area concerns (Ali Khan & Shafqat, 2014).

The lack of equitable access to urban green infrastructure is a multifaceted problem with profound consequences for health, social inclusion, environmental justice, and economic opportunities (Rao et al., 2022) cited in (Badar & Kalbani, 2024). Addressing these issues through the lens of social equity is essential for creating truly inclusive and sustainable urban environments (Badar & Kalbani, 2024).

Highly the reason to investigate this UGI and UGS study is to meet the need for access to urban green infrastructure (UGI) for many reasons, including overall health, community and

empowerment. Promoting Social Inclusion Equity UGI often and does not distribute well, underserved communities where green makes limited opportunities this is not perceived as good for community. It reflects this in educational accessibility and stimulates equitable access to good for all racialized, non-gendered socioeconomic residents. Also, Informative Data for Planning and Policy which provides valuable data for urban planners and policymakers. This allows them to make informed decisions regarding green space development, infrastructure improvements, and policy changes aimed at fostering equity and sustainability.

In Addition, studying the accessibility of urban green infrastructure is essential for achieving a more just, healthy, and sustainable urban environment. It empowers us to understand existing inequalities, make informed decisions, and create a city that truly values and embraces its green spaces for the benefit of all residents.

There are many existing scholars focus narrowly on urban green infrastructure and often rely on incomplete or outdated data, which can result in misleading representations of UGI accessibility. These limitations overlook broader components of green infrastructure and fail to capture spatial and temporal variations timely acquired data. To ensure more precise and comprehensive valuations, it is essential to integrate geospatial techniques such as GIS and remote sensing, using vegetation indices like the Normalized Difference Vegetation Index (NDVI) to quantify greenery (Das et al., 2023). Additionally, incorporating historical satellite imagery and long-term land use data can help track changes in UGI distribution over time, providing valuable insights for planning and policy-making.

In Koye Feche Sub City, there are notable inequalities in low-income households' access to green infrastructure, despite the acknowledged health and environmental advantages of urban green infrastructure (Desta & Takele, 2008). This research was aimed to utilize GIS and remote sensing in order to analyse and the spatial distribution of UGI and its closeness to neighbourhoods, identify accessibility hurdles, and examine the physical, environmental, and social factors influencing UGI accessibility in the Koye Feche Sub City.

1.3 Objectives

1.3.1. General objective

The general objective of this study is to evaluate the spatial Distribution and accessibility of urban green infrastructure (UGI) in Koye Feche Sub City using GIS and remote sensing techniques.

1.3.2. Specific objectives

- ✓ Identify factors affecting UGI accessibility in study area, including Physical and Social factors using socio-economic data.
- ✓ Identifying areas with limited or unequal access based on proximity, population density, and socio-economic indicators.
- ✓ Classify the various kinds of green spaces and their spatial attributes inside Koye Féche Sub City by mapping the distribution of UGI using GIS and remote sensing images (NDVI).
- ✓ To compare planned UGI and actual UGI in the study area

1.4. Research Questions

- ✓ What physical and social factors influence the accessibility of urban green infrastructure (UGI) in Koye Feche Sub City, and how do socio-economic data reveal patterns of accessibility disparities?
- ✓ How accessible is urban green infrastructure (UGI) to residents in Koye Feche Sub City residents, and which neighbourhoods exhibit limited access to green spaces?
- ✓ What is the spatial distribution of urban green infrastructure (UGI) within Koye Feche Sub City, and how do different types of green spaces vary in their spatial characteristics?
- ✓ How do the planned UGI features (e.g., parks, green roofs, community gardens) differ from those currently available in the area?

1.5. Significance of the Study

The accessibility of urban green infrastructure in Koye Feche Sub City will be the focus of this study. In particular, to use GIS and remote sensing methods to assess the spatial accessibility of urban green infrastructure (UGI) in Koye Feche Sub City. The findings will inform proposed policies aimed at improving UGI accessibility and promoting environmental justice in the city.

The results contribute new knowledge about UGI accessibility assessment, by incorporating GIS and remote sensing for a more accurate and comprehensive approach. The findings

regarding practical implementation can be used to inform urban planning decisions for the public and professionals, to guide UGI development and management, and to promote equity in all aspects of access to green space.

Although ultimately the results of this study are expected to be useful, this study will be used to improve UGI accessibility policies and strategies and to address disparities in access to green space. These findings serve various purposes such as involving the community in the planning process mainly in the public sector and providing adequate information to the community to ensure equitable access to the benefits of green infrastructure. It will be used as input for further research to conduct this and other greening-related research in any city or country.

1.6. Scope of the study

The spatial scope of this study was limited to Sheger City, Koye Feche Sub City. Whereas, the contextual scope was to examine evaluate the spatial accessibility of urban green infrastructure (UGI) in Koye Feche Sub City. Particularly in order to identify accessibility hurdles, and examine the physical, environmental, and social factors influencing UGI accessibility, map the spatial distribution of UGI and its closeness to neighbourhoods, in the Koye Feche Sub City using geospatial technology. The study will emphasize on the application of Remote Sensing and GIS technologies on generating a valuable information regarding NDVI, Land-use and Land-cover assessment and distribution of urban green infrastructure, in analyzing the accessibility of major green spaces with in the study area.

This perspective allows for a deeper understanding of ongoing challenges and growing opportunities for improvement, and ultimately, this comprehensive approach aims to identify valuable insights into effective strategies for transforming green infrastructure into resilience and effective strategies towards urban sustainability.

1.7. Limitation of the study

Furthermore, the analysis primarily focused on major green spaces, which may have resulted in the exclusion of smaller or informal green areas that also contribute to urban green infrastructure. Additionally, the study relied on survey data, which may be affected by respondent bias or limited demographic representation. Delays in questionnaire responses also impacted the data collection timeline and may have influenced the completeness and accuracy of the survey findings. As a result, while the research provides valuable insights

into UGI accessibility within Koye Feche Sub-City, the findings should be interpreted with these limitations in mind.

1.8. Operational Definitions

Urban Green Infrastructure (UGI): Urban Green Infrastructure (UGI) refers to a strategically planned network of natural and semi-natural areas, features, and systems that provide ecological, social, and economic benefits to urban areas (Burlando et al., 2025). UGI includes both traditional and innovative green solutions integrated into urban planning and development, such as green roofs, urban forests, green corridors, rain gardens, parks, and sustainable urban drainage systems. These green systems work in tandem with the built environment to address urban challenges such as climate change, stormwater management, and biodiversity conservation (Burlando et al., 2025).

Measurement Criteria: UGI is quantified by the extent (area in hectares or square meters) and types of green spaces present in the urban landscape, as well as their ecological functions (e.g., stormwater management, carbon sequestration, biodiversity).

Urban Green Space: UGS is any publicly or privately-owned green land within an urban area that is mainly covered with vegetation and selected for human use, nature conservation, or both. This includes areas like parks, gardens, sports fields, playgrounds, and green roofs, primarily designed for leisure, recreation, or aesthetic purposes.

Measurement Criteria: UGS is measured by its total area (in hectares or square meters), type (e.g., park, garden, forest), and accessibility (e.g., walkability to population centers). It is also assessed by its maintenance and usability for recreational activities.

Spatial Accessibility: Spatial Accessibility refers to the physical proximity or ease of reaching urban green spaces or UGI from various locations within a city (D. J. Du & Sharples, 2024). It is often quantified using geographic tools and measurements, such as walking distance, time, or transportation routes to the nearest green space.

Accessibility: Accessibility in the context of urban green infrastructure refers to the ability of individuals or groups within an urban area to reach and utilize green spaces or infrastructure, based on both physical distance and the availability of transport options. It encompasses both the physical proximity to UGI and the ease with which individuals can access and use these spaces.

Equitable Access: Equitable Access refers to the fair distribution of urban green infrastructure and green spaces across different socio-economic, demographic, and

geographic groups within a city. It focuses on ensuring that all communities, regardless of income, race, age, or ability, have equal access to the benefits provided by green spaces and infrastructure. This concept highlights addressing disparities in access and ensuring that underserved or marginalized populations can equally benefit from UGI.

1.9. Thesis organization

This thesis is structured into five chapters to systematically address the research topic. Chapter One introduces the study area, outlines the key research problems, and sets forth the study's objectives, research questions, hypotheses, conceptual framework, and the overall layout of the thesis. The second Chapter presents theoretical foundation, offering a review of related literatures that informs and supports the research context. Chapter Three gives a brief description of the Koye Feche Sub City study area and explains the research methodology, including field data collection and analysis procedures. This chapter lays the groundwork for the interpretation of results. Chapter Four presents the main research findings and analytical results, followed by a discussion of their implications within the context of the study area. Chapter Five concludes the thesis by summarizing key findings and providing recommendations derived from the study's conclusions.

CHAPTER II: LITERATURE REVIEW

This chapter examines the theoretical, empirical, and conceptual frameworks related to assessing the accessibility of urban green infrastructure (UGI) using Geographic Information Systems (GIS). It identifies key concepts, research methods, and limitations, paving the way for future research in this critical field.

I. Theoretical Literature Review

2.1. Definition and the Concepts of urban green Infrastructure (UGI)

Urban green infrastructure (UGI) encompasses a network of green spaces and natural features within and around cities. These elements work together to provide a range of ecological, social, and economic benefits, contributing to a more sustainable and resilient urban environment (P. Du et al., 2024).

(Tamiru, 2017) Green Infrastructure is a network of structure and sub-structures engineered green infrastructures which impersonator nature and advocates design with nature. Usually, Green Infrastructure is define as the network of green space, engineered green structure and substructure in a city and consists of natural and developed systems of parks and reserves, backyards and gardens, waterways and wetlands, streets and transport corridors, pathways and greenways, farms and orchards, squares and plazas, roof gardens and living walls, sport fields and cemeteries (Martin and Pitman, 2012) and (Tsige, 2015) cited in (Tamiru, 2017).

According to (Tamiru, 2017) many studies have adopted the definition of Green Infrastructure inversely in relation to the contexts and concern of different area or country. As their definition it's a network of natural systems in urban areas (Fawn and Chau, 2009) sited in (Tsige, 2015). Emphasizing networking green area is a strategic plan which integrates different green spaces and enhance biodiversity (Mell, 2011). Outside the working of Green infrastructure to connect green, it recreates systems of declined and destroyed natural habitats (Lucius, et al., 2011). (Tamiru, 2017) defined as in some area it is a network of decentralized storm water management and to some other country, Green infrastructure is a hierarchy of network of hydrological techniques and projects of a city.

Generally, urban Green infrastructure is a system of connected natural and manmade structures of urban areas that creates harmony of green networks and green systems, which accommodates biodiversity in the urban areas(Tamiru, 2017).

2.1.2. Concepts of UGI Accessibility

Accessibility in urban planning refers to the ease with which individuals can reach and utilize urban resources and services (Ummah, 2019). This is influenced by factors like distance, transportation, infrastructure, and personal mobility. Accessibility to Urban Green Infrastructure is vital as it impacts public health, social equity, and environmental sustainability.

The definition and history of equitable Accessing for Urban Green Infrastructure (UGI) The concept of equitability and accessibility to urban green infrastructure shapes upon the foundational principles of social and environmental justice, and the inherent right to a healthy and blooming urban area. This theory suggests that everyone, regardless of socioeconomic status, ethnic group, age of people, their ability, or location, should have fair and equal access to the benefits of UGI, such as;

Improved health and well-being which Access to green spaces contributes to physical and mental health, reduces stress, and promotes active lifestyles. Secondly environmental benefits that equitable access to green space allows all communities to benefit from its contributions to air and water quality, climate mitigation, and biodiversity conservation for all. Thirdly Social cohesion and community building according to (Burlando et al., 2025) Green spaces provide opportunities for social interaction, community engagement, and fostering a sense of belonging. This also economic opportunities like equitable access to green infrastructure can promote local economic development, make a job opportunity for local community, and enhance property values in underserved Community.

2.2. Types of urban green Infrastructure

Urban green infrastructure includes a wide array of green spaces and natural features within and around cities or towns, each playing a distinct role in shaping a more sustainable and resilient urban environment.

2.2.1. Green Park and Open Spaces

Urban Parks and open spaces are integral components of urban green infrastructure (UGI), playing a vital role in shaping sustainable and resilient cities (Cardone et al., 2024). They contribute to a multitude of environmental, social, and economic benefits, enhancing the quality life for urban inhabitants (Crain, 2011).

The following are some of the major ways that urban green and free space are used as Ecosystem Services: Air Purification (because trees and vegetation absorb pollutants);

Climate Regulation; Green spaces help reduce the urban heat island effect by absorbing solar radiation and releasing cooler air; and Water Management Park, which can help to decrease stormwater overflow, improve water quality and cleans, and mitigate flood hazard.

In this case majority of urban park and open space type's urban parks are huge green areas in the middle of cities that are intended for leisure, relaxation, and biodiversity. Community parks are smaller parks that are situated inside neighbourhoods and offer local communities' green areas and recreational activities. Pocket parks are little, well-located green areas that provide beauty, microclimate benefits, and a place of refuge in crowded regions. Recreational spaces and playgrounds are made for active play and exercise, frequently with natural components. Linear green spaces that link parks, forests, and other natural areas are known as greenways or linear parks. They encourage wildlife mobility, leisure, and ecological connectedness (NRAPA, 2021).

In conclusion Parks and open spaces are essential elements of urban green infrastructure, contributing significantly to environmental, social, and economic well-being in cities (Tamiru, 2017). By investing in and maintaining these green spaces, cities can enhance their livability, promote sustainability, and generate a more equitable and stronger urban environment for all peoples and community.

2.2.2. Green Roofs and Wall

One of the types of urban green infrastructure was Green roofs and walls which are highly recommended to improve the environment in towns and mitigate climate changes (Barriuso & Urbano, 2021). A green roof is a roof surface, flat or pitched, that has a growing medium over a waterproof membrane planted partially or completely with vegetation. Green walls are external or internal vertical building elements that support a cover of vegetation, rooted either in stacked pots or growing mats (Barriuso & Urbano, 2021). (Aryal & Sitaula, 2022) Green roof walls can modify the city ecosystem. It has been proved that Green roof mitigate the urban heat island effect, reduce the greenhouse gas emissions, attenuate the environmental pollutants, manage urban stormwater runoff, reduce noise, and enhance biodiversity. Urban green spaces and the influence on vehicular traffic noise control (Aryal & Sitaula, 2022). The Common types of green roof and walls are as follows

- Extensive Green Roofs: Shallow, low-maintenance roofs planted with grasses and drought-tolerant plants, providing insulation, water retention, and habitat.

- Intensive Green Roofs: Deeper roofs with a wider range of plants, requiring more maintenance but offering greater aesthetic appeal and biodiversity benefits.
- Living Walls: Vertical green structures, either free-standing or integrated into building facades, enhancing aesthetics, reducing heat islands, and providing habitat.

2.2.3. Urban Forests

An urban forest is an area of trees that is large enough to impact the quality of life, air quality and temperature of a city (John, 2017). It is believed that trees have a positive impact on urban heat islands and reduce atmospheric pollutants. Street trees, which are planted along streets and avenues and offer shade, cooling benefits, air purification, and aesthetic appeal, are a part of urban forests. Urban woodlands and forest patches are larger tracts of woodland inside cities that provide leisure possibilities, wildlife habitat, and important ecological advantages. Urban Forestry Initiatives Programs that increase the canopy cover of trees in urban areas by encouraging their planting, maintenance, and conservation. Other water elements found in urban parks and open spaces include rivers, lakes, and canals. These natural or man-made bodies of water within cities offer habitat, flood protection, and aesthetic value.

These types of UGI collectively donate to a more supportable, livable, and strong urban environment. Understanding the distinct roles of each type allows us to create well-integrated green infrastructure networks that address multiple challenges and enhance the quality of life for all urban community and inhabitants.

2.3. Benefits of urban green Infrastructure

(Burlando et al., 2025) Urban Green Infrastructure planning is a strategic approach to develop interconnected and multifunctional networks of blue and green spaces that potentially provide a wide range of environmental, social and economic benefits and simultaneously enhance the climate resilience of cities (Przewoźna et al., 2024) cited in (Burlando et al., 2025).

2.3.1. Environmental Benefits of green Infrastructure

Urban green infrastructure plays a great role in mitigating environmental challenges faced by cities. Its presence offers a multitude of ecological benefits, contributing to a healthier and more sustainable urban environment (Rakhshandehroo, 2017). Urban greenery and free

spaces are necessary in urban because they improve our health, wellbeing, and healthy environmental (Tamiru, 2017). The best examples of natural and semi-natural ecosystems that have green cover and open areas include parks, gardens, and infrastructure like plant walls and green roofs. Greenery and open spaces naturally cool the air and surfaces and support water management in urban settings. According to the author The vegetation used in these areas absorbs carbon dioxide to reduce greenhouse gas emissions (Tamiru, 2017).

According to scholars many decreasing heat islands result urban green infrastructure. Particularly trees and green roofs, help reduce urban heat island effect by absorbing solar radiation and releasing cooler air. (Tamiru, 2017) heat waves, drought, rainfalls, and storms are becoming increasingly severe and frequent as a result of climate change (Lee et al., 2015) cited in (Tamiru, 2017). According to scholars in Ethiopia many cities are impacted by these extreme weather events, which also have an influence on the amount of greenery and open space, which makes it harder for them to combat the effect of climate change (Tamiru, 2017). Thus, to mitigate the effects of climate change in healthy environment, updating and upgrading existing green space and open areas must be created and kept. This will support the future viability and resilience of our towns and cities (Tamiru, 2017).

Based on this review urban green infrastructure offers a multitude of environmental benefits, contributing to a healthier, more sustainable, and resilient urban environment. Participating in green space cities can mitigate climate change, improve air and water quality, conserve biodiversity, and enhance overall livability. Continuous research and implementation of urban green space strategy are vital to creating an additional environmentally sustainable future for urban inhabitants.

2.3.2. Physical (health) benefits of Urban Green Infrastructure

Access to green infrastructure has a number of human health and wellbeing benefits such as increased levels of physical activity, decreased low mental health and stress, increased levels of communal activity, and well-organized chance for active transport by encouraging walking and cycling area (Janicki, 2017). The ecological services offered by green space parks help users' physical, emotional, and social well-being (Tamiru, 2017). According to research, the presence of green space has an independent relationship with older people's survival rates. A different study found a connection between more environmentally friendly environments and lower stroke mortality. The negative impact of stressful life events on

health can be buffered by green spaces. A natural outdoor setting can benefit mental health because of the physiological changes it causes in the body. A Japanese study indicated that being in and walking through forests can encourage lower cortisol levels, lower pulse rates, and lower blood pressure when compared to city surroundings (Tamiru, 2017).

2.3.3. Socio-cultural benefits of green Infrastructure

Urban green infrastructure (UGI) provides not only environmental benefits but also significant socio-cultural advantages that enhance the quality of life in urban areas. Here, various socio-cultural benefits associated with UGI, supported by relevant study. Urban green areas can promote beneficial interactions that improve health and wellness and social cohesion (Tamiru, 2017). UGSs are also connected to better health outcomes, including encouraging social interaction and physical activity in urban areas. These UGSs give people of all ages the chance to interact socially, improving their social health (Jennings & Bamkole, 2019) giving them a sense of meaning and purpose, all of which lessen the symptoms of depression (Kondo et al., 2018).

In urban green infrastructures, individuals can connect and develop social ties by feelings of isolation and a perceived decline in social support were connected to lower levels of UGS in the environment (Tamiru, 2017). According to researcher this, urban green spaces are supposed as promoting social safety (Holtan et al., 2015) cited in (Kondo et al., 2018), while those that are enclosed are linked to a problem of environmental safety and security purpose. Urban green infrastructure offers significant socio-cultural benefits that enhance urban life, from improving mental and physical health to fostering community cohesion and providing experienced community as well as educational opportunity. Thus, by integrating UGI into urban planning, urban area towns and cities can promote healthier, more vibrant, and it must be inclusive and facilitative of the community.

2.3.4. Economic benefit of urban green Infrastructure

Urban green infrastructure (UGI) not only contributes to environmental and socio-cultural well-being, but also offers a range of economic benefits that can contribute to a more sustainable and prosperous urban future. Studies have shown that properties located near green spaces and parks tend to have higher property values, leading to increased tax revenues for cities (Tzoulas, K., et al., 2007) cited in (Burlando et al., 2025). Economic benefits of green spaces come from the increased values of properties near green spaces and the

increased sales of properties along green commercial corridors (Heckert & Mennis, 2012). In this line, studies in China (Jim and Chen, 2010) and Adelaide in Australia (Mahmoudi P. et al., 2013) indicated that higher housing prices and property values are evident for sites situated in the vicinity of accessible green space (gerbaba, 2021).

As many studies have pointed out in addition, the economic benefits of green space include increased tourism outcomes and its links to urban food (Ely & Pitman, 2014). As they explained the importance of integrating food production into urban areas and preserving productive agricultural land on the outskirts of cities, which would expand and closely link green space and urban food. Economically Many financial benefits from urban or rural green infrastructure can help create more sustainable and successful urban areas in the future. By funding urban greening, communities can raise property values, boost tourism, improve public health, reduce the impacts of climate change, and open up new business opportunities all contributing to a prosperous and sustainable urban environment.

2.4. Status of Urban green Infrastructure

2.4.1. Global status of urban green infrastructure

Currently as described by many researchers the global scenario of urban green infrastructure (UGI) is a complex and evolving scenario with different levels of development, challenges and opportunities in cities around the world. While some cities have made great strides in making their suburbs more comfortable and greener, others continue to struggle with limited resources, competitive priorities, and lack of awareness about the value of UGI which is a direction to easily identify community greening efforts.

Examples of Successful urban green infrastructure Initiatives over worlds are;

Cities like Singapore which has achieved significant success in integrating green spaces into its urban fabric, leading to improved air quality, biodiversity, and quality of life. The New York City's also innovative urban parks, built on a former elevated railway line, has transformed a neglected space into a vibrant public green space, contributing to tourism, recreation, and community revitalization.

Another example was City of London green infrastructure strategy which has developed a comprehensive UGI Strategy that aims to create interconnected green spaces across the city, enhancing ecological connectivity, biodiversity, and recreational opportunities. Currently the global status of urban green infrastructure is a work in progress, with a mix of

advancements and some challenges makes environmental and weather condition. And livable urban environments.

2.4.2. Status of Urban Green Spaces in Ethiopia

The progress status of urban green infrastructure (UGI) in Ethiopia is a complex issue, reflecting a mix of challenges and opportunities that are emerging across the country from small towns to major cities. Ethiopian cities, especially those experiencing rapid growth, are facing a shortage of green space. Regarding greenery the limited availability of parks, gardens, recreation and green roofs limits the benefits of UGI. Green infrastructure development in Ethiopia often lacks a coherent strategy and is dispersed across institutional and institutional initiatives. This leads to inconsistency and limited impact (Ayele et al., 2022).

According to (Terefe & Girma, 2022) the survey confirmed that the forestry practices in Oromia cities suffered from arboriculture challenges, canopy space challenges, poor soil quality, deficiency or excess of water and light, pollution, mechanical and chemical damage to trees. Tree management challenges include maintaining a tree and planting site inventory, quantifying and maximizing the benefits of trees, minimizing costs, obtaining and maintaining public support, funding and establishing laws and policies for trees on public and private lands (Hordofa & Shaoxian, 2021). In Adama and Bishoftu, destruction from domestic animals, illegal cutting of trees, waste disposal on the green space and illegal land use changes were observed as the main constraining factors. There was no provision for a site plan for green infrastructure components in all cities(Hordofa & Shaoxian, 2021). Compared to the international greenery standards of 20 m² /person (Ali Khan & Shafqat, 2014; Ruiz-Apilánéz et al., 2023), the greenery spaces in the studied cities 0.0035 m² /person are less than Dire Dewa 5.6 m² , and Bahir Dar 8.2 m² per person as confirmed by the study of (Hordofa & Shaoxian, 2021) cited in (Terefe & Girma, 2022).

(Hordofa & Shaoxian, 2021) Even Addis Ababa, the capital of Ethiopia, is grappling with the challenges and opportunities associated with urban green infrastructure (UGI) development. While the city boasts some green spaces, including parks and trees along avenues, the overall status of UGI remains inadequate, facing challenges (Ayele et al., 2022). Addis Ababa's journey towards a greener and more sustainable urban environment is ongoing. While challenges persist, the growing awareness, government initiatives,

community engagement, and emerging opportunities point towards a brighter future for UGI in the city.

According to studies by embracing a comprehensive approach that prioritizes urban green, addresses funding constraints, enhances capacity, and enhances community engagement, the capital city of Addis Ababa can harness the potential of city-wide green infrastructure to create a healthy, vibrant and resilient city for its community. It shows that by embracing these problems and the opportunities to address these Challenges, Ethiopia can create a sustainable and resilient urban future for its citizens.

