SUITABILITY ANALYSIS FOR URBAN GREEN SPACE DEVELOPMENT USING GEOSPATIAL TECHNOLOGY: A CASE OF ADAMA TOWN, ETHIOPIA

Yirgalem Gerbaba Gurmessa

A Thesis Submitted to

The Department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Geo-informatics Engineering

Office of Graduate Studies

Adama Science and Technology University

July, 2021

Adama, Ethiopia

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APPROVAL SHEET

I, the advisor of the thesis entitled "Suitability Analysis for Urban Green Space Development Using Geospatial Technology: A Case of Adama Town, Ethiopia" and developed by Yirgalem Gerbaba Gurmessa, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Roba Gemechu(PhD)	______________	______________
Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Yirgalem Gerbaba Gurmessa have read and evaluated the thesis entitled "Suitability Analysis for Urban Green Space Development Using Geospatial Technology: A Case of Adama Town, 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 Engineering.

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Finally, 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).

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

DECLARATION

I, Yirgalem Gerbaba Gurmessa hereby declare that this Master Thesis entitled "Suitability Analysis for Urban Green Space Development Using Geospatial Technology: A Case of Adama Town, 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.

Yirgalem Gerbaba Gurmessa	______________	______________
Name of the student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Suitability Analysis for Urban Green Space Development Using Geospatial Technology: A Case of Adama Town, Ethiopia" prepared under my guidance by Yirgalem Gerbaba Gurmessa submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Geo-Informatics Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Roba Gemechu(PhD) _______________ ________________

Advisor Signature Date

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TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

LIST OF APPENDICES

APPENDIX PAGE

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
GII	Geospatial information 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
UGS	Urban Green Space
UTM	Universal Transfer Mercator
WLC	Weighted Linear Combination

ABSTRACT

Urban green space (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. Urban green spaces are an important component of the urban ecosystem that provide many environmental, socio-cultural and economic services that contribute to the quality of life in urban areas. One of the major impacts of urbanization is a shrinking of urban green spaces, through the development of infrastructures and various development projects. LULC change particularly in urban areas is becoming the major factor in reducing green spaces extent. In the planning, management and development of urban areas, attention to the appropriate selection of urban green spaces with regard to the importance that these spaces have from the perspectives of environmental, socio-cultural and economic aspects is an essential requirement. 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, this study aimed at identifying suitable sites for urban green space development in Adama town using geospatial technology that assists an effective planning process of green areas in a sustainable way. The extent of LULC change with respect to urban green space from 1991 to 2021 was assessed using geospatial technology. The suitability analysis was done by adopting GIS-based Multi-criteria analysis (MCA) using the analytical hierarchy process (AHP) to select suitable sites for urban green spaces. Several spatial and non-spatial datasets i.e., LULC, population density, transportation, stream, noise influence, residential area, facility locations, slope, and soil type were recognized as the key factors affecting urban green space suitability. Based on GIS-based Multi-Criteria Analysis (MCA) 6.39%, 25.41%, and 36.42% of the study area has been identified as highly suitable, moderately suitable, and less suitable for green space development respectively. The remaining 26.07% and 5.71% of the study area has been identified as unsuitable and permanently unsuitable 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.

Keywords: Adama, Urban Green Space, LULC, Geospatial technology, MCA, AHP

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 (Satterthwaite et.al., 2015). Urbanization is a global process which demonstrates itself through rapidly changing human population densities and land use and land cover. Land use and land cover (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 Africa will 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).

Urbanization has a crucial role to play on land use and land cover changes and ecological degradation, in return with some socioeconomic benefits. Despite the socioeconomic benefits, the rapid rates of urbanization and unplanned expansion of cities have resulted in several negative consequences (Zubair, 2006). Mensah (2014) argued that urbanization has a negative impact on the natural environment by encroaching green spaces in many cities in Europe, North America, South America, Asia and Africa with the situation in Africa being critical. 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, 2019).

Green spaces refer to those land uses that are covered with natural or semi-natural vegetation in the built-up and planning areas (Karen, 1995; Wu, 1999; Cemil & Gökyer, 2012). Urban green spaces are of crucial importance, especially in an urbanized world, as they are the key providers of ecosystem services and improve the quality of life of urban dwellers. Urban Green Spaces (UGS) provide various environmental, socio-cultural and economic benefits to cities and their population. According to the World Health Organization (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 serve as a health-promoting setting for the entire urban community (WHO, 2017). According to (Mitchell & Popham, 2007), people who live near green spaces are healthier than people who live farther from green spaces. Therefore, it is necessary that they are distributed equitably to all population groups in the city and town (WHO, 2017). 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. These benefits can be maximized for all communities through adequate planning, design collaboration and evaluation (WHO, 2017).

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 and Nebel, 2002; Ahmadi et al., 2016). The urban green spaces exposure is not enough to meet the increasing population pressure per unit area along with growing human pressure, expansion of building construction sites and industrialization in the process of urbanization (Cetin, 2015). Spontaneous construction of unplanned informal houses in and outside the administrative boundaries of towns and cities is common in developing countries. Urban planners and city administrators have to visualize such growth during planning, policy and decision-making. According to Jim and Chen (2003), with the increasing populations require for municipal areas, some ecological and environmental roles move towards improving the eminence of life. 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 and Megento, 2017). Therefore, by taking into consideration environmental, physical, accessibility and socio-economic factors, well planned and well-designed green spaces within the reach of the community are mandatory in order to maximize the value that green spaces bring to urban dwellers and their environment in a sustainable way (Giles-Corti et al., 2005).

Land Suitability Analysis refers to a procedure or tool used for the identification of the most spatially appropriate pattern for locating current and future specific land uses (Collins et al., 2001). Therefore, LSA is a function of specific requirements, preferences, or predictors of a defined activity (Malczewski, 2004). Land suitability analysis is a GIS-based process applied to determine the suitability of a specific area for considered use, i.e., it reveals the suitability of an area regarding its intrinsic characteristics /suitable or unsuitable (Jafari and Zaredar, 2010). This analysis involved considering wide rages of criteria including accessibility, environmental, physical, and socio-economic factors. Thus, suitability analysis is the process to determine whether the land resource is suitable for some specific uses and determine its suitability level.

Land Suitability Analysis (LSA) is vital in urban green spaces planning as it gives room for choosing the most suitable site from among various alternatives (Sahabo and Mohammed, 2016). Multi-criteria analysis (MCA) approach that is integrated with the Geographical Information System (GIS) has been increasingly used for suitable site selection (Van Berkel et al., 2014; Ustaoglu and Aydınoglu, 2020).

Geographic Information System and Remote Sensing are now providing new tools for advanced ecosystem management. 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, 1985; Saaty, 2003) and MCA is also one of the most viable methods addressed in many studies on the land suitability analysis through GIS (Youssef & Pradhan, 2010; Store & Kangas, 2001). According to (Mohit, 2006; Chandio, 2009), GIS-based land suitability analysis techniques are useful for decision makers, engineers and planners to provide a framework for land development.

In parts of developed countries MCA approach that is integrated with the GIS to identify suitable site for urban green spaces has been receiving more attention and it is considered as one of the crucial tools for urban green spaces planning (Nowak et al., 2003; Ustaoglu and Aydinoglu, 2020). 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 and Privitera, 2013; Chandio et al., 2014; Morckel, 2017; Merry et al., 2018; Pokhrel, 2019; Ustaoglu and Aydınoglu, 2020). However, in developing countries, while some green spaces studies have been performed, the available studies have focused largely on the evaluation of urban green spaces with less emphasis on the study of the suitability analysis for green spaces development site selection. Various previous studies in sub-Saharan African countries are primarily related to distribution, abundance and composition of street trees (Kuruneri-Chitepo and Shackleton, 2011), urban green spaces nature and challenges (Mensah, 2014), green space extent (McConnachie et al., 2008; McConnachie and Shackleton, 2010) and planning aspects (Cilliers, 2009; Fohlmeister et al., 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 and Gebre Egziabher, 2018; Abo El Wafa et al., 2018), climate change adaptation (Lindley et al., 2015), the development of functional green infrastructure and ecosystem service (Woldegerima et al., 2017), planning aspect (Girma et al., 2019), green spaces depletion (Girma et al., 2019a) and utilization pattern (Molla et al., 2017; Yeshewazerf, 2017; Girma et al., 2019b). However, these studies did not give attention to the issue of site suitability analysis for green space in the urban environment and they did not used up-to-date data from geospatial technology (such as google earth) most of them used out-of-date data from municipality of respective town or city. Besides, there were no studies conducted in the study area related to site suitability analysis for green space in the urban environment in the context of LULC dynamics. Therefore, this study aimed to fill the existing research gap by using geospatial technology and applying GIS-based multi-criteria analysis method to examine changes in the LULC patterns particularly green space and identify suitable sites for urban green space development in Adama Town.

1.2. Statement of the Problem

Rapid Urbanization is an important global phenomenon and it becomes a great concern for many parts of the world. According to the World Health Organization (WHO, 2017) a brief for action, Urban living limits access to nature and can increase exposure to certain environmental hazards, such as noise and air pollution. This rapid urbanization has posed greater pressure on natural resources and the environment and the amount of land exploited for development of infrastructure and buildings has increased at the expense of urban green spaces (Rees and Wackernagel, 1996; Shi, 2002; Sandstrom, 2002). LULC change particularly in urban areas is becoming the major factor in reducing green spaces extent.

One of the major impacts of urbanization is a shrinking of urban green spaces, through the development of infrastructures and various development projects. Lack or degradation of urban green space can contribute to the burden of disease by worsening the effects of other adverse factors in the urban environment (Kruize et al., 2019). These include air pollution, noise pollution, heatwaves and flooding problems. According to (WHO, 2016), loss and degradation of green space diminishes an important restorative resource for the individual and reduces opportunities to meet people and engage in physical activity in an attractive and relaxing environment.

Urban green spaces are unable to provide urban residents with the desirable services due to rapid urbanization and unplanned urban growth, lack of proper site selection and planning and lack of attention to population thresholds (Wright and Nebel, 2002; Ahmadi et al., 2016). As a result, both quality and quantity of urban green spaces are adversely affected and do not deliver what urban centers demand from urban green spaces as a living organism (Crompton, 2001).

Adama is a Town in Ethiopia, where this study was conducted, has also an experience of greater challenges facing urban areas. According to Yanit Mekonnen (2017), in Adama Town during the last thirty years, urban area has increased by 31.73% (i.e., 42.66 km^2) due to construction and infrastructure development, while Shrub and bushes (greeneries) area has increased only by 0.61% (i.e., 0.82 km^2) which is unbalanced and very small compared with rapid urbanization and population growth.

Due to rapid urbanization and population growth, Adama Town is associated with unplanned and uncontrolled development, occupying unsuitable sites and declining basic services, especially green spaces. The problem is predictable to get worse in the coming years due to the huge construction of buildings, roads and less attention given to urban green spaces. These necessitate the need for analysis of LULC dynamics and suitability analysis for urban green space development using geospatial technology.

1.3. Objectives of the study

1.3.1. General objective

The main objective of this study was to identify suitable sites for urban green space development in Adama Town using Geospatial technology.

1.3.2. Specific objectives

More specifically, the specific objectives of the study aspire to:

i. analyze urban LULC dynamics within Adama Town particularly green space;
ii. identify the main determinant factors for urban green space development;
iii. detect suitable sites for urban green space by using the analytical hierarchy process (AHP) based multi criteria analysis (MCA) methods;
iv. produce urban green space suitability map for the study area;
v. compare the best sensitivity scenario with the proposed structural plan (2017) green area of the Town.

1.4. Research questions

In order to realize the stated objectives, the following research questions were designed:

1. What is the LULC change trend within the study area?
2. What are the main determinant factors for urban green space development?
3. How do analytical hierarchy process (AHP) based multi-criteria analysis (MCA) methods help to detect urban green space site suitability?
4. Which sites are suitable for urban green space development in the study area?
5. How to compare the best sensitivity scenario with the proposed structural plan (2017) green area of the Town?

1.5. Significance of the study

Study of site suitability analysis is an 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 Town management officials in the identification and selection of suitable sites for urban green space development in the Town. 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 was limited to Oromia Regional State, Adama Town Administration. Whereas, the contextual scope was to examine changes in the LULC patterns, particularly urban green space during the study period (1991 to 2021) and suitability analysis for urban green space development using geospatial technology.

1.7. Limitation of the study

One of the major limitations was difficulty to get high resolution satellite imageries for high accuracy and precision results on mapping and classifying LULC maps of the study area. Landsat imageries were used for LULC analysis, Landsat imageries were of 30 m resolution which are not high resolution and incurred some LULC classification errors that were indicated in error matrixes of accuracy assessment. It was not possible to get high resolution satellite imageries such as QuickBird and IKONOS. The other limitation was that parameters or criterion 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 Thesis

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, 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 fourth chapter talks about data analysis, results and discussion of the study. The final part presents the conclusion and recommendations.

