ADDIS ABABA UNIVERSITY
COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES
SCHOOL OF EARTH SCIENCES

Mapping of major urban green spaces and study the accessibility using network analysis in Addis Ababa city, Ethiopia

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN REMOTE SENSING AND GEO-INFORMATICS

BY

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ID: GSR/5287/14

Addis Ababa, Ethiopia
June, 2023

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In Remote Sensing and Geo-Informatics

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Addis Ababa, Ethiopia
June, 2023

Declaration

I hereby declare that the dissertation entitled " Mapping Major Urban Green spaces and study the accessibility using network analysis, a case of Addis Ababa, Ethiopia" has been carried out by me under the supervision of Dr. Suryabhagavan, School of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2021−2023 as a part of Master of Science programme in Remote sensing and Geo-informatics. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa
Date: June, 2023

(Lidya Geletta)

ADDIS ABABA UNIVERSITY

School of Graduate Studies

School of Earth Sciences

The impact of urbanization on environment (Land surface temperature and vegetation) using remote sensing technology: A case of three cities in Ethiopia.

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A Thesis Submitted to

The School of Graduate Studies of Addis Ababa University In Partial Fulfilment of the Requirements for the Degree of Masters of Science in Remote Sensing and Geo-Informatics

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Table of content

List of Figures

List of Tables

ACRONOMY

UGS	Urban green space
SA	Service area
UGI	Urban Green Infrastructures
LULC	Land-Use and Land-cover mapping
AACC	Addis Ababa City Council
CSA	Central Statistics Agency
AMA	Addis Ababa Metrological Agency
SSGI	Space Science and Geospatial Institute
ERDAS	Earth Resources Data Analysis System
GIS	Geographic Information System
GPS	Global Positioning System
NDVI	Normalized Deference Vegetation Index
NDBI	Normalized Deference Built-up Index
OSM	Open street map
UHI	Urban Heat Island
UPs	Urban Parks
AACBPCDA	Addis Ababa City Beautification parks Cemetery Development and Administration

Abstract

Cities in developing countries are growing rapidly. As a result of uncontrolled urban expansion and population growth urban green spaces are deteriorating at an alarming rate. The aim of this study is to assess the status of major urban green spaces and to study their accessibility using GIS based network analysis approach. OBIA (Object Based Image Analysis) classification algorithm is used to map and assess LULC (land-use and land-cover) of the study area. Remote sensing indices such as NDVI (Normalized Difference Vegetation index) and NDBI (Normalized Difference Built-up Index) have also been used to depict the vegetation cover and urban expansion rate which has direct influence on the deterioration of UGSs (urban green spaces). The accessibility analysis was carried out to study the spatial distribution and availability of public recreational parks existing in Addis Ababa city. Three accessibility indicator standards are used. The result shows that the accessibility of public parks are inadequate and their distribution are uneven. The central part of city has a little denser park concentration whereas, the eastern and southern part of the study area doesn't have park facility except the Kality Park located in Akaki sub-city. The network analysis was computed based on residential area coverage and population number enjoying the park facilities. In addition, the current demand of public parks required by the population were assessed. Very low accessibility of parks are recorded for 300 and 800 meter service areas. The 300 m service area serves only 6 % of A.A residential area. Whereas, the 800m SA serves 34 % of the city residential area. Moreover, the population residing in Addis Ababa that enjoys public parks is 7 % for 300 m and 35 % for 800 m service areas. The 300 meter service area refers to 4 minute walking distance whereas the 800m refers to 4 minute walking distance. Therefore, urban residents are forced to walk more than 10 minutes in-order to enjoy park facilities. In addition to the international standards, national accessibility indicators recommended by AACC, is also included in this research. The AACC recommends city parks to be accessed within 10km radius and Sub-city parks in 5km radius. The study finding shows that 70% of residential area access sub-city parks. Moreover, the recorded value of residential area served by city parks is 87 % for all existing sub-cities. In addition, this study demonstrates 72 % of A.A resident's reside with 5 km radius service area. While the population enjoying 10 km SA of City Park is 80 percent.

Key words: RS, GIS, LULC, NDVI, NDBI, UGS, Public Park, Accessibility

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

Urban green space (UGS) improves physical activity, psychological well-being, and the general health of urban dwellers in addition to providing essential ecological services (Assaye et al., 2017; Bekele et al., 2022). Urban green spaces include parks, forests, green roofs, wetlands, and land that is covered in grass, trees, bushes, or other vegetation. Additionally, urban waters such as ditches, canals, rivers, and river side green are considered as UGSs (Warkaye et al., 2018). According to (Wolch et al., 2014), urban green spaces provide a variety of ecosystem services, such as improving resilience to certain natural disasters like floods, promoting biological processes like pollution, and reducing surface erosion from storm water runoff. However, as cities expand, the vegetation's quantity and quality deteriorate. Additionally, there is growing evidence that the advantages of green space are not equally distributed. The desire for increased urban green space is a global issue that ranks highly on city policy agendas (Haase et al., 2014).

Moreover, urban vegetation benefits the urban environment in a variety of ways, one of which is by lowering the urban heat island effect (UHI). Urban heat islands occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. As a result of this, heat island effect causes higher daytime temperatures, reduced nighttime cooling, and higher air-pollution levels (Yang et al., 2016). These, in turn, contribute to heat-related deaths and heat-related illnesses such as general discomfort, respiratory difficulties, heat cramps, heat exhaustion, and non-fatal heat stroke (EPA, 2022).

In addition, UGS is playing a more and more important role in mitigating the effects of climate change on the population (Muluneh et al., 2017; Hou et al., 2018). Therefore, city planners should create and implement policies that support the improvement of urban ecosystem services and climate resilience in order to provide UGSs that are equally distributed and accessible. However, managing UGSs with rapid urban expansion is becoming a top concern for government administrations due to the ongoing environmental, social, and economic transformations of cities. Addis Ababa, Ethiopia's capital, is experiencing a significant rise in population. The rapid increase in population is leading to an increase in built-up area density, infrastructure development, and residential area expansion. Consequently, Green spaces are transformed to built-up areas. As a result of the destruction of green spaces, the native biodiversity and regulated microclimate are lost (Biernacka and Kronenberg, 2018). Therefore, it is essential to generate detailed maps of urban green spaces for policymakers, to implement sustainable land management and evaluation of UGSs based on the availability, quantity and geographical distribution. (Seifu and Stellchmacher, 2020). There are several different methodologies and approaches that have been used to map the spatial distribution of urban green spaces. Remote sensing and GIS technology is one of the integrated approaches that is widely used to understand the green space dynamics. The identification of green spaces, the analysis of land use and land cover data, the analysis of Normalized Difference Vegetation Index (NDVI) for vegetation cover assessment, the analysis of change detection, and the generation of useful information for efficient decision-making processes, are all common uses of geographic information systems and remote sensing technologies (Hoang and Tran, 2021). Remote sensing technologies have significantly contributed to the study of UGSs in recent decades since they have produced continuous and complete coverage at numerous spatial scales for several seasons (Pu and Landry, 2012). Remote sensing is currently providing a useful set of tools that can reduce the need for field survey even in an extremely varied and complex urban patterns, thanks to recent improvements like high spatial resolution imaging and free data access legislation.

Sub-Saharan Africa and Ethiopia in particular have experienced a lack of research on the accessibility of UGSs whereas, there is a plenty of academic research in many parts of the world. The aim of the study is to examine the demand and accessibility of public parks at the sub-city level, by providing highly valuable information to the Addis Ababa city administration. In the context of this study, only three types of UGSs are considered as major UGSs (Urban forest, urban agricultural land and public recreational parks). The study used, Sentinel-2A satellite imagery, Google Earth Engine, ground truth data and land-cover assessment indices (normalized difference vegetation index NDVI, and normalized difference built up index NDBI) to monitor and assess vegetation and built-up coverage.

Finally the, classification was computed via support vector machine and Object based image analysis (OBIA) algorithm. The accuracy of the classification is checked using confusion matrix. After checking the validation, post classification task was performed to identify area coverage of specified land-use land-cover classes. Finally, accessibility of public parks with in the service areas (Sub-city) was analyzed and examined using proximity indicator of Network Analysis tool. Therefore, the research considers the application of Remote Sensing and Geographic Information System in identifying and analyzing the accessibility and the current demand of major urban green spaces in Addis Ababa, city.

1.2 Statement of the problem

Urban green spaces are necessary landscapes that provide a natural environment and accelerate other life events. They are an essential part of any urban structure. On the other hand, unplanned urbanization and the transition from green to grey structures have harmed the ecosystem (Manea & Gabriela., 2011). The demands of urban green spaces differ with changes in population number, different types of urban expansion, and geographical location (Klopp and Petretta, 2017). Green spaces are now the most endangered urban natural ecosystems as a result of fast urban expansion and a high prevalence of unplanned settlements (Cilliers, et al., 2012). Most of large and fast growing cities in developing countries, number and size of UGS are inadequate and an evenly distributed (Kestermont, B., et al., 2011). Moreover, the deterioration of essential green spaces, particularly in urban areas, are causing human-induced climate change which brought dramatic and unmanaged temperature rise. As a result, metropolitan heat stress has a negative impact on urban resident's and the environment (Haaland and Bosch, 2015). As a result of the urgency of the issue this study will explore the distribution of UGS and assess their accessibility with in eleven service areas (sub-cities). In addition, the present demand of UGSs will be investigated considering the population settlement. As a result, relevant recommendation and suggestion will be made up on the completion of these thesis work.

1.3 Research objectives

1.3.1 General objective

The main objective of the study is to map major UGSs and to study the demand and accessibility of public parks in eleven sub cities using network analysis in Addis Ababa city, Ethiopia.

1.3.2 Specific objective

- To Identify and map major urban green spaces using OBIA (Object based image analysis) algorithm in-order to assess the current status of UGSs.
- To assess the present demand of public recreational parks in Addis Ababa city considering the distribution of Public Park provisions in Sub city level.

- To examine the accessibility of existed Public recreational parks with in the service area using Network Analysis tool.

1.4 Research Question

- ✓ Which district has sufficient access to major UGSs (Urban green spaces) with in the service area?
- ✓ Which sub-city is demanding green space infrastructure in Addis Ababa city?
- ✓ What looks like the accessibility of UGSs distribution with in the study area?

1.5 Significance of the study

The study will be helpful to provide spatial data that will show accessibility of the urban green spaces in Addis Ababa city. Government and non-government organizations, policy and decision makers, researchers, and professionals will receive clear and valuable information about UGS distribution in the city for future expansion activities, Urban park accessibility for city residents, recreational park demanding areas and how the application of remote sensing and GIS technologies are helpful in analyzing the status and dynamics of UGSs.

Green parks are an important part of the urban environment and an important way for urban residents to get in touch with nature, improve their physical and mental health, and promote social interaction [9 Urban parks has so many contributions to reduce the negative environmental impacts on residents by reducing noise, air pollution, and urban heat islands. In addition, visiting parks can improve people's psychological and physical restoration ability. However, as urbanization and urban population continue to grow fast, there is serious and growing concern of urban green spaces. Urban green spaces are established to reduce impacts of urbanization. However, in developing countries, this is often neglected. Addis Ababa city, is significantly affected by rapid urbanization that cause the depletion of UGS. Hence, this study's aim is to assess the demand and distribution and of public recreational parks and to determine their accessibility with in the service area. Environmental sustainability will never be achieved without proper monitoring of green spaces. Therefore, the findings of this study will be highly beneficial for Addis Ababa structural planning and sustainable environment management.

1.6 Scope of the study

AABPCDAA (2015) reports that urban green spaces include public parks, greenery alongside road and road divide, road squares, urban forest, trees in churches and non-religious institutions. There are different UGSs found in the study area giving services to the public. Due to the time limitation and availability of resources (financial and material), the study will emphasis on mapping three major UGSs (Urban agriculture, Urban forest and Public recreational parks) and the accessibility analysis has been done only on existed city and sub city public parks . The study emphasized on the application of Remote Sensing and GIS technologies on generating a valuable information regarding NDVI, NDBI, Land-use and Land-cover assessment and distribution of public recreational parks, in analyzing the accessibility of major green spaces with in the study area.

1.7 Limitation of the study

- Scarcity of updated and timely spatial data of AddisAbaba's residential area.
- Scarcity of fine resolution population data

1.8 Organization of the thesis

This thesis will have six chapters. The first chapter contains introduction, statement of the problem, research objectives, scope and limitation of the study. The second chapter focuses on reviewing literatures on urban green spaces definitions and background, urban green space benefits, land use land cover change, indices for detecting built up and vegetation cover change, spatial analysis of green spaces and the advancement of remote sensing and GIS technologies for mapping urban green spaces. The third chapter emphasizes on study area explanation and justification, resource required and methodology followed. The fourth chapter is about results and fifth chapter on discussion part. The six chapter deals with conclusion and recommendation based on results and discussion presented.

CHAPTER TWO
2. LITERATURE REVIEW

Currently, cities occupy only 2.7% of the Earth's surface (UNESA, 2014), but are responsible for 75% of total energy utilization, 80% of greenhouse gas emission and have mainly had a hazardous outcome on natural resources (Gret-Regamey et al., 2013). Therefore, to battle these urbanizations imposed problems, urban green spaces are becoming approved and effective strategy all over the world.

UGI offers cities a number of advantages, but studies reveal that many cities across the world are losing their green spaces. For instance, a recent study conducted in Europe reveals that 75% of the population resides in urban regions, with statistics predicting that this proportion would rise to 80% by the year 2050 (Giuliani et al., 2021). Similar to this, 1.4 million hectares of green space were changed to other land uses in the USA, according to a study on land-use change in 274 metropolitan areas (McDonald et al., 2010). Furthermore, statistics show that green areas only make up a small portion of the land area in many African cities (Adjei, 2014). Furthermore, the majority of city residents are unable to access green spaces, particularly public recreation parks.

The significant percentage of world's population reside in developing countries. The availability and accessibility of UGS services in developing country cities that are rapidly urbanizing have, however, received very little attention so far. Instead, studies (Giles-Corti et al., 2005; Kabisch and Haase 2013; Baycan-Levent and Nijkamp 2009) have mostly concentrated on wealthy nations. In other words, social, economic, cultural, and political elements of African countries that are rapidly urbanizing are very different from developed ones.

2.1 Urban green space definition and background

The Romans were the first to incorporate rural elements into cities. Beginning in the early 1700s, urban areas began to build garden squares and parks. The parkway movement, started by Frederick Law Olmsted, promoted the notion that, in the late eighteenth and early nineteenth centuries, green space was an essential cultural and social component of the urban form (Stanley et al., 2012). The idea of including green space in urban development developed with the revival of the environmental movement in the 1960s (Williamson, 2003). The existence of a green space does not automatically imply public accessibility, even though various green spaces have established public access. The phrase "green space" in this context refers to public open spaces that support people's sociocultural and health necessities, biodiversity preservation initiatives, and discussions of historical green space viewpoints (Konijnendijk, 2005).

It's common to use the terms "open space" and "green space" interchangeably. To eliminate any potential misconceptions, experts defined the key phrases. Urban areas are made up of both the constructed environment and the external space between buildings, according to Swanwick et al. (2003). Their methodology divides the outside world into two distinct spaces: "grey space" and "green space." According to Swanwick et al. (2003), "grey space" describes terrain that is predominantly made up of sealed, impermeable, "hard" surfaces like concrete or asphalt. Green space land is mostly made up of unsealed, permeable, "soft" surfaces like grass, plants, trees, and water, regardless of who controls it the government or a person.

As early as the 1700s and 1800s, enlightened benefactors in many countries understood the importance of parks and green space for the wellbeing of urban residents (Meller, 2001). These business owners were typically wealthy and concerned for the welfare of their staff. Based on their distinct, intuitive judgments of what was advantageous, they built the urban parks. Some of these were carefully landscaped with artificial lakes, fountains, and flowerbeds to give those who were better off a place to "promenade" or those who worked and lived in stuffy settings the chance to breathe fresh air and enjoy gorgeous surroundings. Others were designed specifically for activities like sports and hunting.

Modern urban green space planning and administration are more systematic and typically the result of collaboration between many municipal departments (Randrup et al., 2001). However, the goals are not unlike to those from earlier times. The biggest challenge now is meeting the varied needs of as many different user groups as possible. As a result, municipalities face the challenge of effectively and economically managing green spaces to meet demands for the greatest variety of recreational activities, to enhance the quality of the urban environment, and to satisfy the demands for the preservation of the natural world and culturally significant sites (Jonsson and Gustavsson, 2002).

2.2 Benefits of Urban green spaces

Rapid urbanization is causing an increase in environmental stress signals in cities, including poor air quality, noise pollution, and an increase in air pollutants, traffic congestion, and extreme heat. These negative effects consequently spread and have a negative impact on the local population. It is a fact that the world is engulfed in pollution, which causes asthma, cancer, and persistent coughs (Leavell et al., 2019). Communities should maintain and protect green spaces because they can counteract this unfavorable tendency and improve the general quality of life for urban residents by offering affordable solutions (Van den Berg et al., 2010. For instance, trees can store up to 20 kg of dust and 5.4 tonnes of CO_2 annually. In addition, Green spaces provide numerous social, physical and environmental multifunctional ecosystem.

2.2.1 Social benefits of UGS

Urban green areas can promote beneficial interactions that improve health and wellness and social cohesion. UGSs are also connected to better health outcomes, including encouraging social interaction and physical activity in urban areas. These UGSs give people of all ages the chance to interact socially, improving their social health (Jennings and Bamkole, 2019) giving them a sense of meaning and purpose, all of which lessen the symptoms of depression (Kondo et al., 2018). In UGSs, individuals can connect and develop social ties (Lorson and Hipp, 2022). Feelings of isolation and a perceived decline in social support were connected to lower levels of UGS in the environment (Maas et al., 2009). Similar to this, UGSs are perceived as promoting social safety (Holtan et al., 2015), while those that are enclosed are linked to a lack of safety and security.