2.5. Standard of Urban Green Area

The standards approach is typically used to provide consistency and certainty in urban green space planning (Maryanti et al., 2016) cited in (Apud et al., 2020). According to study it's a respond to the question of how much green space is enough for a person in specific area. (Haaland & van den Bosch, 2015), researcher shared a similar interpretation that a standards approach is basically a planning concept which is developed by planners to determine how much open space is needed to be provided and what kind of open space should be allocated across a city. Study conducted In Malaysia, the National Urbanization Policy has set the standards of 2 hectares per 1000 population by the year 2020. However, due to high urbanization rate and increased densification, some cities, are facing difficulties in achieving the target specified in the policy (Apud et al., 2020).

(Tamiru, 2017) The United Kingdom, the first nation to do so in the late 1800s, created the current standard technique. In order to ensure that every person has access to using it and meeting their social demands, especially in a high-density metropolitan zone, this notion has now become an integral aspect of planning policy and delivery for urban green space (Sipe & Searle, 2010). Numerous cities have set various standards for urban green space. With the exception of African countries, every city should provide a minimum of 9 square meters of urban green space for each person, and 7 square meters for African countries, according to the World Health Organization (WHO). According to WHO, it should also be usable, secure, and accessible. In addition, the WHO recommends that the appropriate quantity of urban green space be generously given at 50 square meters per person (Tamiru, 2017).

(Tamiru, 2017) the study observed that number of factors that have caused the depletion and inadequate access of UGSs in rapidly urbanizing cities. Expansion and density of the built

up environments take the frontline among factor that affect UGS existed in developing countries. (Byrne et al., 2010). In addition, all other feasible challenges of UGS needs to be explored to adopt rationalized policy directions and strategies that assists better administration and maintenance of urban green spaces.

(Tamiru, 2017) Accessible Natural Green Space Standard developed structural policy on the area of accessible green space, considering the minimum distance residents can walk to reach recreational parks (Natural England, 2010). After the United Nations (UN) Sustainable Development Goals (SDG) set a goal to provide “universal access to safe, inclusive and accessible, green and public spaces, the issue of accessibility obtained more recognition (UN, 2015).

Most developed countries implement 20m² park area per capita (Wang, 2009) and urban green infra-structure standard (UGIS) of Ethiopia also suggested 15m² park per capita (MoUD, 2015) cited in (Tamiru, 2017). Per capita ratio standard has recognized by the entire world because of its simplicity of utilization and implementation. However, it doesn't consider the spatial distribution or accessibility of green spaces to city residents (Yao et al., 2014 and de la Barrera et al., 2016). Walking distance accessibility to open green spaces was determined by the European Environment Agency as maximum 1000 m (15 min walking distance), and by English Nature as maximum 300 m (Khalil, 2014).

2.6. Urbanization effects on urban green Infrastructure development

(Pan et al., 2024b) Urbanization plays a crucial role in facilitating the generation and dissemination of green technology innovation through factors such as agglomeration of resources and spillover of knowledge. Then it contributes to the progress of urban green development through technological implementation (Pan et al., 2024a).

The existing body of literature has distinguished three main viewpoints on how urbanization affects green development. The first is that green development can be significantly aided by urbanization. By means of population migration, urbanization results in the concentration of economic activity and the labour force, facilitates the effective distribution of resources and the exchange of knowledge, and establishes favourable conditions for modernizing outdated development modes and upgrading the industrial structure (Somoye & Akinwande, 2023).

(Pan et al., 2024b) the irrational use of resources during the urbanization process can intensify the burden on the urban ecological environment (Lin et al., 2020). as is well known

in many countries Uncontrolled urban sprawl and increasing population and industry contribute to increased environmental pollution and climate change (Somoye & Akinwande, 2023) cited in (Pan et al., 2024b). According to pan study thirdly, a non-linear relationship exists between urbanization and green development. On the one hand, the pattern of rapid urbanization that prioritizes economic growth at the expense of the environment can lead to increased levels of pollution and resource consumption. On the other hand, as urbanization progresses, cities tend to optimize their industrial structure and foster green industries with minimal energy consumption and pollution (Pan et al., 2024b).

II. Empirical literature Review

2.7. Application of GIS and remote sensing in UGI Accessibility and mapping

GIS and remote sensing technologies enable the creation of accurate spatio-temporal urban forest inventories, species distribution maps, and change detection analyses. By integrating remote sensing data with machine learning algorithms, accurate classification and mapping of tree species, health and stress are achieved (Datta & Dash, 2024)

(Tzoulas et al., 2007) Assessing the accessibility of green infrastructure (GI) is essential for ensuring equitable access to its numerous benefits. Accessibility encompasses various dimensions, including physical, social, functional, and temporal aspects. While physical proximity distance is significant, accessibility also considers social, economic, cultural, and functional barriers (Kabisch et al., 2016).

Many scholars study define accessibility among them Study by (Huang & Yang, 2023; Li et al., 2019; Ma et al., 2023) GIS provides powerful tools for mapping Green infrastructure, analyzing spatial distribution, and calculating distance to green spaces. (Huang & Yang, 2023) Accessibility refers to the relative difficulty of getting to the landscape source from the community, and its related indicators include the distance and time to reach the green space (Zhang et al., 2020) sited in (Huang & Yang, 2023).

GIS manage, analyze, and visualize spatial information, constructing intricate maps by integrating diverse data layers. These tools hold significance in environmental monitoring, urban green space accessibility, urban planning, disaster management, and resource assessment, enabling informed decision-making. Various remote sensing methods provide spatial information for thorough GIS analysis. Satellite imagery provides broad coverage and regular updates, while LiDAR (Light Detecting and Ranging) creates precise 3D models

using lasers. GIS merges georeferenced remote sensing data, yielding interactive maps. By overlaying and querying data, users make informed choices. Spatial decision support systems (SDSS) improve analysis and enable accurate decision-making across various domains (Datta & Dash, 2024).

Remote sensing involves the non-intrusive acquisition of Earth's surface information using satellites or aircraft, including imagery and spectral data, to monitor changes in land, vegetation, and the environment. Remote sensing data can assess land cover, vegetation health, and environmental conditions (Rahimi, 2016). The use of geospatial technology like remote sensing in green infrastructure applications offers an inclusive, cost-effective, and scalable approach for assessing, remotely monitoring, and managing green spaces and environment. Remote sensing guide and allows urban planners, environmental scientists, and policymakers to better understand UGS from far, the spatial distribution, condition, and dynamics of UGI, facilitating for sustainable urban development. Thus a continuous advancements in remote sensing technology and data analysis technique, remote sensing will remain a keystone for the management and enhancement of urban green infrastructure (Panagopoulos, 2019).

(Tamiru, 2017) Modern and accurate spatial data of green space is essential for urban land use planning and control in different countries of the world as well as in our country. Due to the rapid pace of urbanization of green spaces changing, dividing and spreading, collecting this data using traditional land survey methods has become a challenge especially in conjunction with geospatial and timely challenges. As indicated its lack of the time and labour requirements for gathering, processing, and reporting field data, and regional surveying operations are challenging. Therefore, there is an urgent need for contemporary ways to automate the process of surveying green spaces (Mengistu & Salami, 2007).

This study combines the methods of accessibility analysis of urban green infrastructure and remote sensing image classification. Remote sensing spectral indices, GIS network analysis tool and image classification using unsupervised algorithm, will be used to estimate the distribution and accessibility of urban green Infrastructure in study area.

2.8. Accessibility of free space, recreational and parks

As scholars defined Accessibility (Tamiru, 2017) as the relative ease with which specific attractive locations may be reached from particular locations as well as how widely visible the site is to the general population.

The term accessibility typically refers to the non-linear distance that must be traversed in a given amount of time in order to get from one site to the users nearest green area. The features of the city's transportation system make accessibility implementation difficult even though its description is rather straightforward. In this study, the population inside the service area polygon that has access to a particular facility (Public Park) is expressed in numerical value or percentage, which represents public park accessibility.

According to rough research, accessibility typically refers to the non-linear distance that must be traversed in a given period of time in order to get from a location to the nearest user green area (So, 2016). Accordingly, in cities the characteristics of the city's transport system make the implementation of accessibility difficult although the description is quite straightforward (Tamiru, 2017) According to this study, the population within the service area polygon that has access to a specific facility was expressed in numerical values or percentages, representing public park accessibility.

A study conducted by (Atiqul Haq et al., 2021) Public parks are crucial for the ecologically viable function of cities because of their influence on routine recreation, the preservation of bio-diversity, the city's cultural identity, the maintenance and improvement of overall environmental quality, and their contribution to technical problem solving through natural solutions. (Nesbitt et al., 2019) In terms of its accessibility to people from different socioeconomic groups, public recreational parks are often not distributed fairly and equally. In numerous empirical studies (Jim and Chen, 2006; Qureshi et al., 2010; Keniger et al., 2013), cited in (Nesbitt et al., 2019) it has been demonstrated that UGS serve certain functions at various levels of urban life (Tamiru, 2017).

2.9. Vegetation and built-up indices

Vegetation Indices (VIs) are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation. They are derived using the reflectance properties of vegetation. Each of the VIs is designed to accentuate a particular vegetation property. (Tamiru, 2017) Surface dynamics inference, modelling, and forecasting

are aided by spectral indices. Indexes are constructed for numerous satellite spectral band combinations. There has previously been study on the use of satellite indices in agriculture, water resources, urban planning, forest ecology, geology, soil sciences, vegetation, and other fields.

2.9.1 Normalized Difference Vegetation Index (NDVI)

Various studies (Rahmawati et al., 2022) have used a single index and a modification in the identification of mangroves by translating the spectral reflected by mangrove vegetation and received by satellite (Rahmawati et al., 2022). As examples the study show, the NDVI index (Normalized Difference Vegetation Index) has long been used in monitoring shrubs and mangroves. A study by (Rahmawati et al., 2022) used an index to map mangroves in Mexico and involved four image sources which used for extraction of UGI, namely Landsat-9, SPOT-5, Sentinel-2, and WorldView-2 for urban green infrastructure.

(Gandhi et al., 2015)Vegetation indices are widely used as criteria for analysing land cover changes and monitoring trends. This factor is frequently used to distinguish between places with unhealthy vegetation and those lack of vegetation. The numerical value of the NDVI falls between 0 and 1. Dense vegetation is indicated by positive numerical values, whereas non-vegetated places, damp areas, and locations close to bodies of water are indicated by zero and values near those (Tamiru, 2017). Eq. (1) is used to calculate this index.

As it described by (Tamiru, 2017) This is one of the most used techniques for assessing how much of an area is covered by vegetation. This measure, which is a ratio, can be used to track crops throughout the growing season because it is unaffected by changes in slope, seasons, illumination, etc. It is calculated by taking a ratio between the difference of reflectance from NIR and Red bands and the sum of reflectance from NIR and Red bands (Bhandari et al., 2012). In this study NDVI indices will use to explore the current vegetation cover in Koye Fechesubcity.

$$NDVI = \frac{(\rho_{NIR} - \rho_{Red})}{(\rho_{NIR} + \rho_{Red})} \dots\dots\dots (1)$$

Where: ρ_{NIR} is the reflection coefficient in near infrared spectrum,
 ρ_{RED} is the reflection coefficient in red spectrum.

NIR is near infrared band Sentinel 2 uses NIR as band 8 and Red as band 4

2.9.2 Normalized Difference Built-up Index (NDBI)

Normalized difference built-up index (NDBI) is proposed to determine the urban area, For Landsat OLI data, its value lies between -1 to +1. A negative value of NDBI represents water bodies whereas higher value represents built-up areas (Majeed et al., 2020). The Normalized Difference Built-up Index (NDBI) was proposed in 2003 as a new method which automatically maps built-up areas. According to this information The method was first applied in practice to extract data for a built-up area of Nanjing city in eastern China (Tamiru, 2017). The NDBI index was able to distinguish between built-up and vegetated or green and wet surroundings for the city of Nanjing (Chunyang et al.,2010) cited in (Majeed et al., 2020).

This index highlights urban areas where there is typically a higher reflectance in the shortwave-infrared (SWIR) region, compared to the near-infrared (NIR) region. Applications include watershed runoff predictions and land-use planning.

This index is calculated using Eq (2)

$$NDBI = \frac{(\rho_{SWIR} - \rho_{NIR})}{(\rho_{SWIR} + \rho_{NIR})} \dots\dots\dots (2)$$

Where SWIR is shortwave infrared band and NIR is near infrared band, Sentinel 2 uses SWIR as band 11 and Red as band 4.

The NDBI was originally developed for use with Landsat TM bands 5 and 4. However, it will work with any multispectral sensor with a SWIR band between 1.55-1.75 μm and a NIR band between 0.76–0.9 μm (Tamiru, 2017).

2.11. Research and knowledge Gaps in Related literature

However, the studies mentioned above offered valuable insight into evaluating urban green infrastructure. In response to current and upcoming urban green infrastructure concerns, they are insufficient and a number of important issues arise. The problem of urban green spaces neighbourhoods poses short- and long-term results connected with environmental changes and socioeconomic failure (Lotfata, 2021). The lack of green areas accelerates the spatial

and socioeconomic decline in the dysfunctional urban landscape as making green spaces are considered a challenge, predominantly in developing countries, in which there is pressure for space, assets, and development. From this perspective, urban green spaces are urban areas in proximity to built-up areas (Lotfata, 2021).

The literature on the accessibility of urban green infrastructures in Ethiopian cities is lacking. Therefore, the purpose of this study will evaluate the spatial accessibility of green infrastructure in Koye face, Ethiopia, using remote sensing and geographic information system technologies. Koye Feche Sub City is populated city area which is more significantly, it welcomes immigrants from nearby big cities Addis Ababa because of its geographic location. It helps lessen the strain that these cities are under from their population. Therefore, evaluating the effects of growing urban built-up areas on urban green spaces in the Study area is important. The green space index, NDVI, and NDBI, which are based on fundamental forms of green space cover and associated attributes, will be used to accomplish the goals of this study.

However, some of the existing social-ecological literature (Pickett et al., 2011) cited in (Pan et al., 2024b) offers a research agenda on urban green areas that recognizes this gap, emphasizing multidisciplinary, interdisciplinary, and trans disciplinary approaches to social-ecological and urban green area studies. Long-term, multi-scalar research is also encouraged in order to enhance our comprehension of social-ecological interactions over time. In order to promote a more sustainable social-ecological system through urban ecological design (Pickett et al., 2011) argue for a social-ecological approach through the lens of land change science and call for the integration of urban design, planning, and ecology.

Ethiopia is not an exception, as there aren't many studies that concentrate on the spatial planning of green infrastructure. (Gashu & Gebre-Egziabher, 2019) conducted a study on the drivers for Green Infrastructure planning in Hawassa and Bahirdar; (Ayele et al., 2022) identified the spatial pattern of urban green spaces in selected Southern Ethiopia; and (Girma et al. 2019) on Urban Green Infrastructure planning of the Oromia special zone in central Ethiopia. In Addis Ababa, the capital city of the country, (Eshetu et al., 2021) identified the need to create a large urban green infrastructure network; and (Azagew & Worku, 2020) studied the status and challenges toward the accessibility of UGI. Studies on Green Infrastructure planning, specifically on evaluating Green Infrastructure spatial planning, are relatively scarce.

To address the research gap, this research aims to review and analyze Green Infrastructure Accessibility in Koye Feche Sub City, Ethiopia. The research analyses the extent to which Green Infrastructure principles are incorporated in urban planning, and whether the multiple roles of green infrastructure have been addressed in urban planning or Accessible for all or not. This research sheds light on knowledge gaps, contributes to the existing knowledge on spatial distribution, planning, and contributes to increasing the understanding of planners toward the development of Green infrastructure spatial planning. Therefore, this study aims at filling this critical knowledge gap through assessing the Accessibility of urban green infrastructure and map the distribution of UGI by applying NDVI and NDBI Indices in remote sensing imagery, classifying different types of green spaces and their spatial characteristics within Koye Feche Sub City using GIS and remote sensing.

2.10. Conceptual Frame Work of Study

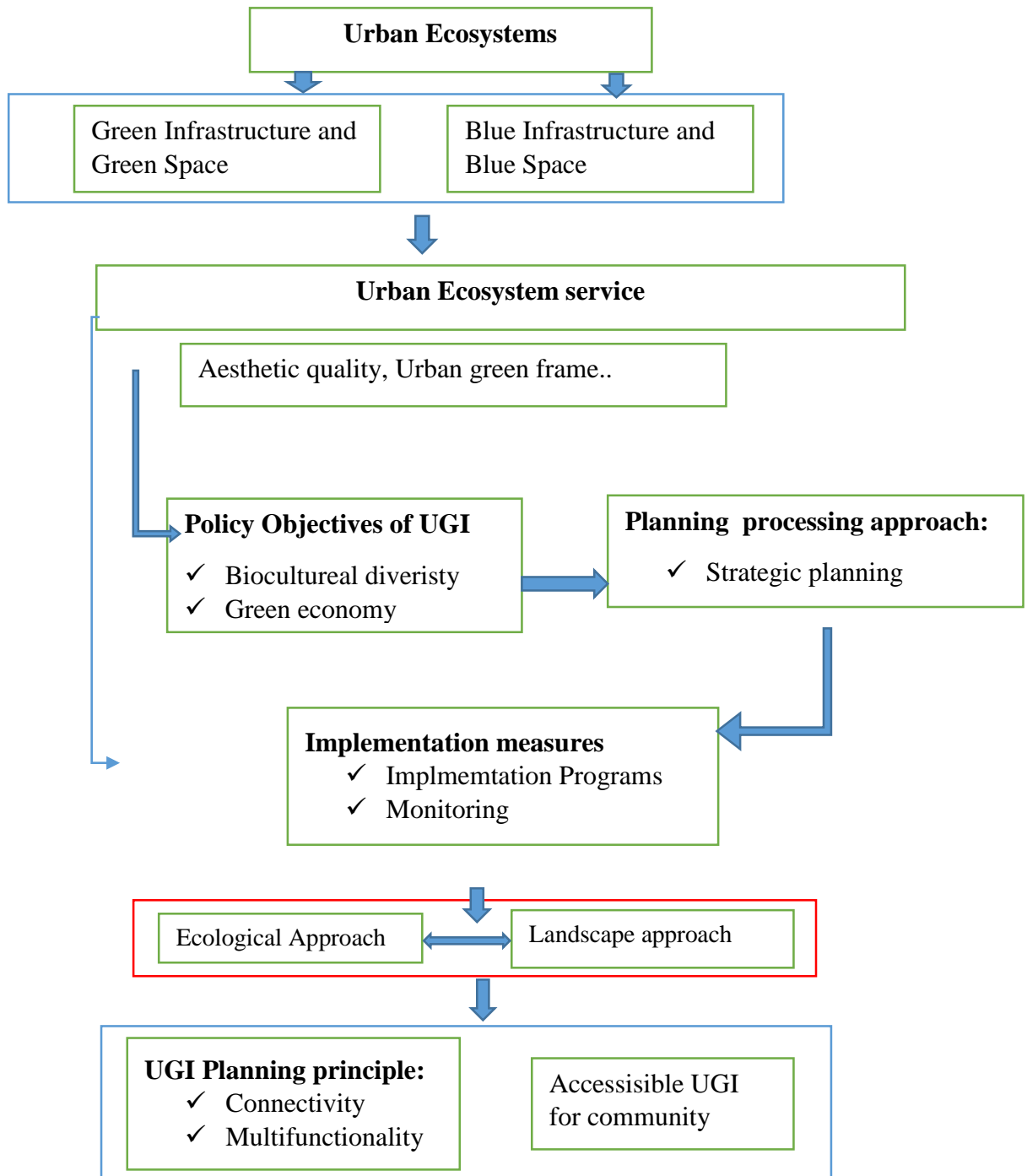


Figure 2.1. Conceptual frame work of the study

CHAPTER III: MATERIALS AND METHODS

3.1. Description of Study Area

Koye Feche Sub-city (Oromo: Koyyee Faccee) is a town in the new Sheger City of Oromia Region, Ethiopia, formerly located in the Oromia Special Zone Surrounding Finfinne. The city was established in February 2015 by the self-governing district administration of Koye Feche. The city government has been paying special attention to the cities for the use of our people as per the needs of the city to make. Our government for the benefit of the people it's embracing the former villages of Akaki District and working to benefit our community. Figure 3.1. location of the study area.

(Sources: - Spatial Development Plan Of Koye Feche Sub City, Sheger City, Ethiopia

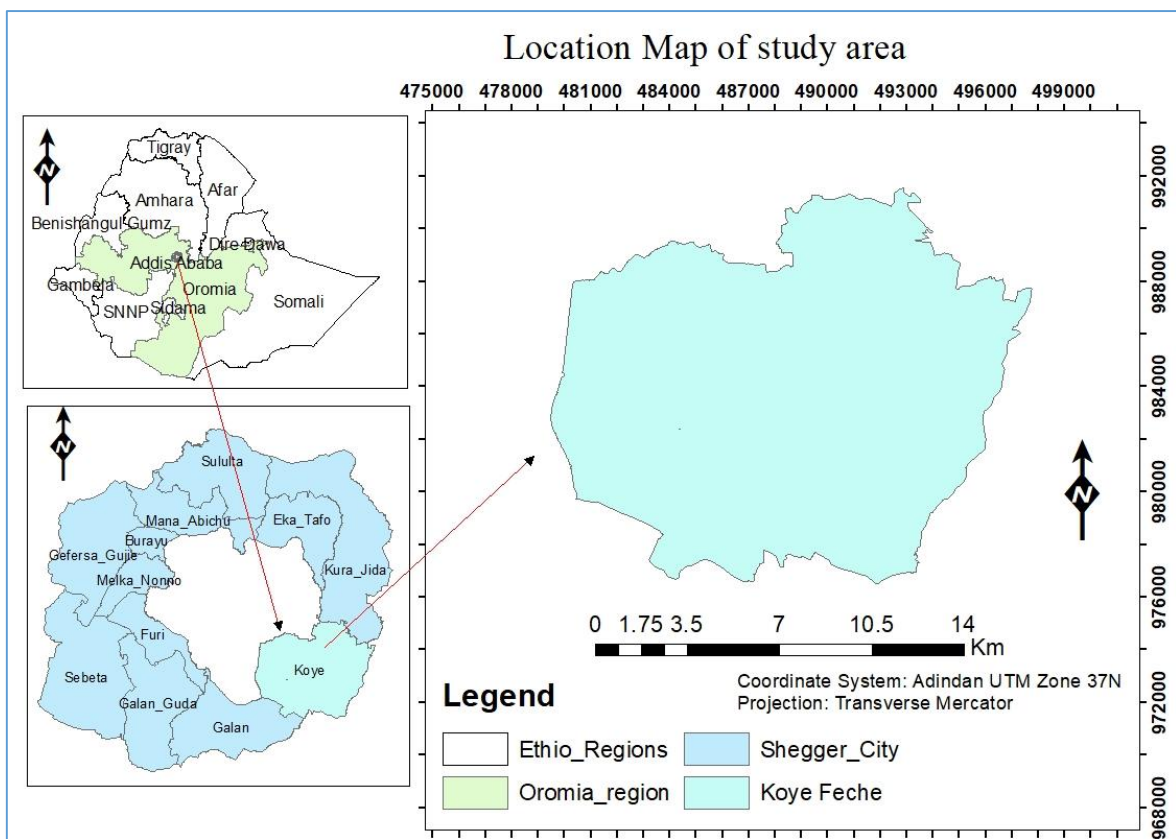


Figure 3.1. Location Map of Koye Feche Sub City in Sheger, Ethiopia.

3.1.1. Location Description

Koye- Feche is located in the southeast direction of Addis Ababa or Finfinne, the capital city of Ethiopia at geographic coordinates of $8^{\circ} 54' 11''$ North and $38^{\circ} 49' 60''$ East. The town is located 28 KM east of the capital city of Addis Ababa or Finfinne and is a residential

town. The town is said to be a very attractive tourist destination in East Africa as it is located close to the capital city of the country it is thought. Geographically The city is bounded by: East :- Gelan Sub City South:- Gelan Sub City and Finfine City West:- The City of Finfine District, North:- Finfine and Laga Xaafoo with a total land area of 18,725 thousand hectares.

3.1.2. Climate, Temperature, and Topography

The City is located to the, east of the capital city of Addis Ababa, and its climate is desert-plain and suitable for human habitation. Its geographical location is mostly flat with an elevation of 2140m /7024 feet/. The average temperature in the city is 15-20 C⁰, Average rainfall is 700mm - 800mm. On the other hand, the soil type of the city is predominantly black with occasional red soil. In general, the existing soil is found to be unsuitable for various constructions.

3.1.3. Population

The Sub City has 3 districts and a total population of 196,944 males 92,769 and females 104,175, with a total land area of 18,725 thousand hectares. The population is diverse, with various ethnic groups represented, including the Oromo, Amhara, and Tigray. The population growth rate has been steadily increasing over the past few decades, fueled by urbanization, migration from rural areas, and a high birth rate.

