ADDIS ABABA, UNIVERSITY
COLLEGE OF SOCIAL SCIENCES

LAND USE LAND COVER CHANGE DETECTION OF URBAN GREEN AREAS IN ADDIS ABABA BY USING GEOSPATIAL TECHNIQUE: THE CASE OF NIFAS SILK LAFTO SUB-CITY

BY

MERYEM HUSSEIN

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Art in Geography and Environmental Studies (Specialization in GIS, Remote Sensing, and Digital Cartography)

JUNE 2024
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SCHOOL OF GRADUATE STUDIES

This is certify that the thesis prepared by Meryem Hussein entitled: Land Use Land Cover Change Detection of urban green areas in Addis Ababa by using Geospatial Technique: the case of Nifas Silk Lafto Sub-city and submitted in partial fulfillment of the requirements for the Degree of Master of Arts Geography And Environmental Studies (Specialization in GIS, Remote Sensing, and Cartography) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Chair of Department or Graduate Program Coordinator

DECLARATION

I declare that this Thesis is originally prepared by me. it is based on my work, with acknowledgments of other sources, and has not been submitted in whole or part for any other professional qualification.

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Place:

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ABSTRACT

The purpose of this study, titled "land use land cover change detection of urban green areas in Addis Ababa by Using Geospatial Technique: The Case of Nifas Silk Lafto Sub-City," is to Evaluate from 2004 to 2024, the distribution and dynamics of urban green spaces, assess the impact of urban expansion on these spaces, and provide recommendations for sustainable urban planning. The research focuses on Nifas Silk lafto Sub-city, a densely populated area facing significant challenges to its green spaces due to rapid urban growth. Using Landsat and sentinel Imagery, and employing object-based classification with eCognition software and NDVI calculations, the study analyzes land use changes over a 20-years period and compares them with the city's master plan.

Key findings reveal an increase in urban green spaces and forests, although open spaces have declined due to urban expansion and regulatory challenges. The NDVI results shows increase followed by decrease, due to a significantly reduction in urban agriculture in the study area, the structural plan indicates and increase in urban green spaces. The study identifies an even distribution of green spaces and emphasizes the need for sustainable urban planning, community engagement, enhanced reforestation, and effective policy measures to balance development with environmental sustainability. Initiative like the Addis Ababa Riverside Development Project and the Green Legacy Program are essential for ecological sustainability the livability and environmental quality of NSL and Addis Ababa as a whole.

Key words: UGS – urban green space, GI – green Infrastructure, LULC – land use land cover changes

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ACRONYMS AND ABBREVIATIONS

AA	Addis Ababa
AACAUBGDB	Addis Ababa city Administration Urban Beautification and Green Development Bureau
AAEPA	Addis Ababa City Environmental Protection Agency
AOI	Area of Interest
CRRSA	Civil Registration and Residence Service Agency
CSA	Central Statistical Agency
ETM	Enhanced Thematic Mapper
GEE	Google Earth Engine
GIS	Geographic Information System
GTPs	ground truth points
LDP	Local Development Plan
LULC	Land Use Land Cover
NDVI	Normalized Difference Vegetation Index
NIR	near-infrared
NLF	Nifas Silk Lafto
OBIA	Object-Based Image Analysis
UGS	Urban Green Space
UN Habitat	Uniteed Nation Habitat
WHO	World Health Organization

CHAPTER ONE

1. INTREODUCTION

1.1. Background of the Study

The 20th century witnessed a significant shift towards urban living, marking the first time in history that the majority of the global population resided in urban areas (UNPF, 2007). Presently, more than half of the world's inhabitants live in urban zones, with projections indicating a doubling of urban populations by 2030. The emergence of urban green infrastructure is becoming increasingly crucial for enhancing the quality of life in our rapidly urbanizing societies. This evolution in green infrastructure is reshaping community perspectives and fostering sustainability efforts aimed at enhancing the well-being of current and future residents.

Urbanization is a global phenomenon that can significantly alter the physical landscape of the world. The process of urbanization leads to changes in urban areas, with urban fringes being continuously transformed for urban purposes (Sushil, 2010). These changes involve alterations in land use and land cover patterns, industrialization, and social transformations (Sushil, 2010).

The expansion of urban areas due to urbanization has had adverse effects on the natural environment, particularly through the encroachment on green spaces in cities across different continents, including Europe, North America, South America, Asia, and Africa. The situation in Africa, in particular, has been described as critical(Mensah, 2014). Many urban areas in countries such as Nigeria, Egypt, Ghana, Rwanda, Somalia, and South Africa have less than 10% of their land area designated as urban green spaces(Mensah, 2014).

Ethiopia is experiencing rapid urban population growth, with the number of city dwellers expected to almost triple over the next three decades. The capital city of Ethiopia, Addis Ababa, has been undergoing significant growth and expansion in various directions (UN, 2015).Addis Ababa (AA) as the capital city of Ethiopia has been growing and expanding in all directions since its establishment. It has become the political administrative, business, and cultural center of the country, and faces rapid urban population growth mainly because of natural urban population increases and in-migration from the rural areas in search of better life, education, and work.

(Anteneh & Et.al, 2023) the population growth and development projects has increased the land demand for residential, commercial, and industrial purposes. As a result the horizontal expansion of the city causes serious damage to urban agriculture, green space, and the environment.

Nifas silk sub-city (NSL) is one of the most populated sub-cites in Addis Ababa, covering an area of 4233.48 hectares and 445,683 projected populations in 2022. It is facing rapid urban expansion, built-up expansion, and high threats to its urban green space. The sub-city consists of residential areas, commercial activities, and industrial districts, but faces challenges in achieving sustainable urban development and preserving green spaces. The conversion of green spaces to other land uses, such as residential and commercial construction, poses a significant threat to Addis Ababa's green areas. Although mayors of Addis Ababa efforts have been made to increase green coverage throughout the city, an assessment is needed to understand the current situation of urban greenery (Abebe & Megento, 2016).

The proposed urban green spaces in Addis Ababa's structural plan for 2022 aim to develop a total of 2730 ha at the city, sub city and woreda levels. If implemented this plan would greatly improve green spaces in all sub cities. However proposed areas distribution is not equal throughout the city, high concentrations in the northern parts. According to the study of Cities4Forest current situation of Addis Ababa report in 2023, around 14% coved by green spaces, 7% by urban forests, and 9% by urban agricultural land. 70% of majority of the land covered by built-up areas and other infrastructure (Cities4Forest, 2023). UGS are critical for sustainable development in any urban settlement and have numerous socio-economic, environmental, and aesthetic functions (Haq, 2011).

There are a lot of factors that contributed to these LULC changes in Addis Ababa including informal settlements, migration, government and non-government institutions, the growth of business centers, revision structural plan and weaknesses in master plan implementation and preservation. These changes, particularly the conversion of open spaces and green areas into built up areas, have significant environmental impacts on both human and wildlife (Yirga Ayele et al., 2022a). LULC change are undeniably the most crucial and top-priority undertakings in spatial data analysis. This method is predominantly employed and well-suited for comprehensively examining and intensely displaying the complex land utilization patterns, sharp modifications occurring within these patterns, and evaluating the profound impact these modifications unavoidably have on the delicate balance of our environment (Arowolo & Deng, 2018).

Geospatial techniques, GIS and RS are the most suitable approaches for detecting land use, land cover and their changing patterns. Over the last two decades, there has been rapid growth in the development of methods for RS, GIS and image processing that enable changes in land use to be detected. RS offers a synoptic, current and repetitive view and provides accurate details on a given element of the earth's environment (Arowolo & Deng, 2018). The competence of this technology for detecting change has long been recognized, and now these changes in land use have become a major concern for many groups, from researchers and the private sector to policymakers and the public.

The sub-city thus forms a possible case for assessing LULC changes and their implications for urban green areas, with a view to providing guidance for sustainable development. However, there have not been enough studies on the extent and patterns of LULC change in the Nifas Silk Sub-City, thus the NSL LULC situation is not well understood. The purpose of this study is to determine the current situation of urban green spaces, detect changes in LULC of urban green spaces, conduct a socio-temporal analysis, and compare the UGS to the structural plan and the existing status. Geospatial approaches were the key instruments used in this investigation. The study's findings are considered more significant because they may improve the sub-city's understanding of its current situation.

1.2. Problem Statement

Urban expansion affects the natural environment in many places across Europe, North America, Asia, and Africa, with the situation in Africa being particularly dire. Green spaces are under pressure and are becoming fewer in number (Mensah, 2014). The same source claims that urban green spaces make up less-Saharan Africa with 16-17% of its population living in urban areas. However, with an annual growth rate of more than 5%, Ethiopia has been grouped among countries with the fastest urban expansion processes in the world (CSA, 2022).

Addis Ababa, hosting nearly 30% of the urban population of Ethiopia, reveals typical primate city characteristics, having overwhelming dominance in the economic, social and political affairs of the country. The city of AA has experienced enormous development, resulting in a decrease of green spaces o the point where several districts, including the study region NFS sub-city, show signs of rising temperatures and hot weather (Abebe & Megento, 2016). AA was formerly referred to as a "forest city." With some many homes, buildings, and highway being build and not enough focus being placed on green spaces, it is expected that the issues will only get worse in the upcoming years. Furthermore, the city lacks current data that could provide an understanding of the overall physical changes and the quality of green space in particular (Abebe & Megento, 2016).

Urban areas, especially rapidly growing cities like AA face significant challenges in preserving green spaces among ongoing land use and land cover changes (Azagew & Worku, 2020). The rapid expansion of urbanization often leads to the conversion of green areas into built-up environments (Asabere et al., 2020), resulting in environmental degradation, loss of biodiversity, and decreased quality of life for residents (Morar et al., 2022) (Tassew & Fikresilassie, 2024). In the case of Addis Ababa, the Nifas Silk big-city represents a small-scale version of this urban expansion process; the conversion of green spaces to built-up areas that led to the loss of Green spaces is recognized (Yirga Ayele et al., 2022a). while Green legacy initiative and Addis Ababa City Plan are hardly working on greenery during this time to expand the extent of green areas and make the city beautiful, trees are being planted along streets and designated spaces are being allocated. Assessment of land use and cover changes in urban green areas is necessary to determine the current status of greenery (Citis4Forest, 2023).

This research fills the gap by addressing the lack of analysis on urban green areas assessment in Nifas Silk Lafto sub-city, which has the highest population density and is undergoing rapid urban expansion. Previous studies primarily focused on areas like Gulele, Yeka, and Bole sub-cities with abundant greenery. Despite existing literature discussing changes in urban land use and land cover management of green spaces, there remains a knowledge gap regarding the specific dynamics and challenges faced by rapidly growing sub-cities like Nifas Silk. While a few studies have emphasized the significance of green spaces for the sustainability of cities and the well-being of people, very few have conducted a thorough examination of how changes in land use and land cover affect urban green areas at the sub-cities level. These highlight the need for analyzing urban land use and land cover change, particularly urban green space, using geospatial techniques.

This study aims to assess the extent, pace, and pattern of urban expansion and its effects on green areas, providing insights into the current status of green area in NSL, change rates, patterns of change over time, and factors driving changes. Additionally, the majority of the literature on the assessment of greenery in Addis Ababa or for NSL Sub-city has mainly relied on techniques such as the Normalized Difference Vegetation Index (NDVI), which may have limited the understanding of land cover change. This study goes beyond NDVI and applies advanced techniques to evaluate vegetation, with a particular focus on Addis Ababa’s NSL Sub-city. It uses satellite imagery and NDVI techniques to enhance the accuracy and understanding of NSL urban green spaces.

Findings from this research will inform urban planning strategies to preserve and increase green spaces in Addis Ababa, with potential implications for other rapidly urbanizing cities globally facing similar challenges. The study will provide insights into the dynamics of urban greenery and offer recommendations for more equitable distribution. This comprehensive approach aims not only to enhance sustainability and livability within rapidly developing areas like Nifas Silk but also to guide policymakers and urban planners in implementing effective urban greenery strategies aligned with city-wide master plans.

1.3. Research objective

1.3.1. General Objective

The aim of this research is to assess the existing state of urban green space in the Nifas Silk Lafto Sub-city.

1.3.2. Specific Objectives

1. To assess the spatiotemporal patterns of changes in urban green spaces from 2004-2024 in the study area.

2. To compare master plan’s allocation of urban green space in Nifas Silk Lafto Sub city with the existing land cover pattern.
3. To identify the major driving factors behind land use land cover changes of urban green space in the study areas.

1.4. Research Questions

1. What do the pattern of urban green spaces in the study area look for 2004-2024 in the study area?
2. What is the difference between the master plan’s allocation of urban green space and the existing distribution in the study area? how the master plan’s proposed allocation of urban green space differs from the existing distribution in the study area

   How does the master plan’s proposed allocation of urban green space differ from the current distribution in the study area?

3. What are the major driving factors for changes inland use land cover of urban green spaces in the study area?

1.5. Significance of the Study

This research holds significant importance as it examines the dynamics of urban green areas within NSL sub-city, Addis Ababa, contributing crucial insights for sustainable urban planning and policy-making in Ethiopia. By analyzing changes in master plan design and exploring factors affecting urban greenery, the study offers valuable scientific perspectives. It serves as a pivotal resource for understanding the current status and trends of urban green spaces, essential for enhancing biodiversity, improving quality of life, and mitigating environmental challenges in rapidly urban expansion areas.

Furthermore, this research provides a foundation for future investigations into the intricate relationship between urban expansion and urban greenery across Ethiopia. It informs policymakers and planners on strategies to preserve existing green spaces. Ultimately, the findings aim to shape effective policies at regional and federal levels, fostering sustainable urban development practices that prioritize environmental health and community well-being.

1.6. Scope of the Study

The scope of the study is defined geographically and temporally. Geographically, the research is confined to Nifas Silk Lafto Sub-city, one of the eleven sub cities of Addis Ababa, comprising 13 weredas. In 2022, this sub-city had a population of 4445,683 and covers an area of 4233.63 hectares.

Temporally, the study spans from 2004 to 2024, assessing trends and patterns in urban green areas using historical and current geospatial data. Thematically, the study focuses on identifying the current status of urban green areas within NSL Sub-city, examining the dynamics of land use land cover changes, crucial for sustainable urban planning and management.

1.7. Limitations of the Study

As it is common in many studies, there are some constraints while doing study concerning the shortage of budget and time. Since, getting very high-resolution satellite date commercially is much expensive, the researcher was forced to use open source data which have relatively lower spatial resolution.

A major limitation of the study was the use of Landsat 7 and Sentinel-2 imageries with different spatial and temporal resolutions for comparison, because Sentinel images were not available for 2004. The researcher attempted to use pan-sharpening to enhance the 2004 images with sentinel data, but this resulted in accuracies, with many urban agriculture areas being misclassified as built-up areas, particularly around the Jemo. To address these limitations, the researcher reviewed relevant literature, utilized Google Earth, and applied prior knowledge of the study area at the time of classification

Another challenge was distinguishing partial wetness in vegetation canopies, which led to misclassification involving grass land, agriculture, and various succession stages in wetlands. The reflection of red and near infrared wavelengths of vegetation analysis was beyond the scope of this study due to the limitation of using only free handset and sentinel imagery and software.

Furthermore, the researcher faced difficulties in comparing data over time due to changes in the boundaries and size of coverage of the NSL Sub-city. To address this issue and ensure consistency in the study area for more accurate comparisons, the researcher used the updated boundaries as of 2022 for all study years.