CHAPTER II: LITERATURE REVIEW

2.1. Land Use and Land Cover Change

The Earth's surface is experiencing rapid LULC changes as a result of numerous socio-economic activities and natural phenomena (Cheruto M.C. et al., 2016). Nowadays the rapid growth and expansion of urban areas, rapid population growth, land scarcity, increasing production demands and growing technology are some of the drivers of LULC change (Barros, 2004). Changes in Land Use Land Cover (LULC) can also affect biological diversity, alter ecosystem services, lead to soil erosion, disrupt socio-cultural practices and increase natural disasters, like flooding. LULC change particularly in urban areas is becoming the major factor in reducing green spaces extent. LULC change needs global attention for continuous monitoring of the changes. Up-to-date datasets on land use land cover change provide critical inputs to evaluate complex causes and responses in order to project future trends. They are also prerequisites for making development plans. However, according to (Mengistie et al., 2013), the magnitude of LULC change differs with the time period being examined, geographical location, slope gradient and elevation range.

2.2. Definition and Concepts of urban green space

There is large literature on definitions of urban green spaces (UGS). In the views of Jim and Chen (2003), urban green spaces consist of outdoor places which have some amount of vegetation and can mainly be found in semi-natural areas. This includes urban elements such as green walls, green parks and green roofs that host biodiversity and allow ecosystems to function and deliver their services by connecting urban, peri- urban and rural areas (Verdú et al., 2020). Fam et al. (2008) defines urban green spaces as all vegetated spaces including trees, shrubs, and grasses. An urban green space can be defined as formal and informal (According to Alamrew (2002) citing different sources). Formal green areas include playgrounds, sport fields, protected public parks, street gardens squares, private gardens, and vegetation cover in schools, hospitals, churches, mosques, embassies, cemeteries, parking lots, pedestrian lanes (Mainardi, 2019). In other hand, informal green areas include forest areas, river valleys, reserved expansion areas, agricultural lands, open leftover spaces, grazing lands, steeper degraded areas, shrub lands, etc. Urban green spaces are used to connect urban to nature (Teuber et al., 2019). In this respect, green areas are the reflection in the urban spaces of natural or near natural areas surrounding the cities. Urban green spaces consist of any vegetated land or structure, water or geological features found in a given area (Kit Campbell Associates, 2001).

2.3. Types of urban green space

Urban green spaces have different forms and types of open spaces, community parks, gardens and landscaped areas (Vargas et al., 2018). 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 et al., 2018). According to (Roy et al. 2012), urban green spaces include public parks, reserves, sports fields, streams, river banks and other riparian areas, greenways, walkways and trails, communal shared gardens, street trees and bushes, nature conservation areas and less conventional spaces such as green walls, green alleyways and cemeteries (Vargas et al., 2018).

(a) (b)

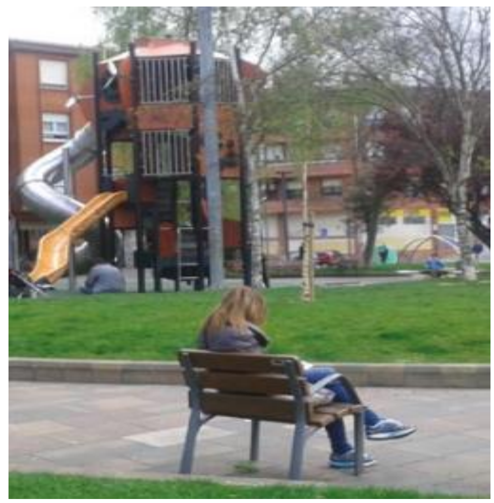
Figure 1: Green roof (Gushan, Dhaka) (a); Green roof and facades(b)

Source: (Hossain et al., 2019(a); WHO, 2017(b))

2.4. Benefits of urban green spaces

Nowadays, urban green space is increasingly gaining attention as a source of multiple benefits (Jorgensen and Gobster, 2010; Byrne JA. et al., 2015). Different authors (Ahern, 2013; Roe and Mell, 2013) 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, 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 S. et.al. 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).

(a)



(b)

(c)

Figure 2: Roadside greenery and vegetation barriers along streets(a); Small urban green spaces (such as gardens or pocket parks) and playgrounds(b) and parks and urban meadows(c)

Source: (WHO, 2017)

2.4.1. Environmental Benefits of urban green space

The environmental benefits of green space include local temperature moderation during hot weather cooling of the air temperature through shade provision and mitigation of urban heat island effects (Cao X.et al., 2010; Bowler DE.et al., 2010; Mullaney, 2015; Nowak DJ.et al., 2006). The roles of green space in reducing noise pollution, in mitigating floods in enriching biodiversity and improving ecosystems are also taken as environmental benefits (Haq, 2011; Bolund and Hunhammar, 1999; European Commission, 2013).

According to Heidt and Neef (2008), solar radiation, air temperature, wind speed and relative humidity vary significantly due to the built environment in cities. The urban heat island outcome is caused by the large areas of heat absorbing surfaces, in a combination of high energy use in cities. Consequently, adequate forest, plantation and vegetation around urban dwellers and management of water bodies can help to mitigate the situation. Urban green spaces are not only improving the whole ecological environment of the city region and its neighbors but also provides important support for urban environmental improvement. Additionally, introduction of sub-urban green space into the city also acts as the base of ecological balance (Sadeghian & Vardanyan, 2013).

2.4.2. Socio-cultural benefits of urban green space

Socio-cultural benefits are the non-material benefits people obtain from green space (Mullaney J.et al., 2015). These include educational values, aesthetic values, social relations, sense of place, cultural heritage values, recreation, ecotourism and psychological well-being (O'Brien L.et al., 2017). Socio-cultural benefits of green space for urban residents include mental and physical health improvements such as stress reduction and relaxation (Hansmann R.et al., 2007; Konijnendijk CC.et al., 2013). Further, green space directly increases the quality of life through active and passive recreational social benefits (Kabisch and Haase, 2014). Physical activities such as sports, playing with children etc., signify active benefits while the passive ones include relaxations, meeting with friends or experiencing nature and the like (Byrne and Wolch, 2009). In addition, green space acts as a meeting place for local residents and facilitates social interaction (Wolch JR.et al., 2014). These elements illustrate the range and the breadth of socio-cultural benefits of green space and they cover two specific elements (Hansmann R.et al., 2007): first benefits people derive from their feelings of being connected to green space and, second benefits people derive from diversity and complexity of green space. Unfortunately, the socio-cultural dimensions of green space have received much less attention than the environmental considerations in infrastructure planning and development endeavors (Byrne and Yang, 2009; Hitchings, 2013).

2.4.3. Economic benefit of urban green space

Economic benefits of green spaces come from the increased values of properties near green spaces and the increased sales of properties along green commercial corridors (Heckert and Mennis, 2012). In this line, studies in China (Jim and Chen, 2010) and Adelaide in Australia (Mahmoudi P.et al., 2013) indicated that higher housing prices and property values are evident for sites situated in the vicinity of accessible green space. In addition to this, the economic benefits of green space include its contributions to tourism and its link with urban food (Heckert and Mennis, 2012). Pitman and Ely (2013), explained that green space and urban food are intimately related through the perceived needs to retain productive agricultural land on the urban fringe and to integrate food production into urban areas.

2.5. Status of urban green spaces in Ethiopia

Ministry of urban development, housing and construction is trying to address the green space problem by producing National Urban Green Infrastructure Standards (NUGIS) which create the framework for municipalities to provide effective and sustainable urban green infrastructure (UGI) for their residents to protect public health and environmental quality (MoUDC, 2014). MoUDC 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. It has also recognized cities as entities that try to work towards minimizing serious urban environmental causes.

Furthermore, the Environmental Policy of Ethiopia has documented the importance of planning of green spaces within urban areas. This gives room for various stakeholders to develop and manage urban forests, street trees and so on as elements of urban green areas.

The urban planning, preparation and implementation strategy allocated 30% of the land for roads and infrastructure, 30% for green areas and shared public use and 40% for building construction in their urban land management plan (MoUDH, 2015).

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 et al., 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.

2.7. Land suitability classification

Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. According to FAO (2007), land suitability classification is divided into order, class, sub-class and unit.

Land Suitability Orders

Land suitability orders indicate whether the land is assessed as suitable or not suitable for specific use under consideration. There are two orders represented in maps, tables, etc., by the symbols S and N. Order S represents suitable land on which sustained use of the kind under consideration is expected to benefit, without unacceptable risk of damage to land resources. Order N represent not suitable land which has qualities that appear to preclude sustained use of the kind under consideration (FAO, 2007).

Land suitability classes

According to FAO (2007), land suitability classes reflect degrees of suitability and the classes are numbered consecutively, in sequence of decreasing degrees of suitability within the order and within the order suitable the number of classes is not specified, for example, there might, be only two, S1 and S2. The number of classes recognized should be kept to the minimum necessary to meet aims of interpretation; five should probably be the most ever used (FAO, 2007). As stated on FAO (2007) land suitability classification, if three Classes are recognized within the order suitable, the following names and definitions may be appropriate in a qualitative classification. The first class (class S1) represents highly suitable; land having no significant limitations to sustained application of a given use or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level (FAO, 2007). The second class (class S2) represent moderately suitable; land having limitations which in aggregate are moderately severe for sustained application of a given use, the limitations will reduce productivity or benefits and increase required inputs to the extent that the productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land (FAO, 2007). The third Class (Class S3) represents marginally suitable; land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits or increase required inputs, that this expenditure will be only marginally justified (FAO, 2007). Within the order not suitable, there are normally two classes (Class N1 and Class N2): The first Class of not suitable (Class N1) represent currently not suitable; land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost, the limitations are so severe as to preclude successful sustained use of the land in the given manner (FAO, 2007). The second class of not suitable (Class N2) represents permanently not suitable; land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner (FAO, 2007).

Land Suitability Subclasses

The Subclasses are a more detailed division of classes based on land quality and characteristics (soil properties and other natural conditions). For example, Subclass S3rc is land that is marginally suitable due to rooting condition (rc) as the limiting factor (FAO, 2007).

Land Suitability Units

According to FAO (2007), land suitability classification, land suitability units are subdivisions of a subclass, all the units within a subclass have the same degree of suitability at the class level and similar kinds of limitations at the subclass level (FAO, 2007). The units differ from each other in their production characteristics or in minor aspects of their management requirement often definable as differences in detail of their limitations. Their recognition permits detailed interpretation at the farm planning level (FAO, 2007). Suitability units are distinguished by Arabic numbers following a hyphen, e.g., S2e-1, S2e-2, and there is no limit to the number of units recognized within a subclass (FAO, 2007).

2.8. Application of Remote Sensing and GIS for site suitability analysis

2.8.1. Application of Remote Sensing (RS) for site suitability analysis

Remote sensing is the capability to gather information without being in direct contact with it (Lillesand et al., 2014). The modern use of the term remote sensing has more to do with technical ways of collecting airborne and space born information. Earth observation from airborne platforms has 150 years of history, although the majority of the innovation and development has taken place in the recent decade's years (Zubair, 2006). According to (Lillesand et al., 2014), the first earth observation using balloons in the 1860s was regarded as an important benchmark in the history of remote sensing.

Satellite based remote sensing provides valuable information that can be used in the assessment of the various aspects of atmospheric environment, climatology, meteorology, ecology, agronomy and environmental protection (Kern, 2011). The essence of remote sensing is measuring and recording the electromagnetic radiation emitted or reflected from the earth's surface (Hardegree, 2006). Remote sensing is one of the incomparable tools for sensing the earth surface to make the interface of object property and measurement analysis as well as inventory of environment and its resources, and has a unique ability of providing the synoptical view of a large area with the capacity of repetitive coverage.

One of the most applications of remote sensing in site suitability analysis for green space development is where remote sensing data like satellite images are used for extracting green space development criteria (example; land use land cover and surface water) with saving time and cost.

2.8.2. Application of Geographic Information System (GIS) for site suitability analysis

Geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. The data type in GIS can be classified into two major groups as spatial and non-spatial data. The spatial data are the data that have location value and that non-spatial data are data, which describe more the spatial data in the form of a table. According to Burrough (1990), data in GIS is composed of three dimensions that mean spatial (geographic), time and attribute. Some people believe that a geographic information system is the system of hardware and software, which contributes to analyzing applications or information processing (Maguire, 1991). Geographic information system is not only a digital store of spatial objectives (areas, points and lines) but also capable of spatial analysis based on the relation between these objects, including the relationship between objects defined by their location and geometry.

According to Foresman (1998), the combination of computer technology and cartography in the 1960s paved the way for the possibility of using techniques of superimposing and overlaying maps in fields other than cartography. GIS is a digital database management system designed to manage large volumes of spatially distributed data from a variety of sources (Chezgi et al., 2015). It is ideal for preliminary site selection studies because it efficiently stores, retrieves, analyzes and displays information according to user defined specifications. Once a GIS database is developed it can provide an efficient and cost-effective means of analyzing potential green space site attributes.

2.9. Multi Criteria Decision Making (MCDM)

The techniques adopted in the various approaches of decision analysis are multi criteria decision methods (MCDM). Research on land evaluation requires a large amount of spatial and non-spatial data, which GIS are capable of easily and efficiently handling. Therefore, many researchers have used GIS for land evaluation, a process, which enables the integration of multiple attributes and different criteria that are involved in decision-making (Malczewski, 2006; Shalaby A.et al., 2017). 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.

