Analyzing the Spatial Distribution of Urban Green Space and Identification of Its Potential Expansion Areas: A Case Study in Adama City, Ethiopia

Kefelegn Wagamyelew Gobena

A Thesis Submitted to the Department of Geomatics Engineering
School of Civil Engineering and Architecture

Office of Graduate Students
Adama Science and Technology University

June 2023
Adama, Ethiopia

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Advisor: Yared Girma (PhD)

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DECLARATION

I hereby declare that this Master Thesis entitled "Analyzing the Spatial Distribution of Urban Green Space and Identification of Its Potential Expansion Areas: A Case Study in Adama City, Ethiopia" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Kefelegn Wagamyelew Gobena	_______________	_______________
Name of student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Analyzing the Spatial Distribution of Urban Green Space and Identification of Its Potential Expansion Areas: A Case Study in Adama City, Ethiopia” prepared under my guidance by Kefelegn Wagamyelew submitted in partial fulfillment of the requirements for the degree of Mater’s of Science in Geo-informatics. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Yared Girma (PhD)		
Major Advisor/Supervisor	Signature	Date

APPROVAL SHEET

I, the advisors of the thesis entitled "Analyzing the Spatial Distribution of Urban Green Space and Identification of Its Potential Expansion Areas: A Case Study in Adama City, Ethiopia" and developed by Kefelegn Wagamyelew, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Yared Girma (PhD)		
Major Advisor/Supervisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Kefelegn Wagamyelew have read and evaluated the thesis entitled "Analyzing the Spatial Distribution of Urban Green Space and Identification of Its Potential Expansion Areas: A Case Study in Adama City, Ethiopia" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geo-informatics.

Chairperson	Signature	Date
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External Examiner	Signature	Date

Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate Studies, Dean	Signature	Date

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TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF ACRONYMS

AHP	Analytic Hierarchy Process
ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
CSA	Central Statistical Agency
DEM	Digital Elevation Model
ERDAS	Earth Resource Data Analysis System
FAO	Food and Agriculture Organization
FAHP	Fuzzy Analytical Hierarchical Process
SSGI	Space Science and Geospatial Institute
GIS	Geographic Information System
GPS	Global Positioning System
LULC	Land Use and Land Cover
MCA	Multi-criteria Analysis
MCDA	Multi Criteria Decision Analysis
MCDM	Multi-criteria Decision Making
MoUDC	Ministry of Urban Development and Construction
MoUDH	Ministry of Urban Development and Housing
NUGIS	National Urban Green Infrastructure Standards
RS	Remote Sensing
TIFF	Tagged Image File Format
UGI	urban green infrastructure
UGS	Urban Green Space
UTM	Universal Transfer Mercator
WLC	Weighted Linear Combination
WGS	World Geodetic System

ABSTRACT

Today, some 55% of the world's population 4.2 billion inhabitants live in cities. This trend is expected to continue. By 2050, with the urban population more than doubling its current size, nearly 7 of 10 people in the world were live in cities. Africa's urban population increased more than sixteen-fold between 1950 and 2018, rising from 33 million to 548 million and is likely expected to nearly triple between 2018 and 2050. Ethiopia, has a very low level of urbanization 21.2% in 2019, is among the least urbanized but fast urbanizing countries in sub-Saharan Africa. Nowadays, land suitability analysis methods and geospatial technologies have been used to support urban green space planning in developed countries; however, its application and practices are limited in developing countries, like Ethiopia. Therefore these studies aimed at analyzing the spatial distribution of UGS in Adama City Ethiopia, and evaluate existing GS and then scientifically select potential expansion sites for its development. Based on the analysis the overall city per-capita is about 5.15m^2 with respect to the total population and total area in m^2.Through object based image classification of planet image using the nearest neighboring algorithm, the LULC maps of the study area with the land use type of Bare Land, Built Up, Vegetation, Farm Land and Water Body was prepared. The suitability analysis was done by adopting GIS-based Multi-criteria analysis (MCA) using fuzzy analytical hierarchy process (FAHP) to select suitable sites for urban green spaces development. Factors for UGS development were identified through a literature review, focal group discussion and Outers decision based on availability of data in the study area. So, factors including LULC, population density, Road, stream, noise influence, residential area, facility location, slope, and soil type, were identified as the main determinants for UGS development. Based on GIS-based Multi-Criteria Analysis (MCA) 11.41%, 49.19%, and 27.74% of the study area has been identified as highly suitable, suitable, and moderately suitable for green space development respectively. In addition to this 8.77% and 2.89% of the study area has been identified as less suitable and very less suitable for green space development respectively. Finally, geospatial technologies and application of GIS-based Multi-Criteria Analysis (MCA) has provided an effective methodology to solve a complex decision problem in urban green spaces site selection process.

Key Words: Adama, UGS, FAHP, MCDM, OBIA, Spatial Distribution, potential site

CHAPTER I: INTRODUCTION

1.1. Background of the study

Urbanization is a worldwide phenomenon that emphasizes the process of both vertical and horizontal physical expansion of urban areas (Ibido, 2020). It is mainly the process by which towns and cities are formed and become larger gradually as more people begin living and working in cities (Satterthwaiter D, (2015). Urban areas are home to 55% of the world's population, and that figure is expected to grow 68% by 2050. Urbanization is a global process which demonstrates itself through rapidly changing human population densities and land use and land cove r (LULC). LULC pattern change; industrialization and social transformation occur during the urbanization processes.

The world has experienced tremendous urbanization and population growth. According to United Nations report (United Nations, 2019), the world's population is expected to increase by 2 billion persons in the next 30 years, from 7.7 billion currently to 9.7 billion in 2050. In recent decades cities around the world including in developing countries have been facing rapid urbanization and expansion of cities (UNDESA, 2015). Sub-Saharan African were account for most of the growth of the world's population over the coming decades (World Population Prospects, 2019). Ethiopia is the second most populous country in Africa with 107 million inhabitants (United Nations, 2017). According to the National Report on Housing & Sustainable Urban Development, Ethiopia is one of the least urbanized countries in Sub-Saharan Africa. Currently, 20 percent of the total population lives in urban areas (MoUDC, 2014). However, the country has one of the highest rates of urbanization even by the standards of developing countries, which is estimated at 4.1 percent (MoUDC, 2014)

Due to this rapid and unplanned urbanization, in the developing world the municipal administrators and urban planner are facing numerous difficulties in meeting growing demands for the basic services like green space, sanitation, water supply, mobility, and primary health services centers, schools, public services providing offices with or nearby them at least need some more green space to maintain appropriate carrying capacity (Pokhrel S. , 2019). The urban green spaces' coverage is not adequate to meet people's needs due to population pressure, expansion of industry, and construction in the process of urbanization (Cetin.M, 2015).

Urban green spaces are an important part of urban ecosystems, play a vital role in environmental, economic and social aspects in urban areas (Mensah, 2014). Moreover, green spaces sequester CO_2 and produce O_2; they reduce air pollution and noise; regulate microclimates; reduce the heat; maintain diversity; have recreational and social values; and produce a vitamin „„G"" for health, well-being and social safety. According to the (WHO, 2017), urban green spaces are innovative, nature-based approaches that increase the quality of urban settings, enhance local resilience and promote sustainability in response to pressures of urbanization and climate change.

Urban green spaces are often a component of green infrastructure that serves as a health promoting setting for the entire urban community; therefore, it is necessary that they are distributed equitably to all population groups in the city and town (WHO, 2017). (Popham, 2007), people who live near green spaces are healthier than people who live farther from green spaces. As noted by (WHO, 2017), green space interventions can improve environmental conditions (e.g., filtering pollutants and CO_2 from air), protect and improve biodiversity, promote outdoor activities and active lifestyles, increase social interactions and provide healthy urban conditions for good physical and mental well-being.

Despite the numerous above-mentioned benefits, urban green spaces are unable to provide urban dwellers with the desirable services due to increased urbanization and unplanned urban growth, lack of proper site selection and planning and lack of attention to population thresholds (Wright RT, 2002); (Ahmadi N, 2016).

Because of the unplanned urban expansion, no balance is seen between natural land patterns and human settlements, in a phrase of urban green spaces and open spaces urban expansion has been dominating natural networks that provide multifunction for both human and ecology (Abebe, 2017). It is noted, that there have been wide studies carried out on the land suitability analysis using the GIS-based multi-criteria analysis (MCA) procedures for land development. Analytic Hierarchy Process (AHP) has been widely used as a multi-criteria analysis process (Saaty, 2003) and MCA is also one of the most viable methods addressed in many studies on the land suitability analysis through GIS (Youssef, 2010). According to (Chandio I. A, 2009), GIS-based land suitability analysis techniques are useful for decision makers, engineers and planners to provide a framework for land development.

In order to specifically analyze the characteristics of green areas and possible suitable sites for green spaces in developed countries, numerous studies were conducted (La Rosa D, 2013); (Morckel V, 2017); (Merry K, 2018); (Ustaoglu E, 2020).

Internationally the minimum recommended standard is a minimum of $9m^2$ green space availability per city inhabitant (World Health Organization, 2010) and a standard of 20%

of the total urban area proposed. However, in developing countries, while some green spaces studies have been performed and which focused largely on the evaluation of urban green spaces with less emphasis on the study of spatial distribution with evaluation and identification of potential expansion areas. Various previous studies in sub-Saharan African countries are primarily related to distribution, abundance and composition of street trees (Kuruneri-Chitepo C, 2011), urban green spaces nature and challenges (Mensah, 2014), green space extent (McConnachie MM, 2008); (McConnachie MM S. C., 2010) and planning aspects (Cilliers J, 2009); (Fohlmeister S, 2015).

In Ethiopia, there were some studies conducted on green space using GIS and RS and these studies have focused on the impacts of urban growth on green space (Gashu K, 2018); (Abo-El-Wafa H), climate change adaptation (Lindley SJ, 2015), the development of functional green infrastructure and ecosystem service (Woldegerima T, 2017), planning aspect (Girma Y, 2019), utilization pattern (Molla MB, 2017) and suitability analysis (Yirgalem, 2021).

However, these studies did not give attention to the issue of Evaluation of existing green space, spatial distribution and identification of potential expansion areas for green space development in the urban environment in once and they did not used up-to-date data from geospatial technology. Besides, there were no studies conducted in the study area related to assessment of spatial distribution, evaluation and identification of potential expansion areas for green space in the urban environment in once. Therefore, this study aimed to fill existing research and knowledge gap by using geospatial technology and applying GIS-based multi-criteria analysis approach to examine spatial distribution of green space, evaluation of existing green space and then identify potential expansion sites for urban green space development in Adama City.

1.2 Statement of problem

Urbanization is a worldwide phenomenon that emphasizes the process of both vertical and horizontal physical expansion of urban areas (Ibido, 2020). Shrinking of urban green spaces through the development of infrastructures and various development projects is one of the major impacts of urbanization. In 2014, 54% of the world’s populations were living in urban settings and it is projected to reach 70% by 2050 which is an implication for the conversion of green spaces to other urban land uses (Hernandez, 2018). It practically never provides for future green space, thus most new Third World urban areas are commonly treeless (Olembo and Rham, 1987).

Adama is a City in Ethiopia, where this study was conduct, has also an experience of greater challenges facing urban areas. Based on (Yanit Mekonnen, 2017), in Adama City during the last thirty years, urban area has increased by 31.73% (i.e., 42.66 km2) due to construction and infrastructure development, while Shrub and bushes (greeneries) area has increased only by 0.61% (i.e., 0.82 km2) which is unbalanced and very small compared with rapid urbanization and population growth. According to **(**Mohammed et.al., 2019) between the year 2002 and 2017 built up, dense vegetation and sparse vegetation increased in area of approximately 160%, 30% and 78% respectively at the expense of barren land which decreased at 8.5%,. Dense vegetation cover were reduced from 29.3Km^2 (21.20%) in 2000 to 18.17Km2 (13.15%) in 2020. So, rapid expansion of built-up areas is the main cause to increase in LST. The model indicates that built up and green areas contributed 75.2% of the LST variations in Adama City. Based on (Biratu et al., 2021) the cooling efficiency (CE) and the threshold value of efficiency (TVoE) of green space in Adama City were calculated as 5.5 ± 0.5 ha. The finding implies that allocating a green space area of 5.5 ± 0.5 ha reduces surface temperature by about 2.85 0C which is the most efficient to reduce heat effects.

According to (Yared, 2018) (Samuel, 2014) in Adama and Bishoftu, destruction from domestic animals, illegal cutting of trees, waste disposal on the green space and illegal land use changes were observed as the main constraining factors and there was no provision for a site plan for green infrastructure components. Therefore due to rapid urbanization and population growth, Adama City is associated with unplanned and uncontrolled development, occupying unsuitable sites and declining basic services, especially green spaces. Therefore, this study were conducted to fill the existing information and knowledge gap by using geospatial technology with OBIA techniques and FAHP method to analyze and evaluate spatial distribution of existing green space and apply GIS-based multi-criteria analysis method to select potential areas for UGS development in Adama City using FAHP method for determining the weight of each factor.

1.3. Objective of the Study

1.3.1. General Objective

The main objective of the study is analyzing spatial distribution of urban green space and identification of its potential expansion areas in Adama City using geospatial technologies.

1.3.2. Specific Objective

- To analysis the spatial distribution of urban green space in Adama City.
- To evaluate existing urban green space respect with distribution and accessibility.
- To identify determinant factors for UGS development in the study area.
- To identify potential sites for UGS development.

1.4. Research Question

- How much the spatial distribution of existing green space in Adama city?
- What is the level of accessibility and distribution of existing UGS in Adama City?
- What are the main determinant factors for urban green space development?
- Which potential sites are suitable for UGS development in the study area?

1.5. Significance of the study

Study of spatial distribution of urban green space and its potential site selection have important for urban and regional planners and decision makers to assess the influences of urbanization on green spaces. Findings of the study will serve as a working document for Adama City management officials in the identification and selection of suitable sites for urban green space development in the city. If the proposed sites are used as an urban green space location with proper management its innovative nature-based approaches that increase the quality of urban settings, enhance local resilience and promote sustainability in response to pressures of urbanization and climate change. Also, the techniques and procedures used in this study will be used as a reference material for any concerned body or individual for further study.

1.6. Scope of the study

The spatial scope of this study where limited to Adama City, Ethiopia. Whereas, contextual scope of the study is examine the spatial distribution of existing green space. So it needs a study to understand clearly the reality and to see different approaches for green space development. City leaders and urban planners are faced with challenges in providing basic services such as green space, sanitation, water supply, transportation, and primary health center due to rapid urbanization and population growth in the developing world (Abebe, 2017), Particularly the study focus on urban green space in the city evaluating existing green space with respect accessibility and distribution and identification of potential expansion areas for urban green space development using geospatial technology.

1.7. Limitation of the Study

In this study the limitations are availability of data and willingness of the organizations to give data's such as land price or land value data with its ownership this is also one of the factor affect the urban green space development. The other limitation was parameters of green space development were set by reviewing different literature and prior knowledge of the study area instead of common standards.

1.8. Organization of the research

This thesis is organized into five chapters. The first chapter is the introduction part, which includes background of the study, statement of the problem, objectives of the study, research questions, and significance of the study, scope of the study and limitations of the study. The second chapter highlights a review of literature that consists of both research related review literature and conceptual review literature. The third chapter gives a description of the study area and methodology of the study. The forth chapter is about result and discussion and the final chapter is about conclusion and recommendation of the study.

CHAPTER-II: LITERATURE REVIEW

2.0. Theoretical Literature Review

2.1. Overview of Urban green space

There is no single universally accepted definition for the term urban green Spaces. Many scholars tried to define the term from their respective research area point of view. According to (Mensah, 2014)'Green space' is a phrase used to describe a large area of land that Some academics use words like "open space" and "public open spaces" interchangeably when referring to green spaces. He clarifies that "green spaces in urban areas cover all areas that to some degree have some vegetation, either natural or artificial. It isn't only confined to city parks and gardens. It refers to land that is primarily made up of unsealed, permeable ‘soft' surfaces such as dirt, grass, shrubs, and trees, and is accessible or maintained privately or publicly.

The physical components of urban green space include urban forests, parks, riverine, and street trees. Natural playfields, community parks, urban agriculture, and rooftop gardens are just some of the prospects for green space. Community gardens provide important social, economic, and environmental benefits to the community. Urban agriculture has a somewhat different emphasis than community gardens, but it has a significant effect on social movement and food security in the community. It is viewed as advantageous to both the environmental and food security movements (Abebe, 2017).

Urban green sp Urban green spaces have different forms and types of open spaces, community parks, gardens and landscaped areas; Some types of urban green spaces are formal green space, informal green space, natural green space, public participation, children’s space, active sports space and recreation activities. Urban green spaces exist in a variety of types, structures, and shapes (Vargas-Hernández J.G., 2018).

According to (Dawit, 2019) citing an urban green space can be defined as formal and informal. **Formal green areas**: such as protected public parks, street gardens, playgrounds, sports fields, squares, private gardens, and vegetation cover in schools, hospitals, churches, mosques, embassies, cemeteries, parking lots, pedestrian lanes, etc. and; **Informal green areas**: encompasses forest areas, river valleys, reserved expansion areas, agricultural lands, open leftover spaces, steeper degraded areas, etc. (Mainardi, 2019). According to (Kmail, 2020)Green space can be defined as a space in an urban area covered by vegetation and it can be publicly or privately accessible and an area of greenery including public parks, playing fields, streets with plants and others in an urban area.

2.2. Benefits of urban green spaces

Nowadays, urban green space is increasingly gaining attention as a source of multiple benefits (Byrne JA, 2015). Different authors defined multi-functionality of green space as composite functions that include environmental, socio-cultural, and economic benefits. It supports many of the components of ecosystem services as defined by the Millennium Ecosystem Assessment (Forest Research, 2021). Ecosystem services include: Supporting services (habitat provision, nutrient cycling, soil formation, and primary production), Provisioning services (fresh water, wood), Regulating services (climate, flood, disease) and Cultural services (aesthetic, educational, recreational). These are intrinsic to biodiversity, and provide for people’s well-being, security, basic materials for good life, health, and good social relations (Diaz, 2006). As most of our communities exist within the urban environment the provision of green space is essential for the wellbeing of society (Forest Research, 2021).

2.3 Status of Urban Green Infrastructure in World Wide

In the 1870s, concepts for green urban structures began with ideas of urban farming and garden allocation. In the UK, Europe, and North America the implementation of green infrastructure is based on the major planning concern or their concentration (Aynachew, 2014). In Europe, green infrastructure growth has been related to the development of the urban greening program and efficiently establish sustainable green space in high-density landscapes (Benedict, 2002) on the other hand United States was based on landscape conservation In mid-1990s (Alexander, 2007). In many cities, Europe, North America, South America, Asia, and Africa, urbanization harms the natural environment (green space), with the situation in Africa being serious (Addo-fordwuor D, 2014).

2.4 Status of Urban Green Infrastructure in Africa

Green infrastructure is a likely solution to sustainable spatial planning. In terms of green infrastructure development over the past few years, the concept of green infrastructure has remained limited and underestimated in the context of broader spatial planning approaches in Africa, particularly in South Africa (Cilliers, 2019). Currently, the rapid depletion of green spaces in Africa has resulted in green spaces occupying a very small percentage of many urban areas ' total land space. For instance, many cities in the Republic of South Africa have less than 10% of their total land occupied by green spaces (McConnachie MM S. C., 2008). The situation in the city of Lagos (Nigeria) is more frightening, and green spaces now occupy less than 3% of the landmass of the city (Oduwaye, 2013). Recent trends have shown that Africa's urbanization rate is twice as fast as Latin America and Asia (Europe, 2007).

Studies have shown that the general attitude of green space planning in many African nations is often articulated with a direct intervention to a visible problem without any long-term plan which is Only the short-term effects that are set against limited time frames are based. However, many urban people in Africa have very limited experience in building green infrastructure and are deficient in land-use decisions so they don't grasp its significance or the promise it can offer to their towns and cities (Youngquist, 2009).

2.5 Status of Urban Green Infrastructure in Ethiopia

The Urban Development Policy of Ethiopia has concerns with incorporating the issue of green areas, considerations of the compatibility of various land use activities, incorporation of generalized environmental objectives and identification of hazardous areas. The policy has also recognized cities as entities that strive to work towards minimizing serious urban environmental causes (Mathias, 2016).