2.2.2 Physical (health) benefits of UGS

The ecological services offered by green space parks help users' physical, emotional, and social well-being. According to research, the presence of green space has an independent relationship with older people's survival rates (wood et al., 2017). A different study found a connection between more environmentally friendly environments and lower stroke mortality. The negative impact of stressful life events on health can be buffered by green spaces. A natural outdoor setting can benefit mental health because of the physiological changes it causes in the body. A Japanese study indicated that being in and walking through forests can encourage lower cortisol levels, lower pulse rates, and lower blood pressure when compared to city surroundings (Park et al., 2010). In a recent study, individuals who were able to view the outside from their homes during the COVID-19 lockdowns reported reduced psychological distress and less stress (Ribeiro et al., 2021).

2.2.3 Environmental benefits of UGS

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

Heat waves, droughts, rainfall, and storms are becoming increasingly severe and frequent as a result of climate change (Andrew 2015). Our towns and cities are impacted by these extreme weather events, which also have an influence on the amount of greenery and open space, which makes it harder for them to combat the effect of climate change. In order to mitigate the effects of climate change, more green space and open areas should be created. This is achieved by providing natural cooling of air and surfaces, supporting water management in urban areas and capturing carbon dioxide from the atmosphere. This will support the future viability and resilience of our towns and cities.

2.3 Urban land-use and land-cover change

While land-use change refers to a change in how the land is utilized or managed by humans, land-cover change refers to a change in the long-term characteristics of the land. According to Patel et al., (2019), this change is a contributor to a number of regional and global issues, such as the loss of habitat and ecosystem services, the decline in biodiversity, and its negative consequences on human health. Urbanization is the main cause of it, and developing and underdeveloped nations are affected by the influences of uncontrolled and unmanaged urbanization. Additionally, although changes in the land cover may be the consequence of natural forces, human activity fuels them.

LULCC, or land-use and land-cover change, is the term used to describe how humans have changed the Earth's surface. People have been altering the land to ensure livelihoods and other necessities for thousands of years. In comparison to earlier times, the extent, severity, and LULCC have considerably increased. The ecosystems and environmental processes are experiencing unprecedented local, regional, and global changes as a result of these changes. LULC changes are crucial to the study and analysis of the current state of global change because the knowledge about these changes is crucial for directing future decisions about ecological management and environmental planning (Zhao et al., 2004; Dwivedi et al., 2005; Erle and Pontius 2007; Fan et al., 2007).

2.4 Urban green space depletion

Urban green spaces are disappearing in urban areas all over the world at an alarming rate. Around 7.3–41% of the area designated for urban green spaces has been converted to other uses, according to a study on land use changes in 25 European cities (Essel, 2017). Similar conclusions were drawn from a study of land use change in 274 American metropolises, which found that between 1990 and 2000, various land developments occupied nearly 1.4 million hectares of urban green space (McDonald et al., 2010). As a result, many nations now follow guidelines for green space that are far stricter than the 9 m^2 per capita minimum that is suggested by organizations like the World Health Organization and the United Nations Food and Agriculture Organization (Wang, 2009).

Numerous cities and communities in Africa have very varied green space status. Less than 10% of the total amount of land in a few municipalities in the Republic of South Africa is made up of green areas (McConnachie et al., 2008). Given that only 3% of Lagos City is made up of green space, the issue is much more worrying and alarming (Oduwaye, 2013). According to Mensah (2014), Alexandria, Cairo, and Luanda all have registered densities below 1 m^2 per resident. Despite the rapid urbanization occurring in the region, Ethiopia is one of the least urbanized nations in Sub-Saharan Africa. At the current annual growth rate of 3.5%, 60% of the population is predicted to reside in cities by 2040 from an estimated 7.1% in 1994. (United Nations, 2014; Lamson-Hall et al., 2018). Therefore, green spaces have to be considered in the urban planning procedures to satisfy the future generation and to preserve the ecosystem.

2.5 Vegetation and built-up indices

Surface dynamics inference, modelling, and forecasting are aided by spectral indices. Indexes are constructed for numerous satellite spectral band combinations. There has previously been research on the use of satellite indices in agriculture, water resources, urban planning, forest ecology, geology, soil sciences, vegetation, and other fields. According to reports, the scientific community has used Landsat-8, Sentinel-2, and the generated spectrum indices over time to address challenging environmental issues as well as for other uses.

2.5.1 Normalized Difference Vegetation Index (NDVI)

Vegetation indices are widely used as criteria for analyzing land cover changes and monitoring trends. This factor is frequently used to distinguish between places with unhealthy vegetation and those lack of vegetation. The NDVI's numerical value ranges from 0 to 1. Positive numerical values are associated with dense vegetation, while zero and values close to those indicate non-vegetated areas, moist areas, and sites near bodies of water have values close to one digit (Meera et al., 2015). This index is calculated using Eq. (1)

This is one of the most used techniques for assessing how much of an area is covered by vegetation. This measure, which is a ratio, can be used to track crops throughout the growing season because it is unaffected by changes in slope, seasons, illumination, etc. It is calculated by taking a ratio between the difference of reflectance from NIR and Red bands and the sum of reflectance from NIR and Red bands (Bhandari, 2012). In this study I have used NDVI to explore the current vegetation cover in Addis Ababa city.

$$NDVI = (\rho NIR-\rho Red) / (\rho NIR+\rho Red) \quad (1)$$

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

2.5.2 Normalized Difference Built-up Index (NDBI)

The Normalized Difference Built-up Index (NDBI) was proposed in 2003 as a new method which automatically maps built-up areas. This method was first applied in practice to extract data for a built-up area of Nanjing city in eastern China. The NDBI index was able to distinguish between built-up and vegetated or green and wet surroundings for the city of Nanjing (Chunyang et al.,

2010) This index highlights urban areas where there is typically a higher reflectance in the shortwave-infrared (SWIR) region, compared to the near-infrared (NIR) region. Applications include watershed runoff predictions and land-use planning. This index is calculated using Eq. (2)

$$(\rho SWIR-\rho NIR) / (\rho SWIR+\rho NIR) \quad (2)$$

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

The NDBI was originally developed for use with Landsat TM bands 5 and 4. However, it will work with any multispectral sensor with a SWIR band between 1.55-1.75 µm and a NIR band between 0.76−0.9 µm (Yasin et al., 2020). In this study I have used NDBI to explore the current urban area expansion in Addis Ababa city.

2.6 Remote sensing and GIS for UGS mapping

Current and precise spatial data on green spaces are necessary for planning and controlling urban land use. Due to the rapid rate at which urbanization has changed, divided, and dispersed green spaces, collecting this data using traditional methods of landscape surveys has become more and more challenging. Because of the time and labor requirements for gathering, processing, and reporting field data, and regional surveying operations are challenging. Therefore, there is an urgent need for contemporary ways to automate the process of surveying green spaces (Mengistu and Salami, 2007).

This study combines the methods of accessibility analysis and remote sensing image classification. Remote sensing spectral indices, GIS network analysis tool and image classification using unsupervised algorithm, have all been used to estimate the distribution and accessibility of urban green spaces.

2.7 Accessibility of public recreational parks

Accessibility is defined as the "relative ease" with which specific attractive locations may be reached from particular locations (Luo and Wang, 2003; Mak et al., 2019) as well as how widely visible the site is to the general population. The term "accessibility" typically refers to the nonlinear distance that must be traversed in a given amount of time in order to get from one site to the users nearest green area (So, 2016). The features of the city's transportation system make accessibility implementation difficult even though its description is rather straightforward (Comber et al., 2008). In this study, the population inside the service area polygon that has access to a particular facility (Public Park) is expressed in numerical value or percentage, which represents public park accessibility.

Public parks are crucial for the ecologically viable function of cities because of their influence on routine recreation, the preservation of bio-diversity, the city's cultural identity, the maintenance and improvement of overall environmental quality, and their contribution to technical problem solving through natural solutions (Gunnarsson et al., 2017). In terms of its accessibility to people from different socioeconomic groups, public recreational parks are often not distributed fairly and equally (Germann-Chiari and Seeland, 2004; Nesbitt et al., 2019). In numerous empirical studies (Jim and Chen, 2006; Qureshi et al., 2010; Keniger et al., 2013), it has been demonstrated that UGS serve certain functions at various levels of urban life.

2.8 Urban green area Standard

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

It is observed that number of factors that have caused the depletion and inadequate access of UGSs in rapidly urbanizing cities. Expansion and density of the built up environments take the frontline among factor that affect UGS existed in developing countries. (Pincetl and Gearin 2005). In addition, all other feasible challenges of UGS needs to be explored to adopt rationalized policy directions and strategies that assists better administration and maintenance of urban green spaces.

Accessible Natural Green Space Standard (ANGSt) developed structural policy on the area of accessible green space, considering the minimum distance residents can walk to reach recreational parks (Natural England, 2010). After the United Nations (UN) Sustainable Development Goals (SDG) set a goal to provide "universal access to safe, inclusive and accessible, green and public spaces, the issue of accessibility obtained more recognition (UN, 2015). World Health Organization (WHO) proposed $9m^2$ park per capita for the world and $7m^2$ for cities of African countries (WHO, 2016). In addition, the green space standard declared by the United Nations is $30m^2$ per capita, the European Union standard is $26m^2$ per capita, the USA (determined by the Public Health Bureau and the department of Housing) is $18m^2$ per capita.

Most developed countries implement $20m^2$ park area per capita (Wang, 2009) and urban green infra-structure standard (UGIS) of Ethiopia also suggested $15m^2$ park per capita (MoUD, 2015). Per capita ratio standard has recognized by the entire world because of its simplicity of utilization and implementation. However, it doesn't consider the spatial distribution or accessibility of green spaces to city residents (Yao et al., 2014 and de la Barrera et al., 2016). Walking distance accessibility to open green spaces was determined by the European Environment Agency as maximum 1000 m (15 min walking distance), and by English Nature as maximum 300 m (Khalil, 2014).

2.9 Road network analysis

In a Mapping operation called network analysis, a geographic network or a real-world network's datasets are analyzed. Network analysis is just a collection of linked lines. These lines represent various networks that must typically be analyzed, such as railroads, streams, roads, waterlines, pipelines, communications lines, etc. (Marshall, S. 2016). In network analysis there are different characteristics of the links considered with in the analysis process such as length, direction and connectivity (lines must connect at least two places).

The network models in GIS have the potential to make the development of spatial analytical network functions simpler. Transportation network or road network, utility network, and stream network are a few examples of data models (Reza et al., 2022). These network features aid in accessibility, development, and planning. Some of integrated operational functions of network analysis are shortest path analysis, closest facility selection and new service area. I have used new service area analyses layer to define the accessibility of the facility located within the study area.

2.10 Service area

The issues with site allocation have long persisted. However, their true value won't be understood until geographic information systems technology can be used to visualize spatial data in the form of networks connecting isolated sites. Prior to this, however, problems of this kind were dealt with using non-spatial representations, such as table-formatted link characteristics and node coordinates. Consequently, a vast body of knowledge is already accessible to tackle many kinds of problems related to networks and discrete locations, making it possible to identify optimal solutions.

Service area or resource allocation is a network analysis application. It is a widely supported facility within many GIS packages. These are often distinct zones that consider distance, time and travel cost to assign the, intended service area polygon to the existing facilities within a certain network nodes than to any other designated point. An organization or individuals can optimize the allocation of resources depending on the capacity of each facility if the goal of creating service areas around a service center is achieved. Allocation algorithms use these centers as destinations then model how people or goods will travel through the network to get there. The result is a map that shows the areas served by each service facility. The service provided to clients (from the facilities that are being situated) sometimes depends on their proximity to the facility to which they are assigned. Customers are often sent to the closest facility, though this is not always the case. Service is frequently considered adequate if the consumer is close to the facility and is considered poor if the distance is greater than a certain threshold.

CHAPTER THREE
3. MATERIALS AND METHODOLOGY

Addis Ababa is a city that is undergoing a massive development project that includes, commercial buildings, government public service buildings, industrial areas and settlement (condominium and real estate residences). The utilization of utilities, infrastructure improvements, paved areas, and impermeable surfaces, including concrete, all rise along with population growth. Together, these changes significantly contribute to the depletion of green spaces. Therefore, OBIA algorithm and accessibility analysis was used to identify, describe, and assess urban green spaces existed in Addis Ababa city. In addition, the network analysis tool in ArcGIS 10.8 was used to map and analyze the current demand and accessibility of public parks along with their distribution. The paper uses a systematic approach to build up a conceptual framework that investigates the availability and accessibility of green space with in the intended study area. The methodology presents a step-by-step process used in the classification of urban green spaces and accessibility analysis of public recreational parks.

3.1 Description of the study area

Addis Ababa is Ethiopia's capital, located in the geographic epicenter of the country, and surrounded by the regional state of Oromia. It is the largest city in the country and plays a central political, economic and symbolic role in Ethiopia. It is located at the foot of Mount Entoto, at an altitude of 2355 meters above sea level. Addis Ababa lies between latitude, 8 o 49'−9 o 5' N and longitude, 38o 38'−38o 54' E covering a total area of 51957.92 ha as show in (Fig 3.1). The city has a total area of 527 km^2 divided into eleven sub cities divided into 117 woredas. Addis Ababa was founded during the reign of Emperor Menelik II in 1886. Under the Italian occupation, the first city plan was designed in 1936 with defined functional and ethnically segregated zones for most parts of the city (Atlas of Addis Ababa, 2023).

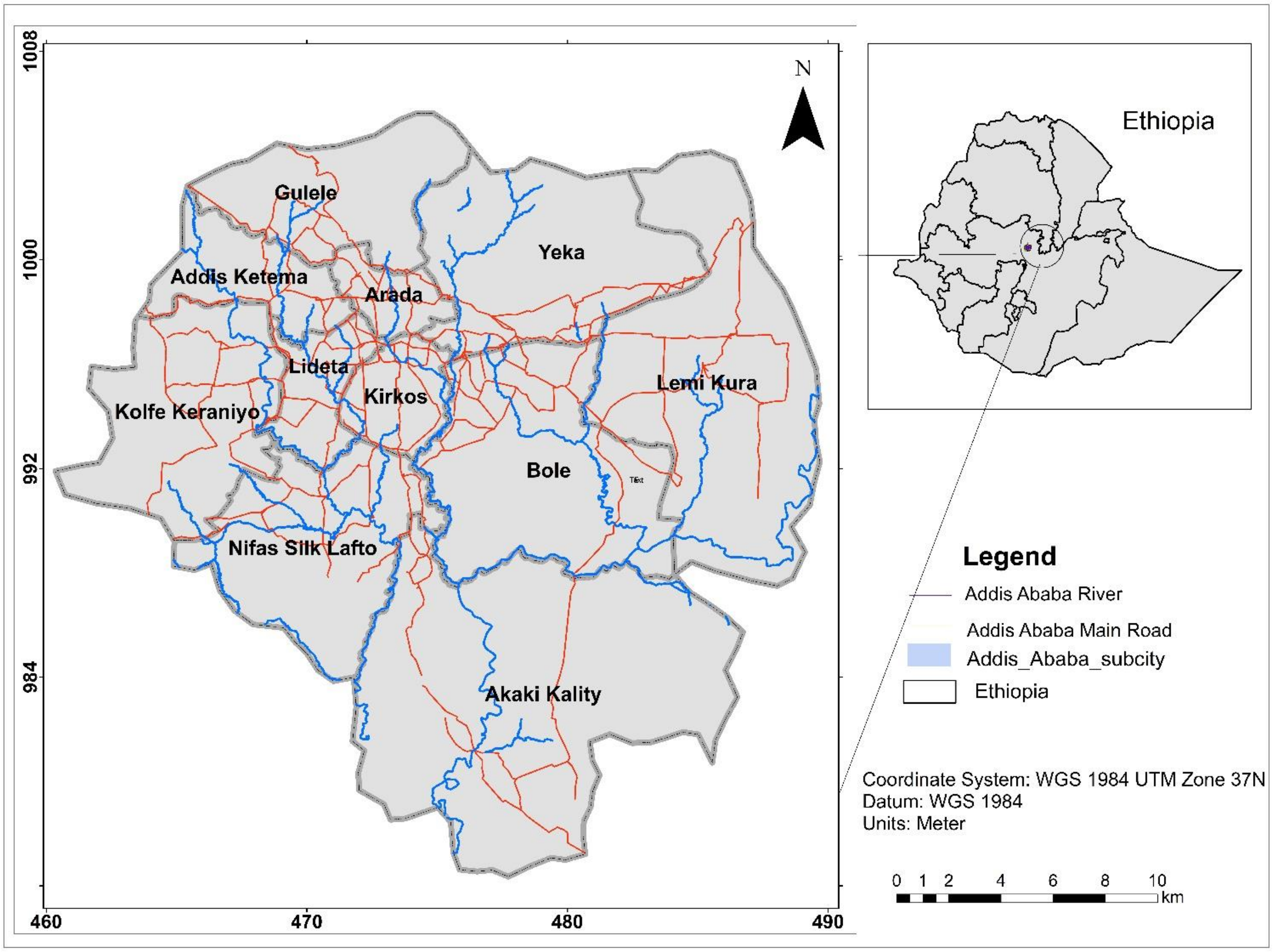


Fig 3.1. Location map of the study area.

3.1.1 Topography

Addis Ababa is located on a well-watered plateau surrounded by hills and mountains. Located at the foot of Mount Entoto, at an altitude of 2355 meters above sea level. The lowest and the highest place with elevation 2,326 meters (7,631 ft.) and 3000 meter (9.800 ft.) above sea level respectively are located around Bole to the south and Entoto Mountain to the north.

3.1.2 Temperature

The mean annual temperature in Addis Ababa, Ethiopia is around 16−17°C (60-63 degrees Fahrenheit). The highest temperatures of the year, about 29/30 °C (84/86 °F), occur from February to May, before the rainy season. The hottest month (May) is somewhat warm with an average temperature of 18 degrees Celsius (64.4 degrees Fahrenheit. The cool season lasts for 2.0 months, from July 7 to September 6, with an average daily high temperature below 67°F. The coldest month of the year in Addis Ababa is August, with an average low of 54°F and high of 66°F. However, temperature can vary depending on the altitude and location within the city.