2.10. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) was introduced by Thomas saaty (saaty, 1980). AHP has been used as an effective tool for dealing with the complex decision-making process and aids the decision makers to set priorities to make better decisions through reducing the complex decision to series of pairwise compression and then producing the results. Though AHP is a conventional land suitability analysis technique and that provides the right decision-making use extensively for site selection process. In a parallel way, AHP has integrated with GIS for land suitability modeling (Malczewski, 1999). AHP helps to capture a mutually subjective and objective aspect of the decision and also for checking the consistency of the decision maker's evaluations, consequently reducing the bias in the decision-making method (Saaty, 1980; Malczewski, 2006).

This study describes the integration of GIS, MCDA and AHP methods that are based on scientific and author judgement to determine the land suitability analysis for urban green space development in Adama Town.

2.11. 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. Significant criteria have been commonly used for developing the framework of AHP method to identify the best location (Pokhrel, 2019). On the other hand, 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. Some most significant criteria used for suitability evaluation are accessibility criteria, environmental Criteria, Physical criteria, and Socio-economic criteria (Javadian et al., 2011; Chakma, 2014). According to different scholars, then those criteria are classified into different sub-criteria for suitability evaluation. Some earlier studies and literature conducted by some researchers had used those criteria and sub-criteria for urban green space development such as 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).

2.12. 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 socio-economic 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 & Worku, 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 et al., 2011; Chakma, 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. For example, soil type, slope, elevation and topography are important parameters in the suitable site selection process. Environmental is an important parameter for suitability analysis such as stream, existing park etc. socio-economic is another significant parameter for suitability analysis such as 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 JA. et al., 2015). Different authors (Ahern J., 2013; Roe M. & Mell, 2013) defined 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 & Nobukazu, 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 socio-economic. 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 3 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.

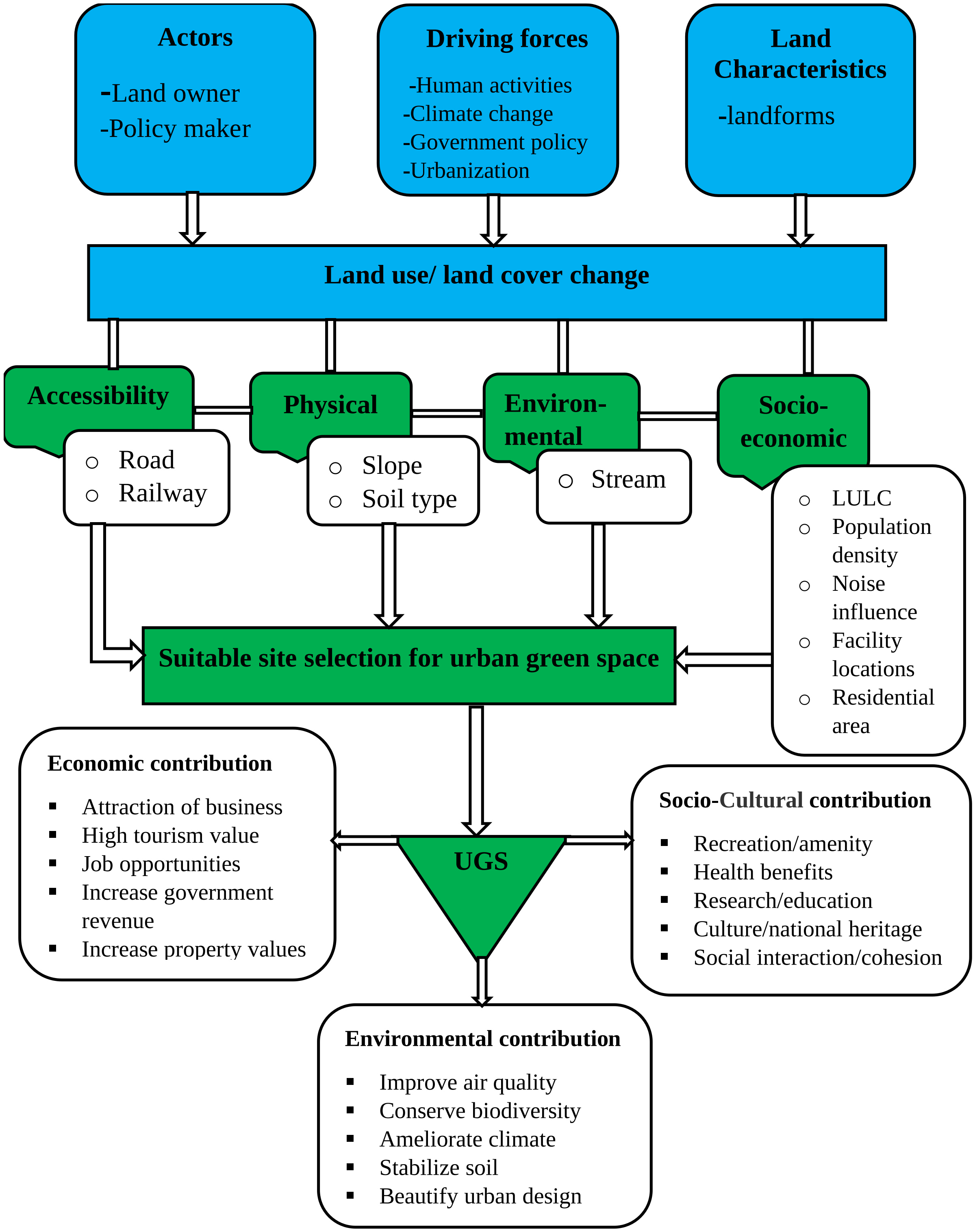


Figure 3: Conceptual framework for the study

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

CHAPTER III: MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Location

Adama Town is situated in the Oromia National Regional State of Ethiopia (Figure 4), in the southeastern direction of Addis Ababa. The Town is located about 99 km along old road and 75 km along new road southeast of Addis Ababa enclosing between 8º 33`35``N to 8º 36`46``N latitude and 39º 11`57``E to 39º 21`15``E longitude covering an area extent of new proposed boundary about 313.04 km^2 with an average altitude of 1620m above mean sea level. Adama lies in the great Ethiopian rift valley on a nodal location along the main national and regional transport lines from the capital city, Addis Ababa, to other important cities and towns like Dire-Dawa, Harar, Semara, Jigjiga and to Djibouti. It is also situated close to natural recreational sites such as Sodare and Boku hot springs (Socio-economic profile of Adama, 2020).

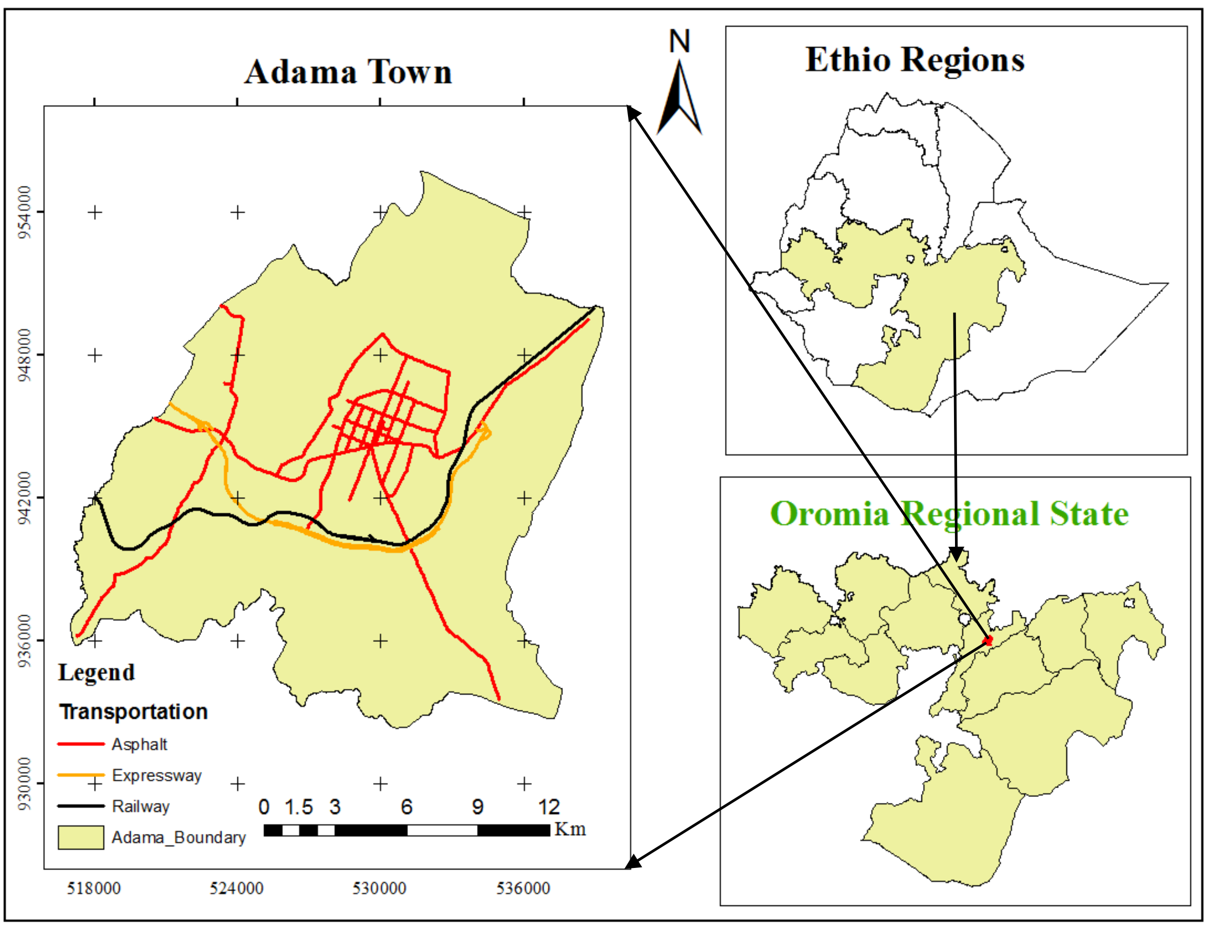


Figure 4: Location Map of the Study Area

3.1.2. Topography

The topography of an area like slope and elevation has an important contribution in selecting suitable sites for urban green spaces development. The topography of this area is characterized by flat land that is surrounded by ridges. The study area is particularly flat with slopes varying between 0 and 159% (Figure 5). According to the extracted elevation of the study area from DEM, the study area is located along an elevation range from 1443m -2055m (Figure 5).