1.8. Organization of the Paper

The research project consists of five chapters. Chapter one is an introduction that presents the background to the study, a statement of the problem, objectives, research questions, significance, scope, and limitations of the study. Chapter two is a literature review that reviews the theoretical and empirical literature it discusses urban green areas definitions and types, urbanization, satellite images, and geospatial techniques. Chapter three describes the study area and outlines the research methodology. Chapter four presents and discusses the results of the study. Chapter five presents the summary, conclusions, and recommendations

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Definition and Concept of Green Space

The Land Use Change Model (LUCM), developed by researchers Eric F and Lambin, is a framework for understanding and predicting changes in land use patterns, influenced by socio-economic, environmental, and policy-related factors. It considers key drivers of change such as economic activities, population growth, technological advancements, and policy changes, which impact land use transitions and spatial patterns. By analyzing historical data and modeling transition probabilities, LUCM helps identify areas most susceptible to change and the feedback mechanisms involved. In the context of Nifas Silk Lafto Lafto sub-city, LUCM can be applied to analyze historical land use changes, identify key drivers like urban expansion, and predict future changes, aiding in sustainable urban development planning (Lambin, Geist, & amp; Lepers, 2003).

Definitions of urban green spaces (UGS) are widely documented in the literature. Urban green spaces refer to any type of vegetal environment found within an urban land region. The phrase “urban green areas” has been used in a variety of disciplines, with variations including “urban green space,” “green open space,” “urban Greenland system,” “urban green infrastructure,” and “ecological Greenland system.” It’s also critical to review a few definitions provided by various authorities and writers (Benedict & McMahon, 2002).

According to WHO definition urban green space is a component of “green infrastructure,” it is an important part of public open spaces and common services provided by a city and can serve as a health-promoting setting for all members of the urban community” (UN Habitat, 2017).

Green space and open space definition according to Ethiopian national urban green infrastructure standards defined as:-

Green space is A proportion of open space that is retained in a mostly undisturbed vegetative state. it can be partly or completely covered with grass, trees, shrubs, or other vegetation (MUDH, 2015).

Open space is any open piece of land that is undeveloped (has no building or other built structures).Open space may be used for passive or active recreation or may be reserved to protect or buffer natural areas. open space can include green space (MUDH, 2015)

Urban green infrastructure is defined as the combined structure and connectivity of recreational parks and other types of green space that deliver multiple benefits for the urban environment (Jennings et al., 2016). GI recent definition of is an urban area that includes a variety of street trees, parks, cultivated land, wetlands, lakes, and Streams. According to the definitions given above, green infrastructure is commonly described as having the following components. connectivity biodiversity, multi functionality, natural and human benefits, spatial variance, and substructure. Green infrastructure should be a part of larger ecological features, these characteristics include the district landscape elements as well as broader interpretations of the term “green spaces” (Benedict & McMahon, 2002).

2.2. Types of Urban Green Space

Ministry of urban development and construction (MUDC, 2015) classified green and open spaces into patches such as parks, gardens, amenity green open spaces, and corridors. The Addis Ababa city plan classified the city parks into recreational and special function parks. The recreational parks include the city, sub-city, woreda (the smallest local administrative), and neighborhood scales, while the special function parks are meant for the conservation of wildlife habitat (AACPO, 2017). Among the types of green spaces selected are recreational parks, botanical gardens, and community (neighborhood) green spaces. A community green space in this research refers to small areas located near residential area to provide green area for residents and serve as the 'lung' of the city. A botanical garden is a special recreational park with rich biodiversity and a protected area in the city.

The urban green space has its own physical components, including urban forest, parks, river line, and street trees. Green space can become so many things like natural play spaces, community gardens, urban agriculture, and rooftop gardens (Farrar, Redhead, 2009). Natural play spaces are growing rapidly in popularity as they become recognized for their significant positive impacts on the health, wellbeing, and growth of children. Natural play spaces use a blend of natural areas, water, and local plants to interest children in learning about the wonders and secrets of the natural world. Community gardens have significant benefits to the community in social, economic, and environmental aspects. Urban agriculture has a slightly different focus than community gardens and exerts an important impact on social movement around the community and food security. It is considered beneficial to both the ecological and food security movement (Samson, 2014).

Rooftop gardens can be an excellent source of organic produce for urban residents, as long as the building structure can handle the weight. There is a distinction to be made between green roof and rooftop gardens. Green roofs are architectural and engineering projects that usually consist of a layer of grasses and low-growing plants integrated into the roof of a building or built into existing roofs but rooftop gardens consist of movable growers strategically placed on existing rooftops that do not always require structural reinforcement.

2.3. Green Infrastructure Components

The number of definitions of green infrastructure that exist at the moment equals the number of authors that are working on the idea. The definitions employed by an organization or an author are directly related to the subject matter of their particular green infrastructure research, as is the case with the majority of academic and practitioners studies (Benedict & McMahon, 2002). According to Benedict and McMahon, for instance, some people refer to green infrastructure as urban trees because of the environmental benefits they offer, while others use the term to describe engineered structures like environmentally friendly green roofs or water treatment facilities.

According to the ministry of urban development and housing construction of Ethiopia, the urban green infrastructure components are listed as recreational parks rights of way, river and canal corridors, and lake shores (MUDH, 2015). Similarly, Andrew Taylor classified urban green spaces as gardens, urban parks, quarter parks, historical gardens, green squares and plazas, green playgrounds, and other site-specific green spaces (Andrew, 2012). There is different way to classify urban green space, such as its size, how people use it, it's intended function, its location, and so on (Bilgili & Gökyer, 2012).

Emil and lasted believed that bell's classification of green spaces serves as the basis for the division of urban green space into eight categories(Emilia, 2013). Additionally, they describe every kind of urban green space including parks, lakes, green spaces, churchyard sports fields, common areas, and agricultural fields. on the other hand, Byrne and Sipe talked about a typology of urban green spaces, which topologists utilized to categorize several elements such as size, purpose, governance, activities, land use history, security, location, state, users, naturalness, development, and facilities(Byrne & Sipe, 2010). According to the federal democratic republic of Ethiopian ministry of urban development and housing construction the different green infrastructure components in urban green areas development strategy neighborhood park or a bigger park, or a comparable green open space) 500m in size of at least 0.3ha, a woreda park or a bigger park should be around 2ha (1,000m to 1,500m), sub-city park (or a bigger park) be around 8 ha (4,000m), a city park should be more than 15ha (6,000m) (MUDH, 2015).

2.4. The Importance of Green Spaces

Urban green spaces are essential for improving the general quality of life in urban contexts since they fulfill a multitude of purpose and give several benefits, numerous beneficial direct and indirect services are provided to neighboring parcels by green areas. These green areas are extremely important to the urban population because they act as a link between them and the natural world (Bilgili & Gökyer, 2012).

The advantages of urban green space can be categorized into four primary categories. Such as environmental benefits, Biodiversity and nature conservation, economic and aesthetic benefits, and social and psychological benefits (Haq, 2011)

2.4.1. Environmental Benefits

Environmental urban green zones provide cities with ecological advantages such as regulating climate and promoting biodiversity. In comparison to rural regions, urban areas experience varying degrees of sun radiation, rainfall patterns, and temperature. Variations in sum radiation, air temperature, wind speed, and humidity are caused by the built environment of cities. Because of heat- absorbing surfaces and excessive energy use, the urban heat island effect raises city temperatures by 5°C. Well-planned green areas protect biodiversity and act as habitats. These green areas support species populations in developed settings by serving as "urban forests" or wildlife corridors (Byrne & Sipe, 2010; Haq, 2011).

Pollution: - Chemical, particulate matter, and biological materials in the form of solid, liquid, or gas are examples of pollution found in cities. Urban areas often have high levels of air and noise pollution. While industrial regions release nitrogen oxides and sulfur dioxide, motor vehicles release carbon dioxide and carbon monoxide.

2.4.2. Biodiversity and nature conservation

Reproduction of many species: By providing visual relief, seasonal change, and a connection to the natural world, these urban green spaces provide as a bridge between urban and rural areas. For the ecological components of a healthy urban environment to be preserved, a functional network of green spaces must be established. This can be accomplished by making use of green ways and adding plant species that are well suited to the regional climate, resulting in low care requirements, sustainability, and self-sufficiency (Haq, 2011).

2.4.3. Economic and Aesthetic Benefits

Energy saving: the financial advantages of using trees to reduce the costs of air conditioning buildings are becoming more widely acknowledged, especially in cities with moderate temperatures. The presence of plants facilitates transportation, improves air circulation, and provides shade from the sun. The cooling effect of these activities eventually causes the air temperature to drop. A park that spans 1.2 kilometers by 1.0 kilometers has the potential to produce a detectable variation in air temperature between its borders and the surrounding metropolis for up to 4 kilometers. Results from a study carried out in Chicago have shown that increasing the number of trees in the city by just 10% may be able to reduce the total amount of energy needed for heating and cooling by an astounding 5 to 10% (Haq, 2011).

2.4.4. Social and Psychological Benefits

Recreation and well-being: Most people's leisure needs are satisfied in their local neighborhoods. Urban green spaces are a handy place to relax and provide emotional comfort. Every week, up to three million people come to Chapultepec Park, which is conveniently located in Mexico City. To engage in a variety of activities (Haq, 2011). Human well-Being stress levels quickly decreased in individuals exposed to a natural environment compared to those exposed to an urban setting. There is little question that vegetation-induced alterations in air quality are good for physical health, with a reduction in respiratory diseases being one of the obvious benefits. Human-nature ties are critical to every human-being, productivity at work, mental health in general (Haq, 2011).

2.5. Urban Green Space in Ethiopia

Ethiopia's tree cove made up 11% of the country's total area as of 2000k, although between 2002 to 2021, Ethiopia lost 80.1 ha of its humid primary forest, accounting for 18% of the country's overall tree cover loss over the same period. During this period, the humid primary forest of Ethiopia lost 4.2% of its total area (Global Forest Watch Report, 2022). Ethiopia lost 204 Mt of CO2 emissions and 448Kha of forest cover between 2001 and 2021, which is 3.7% less than in 2000. In Ethiopia, where the percentage of trees fell by 0.76% between 2001 and 2021, deforestation was the main cause of loss (Citis4Forest, 2023).

Ethiopia has planned and implemented several programs to address climate change, reduce deforestation, control soil erosion, balance the water supply, improve carbon sequestration and increase food security. Among these Ethiopia's national program, the Green legacy initiative, was started in 2018 to plant 20 billion trees by the year 2023. By the end of August 2019, the program had planted 4.74 billion trees (2.45 billion forest trees and 2.3 billion mixed agroforestry species), surpassing its initial goal of planting 4 billion trees manually. This indicates how much Ethiopin values an integrated national greening program that includes integrated water and soil resource management, agroforestry, forest sector development, and urban area greening and regeneration.

This will support the nation's long-term objectives for social, economic, and environmental development as well as its international obligations under the 2030 Agenda for Sustainable Development, the Paris climate change agreement, and the African Agenda 2063. Strategic documents including the ten-year National forest sector development program, the REDD+ strategy, the climate resilient green economy (CRGE) strategy, and the Bamboo development strategy and Action plan provide a roadmap for the efforts being made on the ground for the next ten years, Ethiopia's deforestation, restoration , urban greening, forest protection, and sustainable use of forest resources will be guided by these programs and policies, which are in line with global aspirations (Citis4Forest, 2023).

2.6. Urban Green Space in Addis Ababa

The Addis Ababa Structural Land Use Plan (2017-2027), revised in 2022 by the Addis Ababa City Plan and Development Commission, is an extremely comprehensive map that needs simplification before reaching the updated timeline (AA City Adninistration Plan and Development Commission., 2022). Urban agriculture land covers up around 9% urban forest area covers 77%, and green space covers 14% in Addis Ababa. The majority of land usage, or 70% of the city, is attributable to man-made elements, such as the built-up area overall and some other infrastructure in Addis Ababa (Cities4Forest, 2023). The distribution of green space is highest in the northern section of Addis Ababa, while urban agricultural land predominates in Addis Ababa' eastern, southwestern, and northwestern regions.

The loss of green spaces in Addis Ababa is due to the conversion of green spaces to built-up regions, the transfer of land designated for green areas in the master plan to private use, weak land governance, and a lack of sectoral cooperation in managing green spaces (Yirga Ayele et al., 2022b). Ministry of urban development and construction classified green and open spaces into patches such as parks, gardens, amenity green open spaces, and corridors. The Addis Ababa city plan classified the parks into recreational and special function parks. The recreational park include city, sub-city, woreda (the smallest local administrative), and neighborhood scales, while the special function parks are meant for the conservation of wildlife habitat. Among the types of green spaces selected are recreational parks, botanical gardens, and community (neighborhood) green spaces (Cities4Forest, 2023).

2.7. Impact of Urban Expansion on the Development of UGS

Urban expansion is the major cause of the loss of urban green space, the variables of urban expansion are physical expansion and population growth (Mcdonald et al., 2010). According to (Mensah, 2014), urbanization is still a significant problem that has been primarily related to the degradation of natural spaces. Urban expansion can be obvious as the geographical extension of urban areas outside of their immediate center or as the identification of the urban core (urban sprawl). High population density and a rise in the built environment, That is building structures in relation to open areas are indicators of identification of the urban center (Mensah, 2014). Conversely, urban sprawl related to the external growth of urban areas, frequently occurring in peri-urban regions, former agricultural fields, and the urban edge. According to (Honu et al., 2009). Rapid urban expansion has caused the excessive loss of the natural environment, including green spaces, and the conversion of various urban sites into built-up building.

Urban population in the United States has climbed dramatically in recent decades, from 84.5 million in 1950 to 226 million in 2000 (Mcdonald et al., 2010). The urbanized area drastically expanded as a result of the new inhabitants relatively low density settlement in suburbs located further from the city center (Mcdonald et al., 2010), resulting in a drastic expansion in urbanized area (Theobald, 2005). the expansion of urban area can have significant ecological impacts (Luck, 2007), The amount of open space is reduced(Grimm et al., 2008), fragmenting natural habitat as well as reducing the recreational and other amenities people can enjoy from open space (McDonald & Urban, 2006).

According, to Darkhani there is an increase in the loss of green spaces in less developed countries metropolitan areas and an inadequate management system in emerging nation (Darkhani et al., 2019). Rapid urban expansion a failure to acknowledge the urban environment as a system (Mensah, 2014), a lack of strong institutions for urban development planning and management; and constrained municipal budgets (Yirga Ayele et al., 2022a)are the main causes of the loss of green spaces. According to ministry of urban development, housing and construction, Ethiopia is now one of the least urbanised countries In sub- Sahara Africa, with 20 percent of the total population living in urban areas (MUDHC, 2014).

Addis Ababa is the political capital and diplomatic center. The city is rapidly urbanizing which is influencing the urban green areas of the city. The increase in the number of people migrating to the city seeking jobs, better living, and educational centers, among others, has contributed to the expansion and construction of buildings within the city. This has resulted in the reduction of green spaces within the city. The city started with 400 hectares of forest area in 1977, which was reduced to 185 he 6 in 1986 70 hectares in 2000. The green coverage of the city dropped to 4% in 2000 from 7% in 1987. The green cover will shortly replace with buildings Homes, roads, schools, institutions, hotels, etc. Are all seen to replace green areas (Yirga Ayele et al., 2022a).

Over all these research to fill a gap in the literature by utilizing advanced geospatial techniques, such as NDVI calculation and Object- based classification, to detect land use and land cover changes in urban green areas of NSL Sub-city, AA. Data collection includes satellite images, population statistics, and structural plans. Using object based image Analysis and spatio-temporal change detection, the study classifies land use into urban green areas, built-up areas, and other land uses. By comparing the structural plan with current existing urban greenery, this research provides between urban growth and green space reduction.