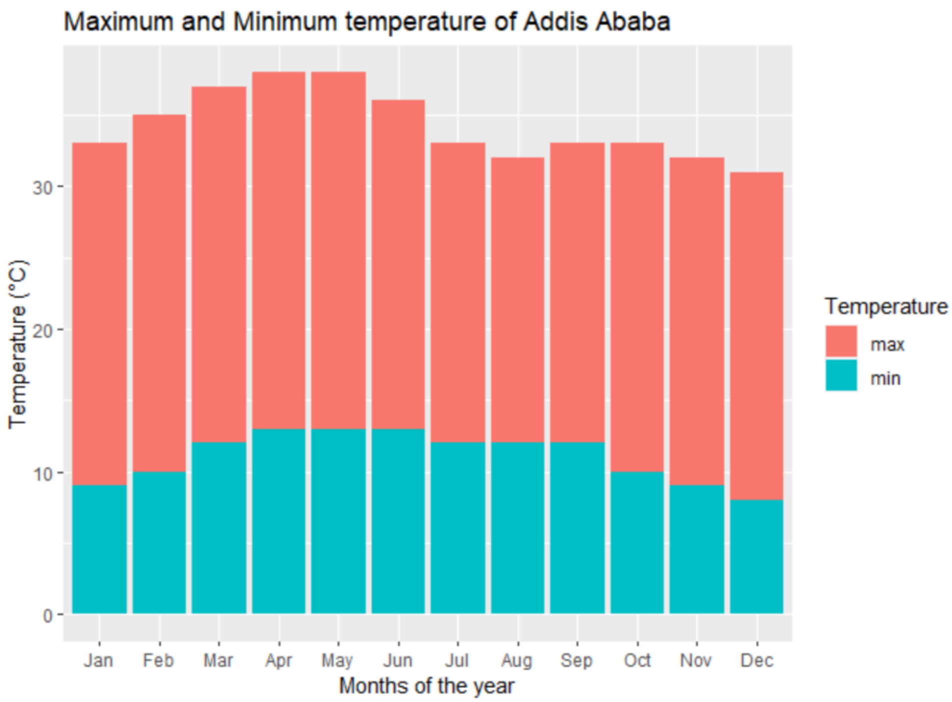


Fig 3.2 Maximum and minimum temprature of Addis Ababa

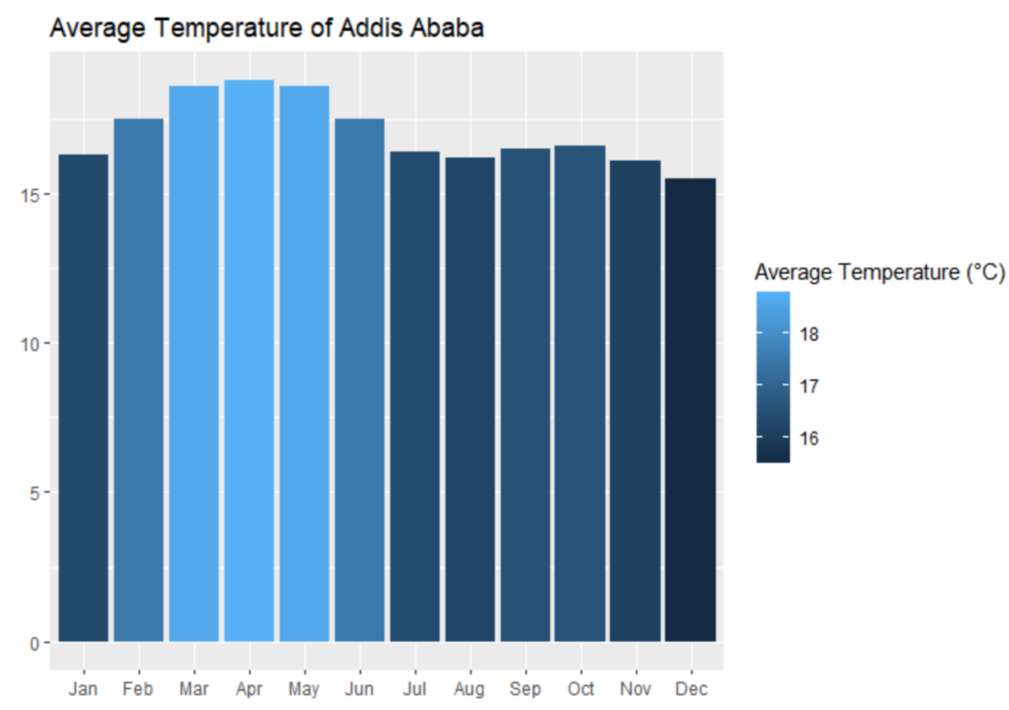


Fig 3.3 Average temprature of Addis Ababa

3.1.3 Rainfall

Addis Ababa has a subtropical highland climate, with two distinct rainy seasons. The first rainy season occurs from February to April, while the second rainy season occurs from June to September. The city receives an average annual rainfall of around 1200mm, with the heaviest rainfall occurring during the months of July and August. The rainfall is vital for agriculture and supports the growth of crops such as coffee, which is a major export for Ethiopia. However, heavy rainfall can also lead to flooding in some areas of the city, particularly in low-lying neighborhoods. During the dry season, which lasts from October to January, the city experiences sunny and warm weather, with temperatures ranging from 15°C to 25°C.

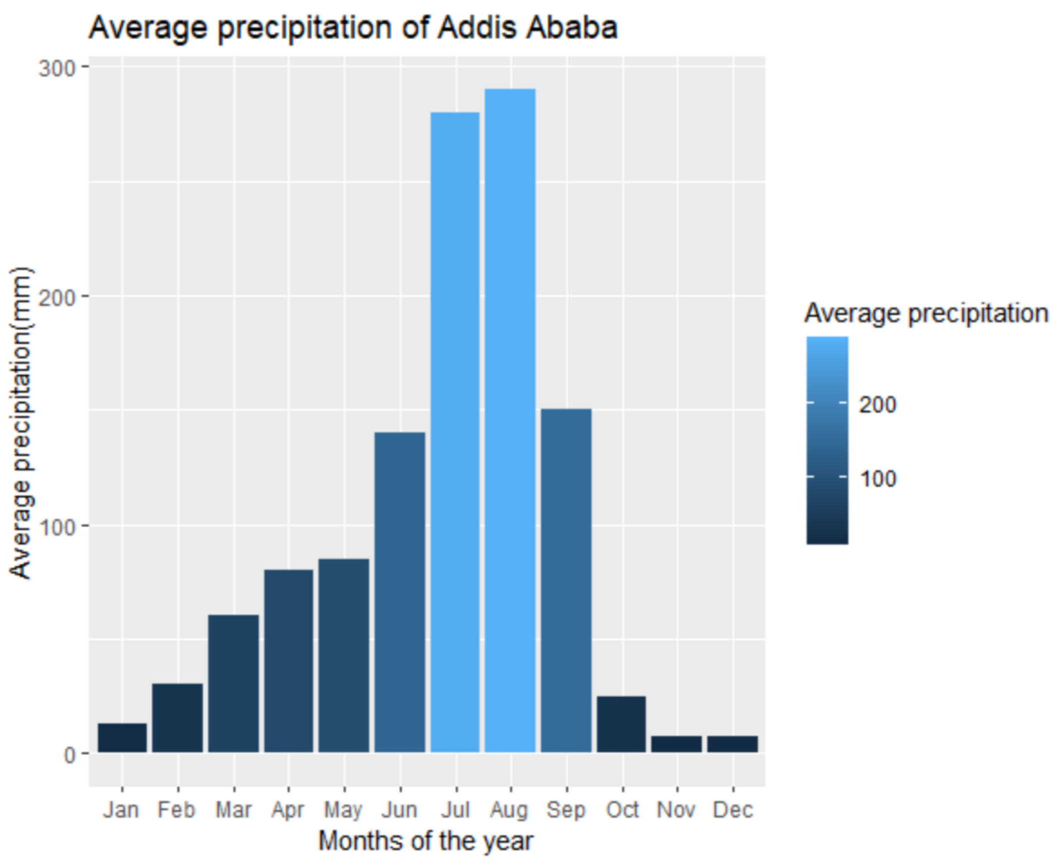


Fig 3.4 Precipitation of Addis Ababa

3.1.4 Population

Addis Ababa is the capital city of Ethiopia and has a population of over 5 million, making it the largest city in the country. The population is diverse, with various ethnic groups represented, including the Oromo, Amhara, and Tigray. The population growth rate has been steadily increasing over the past few decades, fueled by urbanization, migration from rural areas, and a high birth rate. The city is a hub for commerce, industry, and government, which attracts people from all over the country. The population density is relatively high, with many residents living in crowded neighborhoods and apartment buildings. Despite the challenges that come with rapid urbanization, Addis Ababa remains a vibrant and dynamic city with a rich cultural heritage. According to the United Nation estimates, Addis Ababa City has a total population of 5,461,000 with 4.46% annual growth rate, which is about 60% of the total urban population of Ethiopia. Among this the number of female population was 2,084,000 (53%) and the remaining was male 1,861,000 (48%).which shown in (Table 3.1).

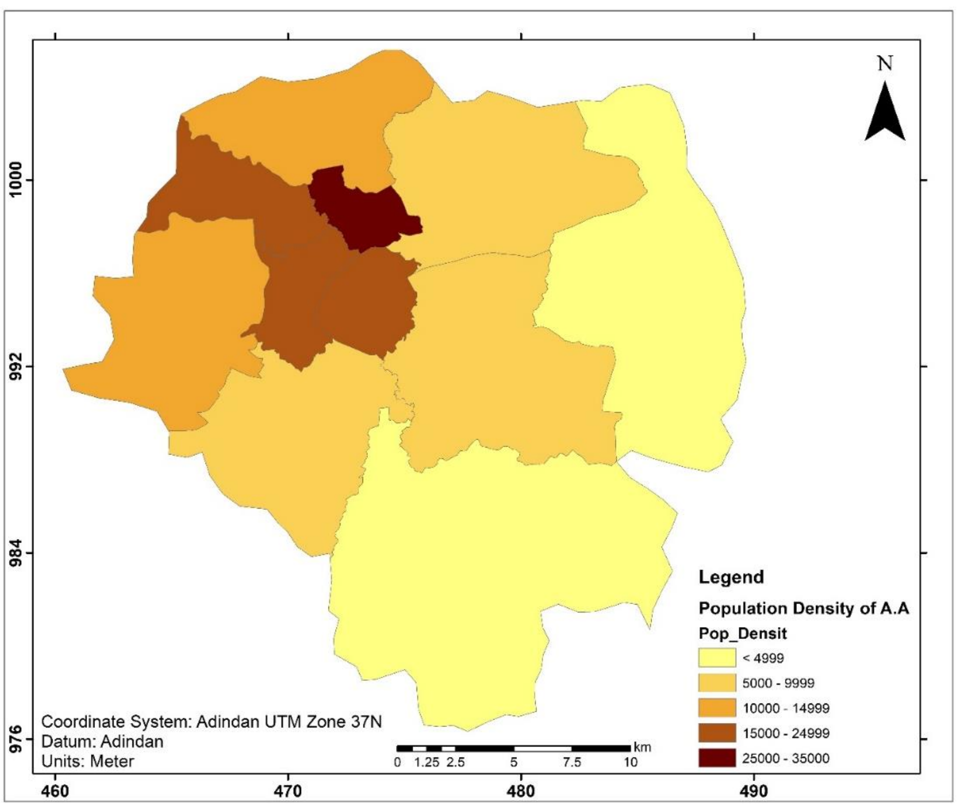


Fig 3.5 Population density map of Addis Ababa

Table 3.1 Addis Ababa Sub city Population number in 2023

No	Sub city	Total population	Population Density
1	Arada	298,043	29,804
2	Addis Ketema	359,735	17,130
3	Akaki-Kality	255,349	2,027
4	Lideta	284.208	18,948
5	Gulele	377,032	10,190
6	Kirkos	311,765	20,784
7	Yeka	459,225	7,918
8	Nifas-silk	445,683	8,739
9	Kolfe-keranio	604,226	11,847
10	Bole	378,816	5,740
11	Lemi-Kura	85,918	965

3.2 Public recreational parks

Public recreational parks are feature amenities such as playgrounds, sports fields, walking trails, and picnic areas. They provide a space for people to connect with nature, enjoy outdoor activities, and socialize with others in the community. Public recreational parks are important for promoting physical activity and mental well-being, as well as providing a sense of community and connection.

The study used twenty two Public recreational parks existed in Addis Ababa city. The parks are categorized as city and Sub city parks by Addis Ababa City Beautification, Parks and Cemetery Development and Administration (AACBPCDA) and AACC (Addis Ababa City Council). Public recreational parks are parks that are typically maintained by the local government or nonprofit organizations. These parks provide service at low cost or free of charge. Table shows name and description of city and sub-city parks used for the accessibility analysis. Table 4.3 and 4.4 shows, the 19 public parks found in the study area and the 8 selected public parks for the study.

3.3 Data collection methods

Satellite data and ancillary data are the two types of data that will be employed in this study. Ancillary data includes shape files of the parks, shape files of the residential area, road network, shape files of the study area, population data and ground truth information for public park facility extraction. The reference data points utilized as the ground truth data was gathered for the year 2023 from online data source (Google Earth) for validating the land-use and land-cover classes. These data will be used for image classification general accuracy evaluation, of the classification results. In addition, to map urban green spaces existed in the study area, supervised OBIA (Object Based Image Analysis) algorithm is employed.

3.4 Data Acquisition

Continuous earth surface remote sensing data acquired from the Sentinel 2 satellite, is used for a variety of purposes, including monitoring natural resources, managing disaster risk, and studying changes in land use land cover. I have used Sentinel 2A data acquired during the dry season (March-April) to assess and detect green spaces that were not caused by changes in precipitation and humidity.

Table 3.2 Data used for the study

No	Data Type	Data Sources	Description
1	Addis Ababa Shape file	OCHA	Shape file
2	Addis Ababa road network	SSGI	Polyline
3	Population Data	OCHA and CSA	Excel, raster
4	Public park	Space science and Geo-spatial institute	Point feature
5	Residential area	SSGI	Polygon
6	Temperature and Rainfall	AMA	Excel file
7	Sentinel 2A	Copernicus Hub	Satellite image
8	World view image	Google Satellite	Satellite image

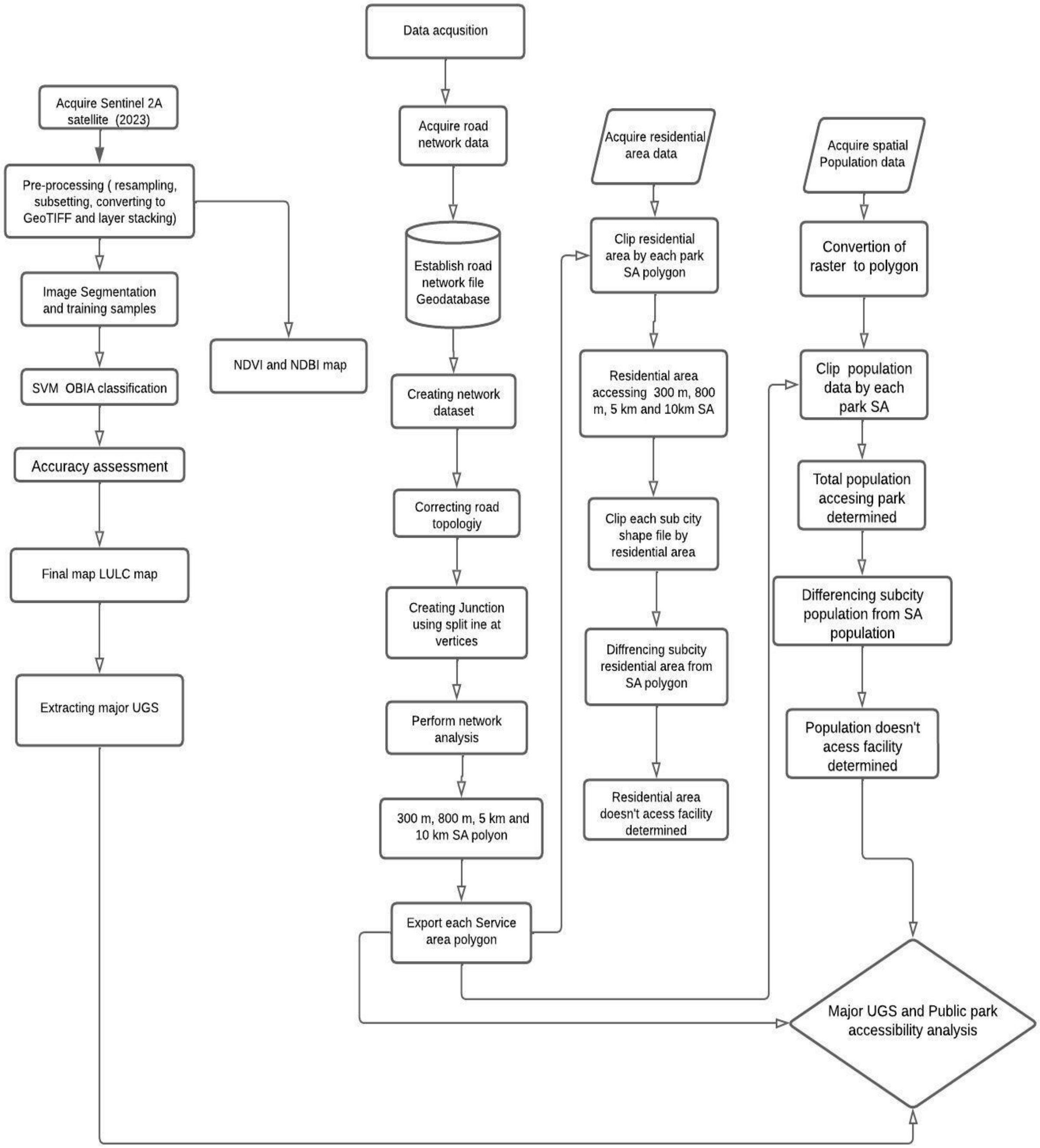


Fig 3.6 Frame work of the methodology

3.5 Sentinel 2A data description

To classify Urban green spaces, Sentinel 2A level 2 satellite image released during the period of February-March, 2023 has acquired from ESA (European Space agency). The approach used to extract UGS, from freely available high resolution Sentinel-2A satellite imagery, provided in the frame of European Copernicus program (Jian and David, 2017). S2A multispectral imager is covering 13 spectral bands as shown on table 3, with a swath width of 290 km and spatial resolutions of 10 m (three visible and a near-infrared band), 20 m (6 red-edge/shortwave infrared bands) and 60 m (3 atmospheric correction bands) (Jian and David 2017). The mission is intended to monitor variability in land surface conditions, and its wide swath width and high revisit time (10 days with one satellite and five days with two satellites after Sentinel-2B is launched in 2016) will support monitoring of changes to vegetation within the growing season (Simonetti, et al., 2017). It also provides data and applications for operational land monitoring, emergency response, and security services.