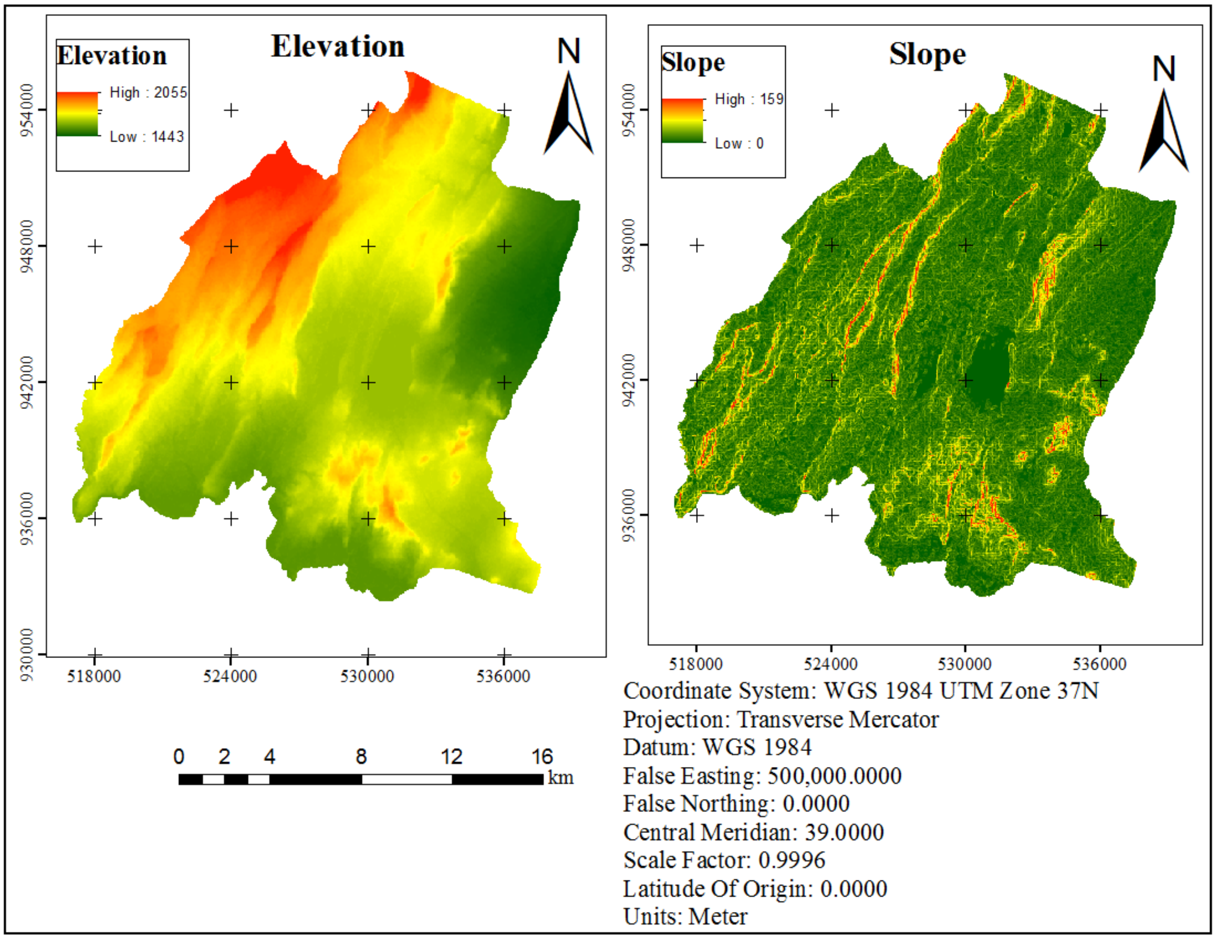


Figure 5: Elevation and Slope map of the study area

3.1.3. Climate

The Town enjoys favorable climatic conditions due to its geographical locations surrounded by plateaus that experiences moderate temperature and rainfall which is favorable for life. Rainfall mostly occurs in the summer season. It receives abundant and heavy rainfall every year during this season. The table below reveals the trends of rainfall and temperature during the consecutive past five years. As can be observed from table 1 during the past five consecutive years the maximum average and minimum average annual temperature was 29.4^{o}c and 15.8^{o}c in the year 2014/15 and 2012/13 (2007 and 2005 E.C) respectively. Similarly, the maximum annual total and minimum annual total rainfall was 934.8 mm and 736.5 mm in the year 2016/17 and 2012/13(2009 and 2005 E.C) correspondingly (Socio-economic profile of Adama, 2020).

Table 1: Rain fall and temperature data of Adama (2005-2009 E.C)

Year	**Cl. type**	**Months**												Annual data
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2005	T RF (mm)	22	0	10.4	17.6	68.7	54.8	215	155.8	192.1	0	0	0	736.5
	M Max (^0C)	27.3	29.4	31	31.2	31.2	30.4	26.1	26.3	27.99	28.1	27.5	26.4	28.6
	M Min (^0C)	14.3	15.1	17.3	17.4	18.3	18.2	15.6	16.7	15.88	14.8	14.2	11.9	15.8
2006	T RF (mm)	4.4	0.2	69.2	35.1	36	38.9	443	105.2	132.8	34	5.2	0	904.2
	M Max (^0C)	28.1	29.5	29.8	30.7	31.4	31.6	28.3	26.7	27.3	26.9	27.5	26.2	28.7
	M Min (^0C)	13.9	16.4	16.7	17.4	17.3	18.1	17.1	16.5	16	14.7	15	13.3	16
2007	T RF (mm)	0	4.8	123	7.1	62.3	7.7	212	180	150.6	91.7	8.9	0	847.8
	M Max (^0C)	27	30.5	31.3	31.5	30.7	30.5	29.5	27.9	28.9	29.9	28	26.9	29.4
	M Min (^0C)	12.6	15.8	17.1	16.4	17.2	18.1	17.4	16.6	16.3	17.1	15.9	15.5	16.3
2008	TRF (mm)	0	0	11	3.6	180	74.9	131	207.9	78.6	2.3	47	1.5	738.5
	M Max (^0C)	28.8	29.8	27.9	26.8	28	29.3	32.7	30.3	29.7	29.5	26.9	27	28.9
	M Min (^0C)	16.3	17	15.8	15.5	15.6	15	18.9	17.7	17.3	17.4	16.5	16.9	16.6
2009	T RF (mm)	135	0.9	33.2	0	0	54.1	29.4	7.6	166.4	31.9	250	226	934.8
	M Max (^oC)	28.3	29.4	27.9	26.6	27.9	28.8	31.5	30.2	28.97	31.6	27.5	26.7	28.79
	M Min (^oC)	15.6	15.5	14.8	12.7	12	14.5	16.9	17.5	16.96	28.7	25.5	16.4	17.25

NB. Cl. Type=climate type, M Max= Monthly maximum temperature, M Min= Monthly minimum temperature, TRF= Monthly total Rainfall

Source: (Socio-economic profile of Adama, 2020)

3.1.4. Population

According to the last three consecutive censuses conducted in the country, Adama Town showed a large increase in population. In the first Ethiopian population and housing census, which was held in May 1984, Adama had a population of 77,237. The second population and housing census conducted in 1994 reported that Adama had a total population of 127,842 of whom 61,965 were males and 65,877 were females. According to the third Ethiopian population and housing census which was conducted in 2007 (the most recent year for which data are available), 220,212 people of whom 108,872 males and 111,341 females were inhabited in Adama. Based on this the projected population of Adama Town including four subs urban Ganda's under the town administration in 2018/19 (2011 E.C) was 433,046 of whom male 216,046 and female 217,000 (Socio-economic profile of Adama, 2020).

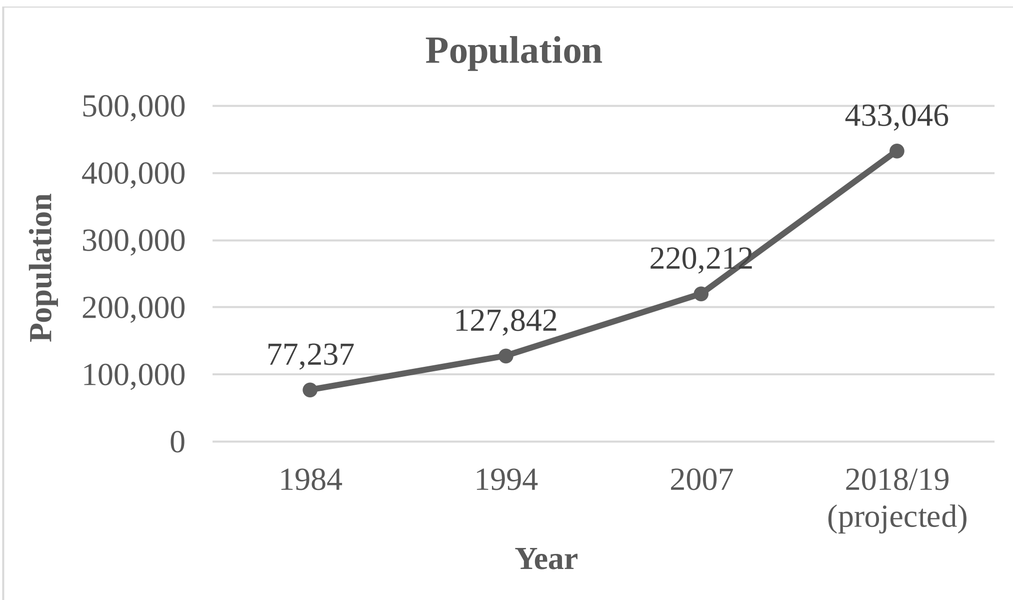


Figure 6: Population of Adama Town from 1984 to 2018/19(CSA, 2018/19 projected)

Distribution of Population and Population Density

Adama is inhabited by 433,046 populations in 2011, according to population projection made based on the result of 2007 housing and population census. Naturally, in urban areas a huge number of populations live on small portions of the earth with uneven distribution across them. The distributions of population in the town are uneven as elsewhere in the country. The pattern of spatial distribution of population shows difference among different quarters of the town. The density of population varies from area to area. The central parts of the town have high population density in comparison with the urban expansion areas. The urban Ganda with the biggest population is irreecha (09), whereas, the urban Ganda with the least population is Boku shenan. Badhatu (07) and Gurmu (06) are the first and the second dense gada respectively (Socio-economic profile of Adama, 2020).

Table 2: Projected Population by kebele in 2011 by sex, sex ratio and Population density

Ganda	Male	Female	Total	Ratio to total pop	Total area in hectare	Population density/ hectare	Sex ratio (F:M)
Goro(01)	17,397	17,227	34,624	7.99	1571.410	22	0.99
Migira(02)	12,041	11,994	24,035	5.55	338.328	71	0.996
Gara lugo(03)	17,649	17,384	35,033	8.09	334.799	104	0.985
Dhadacha arara(04)	17,046	18,677	35,723	8.25	256.039	139	1.096
Dagaga(05)	17,594	16,140	33,734	7.79	351.136	96	0.917
Gurmu(06)	6,128	6,408	12,536	2.89	30.942	405	1.046
Badhatu(07)	10,652	9,922	20,574	4.75	49.429	416	0.931
Oda (08)	10,036	9,399	19,435	4.49	54.921	353	0.937
Irrecha(09)	19,188	19,643	38,831	8.96	482.042	80	1.024
Biqa(10)	15,215	16,260	31,475	7.27	192.887	163	1.069
Barecha(11)	16,245	16,817	33,062	7.63	161.905	204	1.035
Gada(12)	8,979	10,003	18,982	4.38	85.150	222	1.114
Chafe (13)	9,771	9,514	19,285	4.45	127.326	151	0.974
Angatu (14)	18,585	18,206	36,791	8.49	1016.460	36	0.98
Boku shenan	2,640	2,610	5,250	1.21	3466.932	2	0.989
Deka adi	7,650	7,523	15,173	3.5	1683.566	9	0.83
Dabe soloke	5,705	5,619	11,324	2.61	1098.165	10	0.985
Melka Adama	3,525	3,654	7,179	1.66	1910.636	3	1.037
Total	216,046	217,000	433,046		13,212.073		

Source: (Socio-economic profile of Adama, 2020)

Sex Ratio

The majority of the residents of the Town are women as the existing data portrays. As the projection of population made on the bases of 2007 G.C housing and population census results indicates the shares of males and females dwelling in Adama was 193,899 and 197,606 respectively. Table 2 shows the name of kebeles, size of population, total area and population density of Adama Town. It also points out the name given for kebeles, before 2017 the name of 14 kebeles (which listed in table below 1-14) designated in number, later 2017 the name which were called by after number renovated by historical name of the place (Socio-economic profile of Adama, 2020).

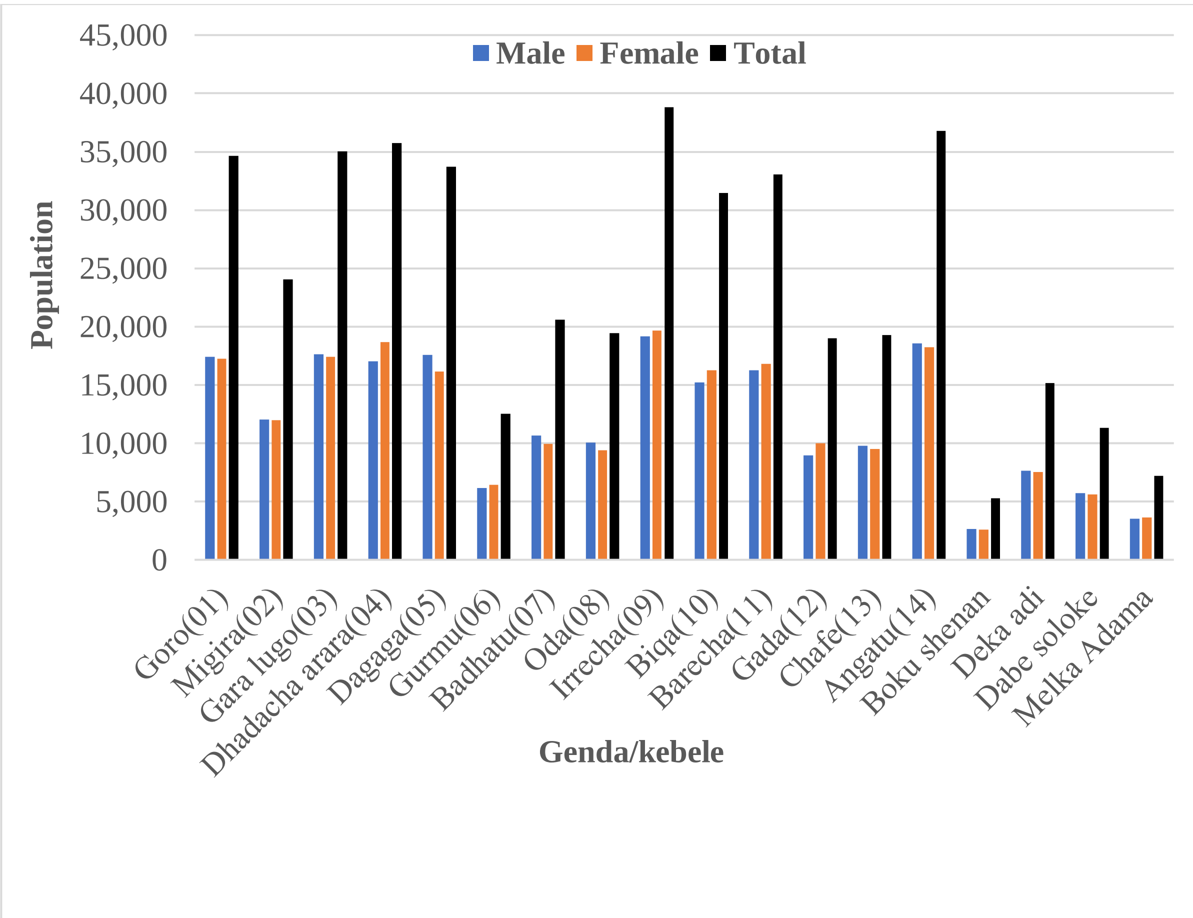


Figure 7: Population of Adama town at kebele level (CSA, 2018/19 projected)

3.2. Data Collection and Data Source

Data from primary and secondary sources were used in this study; it included both spatial and non-spatial data from actual fieldwork and secondary (ancillary) data. The following table describes data required, types of data used in the study, formats and where the data were gathered from (Table 3).