This approach relates to the conceptual frame work by integrating the Land use Change model (LULM) and landscape and ecology principles, offering a robust methodology for understanding and managing urban green spaces, it emphasizes the importance of spatial patterns and ecological processes, aiding in sustainable urban planning and management

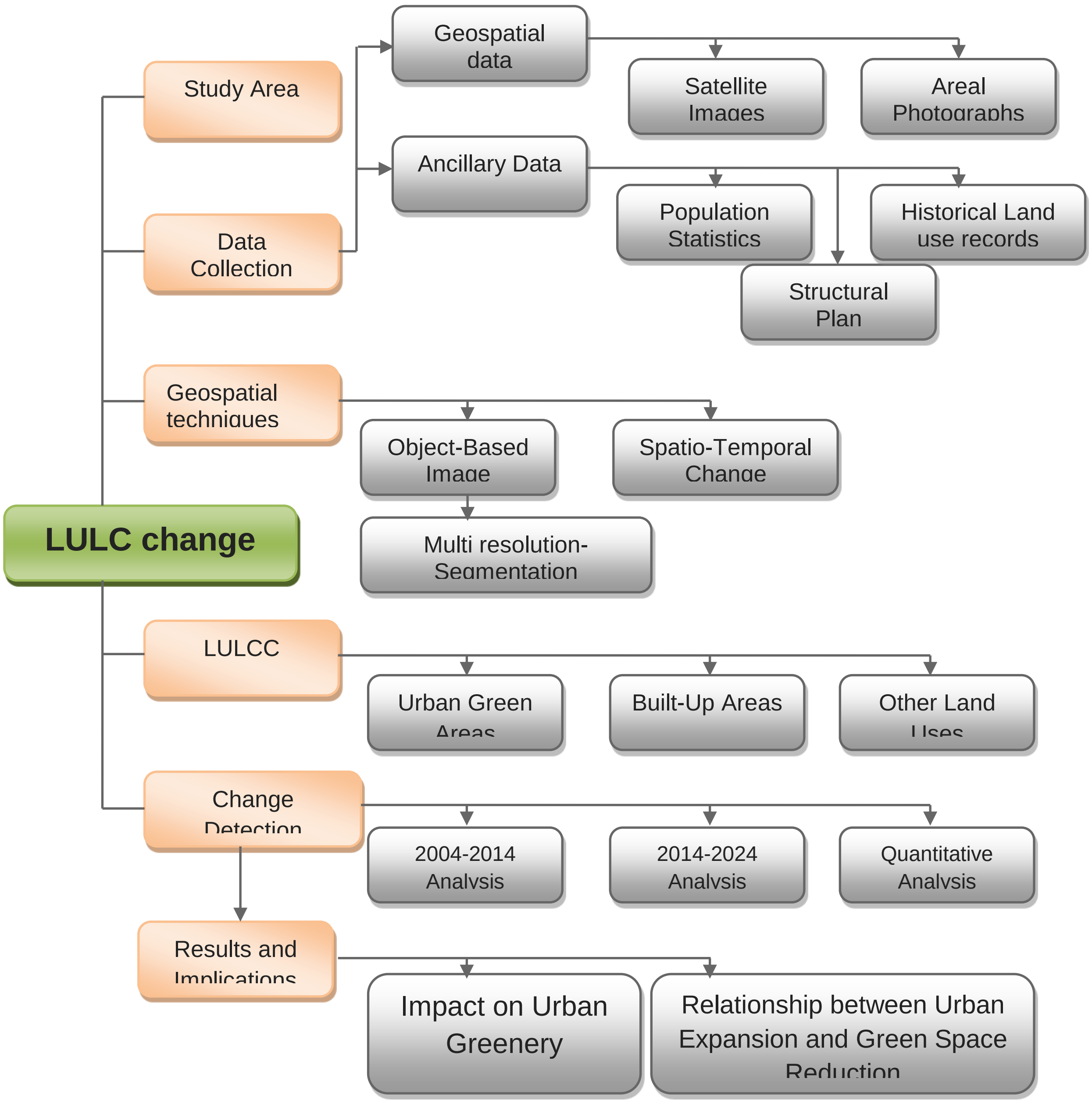

Figure 1 Conceptual Frame work diagram

CHAPTER THREE

3. METHODOLOGY

3.1. Description of the study area

3.1.1. Location

The city Administration of AA released a new structural plan in 2022, covering 432km2 and subdivided into 11 sub-cities. One of these sub-cities, Nifas Sillk Lafto, has a land area of 4233.48hectares comprising 11.31% of the city's total area and ranking 3rd among the eleven sub-cities in terms of land coverage. NSL is located in the southwest region of AA and is bordered by Kolfe Keranyo Sub-CIty to the North West, Bole and Akaki Kality Sub-Cities to the east, Kirkos and Lideta Sub-cities to the north, and the Oromia Regional State to the south.

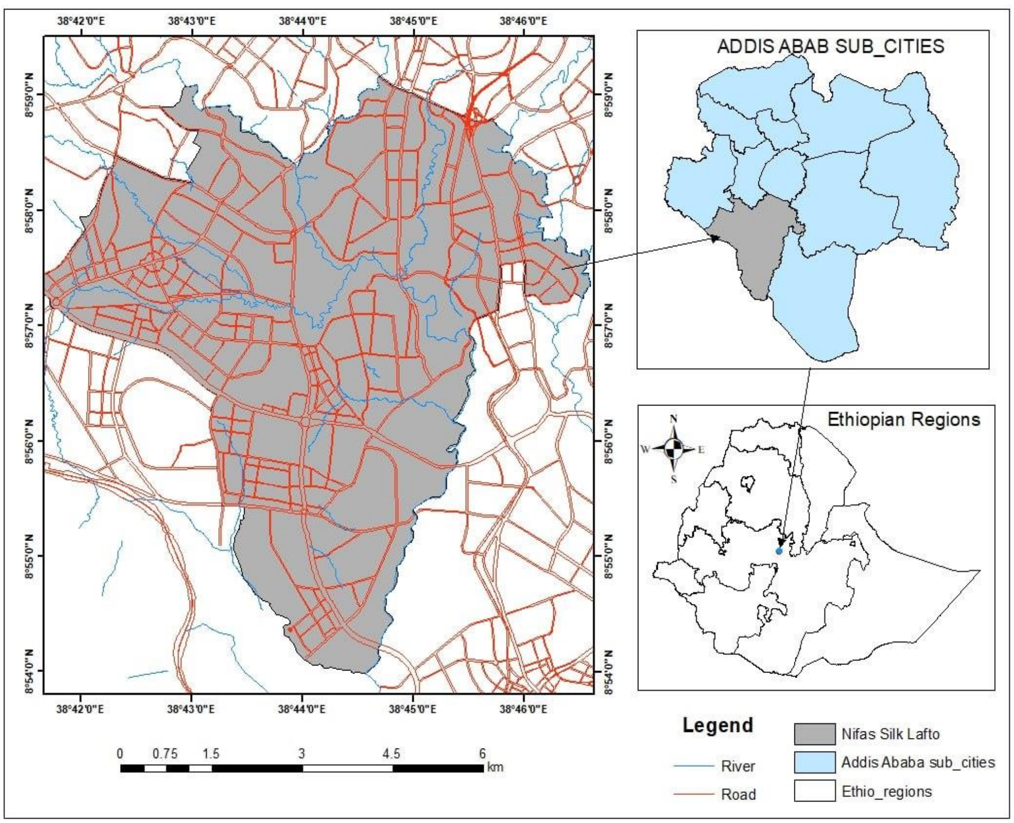

Figure 2 Geographical Location of Study Area

Data Source: Addis Ababa Plan and Development Commission

3.1.2. Topography

NSL sub-city is characterized by a moderately steep type of topography with noticeable elevation differences and a steep landscape. In general, there is a 270-meter range in altitude within the sub-city, form 2016 to 2331 meters above sea level. The highly elevated land exists in South West while relatively lower elevation exists in the South.

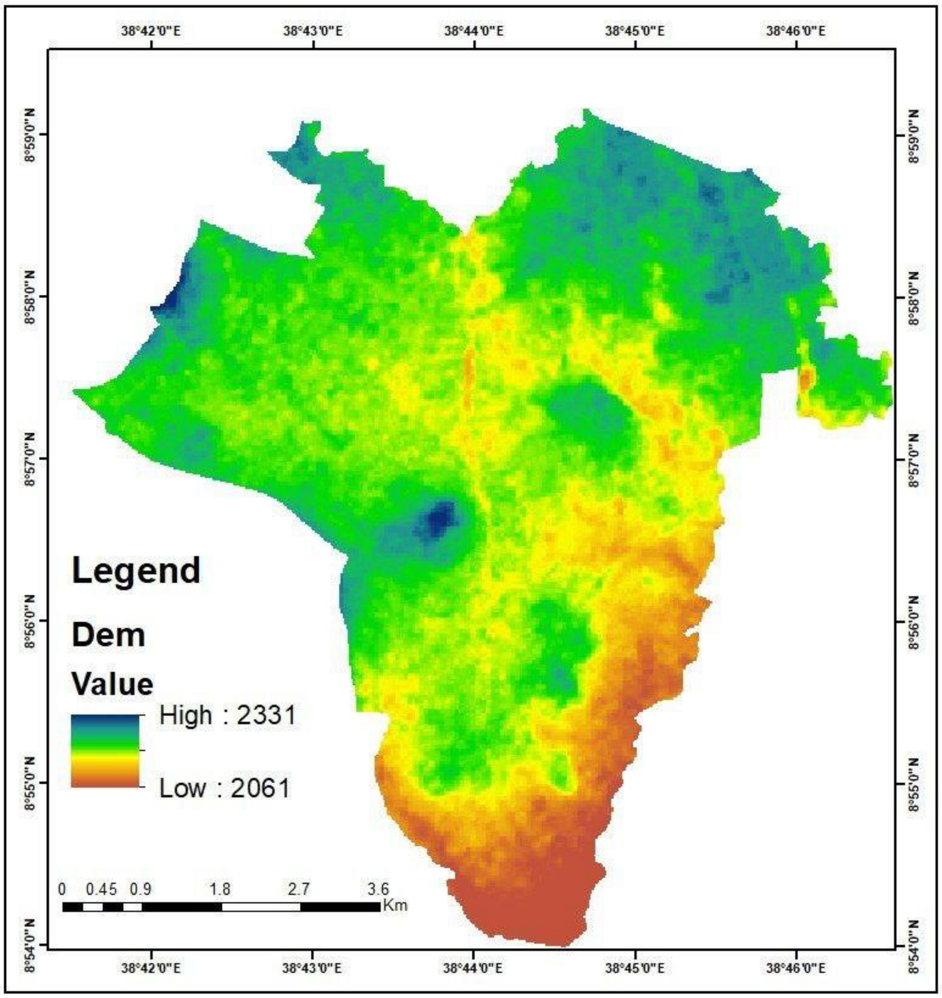

Figure 3 Elevation Map

Data Source: USGS Satellite Imagery

3.1.3. Population and density

According to the 2022 CSA population projected report, the total population within the sub-city is 445,683, consisting of 207,945 males and 237,738 females, which represents 11.54% of the entire population of the city (CSA, 2022).

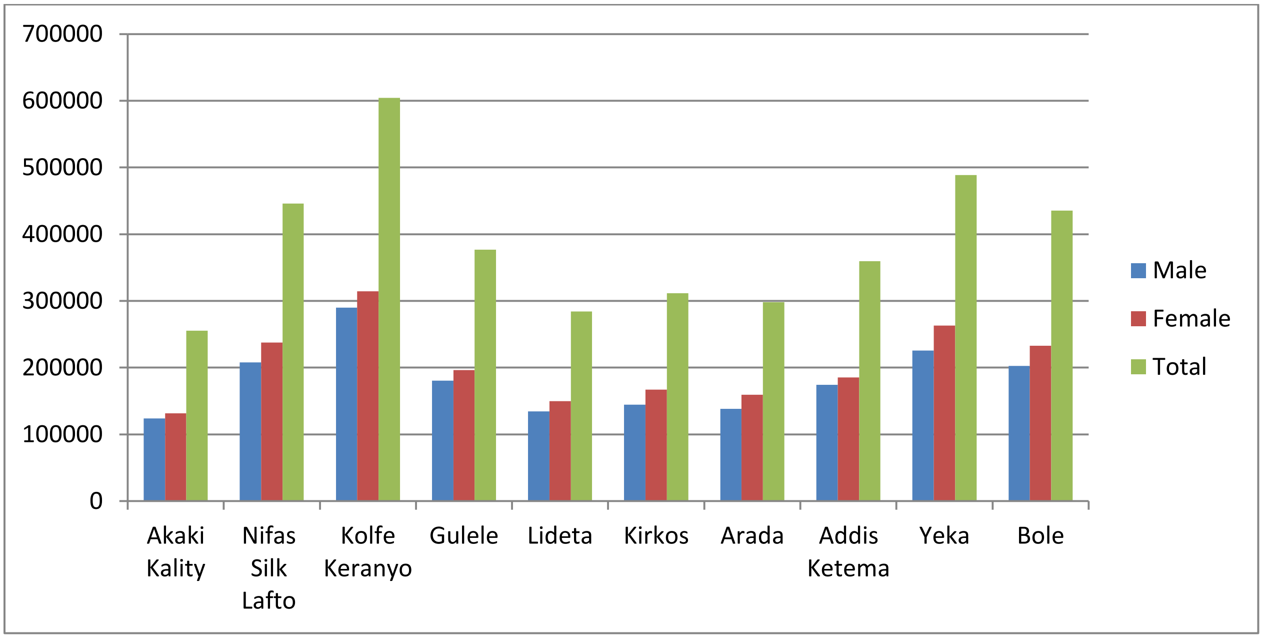

Figure 4 AA 2022 Population Data

Data Source: (CSA, 2022)

3.1.4. Climate rain fall and Temperature

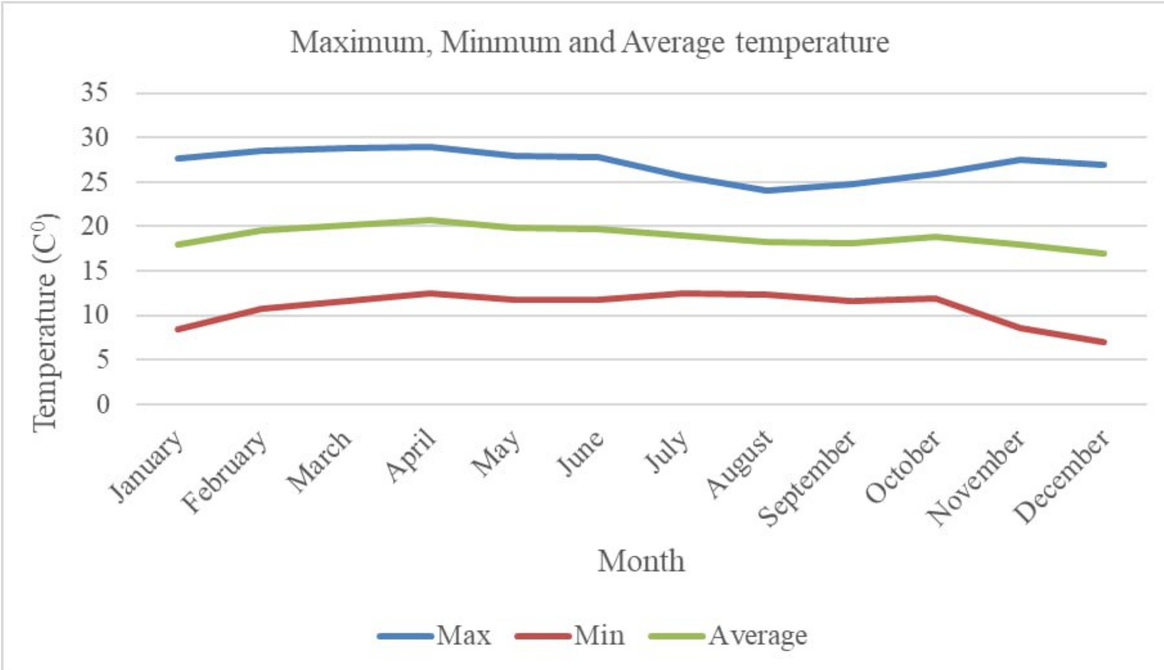

Figure 5 Temperature Graph

Data Source: National Metrological Service Agency (2022**)**

In Addis Ababa the climate data shows notable variations in temperature and rainfall throughout the year:

- **Coldest month**: August with an average high of 19.8°C and low of 11°C,
- **Annual Averages**:
  - High:22.3°C to 23.7°C,
  - Low:7.8°C to 11.4°C and
  - Mean 14.4°C to 17.2°C
- **Warmest months**: February and March with highs around 23.7°C

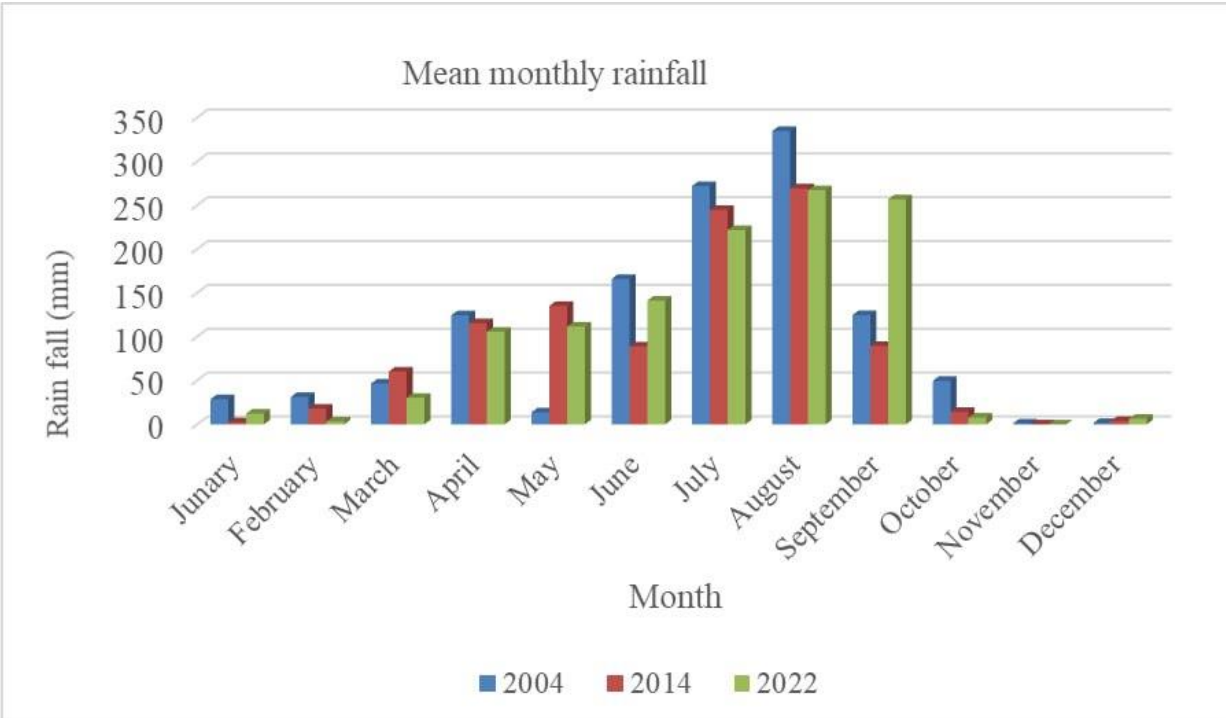

Figure 6 RF Graph

Source: National Metrological Service Agency (2004, 2014, 2022**)**

Rainfall Annual Precipitation: Approximately 873mm Monthly Averages: Dry months: December 7 mm and November 11 mm, Wet months: August 419mm and July 386 mm. This data indicates a clear wet season from June to September and a dry season from October to February, with moderate temperatures throughout the year.

3.1.5. Vegetation

There are various types of urban forests in Addis Ababa, including peri-urban forests, parks for recreation, road side vegetation, river line vegetation, and plantations found in private and institutional gardens (Aynachew, 2014). Urban and natural forests differ greatly from one another. An urban green space is created by replanting trees, shrubs, or herbs with the goal of enhancing the aesthetic value, economic, potential, and environmental quality. Six sub-cities Gullele, Yeka, Kolfe-keranyo, Nifas silk-lafto, Akaki-Kality, and Bole also have significant amount of forest. In 2014, the city had 8,148 ha of urban forests and 81.72 ha of parks (Ayenew, 2014). According to a study of (Tassew & Fikresilassie, 2024) Green space covers around 21%

of Addis Ababa. The Addis Ababa Structural Plan (2017-2027), which was amended in 2022, projected that green space would make up about 27.3% of the city.

3.2. Data Acquisition and Sources

Different organizations provided a variety of spatial and non-spatial datasets, which were then, processed using a variety of GIS tools for mapping and analysis purposes. The researcher used for this study passive microwave satellite datasets, in addition to on-sit and auxiliary data, to drive the land cover change.

3.2.1. Passive Microwave Satellite Imageries

The Landsat 7 Enhanced Thematic Mapper (ETM) and Sentinel-2 satellite images were utilized to determine the LULC changes and NDVI calculation (Anteneh & Et.al, 2023). Landsat 7 (ETM) has 30m spatial and 16 days temporal resolutions, while Sentinel-2 has 10m spatial and 5 days temporal resolutions, Landsat 7 of 2004 and Sentinel-2 of 2004 and 2024 years are downloaded from USGS and Copernicus Hub.

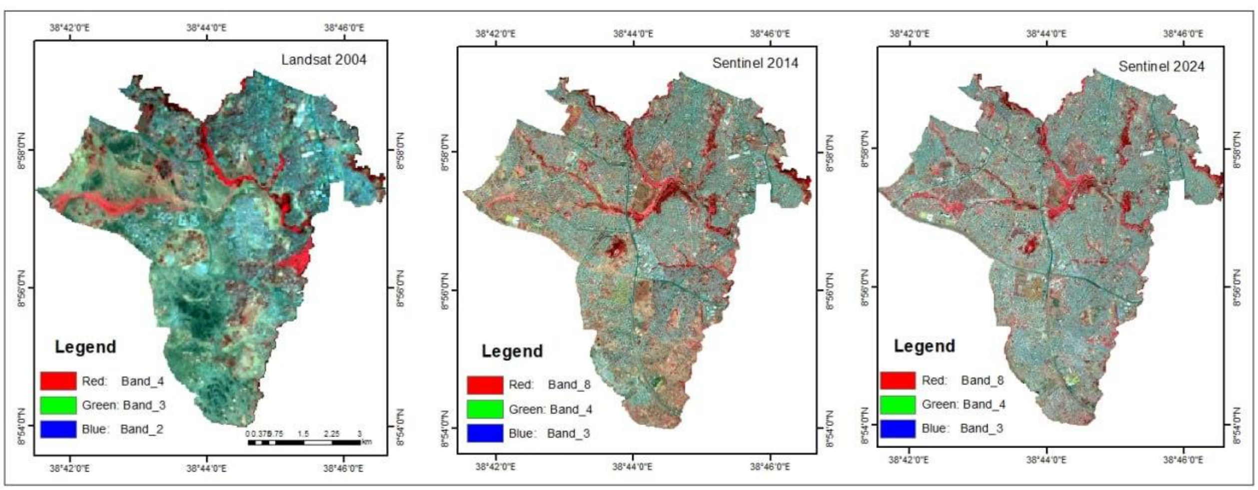

Figure 7 collected RGB data

Data Source: USGS (2004) and Copernicus Hub (2014, 2022**)**

3.2.2. Ancillary data

Several kids of ancillary datasets from different institutions and sources have been used for the validation and verification of the generated land cover patterns. shape files of built-up areas, land use structural plans, strategic plans of urban greenery, Aerial photos, and high-resolution data are a few examples (Lu & Weng, 2007). The researcher conducted site visits and interviews with governmental offices responsible for urban greenery, such as the Addis Ababa city Administration Urban Beautification and Green Development Bureau (AACAUBGDB) and the Addis Ababa City Environmental Protection Agency (AAEPA).

3.2.3. In situ data

Data collection from the field using a variety of techniques is required for land cover classification. To help with the classification process, gathering ground truth points and taking pictures of the based land cover is a common strategy. Ground truth points are particular places on Earth where information is gathered to confirm the accuracy of satellite or remotely sensed imagery. Information of various land cover types, such as vegetation, water bodies, built-up areas, and so forth, is included in this data. Additionally, pictures were taken to show the various types of land cover. The images were taken with a camera and were helpful reference points for identifying and classifying characteristics of the land cover features (Congalton, 1991).

Table 1 Description of datasets

Data sets	Sources	Spatial resolution	Temporal resolution	Acquisition date	Data Type	Data purpose
Sentinel 2A and 2B	Copernicus Hub https://browser.dataspace.copernicus.eu	10m	5 days	01/Jan-30/Jan/2024	Raster	2024 LULC
Sentinel 2A and 2B	Copernicus Hub https://browser.dataspace.copernicus.eu	10m	5 days	01/Dec-30/Dec 2014	Raster	2014 LULC
Landsat 7 (ETM)	USGS https://earthexplorer.usgs.go	30m	16 days	01/Mar-30Dec/ 2004	Raster	2004 LULC
AA-Structural plan	Addis Ababa city administration	-	-	2022	Vector	Analysis
Built-up area	https://sites.research.google/open-buildings/	-	-	2022	Vector	Validation
GTP (Ground Truth Point)	Field Survey	-	-	2024	Vector (xy, points)	Verification

3.3. Software and Tools

In the fields of remote sensing and geographic analysis, the software tools listed have a variety of uses. ERDAS 2015 software is perfect for preprocessing satellite imagery or aerial photos because it specializes in tasks like accuracy assessment and classification (Noor et al., 2013). Another, Arc map 10.8, focuses on mapping and layout design and provides users with all the tools they need to efficiently create detailed maps and visualize spatial data. Open-source QGIS

3.28.3 software is frequently used to harmonize multiple raster datasets, allowing users to easily integrate and manipulate a variety of geospatial data (Noor et al., 2013).

eCognition Developer 10.3 is also open source, specifically designed for Object Based Image Analysis (OBIA) classification tasks, offering advanced algorithms and tools tailored for analyzing land use and land cover patterns. The cloud platform Google Earth Engine is used to calculate the NDVI (Cities4Forest, 2023). Furthermore, GPS technology is important for gathering field data since it gives accurate geographical location information that must be collected for spatial analysis workflows and ground truth validation (Congalton, 1991). Collectively, these software tools cater to a wide range of geospatial needs, from data processing and analysis to visualization and field data collection, supporting professionals in making informed decisions and deriving meaningful insights from spatial data.

Table 2 Software and tools used

Software	Type	Purpose
ERDAS 15	Licensed	For preprocessing raster data's
Arc MAP 10.8	Licensed	For Mapping and Layout
QGIS 3.28.3	Open source	For Harmonizing several raster data's
eCognition Developer 10.3	Open source	Forest classification
GEE	Free and open source	For NDVI calculation
GPS	-	For Field Data collection

3.4. Sampling Techniques

Using a rationale technique, Nifas Silk Sub-city was chosen for this study because it represents an intermediate level of land size, population, and greenery compared to other sub-cities in Addis Ababa. Previous studies on land use land cover change detection, and urban greenery assessment have predominantly focused on either high vegetated sub-cities such as Gulele, Yeka, and Bole or densely populated sub-cities like Kolfe Keranyo, Kirkos, Lideta or Addis Ketema. Consequently, Nifas Silk has received less attention in these areas of research.

Moreover, Nifas Silk is experiencing rapid urban expansion and possesses significant open spaces that are crucial for maintaining urban greenery. According to an interview with the Addis Ababa City Administration Urban Beautification and Green Development Bureau (AACAUBGDB), there is a high risk of losing these urban green spaces due to the fast pace of urban expansion and its proximity to Oromia city to the south.

3.5. Data Pre-processing

Data processing for image classification using object-based methods for assessing urban greenery involves several important step (Lu & Weng, 2007). The first step is image preparation, which adjusts for various factors such as atmospheric brightness variations and alignment distortions. Image enhancement focuses on modifying images to optimize their appearance in the visual system. The researcher used standardized preprocessing techniques for each image, implementing both geometric and radiometric adjustments to ensure accuracy and consistency throughout the collection (Lu & Weng, 2007).

Next, images stacking techniques were applied to combine bands from Sentinel and Landsat imagery to produce composite images that improved spectral information and made classification results more accurate. In Remote sensing and GIS applications, mosaicking techniques are commonly used to seamlessly combine multiple images or tiles into extensive and cohesive maps. The Nifas Silk Lafto sub-city boundary shape file was used to subset the resultant mosaic. Finally, land cover types were classified according color, texture, shape, and size using multi resolution segmentation algorithms (Kindu et al., 2013)

3.6. Image Classification

The object-based classification methodologies were utilized to produce Land Use Land Cover (LULC) maps for the years 2004, 2014, and 2024 in urban greenery, owing to their superiority over traditional pixel-based methods. These techniques offer several advantages, including enhanced spatial context awareness, increased accuracy, reduced spectral variability, integration of diverse data sources, and flexibility in feature selection and classification rule definition (Kindu et al., 2013). The standard procedure involved acquiring high-resolution satellite imagery and aerial photography for the years 2015 and 2021, followed by preprocessing to rectify distortions and artifacts. Subsequently, segmentation was conducted to partition the imagery into homogeneous objects, and feature extraction was employed to capture relevant spectral, spatial, and contextual attributes.

Classification algorithms Multi resolution segmentation algorithms are applied for land cover classification Then, to assess classification accuracy validation procedure were done, followed by refinement based on validation feedback. Post-classification analysis was carried out to gain insight into urban greenery distribution and temporal changes, thus supporting urban planning and environmental management efforts (Kindu et al., 2013).

3.6.1. Development of Classification Scheme

The classification scheme was established using the definitions provide by World Health Organization (WHO) and the Addis Ababa city Administration Urban Beautification and Green Development Bureau definition of green infrastructure. A few changes were made by consulting earlier studies carried out in the field. Seven different types of land use and land cover have been identified for the NSL Sub-city namely built-up, open space, river, agriculture, road, forest, and green area.

Table 3 Definition of Land classes

LULC	Description
Built-up	Area allotted for a residential, commercial governmental and private institution
Road	Area occupied by airport, road network and transport stations
River	Natural watercourse, usually freshwater, flowing towards an ocean, sea, lake, or another river
Urban agriculture	Areas of land prepared for growing vegetables This category includes areas currently under crop and land under
Open space	Refers to land that is not built upon and is preserved for various purposes such as recreation, aesthetics, and urban environmental quality such as: - city Level stadium, festival site, plaza, Sports center, sub-city level stadium, wereda sport field
Forest	Areas dominated by natural high forests, which are covered with natural grass and small shrubs dominated by grass
Green Area	Any space that is covered with vegetation and set aside for recreational, aesthetic, or environmental purposes such as; - city level park, river buffer, sub-city level park, squares, roadside, green cemetery, and river buffer

3.7. Post-classification

3.7.1. LULC Analysis

The classification efforts resulted in four distinct maps: the land use land cover map from 2004, the land use land cover map from 2014, the land use land cover map from 2024, and the accompanying change map. These maps provide important insights into environmental dynamics and land use changes by visualizing the shifting patterns across the specified period. In addition to these maps, comprehensive statistical reports were prepared to summarize the key findings and patterns observed throughout the classification process.