3.6 Material and Software

Remote sensing sand GIS software's provide users with the ability to edit, categorize, and store images obtained from aerial photography, satellite transmissions, or other remote sensing equipment. Different remote sensing and GIS software's were used for data collection, processing and analysis procedures. SNAP software were used for image processing of Sentinel 2A satellite imagery. The techniques used were resampling, sub setting required bands, layer stacking and conversion of Snap file format to Geo-TIFF file formats. In addition, ERDAS Imagine 2014 was used for mosaicking, NDVI and NDBI classification. To verify the LULC classification, Google satellite was used as reference ground truth data. Land-use/land-cover classification and accuracy assessment tasks were computed by using SAGA GIS and ArcGIS 10.8. Moreover relevant GIS analysis were undertaken by using advanced Network analysis tool integrated in the ArcGIS software. The tool has the ability to effectively analyze the accessibility of public parks with in the service area polygon.

3.7 Data preprocessing for Sentinel 2A

Data from Sentinel 2A is provided in Sentinel's proprietary SAFE format as zip-compressed files. The Sentinel2A image provided by ESA, has been atmospherically and radiometrically corrected. However, the cloud coverage should be considered while acquiring satellite imageries. Therefore, I have acquired images with less than two cloud cover percentage. Three distinct geometric resolutions of jpg-files are used to store the spectral bands (10 m, 20 m & 60 m). I have stacked acquired JPG files into a single 10 m-wide geo-tiff file called raster stack. To reduce calculation time and data volume due to the amount of the data, I subset the desired study area data during the preprocessing stages. The S2A data processing and classification will be performed using ESA SNAP 9.0 and SAGA GIS 8.2 software.

Table 3.3 Sentinel 2A band descriptions

Band	Type	Wavelength (µm)	Resolution (m)	
1	Coastal aerosol	0.443	60	
2	Blue	0.490	10	
3	Green	0.560	10	
4	Red	0.665	10	
5	Near infrared	0.705	20	
6	Near infrared	0.740	20	5 days
7	Near infrared	0.783	20	revisit time
8	Near infrared	0.842	10	
8A	Near infrared	0.865	20	
9	Water vapour	0.945	60	
10	Cirrus	1.375	60	
11	Shortwave infrared	1.610	20	
12	Shortwave infrared	2.190	20	

3.8 Data Analysis

Satellite indices

3.8.1 Normalized Difference Vegetation Index (NDVI)

NDVI images was produced before image classification. The NDVI images from the year of 2023 was classified using ERDAS IMAGINE 14 software. By dividing the near infrared (NIR) and red values of the satellite image, NDVI images will be generated.

NDVI= NIR-RED

NIR+RED (3)

In Sentinel 2, NDVI = (Band 8 –Band 4) / (Band 8 + Band 4).

Based on the NDVI values, Sentinel 2A data for the year of 2023 have been classified to assess the status of vegetation cover with in the study area.

3.8.2 Normalized Difference Built-up Index (NDBI)

By mapping the built-up changes, data from remote sensing will enable us to show how cities develop through time (Varshney, 2013). Using the algorithm NDBI, the built-up land information can be extracted, and the number 1 denotes a positive value for the built-up regions (Varshney, 2013; Zhiqiang et al., 2014). The algorithm automates the process of extracting the built-up area.

$$NDBI = \frac{SWIR\text{-}NIR}{SWIR+NIR} \quad (4)$$

Where, SWIR refers is Shortwave Infrared and NIR refers to Near Infrared

In Sentinel 2, NDBI = (Band 11–Band 8) / (Band 11+ Band 8) for Landsat 8 (Zhiqiang et al., 2014)

3.9 Land-use and land-cover classification

The classification algorithm used for this study are SVM (Support vector machine) and Object Based Image Analysis (OBIA) classifier. A brief summary of these classifiers is given below.

3.9.1 Support Vector Machine Algorithm

Remote sensing has proved to be an indispensable tool in providing land cover information required for the management of natural resources. The extraction of land cover information is usually achieved through a classification analysis. The image segmentation algorithm took place before feature selection procedure (setting training samples points). The image segmentation is helpful to train the SVM classifier to perform pattern analysis of the satellite imagery for the purpose of classifying land-uses and land-cover.

Ground data was collected from Google satellite, 5th to 21st February, 2023, near the time of satellite data acquisition. It comprised of a standard training data collection procedure.

In the standard training data scheme, the ground data collected from Google satellite image randomly.

3.9.2 Object-based Classification

Object based image classification is based on the spectral information in each pixel, object-based classification is based on information from a set of similar pixels called objects or image objects. Image objects or features are groups of pixels that are similar to one another based on the spectral properties such as size, shape, and texture, as well as context from a neighborhood surrounding the pixels. Object-based classification is a two-step process, first the image is segmented or broken into discrete objects or features with and then each object is classified. This type of classification attempts to mimic the type of analysis done by humans during visual interpretation. Object-based classification methods were developed relatively recently compared to traditional pixel based classification techniques.

3.10 Segmentation

Image segmentation is a key component to object-based classification. Segmentation is a process by which pixels in an image are grouped into segments, objects or features that have similar spectral and spatial characteristics. Each of these objects or features contain multiple pixels. The segments in the image ideally correspond to real-world features, for example buildings or tree crowns. There are a variety of different parameters that are used in segmentation. The scale of the objects or features is one of the important variables in the image segmentation process. The scale sets the minimum number of pixels that must be contained in a group for it to be a separate segment or object. The study used preprocessed Sentinel 2 image for segmentation and OBIA classification.

3.11 Accuracy assessment

Accuracy assessment is an important part of any classification project. It compares the classified image to another data source that is considered to be accurate or ground truth data. Ground truth can be collected in the field; however, this is time consuming and expensive. Ground truth data can be collected from the field or from high- resolution satellite imagery. The most common way to assess the accuracy of a classified map is to create a set of random points from the ground truth data and compare that to the classified data in a confusion matrix. As ground truth data I have used Google satellite imagery to assess the accuracy of the classification. To verify the classification the study used 270 randomly selected points in total obtained from the five land use land cover classes.

3.12 Network Analysis

Service area or resource allocation is a network analysis application. It is a widely supported facility within many GIS packages. These are often distinct zones that consider distance, time and travel cost to assign the, intended service area polygon to the existing facilities within a certain network nodes than to any other designated point. An organization or individuals can optimize the allocation of resources depending on the capacity of each facility if the goal of creating service areas around a service center is achieved. Allocation algorithms use these centers as destinations then model how people or goods will travel through the network to get there. The result is a map that shows the areas served by each service facility. The service provided to clients (from the facilities that are being situated) sometimes depends on their proximity to the facility to which they are assigned. Customers are often sent to the closest facility, though this is not always the case. Service is frequently considered adequate if the consumer is close to the facility and is considered poor if the distance is greater than a certain threshold.

The analysis is measured using the following parameters.

A. Resident's accessibility: Percentage of population served by the Public Park facility within the walkable distance.
B. Residential area accessibility: residential area accessing facilities per the service areas analyzed per sub-city level.

This study used road network data acquired from Space Science and Geo-spatial institute, the road network topology has been corrected using topological rules. The network dataset were created using edited road network data. The study considers all 22 city and sub-city parks existed in Addis Ababa city. As it is categorized by AACC, 17 sub-city parks and 5 city parks were used in the accessibility analysis. The residential area of and population of Addis Ababa is one input for the accessibility analysis beside the road network. The residential area data were extracted from SSGI land-use/land-cover map. In addition, Point shape files of the parks were also obtained from SSGI and used in the service area tool to depict accessible areas, using proximity indicator. Two sub-cities out of eleven doesn't have any park facility the sub cities Bole and Lemi-kura. During the field visit it is found that Millennium Park in Addis ketema has diminished and changed to other land uses. Africa Park no two found in kirkos sub city has changed its name to Addis Ababa Park. In addition, Nation and Nationalities Park found in kirkos has changed its name to Mayor/W Tsadik Park.

Accessibility of sub city and city parks were determined using network analysis, service area tool. The study considers two international (300 m and 800 m) and national (5 km and 10 km) standard thresholds. This standards were suggested and recommended by WHO, European countries and Addis Ababa city council. This standards were chosen considering different age groups and living situations of the community. The network analysis is computed using ArcGIS 10.8 software. The selected 300 m 800 m, 5 km and 10 km service area polygons were exported separately using new service area computational tool suited to analyze facility service area. Residential area that fall within the service area polygon were analyzed by clipping residential area by the service area polygon. This was done for all 22 city and sub city parks separately. Residential area that doesn't have access to the facility (public parks) with in the service area polygon were computed by differencing the service area polygon from the total residential area of each sub city.

The population data was obtained from Ethio-GIS database for the year of 2007. It shows the population resides with 1 km^2 of the City and the data is in raster format with 1km resolution. To get the population of the accessible area clip tool is used instead of mask tool because the grid cells of the raster data are rather large relative to the service area polygons used for the accessibility analysis. Resampling the data introduces error in raw data. In addition resampling will produce wrong population distribution. Therefore the raster data has been converted to vector format and used clip tool to calculate the population living inside the accessible area.

As the population data was valid back in the acquisition time, I have calculated the current population number using the growth rate .The Residential area with in the service area polygon that have been computed on the above mentioned procedures were multiplied by each grid code for every service area polygons to determine number of residents that have access to the public parks within 300 (4 min) and 800 meters (10 min), 5 km and 10 km. Finally the population number that doesn't enjoy the facility with in the service area is computed by differencing the population number with service area and the total population of each sub city.

CHAPTER FOUR

4. RESULTS

4.1 Land-use and land-cover status of UGS

The result of OBIA classification is presented in (Fig 4.1, Fig 4.2 and Table 4.1). In this work, I have classified Sentinel 2A satellite imagery acquired on March 06, 2023 from ESA (European Space Agency). The land-use and land-cover map was generated using OBIA classification integrated with supervised SVM (Support Vector Machine) algorithm. The land-use and land-cover map is shown below along with the area coverage table. Five land-use and land-cover classes were identified: built up, agricultural land, urban forest, water body and bare land. From the land use land cover map, major urban green spaces such as Urban forest and urban agricultural land were extracted and assessed in the study. The overall accuracy obtained from the land-use and land-cover classification of Addis Ababa is 85.1 and 0.82 kappa coefficient. In addition, accessibility, distribution and demand of public recreational parks were studied using Network analysis tool.

Built up covers the largest portion of the land by occupying 36,352 ha (70%) of the land, urban agricultural land follows by covering 9037 ha (17%) of the land use. Urban forest and water body covers 3357 and 3337 area While bare land occupies only 617 ha (1 %) of the study area. From the total area of land-use distribution in 2023, urban green space constitutes only 29% of the land. Whereas, the land is dominated by built up and impervious land cover types.

Table 4.1 Land-use and Land cover area

No	Green spaces	Area (ha)
1	Agricultural land	9037
2	Urban forest	3357
3	River	3337
4	Built-up	36,352
5	Bare land	617

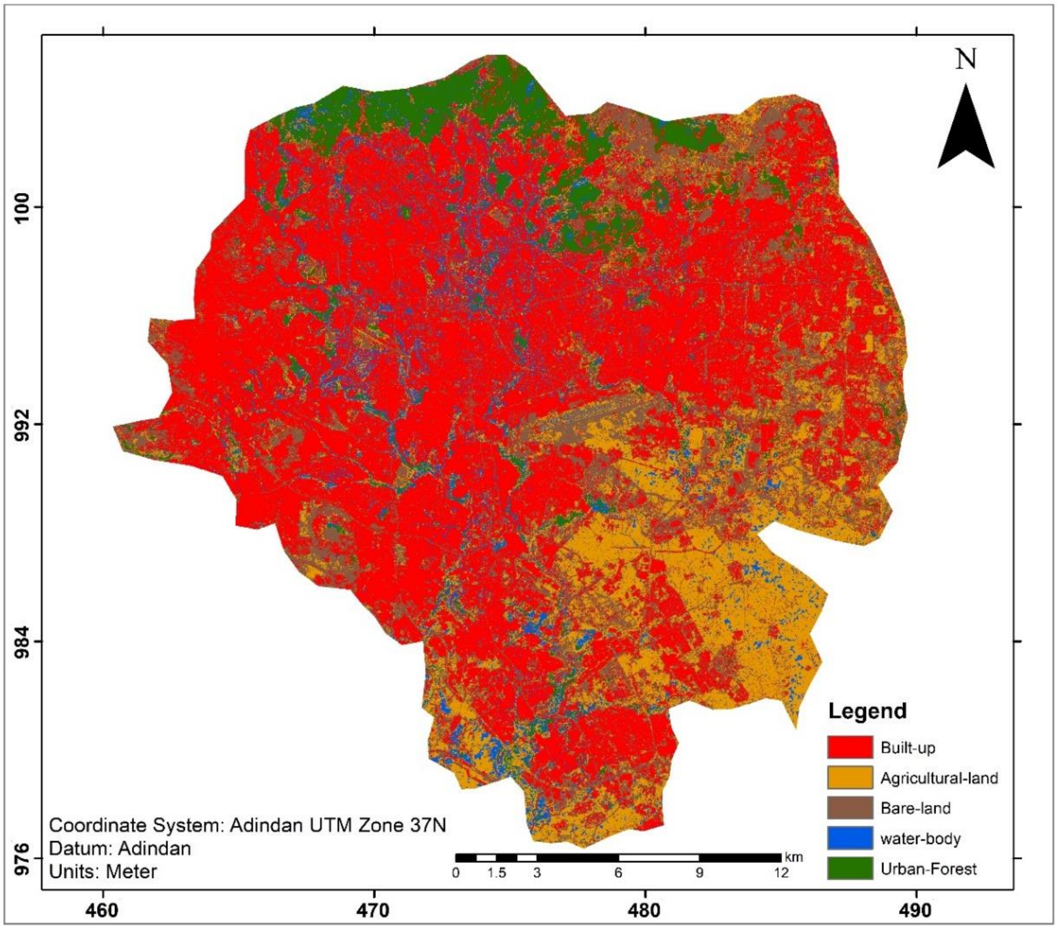


Fig 4.1 Land-use and land-cover map

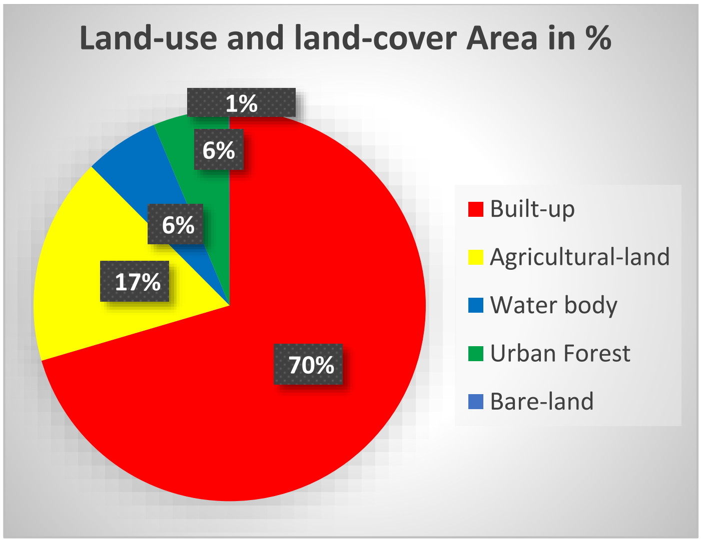


Fig 4.2 land-use and land-cover area (%)

4.2 Urban Forest

A forest, or a group of trees, that are found in a city is known as an urban forest. Urban forests include wood lands and dense plant vegetation growing in urban settlement areas. Urban forests are very significant assets of cities. They provide numerous ecological services such as avoiding runoff, helps to improve air quality by removing harmful pollutants, oxygen production, and carbon storage.

As shown in Fig 4.1, forest areas are located at Northern part of Addis Ababa. Only Gulele has 15 % of forest area coverage. In addition to Gulele and Yeka, has 3 % of forest areal coverage. Gulele is the only sub-city sufficiently access urban forest within a few travel time and distance. The other ten sub cities doesn’t almost have urban forest accessibility.

4.3 Urban Agricultural land

Agricultural land also refers as farmland, is a cultivated land devoted for the purpose of fruit and crop production. It is common to see farmlands in the country side regions. Whereas, Urban areas are mainly populated by built up and different land uses other than Agricultural land. However, these days, the concept of urban agriculture is gaining global attention as the world observed enormous uses of agricultural lands. Urban farmlands has significant contribution for food production and supplies to urban dwellers. Also they are highly advantageous for the environment and the climate.

Currently the study area has 9,037 ha of agricultural land. The majority of farm lands are located in the south east of Addis Ababa as shown in Fig 4.1

As the population number increases dramatically in metropolitan areas, adequate food supplies needs to be facilitated. Therefore, to satisfy the need agricultural food production has to be maximized and promoted.

4.4 NDVI

The normalized vegetation index is used to assess the greenness of a study area. The NDVI map (Fig 4.3) shows vegetation cover of Addis Ababa for the year of 2023. The value ranges from −0.2 to 0.7. The highest value (0.7) depicts vegetated surfaces whereas the lowest value (−0.2) indicates non-vegetated areas. As shown in fig vegetated areas are found in northern part of Addis Ababa. However, riverine vegetation are classified and displayed slightly buffering the river streams. The NDVI illustrates that the study area has very little vegetation cover and most of the areas are populated by built up and other land uses.