In Ethiopia, the cities of Addis Abeba, Adama, and Hawass green areas are being shifted to other land uses such as residential, industrial and commercial developments which leads to environmental deterioration (Senia, 2021). According to the report by Adama specific urban infrastructure standard states" The Municipality shall ensure a minimum of 15 m^2 public green open space per capita within the city boundaries. Every inhabitant of Adama city shall live within 500 m from a public green open space of a size of at least 0.3 ha, an area big enough such as playing football and for other informal play.

2.6. Urbanization effects on urban green space development

According to (Mensah, 2014), urbanization has been increasingly a predominant factor in imparting stress on urban green spaces. Urbanization remains a main factor that has been mainly linked to causing green space destruction (Mensah, 2014). Urbanization takes place in the form of either densification of urban core or spatial expansion of urban areas outwards (urban sprawl). Densification of the urban core refers to high population density and an increase in the built environment (building structures) in relation to open spaces

(Mensah, 2014). The urban sprawl on the other hand, relates to the outward expansion of urban areas often taking place in the urban fringe, peri-urban lands and former agricultural lands (Mensah, 2014).

(Honu, 2009), argued that rapid urbanization has resulted in the conversion of several urban lands into built up structures and excessive destruction of the natural ecosystem, including green spaces. Changes in land use, particularly the replacement of green space by buildings, parking lots and roads causes urban areas to become warmer than surrounding areas because these impermeable materials absorb heat and release it more slowly.According to the policy document, the main challenges facing urban areas in the country are poorly developed social and physical infrastructure; shortage and deterioration of housing; lack of recreation areas; inadequate municipal waste management; absence of well integrated urban-rural linkage; unbalanced urban growth and weakly developed national and regional urban systems (Mathias, 2016).

2.7. Land Use/ Land Cover Change

LULC change has become a central component in current strategies for managing natural resources and monitoring environmental changes. The advancement in the concept of vegetation mapping has greatly increased research on land use land cover change thus providing an accurate evaluation of the spread and health of the world’s forest, grassland, and agricultural resources has become an important priority (Zubair, 2006). LULC change occurs when humans alter the landscape, and this leads to increasing loss, fragmentation and spatial simplification of habitat. Changes in LULC can affect biological diversity, alter ecosystem services and lead to soil erosion, disrupt socio-cultural practices and increase natural disasters, like flooding. It has been found that changes in land use have negative impacts on the climate, ecosystems, surface radioactivity (e.g., increased atmospheric greenhouse gasses, depletion of the ozone layer), agricultural activities, and biodiversity on both local and global scales (Hasan S, 2019).

2.8. Object Based Images Analysis Method

Object-based classification attempts to identify patterns in an image and use contextual information to group pixels into clusters that represent the same object. By grouping pixels into meaningful objects, spectral variability within a segment is minimized and differences between segments are maximized. In general, high-resolution imagery is classified more accurately when using object-based classifications than pixel-based classifications

(Czarnecki, 2012). A substantial difference between traditional pixel-based image classification and object based classification is that pixel-based classification does not use any spatial; object based classification is based on the spectral signature of a single pixel without consideration of other pixels around it (Czarnecki, 2012).With an increase in spatial resolution comes a loss in statistical separability within the spectral data space, thereby reducing the accuracy of pixel-based classifications. Higher spatial resolution increases the spectral variability within the trees or wetland, and therefore can decrease the statistical separation between each pixel. These increases in spectral variability makes separability using pixel-based classification methods more difficult (Czarnecki, 2012). Therefore, this study determines existing LULC types of the year 2022 in Adama City using object-based image analysis technique.

2.9. Application of GIS and Remote Sensing in Suitability Analysis

GIS has been applied in many disciplines including geography, forestry, urban planning, natural hazard management, recreation and tourism management, industrial facility management and environmental studies. Particularly, in suitability analysis, GIS has a great role in multi criteria decision making process. The survey showed that the GIS MCDA approaches were most often used for tackling land suitability problems (Malczewski, 2006).

Suitability analysis is built upon the concept of multi-criteria evaluation. MCDM or multi-attribute decision making (MADM) techniques involve the evaluation of several criteria or datasets to meet a specific objective. In MCDM process, criteria or datasets are examined for assigning relative ranks and individual feature weights based on the land use type for which suitability being examined. Weighted summation is sufficiently straightforward to use GIS data. It incorporated into the land-use suitability analysis (Eastman, 2009).

2.10. Multi Criteria Decision Making (MCDM)

MCDM is an advanced discipline which can be applied to complex decision making problems, by providing an effective solution for ranking of alternatives. The desired result can be achieved, adhering to the appropriate criteria of the related decision making problem (Rashad et al., 2020). Land evaluation can be seen as a multi-criteria decision analysis (MCDA) process which, when combined with GIS, can become a powerful approach for land evaluation (Joerin F. et al., 2001; Malczewski, 2006; Aldababseh, A.et al., 2018). GIS techniques play a crucial role in spatial analysis, whereas MCDA provides a rich collection of tools for structuring decision problems, as well as evaluating and prioritizing alternative decisions. In recent years, the integration of MCDA techniques with GIS has considerably advanced to evaluation/selection the optimum alternative. GIS-MCDA is a process of decision making at which geographic data value judgments are brought together to obtain more information for decision makers.

2.11. Fuzzy Analytic Hierarchy Process

FAHP was adopted to calculate the relative weights of various indicators, and the indicators were dynamically sorted according to their importance (Lin, 2020). The combine effect of fuzzy set theory and AHP gives FAHP as a more powerful methodology for MCDM. The FAHP facilitates decision-making procedures with precise definitions. It is an early used the triangular membership function to represent pair fuzzy ratios to figure out the partial fuzzy priority through the method of least squares (geometric mean method) (Lin, 2020). The traditional AHP method is problematic in that it uses an exact value to express the decision-makers opinion in a comparison of alternatives and AHP method is often criticized, due to its use of unbalanced scale of judgments and its inability to adequately handle the inherent uncertainty and imprecision in the pair-wise comparison process.

To overcome all these shortcomings, FAHP was developed for solving the hierarchical problems. Decision-makers usually find that it is more accurate to give interval judgments than fixed value judgments. FAHP allows decision-makers to evaluate their preferences within a reasonable interval. These intervals result in a fuzzy judgment matrix, corresponding to the rigid value judgment matrix of classical AHP (Abimbola et al., 2020). This study describes the integration of GIS, MCDA and FAHP methods that are based on scientific and author judgment to analysis evaluation and identification of potential expansion areas for urban green space development in Adama City.

2.12. Criteria for suitability analysis of green space

Identifying the best criteria is the key for land suitability analysis (Chakma, 2014). Criteria are very important in the site selection of the identified land use and used as key drivers in the selection of the geographic location. But, selecting criteria may depend on other factors that can influence the selection process i.e., the availability of data extent of the study area, etc. Earlier studies and literature conducted by some researchers used a criteria’s like LULC, proximity to the residential areas, proximity to the urban facilities, proximity to the historical place, distance to the existing local parks, access to transportation, proximity to educational areas, population density, slope, distance to noise influence and hydrology (Heshmat et al., 2013; Kuldeep, 2013; Yousef & Mohammad, 2014; Elahe et al., 2014).

2.13. Empirical Review

Different researchers were attempts to evaluate and analysis UGS development on the characterization of LULC change phenomena on different period of time as internationally and national began decades ago

Most of researchers worldwide as well as in Ethiopia emphasis on evaluation and development of UGS based on LULC dynamics using unsupervised classification, supervised classification technique and AHP method; however, most recent technique and method apply to analysis UGS development like object based image analysis and FAHP are plays an important role in classification of LULC change and determining the weight of each factors respectively and also before selecting suitable site it is better to identify spatial distribution and evaluate existing green space at the same time (Author).

(Yeeun Shin, Suyeon Kim, Sang-Woo Lee and Kyungjin An, 2020) studied about identifying the Planning Priorities for Green Infrastructure within Urban Environments Using Analytic Hierarchy Process. Use expert survey and analytic hierarchy process (AHP) as a methodology and the results provide a roadmap to facilitate more rapid decision-making for UGI development by underscoring the key priorities for UGI.

(Akbar Kiani, Masoume Javadiyan, Vahid Pasban, 2014) studied about Evaluation of Urban Green Spaces and their Impact on Living Quality of Citizens in Nehbandan City, Iran. They Use Cochran formula to determine the sample size and as a result Green spaces within the city of Nehbandan have social, economic and ecological efficiency among which their environmental function or ecological productivity is the most important effect of these spaces making the citizens' quality of life more satisfactory through accessing to suitable green spaces.

(Reza Rafiee, Abdolrassoul Salman Mahiny, Nematolah Khorasani, 2009) studied about Assessment of changes in urban green spaces of Mashad city using satellite data. Use NDVI- for generating Change map and then use a post-classification comparison to determine the changes in green space of the study area during the proposed year covered by the images. Then apply landscape ecology calculations to derive metrics that quantified pattern of the changes in the green areas and assess landscape metrics with Combination of remote sensing image classification.

(Hailemariam B. A, 2021), studied about suitable site selection for UGS development using GIS and remote sensing based on multi criterion analysis. In Ethiopia, urban green areas have been consumed by industrial, commercial, residential and infrastructural developments, as well as by spontaneous and illegal settlements along mountain slopes, river valleys and other open spaces. Public green space are not uniformly distributed in the town in addition to this greening rate is relatively low in contrast to numerous population in the urban center. That is more and more green areas are continuously replaced by other commercial land use every year. Use supervised classification and reclassify to get suitable LULC for urban green space and AHP method for determining weight.

(Yirgalem, 2021) Studied about the suitability analysis of UGS development using geospatial technology in Adama town; the urban areas in Adama town have expanded dramatically while green areas have been declining. UGS plays a vital role in the mitigation of negative impacts of urbanization; however, it is often affected by the process of land use and land cover (LULC) changes in an urban area based on supervised classification and AHP method.

(W/gebriel Mebrahtu, 2017) analyzed about GIS and RS applications for potential UGS development site selection in Abiy Addi town central Tigray; LULC and green cover changes monitoring is required showing a need for green space development sites identification. The main motivation to this was the existence of low and even unplanned leftover greens in the study area. LULC changes in this study based on CORINE classification system, supervised/unsupervised classification and AHP method.

(Abebe, 2017) Studied about UGS development using GIS based multi criteria analysis in Addis Ababa metropolis. The urban/built-up areas in Addis Ababa have expanded dramatically, while green areas declined. According to the new City Development Plan (2001–2010), the city has currently consumed more than 75% of its areas for development, leaving little space for green areas. The LULC of the study area was analyzed using 15 m resolution of Landsat image based on supervised classification and AHP method.

2.14. Conceptual framework

Nowadays, Urbanization is drawing attention since they become major causes for anthropogenic disturbance to the environment and microclimate changes. The city and surrounding areas have experienced massive changes led by excessive agricultural, industrial and urban expansion activities. These land use modifications damaged the ecosystem in terms of weather and climate, land cover, land quality and strength, land quantity that can be maintained, population and socioeconomic determinants (Tadesse et al., 2001). This is mostly because of the rapidly increasing construction and infrastructure development that occupied large tracts of natural green spaces and prime agricultural lands (Mohamed A & Worku H., 2019).

There are three main components which determine LULC change such as actors, driving forces, and land characteristics itself (Hersperger et al., 2010). The driving forces are forces which interact with actors to shape the land change like human activities, climate change, population growth, urbanization and Government policy. Government policy influences the actors through making decisions (e.g., land use policy, urban utilities planning, resettlement, etc.). Actors may be land owner (individuals or groups) and policy maker affect it directly. Land characteristics by itself can also influence the land cover change (e.g., landforms).

Suitable site selection process considers four parameters such as accessibility, physical, environmental and socio-economic (Javadian M et al., 2011); (Chakma S., 2014). Accessibility analysis encompasses any spatial analysis of the area like proximity to road and railway, different services; dangerousness of the location and natural features. Physical features deal with features and attributes of the land surface like, soil type, slope, elevation and topography. Environmental like stream, existing park etc. socio-economic is like LULC, population density, noise influence and historical and cultural area.

Urban green space is increasingly gaining attention as a source of multiple benefits (Wise S et al., 2010); (Byrne et al., 2015). Different authors (Ahern J., 2013); (Roe M & Mell I., 2013)define multi-functionality of green space as composite functions that include environmental, socio-cultural, and economic benefits. Moreover, green spaces sequester CO_2 and produce O_2; they reduce air pollution and noise; regulate microclimates; reduce the heat; maintain diversity; have recreational and social values and produce a vitamin “G” for health, well-being and social safety (Uy P & Nobukazu N., 2008).

Generally, there are many determinant factors (main factors and sub factors) that affect urban green space development. Main factors are accessibility, physical, environmental and socioeconomic. Sub-factors include road, railway, slope, soil type, stream, park, LULC, population density, noise influence and historical and cultural area etc. The conceptual framework illustrated in figure 1 below demonstrates the main components which determine LULC change urban green spaces suitable site selection parameters and benefit of urban green spaces for urban ecosystems.

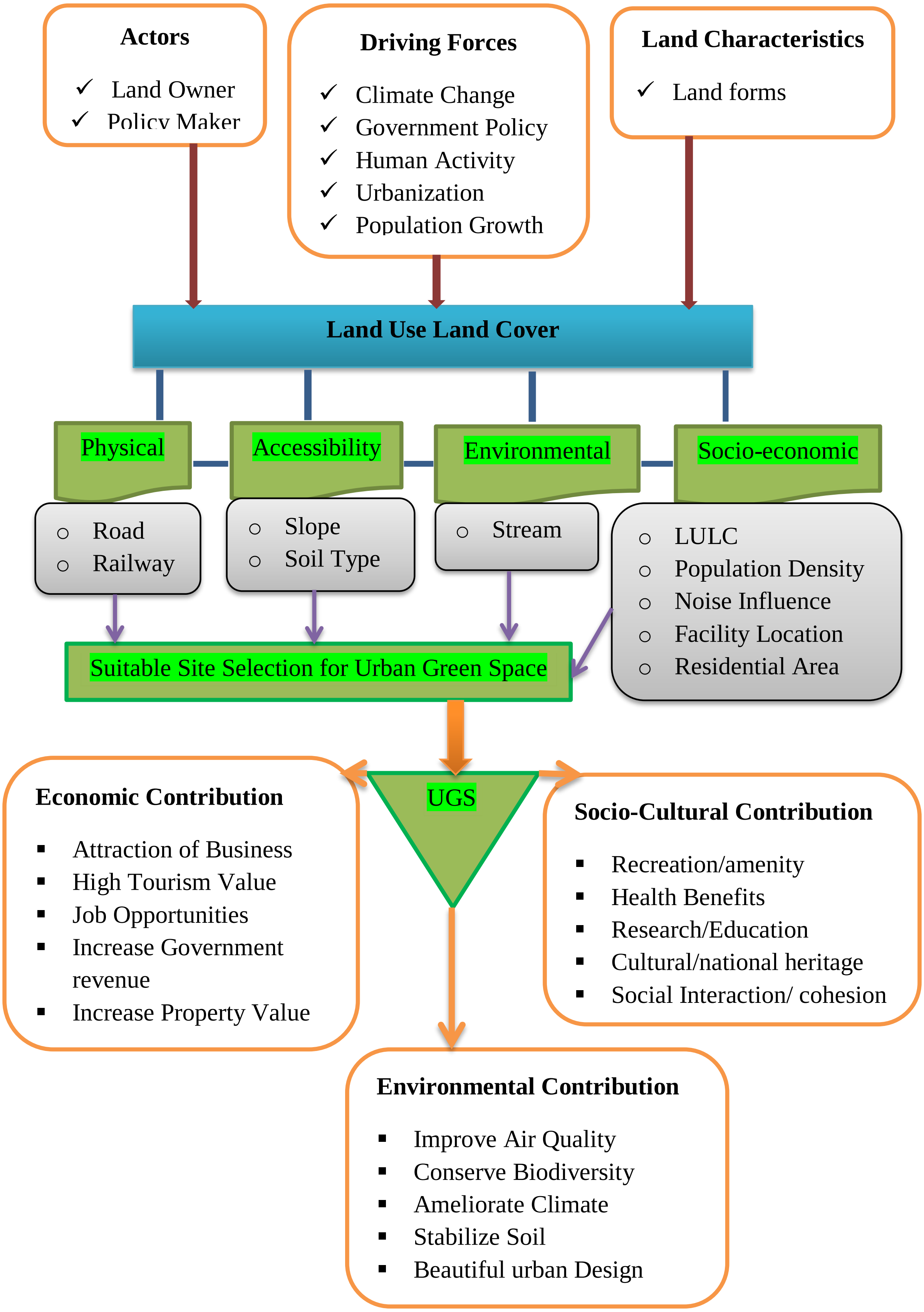


Figure 1: Conceptual frame work of the study

Source: Hersperger et al., 2010; Mensah, 2014 and modified by the author

CHAPTER III: METHODOLOGY

3.0. Introduction

This chapter describes all about the study area of the project, materials used and method of data collection, main components needed for this project, and methodology used to achieve prediction on urban green space assessment and identification of its potential expansion areas in Adama city, Ethiopia.

3.1. Description of the study area

The study area, Adama City, is located in the Main Ethiopian Rift, East Showa Zone of Oromia National Regional State. Geographically, the City is located between 52500 to 534000 m E Longitude and 937000 to 950000 m N Latitude. The City is 100 kilometers far from Addis Ababa along the road that connects Addis Ababa with eastern towns of the country and Djibouti port. According to the climatic zones of Ethiopia, the study area with an altitude ranging from 1500 -2000 m above mean sea level is classified as sub-tropical climate. It receives maximum rainfall during summer season (i.e. July and August). Topographically the area is situated in graven which is bounded by fault escarpments in western and eastern directions. The study area is characterized by flat to gently slope which ranges from 0° to 64°. All the streams flow into the depression bounded by fault. There is no perennial river and the peak discharge from intermittent surface runoffs attained during summer.

3.1.1. Geographic location

Adama also known as **Nazret** or **Nazreth** is a city in central oromia region of Ethiopia and the previous capital of the Oromia Region. Adama forms a Special Zone of Oromia and is surrounded by Misraq Shewa Zone. It is located at (8.54°N 39.27°E) at an elevation of 1712 meters above mean sea level, in the east shewa zone 99 km southeast of Addis Ababa. The city sits between the base of an escarpment to the west, and the Great Rift Valley to the east and its pleasant climatic conditions. The Awash Valley's economic potential and future development are also important aspects in the city's growth and development, as well as the surrounding region as a whole.

There are Eighteen Kebeles in the area of the city. The lowest level of city governance is the Kebele, and there are six Kebeles in the central section of the city, covering 5.8 square kilometers. The remaining eight Kebeles, which have an area of 127.9 square kilometers, are located on the outskirts. In 2017, the city was restructured into six (6) sub cities: Aba geda, Danbala, Bole, Dabe, Lugo, and Boku. These 18 Kebeles were distributed to each sub city.