Table 3: Data Source

No.	Data Required	Data Source	Data Type	Year	Resolution	Data Format
1	Landsat 5 TM	USGS	Secondary data	1991	30m	Raster(.tiff)
	Landsat 7 ETM+			2006		
	Landsat 8 OLI			2021		
2	ASTER Digital Elevation Model (DEM)	Geospatial information institute (GII)	Secondary data	-	20m	Raster(.tiff)
3	Adama Proposed Structural Plan	Adama Town administration urban land sectors office	Secondary data	2017	-	Shape file (.shp)
4	Road	Google Earth pro	Secondary data	2021	-	Kml(.kml)
6	Stream	Google Earth pro	Secondary data	2021	-	Kml(.kml)
7	Population	CSA	Secondary data	2018/19 projected	-	-
8	Soil type	FAO	Secondary data	-	-	Shape file (.shp)
9	Factory	GPS field survey	Primary data	-	-	Point data
10	Health facility			-	-	
11	School			-	-	

3.3. Software/Materials Used

Software/Materials used in this study were selected based on the capability to work on the existing problems in achieving the predetermined objectives. In order to achieve the objective of the study different software and materials were used. Hence software package like ERDAS IMAGINE 2015 was used for image processing and classification activities on satellite images. Moreover, Google Earth Pro was used to digitize road, stream and to check the accuracy of land use/land cover class. Also buffering, rasterization, intersection, reclassification, weight overlay and the factor map development were carried out using ArcGIS 10.8 software package.

Table 4: Software/Materials Used

No.	Software/materials name	Version	Purpose
1	ArcGIS	10.8	For data storing, managing, analyzing (data conversion, reclassifying), geographic modeling functions (calculating distances, areas and generating buffers), weighted overlay analysis and thematic map preparation.
2	ERDAS IMAGINE	2015	For image processing and analyzing satellite images
3	Google Earth Pro	-	For digitization, visual image interpretation and validation of the result.
4	Microsoft Word and Excel	2016	Integrating attribute data and compositing final thesis
5	IDRISI Selva	32	To assign weight for each factor
6	IBM SPSS statistics	22	For tabulations and graphical representations

3.4. Data Analysis Methods

The study analyzes the LULC dynamics and land suitability analysis for urban green space development in Adama Town using geospatial technology. After the data were collected from various sources, the data were analyzed by using different software like ArcGIS 10.8, IDRISI Selva and ERDAS IMAGINE 2015. Urban green spaces have a significant role in enhancing the quality of life of urban inhabitants and in supporting urban metabolism (Braubach et al., 2017). However, urban green spaces have experienced a physical and social decline, while its heterogeneousness and richness are often neglected and its contribution to the well-being of a community ignored within current urban planning instruments. Under this situation, GIS-based multi-criteria land suitability analysis is becoming critical in determining the land resource that is suitable for urban green spaces (Cetin, 2015). According to Manlum (2003), sustained development and refinement of suitability analysis, particularly with GIS technology, can enable urban planners to create a suitable urban green spaces system in the urban environment.

3.4.1. Image Pre-Processing

After the data were collected, the study undergoes the processes of manipulating, sorting, and preprocessing collected data to analyze the LULC dynamics of the study area. The satellite image of 1991, 2006 and 2021 were processed using ERDAS IMAGINE 2015. The coordinate system, layer stacking and layer extraction took place. Then Landsat images were corrected for the atmospheric, sensor and an illumination variance through radiometric calibration procedures.

3.4.2. Image classification

Different feature types on the earth's surface have a different spectral reflectance property, their recognition is carried out through the classification process. Image classification is defined as the extraction of differentiated classes or themes of land use and land cover categories, from raw remotely sensed digital satellite data (Lillesand and Keifer, 1994). It is a technique to identify different features such as urban area, vegetation types and farm land from the satellite images. Satellite images were classified and analyzed using the basic photogrammetric elements (color, tone, texture, size, shape, structure, association, and shadow); the prior knowledge of the study area and field observation.

Land use and land cover map for 1991, 2006 and 2021 were produced by supervised classification using the maximum likelihood classifier of ERDAS IMAGINE 2015 software. LULC classes were mapped from digital remotely sensed data through a supervised classification method (training process), based on the field knowledge to perform the classification. Based on selected training polygons, drive signatures, were subsequently classified with the supervised classification type and used maximum-likelihood classification algorithm in ERDAS IMAGINE software. Supervised classification is based on the quality and quantity of training samples to produce good quality classification results. Accordingly, the images were classified in to five major land-use/land-cover classes such as built up, shrub and bushes, farm land, bare land and water body.

3.4.3. Accuracy Assessment

The term accuracy is typically used to express the degree of correctness of a map or classification in thematic mapping from remotely sensed data. The increased usage of remote sensing data and techniques has made geospatial analysis faster and more powerful; however, the increased complexity also creates increased possibilities for errors (Dagistanli et al., 2018). Therefore, the assessment of the accuracy of mapping generated from remote sensing data is a critical and essential step in the classification process (Dagistanli et al., 2018). The error matrix is the most common tool in terms of determining the accuracy of the classification results (Fan et al., 2007). User accuracy, producer accuracy, overall accuracy and Kappa statistics were then derived from the error matrices for LULC classes. According to Moller-Jensen (1997), Kappa analysis is a discrete multivariate technique used in accuracy assessments. In other words, Kappa analysis is a standard component of accuracy assessment and is considered as a required component of most image analyses (Dagistanli et al., 2018).

Producer's Accuracy (Errors of omission): Producer's Accuracy measures the percentage of correctly classified pixels from a sample data or indirectly indicates errors of omission for a particular class. Producer's accuracy was calculated from dividing the number of correctly classified pixels in each category (on the major diagonal) by the number of training set pixels used for that category (the column total). It is calculated as:

Producer's Accuracy = $\left(\frac{\mathrm{Ci}}{\mathrm{Ct}}\right) * 100$ ……………………………………………………Equation (1)

Where, Ci = correctly classified sample locations of the reference data or column and

Ct = total number of sample locations of the column.

User's Accuracy (Commission error): user's accuracies are computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (the row total). This result is a measure of commission error. It is calculated as:

User's Accuracy = $\left(\frac{\mathrm{Ri}}{\mathrm{Rt}}\right) * 100$ ……………………………………………………Equation (2)

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

Overall Accuracy: Overall accuracy was computed by dividing the total diagonal (i.e., the sum of the correctly classified sample units) by the total number of sample units in the error matrix. This value is the most commonly stated accuracy assessment statistic.

Overall Accuracy = $\left(\frac{\mathrm{Sd}}{\mathrm{n}}\right) * 100$……………………………………………………..Equation (3)

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

Kappa Coefficient: Kappa coefficient can be used as another measure of agreement or accuracy. Kappa was used to measure the agreement or accuracy between the remote sensing derived classification map and the reference data as indicated by the major diagonals and the chance agreement. 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.

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

3.4.4. Land Use and Land Cover Change Detection

Post-classification comparison approach was employed for detection of land use and land cover changes by comparing independently produced thematic maps for 1991, 2006 and 2021. Then, the classified land use and land cover maps were compared to show the changes between each year, i.e., 1991–2006, 2006–2021 and 1991–2021 for the study area. It was also possible to calculate the amount of increase and/or decrease of each category of LULC and see the changes in percentage in each year (Lambin et al., 2001).

LULC change statistics were computed in two different ways:

1) Total LULC change in hectare were calculated using the following equation:

Total LULC change = $\mathrm{Area}_{\text{final year}} - \mathrm{Area}_{\text{initial year}}$……………………………..Equation (5)

Where, area is extent of each LULC type. Positive values suggest an increase whereas negative values imply a decrease in extent.

2) Percentage LULC change were calculated using the following equation:

Percentage LULC change $= \left(\frac{\mathrm{Area}_{\text{final year}} - \mathrm{Area}_{\text{initial year}}}{\mathrm{Area}_{\text{initial year}}}\right) * 100$ …………………..Equation (6)

Where, area is extent of each LULC type. Positive values suggest an increase whereas negative values imply a decrease in extent.

3.5. Site Selection Tools

Geographic information systems (GIS) based multi-criteria analysis (MCA) techniques have been used in solving site selection problems. Site selection process for urban green space involves various environmental, technological, social and economic aspects. GIS based MCA is a process that transforms and combines geographical data and value judgments (the decision maker's preferences) to obtain information for decision making (Malczewski, 2006). According to (Taha & Daim, 2013), GIS based MCA provides a flexible tool that is able to handle and bring together a wide range of variables assessed in different ways and thus offer useful assistance to the decision maker in pointing at appropriate locations.

In this thesis, MCA has incorporated ArcGIS as a method to select suitable locations for urban green space development. Therefore, this study used the application of GIS-based multi-criteria suitability analysis using analytical hierarchy process (AHP) to support the decision-making process on selecting an appropriate site for urban green spaces development.

3.6. Methods of Multi-Criteria Analysis (MCA)

In this study, to select a suitable site for urban green spaces using GIS-based multi-criteria analysis the following six main steps were used (Eastman et al., 1995):

1. Set the goal/ define the problem
2. Determine the criterion (factors/constraints)
3. Standardize the factors/criterion scores
4. Determine the weight of each factor
5. Aggregate the criteria
6. Validate/verify the result

1. Set the goal/ define the problem

In this study the main aim of GIS based Multi-Criteria Analysis (MCA) was to produce a map showing suitable sites for green space development in Adama Town.

2. Determine the criterion (factors/constraints)

There were no universally agreed criteria/factors for urban green space development (Jabir and Arun, 2014). Different literature suggests a variety of factors that may influence growth of green spaces. According to the researchers (Pantalone, 2010; Ahmed et al., 2011; Heshmat et al., 2013; Elahe et al., 2014; Yousef et al., 2014; Abebe and Megento, 2017; Li et al., 2018; Dagistanli et al., 2018; Pokhrel, 2019; Kuldeep, 2019; Ustaoglu and Aydinoglu, 2020), air quality, climate, historic and cultural sites, distance from the Park, distance from roads, LULC, population density, soil type, slope, distance to noisy influence, distance from facility locations, distance from residential area, and distance to stream were often used for green land suitability assessments. Based on the existing situation and availability of data for Adama Town, land suitability analysis for selection of suitable site for urban green spaces development was carried out based on the following factors: distance from roads, LULC, population density, soil type, slope, distance from noisy influence, distance from facility locations, distance from residential area and distance from stream. Though air quality, climate, 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 climate; and regarding air quality. Also, Park, historic and cultural sites are not found in the study area.

3. Standardize the factors/criterion scores

It’s essential to standardize the data in GIS-based multi-criteria decision-making analysis, in order to integrate the data measured in different units and mapped in scale of measurement such as ordinal, interval, nominal and ratio scales (Pereira and Duckstein,1993). Even though there are different methods that can be used to standardize criterion, linear scale transformation is the most frequently used technique (Malczewski, 2003). In this study for factors standardization, all the vector maps of the factors were converted to raster data formats. Then using the Spatial Analyst tool in ArcMap, the raster maps were reclassified. According to (FAO, 1981), land suitability classification, the datasets were reclassified from highly suitable (S1) to permanently unsuitable (N2); where S1, S2, S3, N1 and N2 represents the highly suitable, moderately suitable, less suitable, not suitable and permanently unsuitable conditions for green space development respectively. This method enables all measurements to have an equivalent value before any weights are applied.

4. Defining weights/ Determine the weight of each factor/

Assigning criteria weights for each factor is an important component of GIS-Based multi-criteria decision-making analysis. The purpose of weighing is to express the importance or preference of each factor relative to one another factor effect on urban green spaces. There are Several methods available to determine the weight like Analytical Hierarchy Process (AHP), rating and ranking. For this study the Analytical Hierarchy Process (AHP) method using pairwise comparison matrices was adopted to assign weight for each factor.

3.7. Analytical Hierarchy Process (AHP)

AHP is first developed by Saaty (1980) who combines qualitative and quantitative analysis of complex problems of land management with the best alternatives (Kordi and Brandt, 2012). Analytical hierarchy process (AHP) methodology has been widely used for multi-criteria decision-making regarding land suitability analysis of different land uses. The AHP method determines the weight of importance of different factors influencing land suitability based on pairwise comparisons of the factors considering their relative significance (Kordi and Brandt, 2012). Weighting is an important component of land suitability analysis as it affects the output and is complicated as the considered factors interact with each other.