3.2. Selection process of the study area

The selection processes of the sample study area were made in such a way that it would meet the aforementioned objective of this research. This document outlines criteria for selecting case study areas to assess the accessibility of urban green infrastructure in Koye Feche Sub City, focusing on how readily residents can access and benefit from green spaces. Before selecting the study area, the sampling process that was made by previously conducted studies, which were related to this research was compiled and seen further. Since the results of previously done studies have shown that there is a significant result difference in different topographical conditions, they were shown that the sample study area selection processes should comprise distinct topographical conditions.

Moreover, in order to conduct all round or acceptable studies, the selected study area should contain the most determinant factors and should be representative of Population Diversity, Geographic Distribution, Socioeconomic Backgrounds, Environmental Contexts, Cultural Perspectives, Health Outcomes.

By employing these criteria and conducting thorough analysis, the accessibility assessment study can identify the most crucial case study areas, leading to impactful recommendations and ultimately a more accessible and inclusive urban green infrastructure system in Koye Feche Sub City. The outcome from this Sub City are expected to be representative of broader trends within the city in urbanization patterns, Demographic changes, Access to services, environmental issue, Community engagement's, health impacts and policy effects. Offering useful information for solving equitable distribution of UGS and developing suitable strategies for sustainable urban development.

3.3. Research Design and Approach

The research design for this study was both quantitative and qualitative research designs for the accessibility of urban green infrastructure. In order to widely assess the accessibility of urban green infrastructure in Koye Feche Sub City and understand its impacts on the social, economic, and environmental comfort of residents. A good research design is a systematic plan explaining how a study is going to be conducted to obtain valid, reliable, and worthwhile results. It includes: Clear Objectives, Methodological Framework, Sampling Strategy, Data Collection Techniques, Data Analysis Plan, Timeline, Ethical Considerations, Pilot Testing, Feedback Mechanisms.

By following a properly designed research plan, we can enhance the validity and impact of their findings, which can ultimately culminate in effective decision-making and policy formation. The research plan will be to gather effectively:

- **Data Relevant to the Research:** Collect data that directly addresses the research questions and objectives.
- **Demographic Data:** Gather information on the background of participants to have a proper representation.
- **Qualitative Information:** Gather in-depth information via interviews or focus groups to collect perceptions and experience.
- **Quantitative Measures:** Quantify specific variables via surveys or observational measures to measure access and utilization of UGS.
- **Spatial Data:** Use GIS and mapping techniques to examine the geographical extent of UGS and accessibility.

- **Contextual Factors:** Collect information on environmental, social, and economic determinants that influence access to UGS.
- **Community Feedback:** Engage local residents to get their input and preferences regarding UGS planning and use.
- **Longitudinal Data:** Where possible, track changes over time to assess the impact of UGS on community wellbeing.

The research design will enable critical and informative analysis of urban green space access and equity through consideration of these dimensions.

3.3.1. Qualitative and Quantitative Research Design

This qualitative research aims to explore the perceptions and lived experiences of residents in relation to urban green spaces, with a particular focus on how they access, use, and value these areas. The study seeks to uncover the social and emotional significance of green spaces to different demographic groups, as well as to understand the barriers whether physical, social, economic, or psychological that hinder access. In addition to individual experiences, the research will evaluate the efforts made by local governments and other public institutions in promoting and developing sustainable urban green infrastructure. This includes examining policies, programs, and community engagement strategies aimed at enhancing green space accessibility and inclusivity.

In qualitative research activities, interviews and questionnaires were employed to with participants which selected from population as sample including residents, urban planners, local officials, and community leaders, to gain in-depth insights into personal experiences, policy challenges, and planning priorities. Depths interview was organized to adoptive discussion among community members of various ages, income levels, and cultural backgrounds, allowing for a broad spectrum of perspectives on green space accessibility, safety, and social value.

The result of this qualitative research was reached, descriptive data that enhances understanding of how different demographic groups experience urban green infrastructure. These insights will complement the quantitative findings, creating a more comprehensive picture of urban green space accessibility in urban area.

In quantitative design survey data, spatial analysis using Geographic Information Systems (GIS) was conducted to empirically assess physical accessibility of UGS. The collected data were subjected to statistical analysis using software such as SPSS and excel Descriptive statistics brief key characteristics of the sample and their responses, while inferential methods including correlation analysis were applied to examine relationships between accessibility and demographic variables such as income average, group of age, and educational level. These analyses helped identify significant predictors of accessibility and quantified disparities across different communities.

3.3.2. Integrated Approach

The study employed a mixed-methods research design that combined approaches to provide a more comprehensive understanding of urban green space accessibility. Initially, qualitative methods such as interviews were used to explore key themes and resident experiences, which informed the development of the subsequent quantitative survey distributed to a broader population. This approach allowed for triangulation, where qualitative data were used to contextualize and explain quantitative findings, enriching the overall analysis. The integration of both methods enhanced the depth, validity, and reliability of the research by capturing diverse perspectives and ensuring that the results reflected both measurable trends and lived experiences.

3.4. Population, Sampling technique and Sample Size Determination

In this study, the target population consisted of individuals directly involved in or knowledgeable about urban green infrastructure (UGI) within Koye Feche Sub-City. This included municipal experts, consultants, and members of the local community with relevant experience in the area. Given the large size of the population, it was not feasible to collect data from every individual. Therefore, a stratified random sampling technique was employed to ensure broad and balanced representation across different stakeholder groups.

The total sample size was 384 individuals, selected from the entire population of the sub-city. Participants were divided into strata based on their roles (e.g., municipal staff, professionals, and local residents), and respondents were randomly selected from each stratum. This approach aimed to capture the diversity of perspectives on UGI accessibility and ensure that the sample reflected the population's demographic and professional

composition. Stratified sampling was also used to support qualitative inquiry by identifying specific subgroups of interest. The methodology was designed to improve the reliability of findings and ensure that the results could be meaningfully interpreted in the context of spatial planning and urban development in Koye Feche Sub City.

The formulas commonly used for sample size calculation are variations of the basic formula, sometimes simplified for ease of use. The most accurate formula for a population of 196,944 is one that incorporates the finite population correction (FPC). This correction adjusts for the fact that sampling from a finite population reduces the variability compared to an infinite population.

The formula with the FPC is:

$$n = (Z^2 p (1-p) N) / (E^2 (N-1) + Z^2 p (1-p)) \dots \dots \dots \text{eq3 (Yamane's formula, 1967)}$$

Where:

n = sample size

Z = Z-score (1.96 for a 95% confidence level)

p = estimated proportion of the population with the characteristic of interest (0.5 is used).

N = population size (196,944)

E = margin of error (use a common value of 0.05 or 5%).

Example Calculation (5% Margin of Error):

Let's calculate the sample size for a 5% margin of error:

$$n = (1.96^2 0.5 0.5 196,944) / (0.05^2 (196,944 - 1) + 1.96^2 0.5 0.5)$$

$$n = (3.8416 0.25 196,944) / (0.0025 * 196,943 + 0.9604)$$

$$n = 189,145.0176 / (492.36 + 0.9604)$$

$$n = 189,145.0176 / 492.45$$

n ≈ 384.089 by Rounding up a sample size of approximately 384.

Based on the above formulas results, from total 196,944 people, 384 sample (participant) size was selected for household surveys. In order to increase the accuracy of the research results, the research operated at a 95% level of confidence with a margin of error of 5%. Stratified random sampling will be used for dividing the population into subgroups or strata based on certain characteristics, such as socio-economic status, land use or Green infrastructure characteristics.

3.5. Data Type and Sources

Various data sources were utilized in this study to support the analysis of urban green infrastructure (UGI) accessibility in Koye Feche Sub-City. Satellite imagery from Landsat 9 OLI, obtained from the United States Geological Survey (USGS), was used for NDVI analysis to identify and classify vegetation cover. A detailed structure plan of Koye Feche Sub-City, including road networks, was used to understand the spatial layout and connectivity within the area. High-resolution ortho-photos of the sub-city provided additional spatial accuracy for mapping. Population data was sourced from the Central Statistical Agency (CSA) to assess demographic distribution and inform the accessibility analysis. Information on existing green infrastructure was gathered through field surveys and manual extraction from spatial data. The official city boundary of Koye Feche Sub-City was also used as the geographic frame for the study. All of these datasets, which are illustrated and summarized in Table 3.1, formed the foundation for spatial analysis and interpretation using GIS and remote sensing techniques.

Table 3.1. Data types and material used

No.	Data Required	Data Source	Data Type	Year	Resol ution	Data Format
1	Landsat 9 OLI	USGS	Secondary	2025	15m	Tiff
2	Structure plan	Koye Sub City	Secondary	2024		
3	Ortho Photo	Koye Sub City	Secondary	2024	0.15m	Tiff
4	Road	Structural Plan	Secondary	2024	-	.kml
5	Population	CSA	Secondary	2024		
6	Green Infrastructure	Field survey and Extraction	Primary	2025		Shape
7	City Boundary	Koye Feche Sub City	Secondary	2024		Shape

3.6. Software and Materials Used.

Based on their potential to address current issues in accomplishing the predefined goals, the software and materials used in this study were chosen.

Hence software package like ERDAS IMAGINE 2015 will applied for image processing and bracket conditioning on satellite images. Also, Master Plan or Google earth Pro will employed to digitize road, sluice and to check the delicacy of land use/ land cover class. Remote sensing sand GIS software's provide users with the ability to edit, categorize, and store images obtained from aerial photography, satellite transmissions, or other remote sensing equipment. Remote sensing and GIS software's for data collection, processing and analysis procedures. The techniques used were resampling, sub setting required bands, layer stacking and conversion of Snap file format to Geo-TIFF file formats.

In addition, ERDAS Imagine 2015 software was used for pre-processing satellite imagery, including mosaicking and conducting Normalized Difference Vegetation Index (NDVI) classification. NDVI is a widely used vegetation index that helps to detect and quantify green vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). In this study, NDVI played a critical role in mapping and assessing urban green infrastructure (UGI) by identifying the presence, health, and density of vegetation across Koye Feche Sub-City. NDVI values were classified into different levels to distinguish between low, moderately, and high dense vegetation, providing insight into the quality and distribution of green spaces (Burlando et al., 2025). This allowed for a more accurate spatial analysis of UGI and helped in identifying areas with limited vegetation cover. For increasing the level of accuracy in the Land Use and Land Cover (LULC) classification derived from the satellite image, satellite imagery was used as reference ground truth data additional to google earth. This visual verification process supported the reliability of the NDVI-based mapping and improved the credibility of the study's spatial analysis. The following statistical procedures are typically used:

Classification Algorithms:

Maximum Likelihood Classification: A widely used algorithm that is employed to classify land cover based on probability distributions.

Support Vector Machines (SVM): A machine learning algorithm that classifies classes on the basis of best hyper planes.

Random Forest: An ensemble learning algorithm that works with a set of multiple decision trees to classify.

Accuracy Assessment:

Confusion Matrix: A matrix that is utilized to define the performance of a classification algorithm by comparing predicted classes and actual classes.

Overall Accuracy: Correctly classified instances divided by the total number of instances.

Kappa Coefficient: An inter-rater agreement measure that is sensitive to chance agreement and provides a better accuracy measure.

Statistical Analysis

Descriptive Statistics: For summarizing the data to know the distribution of different land cover classes.

Post-Classification Comparisons: For studying the change over time by comparing the classified maps of different years.

Spatial Analysis

Zonal Statistics: Statistical computation for different zones according to the classified land cover to analyze land use patterns.

These techniques in combination enable accurate classification and validation of land-use/land-cover data in the ArcGIS environment, providing inputs for urban planning and environmental management.

Land-use/land-cover classification and accuracy assessment tasks were computed by using ArcGIS 10.8. Moreover, relevant GIS analysis were undertaken by using advanced Network analysis tool integrated in the ArcGIS software. The tool has the ability to effectively analyze the accessibility of public parks with in the service area polygon.

3.7. Data Collection Methods

Satellite data and ancillary data are the two types of data that will be employed in this study. Ancillary data includes shape files of the green infrastructure, shape files of the residential area, road network, and shape files of the study area, population data and ground truth information for public park facility extraction. The reference data points utilized as the ground truth data will gathered for the year 2024 from online data source (Google Earth), Structural Plan or Master Plan for validating the land-use and land-cover classes. These data

will be used for image classification general accuracy evaluation, of the classification results. In addition, to map urban green spaces existed in the study area,

Supervised Object-Based Image Analysis (OBIA) is a remote sensing and image processing technique in which classification and analysis of images are done based on objects, rather than individual pixels. Supervised OBIA is an effective method for extracting valuable information from complex imagery, and therefore it is required for making sound decisions in various fields.

3.8. Data Analysis Methods

The data gathered from the household survey were processed, managed, and analysed using Statistical Package for Social Sciences (SPSS) software and Microsoft Excel. Pre-coded questionnaires were entered and cleaned in Excel before being imported into SPSS for statistical analysis. Descriptive statistics such as frequencies, percentages, and mean values were used to summarize respondents' demographic characteristics and perceptions of urban green infrastructure (UGI) accessibility. Additionally, cross-tabulation was employed to explore relationships between variables such as income level, gender, and proximity to green spaces. Inferential statistical techniques, including Chi-square tests, were applied to determine the significance of associations between socio-economic factors and access to UGI.

NDVI: - The most important measure employed in determining crop health based on satellite images is the normalized difference vegetation index, or NDVI. Without the need for a sequence of regular field trips, it indicates the status of the plants according to the amount of light of varying wavelengths they reflect and absorb.

Agronomists can track seasonal advancement, identify early indication of stress, and plan intervention before harm if it is to be widespread by looking at trends. A rapid drop can be a sign of pest pressure, disease infection, nutrient lack, or drought pressure. Declines aren't always negative, though. NDVI is also decreased by natural processes like harvest and senescence, or the gradual aging of foliage.

Can also assist in establishing realistic expectations of a crop's growth cycle, particularly in the case of unpredictable weather.

The normalized difference vegetation index usually uses satellite data to measure the reflectance of light on the surface. The NDVI formula is as follows:

NIR is the near-infrared light that is reflected by the surface, and RED is the visible red light that is reflected by the surface.

The formula

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED}).$$

Keep in mind that the precise NIR and RED band numbers vary by satellite when calculating NDVI manually. Nevertheless, a precision agriculture platform is a more comfortable way of calculation. Taking into account all the subtleties, our crop monitoring system automatically processes satellite images, calculates the index for each field, and can show its distribution on interactive downloadable maps.

By dividing the amount of visible red light a plant absorbs and the amount of near-infrared light it reflects, the NDVI equation is calculated. Chlorophyll, occurring in healthy plants, reflects NIR and absorbs RED. Stressed plants absorb more amounts of near-infrared light and reflect less, i.e., when they are very dry or sick. Normalized difference vegetation index provides us with a good approximation of how healthy the plant is based on the level of chlorophyll by measuring the difference in the types of light that are reflected and absorbed.

Applications:-

- ✓ Agriculture: Monitoring crop health and yield prediction.
- ✓ Forestry: Forest cover and health estimation.
- ✓ Environmental Monitoring: Land cover change and vegetation dynamics monitoring.
- ✓ Climate Studies: Investigating the impact of vegetation on climate and carbon cycling.

These indices and metrics provide meaningful information regarding vegetation health, land cover change, and ecological processes.

Geographic information system and remote sensing applications area used for spatial analysis, to identify and manipulate the distribution of UGI within Koye Feche Sub-City.

Using Landsat imagery, the study applied NDVI classification to identify and evaluate different types of vegetation and their density. The classified NDVI data supported the analysis of land use and land cover (LULC), helping to distinguish between formal green spaces, agricultural land, and other vegetated areas. Proximity analysis and spatial overlay techniques in GIS were used to assess UGI accessibility by calculating distances from residential areas to green spaces and identifying neighbourhoods with limited access. This integrated approach allowed for both statistical and spatial insights into the current distribution and accessibility of UGI, supporting recommendations for targeted urban green space development in Koye Feche Sub-City.

After the data were collected from various sources, the data will analyse by using different software like ArcGIS 10.8, and ERDAS IMAGINE 2015. Urban green infrastructure has a great role in attractive the quality of life of urban inhabitants and in supporting urban metabolism (Braubach et al., 2017). However, urban green infrastructure has experienced a physical and social decline, while its heterogeneousness and fruitfulness are often neglected and its contribution to the well-being of a community ignored within current urban planning instruments. The general work flow of the research shown in fig 3.2.

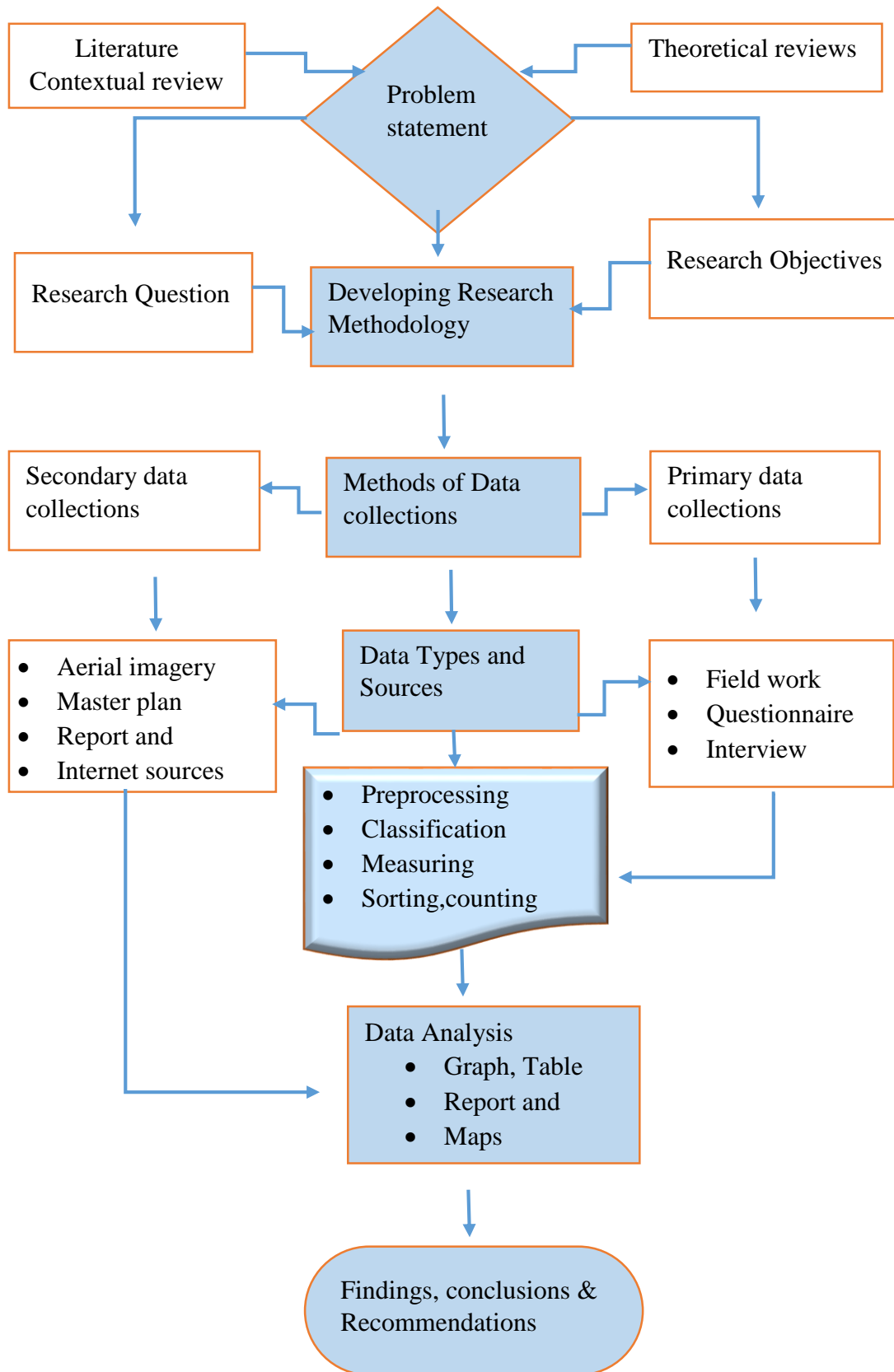


Figure 3.2. Systematic work of research

3.9. Validity and Reliability

It is important to ensure the validity and reliability of the survey instruments to produce reliable and actionable findings. Precision refers to the degree to which a test instrument accurately measures what it is intended to measure. To ensure content validity, surveys and interview questions should be designed to cover all relevant aspects of access, including physical access, perceived safety, social inclusion and usability, and my research shows it was used.

Standard validity involves comparing subjective survey data with objective data such as correlating residents' perceptions of green space accessibility with GIS-based measures of proximity to parks to validate the results. For broader applicability, external validity must be considered by including diverse neighbourhoods within Koye Feche Sub City to ensure that the results can be comprehensive to other urban area.

Reliability, which refers to the consistency of a measurement tool, is equally important. Internal consistency can be assessed using statistical techniques such as Cronbach's alpha to determine whether multiple survey items intended to measure the same concept yield similar responses. Systematically ensuring both validity and reliability, I am conducting research. It can increase the provision of urban green infrastructure (UGI) in Koye Feche Sub-City based on the precision of their results. Carefully developed and tested measurement instruments allow for the generation of accurate insights, which can inform fair urban planning practices and promote the development of green spaces that are more inclusive and sustainable.

3.10. Ethical Considerations

Ethical considerations were treated as essential to ensure the integrity of the research and the protection of all participants. The researcher adhered to established ethical guidelines throughout the entire process, placing a strong emphasis on informed consent, confidentiality, minimizing harm, ethical oversight, and transparency. For all informed permission was obtained from all participants before data collection began. Each participant was clearly informed about the study's objectives, procedures, potential risks, and expected benefits. Confidentiality and obscurity were rigorously maintained throughout the study. All

personal data collected were anonymized, with identifying information either removed or coded to protect the identities of participants. The data were stored securely on password-protected devices, and backups were kept in secure locations. Only authorized members of the research team had access to the data, ensuring that participants' privacy was preserved.

The research process also prioritized minimizing any potential harm to participants. During interviews and focus group sessions, the researchers created a respectful and supportive atmosphere, which helped participants feel at ease while sharing their perspectives. The team remained attentive to signs of discomfort and responded appropriately when needed. Before beginning the study, the research proposal was submitted to a recognized ethical review board for formal approval Advisors and departments. This step ensured that the research complied with all necessary ethical standards. Ethical oversight was maintained throughout the study period, allowing the team to address any emerging concerns or challenges in a timely and responsible manner. Transparency and accountability were also central to the research process. The findings were shared with both academic and local communities in accessible formats, making the results understandable to non-specialist audiences.

CHAPTER IV: RESULTS AND DISCUSSIONS

4.1. Demographic characteristics of the Respondents

In this study the analysis of factors influencing Urban Green Infrastructure accessibility in Koye Feche Sub-City was carried out using a combination of socio-economic data, structured questionnaires, and field interviews. A survey of 341 people was conducted using the socioeconomic data as a basis. From the total participants 184 completed the questionnaire completely, and 198 of them gave input via the questionnaire and the interview, A 58.1% response rate for quantitative analysis is good and can be deemed strong in the majority of research contexts matter, survey design, follow up. Ten surveys were also partially filled out, offering helpful answers to particular queries. However, four entries were incorrect and difficult to understand the responses because they contained redundant data, misunderstandings, or inconsistent information that undermined their legitimacy. Furthermore, throughout the interviews, the remaining respondents provided oral comments, offering insightful opinions and recommendations about the topic of interest.

Table 4.1 illustrate the results show that these respondents represented a gender participant with 70.65% male and 29.3% female participants. Participants were almost All of them are aged more than 25 years or older, with the largest proportion (43.48%) falling within the 35 to 44-year age range. This age group, often actively engaged in the workforce and urban life, provided particularly relevant insights into daily accessibility challenges and usage patterns of green spaces. Additionally, respondents were asked about their duration of live residence in the area, which is an important indicator of their familiarity with local infrastructure and services area knowledge. The responses showed that 11.96% had lived in the area for 1 to 3 years, 48 participants which account for 26% for 4 to 6 year. Other ranges from seven to ten years 56 participant which account for 30.43% lived in the area and the high percentage 31.5% of participants are live more than ten years and above in study area.

The results indicate several physical factors that influence access to green spaces. These include the distance between residential areas and green infrastructure area, the condition and presence of pedestrian-friendly infrastructure such as sidewalks, and the availability of public transportation. Another one is Poor maintenance of pathways and unsafe or

inconvenient routes were reported as barriers, particularly for women and older adults. In addition to these physical elements, several social factors were identified as significant. Many respondents raised concerns about personal safety in green spaces, citing issues such as crime and inadequate lighting. Social norms and cultural expectations also influenced who felt comfortable accessing public green areas. In some cases, a lack of awareness or information about the existence and location of green spaces limited their use, even when those spaces were physically nearby. These findings highlight the importance of considering both tangible infrastructure and intangible social dynamics when planning for equitable UGI access. Addressing these combined factors is essential for creating inclusive, accessible, and analyse the spatial distribution of UGI accessibility and identify areas with limited access.