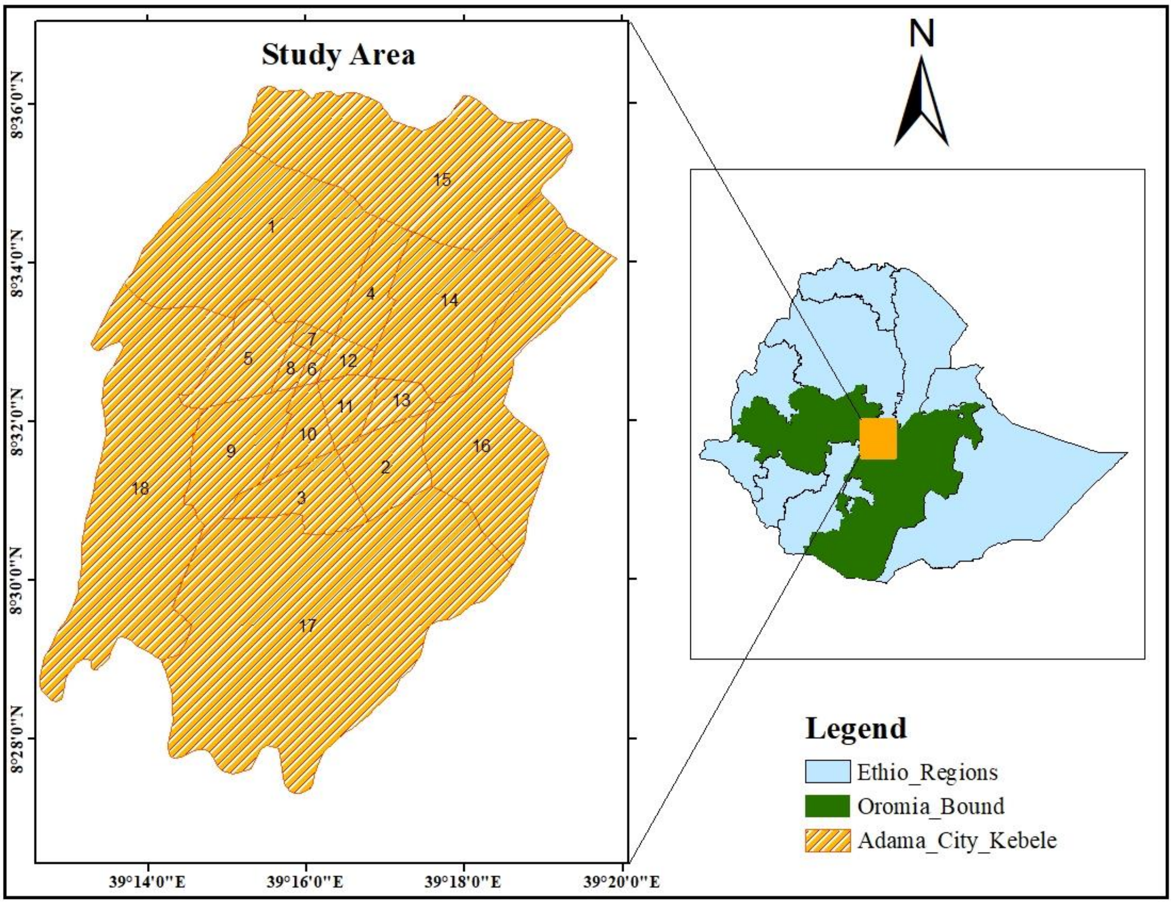


Figure 2 Location map of the study area

3.1.2. Population distribution by Kebele

The city's total population in 2006 was 356, 304 (Adama Science and Technology University (ASTU), 2016) up from 127,842 in 1994. As the data showed that the population of the City is unevenly distributed. Kebele 11 accounts the highest population size making 14.7 % of the total urban population followed by Kebele 10 (13.24%); Kebele 09 (9.26%) and Kebele 16 (6.54 %). On the other hand, Kebeles accounting less than 3% of the total population are Keble 05 (2.03 %); Kebele 08 (2.36 %), Kebele 18 (2.75%) and Kebele 19 (2.78%). The most of the Kebeles account less than the average (5%) of the total urban population (CSA, 2022).Previously there were 20 Kebele in the city, this restructured into 18 Kebeles now. In 2022 the total population of the city was estimated to be 456,868 with 223,560 being male and 233,308 female (Central Statistical Agency (CSA, 2022).

3.2. Data Collection and Data Source

The study used primary and secondary data which include both spatial and non-spatial data from the field and secondary data from different sources. The table below shows the required data, resolution, its source, data format and where it collects from.

Table 1: Required data with its source and format

No	Required Data	Resolution	Year	Source	Purpose	Data Format
1	Planet Image	0.3m	2022	SSGI	LULC classification	Raster (.tiff)
2	Boundary of Adama City	-	2018	Adama City municipality office	To subset/extract the study area	Shape file
3	DEM	20m	2022	SSGI	For slope and Stream generation	Raster (.tiff)
4	Soil	-	-	FAO	For knowing soil types.	Shape file (.shp)
5	Adama City Structural plan	-	2018	Adama City Land Administration	For boundary delineation & Land use extraction	Shape file (.shp)
6	Population	-	2022 projected	CSA	To know population density	Excel
7	Ground truth			Researcher	For accuracy validation.	-
8	Road	1m	2022	Google Earth pro	For Road network extraction	Shape file (.shp)
9	Facility center			GPS field survey	For factor generation	Point
10	Factory			GPS field survey	For factor generation	Point

3.3. Materials and software's used

In order to achieve the objective of the study different materials and software's were used. In this sense materials are instruments which used to collect and record data whereas Software's are programs which used for collection, organization, analysis, interpretation and presentation of data. The table below shows type of materials and software's to be used in the study with its purpose.

Table 2: Type of Materials and Software's used

No	Name of materials and software's	Version	Purpose
1	Personal computer mouse and flash disk		For entering, processing, displaying and storing all type of data
2	Handheld GPS		To collect facility center and factory data
3	ArcGIS	10.8	For data storing, managing modeling weighted overlay analysis and thematic map preparation.
4	ERDAS IMAGINE	2015	For processing and analyzing satellite image
5	eCognition	8.9	For LULC classification
6	IDRISI selva	32	To assign weight for each factor
7	IBM SPSS statistics	22	For tabulation and graphical representation
8	Google earth pro		For visualization, visual image interpretation and validation of the result
9	Microsoft Office	2010	For integrating attribute data and report compilation

3.4. Data analysis method

The techniques used to analyze and organize the collected data for the current study were briefly explained as follows. Qualitative and quantitative data were prepared for the analysis by following the metadata and analysis specification: coordinate system and datum (i.e. UTM- zone 37N, WGS 84), extent (Easting range 523818.657500 m to 536068.560100 m and Northing range 934241.571800 m to 950845.008800 m). After the data were collected from various sources it analyzed by using different geospatial software's to analyze urban green space and identification of its potential expansion areas in Adama City. The study was composed of three phases. The first phase is Classification of LULC and Accuracy assessment in order to identify green space spatial distribution for the study area. The second phase is evaluation of existing urban green space of Adama city and the third phase is identification of potential expansion areas of UGS development for the study area.

3.4.1. Image Pre-Processing

Here the collected data which is satellite image was processed (layer stacking, radiometric correction, subset, mosaic, image enhancement using panchromatic band (pan sharpened) takes place) using ERDAS IMAGINE 2015. The entire image (map) data were prepared using WGS 1984 and UTM Zone 37N.

3.4.2. Image classification

In this study, an object-based image classification is utilized to determine the LULC spatial distribution of land use in Adama City. When classifying an image, five different land use class (Bare land, Vegetation, Farm land, Built-up and Water body) classified with colors. The first step of classification is segmentation and the second is classification. To classify the image this study used multi-resolution segmentation and after that use class hierarchy to create the classes for LULC and The classification were done using nearest neighboring (based on the quality and quantity) algorithm.

3.4.3. Accuracy Assessment

Here the error matrix is the most common tool in terms of determining the accuracy of the classification results (Fan F, 2007) User accuracy, producer accuracy, overall accuracy and Kappa statistics were then derive from the error matrices for LULC classes. Here, GPS based ground information used for the classification and accuracy assessment.

Producer's accuracy: Is calculated as:

$$\text{Producer's Accuracy} = (Ci/Ct) * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (1)}$$

Where, Ci is correctly classified sample locations of the reference data or column and Ct is total number of sample locations of the column.

User's Accuracy (Commission error): Is calculated as:

$$\text{User's Accuracy} = (Ri/Rt) * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (2)}$$

Where, Ri = correctly classified samples and Rt = total number of samples in the row.

Overall Accuracy:

Is the most commonly stated accuracy assessment statistic & calculated as:

$$\text{Overall Accuracy} = (Sd/n) * 100 \quad \text{……………………..Equation (3)}$$

Where, Sd = sum of values along diagonal and, n = total number of samples.

Kappa Coefficient: This was indicated by the row and column totals. Kappa values can range from +1 to –1. But, as there should be a positive correlation between the remotely sensed classification and the reference data, positive values were expected. Landis and Koch (1977) taken the possible ranges for kappa into three groups: a value greater than 0.80 (i.e., 80% and above) represent strong agreement; a value between 0.40 and 0.80 (i.e., 40%–80%) represents moderate agreement; and a value 0.40 (i.e., 40% and below) represents poor agreement.

$$K^{\wedge} = \frac{n\sum_{i=1}^{r} xii - \sum_{i=1}^{r}(xi+.x+i)}{N^2 - \sum_{i=1}^{r}(xi+.x+i)} \quad \text{…………………………………..Equation (4)}$$

Where r = number of rows in the error matrix; Xii = number of observations in row i and column i (on the major diagonal); Xi+ = total of observations in row i (shown as marginal total to right of the matrix); X+i = total of observations in column i (shown as marginal total at bottom of the matrix) and N = total number of observations included in matrix.

3.5. Spatial Distribution of UGS analysis

The following indices were used for the assessment of the distribution of green spaces:

1. green space per capita (m2), the results of Jeddah was compared to the international standards such as United Nations (30 m2 per capita) (Laghai and Bahmanpour 2012), European Union standards (26 m2 per capita) (Vlad and Brătăşanu 2011), public health bureau and the ministry of housing of the united states of America (18 m2 per capita) (Laghai and Bahmanpour 2012) and World Health Organization standards (9 m2 per capita) (Saz.S.D and Rausell P. 2008).

2. accessibility to green spaces, measured by the percentage of the total population of the districts living in less than 300 m, 500 m and 15 minutes walking distance (≈1000 m) from urban green areas.

3.6. Accessibility of UGS Analysis

According to the survey, accessibility was characterized as being the most ideal when the time required to reach a green park was less than three minutes by walking (walking speed was approximated at between 1.1 and 1.3 m/s), while a travel time of between three and eight minutes was viewed as being comparatively ideal (“Raster Calculator”) (Yuan, Y.; Xu, J.; Wang, Z. 2017). This study analyzed the accessibility level of UGS in Adama City in terms of distance and per capita.

3.6.1 Per capita green indicator

For calculating the Green space per capita, the aggregate of Green space acreage available for the city and each sub-city is calculated using “calculate geometry” tool in ArcGIS 10. Then per capita park index was calculated based on city and each kebele population. The following Equation (equation 5) was used for calculating per capita green index (Anguluri and Narayanan 2017). Where; GAi-refer to the park area and SPi-is a population which enjoys services within the boundaries of the kebele i, APi- per-capita park index indicated the amount of parks available in a kebele for every inhabitant of the kebele. Whereas, to calculate the service area gap/deficit of UPs in the city Eq. 6 was used (Anguluri and Narayanan 2017). where; GAg-shows a shortage area of the Green space, P- Population number of the region, NP-denotes the international standard and APi-per-capita park index indicated the amount of Green space available in a Kebele for every inhabitant of the kebele.

Using the "calculate geometry" tool in ArcGIS 10.8, the total amount of Green space acreage accessible for the city and each Kebele is calculated in order to determine the Green space per capita. Following that, the population of the city and each sub-city was used to construct the per capita park index. According to Anguluri and Narayanan (2017), equation 5 was used to calculate the per capita green index.

$$APi = \sum_{k=0}^{n} \frac{GAi}{SPi} \quad \text{………………………………………………… Equation (5)}$$

Where; GAi refers to the park area and

SPi is the population that uses services inside the sub-city's boundaries.

The per-capita park index (APi) calculated the number of parks that are available to each Kebele resident. However, Eq. 6 was employed to determine the service area gap or shortage of Green space in the city (Anguluri and Narayanan 2017).

$$GAg = (Np - Api) \times P \quad \text{……………………………………………… Equation (6)}$$

Where; GAg-shows a shortage area of the park,

P-Population number

3.6.2 Proximity indicator

The level of Green space availability to the city's population was examined in this study using a proximity indicator in addition to the per capita green indicator. The fraction of the population with and without access to Green space is measured using this commonly used indicator, which was modelled in GIS using network or Euclidean distance (Nicholls 2001). Using certain general guidelines as a minimum baseline, planners have been able to determine how willing and able citizens are to walk to the closest neighbourhood park (Nicholls 2001; Van Herzele and Wiedemann 2003; Boone et al. 2009).

It is vital to establish some standards against which the citywide park access may be measured, even though there aren't any available for monitoring the accessibility of Green space in Ethiopia.

While the latter is a little bit longer than the former, it is still within acceptable limits for most adult individuals. For the purpose of identifying neighborhoods with adequate Green space accessibility, various proximity measuring approaches are used (Nicholls 2001; La Rosa 2014). In this study, Euclidian distance of Green space has been determined. The study produced maps of to allow comparison and difference visualization.

3.7. Site Selection Process in Multi-Criteria Analysis Method

Site selection process for UGS involves various social, technological, environmental and economic aspects. In this study GIS used for real time database development, digitization and rasterization of vector data, buffering/distance calculation, reclassify, weight overlay and thematic map preparation etc. Therefore, this study used GIS-based multi-criteria suitability analysis with FAHP to support the decision making process on selecting an appropriate site for UGS development.

The study was the follow seven (7) main steps to identify potential sites for UGS development using GIS-based multi-criteria analysis.

1. Set the goal/ define the problem
2. Spatial and non-spatial data collection
3. Determine the criterion and sub criteria (factors/constraints)
4. Standardize the factors/criterion scores and factor map generation
5. Determine the weight for each factor
6. Aggregate the criteria(weighted overlay analysis)
7. Validation/verification of the result

1. Set the goal/ define the problem

In this study the main aim of GIS based Multi-Criteria Analysis (MCA) were to evaluate existing urban green space and produce a thematic map which shows potential expansion areas for green space development in Adama City.

2. Spatial and non-spatial data collection

Collecting accurate and reliable data is the most determinant factor for any research as it determines the quality of the research. In this particular research, the first steps was to identify the social, physical and economic factors to be considered for potential expansion area identification of UGS followed by setting criterion based on the method and collecting both primary and secondary relevant data. Second apply LULC classification in order to employ the class, selection of training sites were conduct in the year 2022 then by reference data/ sample points (create random points) was conduct in the year 2022.

3. Determine the criterion and sub criteria (factors/constraints)

There were no universally agreed criteria/factors for urban green space development (Jabir K, 2014). Different literature like (Pantalone S, 2010); (Ahmed IC, 2011); (Heshmat P, 2013); (Elahe T, 2014); (Abebe, 2017); (Dagistanli C, 2018); (Pokhrel S. , 2019); (Ustaoglu E A. A., 2020); (Gelan, 2021); (Yirgalem, 2021); (Kayo Mulisa Dendena, 2022), suggests a variety of factors that may influence growth/ development of green spaces.

For this study based on the existing situation and availability of data in the study area, land suitability analysis for selection of potential expansion areas for urban green spaces development was carried out based on the following nine(9) factors: LULC, population density, soil type, slope, distance from roads, distance from noisy influence, distance from facility centers (educational center and healthy center), distance from residential area and distance from stream were used as factors/criterion. Though air quality, distance from the park, historic and cultural sites, are the other factors influence land suitability as well, but they were not included in this analysis, because there is not much variety in the study area in terms of Park, historic and cultural sites are not found in the study area.

4. Criteria Standardization and Factors Map Generation

In GIS-based MCDM analysis, it’s essential to standardize the data in order to integrate the data measured in different units and mapped in different scale of measurement such as ordinal, interval, nominal and ratio scales (Gelan, 2021). Even though there are different methods that can be used to standardize criterion maps, from those linear scale transformation is the most frequently used technique (Malczewski, 2004). According to (FAO., 2006) rating of factors has usually made in terms of five classes: highly suitable, suitable, moderately suitable, less suitable, and not suitable.

For criteria standardization in this study, all the vector maps of the criteria were converted to raster maps data formats. After that using the Spatial Analyst tool in Arc Map the raster maps was reclassified into five classes according to (FAO., 2006) with the values that range from 1 to 5, where the value of 5 was taken as highly suitable while that of 1 ws very less suitable for all factors considered. This approach enables all measurements to have an equivalent value before any weight applies. However, it is important to note that there are some variables that did not fulfill the whole range of the criteria. Once all the criteria maps was standardize, a weight of each criteria map is calculated using FAHP.

5. Determine Weight of Factors Using Fuzzy Analytical Hierarchy Process

In this study, the FAHP was used to calculate weights for the criteria maps. In MCDM, fuzzy or uncertain preferences can be written as fuzzy utilities or weighted sums which are fuzzy numbers. In addition, consistency checking is an important factor in the FAHP method. Consistency checking proves that the constructed fuzzy pair wise matrices are acceptable and consistent (Rashad A, 2020). In this study Triangular fuzzy numbers are adopted in the FAHP methods. TFN can be defined as a triplet (l, m, and u). The parameters l, m, and u., indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event respectively.

FAHP carry out the following four steps to identify potential sites for UGS development:

1. Establish Fuzzy Pair wise Comparison Matrices of Criteria.
2. Determine Fuzzy Weights of Criteria
3. Defuzzify or De_fuzzification and Normalize the Relative Fuzzy Weights of Criteria
4. Computing the consistency ratio

The weights of the nine-level fundamental scales of judgments (9-degree preferences scale) are expressed via Triangular Fuzzy Numbers (TFN) due to its simplicity and effectiveness. In this case, all pair wise comparison judgments are represented as fuzzy triangular numbers. The linguistic scale, fundamental to TFN that is used to measure the relative importance of fuzzy weights show in Table 18 as summarized by (Abimbola H. A, 2020)

Table 3: Saaty's Scale versus Fuzzy AHP

Linguistic Variables	**Saaty's (Crisp AHP) Scale**	**Fuzzy AHP Scale**	
		TFS	**Reciprocal TFS**
Equally importance	1	(1, 1, 1)	(1, 1, 1)
Equally to moderately important	2	(1, 2, 3)	(1/3, 1/2, 1)
Moderately important	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Moderately to strongly important	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Strongly important	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Strongly to very strongly important	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Very strongly important	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Very strongly to extremely important	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Extremely important	9	(8, 9, 9)	(1/9, 1/9, 1/8)

Source: (Abimbola H. A, 2020). Determine Fuzzy Weights of Criteria

In this study, the fuzzy geometric mean was used to calculate the fuzzy weights. The fuzzy weights of each criterion were calculated by three sub-steps:

a. Find the vector product of each fuzzy number ($\tilde{r}i$)

$$\tilde{r}i = \bar{A}1 \otimes \bar{A}2 = (l1, m1, u1) \otimes (l2, m2, u2) = (l1 \otimes l2, m1 \otimes m2, u1 \otimes u2) \qquad (7)$$

Where $\bar{A}$ is Fuzzy number and l, m, u is lower, middle and upper value of fuzzy number respectively.

b. Calculate Fuzzy geometric mean (ri)

$$ri = (\tilde{r}i)^{1/n} = (\bar{A}i1 \otimes \bar{A}i2 \otimes \ldots \otimes Ain)^{1/n} \qquad (8)$$

c. Find the (-1) power of the summation of fuzzy geometric mean.

Replace the TFN, and rearrange it in increasing order.

$$\bar{A}1 \oplus \bar{A}2 = (l1, m1, u1) \oplus (l2, m2, u2) = (l1 \oplus l2, m1 \oplus m2, u1 \oplus u2) \qquad (9)$$

The inverse formula of one fuzzy numbers is:

$$\bar{A}^{-1} = (l, m, u)\text{-}1 = \frac{1}{u}, \frac{1}{m}, \frac{1}{l} \qquad (10)$$

$$-1 = (ri1 \oplus ri2 \oplus \ldots \oplus rin)^{-1} \qquad (11)$$

Fuzzy Weight ($\tilde{w}$) was calculated according to Eq.14.

$$\tilde{w} = ri \otimes (ri1 \oplus ri2 \oplus \ldots \oplus rin)^{--1} \qquad (12)$$

3. Defuzzify or De_fuzzification and Normalize the Relative Fuzzy Weights of Criteria

Since fuzzy weight is still TFNs, defuzzify fuzzy weight using the center area method.

Center of area (COA) = $\frac{L+m+u}{3}$ (13)

Weights of Criteria are calculated using this COA formula:

$$Wi = \frac{L\bar{\bar{\omega}}i + m\bar{\bar{\omega}}i + u\bar{\bar{\omega}}i}{3} \quad (14)$$

Where Wi is the relative non-fuzzy weight of each criterion To normalize Wi, matrix Wi is transformed into matrix F = [f] the elements of matrix.

$$fi = \frac{Wi}{\sum_{i=0}^{n} Wi} \quad (15)$$

Where fi is the normalized non-fuzzy weights

4. Computing the consistency ratio

Since the numeric values was derived from alternative (interval) preference, to calculate consistency ratio first convert the fuzzy pair wise comparison matrix into crisp pair wise comparison matrix of subjective preference of individuals by defuzzified matrix (taking ratio). Consistency Ratio is a comparison between Consistency Index and Random Index.

$$CR = \frac{C.I}{R.I} \quad (16)$$

Where C.I is the consistency Index and R.I is the Random Consistency Index. Judgments that have a consistency ratio lower than 0.1 are acceptable and higher than 0.1 are not acceptable (i.e. are not consistent) (Abimbola H. A, 2020) and RI is the random index and depends on the number of parameters being compared and detailed in the Table below:

Table 4: Random Index

Order Matrix	1	2	3	4	5	6	7	8	9	10
RI	0.0	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Source: (Abimbola H. A, 2020)

Consistency Index is calculated using equation 17

$$C.I = \frac{\lambda max - n}{n-1} \quad (17)$$

Where n is the number of rows in the decision matrix and λmax is the largest eigenvalue of the comparison matrix.