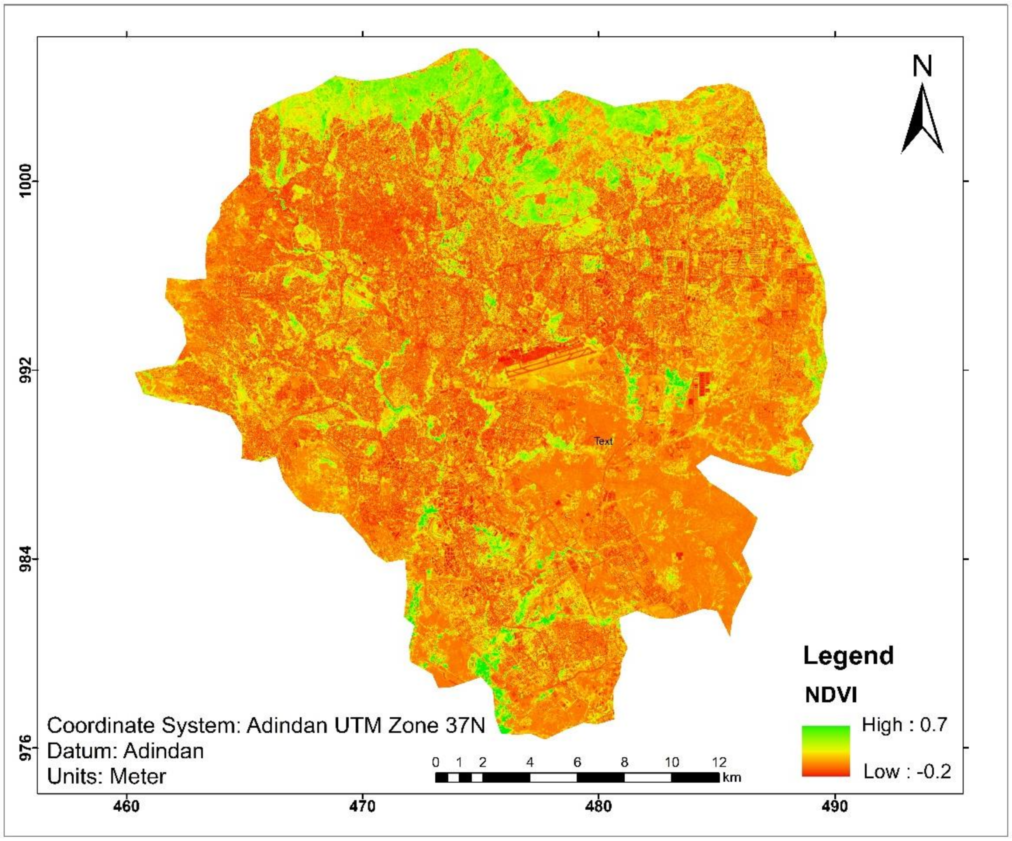


Fig 4.3 Normalized difference vegetation index map

4.5 NDBI

The built-up index in the figure 4 indicates that, the positive values are referred to the area dominated by built-up is large. As it is presented in the map approximately more than 70 % of the study area is occupied by built-up area. The positive value from the Fig.4.4 illustrates the land-cover area under built-up.

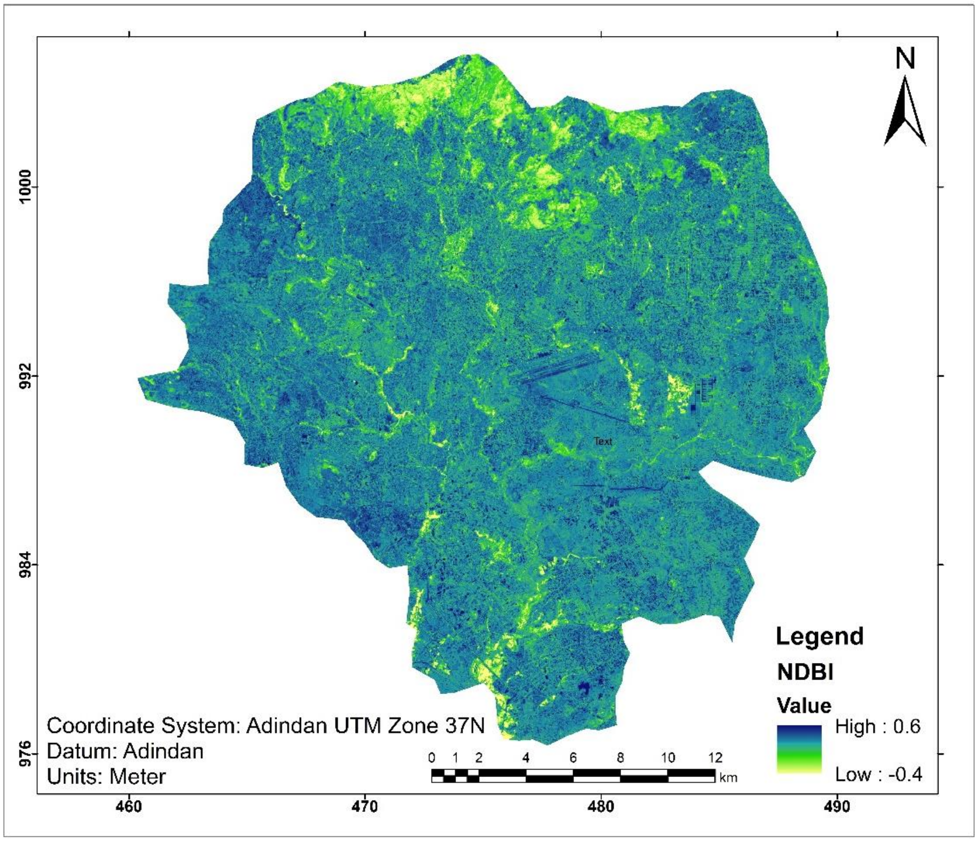


Fig 4.4 Normalized Difference Built-up Index

4.6 Public recreational parks

In the study area 22 public recreational parks are existing. These parks are providing recreational services to public. From the 22 parks 17 parks were assigned as sub city parks, the rest five parks are city parks. The park categorization were made by Addis Ababa City Beautification, Parks and Cemetery Development and Administration (AACBPCDA). The master plan of Addis Ababa have, proposed recreational park hierarchy based on park size as illustrated below in Table 4.2

Table 4.2 Park categorization in A.A

Park type	Size
City parks	>10 ha
Sub city parks	1-10 ha

4.6.1 Sub city parks

The sub city parks measure 62 ha in total. During the field visit it is found that Millinium Park found in Addis ketema have diminished and changed to other land-use types. In-order to address all classes of the community, only public recreational parks are considered as they are accessible freely and at low cost to the community. From all Addis Ababa sub cities Gulele has the largest park area of 0.157 km^2, Kirkos sub city follows with 0.121, km^2 area coverage, yeka has the third largest park area of 0.09 km^2, Lideta comes fourth with an area of 0.068 km^2 following Lideta, Kolfekeranio is the fifith largest sub-city with an area of 0.067 k m^2. Nifassilk, Arada, Akaki-kality and Addis ketema has one sub-city parks with an area of 0.029 k m^2, 0.015 km^2, 0.013km^2, and 0.0073 km^2 area. The highest concentration of parks are in central part of the city mainly on Lideta and kirkos. Kirkos has the highest number of sub-city parks which is four, Gulele and Lideta comes next with three number of parks. Yeka comes fourth with 2 number of parks, while Nifassilk, Arada, Kolfe, Akaki and Addis ketema each sub cities has 1 number of public parks.

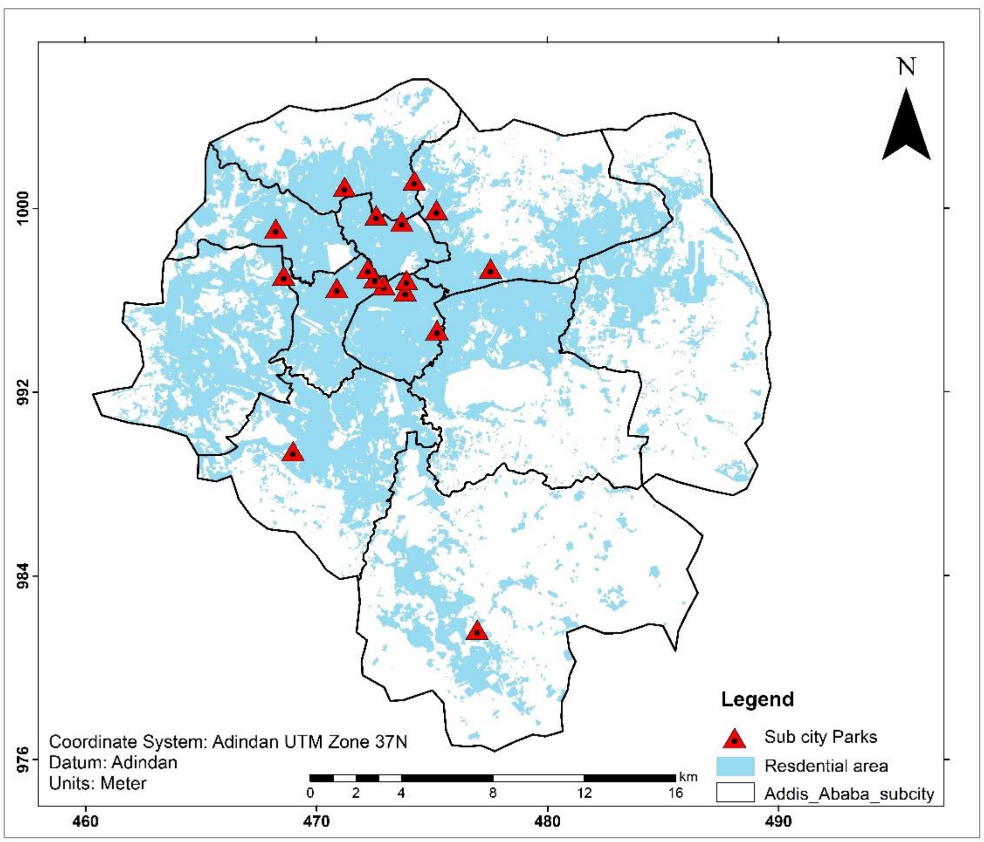


Fig 4.5 Sub-city parks

4.6.2 City parks

Addis Ababa has five city parks located in Gulele, Arada and Nifas silk. The park name, sub-city and area has presented within the appendix section. The city parks measure 2,087 ha of the land. Two city parks namely Entoto Park and Gulele Botanical Garden are located in Gulele sub city. The newly constructed Entoto park has the largest area of all parks existed with in the study area. Entoto has1300 ha area. The Park is a unique natural sight in a mountain area and delivering services with many indoor and outdoor adventure and recreational activities. Gulele Botanical Garden has an area of 710 ha which provides ecological functions and it is home to many wild animals. I have included the garden with in this study because it also serves as recreational amenities beyond its use for research and ecological functions. The other two of the city parks (Unity and Friendship Park) found in Arada sub city. This parks are also newly constructed under the project of beautifying Addis Ababa. Unity Park is amusement park composed of various historical, natural and cultural sites. The park has 20 ha area coverage. The other city park found in Arada sub city, Friendship Park is the second largest park in Addis Ababa next to Entoto Park and it measures 46.42 ha. The park has interconnected water ponds, trees, benches, theaters, flower belts, fountains and an artificial lake of 16,900m^2 surface area filled by 12,000 litters. The park is located near Unity Park.

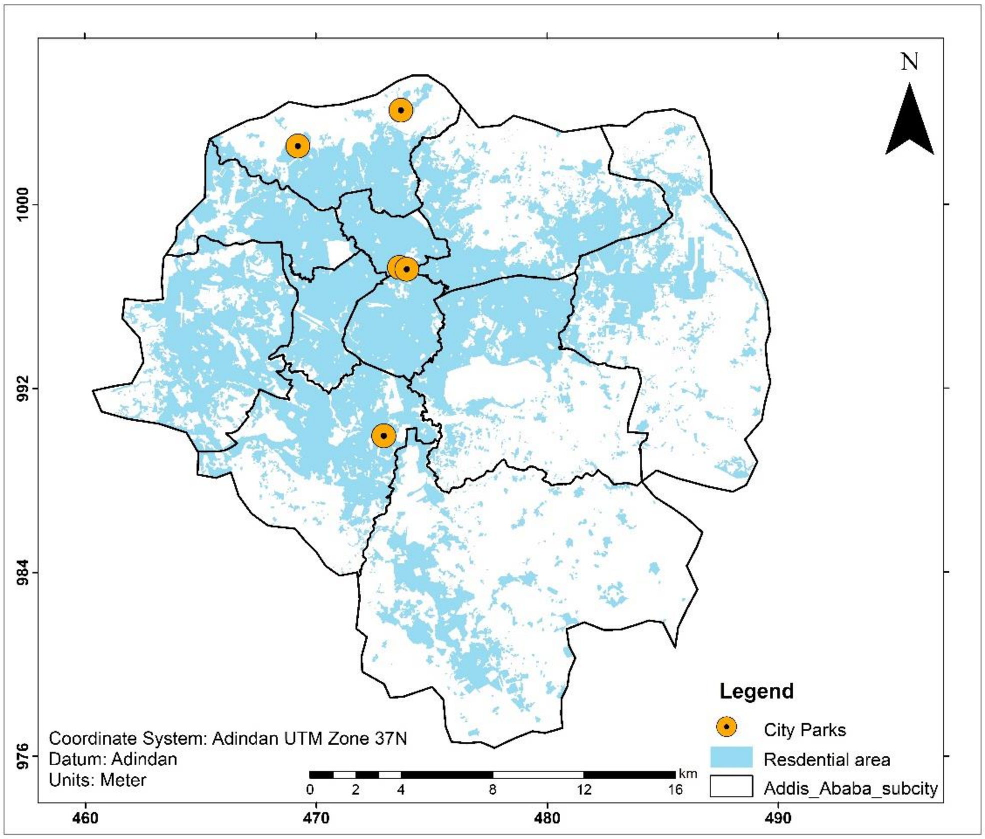


Fig 4.6 City Parks

4.7 Accessibility of the existing parks

The green infrastructure are natural and built facilities that provide recreational services, cleaner air and protection of biodiversity. Public parks are one of UGIs (Urban green infrastructure) which has been discovered as vital tool to regulate the urban temperature and cool down the city. Therefore, it is vital to assess the spatial disparity regarding citizens' access to parks due to the uneven spatial distribution of parks. This study uses only public recreational parks to assess accessibility as they can be accessed by every community with free of charge and at minimum cost.

This section presents accessibility results of the two park categories namely City and Sub-city parks. I have used four accessibility standards recommended by international and local organizations such as WHO, ANGST and AACC to assess and study the demand and accessibility of existing parks. The accessibility standards are explained separately below with obtained results based on city and sub-city level.

The accessibility of parks are measured considering the ability of residents to reach the facility. Different accessibility standards are applied throughout the world to determine availability and accessibility of public parks with in a standardized impedance or distance. The most common methods are minimum distance and travel distance. This study uses the travel distance or proximity indicator approach performed using network analysis. Network analysis is powerful ArcGIS extension used to study and identify relationships between different entities using road networks.

4.8 Proximity indicator

A proximity indicator is a tool used to measure the accessibility of public parks. It measures the distance between the park and the surrounding neighborhoods, providing an indication of how easily residents can access the park. The study used proximity indicator to assess the percentage of residential area and the population number that have access to public parks with in the intended service area standards. Additionally, it can be used to evaluate the effectiveness of existing parks and identify potential areas for improvement. This information can be used by city planners and policymakers to identify areas where there may be a lack of access to parks and to prioritize the development of new parks in those areas. The advantage of using a proximity indicator is that it provides a quantitative measure of the accessibility of public parks. By using a proximity indicator, city planners and policymakers can make data-driven decisions to ensure that all residents have access to safe and enjoyable public spaces, which is important for promoting physical activity, social interaction, and overall health and well-being of the society.

4.9 Service area accessibility standards

Every park has to full fill the requirements of accessibility by maintaining standardized park measurement parameters. Parks have to provide service for the community at any time without restriction and the distance should be within specified range of impedance that different class of society can access. Also they have to be usable in-terms of the service quality they provide. In this study I have used two determinant availability measurements. The first one is residential area, residential areas are places where the society settles. This places are initial points where the travel begins. Therefore, to assess the accessibility, the proportion of residential areas that falls within the service area are examined.

Addis Ababa is one of metropolitan city built without proper urban planning design. Commercial areas and industrial areas are mixed with residential areas. As a result, I have taken built up areas to analyze residential area accessibility. The residential areas of each sub city has been computed by clipping the settlement areas by each sub city. Table 4.9 shows residential areas of Addis Ababa sub cities in $km^{2.}$

The second determinant factor used to measure accessibility is population number. The population that has access to the facilities (parks) is examined using the service area polygon. The population enjoys the park within the specified impedance and the population that doesn't enjoy the parks within the service area are analyzed.

4.9.1 International service area standards

International park accessibility standards were set and recommended by different organization and countries. The first and the minimal standard used in the research, to assess accessibility of urban parks is 300 meter service area. The 300 meter SA is approximated to 4 minute walking distance. From multiple available standards I have selected two international standards considering the different age classes and status of the society. The second internationally accepted standards is 800m service area. The 800 meter service area is approximated to 10 minute average walking distance. The two standards are applied to both city and sub city parks existed within the study area. The results obtained from the two accepted and internationally recognized accessibility measurements are presented below in tables and figures.

A. Service area of 300 meter

The 300 m park service area is recommended park accessibility threshold by WHO and some European countries. This service area approximates to 4 minute walking distance which urban dwellers are expected to travel to access nearby public park facilities. The 300 m park service area analysis result shows Kirkos has the highest number of residential area accessibility followed by Lideta and Arada Sub-cities. Kirkos sub-city has 12 % residential area accessibility to the park facilities. Arada comes third with 9 % residential area accessibility next to Lideta, the second largest sub-city that has 11 % settlement area accessibility. Yeka, Nifassilk and Addis ketema sub-cities comes fourth with 4 percent of their residential area falls within the specified service area threshold. The lowest value is recorded for kolfe and Akaki which is only 1 % their residential area access parks within 300m threshold standard. The recorded accessible residential area coverage of all 9 sub-cities show that more than 87 percent of their residential area doesn't have park access within 4 min walking distance. Moreover, the other two sub cities of Addis Ababa namely Bole and Lemikura doesn't have park facilities. The residential area accessing the public parks with in 300m threshold is presented in Fig 4.7 and table 4.3 below, along with the area percentage.