The reports include detailed matrix tables that illustrate classification outcomes for each type of land cover, emphasizing measures such as recall, precision, and accuracy. Additionally, the researcher used graphical representations like bar charts, pie charts, and line graphs to show how different types of land cover are distributed, changing over time, and trending in the study area. This makes the analysis results easier to understand and more accessible to readers.

Combining these findings provides a comprehensive and insightful assessment of changes in land cover. Decision-makers can better understand and address significant environmental concerns, challenges, and management strategies with this information.

3.7.2. NDVI Calculation

In this study, the Google Earth Engine (GEE) platform and Sentinel-2 imagery were used to calculate the Normalized Difference Vegetation Index (NDVI). To ensure a targeted analysis, the area of interest (AOI) was first established using the Nifas Silk Lafto sub-city shapefile. The Sentinel-2 surface reflectance image collection was then loaded and filtered according to the desired AOI and date range. A cloud masking function was employed to remove clouds and cloud shadows from the images, using cloud masking function was employed to enhance data accuracy (Cities4Forest, 2023).

The NDVI was computed using the near-infrared (NIR) and Red bands from the sentinel-2 imagery, following the formula (NIR - Red) / (NIR + Red). This calculation was applied to each image in the collection, resulting in a new band named ‘NDVI’. The NDVI images were then composited into a median to reduce noise and improve data quality. This composite image effectively combined multiple NDVI calculations, smoothing out anomalies and providing a more accurate representation of vegetation health over the specified period.

Finally, a color palette ranging from red (low NDVI) to green (high NDVI) was used to visualize the NDVI composite on the map, making it easy to identify the density and health of the vegetation. The processed NDVI data was then exported in GeoTIFF format to Google Drive for additional analysis and use. This method ensures accurate and dependable NDVI calculations for environmental and agricultural monitoring by utilizing the robust computational capabilities of GEE and the high-resolution data provided by Sentinel-2 (Abebe & Megento, 2016; Kindu et al., 2013).

3.8. Accuracy Assessment

Accuracy assessment is an important step in the image classification process. It was determine whether the output map meets the required level of acceptance. Land use/cover classification is prone errors. which can arise from the method of image capturing to the classification technique implemented. Therefore, accuracy assessment is necessary at the final stage of image classification. This assessment was done using first-hand data collected with the help of GPS (Abebe, 2016).

The most common and widely used method for classification accuracy assessments is the classification error matrix, also known as a confusion matrix. The matrix was created using various techniques to assess classification accuracy. The overall classification accuracy indicates the degree of accuracy, while the Kappa coefficient measures the errors that could arise from simple random classification. Additionally, the matrix was used to determine produce and user accuracy

Producer accuracy, or the likelihood that a reference pixel will be correctly classified, is determined by dividing the total number of correct pixels in a category by the total number of pixels in that category as determined by the reference data (Lu & Weng, 2007). Conversely, user accuracy or reliability, is defined as the total number of correct pixels in category divided by the total number of pixels that will be classified in the category.

$$Kappa = \frac{N \sum_{i}^{r} - \sum_{i}^{r}(xi + x + i)}{N^2 - \sum_{i}^{r}(xi + x + i)}$$

The formula used is as follows: N is the total number of observed pixels, r is the number of rows, xi is the number of observations in row i and column i, xi+ and x+i are the marginal totals of row and column (Congalton, 1991).

3.8.1. Reference Data Collection

High-resolution imagery is essential for gathering reference data for geospatial analysis because it provides valuable insights into the characteristics of the Earth’s surface and patterns of land use. It is possible to obtain detailed information with previously unheard-of clarity and precision by using advanced satellite sensors like SPOT 7 and aerial photographs, which provide a remarkable spatial resolution of 1.5 meters. This dataset is further enhanced by aerial photographs, which provide thorough coverage and in-depth views of particular areas of interests (Lillesand, T., Kiefer, R. W., & Chipman, 2015).

3.8.2. Ground Truth points

Data points that are regarded as precise and trustworthy references for a particular task or analysis are referred to as ground truth points. These points are used as standards by which models, algorithms, and analyses are judged. GPS was used to precisely record the positions of the Land Use Land Cover (LULC) training sites identified during fieldwork and to assess the accuracy of the data for the year 2024.

The determination of the reference sample size lacks a common, standardized consent. some researchers, such as Gao (2009), suggest that the minimum sample size for each LULC class should be set at 10-20 for 85% accuracy and 30 for 90% accuracy (Lillesand, T., Kiefer, R. W., & Chipman, 2015).

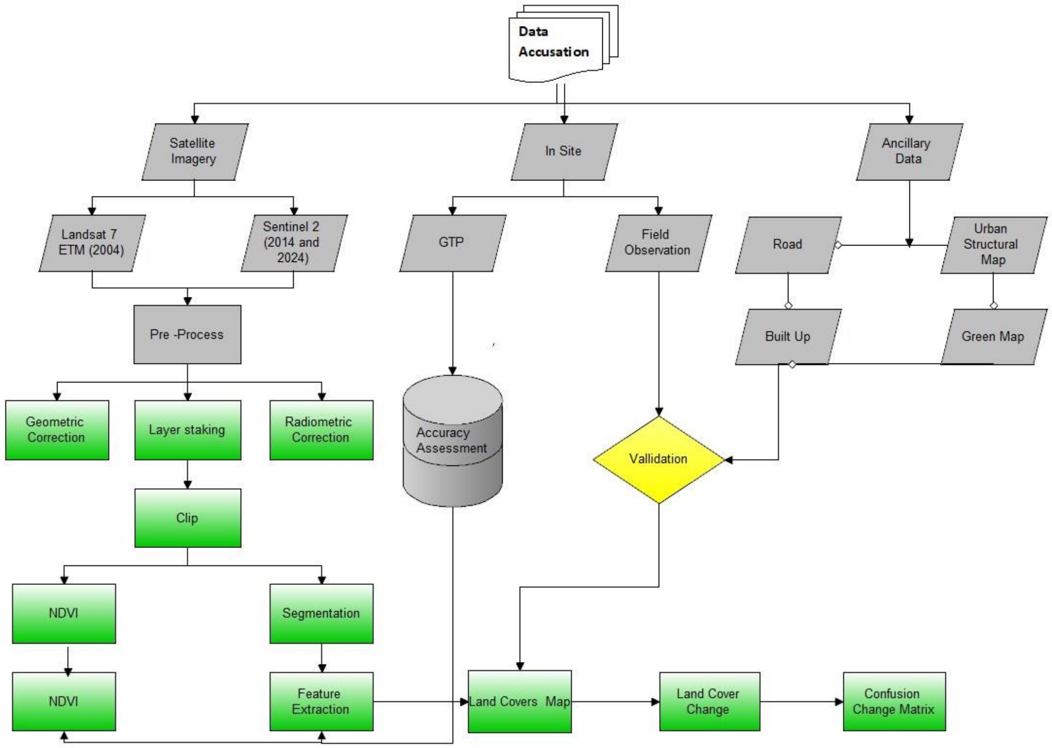

Figure 8 Flow Chart of Methodology

Source: Developed by the Researcher

3.9. Methods of Data Analysis

The thesis research primarily used spatio-temporal change detection for its results and employed an advanced Object-Based Image Analysis (OBIA) approach for land cover classification. Rather than treating each pixel as a separate entity, this method starts by segmenting the image into meaningful objects. The multi-resolution segmentation algorithm, essential to OBIA, is used in the segmentation process. Iteratively combining pixels, it creates homogeneous segments according to color, texture, shape, and size parameters. This method captures details at various scales, allowing for an accurate representation of the landscape's complexity by skillfully balancing the level of detail and spatial resolution (Lillesand, Kiefer, & Chipman, 2015).

The eCognition Developer 10.3 software platform served as the main instrument for this classification process. Significant for its resilient abilities in managing data from remote sensing and advanced image processing, eCognition facilitated the OBIA approach with its extensive feature set. The segmented objects were processed and analyzed with customizable algorithms, rule-based classification, and machine learning integration. The software improved the effectiveness and precision of the classification process by enabling interactive and automated workflows through its graphical user interface and scripting capabilities (Kindu et al., 2013).

The classification process involved multiple steps: pre-processing, segmentation, feature extraction, classification, and post-processing. To ensure data accuracy, pre-processing included geometric correction and noise reduction. After segmenting the image into meaningful objects, the multi resolution-segmentation algorithm allowed for the extraction of features like spectral values, texture measures, and shape descriptors. The features were used in classification algorithms to classify the segments based on land cover. Post-processing steps like filtering and smoothing improved the results. A comprehensive validation against ground truth data was then performed to evaluate accuracy using statistical metrics like kappa coefficient and overall accuracy. This methodical approach, leveraging OBIA and eCognition Developer 10.3, ensured a detailed and precise land cover classification (Kindu et al., 2013).

Additional data, including ground truth points (GTPs) and information about built-up areas were added to the analysis once the classification process in eCognition Developer 10.3 was finished. Geographic Information System (GIS) software, specifically QGIS 3.28.3 and Arc Map 10.8, was used to harmonize ancillary data with land cover classes. An extensive analysis and validation of land use and land cover patterns by overlaying and integrating the ancillary datasets with the classified land cover map (Adam et al., 2016; Kindu et al., 2013; Lu & Weng, 2007).

CHAPTER FOUR

4. RESULT AND DISCUSION

4.1. Structural Plan of Addis Ababa UGS Distribution

A structural plan is a technical, institutional, and legal framework for guiding the long term social, economic, environmental, and spatial development of the city and its surroundings. The Addis Ababa City Plan and Development Commission revise the structural plan every five years. The last 2017 structural plan was revised in 2022, and this revised version was utilized as a dataset to determine the planned coverage of green space. For the sake of mapping green spaces, this extremely comprehensive map needs to be simplified. This discussion will analyze the distribution, transformation, and factors influencing urban green spaces, highlighting the implications for urban planning and sustainable development.

The structural plan of Addis Ababa shows an uneven distribution of urban green space around the city. UGS not equally distributed throughout all sub-cities. The northern part of AA has a high concentration of urban green space, while the southeast of the state has a high concentration of urban agricultural land. The central region lacks greenery, and non-vegetative LULC types dominate in the eastern, southwestern, and northwestern regions of the study area. At the sub-city level, the distribution of green areas shows that manmade features predominate in Arada, Kirkos, Lideta, and Addis Ketems sub-cities.

The uneven distribution of urban green spaces in Addis Ababa, as highlighted in our study, align with findings (Cities4Forest, 2023) research's on Addis Ababa and from other urban areas worldwide. For instance, (Baró et al., 2019). Observed similar disparities in Barcelona, where affluent neighborhoods had better access to green spaces compared to lower-income areas. This reinforces the notion that urban planning often favors economically advantaged regions, leading to inequitable access to UGS (Wolch et al., 2014). Our findings emphasize the need for policies that ensure equitable distribution of green spaces across all sub-cities of Addis Ababa to enhance urban livability and environmental justice.

4.2. Structural Plan of NSL UGS Distribution

Addis Ababa structural plan is classified into 71 individual detailed classes, of which 45 classes are found in the Nifas Silk Lafto sub-city, as shown in figure 9.

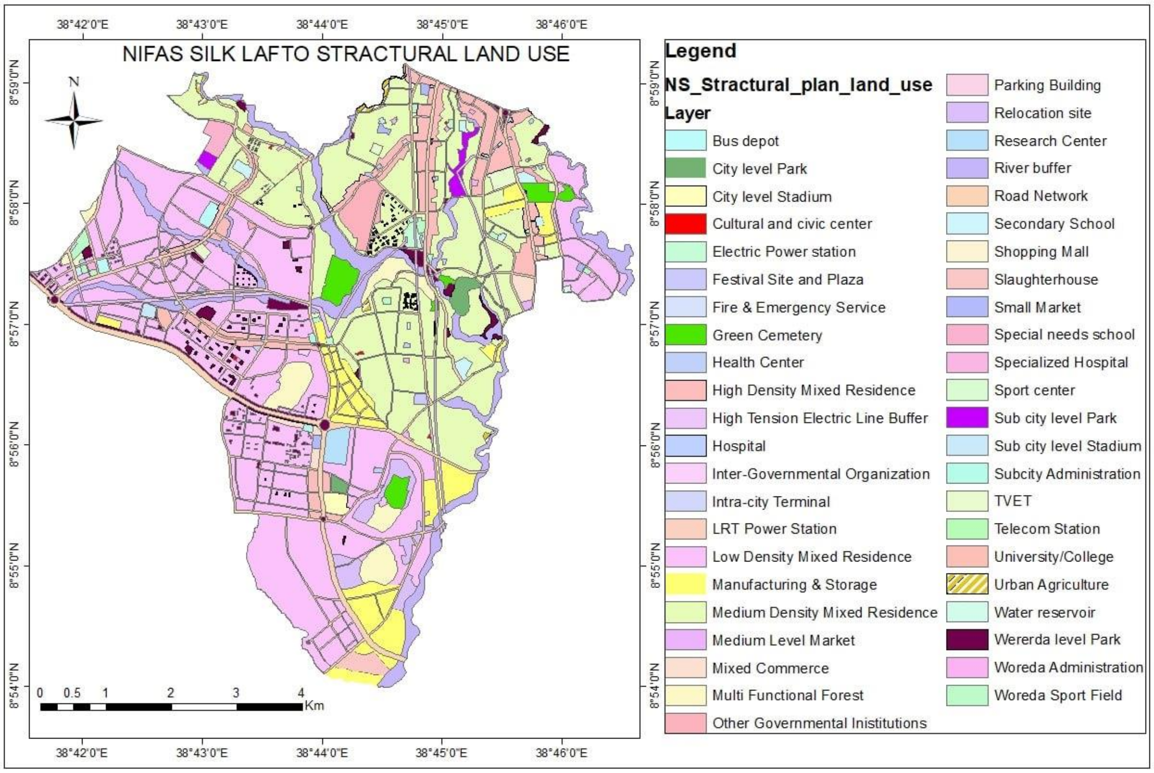

Figure 9 Structural Plan of NFL Sub-City
Source: Addis Ababa Plan and Development Commission

As the researcher focuses on a class of urban greenery space, 11 green infrastructure categories were identified, such as city-level parks, a city-level stadium, a festival site and plaza, a green cemetery, a multifunctional forest, a river buffer, a sport center, a sub-city level park, a sub-city level stadium, a wereda level park, and wereda sport fields, as shown in figure 10.