Table 4.1: the general information of respondents Gender and age group distribution

Gender		Frequency	Percentage
Valid	Male	130	70.65
	Female	54	29.35
	Total	184	100
Age group		Frequency	Percent
Valid	25-34	28	15.22
	35-44	80	43.48
	45-60	35	19.02
	60 or older	41	22.28
	Total	184	100
how long you live in this area		Frequency	Percent
Valid	1–3 years	22	11.96
	4–6 years	48	26.09
	7–10 years	56	30.43
	More than 10	58	31.52
	Total	184	100.00

Table 4.1 presents the gender and age group of the respondents, along with data on their distance of residence in the study area.

4.1.1. Quality and Accessibility of Green Infrastructure

Numerous metrics and techniques can be used to evaluate the quality of green infrastructure, including Spatial analysis, ecological assessments, user feedback, safety evaluations, and community engagement are all components of a thorough method for gauging the quality of green infrastructure. This comprehensive assessment guarantees that green areas successfully serve community needs while advancing environmental well-being.

In order to better understand respondents' opinions and experiences, the researcher asked them a number of important questions as part of the examination into the quality and accessibility of Urban Green Infrastructure. In addition to describing their primary means of transportation for daily commuting and accessing green spaces, participants were asked to rate the general quality of the green spaces in their area and to identify the key variables influencing their ability to access these areas.

Another variable that examined were whether they believed there is equitable access to green spaces within their neighborhood. These questions aimed to capture both individual and practical dimensions of UGI accessibility, reflecting the lived experiences of urban residents. The responses to these questions provide valuable insights into how green infrastructure is perceived and utilized, and the results are summarized and presented in Tables 4.2 and 4.3.

The results presented in Table 4.2 provide insights into respondents' perceptions of the quality of green spaces in their area, as well as the modes of transportation they use to access these spaces or commute daily. When asked to rate the quality of green spaces in their neighbourhood, only 15.22% of respondents described them as excellent, and 20.11% rated them as good. A smaller portion, 14.13%, considered the quality to be average. However, a significant number of respondents expressed dissatisfaction, with 25.54% rating the green spaces as poor and 25% as very poor. These findings indicate that more than half of the respondents perceive the green infrastructure in their area to be of low or very low quality, suggesting a need for improvement in the maintenance, design, and accessibility of these spaces.

In terms of transportation, the majority of respondents (35.33%) reported walking as their primary means of accessing green spaces or commuting, highlighting the importance of pedestrian-friendly infrastructure. Public transportation was the second most common mode, used by 27.17% of respondents, followed by private cars at 12.5%. Only 15.76% used

bicycles, while 9.24% indicated other forms of transport, possibly including shared rides or motorcycles. These patterns suggest that accessibility to green spaces is closely tied to non-motorized and public transport options, underlining the need for integrated urban planning that supports sustainable and equitable mobility for all residents.

In this study, the quality of Urban Green Infrastructure (UGI) was understood as a multidimensional concept encompassing several key factors. These include Maintenance and cleanliness: such as the presence of litter, overgrown vegetation, and damaged or poorly maintained facilities. Design and aesthetics also play a crucial role, referring to the visual appeal of green spaces, including the presence of trees, landscaping, seating, and walkways. Safety and security were important considerations, with factors like lighting, visibility, and the perceived risk of crime influencing how residents experience and use these areas. Functionality and usability relate to how well green spaces serve the needs of the community, including recreational opportunities and accessibility for people of all ages and abilities. Ecological health was another component, measured by vegetation density, plant diversity, and overall environmental condition. Finally, accessibility, including the ease of entry, walkability, and proximity to residential zones, also contributed to the perceived quality of UGI. The high proportion of respondents who rated green spaces as poor or very poor indicates deficiencies in one or more of these areas. These findings point to the need for targeted improvements in green space management, enhanced design standards, and community-driven planning to strengthen both the environmental and social functions of UGI in Koye Feche Sub-City. Table 4.2 show Based on the above quality, respondents were asked to rate it as: Excellent, Good, Average, Poor, or Very Poor

Table 4.2 Quality of existing UGI and mode of transportation for accessibility

Quality of UGI in your area	Frequency	Percentage
Excellent	28	15.22
Good	37	20.11
Average	26	14.13
Poor	47	25.54
very poor	46	25.00
Total	184	100.00

Mode Of Transportation For Daily Commuting Or Accessing UGI	Frequency	Percentage
Walking	65	35.33
Cycling	29	15.76
Public transportation (Bus, Train, etc.)	50	27.17
Private car	23	12.50
Other	17	9.24
Total	184	100.00

In conclusion, the findings from the survey reveal significant challenges related to both the quality and accessibility of Urban Green Infrastructure (UGI) in the study area. A large portion of respondents rated the quality of green spaces as poor or very poor, indicating widespread dissatisfaction with the condition, maintenance, or usability of these areas. This perception reflects a need for targeted improvements in the design, upkeep, and functionality of green infrastructure to better serve the local community.

Additionally, the data on transportation modes shows that most residents rely on walking and public transport to access green spaces, underscoring the importance of safe, accessible pedestrian pathways and efficient public transit systems. The relatively low use of bicycles and private cars suggests that green infrastructure should be better integrated within walkable distances and supported by inclusive urban mobility strategies. Together, these results highlight the urgent need for urban planning initiatives that prioritize both the enhancement of green space quality and the removal of access barriers to ensure that all residents, regardless of their location or mode of transport, can benefit from urban green infrastructure.

I) Factors influence access to green spaces in study area

Another aspect explored is the factors that affect individuals' access to green spaces, as presented in Table 4.3. The most influential factor was the lack of green space options, cited by 21.74% of respondents. This was followed by proximity to home (19.57%), and personal physical limitations, such as mobility issues (16.85%). Other significant factors included maintenance and cleanliness (14.13%) and the availability of amenities like benches and

lighting (12.5%). Less commonly reported barriers were safety concerns related to crime (6.2%) and accessibility issues such as poor walkability or limited public transport (16.85%).

Table 4.3: factors influence access to green spaces

Factors Influence Access To Green Spaces	Frequency	Percentage %
Proximity to home	36	19.57
Safety (crime rates in the area)	15	8.15
Accessibility (walkability, public transport availability)	13	7.07
Availability of amenities (benches, lighting, toilets)	23	12.50
Maintenance (cleanliness, infrastructure condition)	26	14.13
Personal physical limitations (mobility issues)	31	16.85
Lack of green space options	40	21.74
Total	184	100.00

The availability of amenities such as benches, lighting, and toilets influenced 12.5% of responses, pointing to the role of comfort and convenience in enhancing user experience. Although less frequently mentioned, safety concerns related to crime (8.15%) and accessibility challenges like limited public transport or poor walkability (7.07%) remain important considerations. Collectively, these findings stress that both the availability and quality of green spaces, as well as ease of access, are crucial for ensuring that all individuals can benefit from them.

ii) Equitability access to green spaces in neighborhood in study area

To understand current levels of accessibility to urban green infrastructure (UGI), respondents were asked the following key question: "Do you feel there is equitable access to green spaces in your neighbourhood?" This question aimed to gather perceptions on whether all community members have fair and equal access to green areas. The responses, detailed in Table 4.4, showed that only 30.98% of respondents believed that all areas within their neighbourhood had similar access to green spaces. In contrast, a significant majority 51.63% felt that some areas were better served than others in terms of green space availability. Additionally, 17.39% of the respondents indicated that they were unsure about the level of access.

Table 4.4: Equitability access to green spaces in neighborhood

Equitability access to green spaces in neighbourhood	Frequency	Percent
Yes, all areas have similar access	57	30.98
No, some areas have better access than others	95	51.63
Not sure	32	17.39
Total	184	100

The survey results reveal a notable disparity in perceived access to green spaces among residents. While just over a quarter (30.98%) of participants believed that green space access was equitable across their neighbourhood, the majority (51.63%) disagreed, reporting that certain areas enjoyed better access than others. This suggests potential spatial inequalities in the distribution of urban green infrastructure. A smaller portion of respondents (17.39%) were uncertain, possibly reflecting a lack of awareness or exposure to different parts of the neighbourhood. These findings highlight the need for more inclusive urban planning strategies to ensure equitable distribution of green spaces.

4.1.2. Physical Factors Affecting UGI Accessibility

To better understand the physical factors influencing accessibility to Urban Green Infrastructure (UGI), several key aspects were explored through a structured questionnaire. The data collected focused on both the availability and condition of UGI facilities, as well as the physical ease of accessing them. Respondents were first asked about the types of UGI infrastructure available in their area, providing insight into the variety and presence of green spaces such as parks, gardens, green corridors, and street greenery. Secondly, participants indicated how far the nearest UGI facility (e.g., park, public transport stop) was from their residence, helping to assess spatial proximity and convenience of access.

In addition, the survey inquired about the condition of UGI infrastructure in their neighbourhoods, enabling an evaluation of whether existing facilities are functional, inviting, and fit for use. Another critical element examined was the accessibility of UGI facilities in terms of physical barriers such as uneven pathways, lack of ramps for individuals with mobility issues, or poor signage, which can significantly hinder equitable access. Respondents were also asked to assess the safety of pathways leading to UGI spaces,

particularly with respect to pedestrian-friendly features like proper street lighting and the absence of traffic hazards. Lastly, perceptions regarding how well-maintained the UGI facilities are were gathered to understand upkeep practices and their impact on usability.

The data collected for these questions are presented and analysed in Tables 4.5 to 4.7 and Figures 4.1 to 4.2, providing a comprehensive overview of the physical dimensions influencing UGI accessibility in the study area.

I) Availability of UGI Infrastructure

Availability of urban green infrastructure was presented in table: 4.5 the results show the distribution of numerous types of Urban Green Infrastructure (UGI) available in the study areas, offering insight into how different components of UGI are represented within the urban landscape. According to the respondent's response, parks were the most commonly reported type of infrastructure, cited by 25.54% of respondents. This indicates that parks remain a central and widely accessible feature of urban green space, playing a significant role in providing recreational opportunities, promoting physical activity, and enhancing mental well-being. Playgrounds accounted for 15.76% of the responses, highlighting their importance as key facilities for children's outdoor activities and social interaction. Public transportation hubs, such as bus or train stations, were mentioned by 15.22% of respondents, reflecting the integration of green infrastructure with transit systems and their potential role in promoting sustainable urban mobility when designed with green elements like shaded waiting areas, green roofs, or surrounding vegetation.

Streets and pedestrian pathways were identified by 17.29% of respondents, suggesting a moderate presence of green-integrated walkways that support active transportation modes like walking and cycling. These pathways, when well-designed with trees, benches, and green buffers, contribute to a more comfortable and environmentally friendly urban experience. Other types of UGI were less commonly reported. Waste management facilities (7.07%), water treatment and sanitation systems (9.78%), and storm water management systems (9.24%) received fewer mentions. Although these systems play a vital role in urban sustainability such as managing runoff, reducing pollution, and supporting water reuse their lower visibility or public awareness may explain their limited recognition. It is also possible

that these facilities are not equitably distributed or are less integrated into public-facing green space design.

Table 4.5: Types of UGI infrastructure are available in area

Types of UGI infrastructure	Frequency	Percentage
Parks	47	25.54
Playgrounds	29	15.76
Public transportation hubs (bus/train stations)	28	15.22
Streets and pedestrian paths	32	17.39
Waste management facilities	13	7.07
Water treatment and sanitation systems	18	9.78
Storm water management systems	17	9.24
Total	184	100.00

The results suggest that while traditional recreational green spaces like parks and playgrounds are relatively prevalent, there is a need to improve the visibility, accessibility, and public awareness of more functional and infrastructural components of UGI. Integrating these systems more visibly and effectively into urban environments could enhance both their ecological benefits and public engagement.

ii) **Proximity to the Nearest UGI Facility**

The distance between respondents' residences and the nearest Urban Green Infrastructure (UGI) facility such as a park or public transportation stop was used to assess spatial accessibility and convenience of access. As illustrated in Figure 4.1, the responses show a wide variation in proximity. Only 18% of participants reported having a UGI facility within a 5-minute walk from their home, indicating limited immediate access for a small portion of the population. A slightly larger group, 26.6%, stated that it took them between 5 to 10 minutes to reach the nearest facility, while 23.14% reported a walking distance of 10 to 20 minutes. However, a significant 32.16% of respondents noted that it takes them more than 20 minutes to access the closest UGI feature.

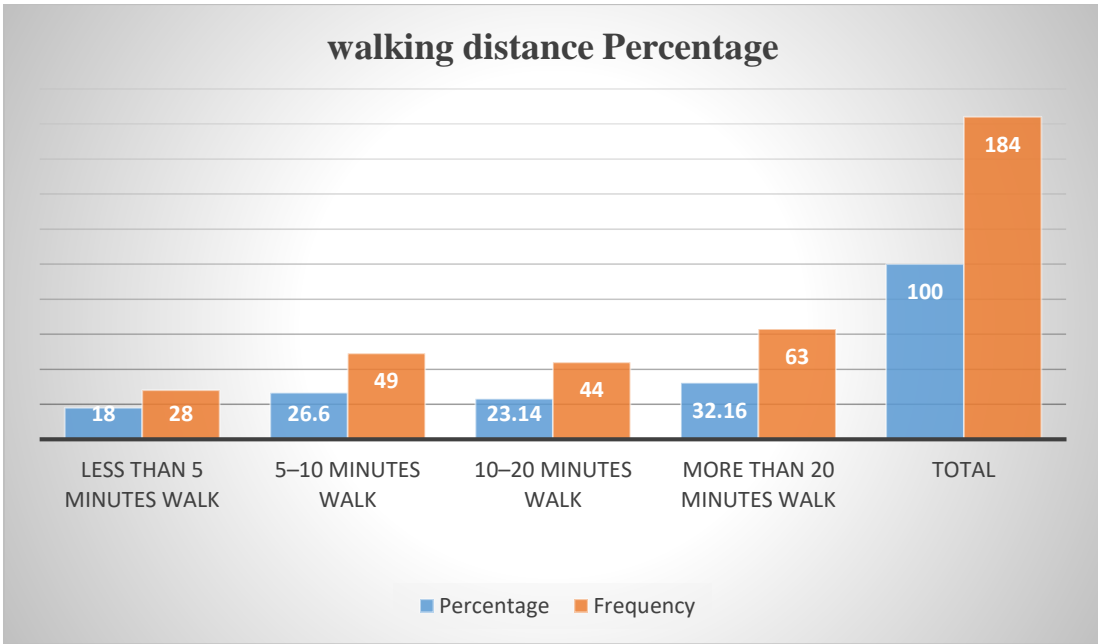


Figure 4.1: Proximity to the Nearest UGI Facility

The above results that a substantial portion of the population does not enjoy convenient access to UGI, which may delay regular use and reduce the associated environmental and health benefits. The fact that nearly 40% of respondents live more than a 20-minute walk from UGI highlights potential spatial inequities and points to the need for improved planning and distribution of green spaces and related infrastructure. Urban planners and local authorities may need to prioritize the development of smaller, more distributed green spaces within residential areas to enhance equitable access and reduce walking distances for the majority of urban residents.

iii) Condition of UGI Infrastructure

Respondents were also asked to evaluate the current condition of UGI infrastructure in their area. The feedback reflects a wide spectrum of opinions, with a considerable lean toward dissatisfaction. Only 15.76% of respondents rated the condition of their local UGI as excellent, and just 13% rated it as good. Meanwhile, 21.74% considered it average. A significant portion of the respondents expressed negative views, with 26.1% rating the condition as poor and another 23.4% describing it as very poor.

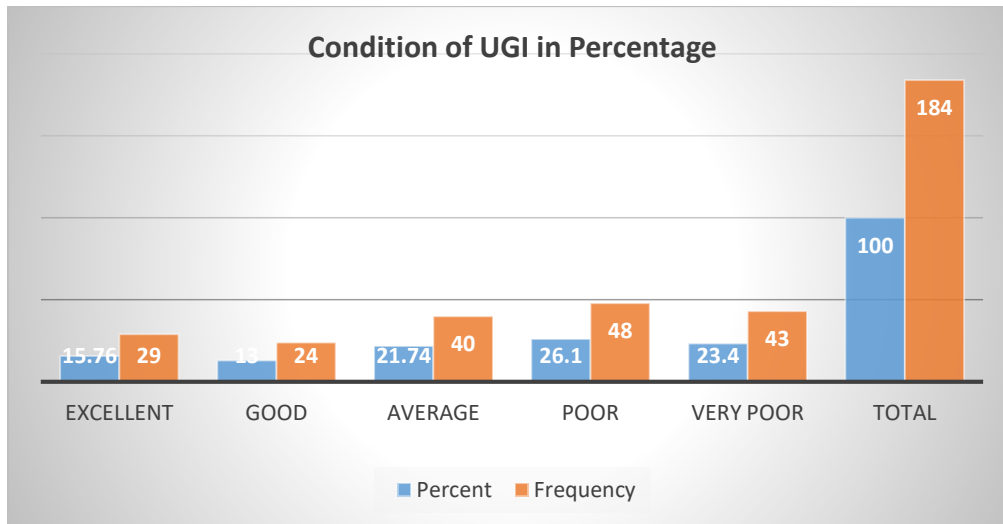


Figure 4.2: Condition of UGI Infrastructure

Thus, the results indicate the small group of villages are sufficient facility and large group of community are not satisfying to facility. Poorly maintained infrastructure can discourage use, decrease safety and aesthetic appeal, and ultimately undermine the environmental and social functions that UGI is meant to serve. The high percentage of negative responses underscores the urgent need for investment in maintenance, rehabilitation, and community-led initiatives to restore and preserve UGI spaces. According to gathered data in addition these perceptions may be tied to local governance, budget allocations, and varying standards of infrastructure management across neighbourhoods, pointing to the importance of inclusive and accountable urban management strategies.

Another major line of research focuses on the accessibility of Urban Green Infrastructure (UGI) institutions, especially in relation to physical barriers. This includes assessing whether uneven terrain, inadequate or missing ramps, and poor or inadequate signage may impede access, particularly for individuals with mobility impairments, the elders. A second important question examines the safety and convenience of pedestrian routes to UGI sites. This involves assessing factors such as the availability and effectiveness of street lighting, the presence or absence of traffic-related dangers, and whether crosswalks and pedestrian pathways are clearly marked and secure for users of all ages. The third question addresses the maintenance standards of UGI facilities within the study area. This includes looking at the cleanliness, structural condition, upkeep of vegetation, and functionality of public amenities such as benches, trash bins, playground equipment, and water fountains.

The findings related to these three questions are summarized and visually represented in Figure 4.3 and figure 4.4, which highlights patterns of accessibility, safety, and maintenance levels across the surveyed UGI sites.

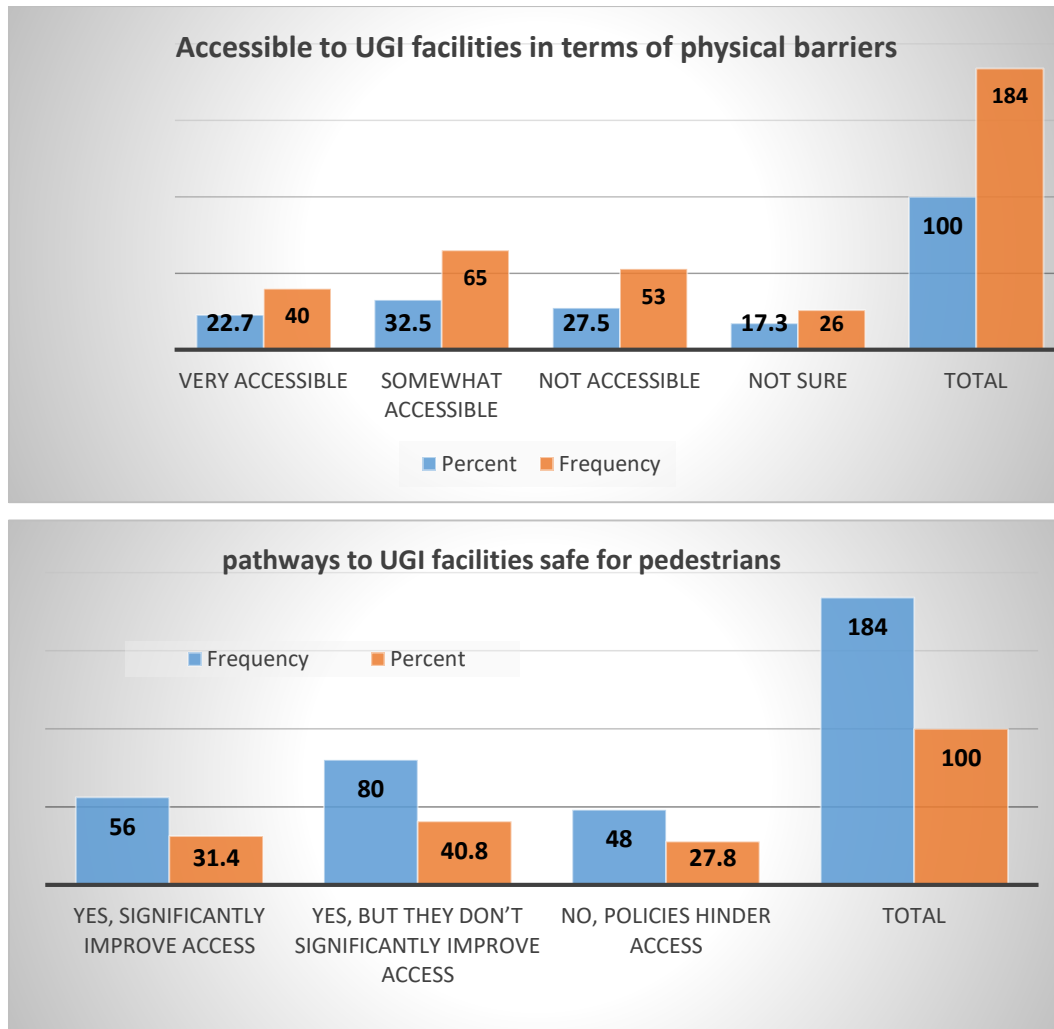


Figure 4.3: Accessible to UGI in terms of physical barriers and facility safety for pedestrians

Figure 4.3 illustrates public perceptions regarding the accessibility of Urban Green Infrastructure (UGI) facilities, specifically in relation to physical barriers such as uneven surfaces, missing ramps, or inadequate signage. As reflected on the left side of Figure 4.3, 22.7% of respondents rated UGI spaces as very accessible, indicating minimal physical obstacles and ease of entry for most users. A further 32.5% described them as somewhat accessible, suggesting that while access is possible, there are still notable challenges that may inconvenience certain groups such as the elderly, people with disabilities, or those with strollers. In contrast, 27.5% considered the facilities not accessible, pointing to significant

limitations that prevent easy or inclusive use. Additionally, 17.3% of participants were unsure, likely reflecting a lack of familiarity with these spaces or uncertainty about what constitutes accessibility.

On the other hand, on the right side of Figure 4.3, the perception of pedestrian safety was also assessed on the roads leading to the UGI sites. 31.4% of respondents believed that these roads were very safe, indicating features such as adequate lighting, traffic separation and clear walkways. A high responses 40.8% fall the paths were somewhat safe, implying that while generally usable, there may be minor safety concerns such as insufficient lighting or occasional traffic hazards. However, 27.8% perceived the paths as not safe, highlighting more serious issues like poor infrastructure, lack of crosswalks, or exposure to vehicular traffic.

To summarise, the data highlights a mixed yet informative picture of how UGI facilities are experienced by the community. The data show above half of the participants find these urban green spaces and their access routes at least moderately usable and safe, a significant minority face accessibility challenges and safety risks. These results suggest the need for targeted improvements in physical infrastructure such as smoother pathways, better lighting, and inclusive design features to enhance both access and safety, ensuring that UGI benefits are equitably available to all members of the community.

The final physical factor assessed in the survey was the overall maintenance condition of Urban Green Infrastructure (UGI) facilities in the respondents' area. The results, as illustrated in Figure 4.4, reveal a wide range of perceptions regarding upkeep and facility management. Only 16.8% of respondents rated the UGI facilities as very well-maintained, indicating that a relatively small portion of the population finds these spaces to be in excellent condition, likely characterized by clean environments, healthy vegetation, functioning amenities, and regular upkeep. An additional 31% believed the facilities were well-maintained, suggesting that while not perfect, the spaces are generally cared for and remain usable for public enjoyment.