In this study, max was calculated from weight sum value or weight vector and λ.

Weight sum value = Awi (18)

$$\lambda = \frac{AWi}{Wi} \quad (19)$$

$$\lambda max = \frac{\sum_{i=0}^{n} \lambda}{n} = \frac{AWi}{nWi} \quad (20)$$

3.8. Weight Overlay Analysis

Once the criteria maps and weights have been developed and established, a decision rule of multi-criteria analysis was used.

In this study, to aggregate the standard layers could apply the weight linear combination technique and the factors or parameters (xi) are multiplied with the weight of the suitability parameters (Wi) to get the composited weights and then summed. This can be done by using the following formula to derive the intended map in Arc GIS raster calculator i.e. urban green space suitability map for Adama town.

$$S = \sum_{i=0}^{n} (WiXi) \qquad (21)$$

Where S is the composite suitability score, Wi is weights assigned to each factor, Xi is factor scores (normalized cell values) and n is total number of suitability criteria layer.

3.9. Validation/Verification of Result

Validating or verifying the final result helps to evaluate whether the obtained result is reliable or not. According to (Abebe, 2017), Ground truth verification were done by conducted field surveys and sensitivity analysis was performed by changing the weight of criteria.

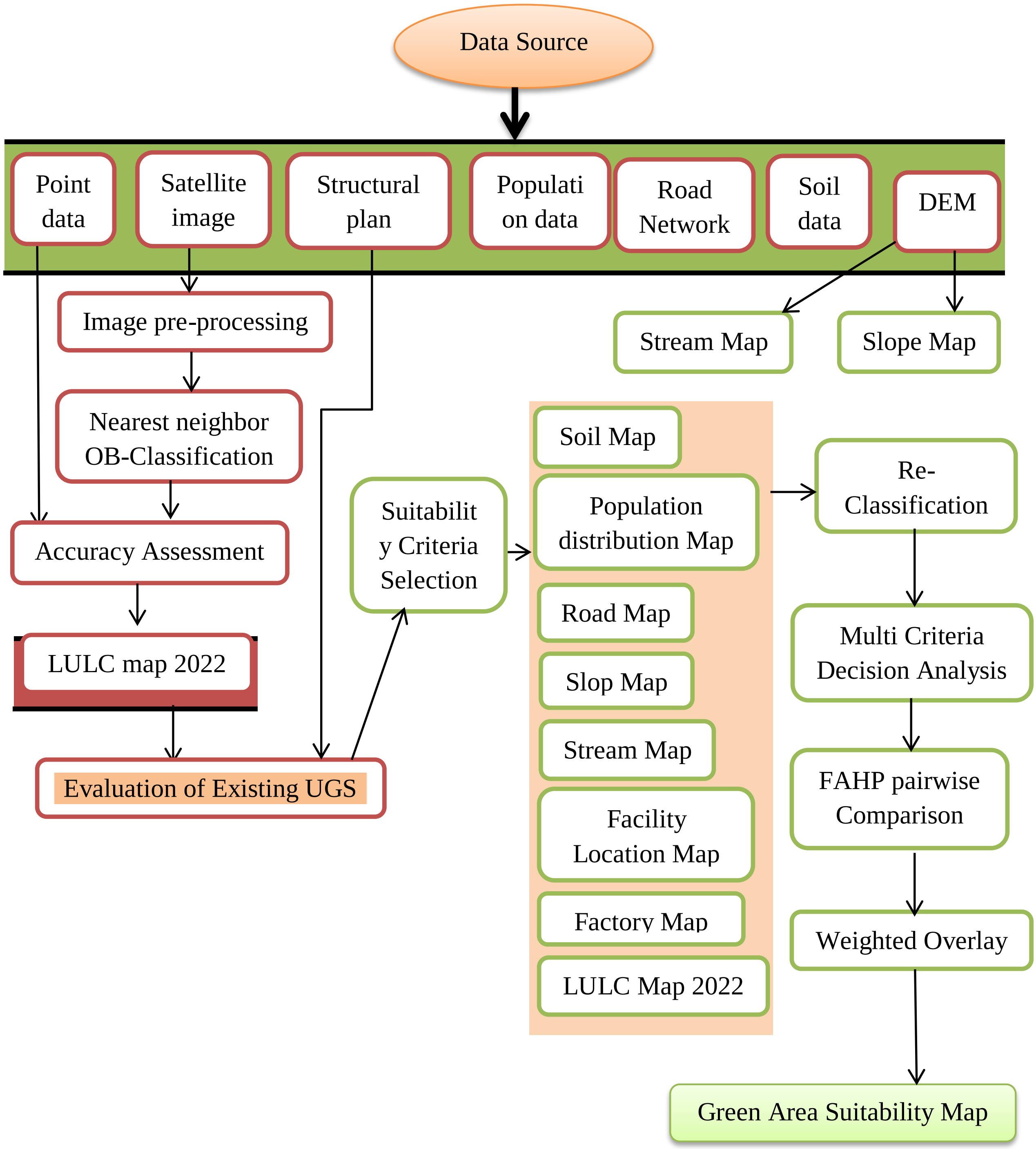


Figure 3 Technological scheme of the study

CHAPTER IV: RESULT AND DISCUSSION

4.1 Introduction

This chapter discusses the result of different data sets. LULC were extracted using object based image classification techniques for the data of 2022 satellite image using eCognition 8.9software. The classification results were then analyzed to determine the amount of green available, their distribution and accessibility, potential site analysis and a wide variety of criteria (factors) have been selected for UGS development. Additionally, maps of potential site analysis for urban green space development were created for each suitability criteria and the final composite map were finally produced by using GIS tool and weighting sum of FAHP method and Reclassified criterion, standardization score, area coverage of suitability levels and weights of each factor were summarized using tables.

4.2. Land Use Land Cover Classification

To accomplish the objectives of the study, existing LULC of the study area were first classified from Planet image of 2022. The images were interpreted or classified into five LULC classes, namely Built up, Vegetation, Farm land, Bare Land and Water body. The results showed that, in the study year (2022), the dominant land cover type in the study area was farm land which covers 34.70 % of the total area.

4.3. Accuracy Assessment of Classification

In this study accuracy assessment of the current years analyzed based on confusion matrix. Hence the accuracy assessment revealed the overall accuracy of 98.5% recorded whereas the kappa coefficient value was 98.1%. According to (Landis, 2020), a Kappa statistic value between 0.81 and 1.00 indicates almost perfect agreement, 0.61 to 0.80 indicates a significant level of agreement, and 0.41 to 0.60 indicates a moderate level of agreement. So, the classification in the study year is within acceptable accuracy.

Table 5: Confusion matrix of LULC classification in 2022

Classified Map	Classified Data	Farm Land	Bare Land	Built Up	Vegetation	Water Body	Row Total	User Accuracy (%)
	Farm Land	82	0	1	1	0	84	97.6
	Bare Land	1	44	0	0	0	45	97.8
	Built Up	0	0	98	0	0	98	100
	Vegetation	1	0	1	75	0	77	97.4

	Water Body	0	0	0	0	30	30	100
	Column Total	84	44	100	76	30	334	
	Producer Accuracy (%)	97.6	100	98	98.7	100		
	Overall Accuracy = 98.5 Kappa Statistic = 98.1							

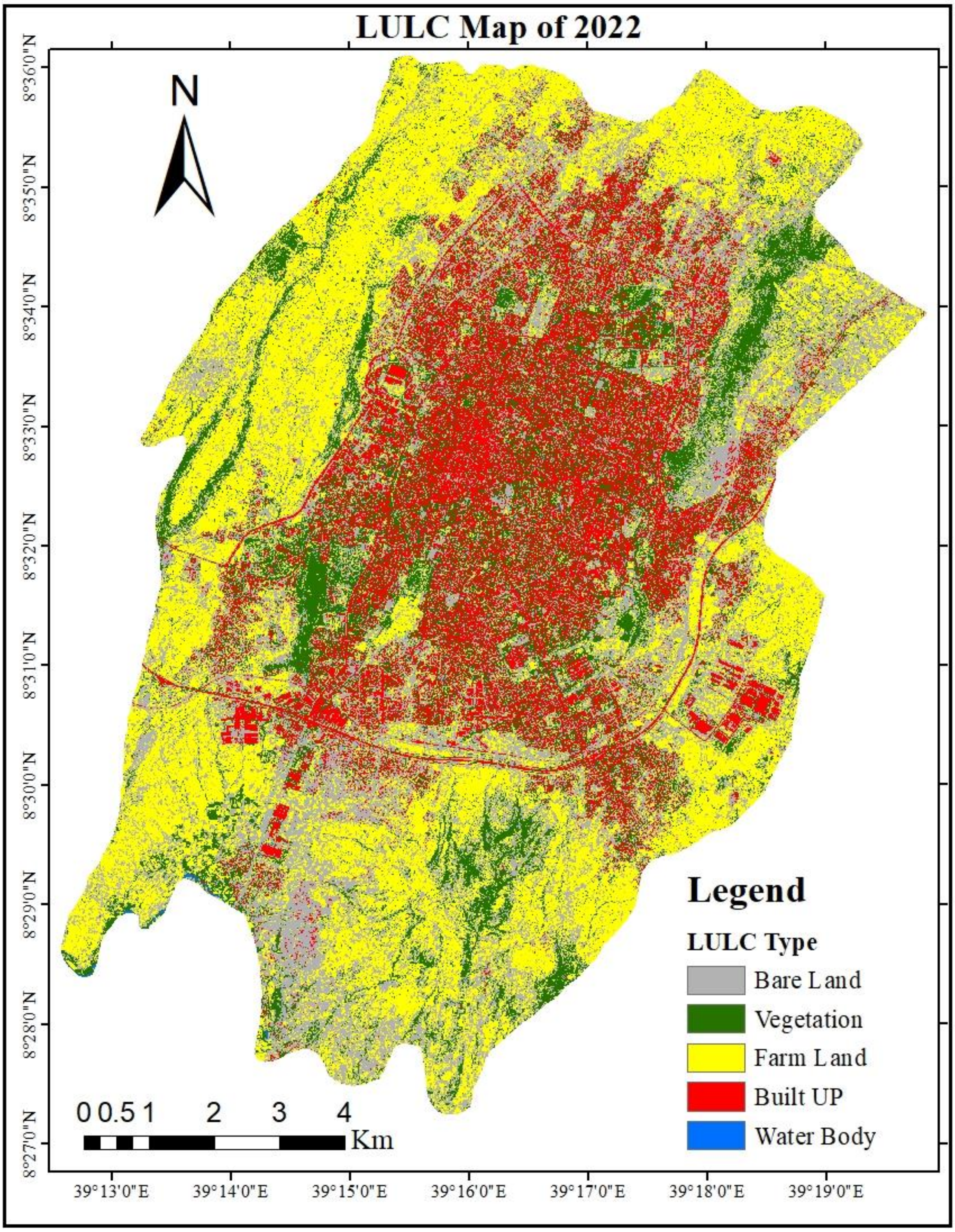


Figure 4: Existing LULC map of the study area

4.4. Accessibility of Existing Green Space

4.4.1. Per Capita of Green Space

When the per-capita of currently existing Green space is evaluated, the overall city average is 0.16 % and it ranges from 0 to 0.51 % with respect to the total area in km^2 at Kebele level. Among the Kebeles, Dabe Solloque, Melka Adama and Irecha have relatively the highest percentage, while the other Kebeles have the lowest Green space per person ratio. The densest Kebeles such as Gurmu (42,890 per km2), Oda (37, 490 per km2) and Badhatu (44, 087 per km2) have a very small park per-capita in relation to other Kebeles.

Table 6: Per capita of existing Green space

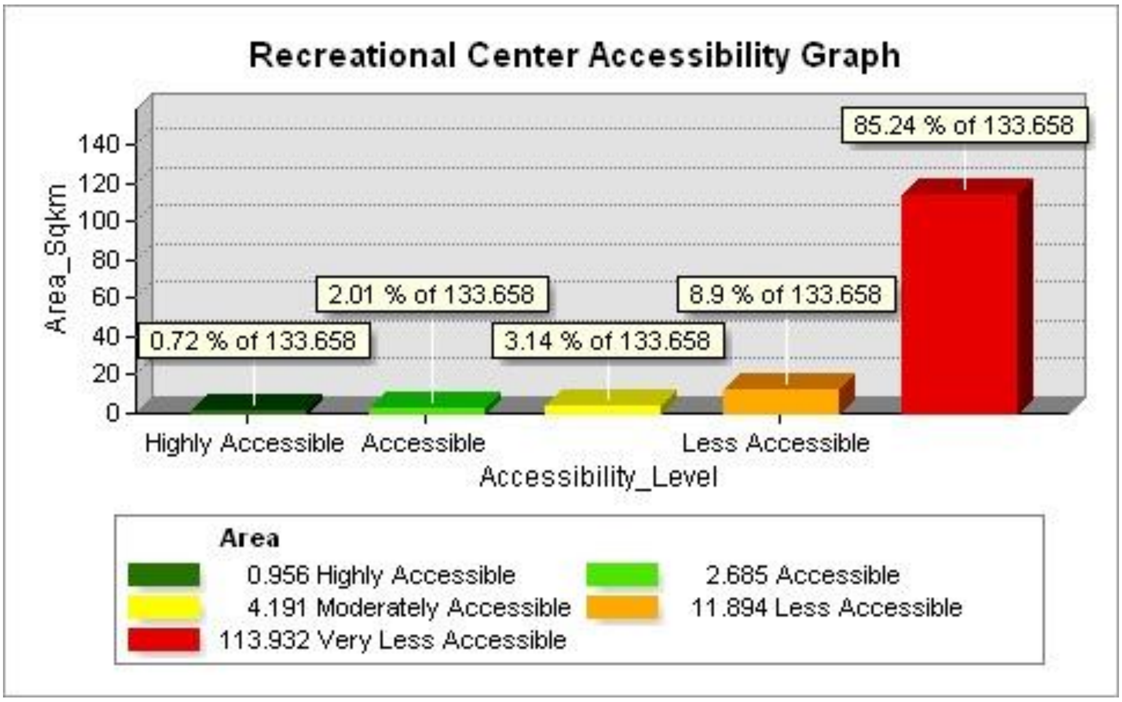
Kebele **Name**	Area (Km^2)	Total Population	Population Density/km^2	Area of Green space/m^2	Green space LU(%)	Green space Per capita (m^2)
Boku Kebele	16.782	12215.000	727.868	97725.000	0.073	8.000
Dabe Solloque	33.504	16298.000	486.453	682439.000	0.511	41.873
Goro	15.731	35578.000	2261.615	127521.000	0.095	3.584
Dh_Arara	2.560	37854.000	14785.489	-	-	-
Badhatu	0.494	21790.000	44086.691	9117.000	0.007	0.418
Gada	0.851	20102.000	23609.420	6178.000	0.005	0.307
Oda	0.549	20588.000	37489.510	-	-	-
Gurmu	0.309	13270.000	42889.502	-	-	-
Barecha	1.619	35032.000	21638.938	123446.800	0.092	3.524
Bika	1.929	33350.000	17291.174	11213.000	0.008	0.336
Melka Adama	20.561	7818.000	380.226	595841.000	0.446	76.214
Degaga	3.511	35746.000	10180.832	-	-	-
Gara_Lugo	3.508	37121.000	10581.293	-	-	-
Irecha	4.825	39420.000	8170.654	464328.000	0.347	11.779
Café	1.273	20425.000	16042.677	-	-	-
Migira	3.383	25461.000	7526.072	192943.000	0.144	7.578
Dhaka Adil	11.482	5774.000	502.880	40574.000	0.030	7.027
Hngatu	10.622	39026.000	3674.189	-	-	-

4.4.2 Proximity of existing Green Space

Based on the result using Euclidian distance proximity analysis 0.956095 km^2 (0.72%), 2.685433km^2 (2.01%), 4.190958 km^2 (3.14%), of the total area is highly accessible, accessible and moderately accessible areas respectively whereas 11.893562 km^2 (8.9%) and 113.932211 km^2 (85.24%) of the total area is less accessible and very less accessible area respectively. In general more than 80% of Green space in the study area is not accessible in terms of distance.

Table 7: Accessibility level of Green space and its area coverage

Accessibility Level	Distance(m)	Area (Sq. Km)	Area Coverage in %
Highly Accessible	100	0.956095	0.72%
Accessible	200	2.685433	2.01%
Moderately Accessible	300	4.190958	3.14%
Less Accessible	500	11.893562	8.9%
Very Less Accessible	>500	113.932211	85.24%



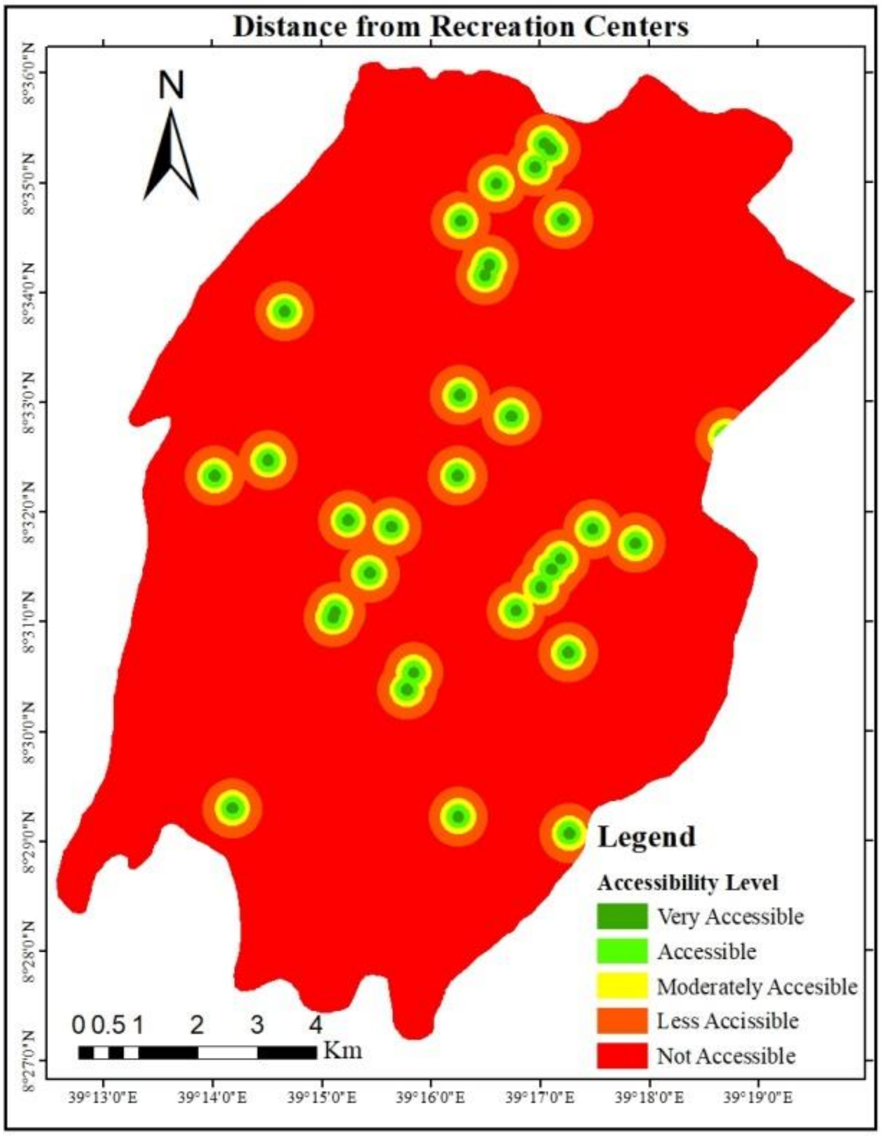


Figure 5: Accessibility of Existing Green space in the study area

4.5. Urban Green Space Distribution in Adama City

Our result in terms of Green space per capita indicated the city has no sufficient amount of distribution and accessible Green space that serve the city residents. As per the existing land use analysis of the city, currently areas under existing Green space is around 3.6 km^2 (2.7%) for a population of 456868 (more than 0.46 million), making the overall per capita availability of parks is about 5.2 m^2. This is insufficient and very small as per the standard set by Ethiopian UGIS (15 m^2), WHO (9 m^2) and the African green index (7 m^2). It is far behind that of some African countries such as Tunis Tunisia (14 m^2), Nairobi-Kenya (37.3 m2), (Langer and McNamara., 2011). Urban expansion occurs mainly in relatively low-altitude areas, and thus elevations are a constant barrier for expansion. On the other hand, the UGS coverage in the inner city (oldest city neighborhoods) areas was very low compared to peripheral areas.