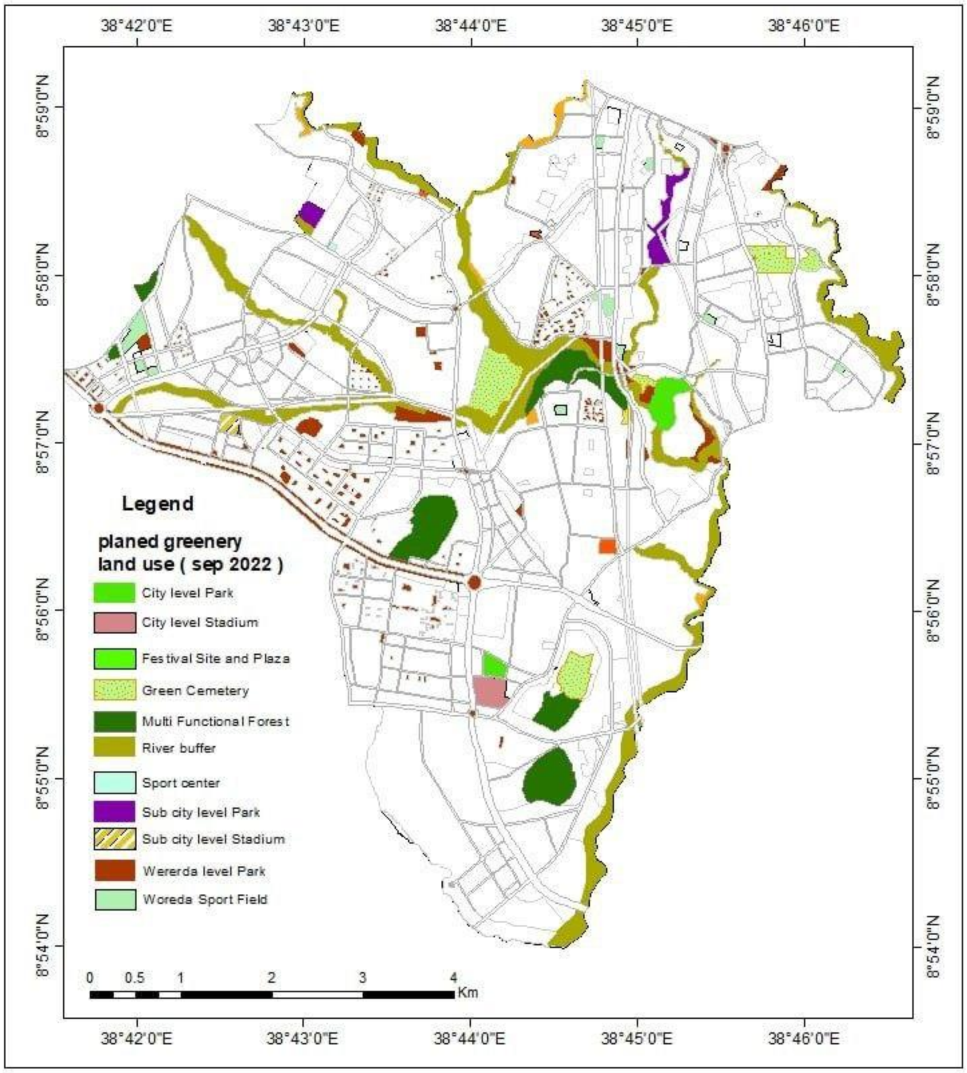

Figure 10 Structural Plan of UGS in NFL Sub-City
Source: Addis Ababa Plan and Development Commission

4.3. Land use Land covers Dynamics Analysis

Form Figure 11 in 2004, the land cover of NSL Sub-City was predominantly characterized by built-up areas and agricultural land. Specifically, urban green spaces were distributed as follows: open spaces covered 274 hectares, green areas spanned 102 hectares, and forests occupied 54 hectares, as detailed in Table 7 the road infrastructure encompassed 49 hectares, while water bodies were minimally present, covering only 8.97 hectares.

By 2014, significant changes were observed. The built-up area expanded to 952 hectares, while agricultural land decreased to 549.16 hectares. Green area saw an increase to 190.52 hectares, although open spaces slightly reduced to 253.89 hectares. Notably, forest coverage experienced a substantial rise to 200 hectares. The road network extended to 80.41 hectares, with water bodies remaining relatively constant as per Table 4.

Projected figures for 2024 indicate further transformations in land cover. The built-up area is anticipated to grow to 3207.07 hectares, whereas agriculture land is expected to shrink to 227.57 hectares. Open spaces are predicted to increase to 271.22 hectares, and green areas to 253.44hectares. The road network is projected to expand to 105.8 hectares, and water bodies are forecasted to increase slightly to 11.26 hectares, as summarized in Table 4.

These land cover dynamics underscore the evolving urban landscape of Nifas Silk Lafto sub-city over two decades, reflecting trends in urban expansion, agricultural land reduction, and changes in green space distribution.

The increase in total green area in NSL sub-city from 102.52 hectares in 2004 to 253.44 hectares in 2024 aligns with urban greening efforts observed in other cities. For example, New York City's Million trees NYC initiative resulted in a significant increase in urban green cover (NYC, Parks, 2015). However, the fluctuating pattern of open spaces in our study indicates ongoing challenges in maintaining and expanding UGS amidst urban development pressures, a trend also reported by (Jim & Chen, 2009) in rapidly urbanizing Chinese cities.

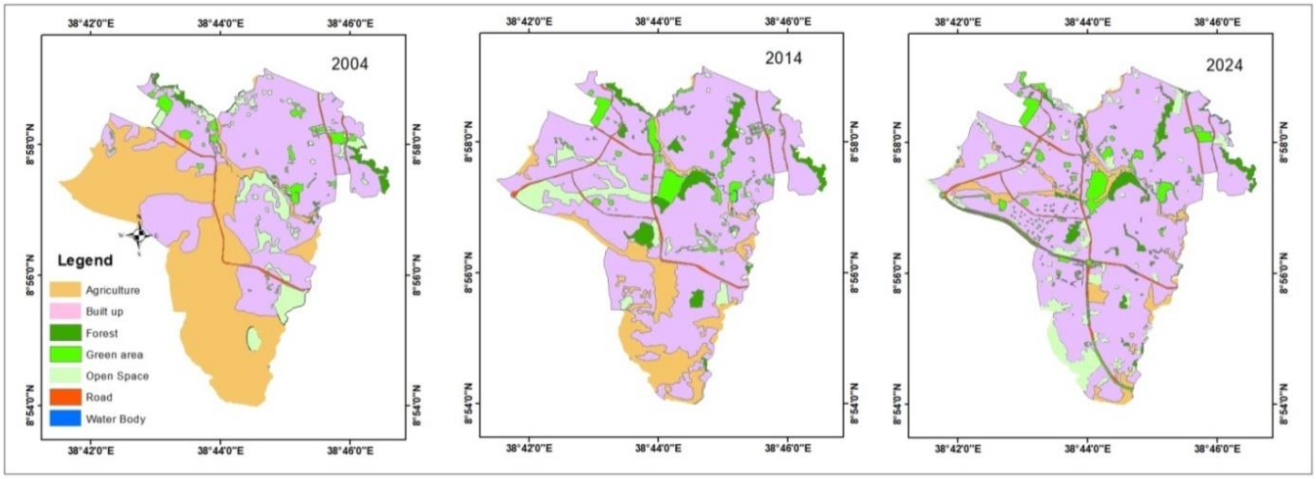

Figure 11 LULC Change Map of Three Periods

Source: OBI Classification Done by the Researcher

From figure 12, the trend indicates that built-up areas have the largest coverage, showing a steady increase from the initial period to the most recent one. Agriculture, while also having substantial coverage, has significantly decreased over the same timeframe. In contrast, roads and water bodies, although covering smaller areas, have demonstrated a consistent increase.

Among the urban green space categories, the green area shows a notable increase in coverage from 2004 to 2024. However, forest and open spaces exhibit a fluctuating pattern, with periods of both increase and decrease. This variation underscores the dynamic nature of land use changes and the challenges in maintaining consistent growth in UGS components

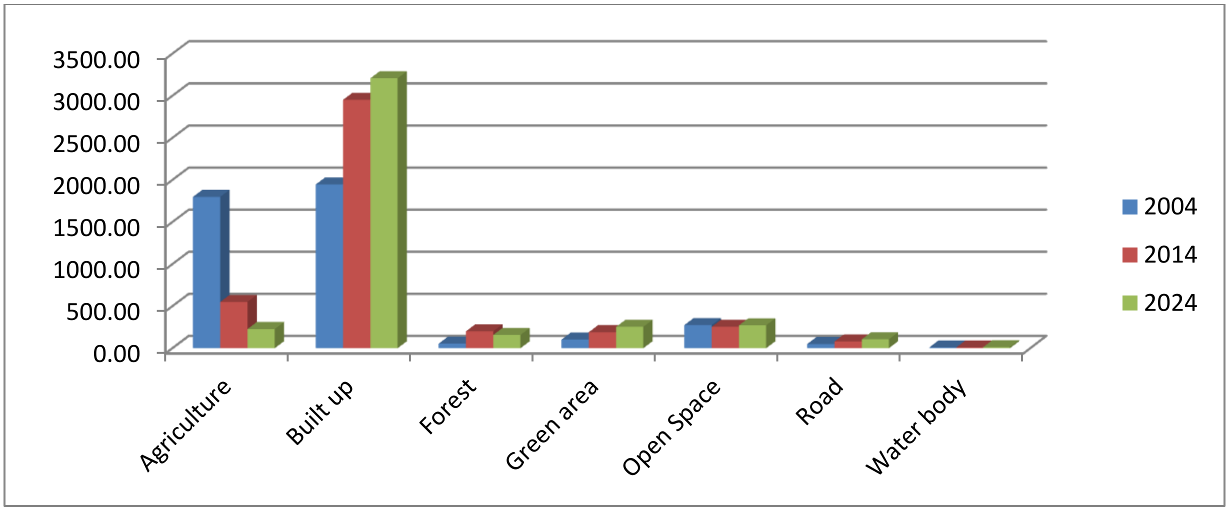

Figure 12 Land use land cover change graph
Source: Analyzed by the Researcher

4.3.1. Annual Change Rate of UGS

Over the past 20 years, there has been a significant increase on urban green spaces, with a total expansion of 150.93 hectares. This growth translates to an average annual increase of 7.55 hectares per year, indicating a substantial enhancement in urban greenery. Similarly, forested area has experienced an increase, growing by 103.12 hectares during the same period, resulting in an annual change rate of 5.16 hectares per year. This highlights ongoing efforts in forest conservation and expansion. In contrast, open spaces have faced a decline, shrinking by 3.38 hectares over the past two decades, which corresponds to an annual reduction rate of 0.17 hectares per year. This decrease signals a reduction in available open land Table 4. These trends underscore the dynamic nature of land use changes, with notable gains in green and forested areas alongside a reduction in open spaces.

In contrast, other land uses, including built environments, roads, and water bodies, have exhibited annual increases of 63.05, 2.8, and 0.14 ha per year, respectively. The expansion of these land use types has implications for urban greenery, potentially limiting its growth due to increased development and infrastructure demands. Meanwhile, agricultural land cover has been decreasing at a rate of 78.52 hectares per year, a substantial decline that contributes to the observed annual increase in UGS. This shift from agricultural to urban green areas indicates a reallocation of land resources, where the reduction in agricultural land facilitates the expansion of UGS, enhancing urban environmental quality and green infrastructure.

Table 4 LULC Annual Change Rate

LULC	2004	2014	2024	Change			Change rate
				2004-2014	2014-2024	2004-2024	Annually
Agriculture	1797.96	549.16	227.57	-1248.81	-321.58	-1570.39	-78.52
Built-up	1946.04	2951.49	3207.07	1005.44	255.58	1261.03	63.05
Forest	54.05	200.32	157.17	146.27	-43.15	103.12	5.16
Green area	102.52	190.27	253.44	87.76	63.16	150.92	7.55
Open space	274.60	253.89	271.22	-20.70	17.33	-3.38	-0.17
Road	49.65	80.41	105.80	30.76	25.39	56.15	2.81
Water body	8.97	8.26	11.79	-0.71	3.53	2.82	0.14

4.3.2. Confusion Change matrix analysis

According to Table 5, a significant portion of urban green spaces has been converted into built-up areas over the past 20 years. Specifically, of the 274.6 hectares of open space recorded in 2004, 155.81 hectares have been transformed into built-up areas by 2024. Similarly, out of the 102.52 hectares of green areas in 2004, 42.09 hectares have been developed into built-up areas by 2034. Forest land has also seen a reduction, with 15.07 hectares of the original 54.04 hectares in 2004 being converted to built-up areas by 2024. This trend highlights the substantial impact of urban development on UGS.

In addition to the conversion to built-up areas UGS features have also been list to agricultural land between 2004 and 3024. From the initial 274.6 hectares of open space in 094, 35.81 hectares have been repurposed for agricultural use by 2024. Green areas have also seen a minor loss of 0.08 hectares to agricultural land. Similarly, 1.37 hectares of forest land out of the 54.04

hectares recorded in 2004 have been converted to farmland by 2024. These changes indicate a shift in land use priorities, with some green spaces being allocated for agricultural purposes.

Another factor contributing to the reduction of UGS is the expansion of road infrastructure. Reconstruction and the removal of ring roads and squares, which were previously considered green spaces, have led to a decrease in UGS. Specifically, 0.61 hectares of open space, 0.26 hectares of forest, and 0.12 hectares of green areas have been converted to road construction by 2024. This illustrates the complex interplay between urban development, infrastructure expansion, and the preservation of green space.

Table 5 Confusion matrix of 2004 and 2024 LULC change.

		2024							
	Row Labels	Agriculture	Built up	Forest	Green area	Open Space	Road	Water Body	Grand Total
2024	Agriculture	164.17	1234.91	31.92	114.61	204.31	45.17	2.94	1798.03
	Built up	23.16	1758.11	48.19	62.12	38.28	13.47	2.93	1946.26
	Forest	1.37	15.07	27.03	5.48	3.5	0.26	1.33	54.04
	Green area	0.08	42.09	11.09	46.07	2.9	0.12	0.17	102.52
	Open Space	35.81	155.81	38.13	21.96	21.61	0.61	0.67	274.6
	Road				2.79	0.63	46.17	0.05	49.64
	Water body	2.99	1.08	0.81	0.41			3.69	8.98
	Grand Total	227.58	3207.07	157.17	253.44	271.23	105.8	11.78	4234.07

4.4. NDVI Analysis

In Figure 13, the highest mean value of the Normalized Difference Vegetation Index (NDVI) demonstrates an increasing trend from 2004 to 2014 followed by a decrease from 2014 to 2024. Specifically, in 2004, the highest mean NDVI value was 0.36, while the lowest was -0.39. By

2014, the highest mean value had risen to 0.75, with the lowest mean value improving to -0.10. However, in 2024, the highest mean NDVI value decreased to 0.64, and the lowest value declined to -0.12. This pattern reflects variations in vegetation health and density over the 20-year period.

The trends observed in NDVI values in our study, with initial increases followed by decreased, reflect the impacts of urbanization on vegetation health. Similar patterns have been reported by Yuan and Bauer (2007) in the Twin Cities Metropolitan area. Urban expansion has led to fluctuations in NDVI values. Continuous monitoring and adaptive management are crucial to maintain vegetation health and enhance urban greenery amidst ongoing urban development

Urban expansion has led to fluctuations in NDVI values. Continuous monitoring and adaptive management are crucial for maintaining vegetation health and enhancing urban greenery amidst ongoing urban development.

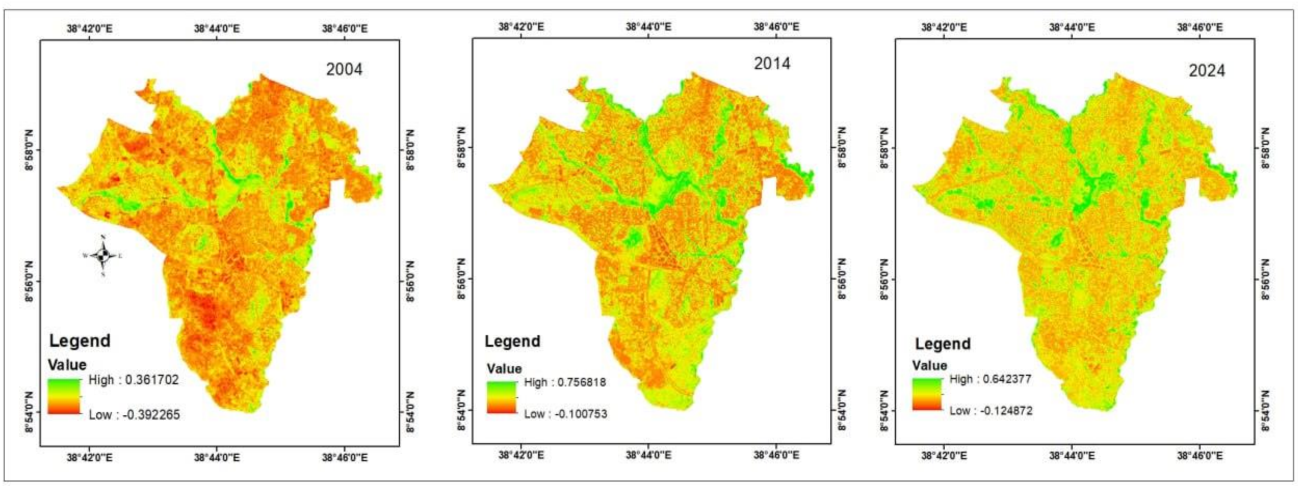

Figure 13 Normalized difference vegetation index

Source: Done by the Researcher

4.5. Accuracy Assessment in Land Cover Classification

Accuracy assessment is a crucial final step in the land cover classification process. It quantitatively evaluates the effectiveness of pixel classification into the correct land cover categories. This study employed high-resolution imagery from Landsat, Sentinel, Google Earth, and Google Maps to select clearly identifiable areas for accuracy assessment. A total of 112 locations were generated in the classified image of the study area using an equalizer sampling system.