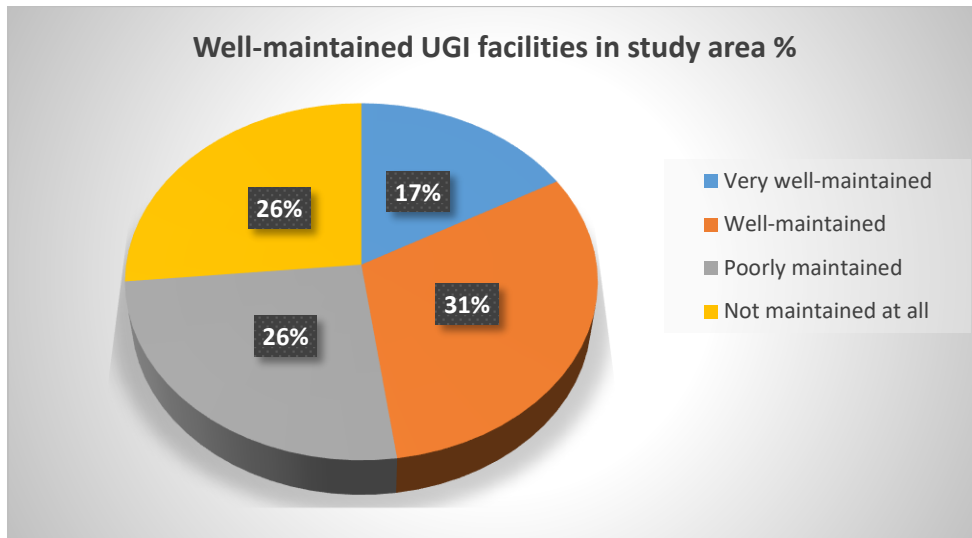


Figure 4.4: overall maintenance condition of Urban Green Infrastructure.

On the other hand, a considerable share of participants expressed concerns about the quality of maintenance. 25.7% rated the facilities as poorly maintained, likely pointing to issues such as overgrown vegetation, broken infrastructure, littering, or infrequent cleaning. Even more concerning, 26.5% reported that UGI facilities were not maintained at all, indicating severe neglect in some areas possibly leading to unsafe or unusable conditions. This is because a segment of the population experiences well-maintained green space and about 52% feel that maintenance is inadequate or non-existent at all which reveals that there is a lack of maintenance.

4.1.3. Social factors affecting UGI accessibility

As mentioned previous identification of facts that affect UGS the analysis of social factors influencing access to Urban Green Infrastructure (UGI), as presented in Figure 4.5 to 4.7, show several critical challenges that affect how different groups engage with these spaces. A significant number of respondents indicated that social and economic conditions such as residing in low-income areas or being part of marginalized communities can limit access to UGI, suggesting a clear link between socioeconomic status and availability or quality of green space.

i) Perceived Social and Economic Barriers to Access in Koye Feche Sub-City:

The results of survey highlight the extent to which social and economic factors influence access to Urban Green Infrastructure (UGI) in Study area. As illustrated in Figure 4.5: an important 54% of respondents believe that social or economic barriers significantly limit access to UGI in their area. This suggests that individuals living in low-income neighbourhoods or belonging to marginalized communities such as ethnic minorities, informal settlers, or unemployed populations face greater difficulty in reaching and utilizing green spaces. An additional 39.8% approved that while these barriers exist, they do not affect access significantly, implying some level of disparity that, while present, may not be perceived as severe. Only 6.2% of participants felt that all groups have equal access, indicating a strong consensus that inequalities persist within the community.

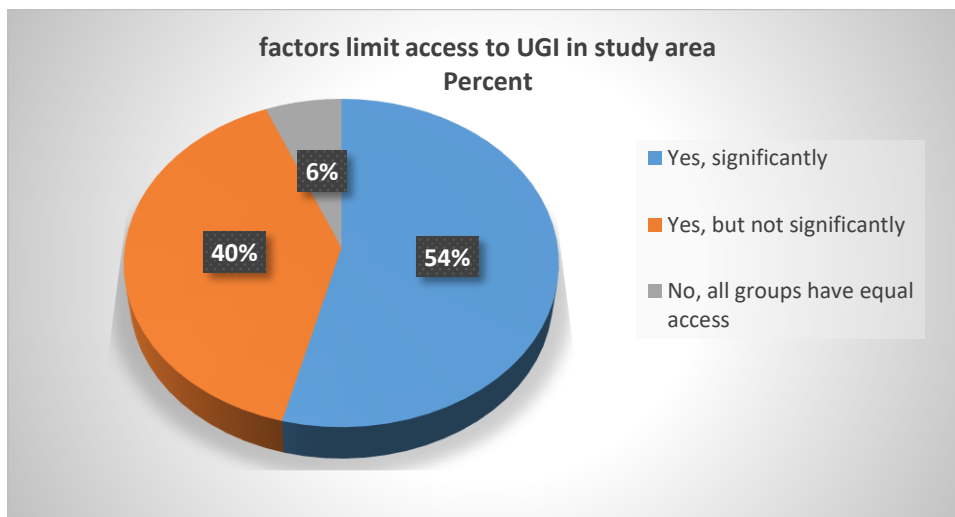


Figure 4.5: Level of social or economic factors limit access to UGI in study area

As illustrated in above figure 4.5 these findings point to a clear socio-spatial divide, where access to environmental benefits like green infrastructure is not equitably distributed. The presence of structural limitations such as underinvestment in UGI development in low-income areas, lack of safe or convenient transport routes, and absence of inclusive design likely contributes to this uneven access. In conclusion, the data underscores the urgent need to prioritize equity-focused urban planning in Koye Feche Sub-City. Addressing these barriers requires both policy-level interventions and on-the-ground improvements, including targeted investment in UGI for disadvantaged areas, inclusive community engagement in

planning processes, and the implementation of strategies that reduce social and economic obstacles to green space use.

ii) Impact of Social Inequality on UGI Accessibility:

Based on responses and interviews with people the findings presented in Figure 4.6 provide sufficient insight into how Koye Feche Sub City residents perceive the role of social inequality including factors such as income level, and gender in shaping access to Urban Green Infrastructure (UGI). The majority of respondents among those who participated (50%) indicated that this equality has a significant impact on how easily different groups in their communities can access UGI. This indicates that marginalized or low-income individuals may face greater challenges in accessing green space, he said, due to the location of the UGI, lack of inclusive cultural design, or broader systemic disadvantages.

Further, 40% agreed that social inequality affects access, although not to a significant extent, indicating that although the issue is recognized, its severity may vary by location or group. Only 10% of participants felt that all groups have equal access, reflecting a strong perception among residents that access to UGI is not equitable across different social demographics in Koye Feche Sub City.

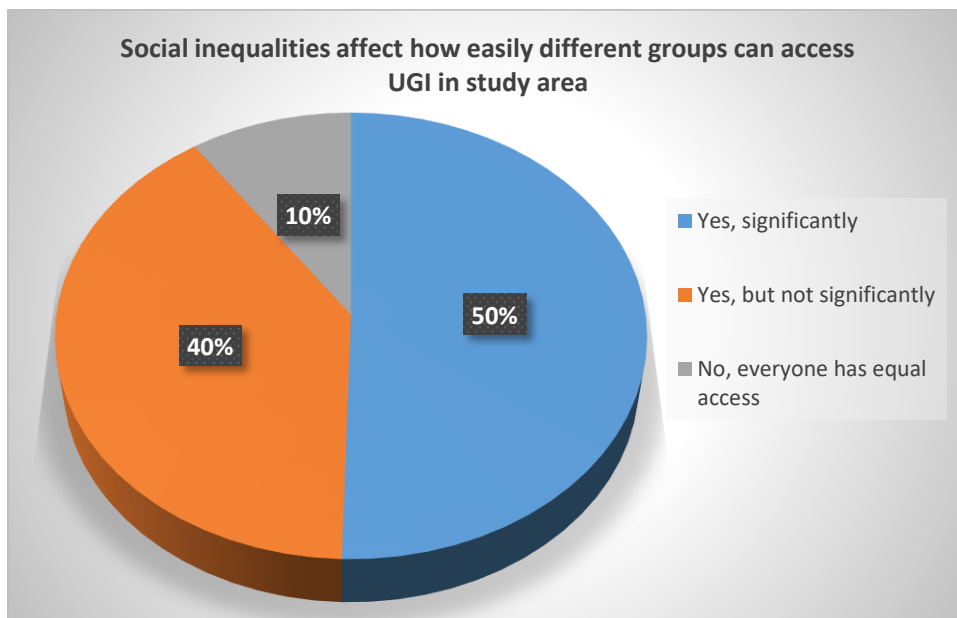


Figure 4.6: social inequalities affect how easily different groups can access UGI in study area

This shows that social inequality is a real and ongoing barrier to inclusive green space use in the sub-city. These results emphasize the need for targeted urban interventions that prioritize equity such as increasing UGI development in underserved areas, involving diverse communities in planning processes, and designing spaces that are accessible, safe, and welcoming for all. By addressing these disparities, Koye Feche can move toward a more just and inclusive urban environment where UGI benefits are shared equitably among its residents.

iii) Availability of Information on UGI in Koye Feche Sub-City:

The survey results regarding the availability of information on Urban Green Infrastructure (UGI) in Koye Feche Sub-City provide valuable insight into how well the local municipality communicates with its residents about green spaces. As shown in Figure 4.7, 35.4% of respondents stated that information about UGI such as locations, opening hours, and accessibility features is very accessible, indicating a moderately effective information dissemination system. A larger share, 45.1%, felt that such information is only somewhat accessible, suggesting that while some efforts have been made, gaps remain in clarity, reach, or inclusiveness. Meanwhile, 19.5% of participants reported that UGI-related information is not accessible at all, highlighting a significant shortfall in municipal communication efforts that may leave many community members unaware of the green spaces available to them or how to use them.

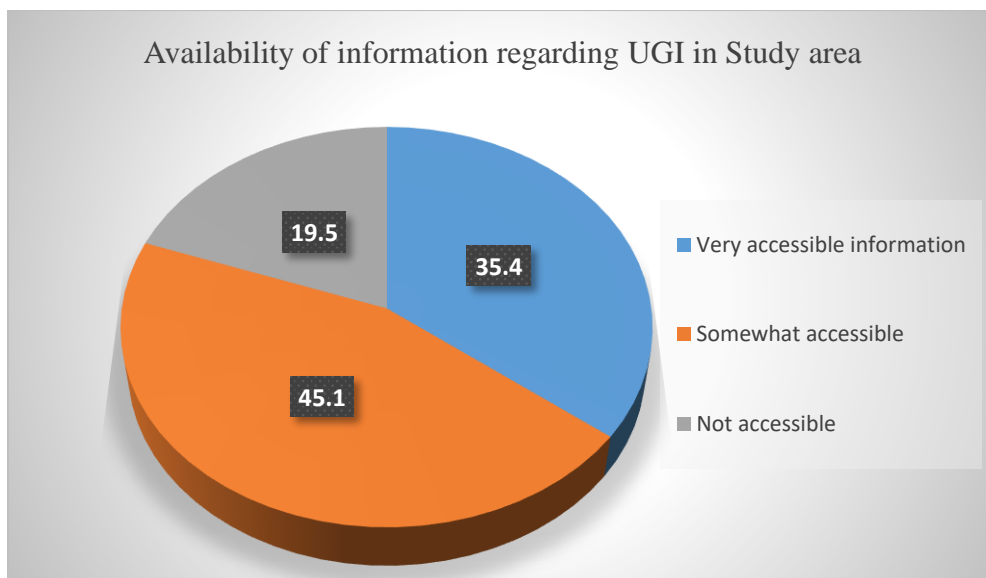


Figure 4.7: Availability of information regarding UGI in your area

These findings reflect a mixed performance in terms of public awareness and outreach. While over one-third of residents receive adequate information, nearly two-thirds still face challenges accessing clear and comprehensive guidance about UGI, which can hinder community engagement and limit equitable use especially for vulnerable groups who rely on public information to make informed choices.

In conclusion, the availability and distribution of UGI information in Koye Feche are insufficiently consistent, and this information gap may contribute to underuse or unequal access to these vital community resources. It is recommended that the municipality adopt more inclusive and proactive communication strategies, such as community notice boards, multilingual signage, digital platforms, and partnerships with local organizations to ensure that all residents regardless of literacy, language, or socioeconomic background are informed about the presence, features, and accessibility of UGI in their area. Enhanced transparency and outreach can significantly improve public engagement and ensure that green infrastructure fulfils its role as an inclusive and widely used public good.

4.1.4. Community Perspectives on UGI Accessibility Challenges and Solutions in Koye Feche Sub-City

In Koye Feche Sub-City, three key survey questions were used to assess deeper community perceptions regarding barriers to Urban Green Infrastructure (UGI) accessibility, the influence of public policy, and potential improvements. The results, as illustrated in Figures 4.8, 4.9, and 4.10, provide a comprehensive view of both the challenges residents face and the opportunities for more inclusive urban development.

i) Barriers to UGI Accessibility Identified by Residents of Koye Feche Sub-City

Figure 4.8 presents the community's responses to the question, "What do you think are the primary barriers to accessing Urban Green Infrastructure (UGI) in your area?" The data highlights a range of challenges that limit effective and equitable use of green spaces in Koye Feche Sub-City. The most commonly reported issue was the distance to the nearest UGI facility, cited by 27.4% of respondents, indicating that many green spaces are not located within easy walking or commuting range for a large portion of the population. Closely following this, 26.5% identified the lack of transportation options such as public transit or

safe walking routes as a significant barrier, particularly affecting those without access to private vehicles.

Other notable concerns included the poor maintenance of UGI facilities (13.3%), which can discourage use due to unclean conditions, broken equipment, or overgrown vegetation. Safety concerns (e.g., related to crime or vehicular traffic) were also highlighted by 12.4% of respondents, pointing to the need for better lighting, surveillance, and safe access routes.

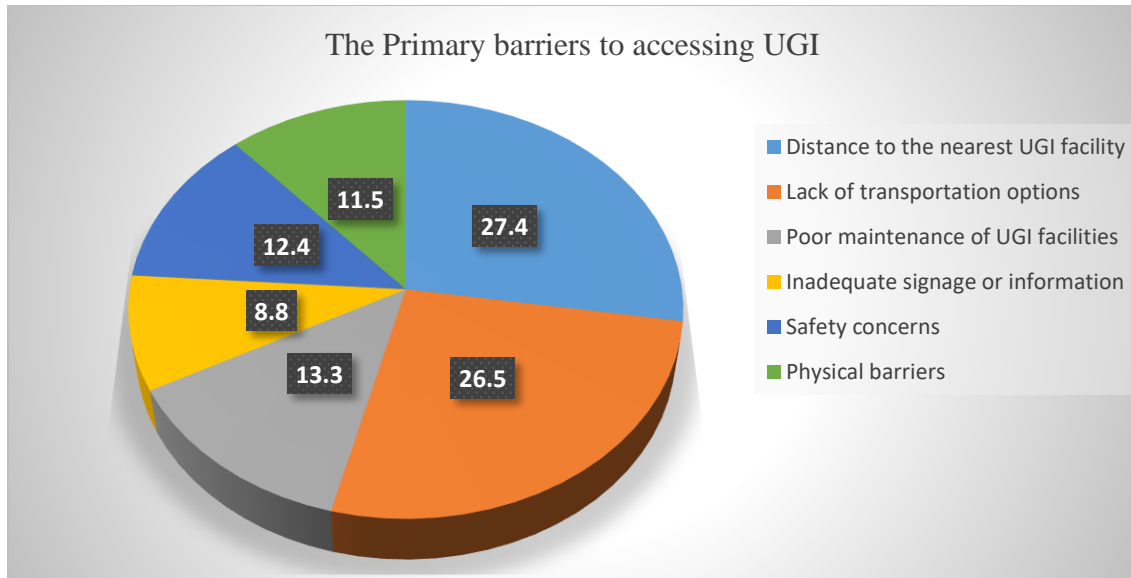


Figure 4.8: primary barriers to accessing UGI in study area.

Additionally, physical barriers such as stairs and absence of ramps were mentioned by 11.5%, revealing the exclusion of individuals with disabilities or limited mobility. Lastly, 8.8% of respondents cited inadequate signage and lack of public information as an obstacle, underscoring the importance of clear, visible communication about the presence and features of UGI spaces. Collectively, these findings emphasize that both spatial planning and infrastructure design must be addressed to enhance accessibility. There is a need for more strategically located, inclusive, and well-connected green spaces, alongside better maintenance and public outreach, to ensure all residents of Koye Feche Sub-City can equitably benefit from UGI.

ii) The Role of Public Policies in Determining UGI Accessibility in Koye Feche Sub-City

The influence of public policies and local government decisions on Urban Green Infrastructure (UGI) accessibility was examined in the survey, with results illustrated in Figure 4.10. When asked whether these policies improve or hinder access to UGI, 28.3% of respondents felt that government actions significantly improve access, suggesting that some planning efforts and investments have had a noticeable positive impact such as the development of new green spaces or upgrades to existing facilities. However, a larger proportion, 49.6%, believed that while policies exist, they do not significantly enhance accessibility.

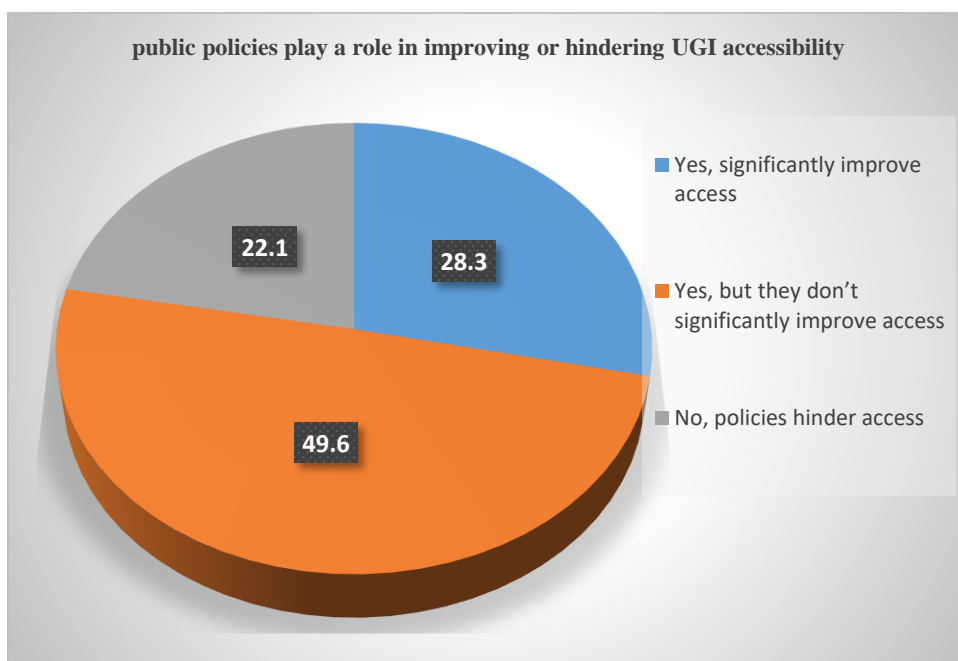


Figure 4.9: public policies (local government decisions) play a role in improving or hindering UGI accessibility

This response may reflect a lack of effective implementation, uneven distribution of resources, or limited follow-through on planning commitments. Meanwhile, 22.1% of participants indicated that policies actually hinder access, pointing to possible neglect of marginalized areas, poor prioritization of UGI in urban planning, or decisions that result in displacement, exclusion, or underinvestment in essential green infrastructure.

These findings reveal that while public policy has the potential to drive equitable UGI access, its impact remains inconsistent in Koye Feche Sub-City. The mixed perceptions suggest that policies may be well-intentioned but often lack execution, inclusivity, or accountability, leading to limited outcomes. In conclusion, for local governments to be effective in improving UGI access, they must move beyond symbolic planning and commit to transparent, community centred, and equity-driven urban policies. This includes engaging residents in decision-making, ensuring fair distribution of green spaces, and integrating UGI goals into broader urban development frameworks to foster lasting and inclusive environmental benefits.

iii) Community improvements suggestion for Enhancing UGI Accessibility in study area

In Koye Feche Sub City suggestions from were invited to share their recommendations for enhancing access to Urban Green Infrastructure (UGI), with their responses detailed in Figure 4.10. The most frequently suggested improvement was better maintenance and cleanliness of UGI facilities, cited by 25.7% of respondents. This highlights a strong demand for regular upkeep, trash removal, and repairs to make green spaces more inviting and usable for all. The second most common recommendation was the removal of physical barriers, such as the addition of ramps and smoother, more navigable pathways (16.8%), which would significantly benefit individuals with mobility challenges, the elderly, and parents with young children.

Improving transportation access to green spaces was another priority, identified by 15.9% of respondents, indicating that distance and lack of affordable or safe transport options still prevent many from using UGI. Enhancing safety, including better lighting and measures to reduce crime, was also emphasized by 11.5%, reflecting ongoing concerns about personal security in public spaces. Meanwhile, 10.6% of participants suggested increasing the number of green spaces, such as parks and playgrounds, to ensure wider and more equitable access. An equal percentage also emphasized the need for better information, including details about locations, hours of operation, and features of UGI sites pointing to an ongoing communication gap. Lastly, 8.8% called for policy reforms that address social inequalities, emphasizing the need for systemic changes to ensure fair distribution and inclusive access across all social groups.

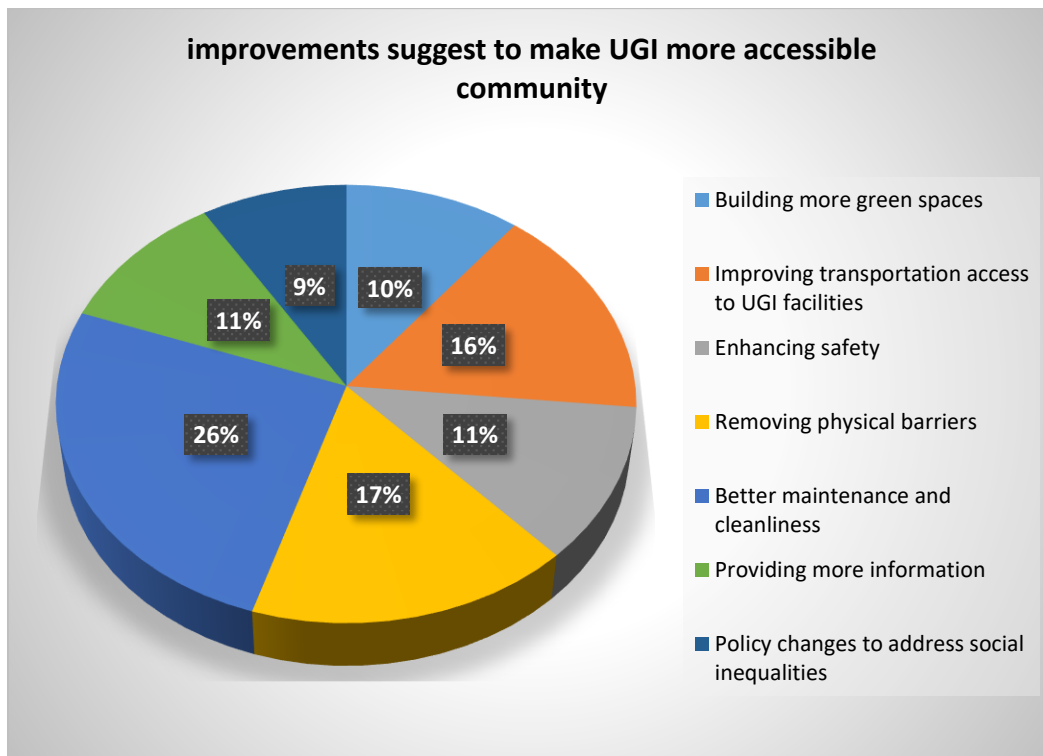


Figure 4.10: improvements suggest to make UGI more accessible in study area

In summary, the community's suggestions demonstrate a comprehensive understanding of the multifaceted barriers to UGI access ranging from infrastructure and transportation to safety, information, and policy. To create truly inclusive and accessible green spaces in Koye Feche Sub-City, local authorities must adopt a holistic approach that combines physical improvements with targeted policy interventions and active community engagement. By responding to these diverse needs, urban planners can ensure that UGI serves as a shared, equitable resource for all residents.

4.2. Identification of areas with limited UGI access a spatial and community-based approach

In this section, efforts to identify areas with limited access to Urban Green Infrastructure (UGI) in Koye Feche Sub-City were carried out using both spatial and non-spatial methodologies. The spatial analysis involved the use of land use/land cover (LULC) image classification in ArcMap along with the Normalized Difference Vegetation Index (NDVI) to detect the distribution and density of vegetated areas across the sub-city. These geospatial tools allowed for the visual mapping of green space coverage, helping to pinpoint

neighbourhoods with minimal or no access to UGI. This was complemented by non-spatial data, primarily collected through community questionnaires.