In this study, to select a suitable site for urban green spaces development the AHP was carried out in the following three steps:

- Pair-wise comparison of criteria
- Calculating criterion weights
- Calculating consistency ratio (CR)

A. Pair-wise comparison of criteria

Pair-wise comparison of criteria was performed first and results were put into a comparison matrix. A Pair-wise comparison matrix was constructed, where each criterion was compared with the other criteria, relative to its importance, on a scale from 1 to 9 which is suggested by Saaty (1980) (Table 5).

Table 5: AHP Scale of Relative Importance

Intensity of relative importance	Definition	Explanation
1	Equal Importance	Two activities combine equally to the objective.
3	Moderate importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another.
7	Demonstrated importance	An Activity is strongly favoured and its dominance is demonstrated in practice.
9	Extreme Importance	The evidence favouring one activity over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed.
Reciprocals of above non zero numbers.	If an activity has one of the above numbers (e.g.,3) compared with a second activity, then the second activity has the reciprocal value (i.e., 1/3) when compared to the first.	

Source: Saaty (1985)

According to Saaty (1980), the values in the matrix need to be consistent, which means that if x is compared to y, it receives a score of 9 (extreme significance), y to x should score 1/9 (less significance) and something compared to itself gets the score of 1 (equal significance).

In this study the pairwise comparison matrices were developed by taking into account the information provided by various literatures (Elahe et al., 2014; Yousef et al., 2014; Abebe and Megento, 2017; Dagistanli et al., 2018; Pokhrel, 2019; Ustaoglu and Aydinoglu, 2020).

B. Calculating criterion weights

The weights of all factors are calculated by normalizing the eigenvector associated with the maximum eigenvalue of the (reciprocal) ratio matrix. Manually the computation of the criterion weights involves the following operations: (a) summing the values in each column of the pairwise comparison matrix; (b) dividing each element in the matrix by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix and (c) computing the average of the elements in each row of the normalized matrix that is, dividing the sum of normalized scores for each row by the number of criteria. In this study the computation of the criterion weights was calculated by using IDRISI Selva software.

C. Calculating consistency ratio (CR)

After the pair-wise comparison was filled and the weight of the factors was determined, a consistency ratio (CR) was calculated to identify inconsistencies and develop the best-fit weights in the complete pair-wise comparison matrix. Consistency ratio of 0.1 or less is acceptable to continue the AHP analysis (Saaty, 2008). But if a consistency ratio is greater than 0.1, then there are inconsistencies in the evaluation process and the AHP method may not yield a meaningful result (Saaty, 2007). A consistency ratio was calculated for the matrix to verify the degree of credibility of the relative weights, by using the following formula:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad \text{……………………………………………………………………………Equation (7)}$$

where CR=Consistency ratio, CI = referred to as consistency index, RI = is the random consistency index whose value depends on the number (n) of factors being compared; as illustrated in table 6 (Saaty, 1980). The consistency index (CI) was calculated by the following formula:

$$\mathrm{CI} = \frac{\lambda\mathrm{max} - \mathrm{n}}{\mathrm{n} - 1} \quad \text{………………………………………………………………………… Equation (8)}$$

Where λ max is the principal eigen value; n is the number of factors. λmax = Σ of the products between each element of the priority vector and column totals.

Table 6: Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty (1980)

5. Aggregate the criteria

Step five was to aggregate the criteria using weighted linear combination (WLC) and apply it in the ArcGIS raster calculator.

3.8. Weighted overlay analysis

After the criteria maps and weights have been developed and established, a decision rule of multi-criteria analysis was used. There are three common decision rules in multi-criteria analysis namely weighted linear overlay, boolean overlay and ordered averaging (Jiang and Eastman, 2000; Malczewski, 2003). In this study the weighted linear combination (WLC) technique was applied to aggregate the standardized layers. In this technique, factors or parameters (Xi) are multiplied by weight of the parameters (Wi) to get composited weights and then summed. WLC technique is a straightforward linear method calculating composite weights. WLC multiplies and sums up the layers to produce suitability maps for green space. This can be done by using the following formula to derive the intended map (i.e., urban green spaces suitability map for Adama Town).

$S = \sum_{i=1}^{n}(WiXi)$ ……………………………………………………………Equation (9)

where S = Suitability, Wi = relative importance or weight of factors / parameters i,

Xi = parameters i, and n = total number of parameters related to the study.

6. Validate/verify the result

Validating or verifying the result was the final step and it helps to assess the reliability of the output and usually assessed by ground truth verification and sensitivity analysis. According to Abebe and Megento (2017), sensitivity analysis was performed by changing the weight of criteria and field surveys were conducted for ground truth verification.

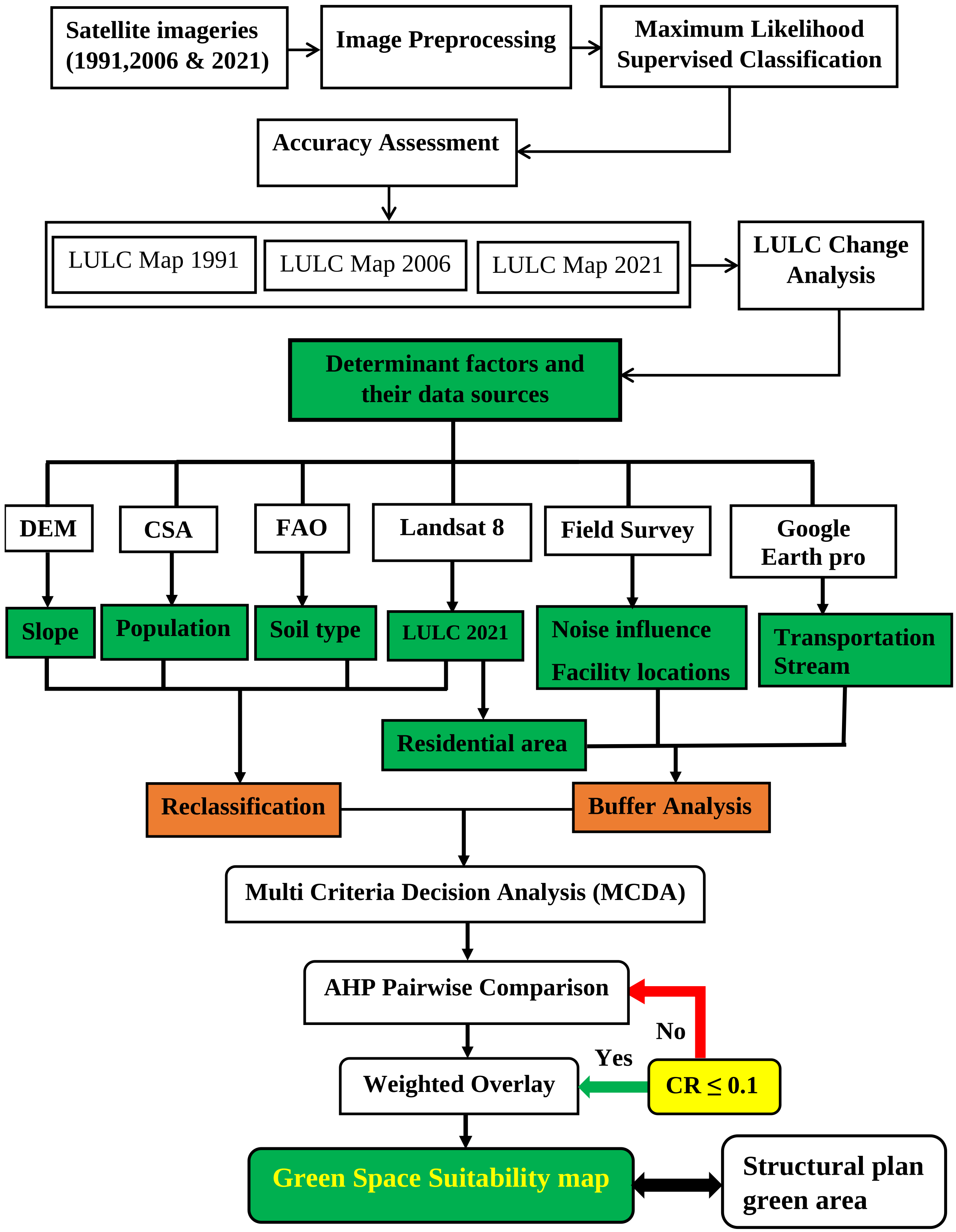


Figure 8:Technological Scheme of the Study

CHAPTER IV: RESULT AND DISCUSSION

This chapter discusses different data sets that were used to examine changes in the LULC patterns and Land suitability analysis for urban green space development in Adama Town. Based on the data gathered, data analysis performed and LULC maps developed for 1991, 2006 and 2021 years presented in the following figure 9 and table 11 shows the statistical change analysis of LULC over the study period (1991 – 2021). An overall change in LULC of all the three reference years is shown in figure 10. Additionally, maps of suitability analysis for urban green space development were created for each suitability criterion and the final composite map was finally produced by weighted overlaying of the individual maps. Reclassified criterion, standardization score, area coverage of suitability levels and weights of each factor were summarized using tables.

4.1. Land Use and Land Cover Classification

To accomplish the objectives of the study, LULC of the study area were first classified from Landsat satellite images of 1991, 2006 and 2021 to compute the LULC change trend of Adama Town. The images were interpreted or classified into five LULC classes, namely built up, shrub and bushes, farm land, bare land and water body. The LULC maps generated after running a maximum likelihood supervised classification in ERDAS IMAGINE software. The results showed that, over the study period (1991–2021), the dominant land cover type in the study area was farm land ranging between 65.43% and 75.86% of the total area.

4.2. Accuracy Assessment of the Classification

Accuracy assessment in this study revealed the overall accuracies of 93.87%, 96.56% and 94% with the Kappa statistics of 0.895, 0.952 and 0.921 were calculated for the three reference years 1991, 2006 and 2021 respectively. This indicates that all classifications are in acceptable range because an overall accuracy of each year was greater than 85% and kappa coefficient greater than 0.80 represents strong agreement (Landis and Koch, 1977) is an indicator for a strong accuracy. Hence, the maps met the accuracy requirements for change detection analysis (Anderson et al., 1976), and there is a positive correlation between the remotely sensed classified samples and the reference data.

Results of user's accuracy in this study showed that in 1991 the maximum class accuracy was for water body (100%) and the minimum was for bare land (81.68%).

In 2006, user’s accuracy ranges from lowest accuracy bare land (86%) to relatively correctly classified water body (100%) whereas in the period 2021, it ranges from 80.52% (bare land) to 98.20% (built-up). Most of the LULC classes have a larger producer’s accuracy than overall accuracy almost all are greater than 90% except the class of farmland (85.67%) in 2021. The details of error matrix tables results are shown in (Table 7, Table 8 and Table 9).

Table 7: Error matrix of classification for 1991

Reference Map								
Classified Map	Classified Data	Farm land	Bare land	Shrub & bushes	Built-up	Water body	Row Total	User Accuracy (100%)
	Farm land	2218	0	55	0	0	2273	97.58
	Bare land	37	165	0	0	0	202	81.68
	Shrub & bushes	126	0	989	0	0	1115	88.69
	Built-up	29	0	0	235	1	265	88.68
	Water body	0	0	0	0	191	191	100
	Column Total	2410	165	1044	235	192	4046	
	Producer Accuracy (100%)	92.03	100	94.73	100	99.48		
	Overall Accuracy = 93.87(%) Kappa Statistics $K^{\wedge}$= 0.895							

Table 8: Error matrix of classification for 2006

Reference Map								
Classified Map	Classified Data	Farm land	Bare land	Shrub & bushes	Built-up	Water body	Row Total	User Accuracy (100%)
	Farm land	753	1	11	0	0	765	98.43
	Bare land	22	172	0	6	0	200	86
	Shrub & bushes	15	0	469	0	0	484	96.9
	Built-up	3	0	6	379	2	390	97.18
	Water body	0	0	0	0	82	82	100
	Column Total	793	173	486	385	84	1921	
	Producer Accuracy(100%)	94.95	99.42	96.50	98.44	97.62		
	Overall Accuracy = 96.56 (%) Kappa Statistics $K^{\wedge}$= 0.952							

Table 9: Error matrix of classification for 2021

Reference Map								
Classified Map	Classified Data	Farm land	Bare land	Shrub & bushes	Built-up	Water body	Row Total	User Accuracy (100%)
	Farm land	329	1	14	12	0	356	92.42
	Bare land	30	124	0	0	0	154	80.52
	Shrub & bushes	18	0	455	0	0	473	96.19
	Built-up	3	2	2	546	3	556	98.20
	Water body	4	0	1	5	86	96	89.58
	Column Total	384	127	472	563	89	1635	
	Producer Accuracy(100%)	85.67	97.64	96.39	96.98	96.63		
	Overall Accuracy = 94% Kappa Statistics $K^{\wedge}$= 0.921							