In Adama, inner city areas are located in the urban core, where low-income residents live in neighborhoods undersupplied with basics amenities such as UGS. These areas had a very low proportion of the UGS types, which has been investigated in many earlier studies carried out in other countries (Haaland & Bosch, 2015). Generally this study has shown that the districts in Adama have an uneven distribution of per capita UGS. Inner districts had low per capita UGS levels, while outer districts had higher per capita UGS levels. Inadequate supply of UGS means that the per capita UGS level is low and this has been reported in many developing countries cities and comparable with earlier findings (Chimaimba, Kafumbata, Chanyenga, & Chiotha, 2020)

Table 8: Existing typology of Green space and its area coverage

Typology of UGS	**Area (Km2)**	**Proportion to Study Area**
Sport Field And Recreation	4.022133	3.01%
Green Area	27.99669	20.95%
High Tension Area	0.894578	0.67%
Road side green	5.099012	3.81%
Urban agriculture and horticulture	4.421394	3.31%
Total	**42.43381**	**31.75%**

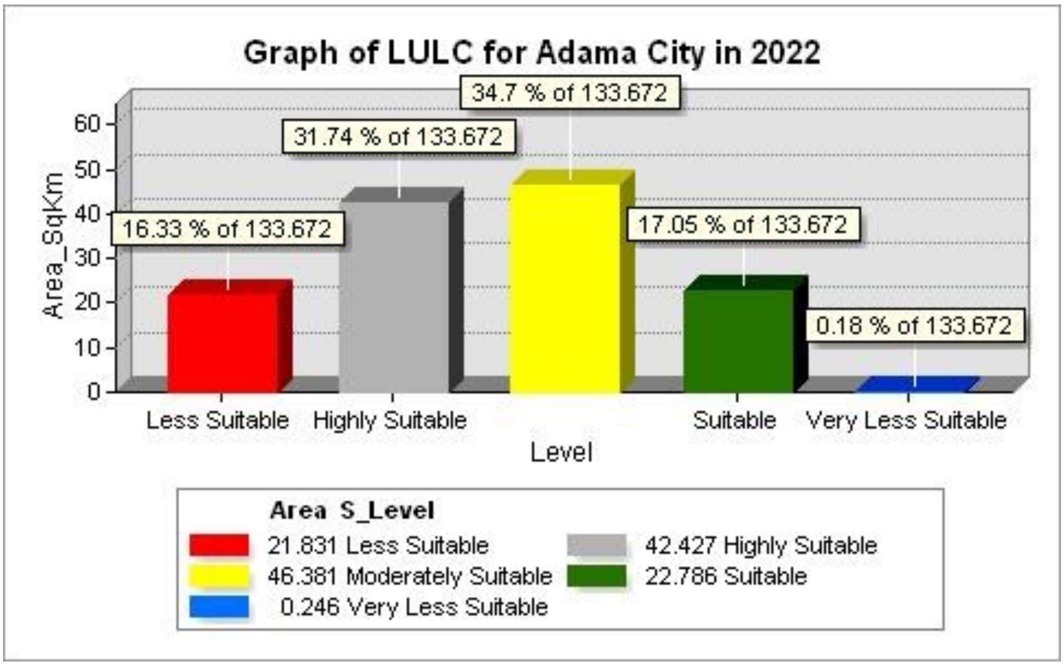
4.6. Potential sites for urban green space development

4.6.1 Suitability of Land Use Land Cover

As previous studies shown the current LULC should be considered when choosing potential sites for urban green space development and have identified the suitability of LULC classes based on their land use type (Abebe, 2017); (Dagistanli C, 2018); (Pokhrel S. , 2019); (Ustaoglu E A. A., 2020)). The LULC of the study area was analyzed from planet image with spatial resolution 0.3m through object based image classification technique by eCognition software application. Based on the knowledge obtained from the analysis of different literatures, bare land and Vegetation and farm land were considered to be highly suitable, suitable and moderately suitable for urban green spaces development respectively. In addition to this Built up area and water body were considered as less suitable and very less suitable conditions respectively for green space development.

Table 9: Existing LULC and area coverage of their suitability level

Land Use Type	Suitability Level	Value	Area (Sq.Km)	Area (ha.)	Area Coverage in %
Bare Land	Highly Suitable	5	42.426884	4242.688	31.74
Vegetation	Suitable	4	22.786063	2278.606	17.05
Farm Land	Moderately Suitable	3	46.381458	4638.146	34.70
Built Up	Less Suitable	2	21.831206	2183.121	16.33
Water Body	Very Less Suitable	1	0.246351	24.635	0.18



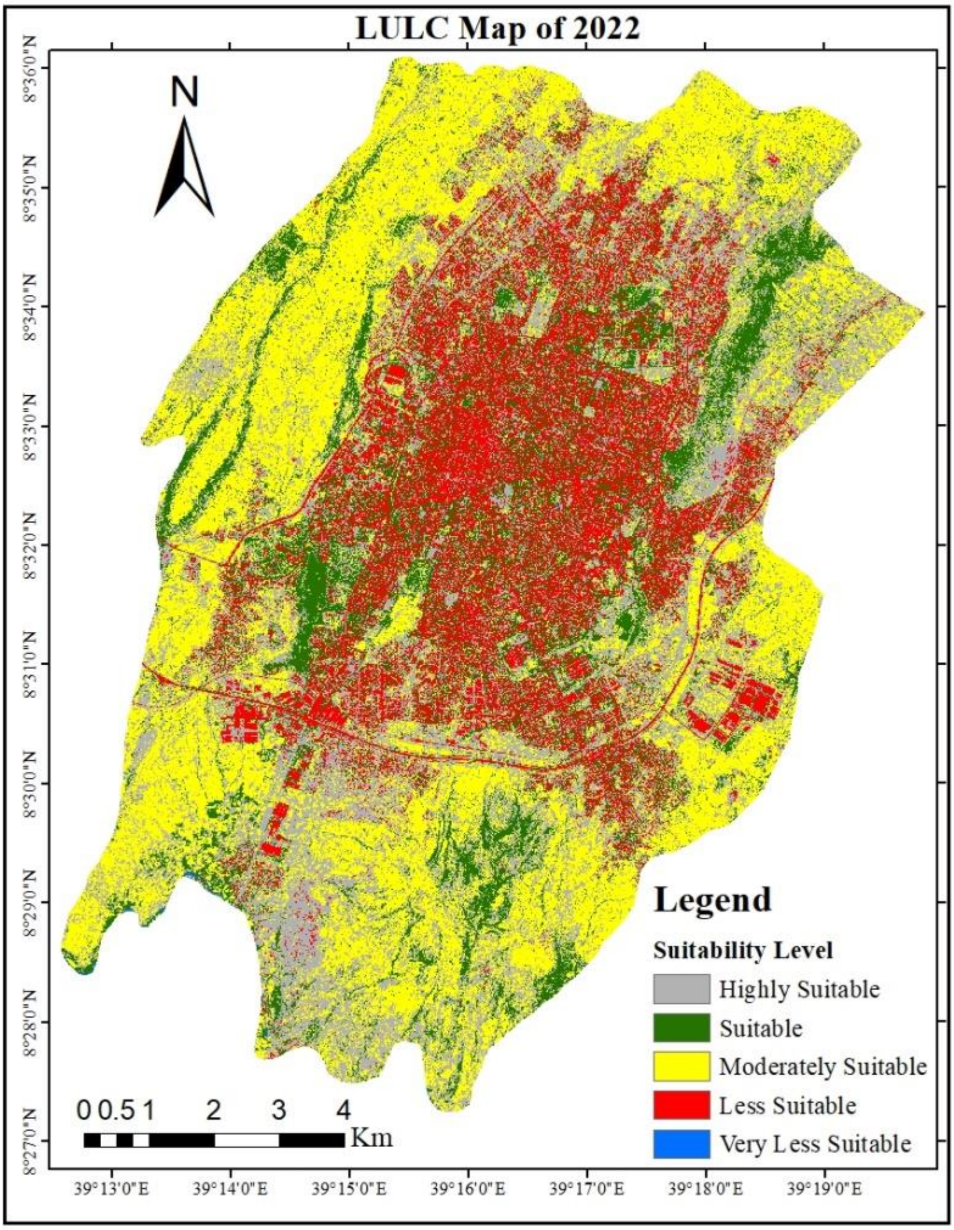


Figure 6: Suitability map for Existing LULC of the study area

4.6.2 Suitability of Distance from Stream

A live organism's growth and development depends heavily on water. According to earlier studies carried out by different researchers like (Abebe, 2017); (Gelan E. , 2021); (Hailemariam B. A, 2021) it is appropriate to develop green space which is closer to water sources like river, reservoir and ponds because they maintain good environmental health and are ideal from ecosystem perspective as well. Based on this distance from the stream less than 250m; between 250 and 500m and in between 500 and 750m are highly suitable; suitable and moderately suitable respectively. In addition to this, between 750m and 1000m and >1000m considered as less suitable and very less suitable respectively.

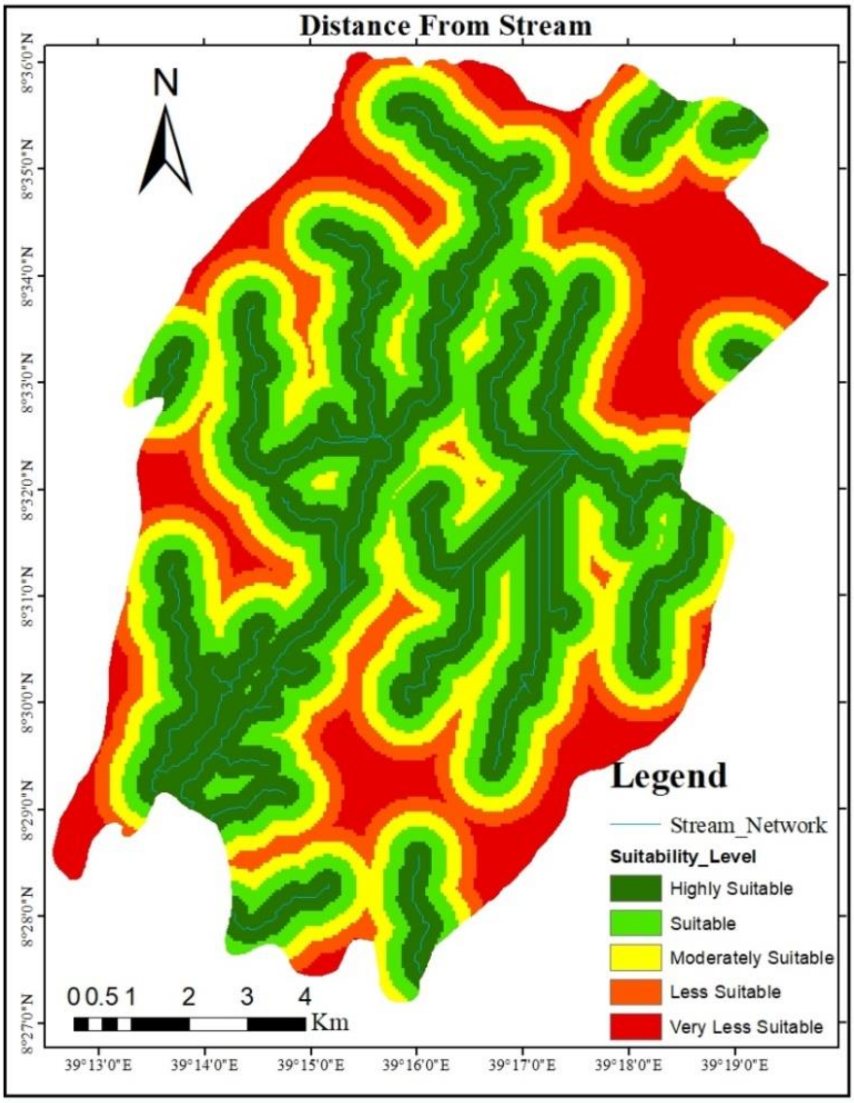


Figure 7: Reclassified distance from the stream map

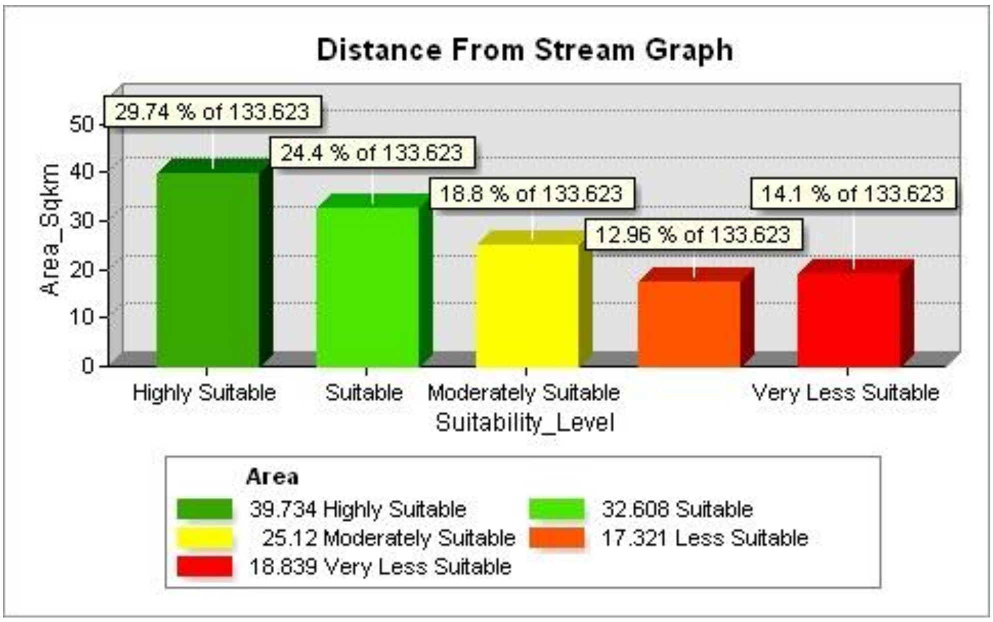


Table 10: Distance from stream and area coverage of their suitability

Distance from Stream	Suitability Level	Value	Area Sq.Km	Area Coverage in %
<250	Highly Suitable	5	39.733755	29.73
250 - 500	Suitable	4	32.615396	24.40
500 - 750	Moderately Suitable	3	25.148469	18.82
750 - 1000	Less Suitable	2	17.321428	12.96
>1000	Very Less Suitable	1	18.839261	14.10

4.6.3 Suitability of Distance from Road

Green space site is preferable when it is located at a suitable distance from roads in order to access transportation according to ((Elahe T et al., 2014) and (Ahmed IC, 2011)). In other words road proximity plays an important role in providing convenient and feasible routes to the local population to reach local green areas in their surroundings ((Kienast F et al., 2012); (Morckel V, 2017)In this study, by making buffer analysis areas within 500m, between 500 - 1000m and between 1000m - 1500m radius of road network have been considered as highly suitable; suitable; and moderately suitable and also areas between 1500m - 2000m and >2000m radius considered as les suitable and very less suitable.

Table 11: Distance from Road and area coverage of their suitability level

Distance from Road	Suitability Level	Value	Area Sq.Km	Area Coverage in %
<500	Highly Suitable	5	60.435407	45.22
500 - 1000	Suitable	4	28.662265	21.44
1000 - 1500	Moderately Suitable	3	14.831656	11,10
1500 - 2000	Less Suitable	2	11.505307	8.61
>2000	Very Less Suitable	1	18.223661	13.64

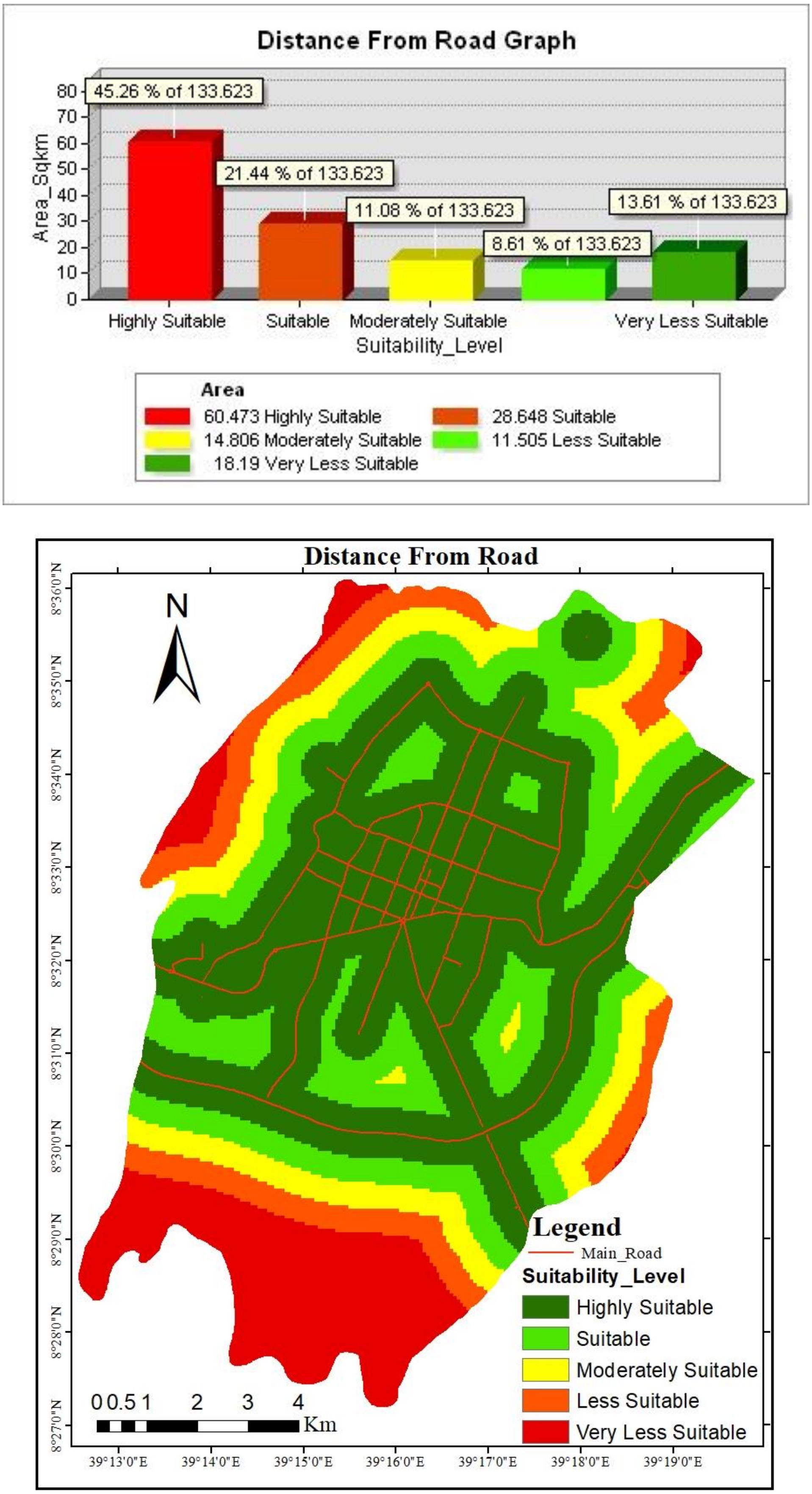


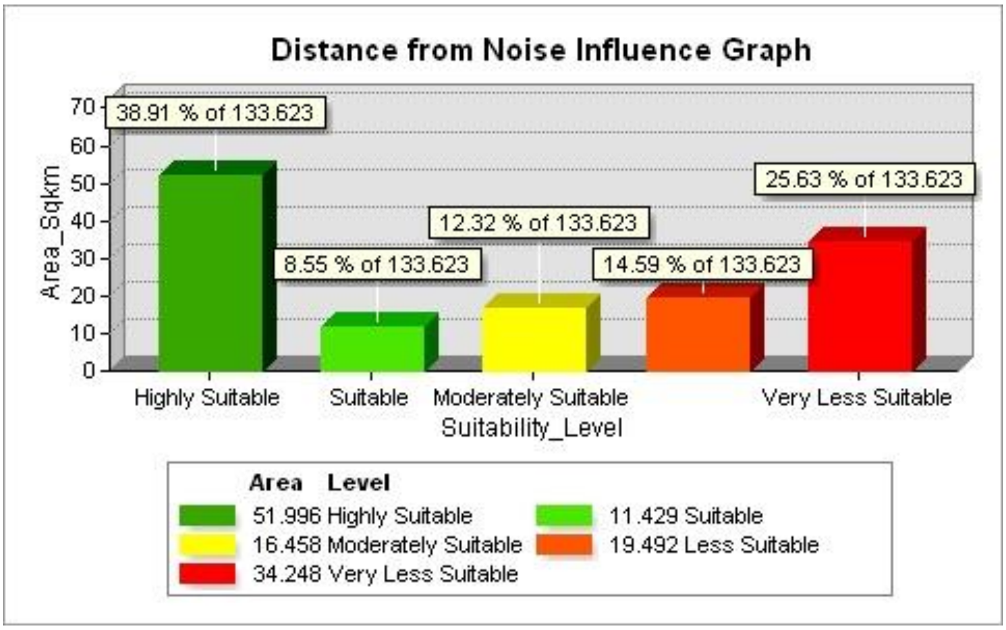
Figure 8: Reclassified distance from the road map

4.6.4 Suitability of Distance from Noise Influence

Noise areas like factory are not suitable for green space development because of high sound pollution and smoke. Therefore, the farther lands from the factory get more preferences for developing green space ((Jabir K, 2014); (Abebe, 2017);(Pareta k., 2019)). Based on this, in this study the areas buffer greater than 1000m, from 750m to 1000m and from 500m to 750m was considered as highly suitable, suitable and moderately suitable respectively and also from 250m to 500m and <250m have been considered s less suitable and very less suitable respectively for green space development.