Participant was asked to suggest improvements for increasing access to green spaces, and their responses provided valuable qualitative data to support the spatial findings. In addition, the study explored community perceptions of the economic benefits associated with green infrastructure, such as increased property values, local job creation, and enhanced neighbourhood attractiveness, which were addressed in related sub-sections. By combining geospatial data with local perspectives, the study was able to offer a more complete understanding of where access disparities exist and what community-driven solutions may be most effective. Finally, this integrated approach merging remote sensing techniques with participatory data provided a nuanced and evidence-based identification of underserved areas. These insights are essential for informing targeted UGI planning and development, ensuring that future investments prioritize equity, accessibility, and environmental sustainability.

4.3. Mapping of Urban Green Infrastructure Distribution in Koye Feche Sub-City

Mapping the distribution of Urban Green Infrastructure (UGI) in Koye Feche Sub-City involves a structured methodology that utilizes Landsat 9 satellite imagery combined with the Normalized Difference Vegetation Index (NDVI) to identify and classify various types of green spaces. The process begins with the acquisition and pre-processing of Landsat 9 images, as outlined in Section 4.3.1. This step includes selecting appropriate imagery and applying necessary radiometric and geometric corrections to ensure accuracy and consistency. In Section 4.3.2, a Level-1 classification is performed to distinguish basic land cover types, primarily separating vegetated areas from non-vegetated ones using supervised classification techniques. Section 4.3.3 involves Level-2 classification, which further categorizes green spaces into broader functional groups such as parks, grasslands, and roadside vegetation. In Section 4.3.4, the analysis is refined through Level-3 classification, which identifies more specific types of UGI based on spatial characteristics and land use context, including institutional greenery, ecological buffers, and recreational zones. To ensure the reliability of the classification results, an accuracy assessment is conducted using ground truth data and statistical validation techniques. The overall workflow of this methodology is visually presented in Figure 4.11.

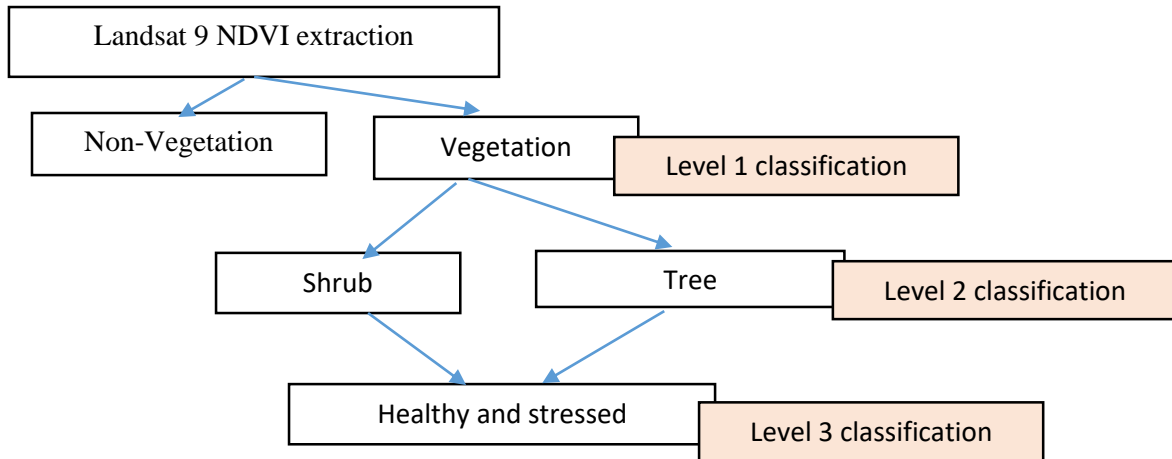


Figure 4.11. High level workflow of, which shows the hierarchical classification at three levels.

The classification process, structured into Level-1, Level-2, and Level-3, is based on fixed NDVI threshold ranges. In Level-1, areas are broadly categorized as either vegetation or non-vegetation. Level-2 further distinguishes vegetated areas into shrubs and trees. Finally, in Level-3, both shrub and tree regions are classified into stressed or healthy vegetation based on their NDVI values.

4.3.1. Acquisition and Pre-Processing of the Landsat Dataset

The initial step of our analysis involved downloading Landsat 9 satellite imagery from the United States Geological Survey (USGS) Earth Explorer platform. One of the main challenges encountered during image acquisition was the presence of cloud cover, which can significantly obscure land surface features and compromise classification accuracy. To address this issue, I applied a cloud cover filter, selecting only images with a cloud coverage percentage between 0% and 10% to ensure clearer observations. Additionally, we defined a specific temporal window from January 01, 2024, to February 2, 2025 to identify the most suitable acquisition dates. This time frame was chosen to increase the likelihood of obtaining cloud-free or minimally cloudy images that align with seasonal vegetation patterns relevant to the study area.

4.3.2. Level-1 Classification

The second step involves classifying the target satellite image into two main categories: vegetation (including features like trees, shrubs, and grass) and non-vegetation (such as

built-up areas, water bodies, and bare land) within the study area. This classification is performed using a fixed NDVI threshold, based on methodologies proposed in earlier research (Aburas et al., 2015) and discussed in the literature review section of this thesis. By applying the NDVI threshold to each pixel in the image, we segment the entire scene into these two broad land cover types. For instance, in Figure 4.12, present the Level-1 classification for the Koye Feche Sub-City, where non-vegetation areas such as urban structures and water are identified by NDVI values below 0.188, while vegetated regions comprising grass, bushes, and trees exhibit NDVI values above 0.188 (as detailed in Table 4.6).

Table 4.6. Level-1 classification of study area into two broad regions non-vegetation and vegetation.

Category	threshold
Vegetation	0.114 to 0.188
non-vegetation	0.188 to 0.5005

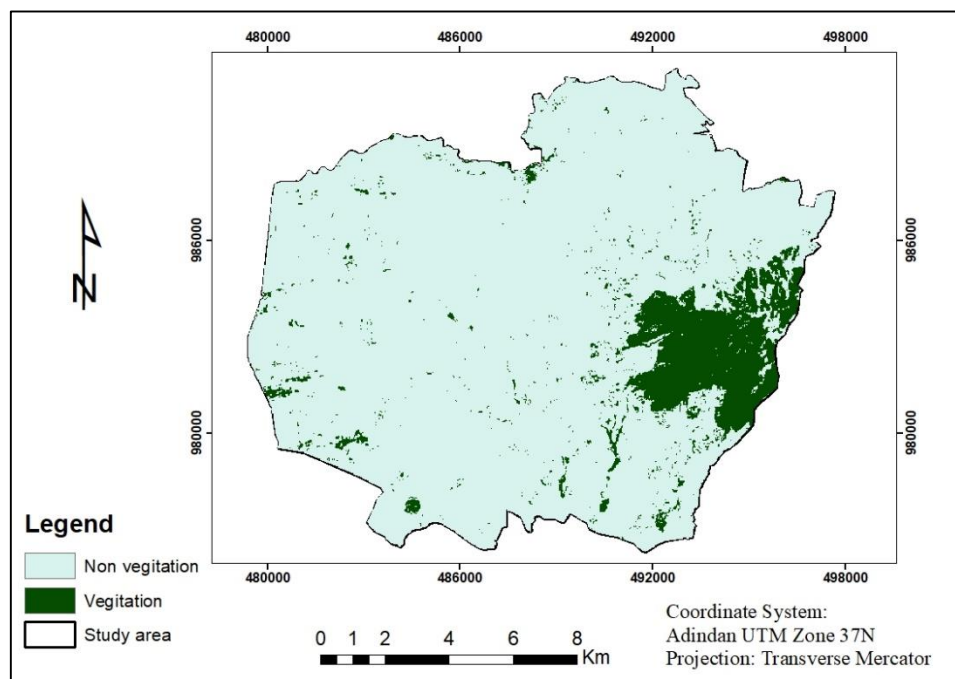


Figure 4.12: Level-1 classification of vegetation and non-vegetation in study area

4.3.3. Level-2 Classification

In the third step of the classification process, we refine the vegetation category by subdividing it into two distinct subclasses: shrub land (which also includes grasslands) and

tree cover. This Level-2 classification enables a more detailed understanding of the spatial distribution and composition of green spaces within the study area. The segmentation is again performed using a fixed NDVI threshold, allowing us to differentiate between areas dominated by lower vegetation, such as shrubs and grasses, and those characterized by taller, denser tree canopies. The NDVI threshold values used for this classification are outlined in table below.

Table 4.7 Level-2 classification of vegetation region into shrub and trees regions.

Category	Threshold
Shrub	0.188 to 0.2601
Trees	0.2601 to 0.5005

A sample output of the Level-2 classification for the Koye Feche Sub-City is illustrated in Figure 4.13, clearly showing how vegetation types are spatially distributed and differentiated within the urban landscape. This step provides a crucial intermediate layer for further analysis of green infrastructure, supporting the identification of ecological structure and landscape functionality.

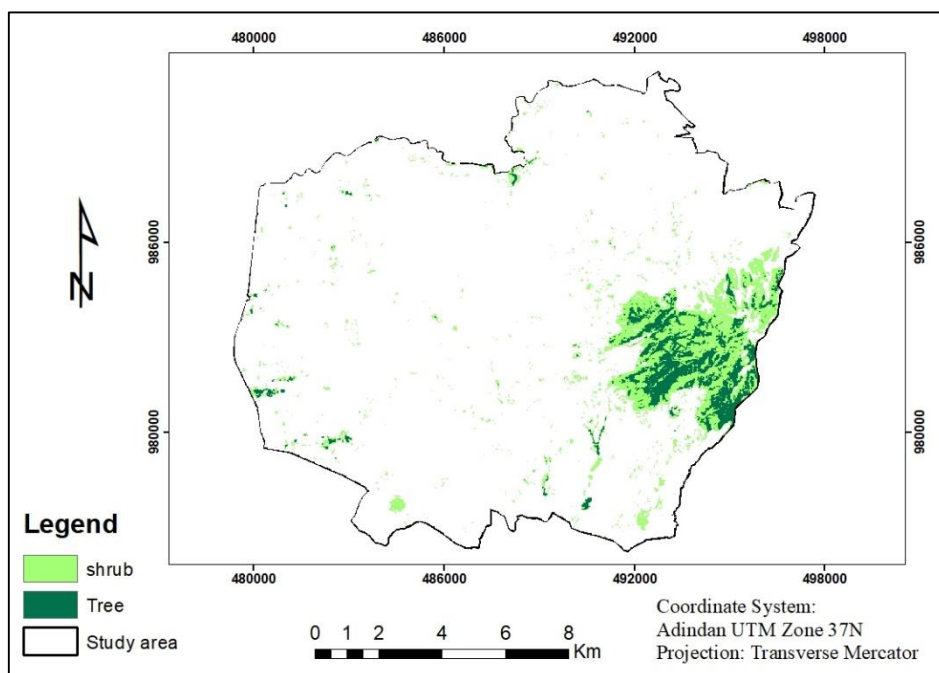


Figure 4.13: Level-2 classification of vegetation region into shrub and trees regions.

4.3.4. Level-3 Classification

In the fourth and final step, we further refine the vegetation categories identified in the Level-2 classification shrubs and trees by subdividing them into two distinct groups: healthy and stressed vegetation (Aryal & Sitaula, 2022). This differentiation is based on NDVI value ranges, where healthy vegetation is characterized by higher NDVI values (ranging from 0.308 to 0.500), while stressed vegetation falls within a lower NDVI range (0.188 to 0.308). This classification approach allows us to assess the overall condition of green cover across the study area.

A visual representation of the Level-3 classification results is provided in Figure 4.14, illustrating the spatial distribution of vegetation health. The specific NDVI thresholds used for this step are detailed in Table 4.8. This final classification enhances our understanding of the ecological status of urban green spaces and supports more informed decision-making for sustainable urban landscape management.

Determining whether the amount of vegetation in Koye Feche Sub-City is sufficient depends on several contextual factors, including urban planning standards, environmental needs, and population density. While the classification results provide a detailed understanding of the type and condition of vegetation through NDVI-based segmentation, this alone does not indicate whether the green cover is adequate. For instance, the World Health Organization (WHO) recommends a minimum of 9 square meters of green space per person, with an ideal standard closer to 50 square meters. Comparing the total vegetated area identified in your analysis to the population size of Koye Feche would offer insight into whether these benchmarks are being met.

Table 4.8. Level-3 classification of shrub region into stressed and healthy regions.

Category	Threshold
Stressed	0.188 to 0.308
Healthy	0.308 to 0.500

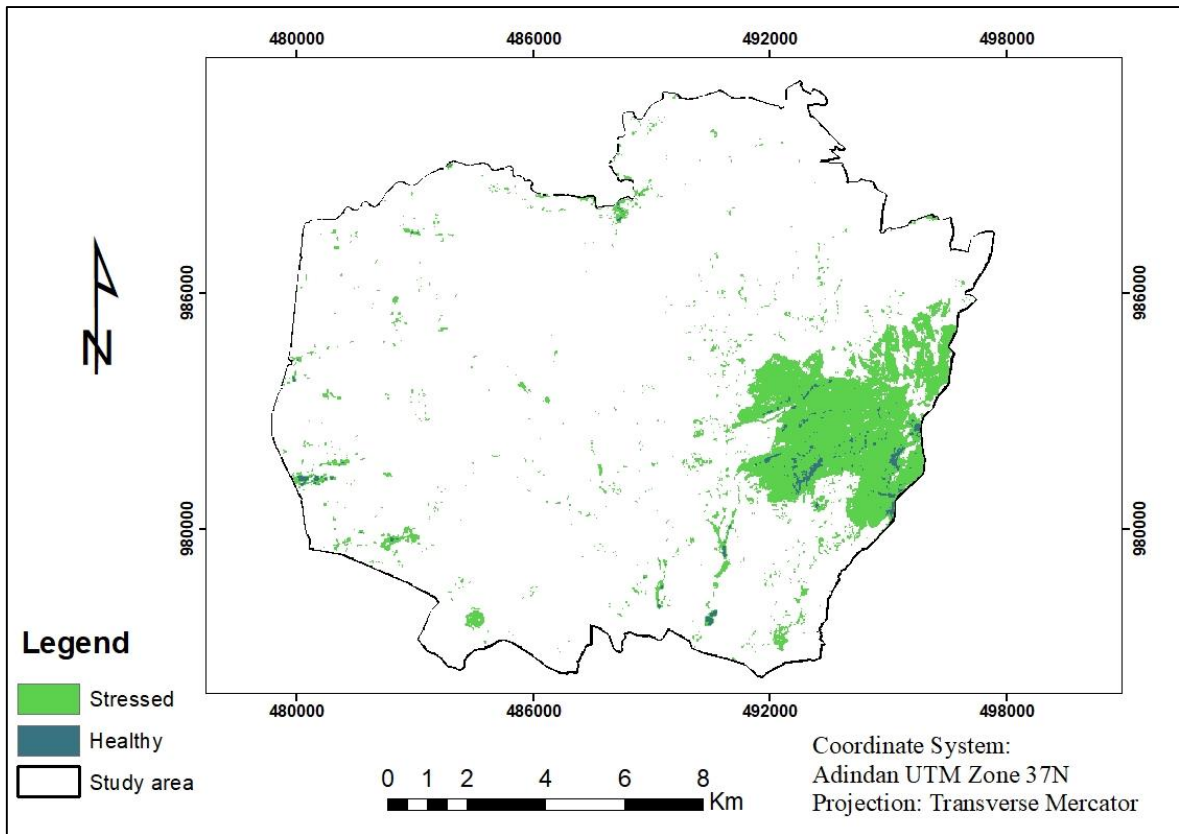


Figure 4.14: Level-3 classification of shrub region into stressed and healthy regions

4.3.5. Land Use/Land Cover Classification to Understand Urban Green Infrastructure in Koye Feche Sub-City

Land Use and Land Cover (LULC) classification is a fundamental approach used in this study to better understand the distribution and role of Urban Green Infrastructure (UGI) within Koye Feche Sub-City. By analyzing satellite imagery and applying classification techniques, the researcher identified five main land cover categories: settlements, vegetation, agricultural land, bare land, and forests. Each of these categories contributes differently to the urban landscape and its ecological functionality. Settlements encompass built-up areas such as residential zones, roads, and infrastructure, typically characterized by high impervious surfaces and limited vegetation. Vegetation refers to green spaces that are not dense enough to be categorized as forests and not cultivated for agriculture, including parks, street greenery, and isolated patches of plant cover these are directly linked to the functioning of UGI. Agricultural land includes areas actively used for crop production and grazing, which, while primarily serving economic purposes, also contribute to ecosystem services and peri-urban green infrastructure.

Bare land includes areas with little to no vegetation, such as exposed soil, degraded land, or sites under development; though currently underutilized, these spaces hold potential for future green infrastructure development. Finally, forests represent areas with dense tree cover that play a critical ecological role in carbon storage, climate regulation, and biodiversity support. The classification of these land cover types provides a comprehensive overview of the urban landscape and helps to assess both the existing green infrastructure and opportunities for improvement in Koye Feche Sub-City.

The Land Use/Land Cover (LULC) classification results for the study area are visually represented in Figure 4.15, while the corresponding area coverage for each land cover class is detailed in Table 4.8. To evaluate the reliability of the classification, an accuracy assessment along with the error matrix was conducted and is presented in Table 4.9.

Table 4.9: overall accuracy Assessment and confusion matrix of classified map

Classified	bare land	Settlement	Agriculture	Vegetation	Open forest	Total	User Accuracy	Kappa
Bare land	7	1	1	1	0	10	0.7	0
Settlement	0	10	0	0	0	10	1	0
Agriculture	0	0	29	1	0	30	0.967	0
Vegetation	0	1	0	9	0	10	0.9	0
Open forest	0	0	0	2	8	10	0.8	0
Total	7	12	30	13	8	70	0	0
Producer Accuracy	1	0.833	0.967	0.692	1	0	0.9	0
Kappa	0	0	0	0	0	0	0	0.864

The results indicate that the classified map achieved an overall accuracy of 90%, which is considered acceptable for remote sensing analysis. Additionally, the Kappa coefficient was calculated at 0.864, reflecting a strong level of agreement between the classified data and reference data, and confirming the robustness of the classification process.

The Land Use/Land Cover (LULC) classification results for the Koye Feche Sub-city reveal a diverse distribution of land uses across the area. According to the data presented in Table 4.9, the largest portion of the land is utilized for agricultural purposes, covering approximately 11,149.3 hectares, which accounts for 61.1% of the total area. This indicates that farming is a major land use activity within the sub-city. Bare land comprises the second-largest category, spanning 3,060.03 hectares or 16.3%, suggesting a significant amount of undeveloped or vacant land. Settlement areas occupy 2,443.21 hectares, making up 12.5% of the total land area, and represent residential and urbanized zones. Green infrastructure is represented by two categories: vegetation cover, which includes grasslands and smaller green areas at 565.92 hectares (3%), and open forests, which cover 1,315.9 hectares or 7% of the area. These green spaces, although relatively limited in extent, are essential for ecological balance and urban sustainability. The spatial distribution of these land use types is visually depicted in Figure 4.13. Overall, the LULC classification highlights the dominance of agriculture, the presence of significant undeveloped land, and the need for enhanced green infrastructure in the Koye Feche Sub-city.

Table 4.10: land use land cover of Koye Feche Sub City and area in hectares

land cover types	area in ha	Area %
bare land	3060.03	16.3
Settlement	2343.21	12.5
Agriculture	11439.3	61.1
Vegetation	565.922	3.0
Open forest	1315.9	7.0
Total	18724.4	100

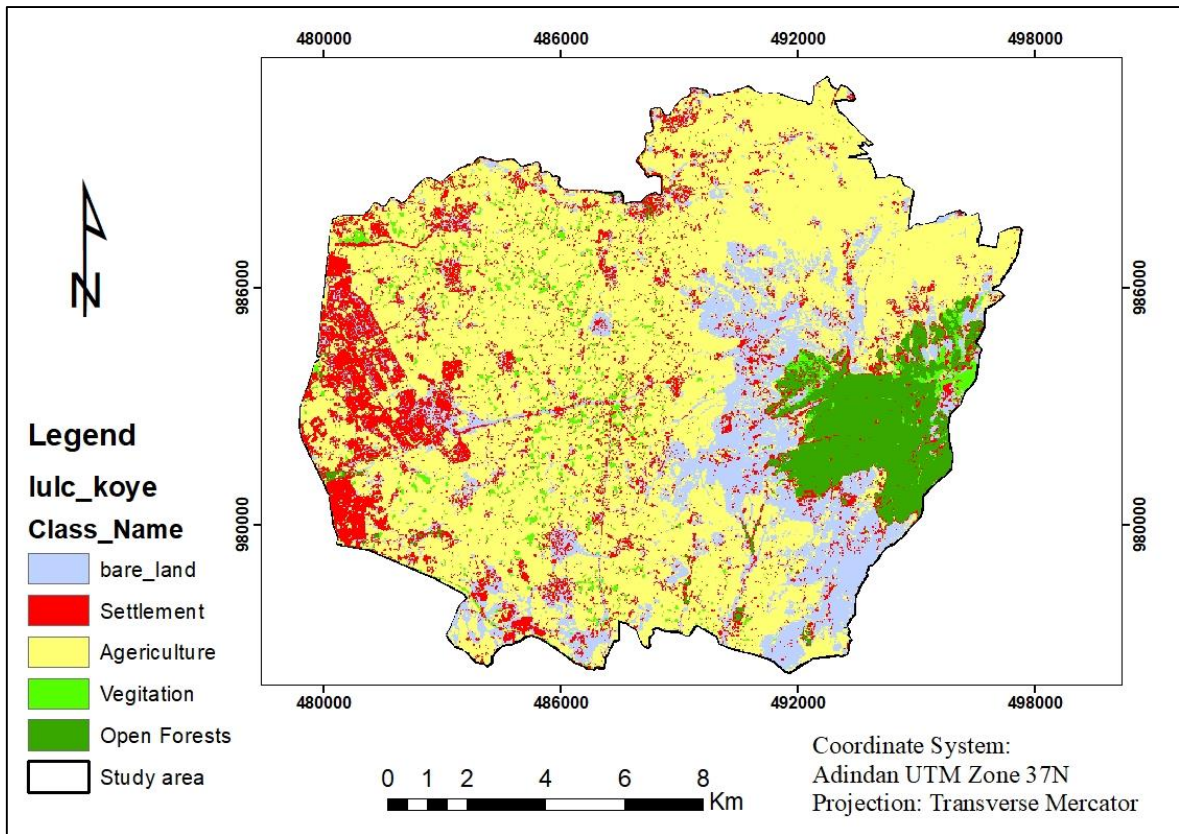


Figure 4.15: land use land cover map of study area.

The LULC classification of Koye Fече Sub-city shows that agriculture is the dominant land use, covering 61.1% of the area, followed by bare land (16.3%) and settlements (12.5%). Green infrastructure, including vegetation (3%) and open forests (7%), is relatively limited. The findings indicate a need for improved planning to enhance green space and support sustainable urban development.

4.3.6 Proposed Land Use and UGI Distribution in Koye Fече Sub-City

The proposed land use allocation for Koye Fече Sub-City emphasizes a balance between residential expansion and ecological sustainability through Urban Green Infrastructure (UGI). As illustrated in Figure 4.18 and Table 4.11, the largest share of the proposed land use is designated for residential development, which accounts for 36.96% of the total area. This is followed by greenery, recreational spaces, and ecotourism zones, which collectively cover 30.39%, reflecting the city's commitment to creating a livable and environmentally resilient urban space.

Urban agriculture is another significant land use category, comprising 17.78%, aimed at enhancing food security and promoting local agro-based economies within the urban fabric. Institutional and administrative uses, however, occupy the smallest portion of the land, at only 0.06%, indicating minimal expansion in government or public service infrastructure in this phase of development.

This proposed land use distribution aligns with sustainable urban planning principles, where green spaces and agricultural areas are prioritized alongside housing to create a well-rounded and ecologically integrated urban environment. In addition to the existing proposed 5,234.5 hectares (30.39%) of green infrastructure, future plans include the expansion of UGI through the development of green corridors, urban parks, community gardens, and riverfront ecological buffers. These forthcoming initiatives aim to further enhance environmental resilience, promote biodiversity, and strengthen the connection between urban residents and natural ecosystems. The continuous integration of UGI in future planning ensures that Koye Feche Sub-City evolves as a sustainable, healthy, and climate-adaptive urban area.