The improvement in the accuracy of land cover classification over time in our study, from 88.75% in 2004 to 96.25% in 2024, aligns with advancements in remote sensing and classification techniques. (Foody, 2002) and (Congalton, 1991) have emphasized the importance of accuracy assessment in LULC studies, highlighting the need for reliable date to inform urban planning and decision-making. Our study contributes to this field by demonstrating the application of improved methodologies in the context of Addis Ababa.

2004 Classification

The accuracy assessment of the 2004 image revealed an overall accuracy of 88.75%. The user's accuracy varied between 75% and 100%, while the producer's accuracy ranged from 75% to 100%. The wide range of accuracies indicates significant confusion between the 'Built-up' class and other land cover classes, as sown in Table 6.

2014 Classification

For the 2014 image, the overall accuracy improved to 92.5%. The user's accuracy ranged from 81.25% to 100%, and the producer's accuracy spanned from 80% to 100%, as shown in Table 7.

2024 Classification

In 2024, the classification achieved an overall accuracy of 96.25%. User's accuracy ranged from 87% to 100%, while producer's accuracy varied between 84.21% and 100% as shown in Table 8.

The overall accuracy results across all periods demonstrate excellent classification performance. The improvements over time reflect enhanced methodologies and possibly better data quality. The consistency in high user and producer accuracy values, particularly in 2024, signifies robust classification processes with minimal confusion among land cover classes.

Table 6 Table Accuracy Assessment of 2004

Class	Reference	Classified	Number	Producers	Users
Name	Totals	Totals	Correct	Accuracy	Accuracy
Agriculture	15	16	15	100.00%	93.75%
Built up	20	16	15	75.00%	93.75%
Open space	13	16	12	92.31%	75.00%
Forest	17	16	15	88.24%	93.75%
Road	15	16	15	100.00%	93.75%
Green area	15	16	14	93.33%	87.50%
Water body	16	16	16	100.00%	100.00%
Totals	112	112	102		
Overall Classification Accuracy = 88.75%					

Table 7 Table Accuracy Assessment of 2014

Class	Reference	Classified	Number	Producers	Users
Name	Totals	Totals	Correct	Accuracy	Accuracy
Agriculture	15	16	15	100.00%	93.75%
Built up	20	16	16	80.00%	100.00%
Open space	13	16	13	100.00%	81.25%
Forest	18	16	16	88.89%	100.00%
Road	15	16	15	100.00%	93.75%
Green area	14	16	14	100.00%	87.50%
Water body	16	16	16	100.00%	100.00%
Totals	112	112	105		
Overall Classification Accuracy = 92.50%					

Table 8 Table accuracy assessment of 2024

Class	Reference	Classified	Number	Producers	Users
Name	Totals	Totals	Correct	Accuracy	Accuracy
Agriculture	15	16	15	100.00%	93.75%
Built up	19	16	16	84.21%	100.00%
Open space	14	16	14	100.00%	87.50%
Forest	16	16	16	100.00%	100.00%
Road	15	16	15	100.00%	93.75%
Green area	16	16	16	100.00%	100.00%
Water body	16	16	16	100%	100%
Totals	112	112	108		
Overall Classification Accuracy = 96.25%					

4.6. Structural plan vs. existing urban green space assessment

When comparing the planned greenery to the existing greenery, the planned greenery is set to cover 14.81% of the total land area, amounting to 627 hectares out of 4,200 hectares. Meanwhile, the existing greenery covers 16.10% of the land area, or 681.83 hectares, as shown in Table 9. This means the existing urban greenery covers 1.29% (54.83 hectares) more than the planned greenery.

Table 9 Structural Plan Vs Existing UGS coverage

Structural Plan UGS Coverage		Existing UGS coverage		Difference
City level park	210	Forest	15.17	15.17
wererda level Park	960	Green Space	253.44	253.44
Sub-city level Park	180	Open space	271.22	271.22
Multi-functional forest	100	-	-	-
City level stadium	110	-	-	-
woreda Sport Field	180	-	-	-
Sub-city level Stadium	40	-	-	-
Sport center	10	-	-	
Festival site and plaza	50	-	-	
Green Cemetery	61	-	-	
River Buffer	288	-	-	
Total	627	Total	681.83	54.8
Total Area of NSL 4233.48	14.81%		16.10%	1.29%

4.7. Major Factors of Urban Greenery Change

4.7.1. Urban Expansion

The main factor driving LULC changes over time is urban expansion. Most studies, including this one, agree that urban expansion significantly impacts LULC changes in any urban area. As shown in figures 14 and 15, the population growth of the sub city increased from 2007 to 2017 and from 2017 to 2022, with a projected growth of 16.63% within 10 years and 20.81within five years. This population growth necessitates more infrastructures, such as expansion of transportation networks, housing, road and public services, which impacts the distribution and availability of green spaces and other land uses.

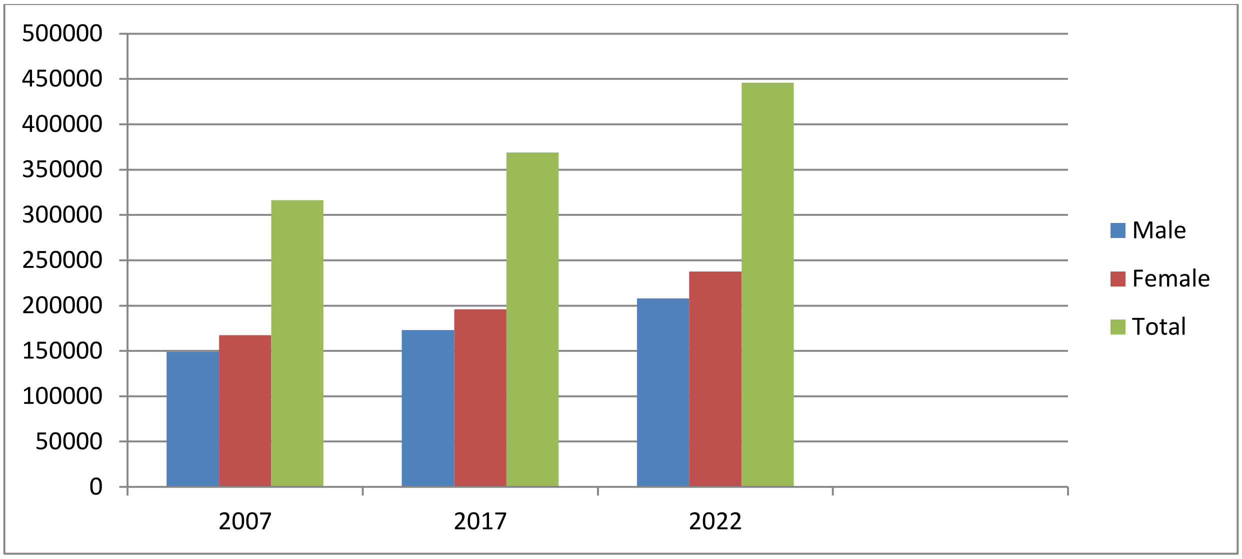

Figure 14 NSL Population Growth
Data source (CSA, 2007, 2017, 2022)

Similarly, the expansion of built-up area has directly impacted green area land use and land cover change. The green areas gained coverage from urban agriculture due to urban expansion. The population increased by 16. 81% and 20.81% over the periods studied, respectively. Built-up areas increased from 1946.04 hectares in 2004 to 2951.49 hectars in 2014, and further to 3207.07 hectares in 2024, as it shown in figure 15, with an annual change rate of 63.05%. This demonstrates a direct relationship between urban expansion and the decrease in urban greenery.

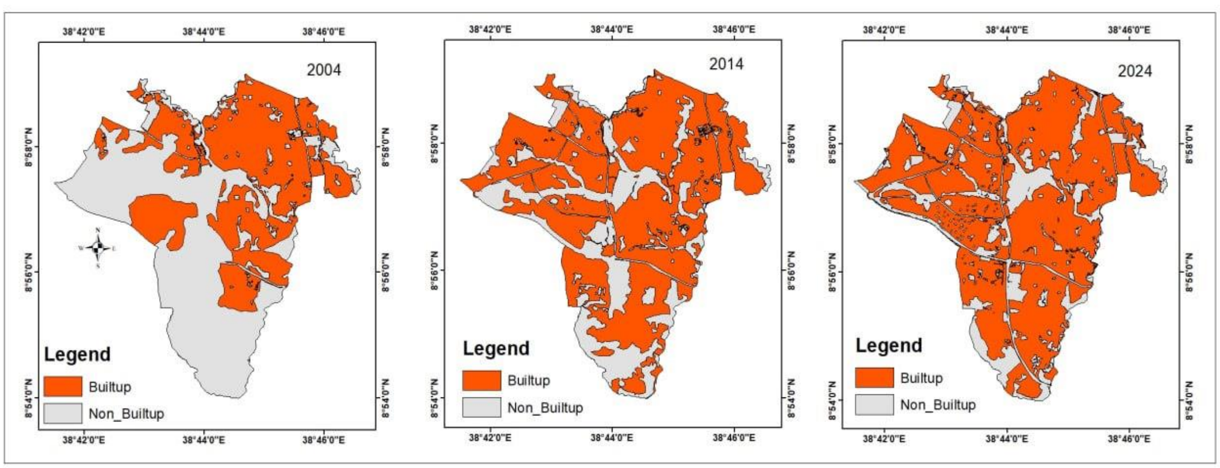

Figure 15 Built-Up Distribution (2004, 2014 and 2024)
Source: Developed by the Researcher

The rapid urban expansion trend in NSL Sub-city, characterized by significant increases in built-up areas at the expense of agricultural land, mirrors global patterns of urban expansion (Seto et al., 2012), documented similar transformations in rapidly growing cities in Asia and Africa. These shifts underscore the pressures of population growth and urban expansion, which often lead to the reduction of agriculture land open spaces (Report, 2020). Our study adds to this body of knowledge by providing detailed, local-level insights into the dynamics of LULC changes in Addis Ababa.

Our finding on urban expansion as a primary driver of land use changes are consistent with the conclusions of (Mcdonald et al., 2020). WHO identified urban sprawl as a key factor impacting green space availability. The transformation of agricultural land into built-up areas and UGS reflects global urbanization patterns, highlighting the need for sustainable urban planning strategies (Angel et al., 2011).

4.7.2. Revision of Structure Plan

The second factor influencing the change in UGS is the revision of the structural map. There is a difference between the LULC maps from 2017 and 2022, as detailed in Table 10. In 2017, the urban green space was designed to cover 6.03 km² however, in the revised structural plan of 2022, the urban green space covers 6.27 km², resulting in a difference of 0.24 km².

The increase in some coverage areas of the UGS in the structural plan reflects government-level interest in enhancing green coverage in the city, which is positive step toward creating more livable and resilient urban environments.

The revision reflects changes in urban planning and land use policies over the years, impacting the extent and distribution of green spaces within the city. The updated structural map may have been influenced by various factors, including population growth, infrastructure development, and environmental considerations. As cities expand and evolve the allocation of green spaces is often reassessed to balance urban development with the need for environmental sustainability and recreational areas for residents. The difference in urban green space between the two periods highlights the dynamic nature of urban planning and the importance of continually updating and revising structural plans to reflect current needs and priorities. This ensures that urban green spaces are effectively integrated into the city landscape contributing to the overall quality of life for its inhabitants.

Table 10 UGS Distribution of 2017 & 2022 Structural Plan

Greenery Land Use Class	20017_km²	2017_%	2022 _km²	2022_%	Difference
City level park	0.16	2.64%	0.21	3.37%	0.05
wererda level Park	0.73	12.16%	0.96	15.32%	0.23
Sub-city level Park	0.19	3.11%	0.18	2.81%	-0.01
Multi-functional forest	1.11	18.42%	1.05	16.75%	-0.06
City level stadium	-	-	0.11	1.75%	0.11
woreda Sport Field	0.10	1.69%	0.18	2.81%	0.07
Sub-city level Stadium	0.22	3.58%	0.04	0.65%	-0.18
Sport center	0.01	0.10%	0.01	0.09%	0.00
Festival site and plaza	0.05	0.76%	0.05	0.73%	0.00
Green Cemetery	0.61	10.13%	0.61	9.74%	0.00
River buffer	2.86	47.41%	2.88	45.98%	0.02
Total	6.03	100.00%	6.27	100.00%	0.24

In 2022 structural plans of NSL sub-city, eleven classes of urban green space were identified, included features such as city-level park, wereda level park, sub-city level park, multi-functional forest, city level stadium, woreda sport field, Sub-city level stadium, sport center, Festival site and plaza, Green Cemetery and River buffer. Notably, the city level stadium was not included in the previous 2017 structural plan. As shown in table 10 the UGS LULC covers a total area of 6 km², which is 14.3% of the sub-city's total coverage of 42km². The river buffer GS accounts for 46% of the total UGS area, making it one of the largest green spaces in the sub-city. Conversely, the smallest green area is occupied by sport center, and the festival site covers just 0.1% of the urban green space.

The impact of structural plan revision on UGS is evident in our study, with the 2022 plan showing an increase in planned UGS compared to the 2017 plan. The 2022 plan also introduced slight changes across all classes except for the sport center, festival site and green cemetery classes. This supports the findings of (Qureshi et al., 2010), who found that structural plan revision has significantly affect urban green space changes. While urban planning revisions can notably influence green space distribution and coverage, our study highlights challenges in implementation that align with Haland and van den Bosch concerns about the gap between planning and practice in urban green space management (Haaland & van den Bosch, 2015).

4.7.3. Implementation and Preservation

This research identifies also factors for urban green space change detection, such as the lack of law enforcement of the local development plan (LDP) and the master plan, poor land use management, and improper documentation for UGS, significant issues have arisen in the sub-city due to a lack of clear enforcement laws and regulations. As shown in figure16 & 17, the space specifically designed for green space between blocks in wereda 02 has been encroached upon and made into personalized property. Additionally, as shown in figure 15 the areas preserved for open space for sports field have partially changed to built-up areas.

Figure 16 wered (2014)

Figure 17 wereda 02 (2024)
Source: Picture by the researcher

As Bayren and Sipe suggest concerning urban planning, parks and other types of green space can play a valuable role in sustainable development. it is therefore useful to consider how planners have traditional planned for parks and open space (Byrne & Sipe, 2010). However, Figure 16 reveals that the plan implementation issues in the sub-city are another main problem in UGAD Implementation challenges: the challenges in implementing UGS plans in Addis Ababa, such as poor law enforcement and lack of coordination among stakeholders, are not unique. Similar issues have been reported in other cities, such as Lagos, Nigeria, where ineffective governance and week institutional frameworks hinder urban green space management (Adegun, 2021). This underscores the need for robust governance structures and effective inter-agency collaboration to ensure the successful implementation of UGS plans.