Table 12: Distance from factory and area coverage of their suitability level

Distance from Factory	Suitability Level	Value	Area_SqKm	Area Coverage in %
>1000	Highly Suitable	5	51.99557	39.91
750-1000	Suitable	4	11.429195	8.55
500-750	Moderately Suitable	3	16.457541	12.32
250-500	Less Suitable	2	19.492375	14.59
<250	Very Less Suitable	1	34.247836	25.53



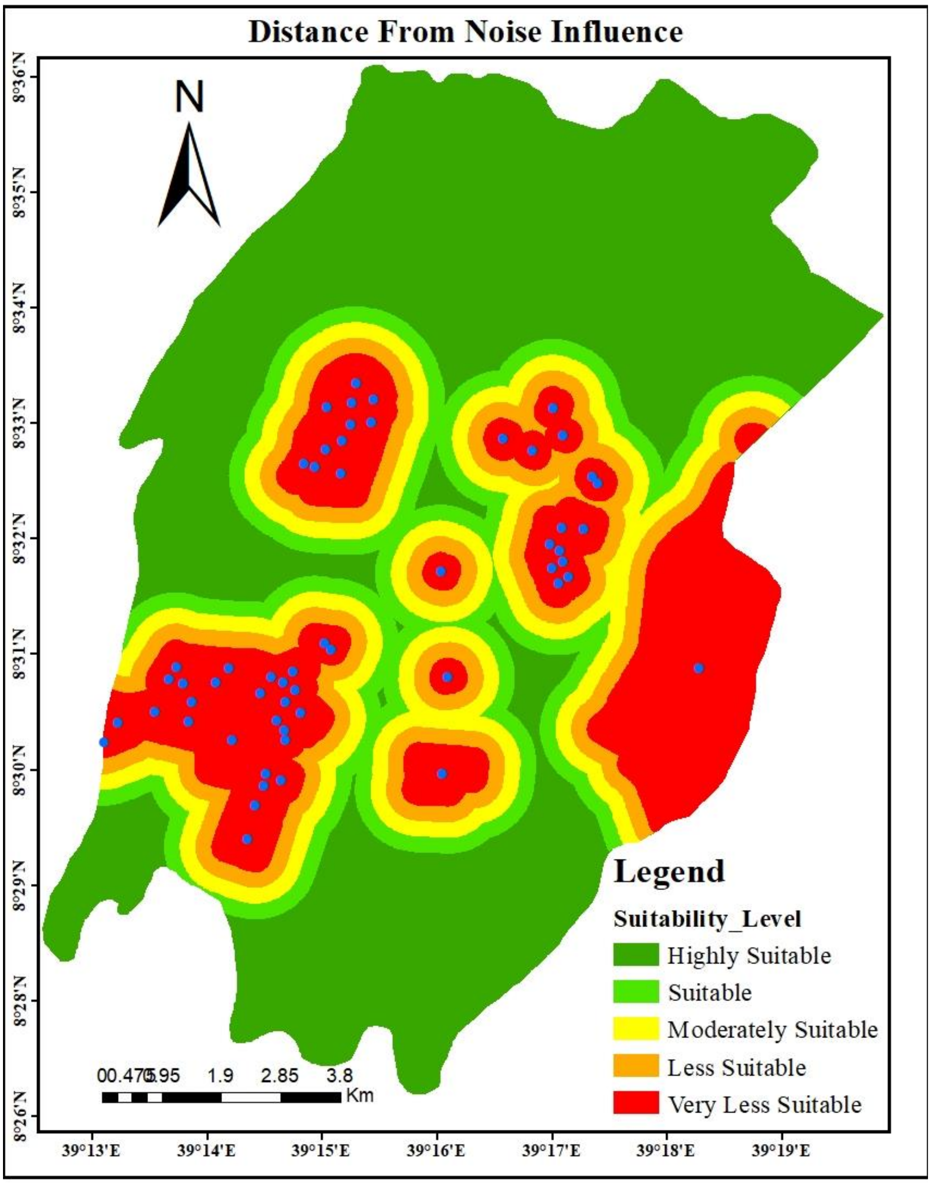
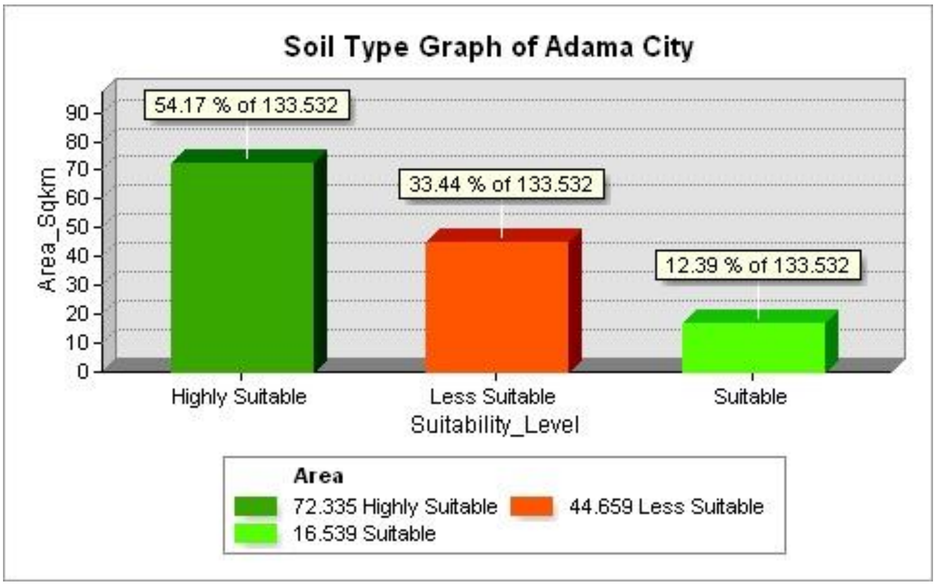


Figure 9: Reclassified distance from factory map

4.6.5 Suitability of Soil Type

In this study area there are three principal soil types which are Eutric Cambisols, Haplic Xerosols and Lithosols. Eutric Cambisols is the most productive soil on the earth and have relatively good structure and chemical properties hence are not greatly affected by degradation processes until these become large. Eutric Cambisols are considered as highly suitable soil because of increasing clay with depth, they tend not to be greatly impacted by degradation. Haplic xerosols are soils of the deserts, with low levels of organic matter and are subject to wind erosion and concentration of soluble salts but relatively suitable. Whereas Lithosols was considered as less suitable compared to the other types because of their Lack of moisture and shallow profile precludes cultivation (FAO–UNESCO., 1974).



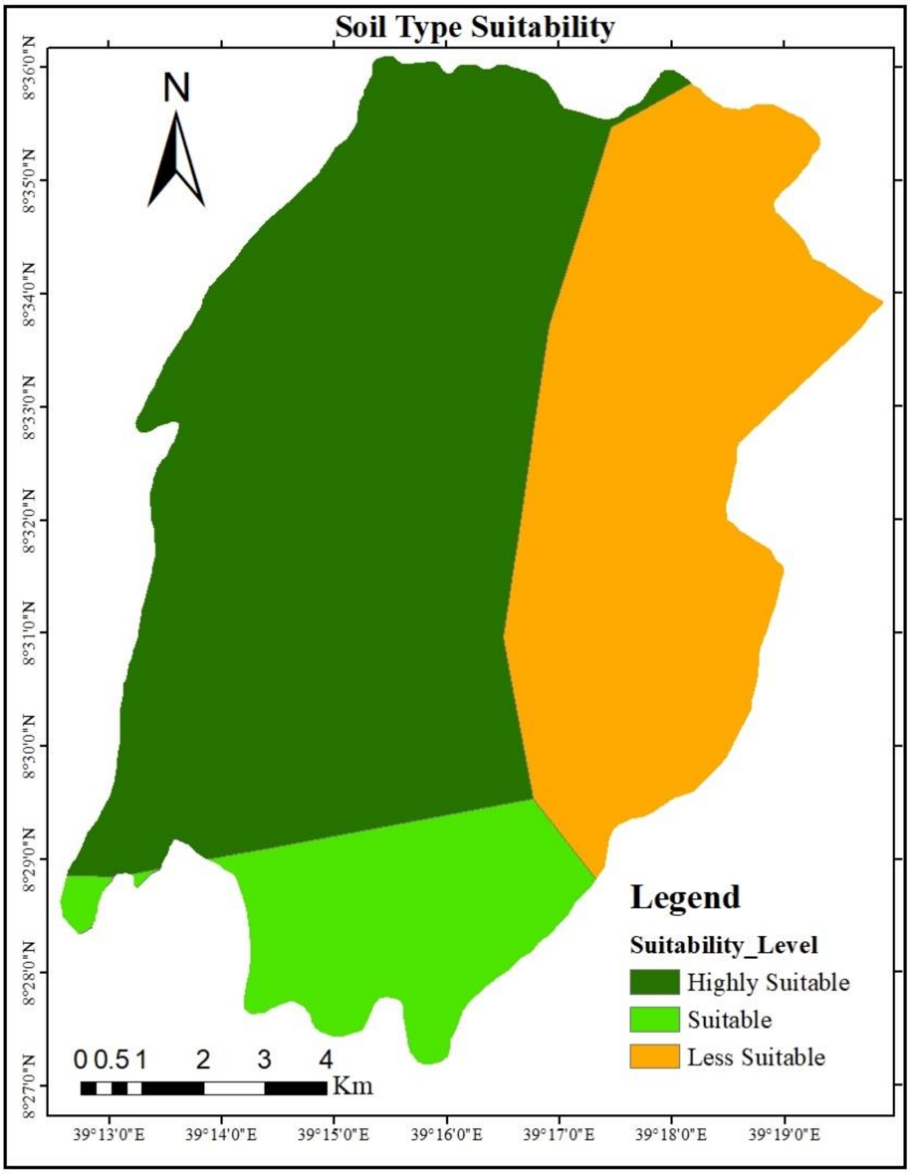


Figure 10: Reclassified soil type map

Table 13: Reclassified soil type and area coverage of their suitability level

FAOSOIL	Soil Name	Suitability Level	Value	Area (Sq.Km)	Area (%)
Be9-3c	Eutric Cambisols	Highly Suitable	5	72.549171	54.28
Xh16-a	Haplic Xerosols	Suitable	4	16.347493	12.23
I-Re-3a	Lithosols	Less Suitable	2	44.713196	33.45

4.6.6 Suitability of Slope

Different studies have shown that low-slope areas are highly suitable for urban green space development ((Abebe, 2017); (Dagistanli C, 2018); (Pareta k., 2019); (Hailemariam B. A, 2021)) and the main objective of green space development is to create a common space for use by all sectors of society such as children, the elderly and the disabled; so, taking the necessary measures in this respect is essential (Yousef AZ, 2014)Based on the (FAO., 2006), the slope value 0 to 0.2 % is considered as flat and up to 5% gently slope and these slopes are considered as highly suitable in this study. Slope value 5 to 10 % and 10 to 15 % is called sloping and considered as suitable and moderately suitable respectively in addition strongly sloping(15 to 20 and >20) considered as less suitable and very less suitable respectively for this study.

Table 14: Reclassified slope and area coverage of their suitability level

Slope (%)	Suitability Level	Value	Area_SqKm	Area Coverage in %
0 - 5	Highly Suitable	5	31.3448	23.45
5 - 10	Suitable	4	44.9912	33.66
10 - 15	Moderately Suitable	3	25.644	19.19
15 -20	Less Suitable	2	13.132	9.83
>20	Very Less Suitable	1	18.5104	13.85

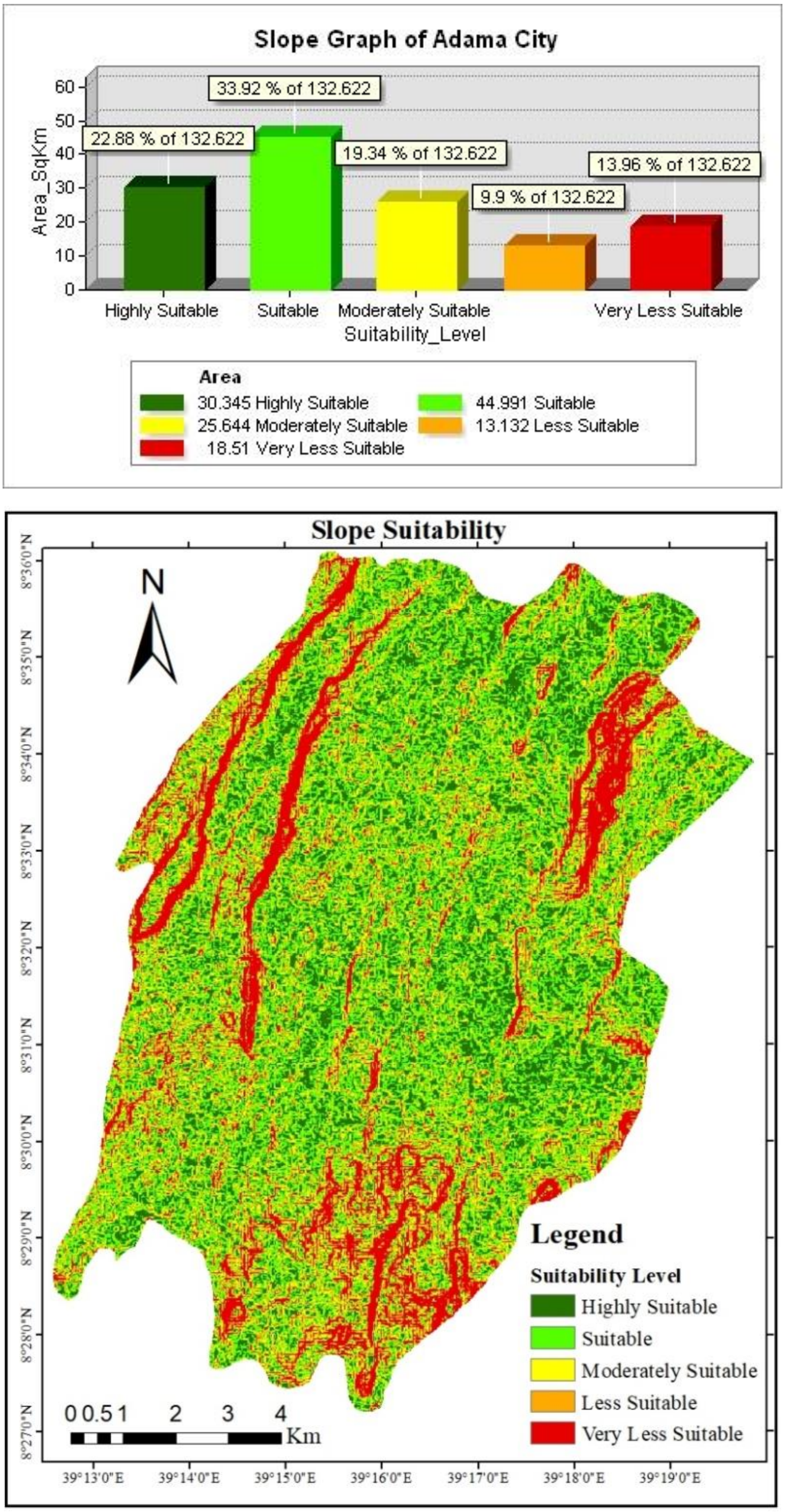


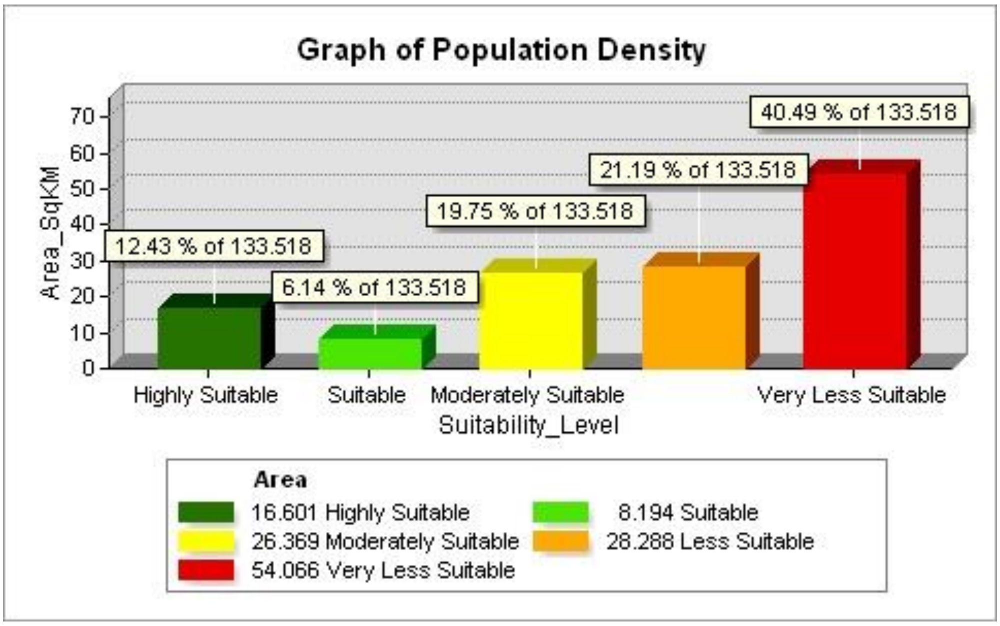
Figure 11: Reclassified slope map

4.6.7 Population Density

Population density is one of the major criteria for suitable site selection of green space. Some researchers ((Elahe T et al., 2014); (Heshmat P et al., 2013); (Pantalone S, 2010); (Ahmed IC, 2011) (Elahe T, 2014); (Yousefi et al., 2016); (Dagistanli C, 2018); (Pokhrel S. , 2019); (Gelan E. , 2021)) recommend that areas closer to residential areas are highly suitable for developing green space. Based on the those researchers claim On the basis of this claim, the study area is densely populated in the central parts of the Town and it is considered as highly suitable for the development of urban green space. The outer portion of the Town is sparsely populated hence it serve as less suitable and very less suitable