Table 4.11: proposed land use and area coverage for each category

Land Use Sub Categories	Area_Ha_	in percentage%
Administration	10.32049	0.06
Commercial, Business and Trade	1696.582	9.85
greenery, Recreational & Envi, Ecotourism	5234.542	30.39
Residence	6367.308	36.96
Manufacturing and Storage	316.3807	1.84
River and Artificial Lake	268.7675	1.56
Social Service	233.1541	1.35
Transport	37.08898	0.22
Urban Agriculture (Crops or Grazing)	3063.161	17.78
Total	17227.30	100.00

Sources koye feche subcity, 2025

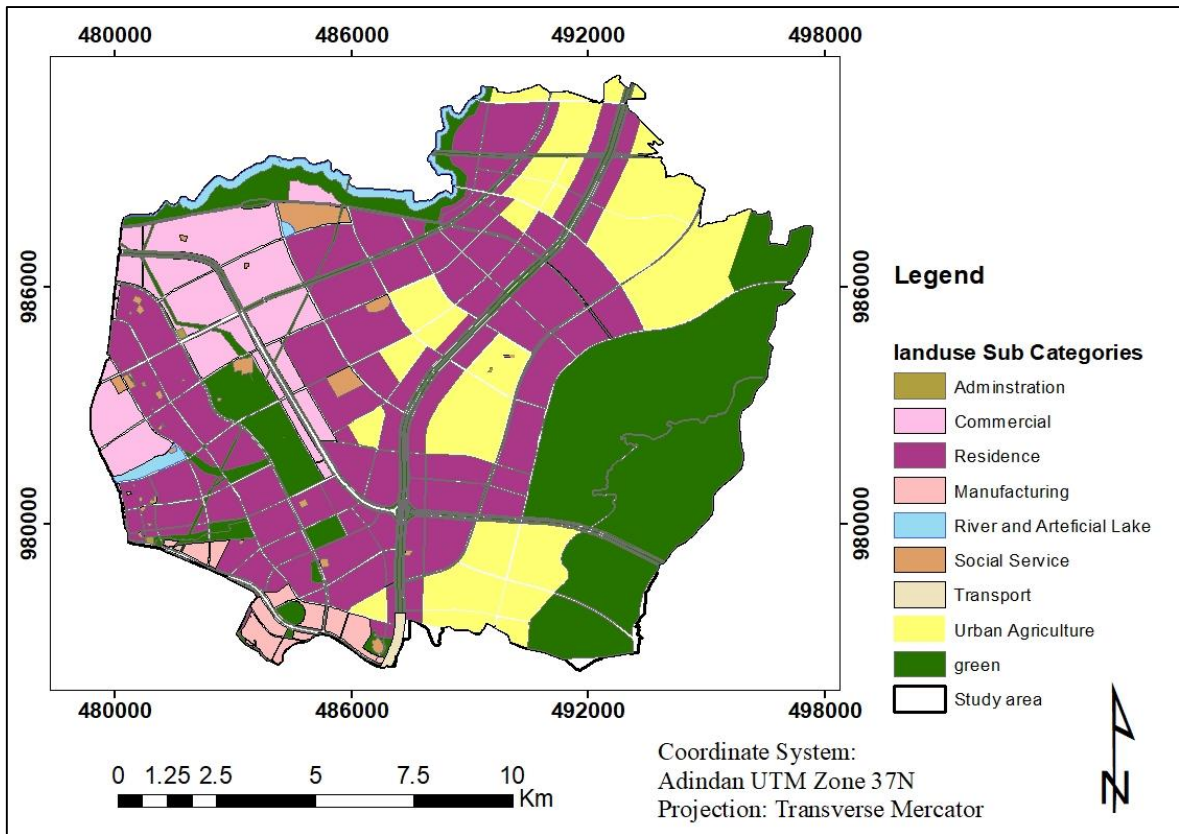


Figure 4.18: proposed land use map of Koye Feche Sub City

Urban Green Infrastructure (UGI) in Koye Feche Sub-City is strategically incorporated to support ecological sustainability, enhance urban resilience, and improve the overall quality of life. The proposed UGI comprising greenery, recreational spaces, and ecotourism areas covers a total of 5,234.5 hectares, which accounts for 30.39% of the sub-city’s total proposed land use, as illustrated in Figure 4.19 (shown in green only). This significant allocation of green space brings numerous environmental benefits, including improved air quality, urban cooling, stormwater management, and biodiversity conservation.

Socially, UGI enhances livability by providing accessible recreational areas that support mental and physical well-being, while economically, it boosts property values and offers opportunities for ecotourism and cost-effective urban services. The prioritization of UGI in the land use plan reflects a strong commitment to creating a balanced and climate-responsive urban environment in Koye Feche. To further strengthen this approach, it is recommended that additional types of UGI be incorporated into future developments, including linear parks along roadways, green roofs and walls on public and residential buildings, community gardens, bios wales for storm water management, and urban wetlands. These elements would

not only improve ecological performance but also create inclusive and multifunctional green spaces that cater to a diverse urban population.

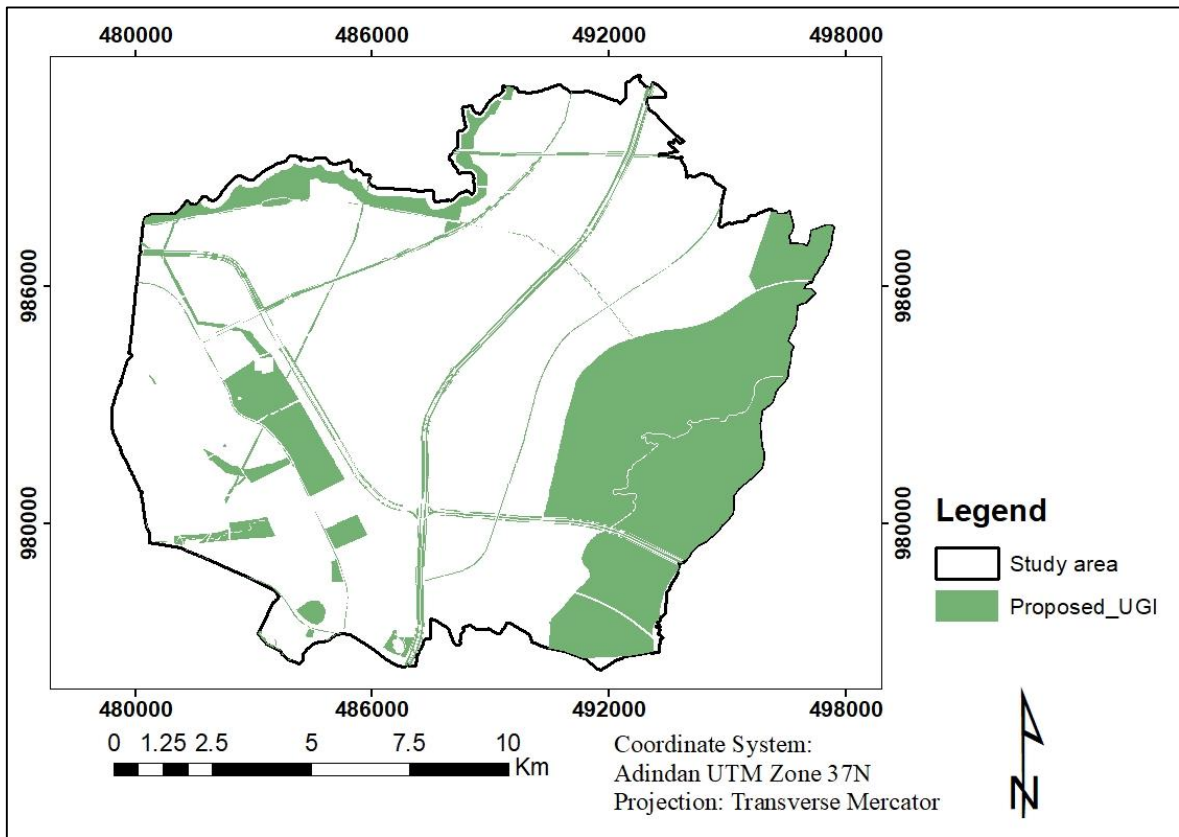


Figure 4.19: UGI distribution in proposed land use in Koye Feche sub-city

Figure 4.19 above Map showing the boundary of Koye Feche Sub-City and the spatial distribution of Urban Green Infrastructure (UGI) within the proposed land use plan, highlighting green areas allocated for recreational, ecological, and tourism purposes.

4.4. Identification of UGI community-based approach

4.4.1. Community Suggestions for Enhancing Green Space Accessibility in Koye Feche Sub-City

To gain deeper insight into community needs and priorities related to green space accessibility, residents of Koye Feche Sub-City were invited to suggest specific enhancements they felt would improve access to Urban Green Infrastructure (UGI) in their locality. The responses, illustrated in Figure 4.14, reflect a variety of community-driven ideas focused on both expanding physical infrastructure and improving user experience.

The most frequently suggested improvement was installing more seating, shaded areas, and other amenities, mentioned by 23.9% of respondents. This highlights the community’s desire for more comfortable and functional green spaces that cater to a wide range of users, including children, the elderly, and people with disabilities. Adding more walking or cycling paths was also a key priority, with 17.7% of participants recommending better connectivity through dedicated pedestrian and bicycle routes, which would encourage active transport and enhance accessibility across neighbourhoods.

In addition, 15.9% of respondents supported expanding or upgrading existing parks, indicating that while green spaces may be present, many require further development or rehabilitation to meet the needs of the growing population. Better maintenance and cleanliness were emphasized by 15%, pointing to ongoing concerns about litter, deteriorating infrastructure, and neglected greenery. Creating new parks or green spaces was suggested by 11.5%, especially in areas currently lacking UGI, showing the need for more equitable distribution of green amenities.

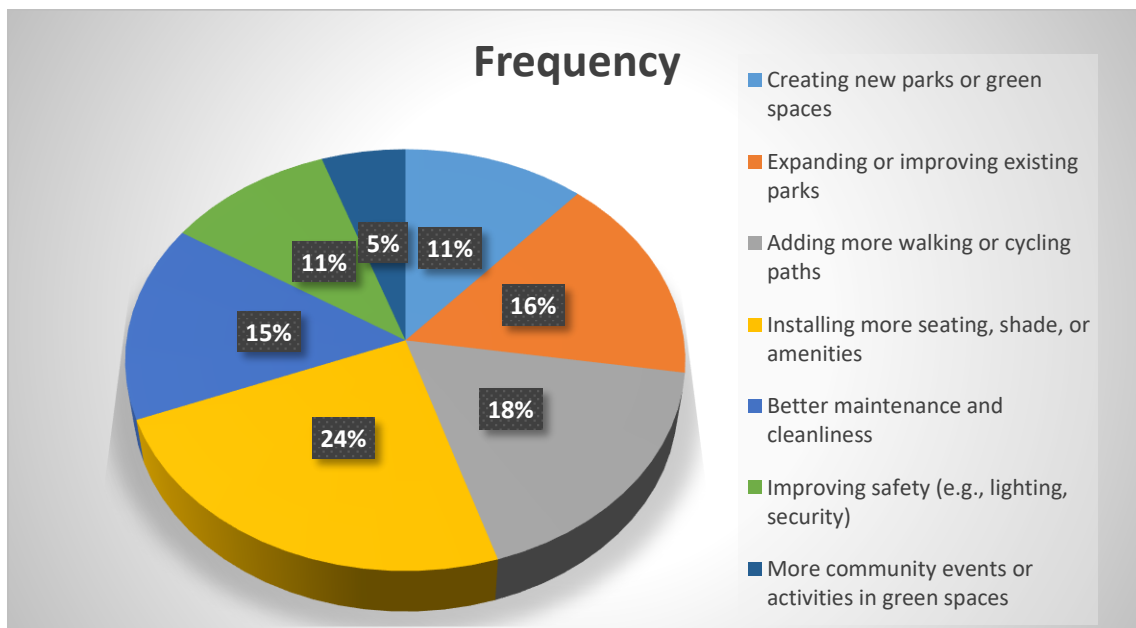


Figure 4.16: improvements suggest to increase accessibility to green spaces in study area

Concerns about improving safety were raised by 10.6% of participants, who called for improved lighting, security measures, and safer pathways to make green spaces more inviting and inclusive. Lastly, 5.3% of respondents expressed a desire for more community

events and organized activities in green spaces, which would not only improve engagement but also foster a stronger sense of community ownership and social inclusion.

In summary, the results show that residents value not only the availability of green spaces but also the quality, safety, functionality, and social vibrancy of these areas. These insights should inform municipal planning efforts, guiding resource allocation toward the most needed improvements to ensure that Urban Green Infrastructure in Koye Feche Sub-City is accessible, welcoming, and beneficial to all.

4.4.2. Perceived Economic Benefits of Urban Green Infrastructure in Koye Feche Sub-City

Residents of Koye Feche Sub-City were asked to identify the key economic benefits they associate with the presence and development of urban green infrastructure (UGI) in their community. The responses, as illustrated in Figure 4.15, highlight a broad awareness of the positive impacts that green spaces can have beyond environmental and social well-being.

The most widely recognized economic benefit, selected by 28.3% of respondents, was that UGI promotes economic growth and attracts investment. This suggests a strong local perception that well-planned green infrastructure can stimulate development, enhance urban appeal, and encourage both public and private sector investment. Following this, 15.9% noted that UGI promotes tourism, indicating that aesthetically pleasing and accessible green spaces are viewed as potential attractions that could boost local businesses and hospitality services. Another important benefit cited was that green infrastructure reduces energy use in buildings for cooling, lighting, and ventilation highlighted by 16.8% of respondents. This reflects an understanding of UGI's role in improving microclimates and contributing to energy efficiency, especially in densely built environments. Additionally, 14.2% of participants recognized that UGI increases property values and generates higher tax revenues, reinforcing the economic argument for investing in green space development.

A smaller but notable group (9.7%) believed UGI enhances workplace productivity, likely due to the psychological and health benefits associated with green environments near offices. Furthermore, 8.8% saw the availability of medicinal plants as an economic and health-related resource, particularly valuable in communities with limited access to modern

healthcare. As shown percentage in figure below lastly, 7.1% of respondents pointed out that UGI improves food security through urban farming, demonstrating how green spaces can serve practical functions by supporting local food systems.

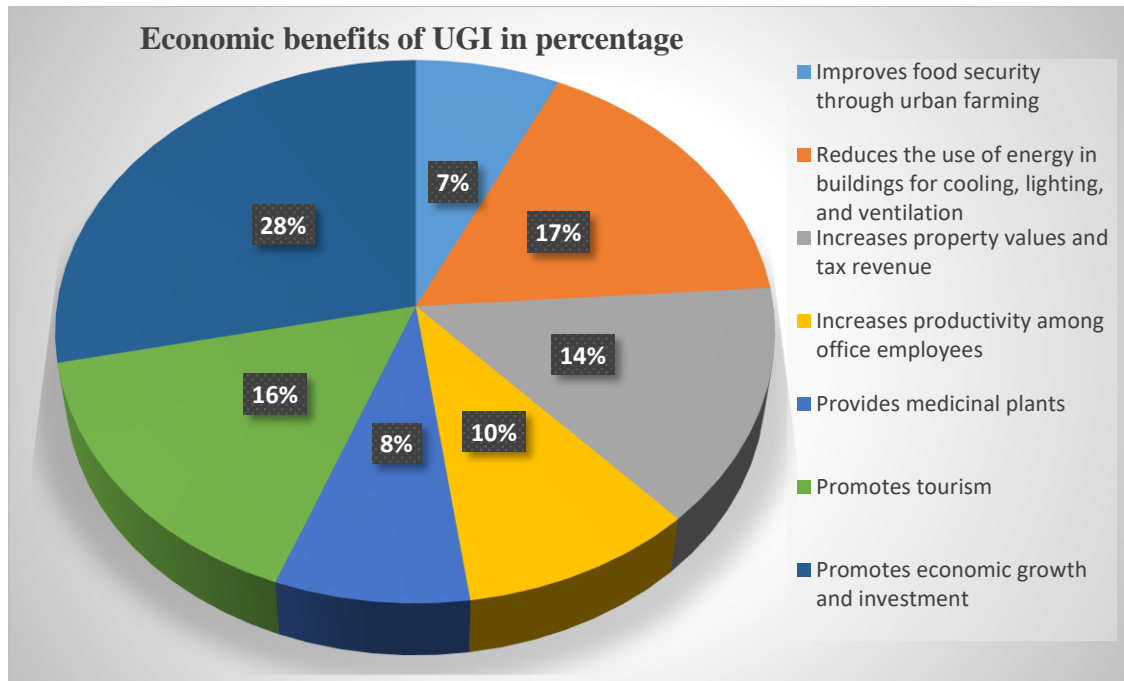


Figure 4.17: Green infrastructure brings the economic benefits in percentage

In conclusion, the survey responses underscore that residents of Koye Feche Sub-City recognize a diverse range of economic advantages tied to green infrastructure. These insights should encourage local authorities and urban planners to view UGI not just as a tool for ecological or aesthetic enhancement, but as a strategic economic asset that supports sustainable development, community resilience, and inclusive growth.

4.5. Discussions

The discussion part is arranged around several key findings of the research first, the identification of factors affecting Urban Green Infrastructure accessibility. The second is spatial distribution of urban green infrastructure is examined through land use/land cover (LULC) classification and NDVI analysis, which help to categorize and understand different types of UGI in the study area. Thirdly, the study explores community-based approaches to UGI management, followed by residents' suggestions for enhancing green space

accessibility. Lastly, the perceived economic benefits of UGI in study area are discussed, providing insights into the socio-economic value of green spaces for local communities.

The study gathered both quantitative and qualitative data to assess the accessibility and quality of Urban Green Infrastructure (UGI) in Koye Feche Sub-City. Out of 341 targeted individuals, 184 fully completed questionnaires were obtained, providing a solid foundation for statistical analysis. Additionally, ten partially completed questionnaires offered usable responses, while four were discarded due to validity issues. Complementing the survey data, 198 individuals participated in face-to-face interviews, enriching the findings with deeper insights into community perceptions and lived experiences related to UGI accessibility. Demographic analysis revealed that most respondents were male and belonged to the 35 to 44 age group. Notably, 43.48% of respondents had lived in the area for over ten years, suggesting a well-informed population with deep familiarity with local green spaces. This long-term residency contributes significantly to understanding the evolution and current status of UGI in the sub-city.

Regarding the perceived quality of UGI, responses indicated widespread dissatisfaction. Only 15.22% rated UGI as excellent and 20.11% as good, while a combined more than 56.6% described it as poor or very poor. Respondents based their evaluations on factors such as cleanliness, design, safety, usability, and ecological health highlighting the multidimensional nature of perceived green space quality. These findings point to the need for improvements in maintenance, design features, and inclusive accessibility. Transportation patterns also influenced UGI access. A significant number of respondents (35.33%) reported walking as their primary mode of access, followed by public transportation (27.17%) and private vehicles (12.5%). These figures emphasize the importance of pedestrian and transit-oriented planning in ensuring equitable green space access. Several barriers to UGI access were identified. The most cited issues included a lack of nearby green spaces (21.74%), long distances from home (19.57%), and physical limitations (16.85%). Other constraints included poor maintenance, limited amenities, and safety concerns. These challenges collectively hinder residents' ability to enjoy local green spaces fully.

In terms of equity, only 26.5% of respondents believed that all areas in their neighbourhood had equal access to UGI, while 62.8% observed significant disparities. This perception of

spatial inequality underscores the need for a more balanced distribution of green spaces across Koye Feche. Physical infrastructure plays a key role in access. Parks were the most reported type of UGI (32.7%), followed by playgrounds (16.8%). However, proximity to these facilities was limited nearly 39% of respondents reported needing more than 20 minutes to reach the nearest green space. These statistics reflect spatial and infrastructural shortcomings that must be addressed through better urban design and strategic placement of UGI. Community perceptions of the current condition of UGI infrastructure mirrored concerns about quality. Only 15% rated conditions as excellent, while more than half expressed dissatisfaction. This aligns with earlier findings on the perceived quality and points to critical gaps in upkeep and infrastructure support. Social and economic factors also emerged as significant barriers. Over half (54%) of respondents felt that socio-economic disparities including income, ethnicity, and employment status limited UGI access. Only 6.2% believed that all social groups had equal access, reinforcing the presence of social inequities. Furthermore, 50.4% highlighted the influence of broader inequalities on UGI use, indicating the systemic nature of these challenges. Access to information about green spaces was another issue. While 45.1% said information was somewhat accessible, 19.5% found it not accessible at all. This gap in awareness may contribute to underutilization and highlights the need for more effective community outreach and communication.

Mapping and spatial analysis using Landsat 9 and NDVI provided a detailed classification of vegetated and non-vegetated areas. While this analysis helped distinguish different vegetation types and health levels, only 10% of the land was identified as green infrastructure. The dominant land use over 60% was agricultural, with substantial bare and settlement land, reflecting both the rural character and development potential of the area. These results emphasize the need for more deliberate integration of green spaces into urban planning as the sub-city continues to urbanize. In summary, the findings reveal significant limitations in both the quality and accessibility of UGI in Koye Feche Sub-City. These challenges are shaped by a combination of physical, social, and spatial factors, including poor maintenance, inadequate distribution, socio-economic disparities, and limited information. Addressing these issues will require coordinated planning, community engagement, and targeted investments to create a more inclusive and sustainable urban environment.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

In this part the findings of the study and discussion were concluded. The theme of this study is summarized and show in this conclusion sub parts. The analysis of factors affecting access to green space in Koye Feche Sub City reveals physical and social barriers that affect resident's ability to engage with Urban Green Infrastructure. The results highlight the lack of green space options as the biggest barrier, followed by proximity to home and physical limitations of privacy. Also, there is a notable inequity in the distribution of green spaces, with the majority of residents reporting unequal access across neighborhoods. This points to spatial disparities in the availability of UGI, emphasizing the need for more inclusive urban planning to address these imbalances. Social and economic factors also play a crucial role, as more than half of respondents believe that these barriers limit access to UGI. Additionally, perceived social inequalities related to income, ethnicity, and gender significantly affect different groups' access to green spaces. Overall, these findings underline the importance of addressing both physical and social factors to ensure equitable and effective access to urban green spaces in Koye Feche Sub-City.

The availability of information about Urban Green Infrastructure (UGI) and the challenges residents face in accessing green spaces in study area. Although 35.4% of respondents find UGI information readily accessible very well, a larger portion (45.1%) feels that information is only somewhat accessible, highlighting gaps in communication and not reachable. Accessibility challenges identified by residents include the distance to UGI facilities and the lack of transportation options, with 27.4% and 26.5% of respondents citing these as significant barriers. Furthermore, the role of public policies in improving UGI accessibility shows varied results a percentage 28.3% of residents believe government, actions have positively impacted access and another 49.6% feel that existing policies have not significantly enhanced UGI accessibility.

Spatial and community based approaches to identifying areas with limited UGI access including the use of LULC classification and NDVI analysis, further reveal differences in green space distribution place to place. These findings highlight the need for improved information dissemination, better transportation options, and more effective public policies to enhance equitable access to UGI in Koye Feche Sub City.

In NDVI classification at Level-1 classification clearly distinguishes between vegetated and non-vegetated areas setting the stage for further analysis. This allow us to simply identify vegetation and non-vegetation area. In classification Level-2 offers a detailed view of the spatial distribution of different vegetation types, contributing to a deeper understanding of the natural structure. The Level-3 classification refines this further by assessing vegetation health, categorizing it into healthy and stressed vegetation. Whereas these results provide valuable insights into the current state of urban green spaces evaluating the adequacy of the green cover requires considering factors like urban planning standards, population density, and environmental needs. Comparing the available green space with established benchmarks will offer a clearer picture of whether the area's green infrastructure meets the community's requirements.

In the analysis of Land Use/Land Cover of study area reveals a strong dominance of agricultural land use which cover more than 60% of the area. This reflects the importance of agriculture to the local economy and land use planning. However, significant portions of bare land and settlements indicate opportunities for future development and urban expansion. While green infrastructure, such as vegetation and open forests, only covers about 10% of the area, these spaces are crucial for environmental health and biodiversity. The findings highlight the need for strategies that promote the integration of more green spaces within the urban landscape to ensure ecological sustainability and improve the quality of life for residents. As urbanization continues, a balanced approach to land use will be essential to foster a healthy and sustainable environment in the sub-city.

5.2. Recommendations

Recommendations of this researches are written as below for different sectors, researchers and future urban planners integrated with urban green infrastructure. Many recommendations can be made for further research and for enhancing the Urban Green Infrastructure (UGI) in Koye Feche Sub-City. First, there is a need for improved communication and information dissemination about UGI. As many residents feel that UGI information is only somewhat accessible, future studies should focus on exploring more effective communication channels, such as digital platforms, community workshops, and local media, to ensure better outreach to the community. Second, addressing the accessibility of green spaces is crucial.

With distance and lack of transportation being key barriers, further research should focus on identifying underserved areas and exploring options for creating more UGI facilities within walking distance of residential zones. Public policies also need further evaluation and enhancement, as many residents feel that current policies are insufficient in improving UGI access. Future studies could assess the effectiveness of existing urban planning policies and recommend adjustments to ensure that green spaces are better distributed and accessible to all. Additionally, social and economic factors significantly affect UGI accessibility.

Future research should explore the role of income, ethnicity, and gender in shaping access to green spaces and propose targeted strategies to overcome these barriers, ensuring that all social groups benefit equally from UGI. Further spatial analysis using tools like Land LULC classification and NDVI should be conducted to pinpoint areas lacking sufficient green space, enabling more targeted interventions.