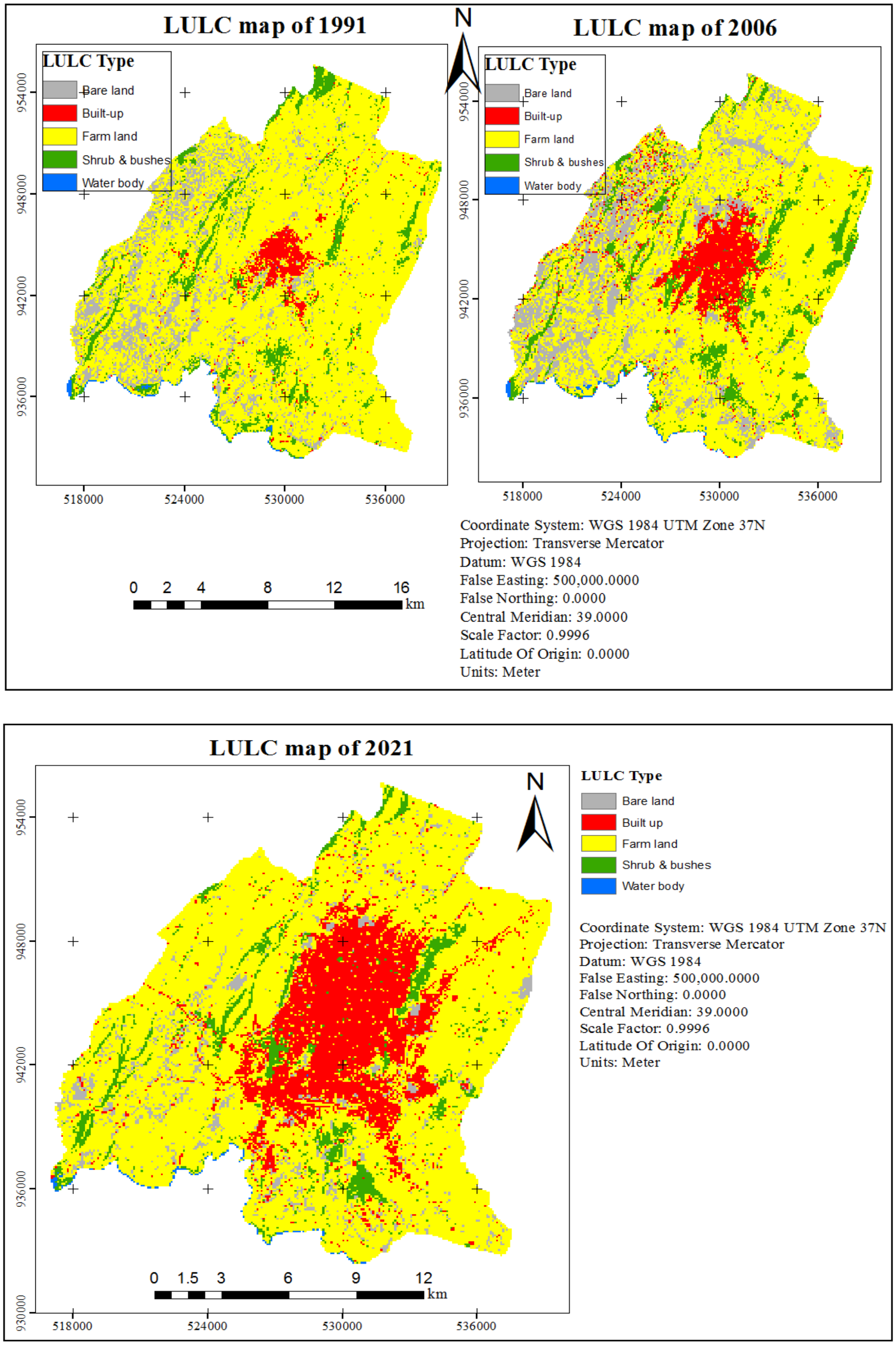


Figure 9: LULC map of study area in 1991, 2006 and 2021

4.3. LULC Change Analysis

In this study, three LULC maps were produced for the study period (Figure 9) and spatio-temporal LULC dynamic process was analyzed (Table 10; Table11). Based on the LULC classification, over the past three decades, LULC in study area such as shrub and bushes were in continuous decline, while farm land and bare land classes showed a varying pattern and water body showed almost the same. In general, out of the five LULC classes identified in the study area, only built-up, showed continuous increment over the past 30 years. The extent of change within the study area of the individual LULC categories in hectare (ha) and the percentage (%) they occupied for 1991, 2006 and 2021 are presented in Table 10.

Table 10: Area statistics and percentage of the LULC units for 1991, 2006 and 2021

LULC Types	**1991**		**2006**		**2021**	
	Area(ha)	Area (%)	Area(ha)	Area (%)	Area(ha)	Area (%)
Farm land	23747.365	75.86	20482.598	65.43	21568.944	68.90
Bare land	3676.222	11.74	5474.912	17.49	1650.961	5.27
Shrub and bushes	2832.216	9.05	2418.881	7.73	1992.234	6.36
Built up	948.796	3.03	2819.943	9.01	5983.908	19.12
Water body	99.615	0.32	107.880	0.34	108.167	0.35
Total	31304.214	100	31304.214	100	31304.214	100

In 1991 the study area was dominated by farm land covering 75.86% followed by bare land covering 11.74% of the study area. Built-up, shrub and bushes and water body shared 3.03%, 9.05%, and 0.32% of the total area respectively. In 2006, farm land, bare land and Shrub and bushes covered 65.43%, 17.49% and 7.73% of the total area respectively. The remaining parts of the area were covered with built-up (9.01%) and water body (0.34%). In 2021 built-up area increased to (19.12%) and the remaining (80.88%) was the share of other LULC classes (Table 10 and Table 11; Figure 9 and Figure 10).

Table 11: Overall amounts and percentage of LULC Change during 1991-2021

LULC Types	**1991-2006**		**2006-2021**		**1991-2021**	
	Change (Δ/ha)	(%)	Change (Δ/ha)	(%)	Change (Δ/ha)	(%)
Farm land	-3264.767	-13.75	1086.346	5.30	-2178.421	-9.17
Bare land	1798.690	48.93	-3823.951	-69.83	-2025.261	-55.09
Shrub and bushes	-413.335	-14.59	-426.647	-17.64	-839.982	-29.66
Built up	1871.147	197.21	3163.965	112.20	5035.112	530.68
Water body	8.265	8.29	0.287	0.26	8.552	8.58

Generally, the decreased trends observed in the shrub and bushes, farm land and bare land LULC classes during the study period. Out of the five LULC classes identified in the study area built-up showed increment during the study period. Water body showed almost the same over the past 30 years. For a better comparison of the change trends occurred in these three study periods are shown in Figure 10.

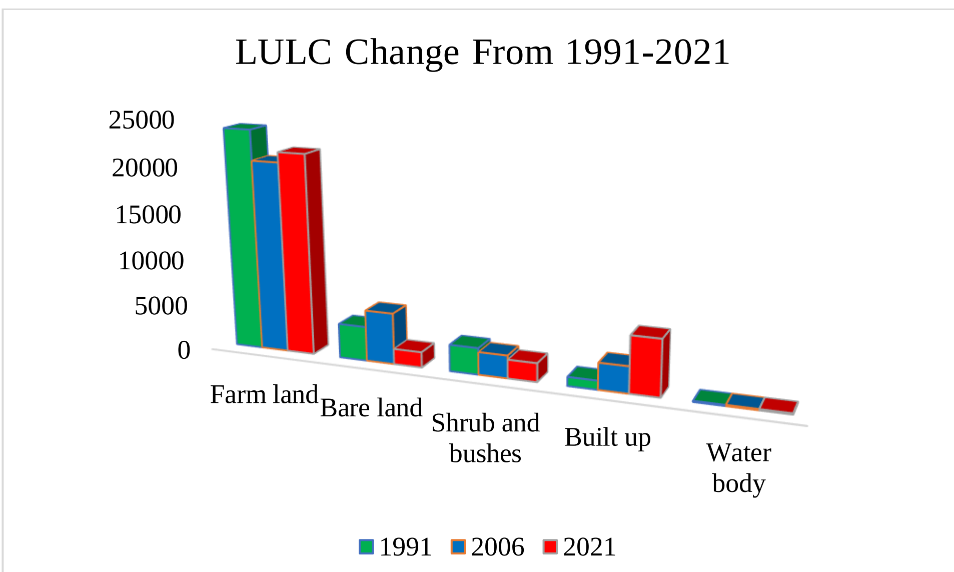


Figure 10: Change Trends of LULC from 1991-2021

The result of LULC change analysis indicated that over the past 30 years built-up area showed continuous increment, whereas shrub and bushes showed continuous decline. Consequently, those areas, which are close to built-up and urban centers, were subjected to significant loss of shrub and bushes (greeneries) in the last three decades. This reduction of green spaces has indicated that the Adama Town administration has a problem of proper planning and implementation to keep the Town green with the exception of the establishment of a few roadside trees in the Town. Therefore, suitability analysis for urban green space development within the Town are mandatory in order to maximize both quality and quantity of urban green spaces that bring value to urban dwellers and their environment in a sustainable way.

4.4. The main determinant factors for UGS development in the study area

The factors used for suitability analysis for UGS development in the study area were selected based on different literatures and prior knowledge of the study area. Based on the existing situation and availability of data for Adama Town, land suitability analysis for selection of suitable site for urban green spaces was carried out based on the following nine factors: LULC, distance from roads/transportation, population density, soil type, slope, distance from noisy influence, distance from residential area, distance from facility locations and distance from stream.

4.5. Suitability analysis for urban green space development

4.5.1. Suitability of land use/land cover

Previous studies have shown that current LULC must be considered when choosing suitable sites for the development of urban green spaces and have identified the suitability of different LULC based on their use type (Heshmat et al., 2013; Abebe and Megento, 2017; Dagistanli et al., 2018; Pokhrel, 2019; Ustaoglu and Aydinoglu, 2020). Based on knowledge obtained from the analysis of literature, bare land and Shrub and bushes were considered to be highly suitable and moderately suitable for urban green spaces development respectively. Additionally, in this study farm land, Built-up area and water body were considered as less suitable, not suitable and permanently unsuitable conditions for green space development respectively (Table 12; Figure 11).

Table 12: Reclassified LULC and area coverage of suitability levels

LULC type	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
Bare land	5	S1	1650.961	5.27
Shrub and bushes	4	S2	1992.234	6.36
Farm Land	3	S3	21568.945	68.90
Built-up area	2	N1	5983.909	19.12
Water body	1	N2	108.168	0.35

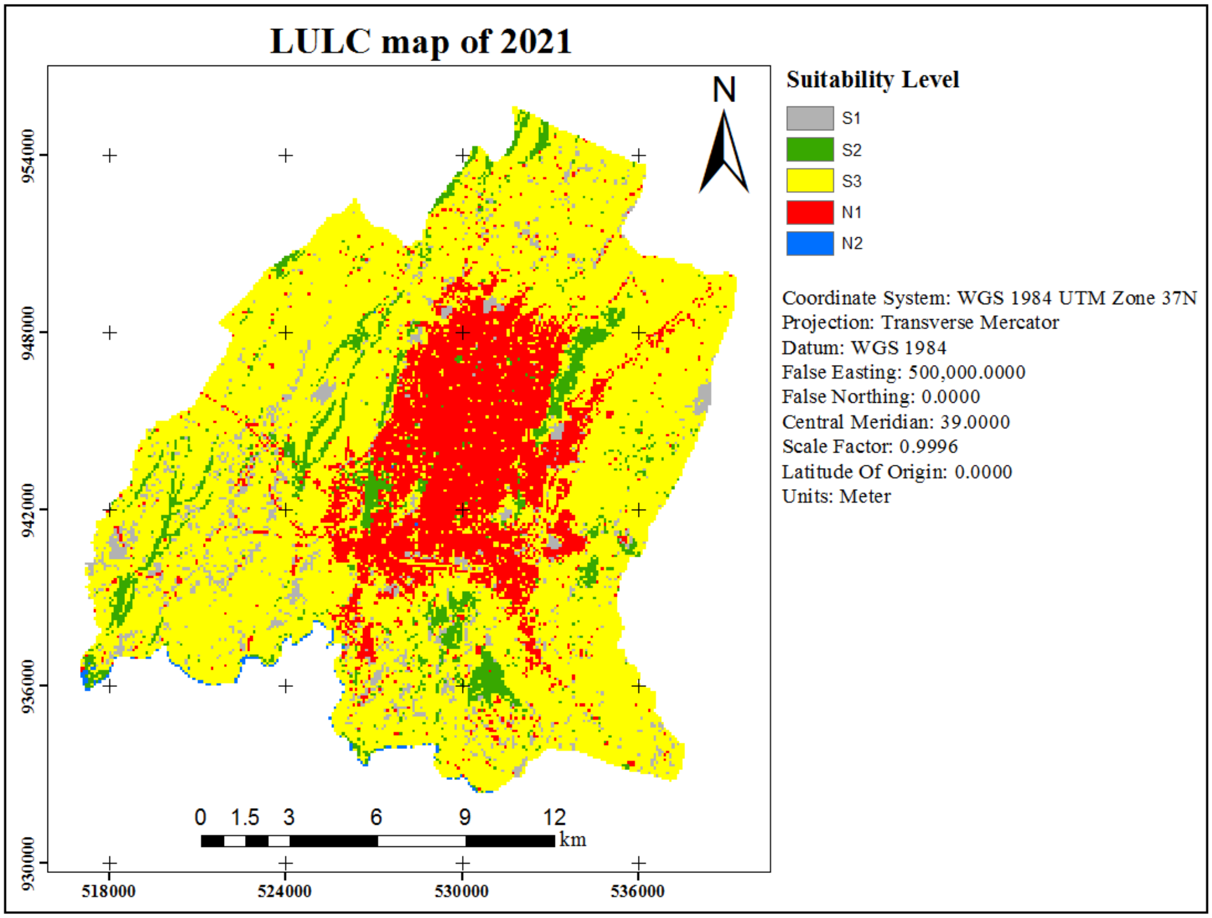


Figure 11: Existing land use and land cover map

4.5.2. Suitability of distance from the stream

Water plays an important role in the growth and development of a living organism. According to some earlier studies carried out by various researchers like (Heshmat et al., 2013) stated that land closer to water bodies like rivers, lakes, reservoirs and ponds are suitable for the development of green space. As they preserve good environmental health and are highly suitable from the ecosystem perspective too. Distance from the stream less than 250m; between 250 and 500m and in between 500 and 750m are highly suitable; moderately suitable and less suitable respectively (Table 13; Figure 12).