Table 15: Population Density and area coverage of their suitability level

Population Density	Suitability Level	Value	Area Sq.Km	Area Coverage in %
<500	Highly Suitable	5	16.600788	12.42
500-2000	Suitable	4	8.19396	6.13
2000-5000	Moderately Suitable	3	26.369388	19.73
5000-8000	Less Suitable	2	28.288116	21.17
>8000	Very Less Suitable	1	54.065556	40.45



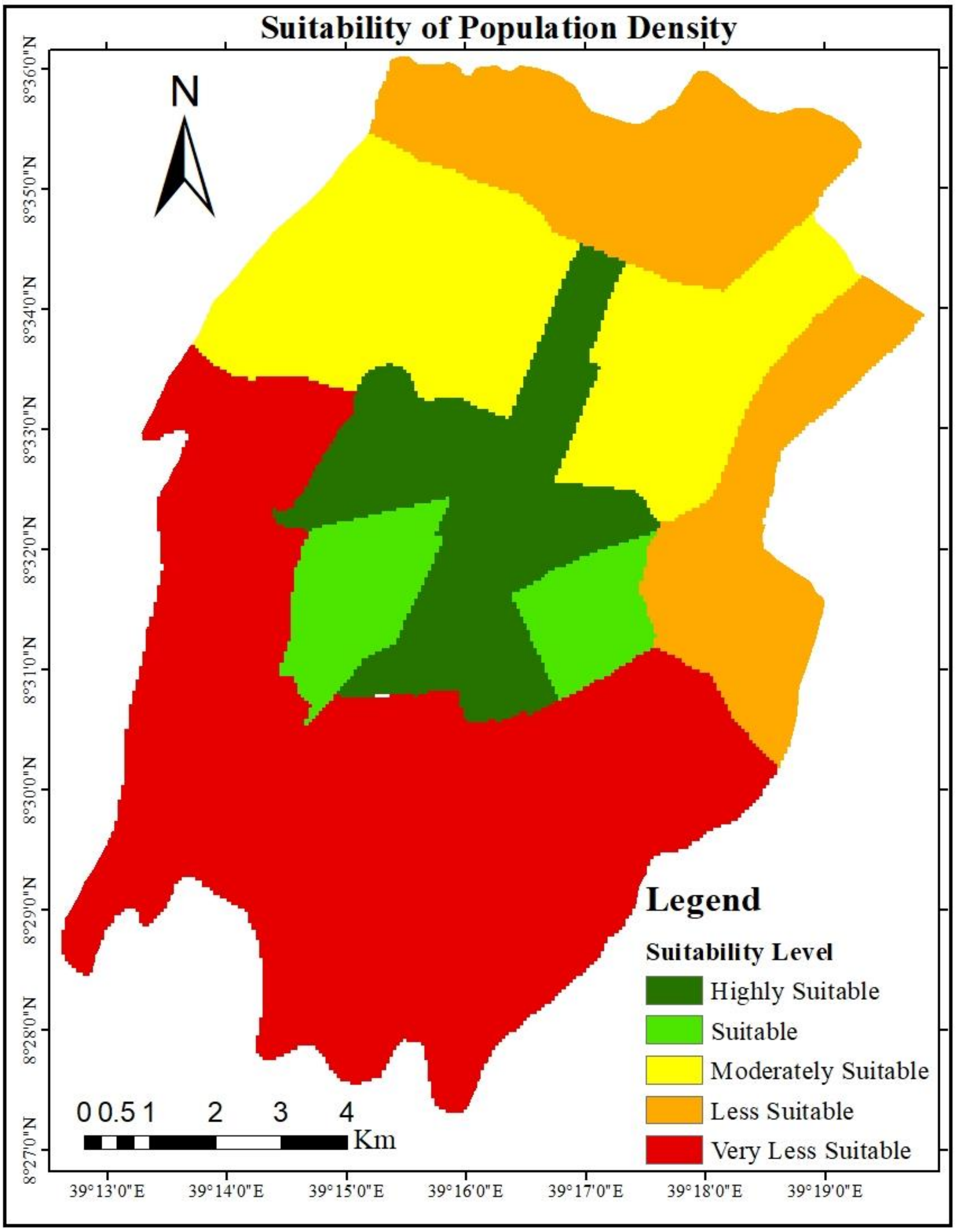
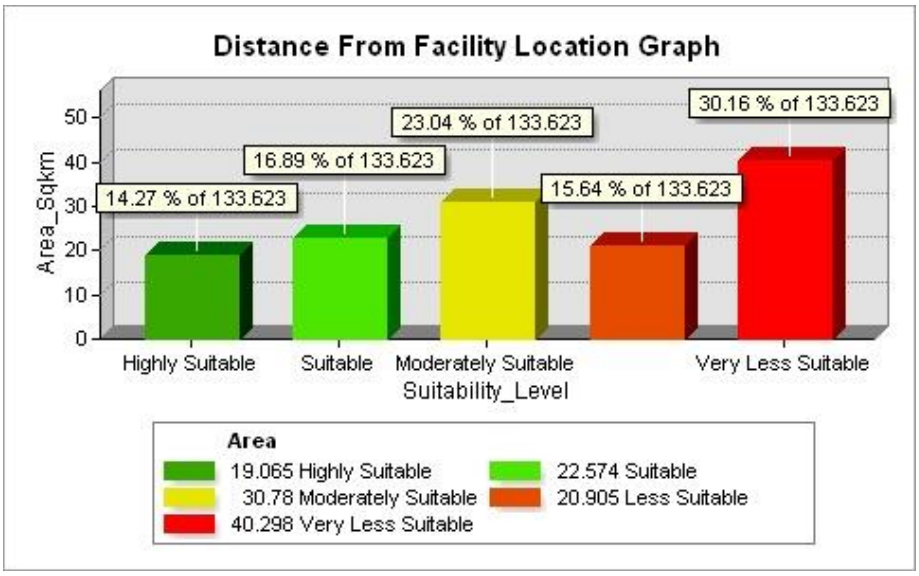


Figure 12: Reclassified suitability level of population density

4.6.8 Suitability of Distance from Facility Locations

Facility locations (which includes: schools, colleges, Hospitals and major health facilities locations) that are essential to get all services and need some green space near by such locations. As different studies claim, the lands which are closer to those facilities are more suitable than farther lands ((Yousefi et al., 2016); (Pokhrel S. , 2019)). Therefore, in this study if distance from the facilities location is less than 500 m, it was considered as highly suitable; 500m – 2000m,suitable; 2000m- 5000m, moderately suitable; 5000m–10000m, less suitable and >10000m, very less suitable for green space development.



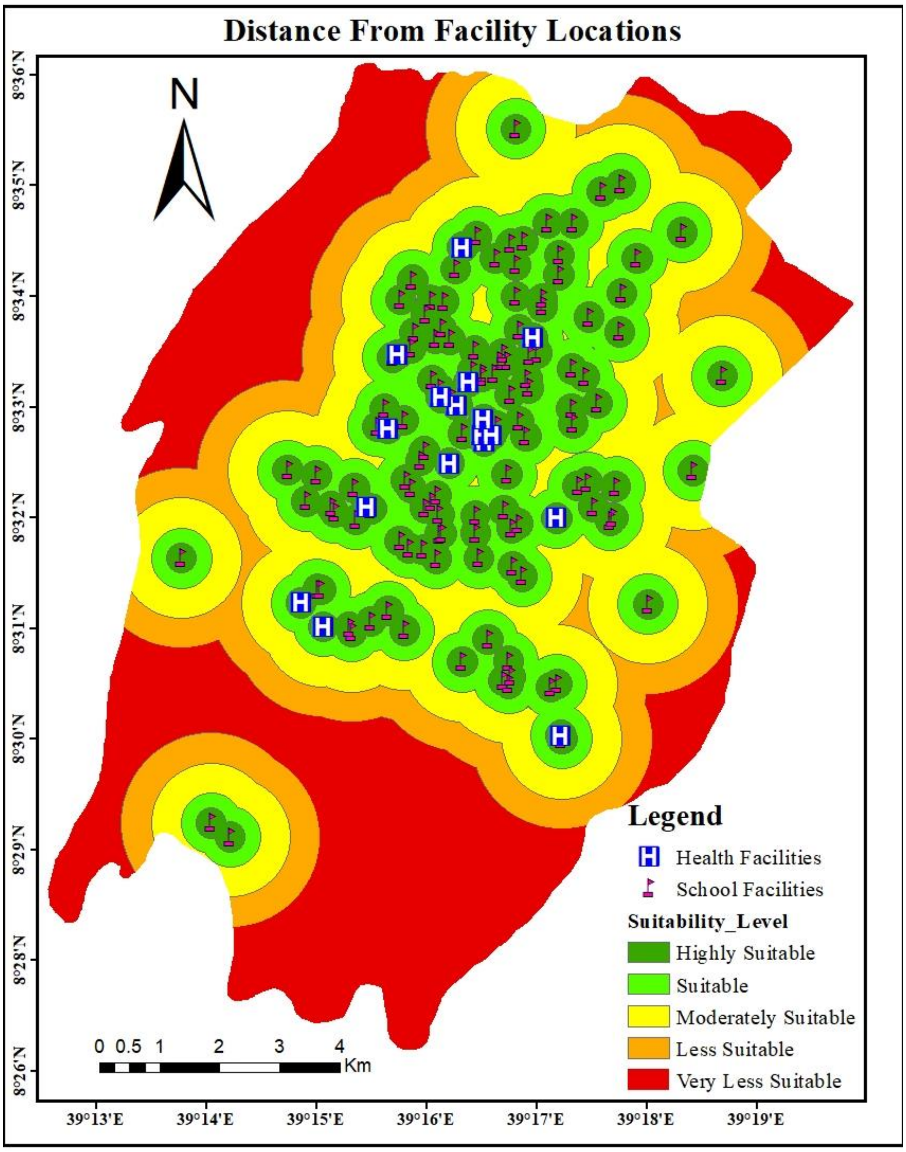


Figure 13: Reclassified Distance from Facility Location map

Table 16: Distance from Facility Location and area coverage of their suitability

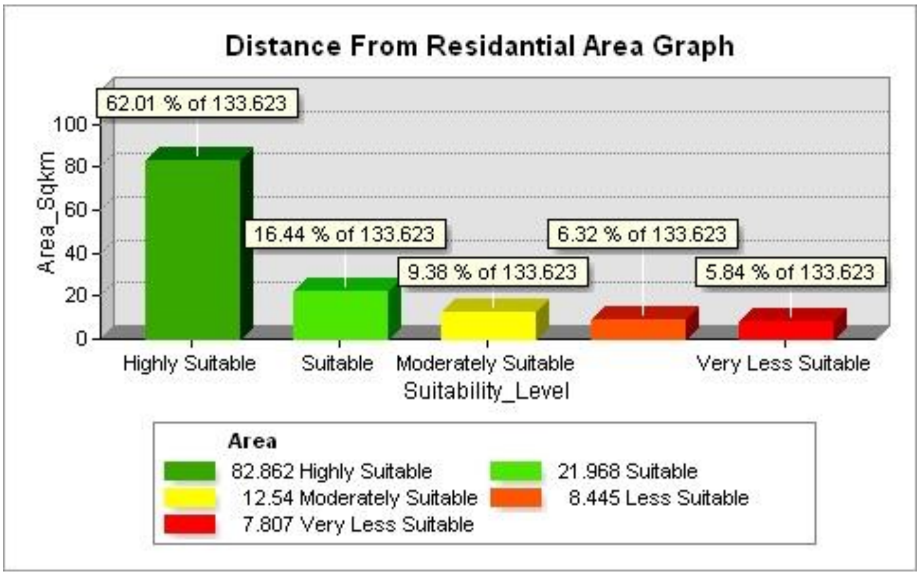
Distance from Facility Location	Suitability Level	Value	Area Sq.Km	Area Coverage in %
<250	Highly Suitable	5	19.06754	14.27
250-500	Suitable	4	22.573027	16.89
500-1000	Moderately Suitable	3	30.779827	23.03
1000-1500	Less Suitable	2	20.904539	15.64
>1500	Very Less Suitable	1	40.333331	30.18

4.6.9 Suitability of Distance from Residential Area

Green spaces should be accessible to settlement areas in urban regions since they have multiple ecological, social, and economic benefits, according to previous studies ((Malmir et al., 2016); (E & Aydınoglu AC., 2020); (Gelan E. , 2021)). Users were negatively impacted by the distance between settlement areas and green spaces, and it was found that the parks, playgrounds, and sports fields nearest to settlement areas are the most well-liked green spaces. As a result, it's crucial to take into account how close to the settlement area green spaces actually exist. For the purposes of this study, distances of 500m, 500m to 1000m, 1000m to 1500m, 1500m to 2000m and >2000m from the settlement area have been rated as highly suitable, suitable, moderately suitable, less suitable and very less suitable, respectively.

Table 17: Distance from residential area and area coverage of their suitability

Distance from Residential Area	Suitability Level	Value	Area_SqKm	Area Coverage in %
<500	Highly Suitable	5	82.862052	62.01
500-1000	Suitable	4	21.967571	16.44
1000-1500	Moderately Suitable	3	12.540226	9.38
1500-2000	Less Suitable	2	8.445214	6.32
>2000	Very Less Suitable	1	7.807455	5.84



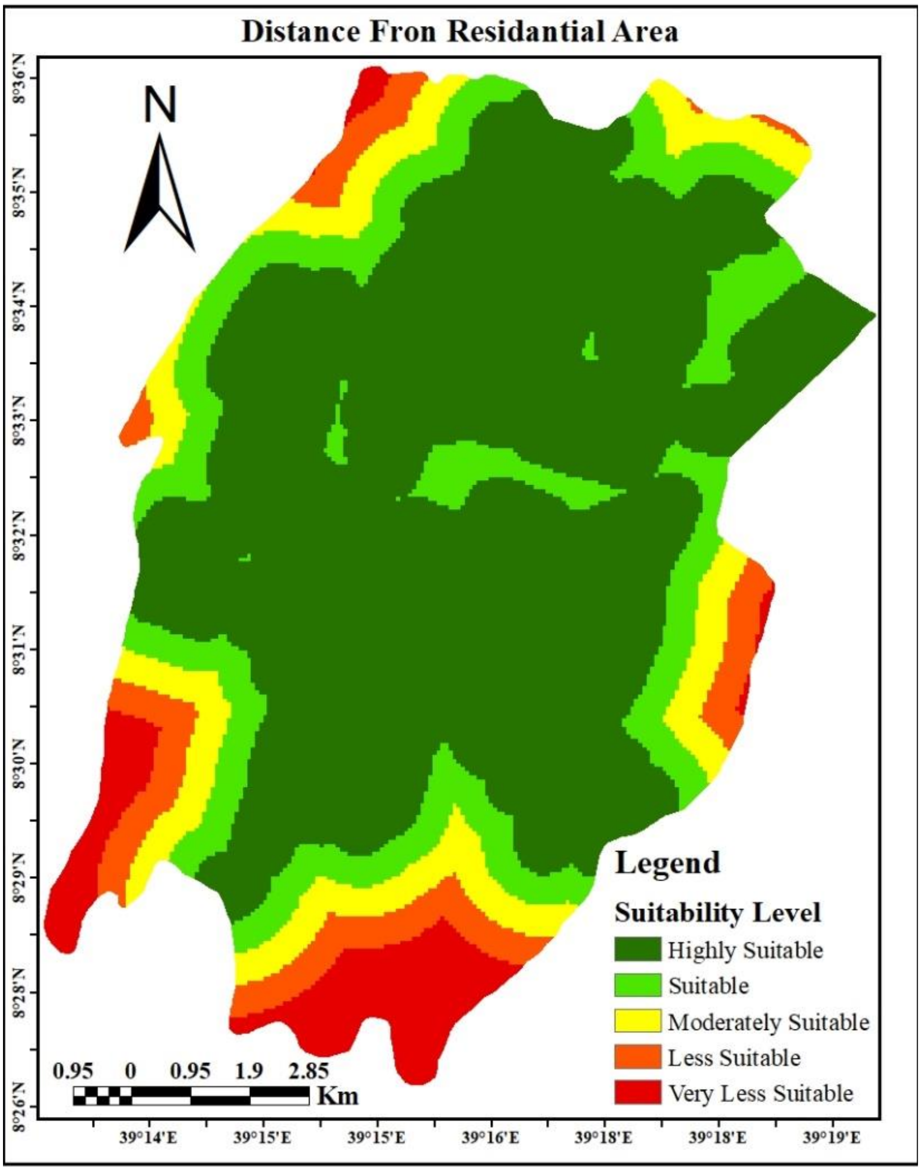


Figure 14: Reclassified Distance from residential area map

4.7. Fuzzy Analytic Hierarchy Process Weight Derivation

4.7.1 Fuzzy pair-wise comparison matrices of criteria

By creating a fuzzy pair-wise comparison matrix, the triangular fuzzy number AHP approach used in this work can significantly improve the computation of fuzzy vectors or criteria weight in the interval. The average of the TFNs' values on a scale from 1 to 9 was used to determine the weights of each criterion. By using consistency ratio, the proposed FAHP performance's accuracy was evaluated. The average pair-wise comparison of the criteria was shown in Table 18 below, with values denoted according to importance or preferences.

Table 18: Fuzzy average pair-wise comparison of the criteria

Criteria	**LULC**			**RA**			**RD**			**STR**			**FL**			**SL**			**ST**			**NI**			**PD**			**Weight**
LULC	1	1	1	1	2	3	1	2	3	2	3	4	3	4	5	5	6	7	7	8	9	7	8	9	9	9	9	**25**
RA				1	1	1	1	2	3	2	3	4	2	3	4	4	5	6	6	7	8	7	8	9	9	9	9	**22**
RD							1	1	1	1	2	3	2	3	4	3	4	5	4	5	6	5	6	7	7	8	9	**17**
STR										1	1	1	1	2	3	2	3	4	3	4	5	3	4	5	5	6	7	**12**
FL													1	1	1	1	2	3	2	3	4	2	3	4	3	4	5	**8**
SL																1	1	1	1	2	3	1	2	3	2	3	4	**6**
ST																			1	1	1	1	2	3	1	2	3	**4**
NI																						1	1	1	1	2	3	**3**
PD																									1	1	1	**3**

Where: LULC = Land use/Land covers RA = Residential Area, RD = Road, STR = Stream FL = Facility Location, SL = Slope, ST = Soil Type NI = Noise Influence, and PD = Population Density

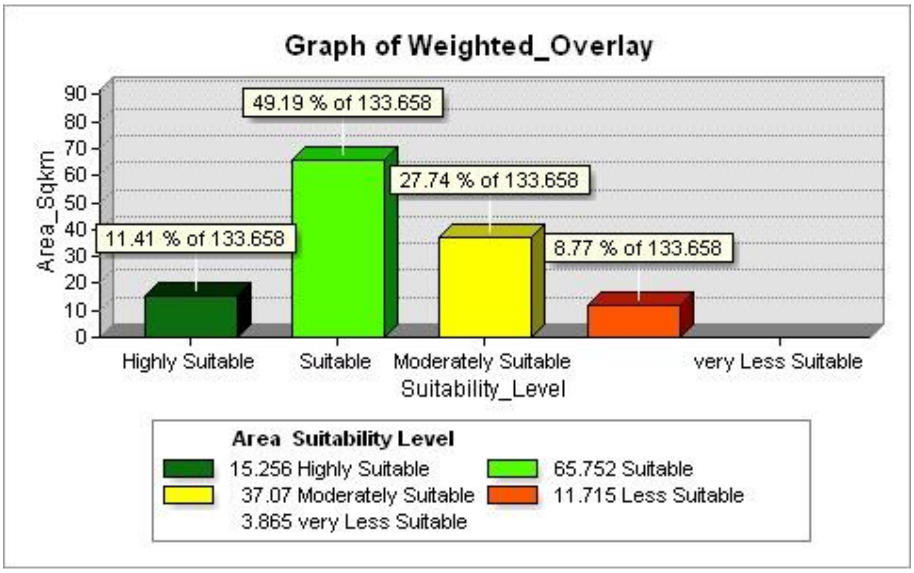
The nine factors were tested on the suggested FAHP technique using the dataset in Table 18 in order to calculate the weight for suitable site selection for urban green space. According to the result produced by the suggested FAHP in Table 18, the disputed criteria have varying degrees of influence on urban green space. As a result, the computed weight value of 25 demonstrates that LULC was given the highest priority. Residential area, road, Stream, facility location, slope, soil type, noise influence, and population density were also given weight values of 22, 17, 12, 8, 6, 4, 3 and 3 accordingly. In addition, the proposed FAHP techniques' consistency ratio was 0.04, which is less than 0.1; this indicates that the suggested FAHP approach is appropriate. Thus, the relevance of each aspect in determining a site's eligibility for UGS is highlighted by the weight provided to each factor.