Community involvement is also essential, and future studies should prioritize engaging local residents in the planning and maintenance of urban green infrastructure, ensuring that green spaces meet the needs and preferences of the community. Lastly, the sustainability and maintenance of UGI should be further explored, with research focusing on long-term upkeep strategies, resource allocation, and sustainable practices to maintain green spaces for future generations. So, addressing these factors, Koye Feche Sub-City can enhance the effectiveness, equity, and sustainability of its urban green infrastructure, contributing to a healthier and more livable environment for all residents.

This study offers new and valuable insights into the accessibility and quality of Urban Green Infrastructure (UGI) in Koye Feche Sub-City, an area where limited empirical research previously existed. By combining survey data, interviews, and spatial analysis using NDVI and land use/land cover classification, the research highlights how physical infrastructure, socio-economic conditions, and spatial planning intersect to shape the use and perception of green spaces. The findings reveal not only widespread dissatisfaction with the quality and distribution of UGI but also significant inequities based on income, location, and social status. Importantly, the study underscores the role of long-term residents in providing informed perspectives on the evolution and current state of UGI, thus highlighting the value of community knowledge in urban development processes. While the study provides a strong foundation, it also opens several avenues for further investigation. One key area for future research is longitudinal studies that monitor changes in green infrastructure access and quality over time. This would allow for an assessment of how urbanization, policy changes, or targeted interventions affect the distribution and use of UGI. In addition, comparative studies involving other sub-cities within Sheger City or similar urban contexts in Ethiopia could help identify broader patterns and best practices in green infrastructure planning.

Another important direction is to examine the health and well-being outcomes associated with UGI accessibility.

Studying the relationship between access to green spaces and public health indicators such as physical activity, mental health, or disease prevalence future research can provide more concrete evidence of the social and economic value of UGI. Similarly, exploring how cultural, ethnic, and gender factors influence the design and use of green spaces could inform more inclusive and community-sensitive planning. Furthermore, additional studies could focus on community-led initiatives for green space development and management. Understanding what makes such initiatives successful could provide scalable models for participatory urban greening, especially in resource-limited settings. Lastly, given the environmental benefits of UGI, future research should also investigate its role in promoting urban climate resilience, particularly in mitigating urban heat island effects and improving storm water management.

Finally, while this research fills a significant knowledge gap on UGI in Koye Feche Sub-City, it also lays the groundwork for broader, interdisciplinary studies that can support sustainable, equitable, and resilient urban planning across similar urban landscapes in Ethiopia and beyond.

REFERENCES

- Aburas, M. M., Abdullah, S. H., Ramli, M. F., & Ash'aari, Z. H. (2015). Measuring Land Cover Change in Seremban, Malaysia Using NDVI Index. *Procedia Environmental Sciences*, 30, 238–243. <https://doi.org/10.1016/j.proenv.2015.10.043>
- Ali Khan, A., & Shafqat, A. (2014). Assessing the Spatial Distribution and Allocation Gaps of Urban Parks in Bahawalpur City of Punjab, Pakistan. *Pakistan Journal of Social Sciences (PJSS)*, 34(2), 545–562. https://www.researchgate.net/publication/274890516_Assessing_the_Spatial_Distribution_and_Allocation_Gaps_of_Urban_Parks_in_Bahawalpur_City_of_Punjab_Pakistan%0Ahttp://search.ebscohost.com/login.aspx?direct=true&db=sih&AN=102133553&site=ehost-live
- Apud, A., Faggian, R., Sposito, V., & Martino, D. (2020). Suitability analysis and planning of green infrastructure in Montevideo, Uruguay. *Sustainability (Switzerland)*, 12(22), 1–18. <https://doi.org/10.3390/su12229683>
- Aryal, J., & Sitaula, C. (2022). *NDVI Threshold-Based Urban Green Space Mapping from*.
- Atiqul Haq, S. M., Islam, M. N., Siddhanta, A., Ahmed, K. J., & Chowdhury, M. T. A. (2021). Public Perceptions of Urban Green Spaces: Convergences and Divergences. *Frontiers in Sustainable Cities*, 3(October), 1–15. <https://doi.org/10.3389/frsc.2021.755313>
- Ayele, B. Y., Megento, T. L., & Habetemariam, K. Y. (2022). Assessing green infrastructure spatial plans in Addis Ababa, Ethiopia. *Socio-Ecological Practice Research*, 4(2), 85–101. <https://doi.org/10.1007/s42532-022-00115-9>
- Azagew, S., & Worku, H. (2020). Accessibility of urban green infrastructure in Addis-Ababa city, Ethiopia: current status and future challenge. *Environmental Systems Research*, 9(1). <https://doi.org/10.1186/s40068-020-00187-0>
- Badar, R., & Kalbani, A. (2024). *A FRAMEWORK FOR ADDRESSING UNBUILT ALLOCATED*.
- Barriuso, F., & Urbano, B. (2021). *Green Roofs and Walls Design Intended to Mitigate*

Climate Change in Urban Areas across All Continents.

- Bhandari, A. K., Kumar, A., & Singh, G. K. (2012). Feature Extraction using Normalized Difference Vegetation Index (NDVI): A Case Study of Jabalpur City. *Procedia Technology*, 6(February), 612–621. <https://doi.org/10.1016/j.protcy.2012.10.074>
- Burlando, P., Ferrante, A., & Vagge, I. (2025). Multiscale and multidisciplinary method for plant selection to design green urban and peri-urban areas. *Frontiers in Horticulture*, 4(April), 1–9. <https://doi.org/10.3389/fhort.2025.1354764>
- Byrne, J., Sipe, N., & Searle, G. (2010). Green around the gills? The challenge of density for urban greenspace planning in SEQ. *Australian Planner*, 47(3), 162–177. <https://doi.org/10.1080/07293682.2010.508204>
- Cardone, B., Cerreta, M., Di Martino, F., Miraglia, V., & Sacco, S. (2024). A fuzzy-based emotion detection method to classify the attractiveness of urban green spaces. *Evolutionary Intelligence*. <https://doi.org/10.1007/s12065-024-00964-1>
- Das, A. C., Shahriar, S. A., Chowdhury, M. A., Hossain, M. L., Mahmud, S., Tusar, M. K., Ahmed, R., & Salam, M. A. (2023). Assessment of remote sensing-based indices for drought monitoring in the north-western region of Bangladesh. *Heliyon*, 9(2), e13016. <https://doi.org/10.1016/j.heliyon.2023.e13016>
- Datta, S., & Dash, P. K. (2024). Remote sensing and GIS applications for monitoring and managing urban forests. *Dynamics of Urban Forestry, February*, 1–14.
- Desta, G., & Takele, A. (2008). *Towards Mainstreaming Environmental Impact Assessment into Housing Development Projects in Ethiopia : The Case of ... Related papers*. 10(1), 41–57.
- Du, D. J., & Sharples, S. (2024). *A comparison of perceived environmental quality , psychological restorativeness , physical activity habits and public satisfaction between ground-level parks and roof gardens : a study in Hong Kong. August.*
- Du, P., Al-Kodmany, K., & Ali, M. M. (2024). The Routledge Handbook on Greening High-Density Cities. In *The Routledge Handbook on Greening High-Density Cities*. <https://doi.org/10.4324/9781003318385>
- Ely, M., & Pitman, S. (2014). *Green Infrastructure, Life support for human habitats*

environments: The compelling evidence for incorporating nature into urban environments. June, 1–380.

- Eshetu, S. B., Yeshitela, K., & Sieber, S. (2021). *Urban Green Space Planning , Policy Implementation , and Challenges : The Case of Addis Ababa.* 1–14.
- Gandhi, G. M., Parthiban, S., Thummalu, N., & Christy, A. (2015). Ndvi: Vegetation Change Detection Using Remote Sensing and Gis - A Case Study of Vellore District. *Procedia Computer Science*, 57, 1199–1210. <https://doi.org/10.1016/j.procs.2015.07.415>
- Gashu, K., & Gebre-Egziabher, T. (2019). Public assessment of green infrastructure benefits and associated influencing factors in two Ethiopian cities: Bahir Dar and Hawassa. *BMC Ecology*, 19(1), 1–15. <https://doi.org/10.1186/s12898-019-0232-1>
- Gelan, E., & Girma, Y. (2022). Urban green infrastructure accessibility for the achievement of SDG 11 in rapidly urbanizing cities of Ethiopia. *GeoJournal*, 87(4), 2883–2902. <https://doi.org/10.1007/s10708-021-10404-7>
- Haaland, C., & van den Bosch, C. K. (2015). Challenges and strategies for urban green-space planning in cities undergoing densification: A review. *Urban Forestry and Urban Greening*, 14(4), 760–771. <https://doi.org/10.1016/j.ufug.2015.07.009>
- Heckert, M., & Mennis, J. (2012). The economic impact of greening urban vacant land: A spatial difference-in-differences analysis. *Environment and Planning A*, 44(12), 3010–3027. <https://doi.org/10.1068/a4595>
- Hordofa, H., & Shaoxian, K. (2021). *Assessment of Urban Greenery Status in Major Cities of Oromia .*, 03(03), 21–27.
- Hou, W., & Li, X. (2024). Assessing urban green infrastructure: A simple and practical measure of its spatial distribution equity and a comprehensive evaluation. *Ecological Indicators*, 158(November 2023), 111408. <https://doi.org/10.1016/j.ecolind.2023.111408>
- Huang, Y., & Yang, S. (2023). Research on Accessibility of Green Infrastructure Based on GIS: A Case Study of Kunhou Neighborhood Planning. *Global Journal of Cultural Studies*, 2, 93–107. <https://doi.org/10.6000/2817-2310.2023.02.07>
- Janicki, R. (2017). *Finding Headspace: A Knowledge Synthesis of the Effects of Urban*

Green Space on Mental Health. <http://www.nccch.ca/sites/default/files/Guelph-Janicki-2017.pdf>

- Jennings, V., & Bamkole, O. (2019). The relationship between social cohesion and urban green space: An avenue for health promotion. *International Journal of Environmental Research and Public Health*, *16*(3). <https://doi.org/10.3390/ijerph16030452>
- Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K., & Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*, *21*(2). <https://doi.org/10.5751/ES-08373-210239>
- Kondo, M. C., Fluehr, J. M., McKeon, T., & Branas, C. C. (2018). Urban green space and its impact on human health. *International Journal of Environmental Research and Public Health*, *15*(3). <https://doi.org/10.3390/ijerph15030445>
- John, (2017). Nine types of urban forest sotoga.
<https://sotoga.com/en/urban-forest>
- Lee, A. C. K., Jordan, H. C., & Horsley, J. (2015). Value of urban green spaces in promoting healthy living and wellbeing: Prospects for planning. *Risk Management and Healthcare Policy*, *8*(August), 131–137. <https://doi.org/10.2147/RMHP.S61654>
- Li, L., Du, Q., Ren, F., & Ma, X. (2019). Assessing spatial accessibility to hierarchical urban parks by multi-types of travel distance in Shenzhen, China. *International Journal of Environmental Research and Public Health*, *16*(6). <https://doi.org/10.3390/ijerph16061038>
- Lotfata, A. (2021). Using Remote Sensing in Monitoring the Urban Green Spaces: A Case Study in Qorveh, Iran. *European Journal of Environment and Earth Sciences*, *2*(1), 11–15. <https://doi.org/10.24018/ejgeo.2021.2.1.102>
- Ma, Y., Brindley, P., & Lange, E. (2023). From Modelling and Analysis of Accessibility of Urban Green Space to Green Infrastructure Planning: Guangzhou as a Case Study. In *Urban Book Series: Vol. Part F737* (Issue July). Springer International Publishing. https://doi.org/10.1007/978-3-030-89828-1_13
- Majeed, H. M. S., Ahmed, R. K., Hameed, T. M., & Amin, R. A. M. (2020). Effect of Urban

- Expansion on the Agriculture Lands of Miqdadiya Effect of Urban Expansion on the Agriculture Lands of Miqdadiya City , Diyala , Iraq (Urban Geomorphology). *Plant Archives*, 20(Vol 20 No. 2), 4027–4031.
- Marrone, P. (2013). Chambers, RT. In *Etica e Politica* (Vol. 15, Issue 1). <https://doi.org/10.1093/acprof>
- Maryanti, M. R., Khadijah, H., Uzair, A. M., & Ghazali, M. A. R. M. M. (2016). The urban green space provision using the standards approach: issues and challenges of its implementation in Malaysia. *Sustainable Development and Planning VIII, 1*, 369–379. <https://doi.org/10.2495/sdp160311>
- Mengistu, D. A., & Salami, A. T. (2007). Application of remote sensing and GIS inland use/land cover mapping and change detection in a part of south western Nigeria. *African Journal of Environmental Science and Technology*, 1(5), 99–109. <http://www.academicjournals.org/AJEST>
- Nesbitt, L., Meitner, M. J., Girling, C., Sheppard, S. R. J., & Lu, Y. (2019). Who has access to urban vegetation? A spatial analysis of distributional green equity in 10 US cities. *Landscape and Urban Planning*, 181(June 2018), 51–79. <https://doi.org/10.1016/j.landurbplan.2018.08.007>
- Pan, Y., Teng, T., Wang, S., & Wang, T. (2024a). Impact and mechanism of urbanization on urban green development in the Yangtze River Economic Belt. *Ecological Indicators*, 158(September 2023), 111612. <https://doi.org/10.1016/j.ecolind.2024.111612>
- Pan, Y., Teng, T., Wang, S., & Wang, T. (2024b). Impact and mechanism of urbanization on urban green development in the Yangtze River Economic Belt. *Ecological Indicators*, 158(January), 111612. <https://doi.org/10.1016/j.ecolind.2024.111612>
- Panagopoulos, T. (2019). Landscape Urbanism and Green Infrastructure. In *Landscape Urbanism and Green Infrastructure*. <https://doi.org/10.3390/books978-3-03921-370-2>
- Pickett, S. T. A., Cadenasso, M. L., Grove, J. M., Boone, C. G., Groffman, P. M., Irwin, E., Kaushal, S. S., Marshall, V., McGrath, B. P., Nilon, C. H., Pouyat, R. V., Szlavecz, K., Troy, A., & Warren, P. (2011). Urban ecological systems: Scientific foundations and a decade of progress. *Journal of Environmental Management*, 92(3), 331–362.

<https://doi.org/10.1016/j.jenvman.2010.08.022>

- Przewoźna, P., Inglot, A., Mielewczyk, M., Maczka, K., & Matczak, P. (2024). Accessibility to urban green spaces: A critical review of WHO recommendations in the light of tree-covered areas assessment. *Ecological Indicators*, 166(September). <https://doi.org/10.1016/j.ecolind.2024.112548>
- Rahimi, A. (2016). A methodological approach to urban landuse change modeling using infill development pattern—a case study in Tabriz, Iran. *Ecological Processes*, 5(1). <https://doi.org/10.1186/s13717-016-0044-6>
- Rahmawati, A. D., Asy'Ari, R., Fathonah, M. A., Priyanto, Zamani, N. P., Pramulya, R., & Setiawan, Y. (2022). Vegetation-Water-Built Up Index Combined: Algorithm Indices Combination for Characterization and distribution of Mangrove Forest through Google Earth Engine. *CELEBES Agricultural*, 3(1), 20–42. <https://doi.org/10.52045/jca.v3i1.298>
- Rakhshandehroo, M. (2017). THE ENVIRONMENTAL BENEFITS OF URBAN OPEN GREEN SPACES * Corresponding author : *Alam Cipta Vol 10 (1) Jun 2017 Universiti Putra Malaysia*, 10(1), 10–16.
- Rao, Y., Zhong, Y., He, Q., & Dai, J. (2022). Assessing the Equity of Accessibility to Urban Green Space: A Study of 254 Cities in China. *International Journal of Environmental Research and Public Health*, 19(8). <https://doi.org/10.3390/ijerph19084855>
- Ruiz-Apilánez, B., Ormaetxea, E., & Aguado-Moralejo, I. (2023). Urban Green Infrastructure Accessibility: Investigating Environmental Justice in a European and Global Green Capital. *Land*, 12(8), 1–30. <https://doi.org/10.3390/land12081534>
- So, S. W. (2016). *Urban Green Space Accessibility and Environmental Justice: A GIS-Based Analysis in the City of Phoenix, Arizona*. August, 89.
- Somoye, O., & Akinwande, T. S. (2023). Can Urbanization Influence Carbon Dioxide Emissions? Evidence from BRICS–T Countries. *Journal of Contemporary Urban Affairs*, 7(1), 164–174. <https://doi.org/10.25034/ijcua.2023.v7n1-11>
- Tamiru, T. (2017). *College of Natural and Computational Sciences Department of Biotechnology*. April, 2019.

<https://scholar.archive.org/work/gpli266x6rb6pfram5sfwwqigy/access/wayback/https://nadre.ethernet.edu.et/record/1837/files/TadeleTamiru2.pdf>

Tsige, 2015. (2015). *Ethiopian institute of Architecture , Building Construction and City Development Enhancing Green Infrastructure of Mekelle City: Through Green Technology , Elements and Green Corridor Development By Tsige Berhe Approved by Examining Board : 42.*

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, 81(3), 167–178. <https://doi.org/10.1016/j.landurbplan.2007.02.001>

Ummah, M. S. (2019). Covariance Structure Analysis of Health-Related Indicators in Homebound Elderly Focusing on Subjective Health. In *Sustainability (Switzerland)* (Vol. 11, Issue 1 <http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017->

APPENDIX

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

COLLAGE OF CIVIL ENGINEERING AND ARCHITECTURE (COCEA)

Department of Architecture

QUESTIONNAIRE ON GREEN INFRASTRUCTURE IN URBAN AREAS OF KOYE
FECHE SUB CITY; SHEGER CITY ETHIOPIA.

BY HAYU ARARSA

Masters of Science in Urban Planning & Design

Dear Participants,

This questionnaire aims to gather information from residents and workers in urban areas of Koye Feche Sub City on various aspects of green infrastructure (such as grasses, plants, trees, water bodies, open spaces, green parks/gardens, etc.). It serves as a tool for collecting data for academic research. By answering the questions, you provide informed consent to take part in this study. Participation carries no health or economic risks, though it will require approximately 15 minutes of your time.

All information provided will be kept strictly confidential and anonymous.

Thank you in advance for your participation in this research.

Introduction: This survey aims to understand the factors that influence the accessibility of Urban Governance Infrastructure (UGI) in your area. These factors include both physical infrastructure characteristics and social factors. Your responses will help us better understand the challenges and opportunities for improving UGI accessibility.

SECTION (I): GENERAL INFORMATION (SOCIO-DEMOGRAPHIC DATA)

1. What is your age group?

Under 18 18–24 25–34 35–44 45–60 61 or older

2. What is your gender?

- Male Female Non-binary Prefer not to answer

3. How long have you lived in this area?

- Less than 1 year 1–3 years 4–6 years 7–10 years More than 10 years

4. What is your mode of transportation for daily commuting or accessing UGI?

- Walking cycling Public transportation (Bus, Train, etc.) Private car
 Other (Please specify) _____

SECTION (II): QUALITY AND ACCESSIBILITY OF GREEN INFRASTRUCTURE

5. How would you rate the quality of green spaces in your area?

- Excellent Good Average Poor Very poor

6. What factors influence your access to green spaces? (Select all that apply)

- Proximity to home
 Safety (e.g., crime rates in the area)
 Accessibility (e.g., walkability, public transport availability)
 Availability of amenities (e.g., benches, lighting, toilets)
 Maintenance (e.g., cleanliness, infrastructure condition)
 Personal physical limitations (e.g., mobility issues)
 Lack of green space options
 Other (Please specify) _____

7. Do you feel there is equitable access to green spaces in your neighborhoods?

- Yes, all areas have similar access
 No, some areas have better access than others
 Not sure

Quality of Green Infrastructure in your area

Please rate by ticking (√) the quality of the following categories of urban green infrastructure in your area/location.

SN	Green Infrastructure	Very poor	Poor	Fair	Good	Very good
1	Green spaces					
2	Urban/street trees					
3	Water features					
4	Green parks for relaxation, recreation, and social interactions					
5	State of green areas in all seasons of the year					
6	Green parks where children can play freely					
7	Foliage (leaves) of plants, shrubs, and tree					
8	Flowers of shrubs and trees					
9	Maintenance of green infrastructure					
10	Water features in all seasons of the year					
11	Accessibility of green infrastructure to most people					
12	Safety of where green infrastructure is					

SECTION (III): PHYSICAL FACTORS AFFECTING UGI ACCESSIBILITY

8. What types of UGI infrastructure are available in your area? (Select all that apply)

- Parks
- Playgrounds
- Public transportation hubs (bus/train stations)
- Streets and pedestrian paths
- Waste management facilities

- Water treatment and sanitation systems
- Stormwater management systems
- Other (Please specify) _____

9. How far is the nearest UGI facility (e.g., park, public transport stop) from your residence?

- Less than 5 minutes' walk
- 5–10 minutes' walk
- 10–20 minutes' walk
- More than 20 minutes' walk

10. How would you rate the condition of UGI infrastructure in your area?

- Excellent
- Good
- Average
- Poor
- Very poor

11. How accessible are UGI facilities in terms of physical barriers (e.g., uneven roads, lack of ramps, insufficient signage)?

- Very accessible
- somewhat accessible
- Not accessible
- Not sure

12. Are the pathways to UGI facilities safe for pedestrians (e.g., street lighting, absence of traffic hazards)?

- Yes, very safe
- Yes, somewhat safe
- No, unsafe
- Not sure

13. How well-maintained are the UGI facilities in your area?

- Very well-maintained
- Well-maintained
- poorly maintained
- not maintained at all

SECTION (IV): SOCIAL FACTORS AFFECTING UGI ACCESSIBILITY

14. Are there community groups or local organizations that facilitate access to urban services (e.g., access to education, healthcare, etc.)?

- Yes
- No
- not sure

15. In your opinion, do social or economic factors limit access to UGI in your area (e.g., low-income areas, marginalized communities)?

Yes, significantly Yes, but not significantly No, all groups have equal access Not sure

16. Do you feel that social inequalities (e.g., income, ethnicity, gender) affect how easily different groups can access UGI in your area?

Yes, significantly Yes, but not significantly No, everyone has equal access Not sure

17. How would you rate the availability of information regarding UGI in your area (e.g., locations, opening times, accessibility features)?

Very accessible information

somewhat accessible

Not accessible

Not sure

SECTION (V): BARRIERS TO UGI ACCESSIBILITY

18. What do you think are the primary barriers to accessing UGI in your area? (Select all that apply)

Distance to the nearest UGI facility

Lack of transportation options

Poor maintenance of UGI facilities

Inadequate signage or information

Safety concerns (e.g., crime, traffic)

Physical barriers (e.g., stairs, lack of ramps)

Other (Please specify) _____

19. Do you think that public policies (local government decisions) play a role in improving or hindering UGI accessibility?

Yes, significantly improve access

Yes, but they don't significantly improve access

No, policies hinder access

Not sure

20. What improvements would you suggest to make UGI more accessible in your community? (Select all that apply)

Building more green spaces (parks, playgrounds, etc.)

Improving transportation access to UGI facilities

Enhancing safety (e.g., better lighting, reducing crime)

Removing physical barriers (e.g., ramps, smoother paths)

Better maintenance and cleanliness

Providing more information (e.g., schedules, locations)

Policy changes to address social inequalities

Other (Please specify) _____

**SECTION (VI): IDENTIFICATION OF AREAS WITH LIMITED ACCESS
(SPATIAL DISTRIBUTION)**

22. What improvements would you suggest to increase accessibility to green spaces in your area? (Select all that apply)

Creating new parks or green spaces

Expanding or improving existing parks

Adding more walking or cycling paths

Installing more seating, shade, or amenities

Better maintenance and cleanliness

Improving safety (e.g., lighting, security)

More community events or activities in green spaces

Other (Please specify) _____

Economic benefits of Urban Green Infrastructure

Please indicate by ticking (√) your level of agreement or disagreement with the following economic benefits of urban green infrastructure using Strongly disagree = 1 Disagree = 2 Undecided = 3 Agree = 4 and Strongly agree = 5.

No.	Green infrastructure brings the following economic benefits	1	2	3	4	5
1	Improves food security through urban farming					
2	Reduces the use of energy in buildings for cooling, lighting, and ventilation					
3	Increases property values and tax revenue					
4	Increases productivity among office employees					
5	Provides medicinal plants					
6	Promotes tourism					
7	Promotes economic growth and investment					

SECTION (VII): Interviews:

1. What improvements would you suggest for the local government to enhance UGI accessibility in your area?

2. Are there any other factors not mentioned in this questionnaire that you believe affect UGI accessibility?

3. Are there any specific areas in your community that you believe have limited or no access to green spaces?

4. In your opinion, are there any groups in your community that have limited access to green spaces?