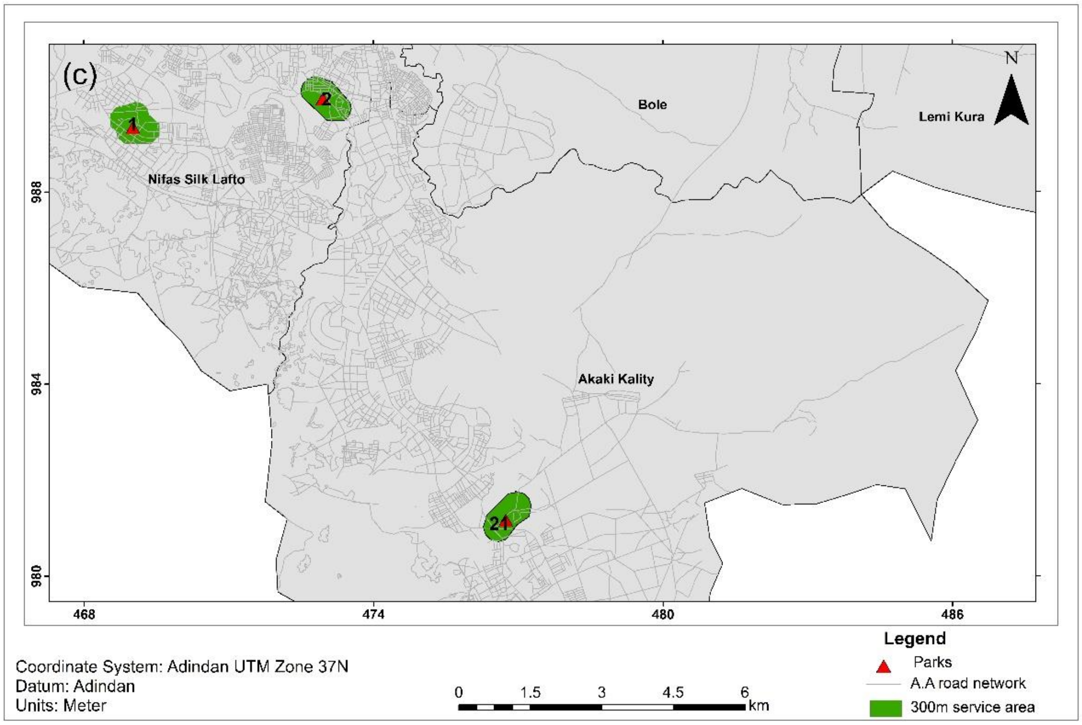


Fig 4.7 (a, b & c) 300 m service area map

Table 4.3. Residential area accessing park facility within 300 m (4 min walking distance)

No	Sub city	Residential area with 300 m service area (km^2)	Total residential area (km^2)	Accessibility of residential area in (%)
1	Arada	0.79	9	9
2	Kirkos	1.67	13.7	12
3	Lideta	1.53	13.33	11
4	Gulele	1.04	17.62	6
5	Yeka	1.115	25.9	4
6	Nifas silk	0.946	27	4
7	Kolfe	0.34	31.2	1
8	Addis Ketema	0.559	15.63	4
9	Akaki	0.261	22.5	1

B. Residents accessing public parks within 300 m service area

The number of residents that enjoy 300 meter park service area are identified as residents access the service area within the service area threshold. Resident's doesn't enjoy the parks are identified as residents demanding park facility within specified accessibility threshold. The highest number of urban dwellers accessing parks with 300 m service area are recorded for Lideta. The sub-city has the 21 % residents that enjoy the park facility with 4 min walking distance from their settlement areas. Kirkos and Arada has 13 and 9 percent of residents that enjoy parks with in the specified service areas. Gulele has the fourth highest number of residents with 7 % of the population lives in side the service area. It has been determined that the other six sub cities has low population number accessibility relatively from the total number of population lives within the sub cities. Residents residing in Yeka, Addis ketema and Nifassilk has recorded accessibility that range between 4 and 5 percentile. Kolfe and Akaki, records below 2 percentage of residents that have access to existing parks within 300 m SA. The residents having access to public parks with specified impedance has been shown in Table 4.4.

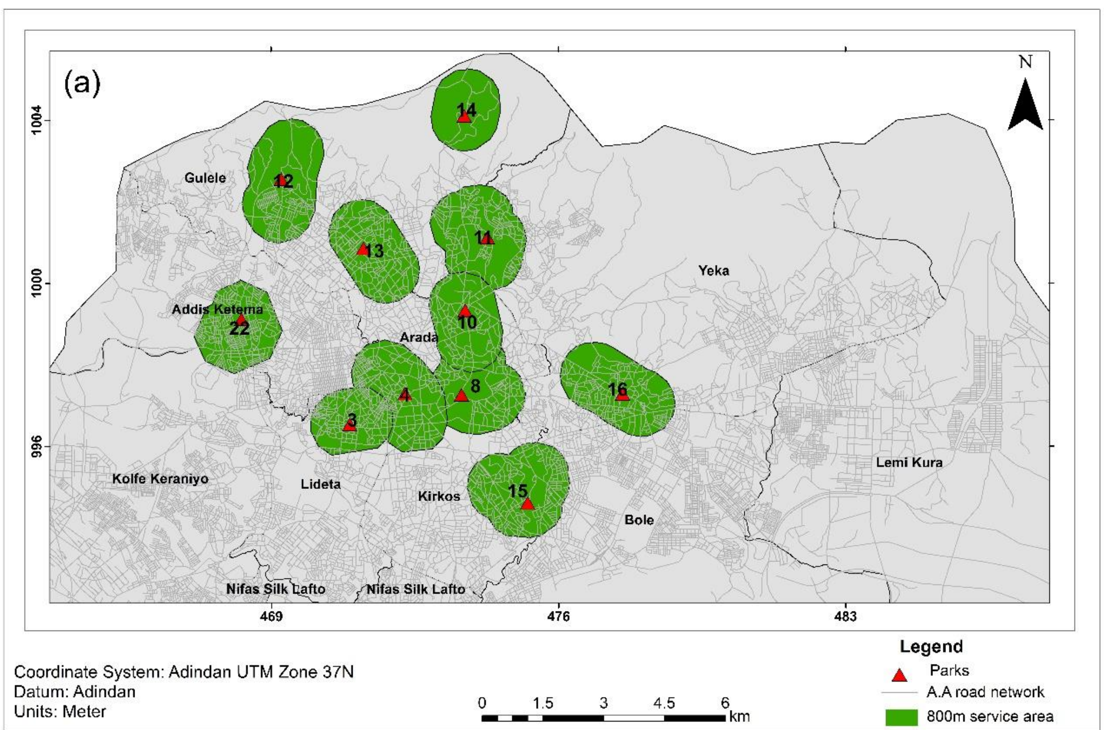
Table 4.4. Residents access public parks within 4 min walking distance

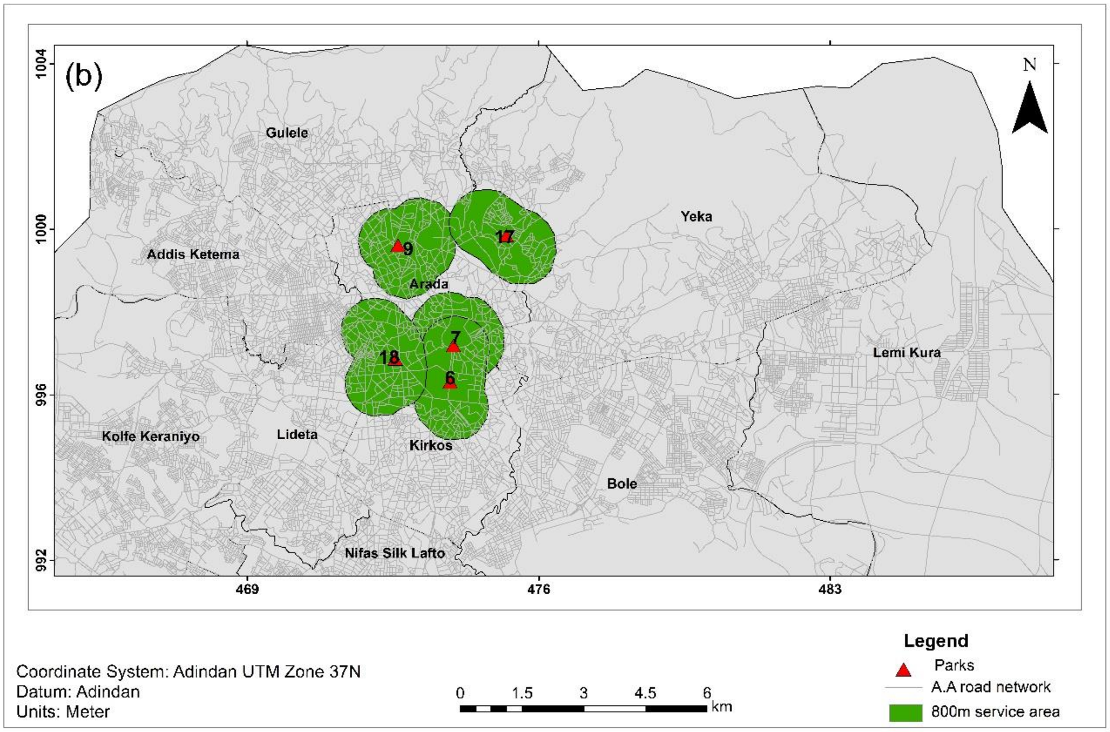
No	Sub city	Residents accessing 300 300 m service area (km^2)	Total population	Accessibility of residential area in (%)
1	Arada	25,713	298,043	9
2	Kirkos	39,013	311,765	13
3	Lideta	61,094	284,208	21
4	Gulele	26,892	377,032	7
5	Yeka	17,605	459,225	4
6	Nifas silk	16,415	445,683	4
7	Kolfe	8,598	604,226	1
8	Addis Ketema	17,923	359,735	5
9	Akaki	687	255,349	0.2

C. Service area of 800 meter

The 800 meter park service area is widely used threshold to assess accessibility of park facilities as it cover more area than 250 m, 300 m, and 400 m thresholds. This standardized threshold is approximated to 10 minute walking distances. In addition, this service area takes rapidly urbanizing states of cities in to consideration as metropolitan cities fails to provide adequate service area provisions for all urban dwellers.

The 800 m park service area analysis result has been elaborated in this section within sub city level. Arada sub-city service area covers 68 % of residential area, Lideta sub-city has 50 % residential area accessibility coverage following Arada sub city. Gulele comes third with 47 % of residential area accessing park facilities with the specified travel distance. Kirkos is the fourth sub-city with 41 percent of its settlement area accessing 800 m park facilities. Both Yeka and Nifassilk recorded 21 percentage of residential area accessibility of parks within 10 min walking distance. Addis ketema which has little variations with yeka and Nifassilk records 18 percentile of residential area accesses existing parks within the sub-city boundary. Whereas, the lowest residential area accessibility is below 8 % which is recorded for Akaki kality and Addis ketema sub-cities. Park facility accessible residential areas and their areal coverage is shown in (Fig 4.8 and Table 4.5).





(b)
N
Gulele
Yeka
Addis Ketema
Arada
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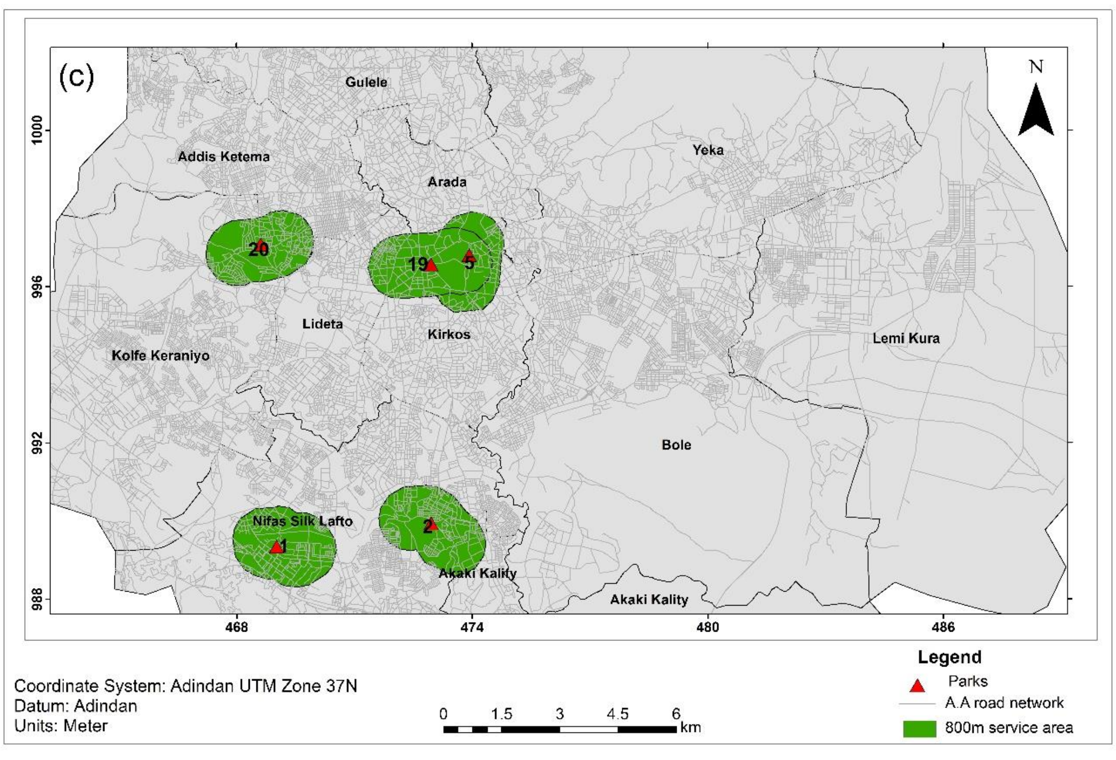
17
7
18
6
Lemi Kura
Kolfe Keraniyo
Lideta
Kirkos
Bole
Nifas Silk Lafto
1004
1000
996
992
469
476
483
Legend
Parks
A.A road network
800m service area
Coordinate System: Adindan UTM Zone 37N
Datum: Adindan
Units: Meter
0 1.5 3 4.5 6
km



(c)
N
Gulele
Yeka
Addis Ketema
Arada
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Lideta
Kirkos
Kolfe Keraniyo
Lemi Kura
Bole
Nifas Silk Lafto
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2
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992
988
468
474
480
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Legend
Parks
A.A road network
800m service area
Coordinate System: Adindan UTM Zone 37N
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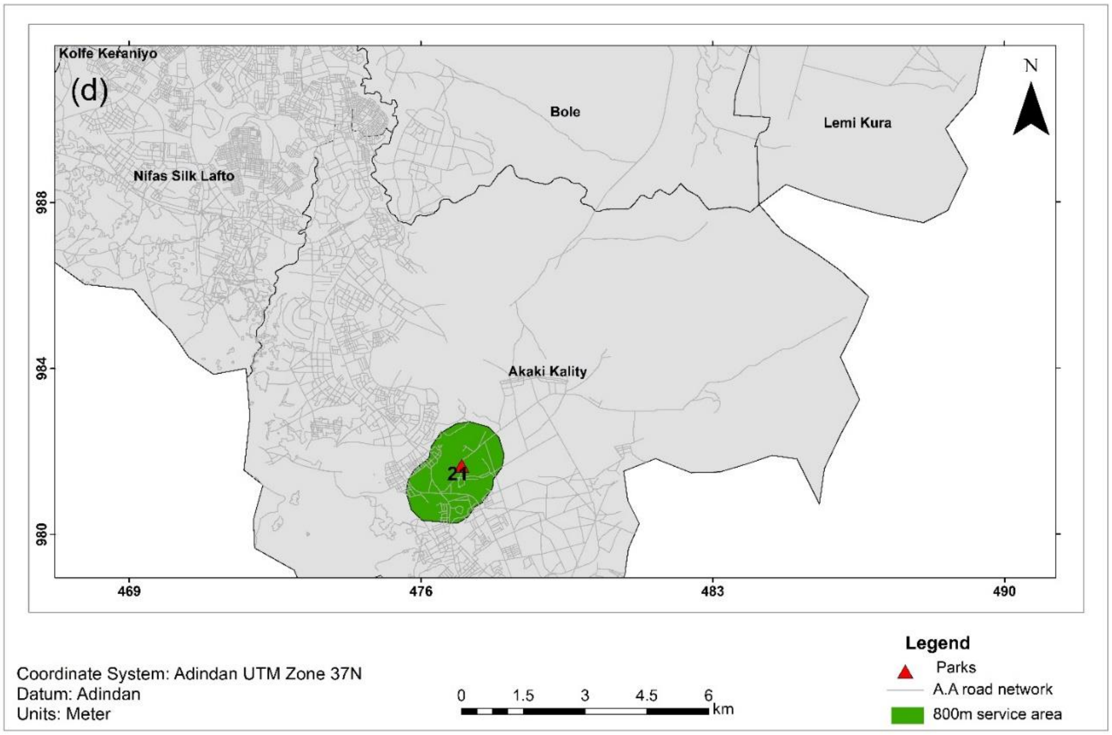

Fig 4.8 (a, b, c & d) 800m service area map

Table 4.5 Residential area accessing park facility within 800 m service area

No	Sub city	Residential area with 800 m service area (km^2)	Total residential area (km^2)	Accessibility of residential area in (%)
1	Arada	6.1	9	68
2	Kirkos	5.5	13.7	41
3	Lideta	6.6	13.33	50
4	Gulele	8.3	17.62	47
5	Yeka	5.4	25.9	21
6	Nifas silk	5.7	27	21
7	Kolfe	1.4	31.2	5
8	Addis Ketema	2.8	15.63	18
9	Akaki	1.6	22.5	7

D. Residents accessing 800 m service area

The 800 m service area facilitates park accessibility for more residents than that of 300 m. From all eleven sub cities of Addis, Arada accounts the highest number of residents which is 73 % of the population enjoys public recreational parks, with 10 min walking distance. Lideta is the second sub-city that has 66 % of the city residents residing within the 800 m park accessibility service areas. Gulele sub city comes third with 60 % of the population enjoying public parks. Kirkos sub-city follows Gulele by recording 51 % of residents accessing the park facilities within 800 m travel distance. Whereas, Addis-ketema, Yeka and Nifas silk is grouped under the 5th class, and their value ranges from 16-23 % of residents enjoying 10 min travel time. The lowest class is populated in Kolfe and Akaki, the recoded value ranges from 2-6 % of urban dwellers having 10 minute walking distance park accessibility. The result of residents accessing 800 m service area is presented in table 4.6 below.