4.8. Weighted Overlay Analysis

The weight overlay tool in the ArcGIS spatial analysis extension was used to execute the overlay analysis once all parameters were prepared in reclassified raster format and criteria weights were determined for each factor. To convey the relative importance of each criterion to the other criterion for the selection of an appropriate location for UGSs, a weight value was provided to the reclassified input datasets. All of the reclassified datasets were overlaid in order to choose the best locations for urban green space development as shown in figure 15 below.

Table 19: Final suitability levels with its area coverage

Level of Suitability	**Area in Sq.Km**	**Percent of Total Area**
Highly Suitable	15.255846	11.4140689
Suitable	65.752221	49.19428138
Moderately Suitable	37.07028	27.73512069
Less Suitable	11.715159	8.765009295
Very Less Suitable	3.864761	2.891524228



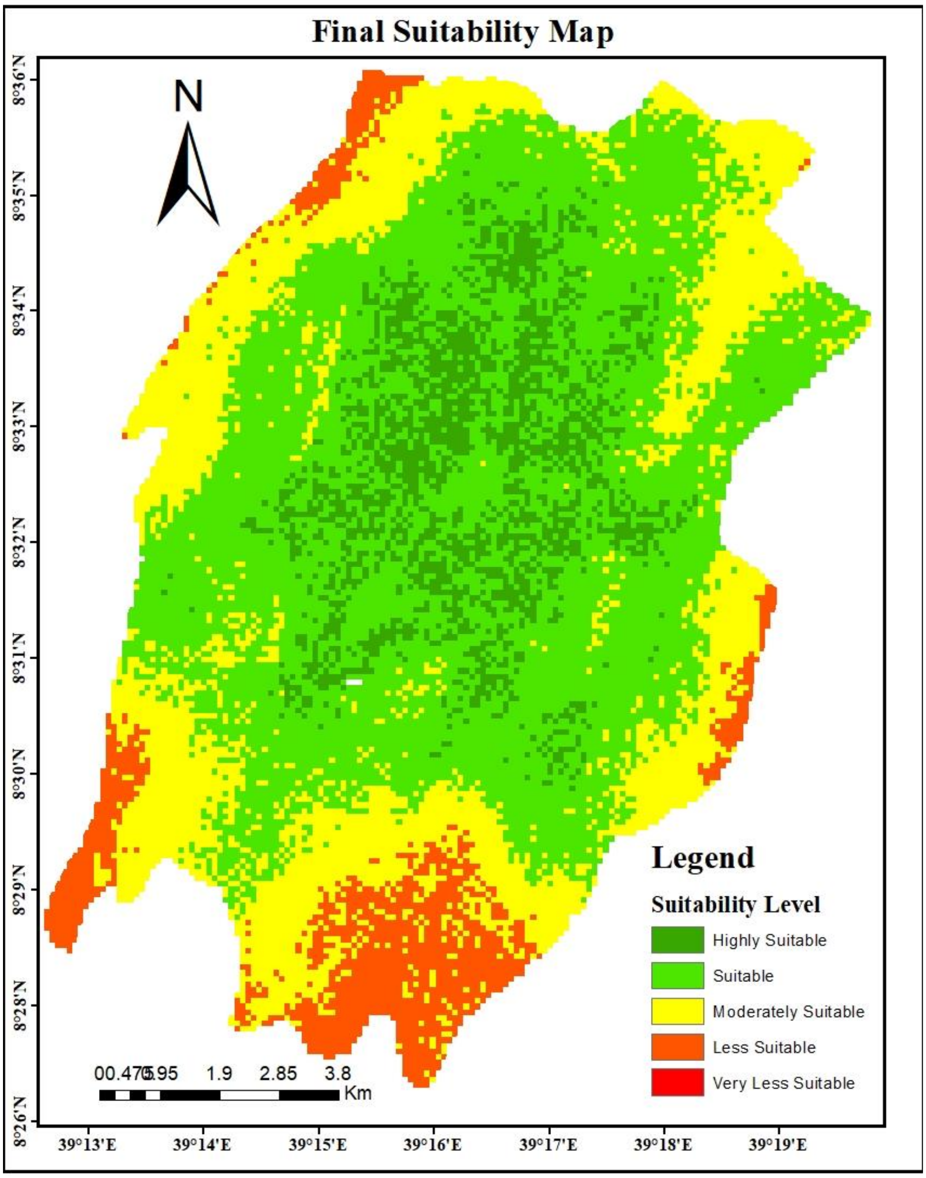


Figure 15: Final Suitability map of urban green space

According to GIS-based multi-criteria analysis, the overall suitability map indicates that 15.255846, 37.07028 and 65.752221 km^2 areas are highly suitable, suitable and moderately suitable respectively, for the development of green space. In addition to this 8.77%(11.715159 km^2) and 2.89% (3.864761km^2) area are less suitable and very less suitable respectively for urban green space development. The majority of the chosen sites are classified as bare land and farm land areas in the land use plan.

4.9. Field Verification

The purpose of the field verification is to confirm the classification and accuracy assessment of the input data. By going to the location and contrasting the findings with your observation, field verification was carried out. Then, using GIS-MCDM, afield verification was conducted to determine the actual location of the suitable area with reference to Sole and Danbela recreational and botanical gardens, Adama Science and Technology University, the north-eastern part of the Town following roads to Dire Dawa are some of the best suitable sites for UGS development.

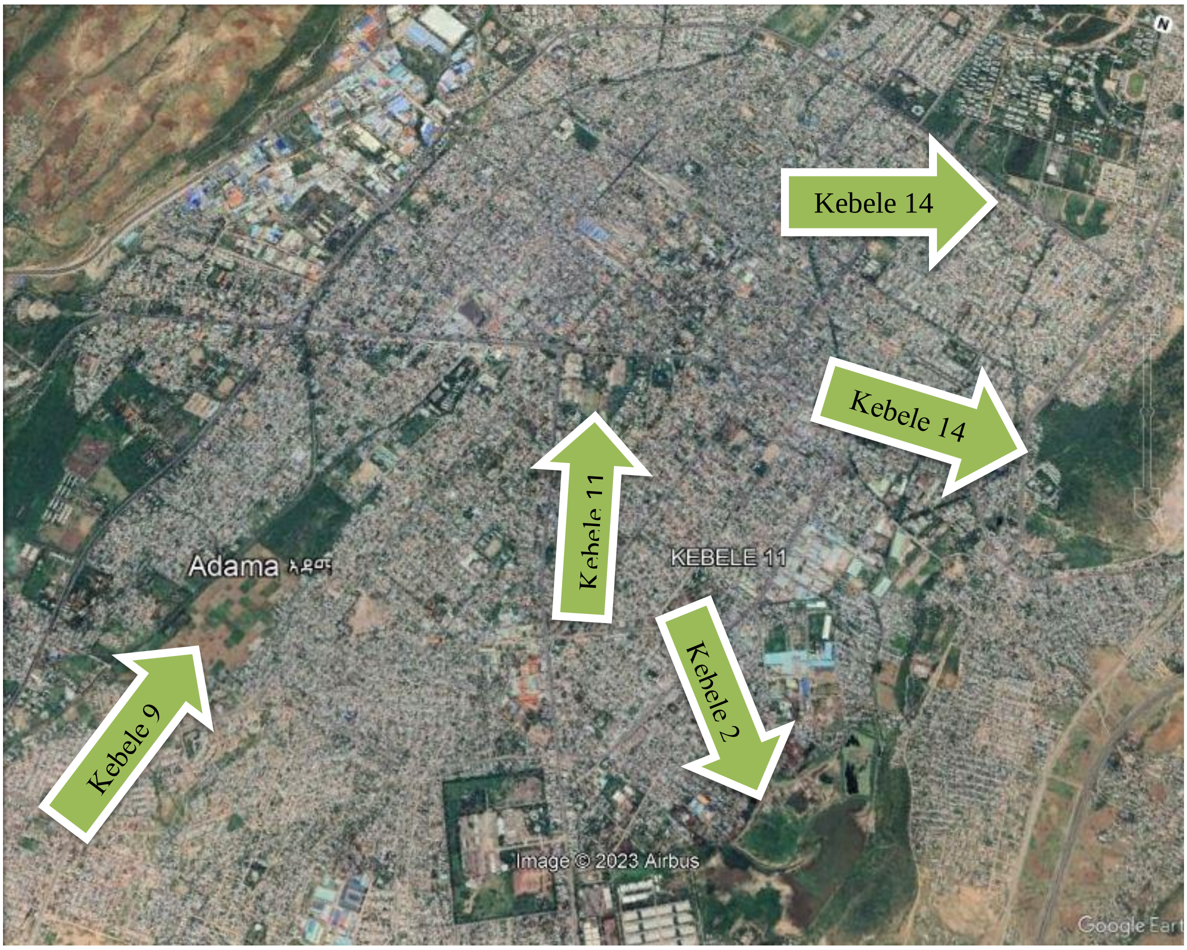


Figure 16: Selected areas for green space development

4.10. Discussion

Globally, urbanization and population growth have both increased rather quickly. Changes in LULC patterns, industrialization, and social transformation are outcomes of urbanization processes. One of the main repercussions of urbanization is the reduction of urban green areas as a result of infrastructure development and other development activities. However, the process of LULC change in urban areas commonly has terrible impacts on UGS (Dinda et al., 2021). Urban green space (UGS) is essential for decreasing the negative effects of urbanization.

There is different result of object based and pixel based classification when using different remote sensing images. Classified LULC maps from remote sensing imageries may contain some errors. Therefore, accuracy assessment was employed to find out those errors so as to ensure reliability of the produced LULC maps. In this study the error matrix of overall accuracy of 98.5% with the kappa statistics 98.1%. So, the effectively classification can be seen from object based classification because it give better accuracy assessment by using high spatial resolution images.

Besides, one comprehensively utilized MCDM strategy is the AHP. AHP, in spite of its simplicity in idea, it can't consider imprecise input. The weights derived by AHP method do not represent the relative importance of decision criteria or alternatives. So, in this study the FAHP has demonstrated its effectiveness as a MCDM technique which includes a few preferences inside uncertain, imprecise and obscure settings than AHP method. Therefore, understanding the existing LULC patterns, requires high resolution remote sensing images that have high accuracy in order to detect different land use in the study area and to identify a suitable sites for UGS development, it requires integration of geospatial technology and GIS based MCDM using FAHP in order to select the suitable site for UGS and assist an effective planning of green area in sustainable way.

The growth of urban green spaces is influenced by a wide range of determining factors (both main causes and sub factors). Accessibility, physical, environmental, and socio-economic considerations are important factors. In order to choose a suitable location for the development of urban green space, the current study used nine site selection criteria, including environmental criteria (stream/river), accessibility criteria (road and railway), physical criteria (slope and soil types), and socio-economic criteria (LULC, population density, noise influence, distance from residential area, and distance from facility locations). The final map reveals that, respectively 11.41%, 49.19%, 27.74%, 8.77% and

2.89% of the research area have been classified as highly suitable, suitable, moderately suitable, less suitable and very less suitable for the development of green space. Therefore, understanding existing LULC patterns and identifying suitable sites for urban green space development, requires accurate use of geospatial technology in order to assist an effective planning process of green areas in a sustainable way.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Urban Green Infrastructure in general and urban Green space in particular is important settings for improving the quality of urban life. In this study, determining spatial distribution and accessibility of existing green space were determined from Structural plan of the city and LULC classifications. In addition to this site suitability analysis using GIS based MCDM, In this study, OBIA or classification were applies to determine LULC dynamics by using eCognition application in order to identify potential sites for urban green space development in Adama City with GIS based MCDM approach. FAHP method has been applied extensively for weight derivation or decision making problems involving multiple criteria evaluation/selection of alternatives. The decision group is therefore combined using the FAHP-GIS-MCDM approach. By using fuzzy numbers as linguistic terms, the subjectivity and ambiguity of the alternative selection process are allocated with FAHP's precise and efficient provision of the ideal weight in the selection of potential site for UGS development.

According to the report, there aren't much potential for developing green spaces in Adama City due to its fast urbanization. In the 2018 proposed structural plan, 42.43381 sq. km (31.75%) of the study area were designated for open spaces, a botanical garden, a mountain green frame, a roadside green, parks, a zoo, urban agriculture and horticulture, and sport fields but most of them were not implemented still now as LULC classification shows. However, the Ethiopian Planning Strategy and Urban Land Management Plan allotted 30% of the land for green areas; therefore there were no appropriate distribution and still not enough green spaces with in this rapid urbanization (MoUDC, 2014). So, in order to select appropriate places, land suitability study is a crucial step for green space development.

OBIA was performed on 0.3m spatial resolutions planet image. As the results of LULC analysis the year 2022 revealed, the major part study area was covered by farm land 46.381458 sq.km (34.70%) of the total area. Vegetation, built-up, bare land and Water body were covered 17.05%, 16.33%, 31.74% and 0.18% of the area respectively.

Identifying potential sites for UGS development is a difficult process that takes into account different conditions and accessibility considerations. In order to properly select a site that would be suitable for UGS development in Adama City, nine criteria were taken into account in this study. These were: LULC (25%), distance from residential Area(22%), distance from road (17%), distance from Stream (12%), distance from facility locations(8%), slope (6%), soil type (4%), distance from factory (3%) and population density (3%) in that order. Site suitability research was carried out to determine potential regions that would be appropriate for UGS development.

Based on the final overlay result of this analysis out of total area 133.658267 sq. km found in study area, 15.255846, 65.752221, 37.07028 sq. km are highly suitable , suitable and moderately suitable respectively whereas 11.715159 and 3.864761 sq.km are less suitable and very less suitable respectively to determining potential side for UGS development.

5.2. Recommendation

Based on the finding of this study the following recommendations were designed. In order to implement appropriate planning, particularly for UGS development, the City Development Plan should emphasize instead of horizontal expansion, use vertical built-up expansion. Additionally, it should be encouraged for the neighborhood and other interested parties to create and manage a community garden in accordance with the City structural plan. In order to enhance and improve both the quality and quantity of UGS at the national level, the modification of green space should be continuously researched and executed with the proper and effective measures.

As a result, the City administration, municipality, and beatification should be required to adhere to the national standard of green space coverage of the city outline in the master plan and follow its implementation, find current information about LULC using geospatial technology, and develop policy to develop and manage UGS in the context of GIS-based MCDM processes.

This study concentrates on spatial distribution of Green space as a whole in this Therefore, future studies should be considering spatial distribution and accessibility of each green area types separately to overcome that problem of insufficiency in green space types and it is better to select different factors for potential site selection.

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APPENDICES

Appendix 1: Coordinate of health facility locations

Name of health facilities	Easting	Northing
Sire Robi Healthy Center	518,139.01	937,384.55
Mary Stop Clinic	521,171.47	940,240.13
Health Center	527,632.54	941,453.07
Health Center	531,585.51	939,640.64
NGO/Mary Stops Hospital	528,358.50	943,443.89
Health Center	531,515.14	943,255.90
Rifty Valley Hospital	529,731.14	944,168.75
Gada Health Center	528,705.16	944,746.32
Noah Hospital	530,306.38	944,532.21
Iyor Clinic	530,273.02	944,633.12
Health Center	530,439.22	944,640.64
Adama Hospital	530,299.25	944,901.72
Health Association	529,858.68	945,129.91
Family Association Clinic	529,594.92	945,266.25
Medhanialem Hospital	530,041.14	945,523.29
Chilalo Health Center	528,866.88	945,980.08
Adama General Hospital	531,125.11	946,255.65
Health Center	529,946.77	947,764.46
New Vision KG School	527267.23	941848.62

Appendix II: coordinate of school facilities

Name of School facilities	Easting	Northing
Abdi boru school	529145	946350
Abebe Lefire Academy	529436	946885
Abnezer KG school	529739	946236
Abuna Georgorios KG school	529063	942759
Abuna Georgorios school	531767	945079
Abuna Georgorios school	530838	947470
Adaamaa Bosat	529575	942991
Adaamaa SAd.2ffaa	530771	943092
Adama Boset Elementary school	529604	942995
Adama no 3 school	528532	944780
Adama no 4 school	530692	943982
Adama youth Academy	529333	946653
Akber Academic School	532129	943449
Almaz KG school	529836	947401
Ambassador School	531795	948163
ASTU	532059	946602
Awash primary and secondary school	531049	945424
Awash primary and secondary school	531023	945579
Barnabas school	529497	946250
Birayit mayindis School KG-10	530891	944864
Birra Academy School	530711	940874
Bole Primary School	532271	948691
Boolee	530680	945867
Burka primary and Secondary School	530636	940552
Burqaa	530718	940505
Catholic elementary school	531771	945741
Catholic primary school	529516	942585
Chefik primary school	530743	945310
Dabe Soloke Primary school	533788	944047
Dabee	534272	945621

Daga Adi Primary school	533603	948010
Daga Adi Primary school	532584	948820
Daga adi school	528657	945074
Dambalaa	527821	943349
Dambela Elementary school	527765	943449
Dana School	530373	941237
Dasangam School	530887	946390
Day_star Academy	532198	945172
Eba primary school	531191	946001
Egziabeher Ab church school	532494	943783
Elementary school	530149	946041
Elementry School	528430	941539
Elementry School	528106	941365
Elementry School	528065	941439
Elementry School	533036	941824
Elementry School no 2	530123	945722
Exa Academy	530638	943384
Excel School	530759	947822
Family School	531981	945603
Fekir KG School	531524	940493
Fekir KG School	530943	942288
Galila school	528150	943758
Gary primary school	528911	942882
Geladios TVET	530277	945662
Gooroo sad.2ffaa	528788	945937
Goyas School	529641	529641
Green Hill school	531794	944831
Guda Miju School	531367	948162
Hamara Noha Academy	531562	947636
Harambe Collage	530514	944791
Hawaas	530276	945605
Hawi Academy	530190	947945
Haylig KG school	529329	943430

Haylig KG school	529431	943526
Hayu Borifan School	530676	945874
Holly angels Elementary school	531072	945954
Holly angelsƒ?? School	528431	943411
Holly savior school	529599	946411
Hunde Gudina primary school	529449	945557
Ifaborusaqaqalloo	530227	942591
Kamara school no2	532562	946359
Kena KG School	532409	943216
Kena KG School	532450	943267
kening school	531004	944624
KG School	526086	937949
KG school	529283	942731
KG School	527350	943538
KG School	529256	944217
KG School	529765	945249
KG School	529564	945412
KG School	530621	945997
KG School	531275	946782
KG School	532856	947583
KG School	531553	947307
KG School	530498	947576
Kidus Kuran School	528985	941390
Kidus Kuran School	528965	944881
Lugo Primary School	528713	941710
M/B.Bultii Addaa WMO	527540	942073
Makobili School	529096	946084
Melka Hidda School	525769	938181
Midland school	530565	945865
Nafyad KG School	529005	943889
Nafyad School no 2	531283	946914
New Vision KG School	527267	941849
Nigat Elemntary school	529121	947217

Nowzer Academy	529641	946866
Oda primary school	530962	947869
Oda School	527588	942063
Preparatory	531604	939584
primary school	530879	943166
primary school	529316	944366
Private School	531419	940448
Private School	527042	944052
progress Academy	530791	942455
Qobo Luto Temsea Elementery School	521189	940775
Qobo Luto Temsea Elementery School	521139	940655
Rift Valley University Collage	529091	943762
Royal Collage	529960	944667
School	530168	943007
school	530167	943298
School	532596	946997
Sekekelo Primary School	530840	949735
Siree Abba Bunaa	525275	942591
Solomon KG and School	531872	943793
St. Joseph School	529517	943639
St.Joseph KG School	529558	943316
Star Academy	528925	946891
TVET(Garment)	530476	945666
Unity Academy	528178	943230
Unity University	527518	943965
Wisdom school	530837	946948
Yalewet School	529949	940865
Yasmin Elementry School	532027	943851
Yomada KG School	530749	940615