There is a lack of collaboration between governmental offices and stake holders. For example, the AA beautification offices count and plan for squares under urban green infrastructure, while other governmental offices like the AA road and transport authorities demolish these plans. one such example is the transformation of two squares, Jermen square, which cover 3290m², and Mekenisa qore as shown in figure 18 and 19. The previous green space of squares has now been converted into a flat road to facilitate traffic flow. This lack of coordination and collaboration between offices has led to the destruction of urban green infrastructure, impacting the overall environment and quality of life in the area.

Figure 18 Jermen square
Source: Google Earth Pro

Figure 19 Mekenisa kore Square
Source: Google Earth Pro

This condition highlights the need for stronger enforcement of current laws and regulations, as well as improved coordination and communication between responsible stakeholders. Without these actions, the loss of UGS and resources will continue to occur at an alarming rate, leading to negative impacts on the environment and overall quality of life in urban areas.

The urban green area, composed of green areas, forests, and open spaces, increased from 471.17 hectares, in 2004 to 644.48 hectares, in 2014, an increase of 213.31 hectares, and further to 681.83 hectares, in 2024, an increase of 37.35 hectares, demonstrating a consistent increase over the 20-year period. As shown in Figure 20, the urban green space is not only increasing but also changing location from 2004 to 2024.

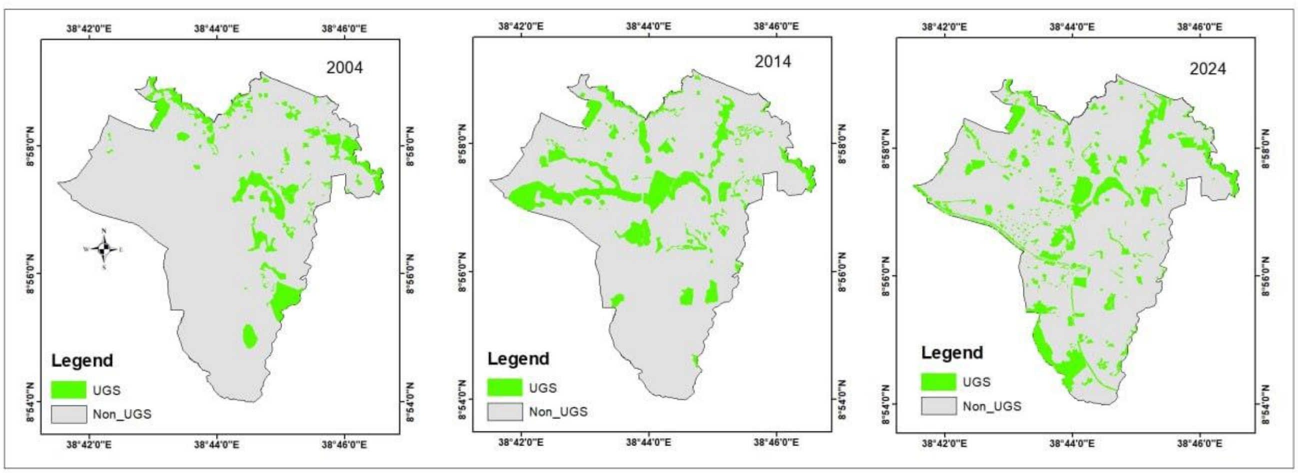

Figure 20 UGS distribution (2004, 2014 and 2024)

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The comprehensive analysis of land use and land cover (LULC) dynamics in the Nifas Silk Lafto Sub-city of Addis Ababa from 2004 to 2024 reveals significant transformations driven by urban expansion and changing land use priorities. The study employed advanced remote sensing

techniques, geographic Information system (GIS), and the normalized difference vegetation index (NDVI) to capture these changes and assess their impacts on urban green spaces (UGS).

Key conclusion from the analysis includes substantial urban expansion, with the built-up area increasing from 1946.04 hectares in 2004 to a projected 3207.07 hectares in 2024. This expansion has primarily come at the expense of agricultural land, which has decreased from 1797.96 hectares in 2004 to 227.57 hectares in 2024.

Despite the overall reduction in open spaces from 274.6 hectares in 2004 to 271.22 hectares in 2024, green areas forest coverage has increased. Green areas expanded from 102.52 hectares in 2004 to 253.44 hectares in 2024, reflecting an average annual increase of 7.55 hectares. Forest coverage rose from 54.05 hectares in 2004 to 200.32 hectares in 2014, although it slightly decreased to 157.17 hectares by 2024, indicating fluctuating land use patterns and reforestation efforts.

Urban development has significantly encroached on UGS, with 155.81 hectares of open space and 42.09 hectares of green areas converted to built-up areas between 2004 and 2024. Forest areas also faced reductions due to urban expansion, with 15.07 hectares transformed into built-up areas.

Road infrastructure has consistently increased, expanding from 49.65 hectares in 2004 to 105.8 hectares in 2024, including ongoing development. Water bodies have shown minimal changes, covering around 8.97 hectares in 2004 and slightly increasing to 11.26 hectares by 2024.

NDVI values reflect fluctuations in vegetation health and density, with the highest mean NDVI value rising from 0.36 in 2004 to 0.75 in 2014, before decreasing to 0.64 in 2024. These variations indicate changes in vegetation quality over time, influenced by both natural and anthropogenic factors.

The classification accuracy for LULC mapping was robust, with overall classification accuracy improving from 88.75% to 96.25% over the study period. High producer and user accuracy for most land use categories ensure the reliability of the results.

Given the significant changes in LULC and their implications for urban green spaces, several policy recommendations emerge. Preservations and expansion of green spaces are essential, implementing stringent policies to protect existing green spaces from urban encroachment and promote the creation of new parks and green areas is necessary. Sustainable urban planning should integrate green infrastructure into development plans to ensure a balance between built environments and natural landscapes.

Community engagement is crucial, as it fosters involvement in urban greening initiative to enhance the maintenance and expansion of green spaces. Enhanced reforestation efforts are needed to counteract the loss of forested areas due to urban development. Regular monitoring utilizing remote sensing and GIS technologies is vital for continuously tracking land use changes, enabling timely interventions and informed urban planning decisions.

In conclusion, the study highlights the dynamic nature of land use changes in the NSL sub-city, driven by rapid urban expansion. While there have been gains in urban green and forested areas, these gains are offset by significant reductions in agricultural land and open spaces.

Sustainable urban planning and proactive measures are crucial to ensure the preservation and enhancement of urban green spaces, thereby improving the livability and environment quality of the sub-city.

5.2. Recommendations

- Preservation and expansion of green spaces: To maintain and enhance the green cover in Nifas slik Lafto Sub-City, it is crucial to implement stringent policies that protect existing green spaces from urban encroachment. Promoting the creation of new parks and green area within urban development plans is essential. This will help ensure a balance between urban expansion and the natural environment, contributing to the overall well-being of residents.
- Sustainable urban planning: Green infrastructure should be integrated into urban planning and development initiatives. New developments must include sufficient green spaces, such as parks, gardens, and green belts. By incorporating these elements, urban area can achieve a harmonious balance between built environments and natural landscapes, fostering a healthier and more sustainable city.
- Community engagement: engaging local communities in urban greening initiative is vital for the successful preservation and enhancement of green spaces. Encouraging residents to participate in the planning, development, and maintenance of these areas can foster a sense of ownership and responsibility. Community involvement can lead to more effective and sustainable management of urban green spaces.
- Enhanced reforestation efforts: Strengthening reforestation programs is necessary to counteract the loss of forested areas due to urban expansion. Focused efforts on planting native species and creating green corridors that connect fragmented green spaces will promote biodiversity and enhance ecosystem services. Reforestation initiatives should be a priority to ensure long-term environmental health.
- Policy and regulatory measures: Developing and enforcing policies that prioritize the conservation of agricultural lands and limit their conversion to urban area is critical. Land use zoning regulations should balance development needs with environmental sustainability. Effective policies can safeguard agricultural land promote the sustainable use of land resources.
- Infrastructure planning: Infrastructure development, including road and utilities, should incorporate green space considerations to minimize the impact on existing green areas. Designing infrastructure projects with an emphasis on preserving and integrating green spaces can mitigate the adverse effects of urbanization and contribute to a more sustainable urban environment.

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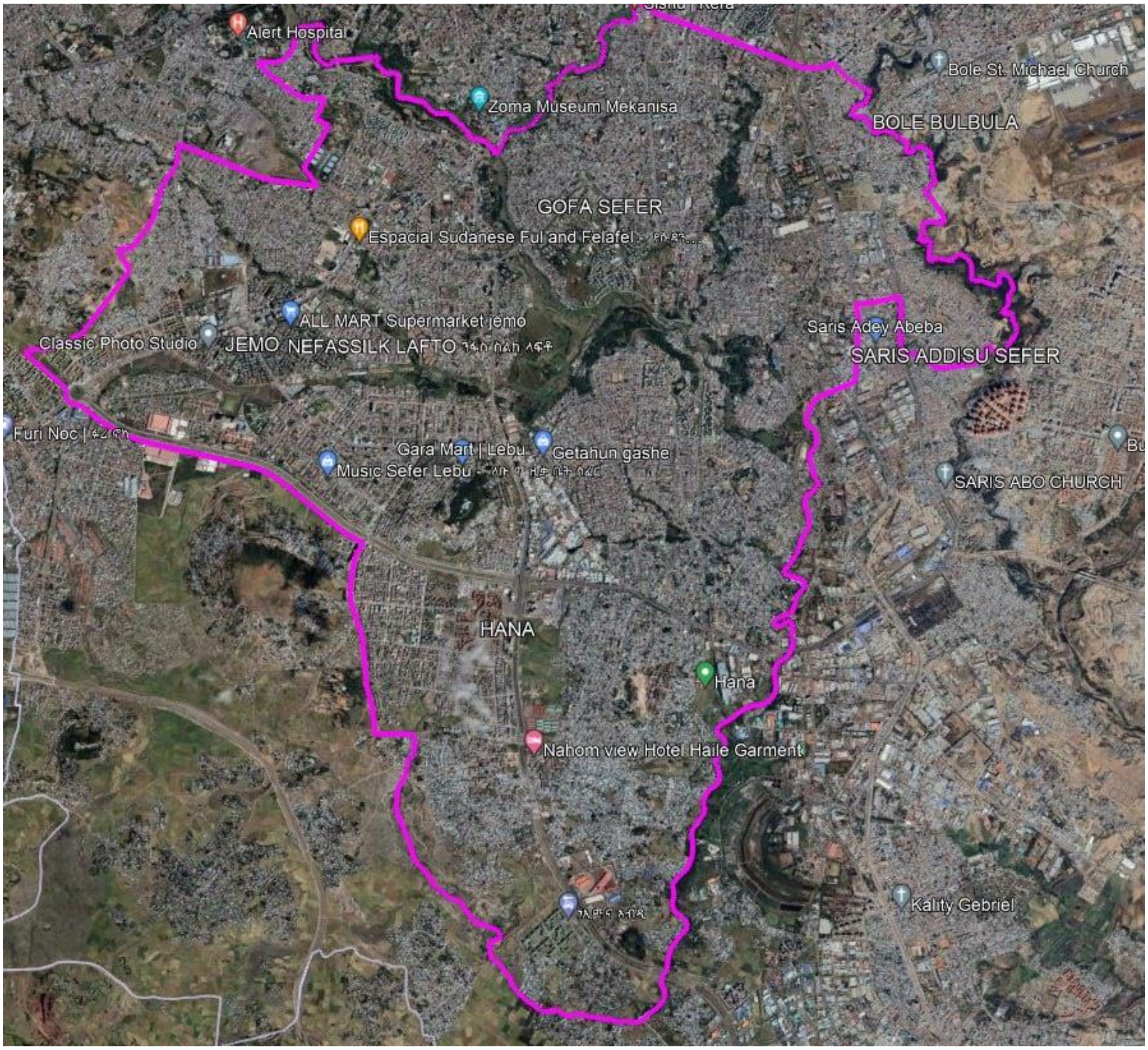
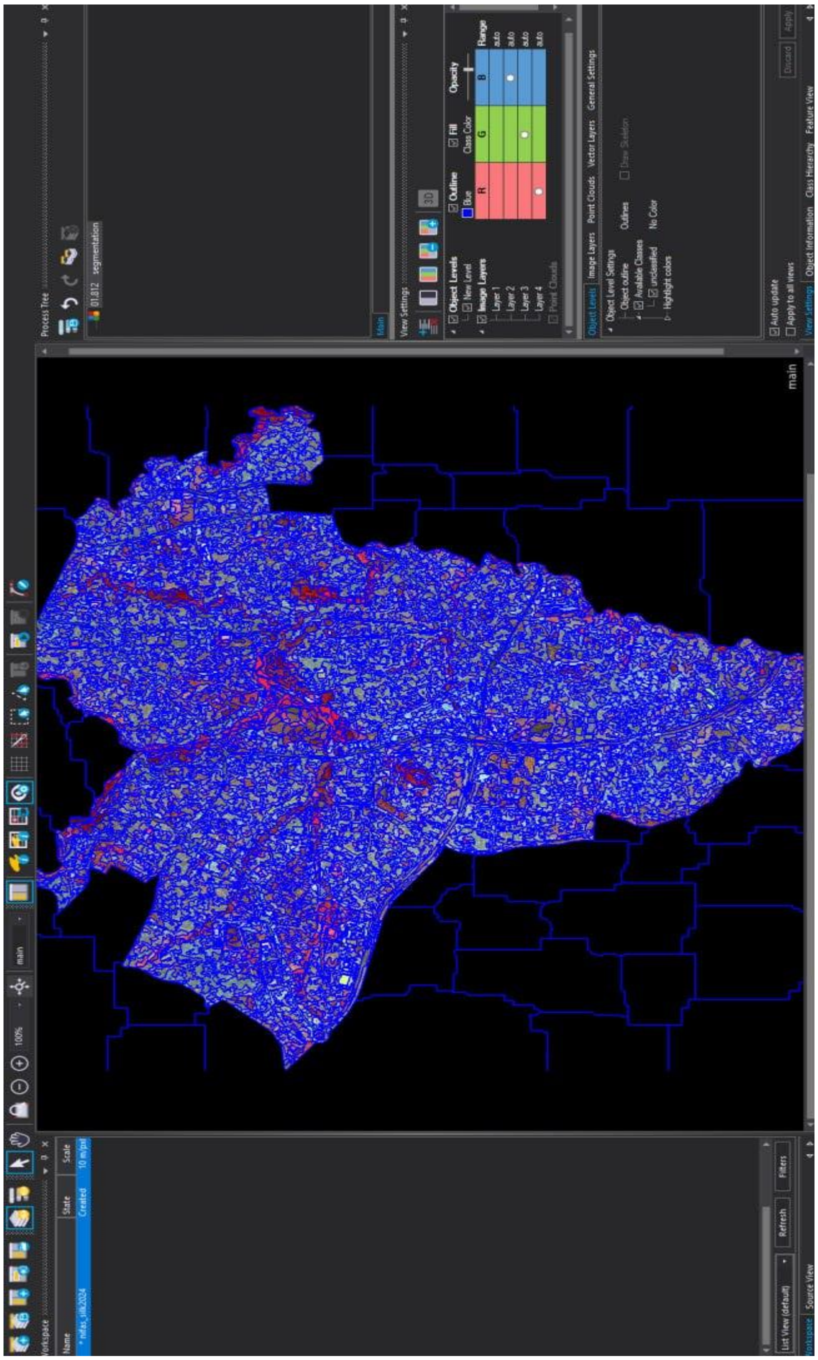
APENDIX

Appendix A. object base classification



Appendix B object -base classification



Appendix C 2017 structural Plan