Table 4.6 .Residents access park facility within 4min walking distance

No	Sub-city	Residents accessing 800 m service area (km^2)	Total population	Accessibility of residential area in (%)
1	Arada	218,067	298,043	73
2	Kirkos	159,120	311,765	51
3	Lideta	193,917	284,208	66
4	Gulele	224,471	377,032	60
5	Yeka	80,858	459.225	18
6	Nifas silk	72,500	445,683	16
7	Kolfe	37,607	604,226	6
8	Addis Ketema	82,848	359,735	23
9	Akaki	5774	255,349	2

4.9.2 National standards of public park accessibility

Addis Ababa city council developed structural plan that consists park accessibility standards. In addition, Addis Ababa’s public recreational parks are categorized in to three classes based on their size. The categorical groups used by AACC is municipal divisions of the city such as City, sub city and woreda. Public recreational parks existing in Addis Ababa has been identified as city parks if the areal coverage of the park exceeds 10 ha and sub city parks areal coverage should be 1ha-10ha. Also woreda parks were categorized based on AACC classification thresholds of 0−1.5km.

A. Sub city parks within 5 km radius

I have assessed the accessibility of sub city parks using the national 5km radius threshold standard.

The result have been presented in table 4.7 and figure 4.9. Addis Ababa has a total of 222.7 km^2 residential area. This study considers all 17 sub-city public recreational parks that provide service to the community. The sub city parks existing in Addis Ababa, covers 62 km^2 total area. The analysis result demonstrates that 186.8 km^2 of Addis Ababa residential area has public recreational park accessibility within 5km radius. The accessibility analysis was done for all existing eleven sub-cities. Four sub cities namely Gulele, Arada, Lideta and kirkos has full residential area coverage with in the 5 km^2 radius. Bole, Nifas silk and Addis ketema has above 78% of residential area accessing parks within 5 km radius. However, it has been recorded that yeka and Kolfe residential area accessibility is below 75%. In addition, Lemi-kura has very low sub-city park access with a recording of 17%.

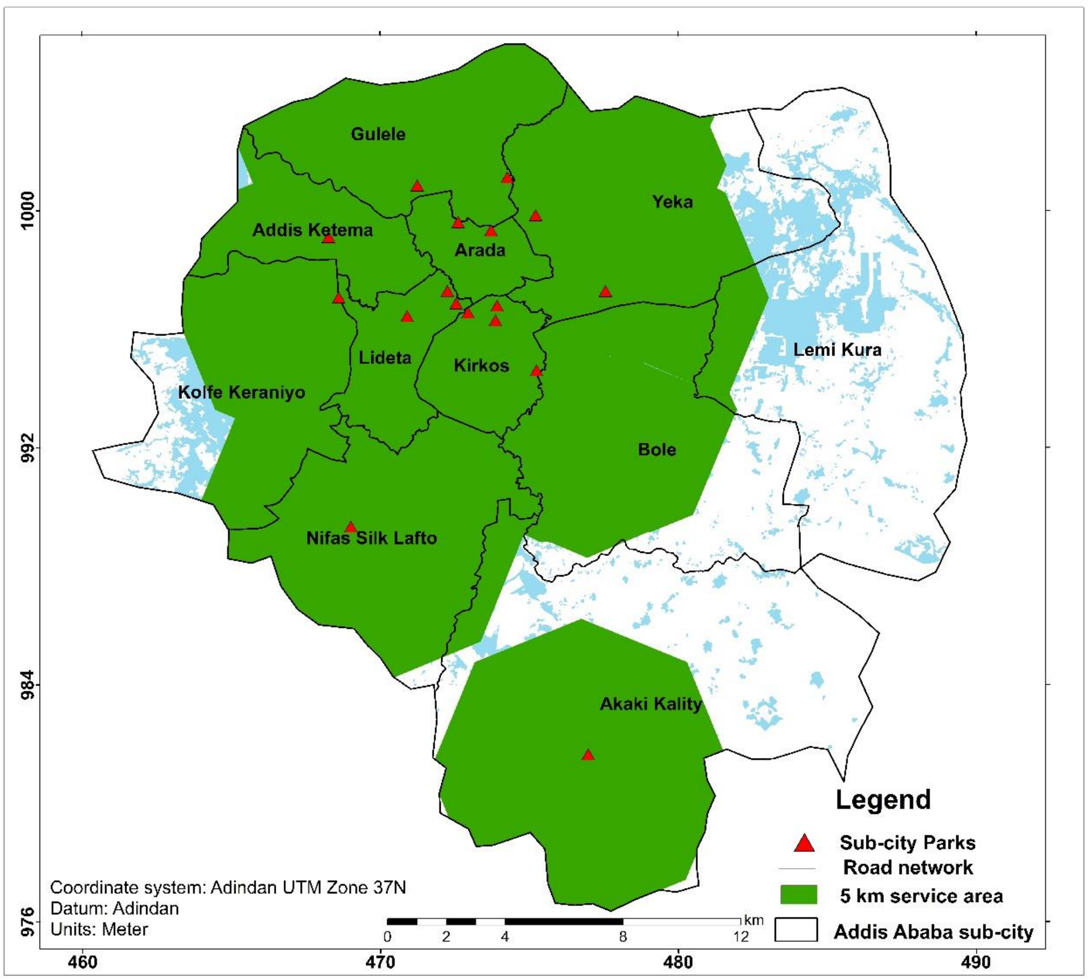

Fig 4.9 5 km Service area of sub-city parks

Table 4.7 Residential area access public parks within 5 km radius

No	Sub-city	Residential area accessibility within 5km radius (km^2)	Accessibility in %
1	Yeka	18.77	72
2	Nifas silk	21.58	80
3	Lemi Kura	3.8	17
4	Kolfe	18.6	60
5	Bole	20.24	82
6	Akaki	17	76
7	Addis Ketema	13.22	85
8	Gulele	17.62	100
9	Arada	9.06	100
10	Lideta	13.33	100
11	Kirkos	13.70	100

B. Residents enjoying sub-city parks

The population entertaining the park facility with in 5km radius is computed for all sub-cities. As AACC structural plan recommends, all residents living in Addis Ababa should entertain sub-city park facilities within 5 km radius from their settlement areas. The analysis considers all sub city parks providing services for the society. The network based service area analysis of 5km result presents that, all residents who lives in Gulele, Arada, Lideta and Kirkos entertains sub-city parks within 5km service area. Addis ketema recorded 85 % of residents accessing sub-city park facility with in the specified impedance. However, from all residents living in Yeka, Nifas silk, Lemi kura, Kolfe, Akaki and Bole sub-cities only 52-63 percent of the population are accessing sub-city parks within 5km radius. Akaki kality sub-city records very low population access to the park facility, which is only 29 % of population is accessing the sub city park services delivered with 5km radius. Table 4.10 shows the population number served with 5km radius.

Table 4.8 Residents enjoying sub-city parks

No	Sub city	Residents enjoy 5 km service area	Percentage of resident's enjoying SA
1	Yeka	254,360	55
2	Nifas silk	269,134	60
3	Lemi Kura	44,583	52
4	Kolfe	372,989	62
5	Bole	190,488	50
6	Akaki	73,366	29
7	Addis Ketema	307,274	85
8	Gulele	All	100
9	Arada	All	100
10	Lideta	All	100
11	Kirkos	All	100

4.10 City parks of 10 km radius

I have assessed residential area accessibility of city parks, using national 10 km threshold standard which has been developed by AACC. There are four city parks such as Bihere-Tsege Park, Unity Park, Friendship Park and Entoto Park. I have included Gulele Botanical Garden. The Garden has been constructed for the purpose of research center. Gulele Botanical Garden is also used for recreational services therefore I have included the garden with in the city park analysis. In addition the parks used for the analysis, fulfills areal coverage of standard of city parks, the size of city parks should be greater than 20ha.

Six out of eleven sub cities has full 10 km residential area access to city parks. The sub cities are Addis ketema, Yeka, Gulele, Arada, Lideta and kirkos. Bole sub city recorded 84% residential area accessing city parks with 10km radius. Whereas 72 % residential area of Nifas silk and kirkos has access to city park facilities within 10km radius. Lemi kura and Akaki has the lowest accessibility values that ranges from 60-66 % residential area coverage. The residential area accessing city parks has explained using spatial map and tables below in Table 4.9 and Fig 4.10.

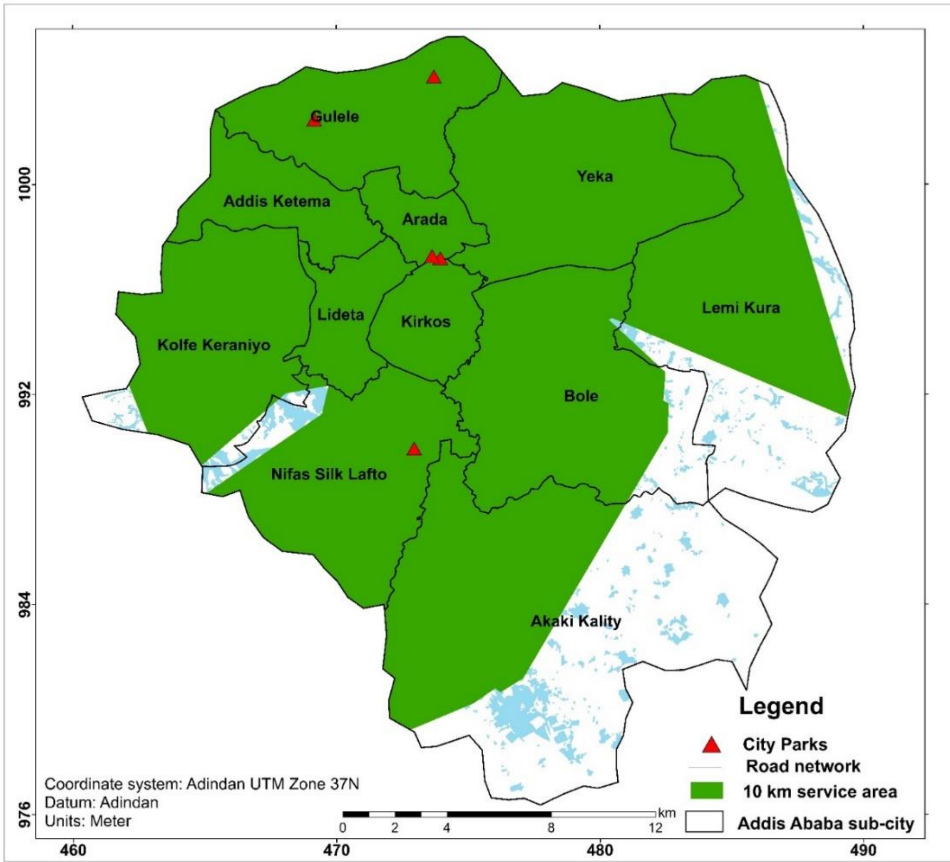

Fig 4.10 City park service area

Table 4.9 Residential area access 10 km service area

No	Sub city	Residential area access	Accessibility in %
1	Yeka	25.9	100
2	Nifas silk	19.5	72
3	Lemi Kura	14.5	66
4	Kolfe	22.5	72
5	Bole	20.6	84
6	Akaki	22.5	60
7	Addis Ketema	15.6	100
8	Gulele	17.62	100
9	Arada	9	100
10	Lideta	13.3	100
11	Kirkos	13.7	100

4.11 Residents enjoying city parks

The result shows residents who lives in Gulele, Arada, Lideta, Addis Ketema, Kirkos and Yeka has 100% city park accessibility. The second highest population number accessing City Park within 10 km radius is 70 percent, recorded for Lemi kura sub city. Bole, Kolfe and Nifas silk has recorded 51, 69 and 54 percent of their population enjoying parks with 10 km radius service area. From Akaki sub-city only 31 % of the population access public parks with 10km radius service area. The population served with 10 km distance has elaborated more in table 4.10.

Table 4.10 Residents enjoying City Park

No	Sub-city	Residents enjoying 10 km service area	Accessibility in %
1	Yeka	All	100
2	Nifas silk	241,413	54
3	Lemi Kura	60,100	70
4	Kolfe	419,103	69
5	Bole	192,302	51
6	Akaki	79,904	31
7	Addis Ketema	All	100
8	Gulele	All	100
9	Arada	All	100
10	Lideta	All	100
11	Kirkos	All	100

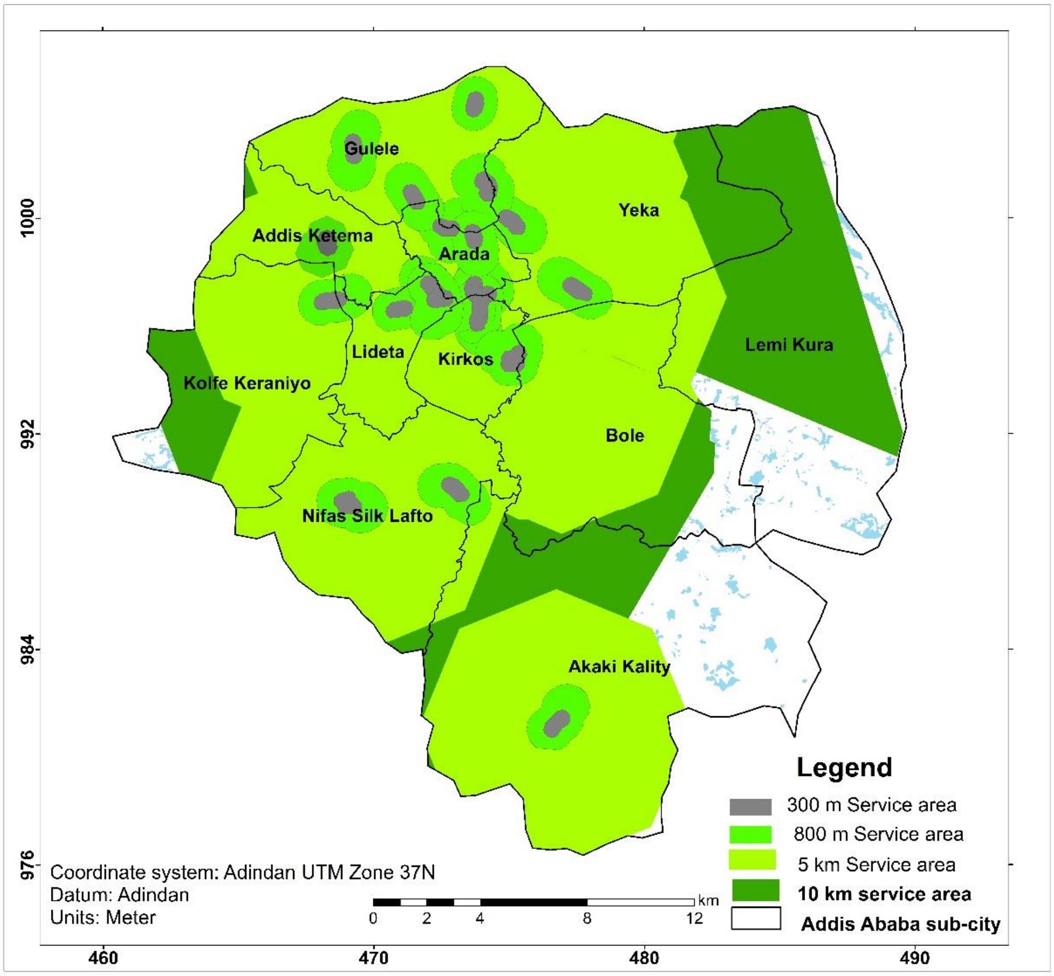

Fig 4.11 Existing Park service areas (300m, 800m, 5km & 10 km)

4.12 Residential area and population demanding park facility

A. Residential area and population demanding parks within 300 m SA

The demand of residential area that doesn't access park facilities with 300 m service area is critically high. Ninety nine percentage of Kolfe and Akaki sub-city doesn't have access to public parks within 4 min walking distance. Gulele, Addis Ketema, Yeka, Nifas Silk and Arada recorded 90-96% of settlement area that doesn't have access to existing parks. In addition, Kirkos and Lideta recorded 88 and 86% of settlement areas demanding public parks with 300 meter SA. The table 4.11 shows residential area in km^2 that doesn't access parks with in 300m service area. Furthermore, the percentage of all sub cities with no facility access exceeds 88%.

4.11 Residential area demanding park facility within 300m service area

No	Sub city	Residential area doesn't access 300m service area (km^2)	Total residential area (km^2)	Residential area doesn't access SA in (%)
1	Arada	8.27	9	91
2	Kirkos	12.03	13.7	88
3	Lideta	11.8	13.33	89
4	Gulele	16.58	17.62	94
5	Yeka	24.84	25.9	96
6	Nifas silk	26	27	96
7	Kolfe	30.86	31.2	99
8	Addis Ketema	15.071	15.63	96
9	Akaki	22.23	22.5	99

The population number of all resident's that doesn't reside with 300 m park service area records above 87%. The results obtained illustrates that Addis ketema, Nifas silk, Kolfe, Arada and Akaki has 91-99 % of the population that doesn't enjoy the park facility with 4 minute walking distance from their settlement areas. Kirkos and Lideta has 87 and 79 % population number that doesn't enjoy public parks with 300m service area. In general, the 300m service area coverage accessibility is critically low for Addis Ababa city residents. The table 4.12 below shows the population number that doesn't access parks with 4 minute walking distance.

Table 4.12 Residents demanding park facility within 4min walking distance

No	Sub city	Residents doesn't access 300m service area (km^2)	Total pop	Residents doesn't access SA area in (%)
1	Arada	272,330	298,043	91
2	Kirkos	272,752	311,765	87
3	Lideta	223,114	284,208	79
4	Gulele	350,140	377,032	93
5	Yeka	441,620	459.225	96
6	Nifas silk	429,268	445,683	96
7	Kolfe	595,628	604,226	99
8	Addis Ketema	341,812	359,735	95
9	Akaki	254,662	255,349	99.8

B. Residential area and population demanding parks within 800 m SA

The residential area that doesn't access facilities with in 800m service area has lower values relatively from the 300 meter service area. Table 4.13 illustrates the present demand of public recreational parks within the 800 m service area. The study determined that Kolfe, Addis Ketema, Akaki and Yeka has been recorded as the most demanding sub-cities with a range of 79-95 % of residential area that doesn't have access to the park facilities within 800 m.

Kirkos, Lideta and Gulele sub-cities recorded 53-59 % residential area that needs park facilities with 10 min travel time. Whereas, Arada sub-city records 32% of residential area that doesn't access public parks within the specified distance. Furthermore, Bole and Lemi kura sub-cities has 0% park facility accessibility records.

Table 4.13 Residential area demanding park facility within 800m service area

No	Sub city	Residential area doesn't access 800m SA (km^2)	Total residential area (km^2)	Residential area doesn't access SA in (%)
1	Arada	2.9	9	32
2	Kirkos	8.12	13.7	59
3	Lideta	6.73	13.33	50
4	Gulele	9.32	17.62	53
5	Yeka	20.56	25.9	79
6	Nifas silk	21.3	27	79
7	Kolfe	29.73	31.2	95
8	Addis Ketema	12.83	15.63	82
9	Akaki	20.84	22.5	93

The least demanding population that doesn't have park accessibility found in Arada and Lideta sub-city, which is 27 % and 34 %. Kirkos and Gulele has 49 and 40 % of the population number that doesn't enjoy the park facility within 10 min walking distance. The most demanding sub-cities are Yeka, Nifas silk, Kolfe and Addis ketema recorded above 75 % of residential areas demanding recreational parks within 800 meter SA. Table 4.14 presents residents doesn't enjoy public recreational parks with 800 m service areas.

Table 4.14 Residents demanding park facility within 10 min walking distance

No	Sub city	Residents doesn't access 800m service area	Total population	Residents doesn't access SA in (%)
1	Arada	79,976	298,043	27
2	Kirkos	152,645	311,765	49
3	Lideta	90,291	284,208	34
4	Gulele	152,561	377,032	40
5	Yeka	378,367	459.225	82
6	Nifas silk	373,183	445,683	84
7	Kolfe	566,619	604,226	94
8	Addis Ketema	276,887	359,735	77
9	Akaki	249,575	255,349	98

C. Residential area and population demanding parks within 5 km radius

The 5km residential area that doesn't access park facility analysis presents that Lemi kura is the only sub city that recorded above 70 percent. The residential area of 83% of Lemi-kura sub-city doesn't access park facilities within 5 km radius. Whereas the other five sub-cities (Yeka, Nifas silk, Bole, Akaki and Addis Ketema) has recorded below 29 % of residential area coverage that doesn't fall under 5km radius service area. Fourthy Percent of kolfe settlement area doesn't have sub-city park provisions within 5 km radius. Table 4.15 presents residential area of Addis Ababa demanding park accessibility with in 5km radius.

Table 4.15 Residential area demanding park facility within 5 km service area

No	Sub city	Residential area doesn't access 5km SA in km^2	Residential area doesn't access SA in %
1	Yeka	7.19	28
2	Nifas silk	5.42	20
3	Lemi Kura	18.1	83
4	Kolfe	12.5	40
5	Bole	4.4	18
6	Akaki	5.4	24
7	Addis Ketema	2.41	15
8	Gulele	None	None
9	Arada	None	None
10	Lideta	None	None
11	Kirkos	None	None

The result in this section, presents the population number that doesn't reside within 5 km SA and unable to enjoy recreational parks within 5 km radius. Five sub-cities namely Yeka, Nifas silk, Bole, Kolfe and Lemi kura has 45-50% population number that doesn't access public parks within 5km service area. Addis Ketema recorded 15 % its population that doesn't access the park facility. However, Akaki recorded the highest number of residents which is 71 % of its population is demanding park facilities within 5 km service areas. Residents doesn't enjoy 5km service area is presented in table 4.16 below.

Table 4.16 Residents demanding park facility within 5 km radius

No	Sub city	Residents doesn't enjoy 5km service area	Pop doesn't enjoy SA in %
1	Yeka	204,865	45
2	Nifas silk	176,549	40
3	Lemi Kura	41,335	48
4	Kolfe	231,237	38
5	Bole	188,328	50
6	Akaki	181,983	71
7	Addis Ketema	52,461	15
8	Gulele	None	None
9	Arada	None	None
10	Lideta	None	None
11	Kirkos	None	None

D. Residential area and population demanding parks within 10 km radius

From all existing eleven sub-cities only five sub-cities doesn't have full residential area access within 10 km radius. The result depicts that Akaki requires 40% residential area accessibility to the city park facilities followed by Lemi Kura who requires 34 % of residential area accessibility. Kolfe, Nifas silk and Bole records below 29 % of residential area that doesn't access city parks. Table 4.17 presents residential area demanding 10km radius city park provisions.

Table 4.17 Residential area demanding park facility within 10 km service area

No	Sub city	Residential area doesn't access 10km radius (Km^2)	Residential area doesn't access SA in %
1	Yeka	None	None
2	Nifas silk	7.4	28
3	Lemi Kura	7.4	34
4	Kolfe	8.6	28
5	Bole	4	16
6	Akaki	8.9	40
7	Addis Ketema	None	None
8	Gulele	None	None
9	Arada	None	None
10	Lideta	None	None
11	Kirkos	None	None

Residents who doesn't enjoy 10 km park service area has higher records for Addis ketema sub-city which is 69 %. Bole and Nifassilk has 49 % and 46 % of residents that doesn't live with 10 km radius park accessibility service area. Kolfe and Lemi kura has 31 and 30 % of population demanding park facilities within 10 km service area. The other six sub cities (Yeka, Addis ketema, Gulele, Arada, Lideta and Kirkos) resident's doesn't demand parks within 10km radius, as all the population that lives with in the six sub-cities enjoy city park facility with 10km distance. Table 4.18 presents residents that doesn't enjoy public park facilities 10 km radius service area.

Table 4.18 Residents demanding park facility within 10 km radius

No	Sub city	Residents doesn't enjoy 10km service area	Pop doesn't access 10km SA in %
1	Yeka	None	None
2	Nifas silk	204,270	46
3	Lemi Kura	25,818	30
4	Kolfe	185,123	31
5	Bole	186,514	49
6	Akaki	175,445	69
7	Addis Ketema	None	None
8	Gulele	None	None
9	Arada	None	None
10	Lideta	None	None
11	Kirkos	None	None

CHAPTER FIVE

DISSCUSSION

5.1 Land-use and Land-cover

This thesis provides information on the accessibility and demand of public recreational parks in Addis Ababa. In addition, the current status of major urban green spaces were analyzed using OBIA algorithm. The study area land-use land-cover is divided in to five class's namely built-up, agricultural land, bare land, urban forest and water body. The classified image depicts that the land cover of major green spaces (urban forest and agricultural land) is below 24 percent. Research conducted by Badassa et al., (2022) shows between 1991 and 2021 the area coverage of agriculture land and vegetation land-use classes has shown a decline by 66.8 km^2 and 25. Km^2 whereas, built-up class shows increase by 88 percent.

5.2 NDVI

In addition to the land-use and land-cover map, I have used NDVI and NDBI indices to assess the vegetation cover and built-up area expansion. NDVI is used to study vegetation cover in several researches. According to Weng et al., (2004), NDVI is found as an efficient tool used to monitor density and health of vegetation. The present study NDVI values are (-0.2-0.7). The lowest value which is close to 0 shows an urbanized area whereas, the highest value which is close to 1 shows the vegetation cover along with its healthiness status. The obtained NDVI values have similarities with a research made by Muralitharan et al., (2021) who studied The NDVI values of Addis Ababa for the year of 2021 ranges from (0.14 to 0.75).

5.3 NDBI

The NDBI is used to assess the urban expansion of the study area. The present study NDBI values are (-0.4-0.6). The lowest value which is close to 0 shows an area where there is no urbanization or the land is covered with other land-use other than built-up area. Whereas, the highest value which is close to one shows the urbanized area. The obtained NDBI values have similarities with a research made by Muralitharan et al., (2021) who studied The NDBI values of Addis Ababa for the year of 2021 ranges from (0.4 to 0.53).

5.4 Public recreational parks

Parks are protected and bounded public open spaces covered with trees and vegetation's. They have great significance inputs to reduce air and water pollution. In addition parks are helpful to regulate temperature and humidity. Also, they are helpful to protect the biodiversity and to advance quality of living. However, green spaces are deteriorating in urban areas as a result of unmanaged and uncontrolled urbanizations.

Therefore, this study is carried out to assess the accessibility, distribution and demands of urban parks existing in Addis Ababa. To determine the accessibility of parks GIS based network analysis is used. A researches carried out on the accessibility of public parks has defined accessibility as urban parks that can be reached or used at any time (Liu et al., 2019) I have also used same definition of accessibility to assess the availability and spatial distribution of the facilities.

5.5 Network analysis

Network analysis is powerful ArcGIS extension model that uses road networks to solve real time and historic network problems. The study have examined the accessibility and demands of urban parks.

Different accessibility analysis methods are used based on the accessibility analysis scope. I have used GIS based network analysis approach as it considers the actual travel time and distance. Also this method consider all the barriers that make routes inaccessible by park users (La Rosa., 2014).

A research conducted by Wang et al., (2021) found that using network analysis, service area tool generates more realistic accessibility measures than other methods.

5.6 Accessibility standards

As I have discussed on the result section, proximity indicator is used to determine residential area and population number accessing the park facility with in standardized thresholds. A study conducted by Azagew et al., (2020) calculates proportion of the population that enjoys park accessibility and that doesn't enjoy park accessibility modelled in in GIS using Euclidean or network distance. This study analyzes park accessibility using four standards. The standards are 300 m (4 minute walking distance), 800 m (10 minute walking distance), 5 km and 10km. The 300 m and 800 m accessibility thresholds were developed by WHO and other international organization. The standard ANGSt recommends that everyone should have access to at least (1) one 20 ha accessible natural green space within 2 km of their home, (2) one 100 ha accessible site within 5 km of their home, (3) one 500 ha accessible site within 10 km of their home, and (4) at least one ha of statutory natural green space for every 1,000 residents (Natural England, 2010).

Sweden recommends keeping a residence's distance from the next UGS to no more than 300 meters (Grahn and Stigsdotter, 2003; Nielsen and Hansen, 2007). Whereas a 1-10 hectare of UGS in Belgium is recommended to be accessed with 5-minute (400 m) (Van Herzele and Wiedemann, 2003), and 2 ha of UGS within 300 m from home or 20 ha within 2 km in the UK (Natural England, 2010).

Since this study has focused on daily services of UPs within walking distance, two distances were applied 300 meter and 800 meter beside the local standards.

In Addis Ababa, AACC developed park accessibility standards based on city and sub city levels. City Parks are recommended to have more than 10 ha and to cover a radius of 10 km, Sub-city Parks with sizes of 1− 10 ha and a 5 km radius (Siefu and stellmacher, 2020). However I have included the 300 m and 800 m walking distance thresholds, to satisfy the older population of the community that couldn’t go too far to access parks.

This results obtained from this paper shows that major urban green spaces is very low and doesn’t sufficiently serve the community. In addition, their distribution is uneven. The central part of Addis Ababa doesn’t have access to urban forests and agricultural lands. Beside the land-use and land-cover map, the accessibility of 300 m service area indicates the population enjoying 300m service area in all sub cities is below 13% and the population enjoying 800m service area in all sub cities recorded below 38%. However, 72% and 80% of Addis Ababa residents enjoy sub city and city parks with in 5km and 10km radius.

CHAPTER SIX

CONCLUSION AND RECCOMENDATION

6.1 CONCLUSION

The advancement of geographic information systems and remote sensing technologies provide unprecedented opportunities for monitoring the environment in-order to preserve the ecosystem. The result of this study shows accessibility of 300 m and 800 m service area doesn't satisfy more than 78 % percent of the population. Also majority of Addis Ababa sub-cities residential area doesn't access public parks, the 300 m service area accessibility shows 94 % and the 800 m service area accessibility demonstrates 65 % of the settlement area doesn't access public park provisions. As a result, the majority of the population is forced to travel longer distance to access public recreational parks. As our community is categorized with different age grouping classes, traveling longer distance may not always recommended. Beside the difficulty of the distance, the community might be hesitant to walk longer or use transportation systems, as it adds travel expenses. In addition to that four wheels are one of major pollutants of air. Therefore, the government needs to consider facilitating nearby parks that can be accessed within 10-15 min walking distance. Moreover, it encourages the society to travel by foot in order to enjoy park facilities.

The other finding of this study is based on AACC suggestions of sub-city and city parks. The findings show that 5km service area covers 185 km^2 residential area from a total of 222 km^2 residential area. Moreover, service area of City Park covers 206 km^2 of residential area from 222 km^2. Sub-city parks satisfy more than 70 % of the residents and city parks satisfy more than 79 % of the society residing in Addis Ababa. Therefore to increase accessibility of sub-city park and city parks urban planners and Addis Ababa City Council should work in collaboration to address areas that doesn't access public park facility.

In conclusion it is observed that within in a ten years period between 1984 and 1994, the population grew dramatically. The record shows from around 1.4 million to 2.7 million. As the growth rate of the society increased from time to time building larger parks is getting a lot harder. Therefore, sheger beautification project which is working on establishing and facilitating public parks, the effort and act of the government, in-order to maximize the accessibility of public recreational parks is encouraged and appreciated.

6.2 RECOMMENDATION

New city parks were constructed under Sheger Beautification project, the two newly constructed parks namely unity and friendship are located in Arada Sub cities. Unity Park is a few miles away from Friendship Park. The areal coverage of the two parks is greater than 20 ha. Rather than constructing nearby parks I recommend to address sub cities where there are shortage of park facility provisions.

As a result of uncontrolled urbanization, it is very hard to find larger sizes of open lands that would be available for public park construction. Therefore, i recommend to construct more small sized parks in-order to increase accessibility with in a range of distance manageable to travel by foot.

As I have discussed, Millennium Park which were located in Addis-ketema sub-city, the park changed to other land-uses. As a result, the park maintenance and protection is highly encouraged to preserve the parks.

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Appendix

Table 1. List of investigated Sub-city recreational parks

No	Park name	Sub-city	Area in (km^2)
1	Sheger Park	Gulele	0.054
2	Hamle 19 Park	Gulele	0.067
3	Ethio-korea Veteran memorial Park	Gulele	0.036
4	Lion- zoo Park	Arada	0.015
5	Addis Ababa Park	Kirkos	0.007
6	Africa Park	Kirkos	0.045
7	Ambassador Park	Kirkos	0.017
8	ECA Park	Kirkos	0.052
9	Gola Park	Lideta	0.012
10	Ethio-Cuba friendship Park	Lideta	0.036
11	Lideta park	Lideta	0.02
12	Ferensay Park	Yeka	0.065
13	Yeka Park	Yeka	0.025
14	Mayor W/Tsadik Park	Nifas silk	0.029
15	Ras-Hailu park	Addis ketema	0.0073
16	Akaki park	Akaki kality	0.013
17	Kolfe park	Kolfe keranio	0.067
Total sub-city park			0.62

Table 2. City parks used in the network analysis

City Parks			
No	Park name	Sub city	Area (km^2)
1	Gulele Botanical Garden	Gulele	7.05
2	Entoto Park	Gulele	13
3	Friendship Park	Arada	0.462
4	Unity Park	Arada	0.2
5	Bihere-Tsege Park	Nifas silk	0.159

Table 3. Land-use and land-cover accuracy assessment

LULC	Built-up	Bare land	Agricultural	Forest	Water body	TOTAL(user)
Built-up	20	8	20	18	11	77
Bare land	13	16	8	5	5	47
Agricultural	19	7	27	10	7	70
Forest	12	6	10	12	7	47
Water body	6	1	5	7	10	29
TOTAL(Producer)	70	38	70	52	40	100
Over all accuracy=85.1 and Kappa=0.82						

Table 4. Park facility Id of 800 m service area

800 meter (10 minutes walking distance)		
Facility Id	Park name	Sub-city
1	Mayor W/Tsadik Park	Nifas Silk
2	Bihere-Tsege Park	Lideta
3	Lideta Park	Lideta
4	Gola Park	Lideta
5	Addis Ababa park	Kirkos
6	Africa Park	Kirkos
7	Unity Park	Arada
8	Friendship Park	Arada
9	Ethio-korea Park	Gulele
10	Lion-zoo Park	Arada
11	Hamle19 Park	Gulele
12	Gulele Botanical Garden	Gulele
13	Sheger Park	Gulele
14	Entoto Park	Gulele
15	ECA park	Kirkos
16	Yeka Park	Yeka
17	Ferensay Park	Yeka
18	Ethio-Cuba Park	Lideta
19	Ambassador Park	Kirkos
20	Kolfe Park	Kolfe Keranio
21	Akaki Park	Akaki Kality
22	Ras-Hailu Park	Addis Ketema

Table 5. Park facility Id of 800 m service area

300 meter (10 minutes walking distance)		
Facility Id	Park name	Sub-city
1	Mayor W/Tsadik Park	Nifas Silk
2	Bihere-Tsege Park	Nifas Silk
3	Lideta Park	Lideta
4	Ethio-Cuba Park	Lideta
5	Gola Park	Kirkos
6	Addis Ababa Park	Kirkos
7	Africa Park	Kirkos
8	Unity Park	Arada
9	Friendship Park	Arada
10	Ethio-Korea Park	Gulele
11	Lion-zoo Park	Arada
12	Hamle-19	Gulele
13	Gulele Botanical Garden	Gulele
14	Sheger Park	Gulele
15	Entoto park	Gulele
16	ECA Park	Kirkos
17	Yeka Park	Yeka
18	Ferensay Park	Yeka
19	Kolfe Park	Kolfe Keranio
20	Ambassador Park	Kirkos
21	Akaki Park	Akaki Kality
22	Ras-Hailu Park	Addis Ketema