Table 13: Reclassified distance from stream and area coverage of suitability levels

Distance from stream (m)	Standardization score/value	Level of suitability	Area (ha.)	Area cover in (%)
<250	5	S1	6398.858	20.44
250–500	4	S2	5451.442	17.41
500–750	3	S3	4429.110	14.15
750–1000	2	N1	3223.021	10.30
>1000	1	N2	11801.785	37.70

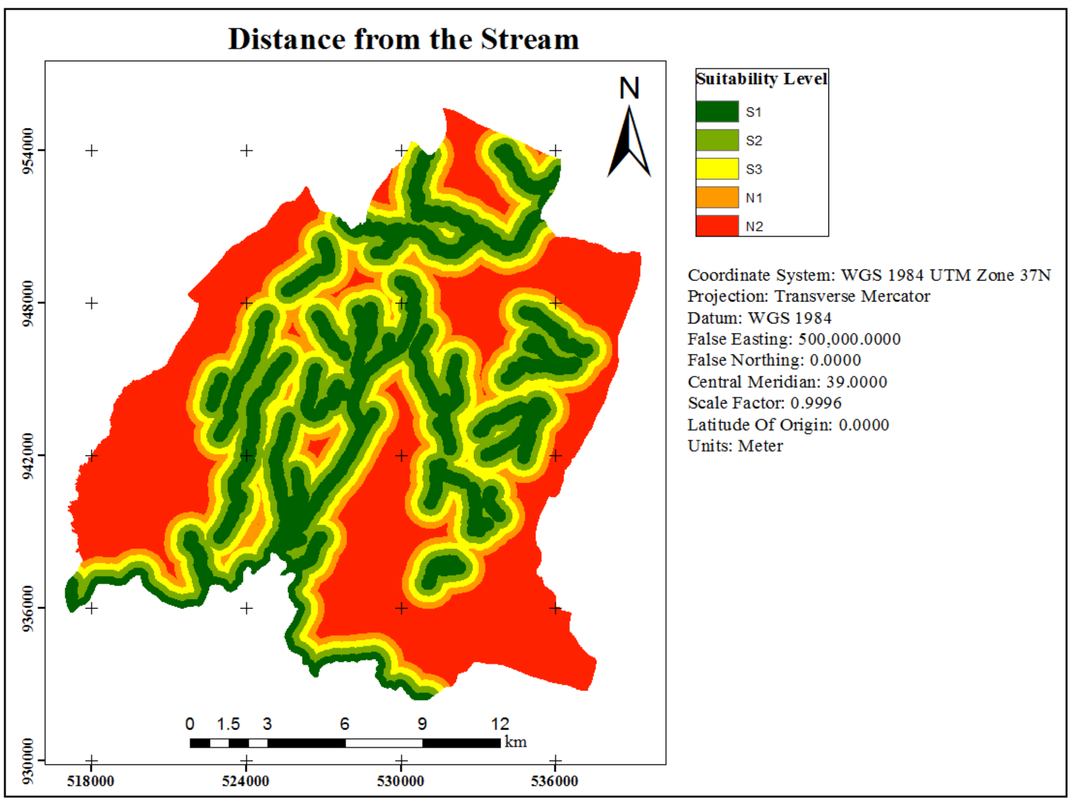


Figure 12: Reclassified distance from stream map

4.5.3. Suitability of distance from transportations

Accessibility depends upon the distance and time the green space should be close to the road and the road is more suitable. 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 et al., 2012; Morckel, 2017). If green space is situated at an acceptable distance from roads in order to access transport, the green space site is preferable (Ahmed et al., 2011; Elahe et al., 2014). In this study, by making buffer analysis, areas within the 500m, 500m-1000m and 1000m-1500m radius of the road network have been considered as highly suitable, moderately suitable and less suitable respectively (Table 14; Figure 13).

Table 14: Reclassified distance from transportations and area coverage of suitability levels

Distance from Road (m)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
<500	5	S1	10386.607	33.18
500–1000	4	S2	5212.222	16.65
1000–1500	3	S3	3703.241	11.83
1500–2000	2	N1	3099.267	9.90
>2000	1	N2	8902.879	28.44

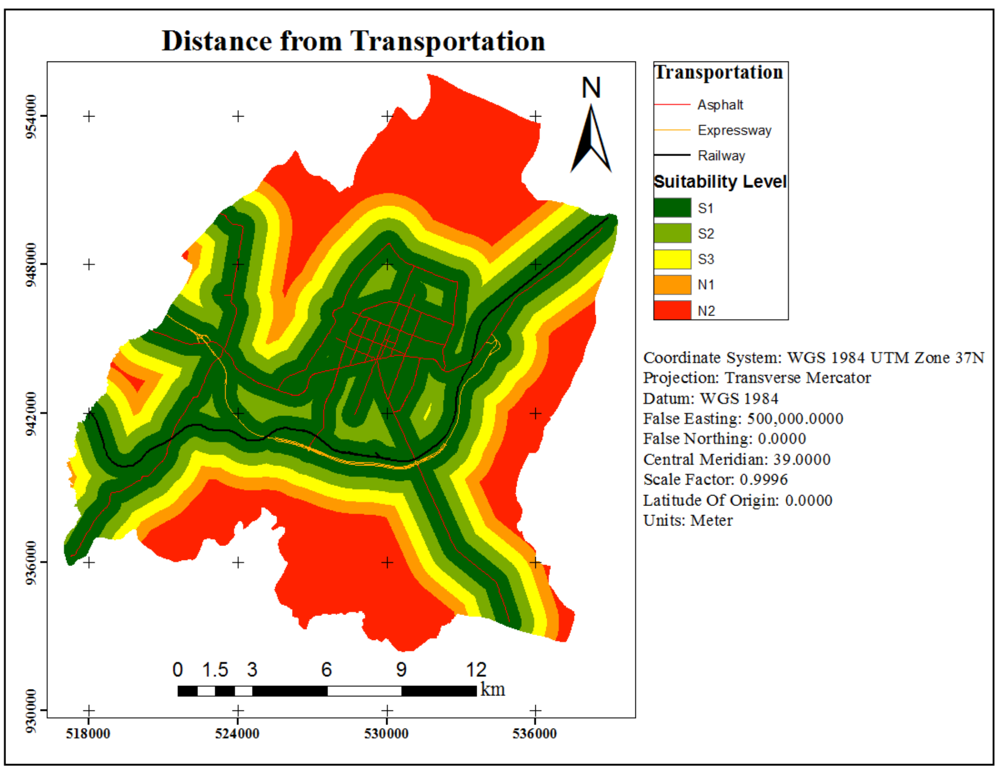


Figure 13: Reclassified distance from transportations map

4.5.4. Suitability of distance from noise influence

Noisy areas are not suitable for green space like the factory area because of high sound pollution and smoke (Manlun, 2003; Pareta, 2019). Therefore, the farther lands from the factory get more preferences for green space development. In this study, by making buffer analysis, as totally unsuitable if less than 1000m, not suitable between 1000m and 2000m, less suitable from 2000m to 3000m, moderately suitable from 3000 to 4000m and highly suitable greater than 4000m for green space development (Table 15; Figure 14).

Table 15: Reclassified distance from factory and area coverage of suitability levels

Distance from factory (m)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
>4000	5	S1	13606.094	43.46
3000–4000	4	S2	4114.139	13.14
2000–3000	3	S3	5180.503	16.55
1000–2000	2	N1	5429.615	17.35
<1000	1	N2	2973.863	9.50

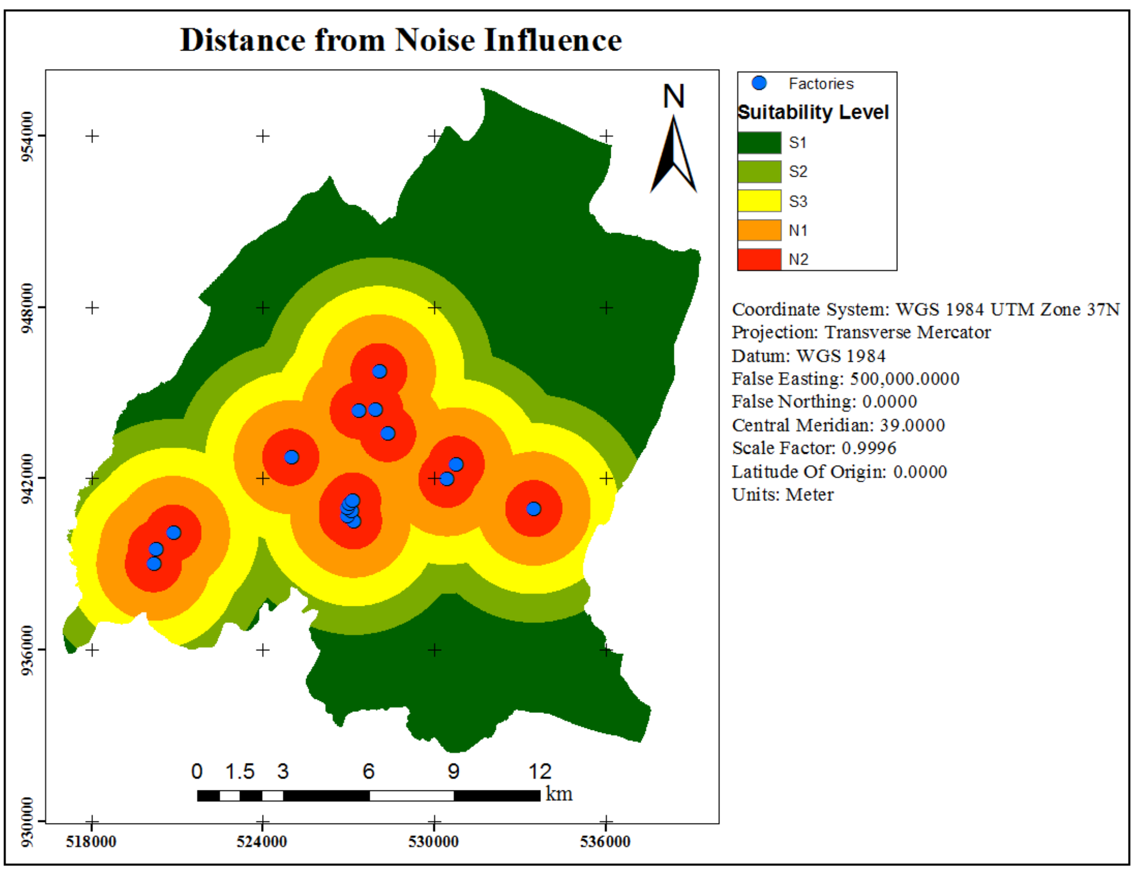


Figure 14: Reclassified distance from factory map

4.5.5. Suitability of soil type

Soils of Adama Town are classified into three principal types such as Eutric Cambisols, Haplic Xerosols and Lithosols. Eutric Cambisols have relatively good structure and chemical properties and are not therefore 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. Haplic xerosols are subject to wind erosion and concentration of soluble salts but relatively moderately suitable compared to the other types. Because of their Lack of moisture and shallow profile preclude cultivation of Lithosols soils, in this study, this soil was considered as not suitable compared to the other types (FAO-UNESCO, 1974).

Table 16: Soil type and area coverage of suitability levels

Soil type	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
Eutric Cambisols	5	S1	17199.705	54.94
Haplic Xerosols	4	S2	3988.176	12.74
Lithosols	2	N1	10116.333	32.32

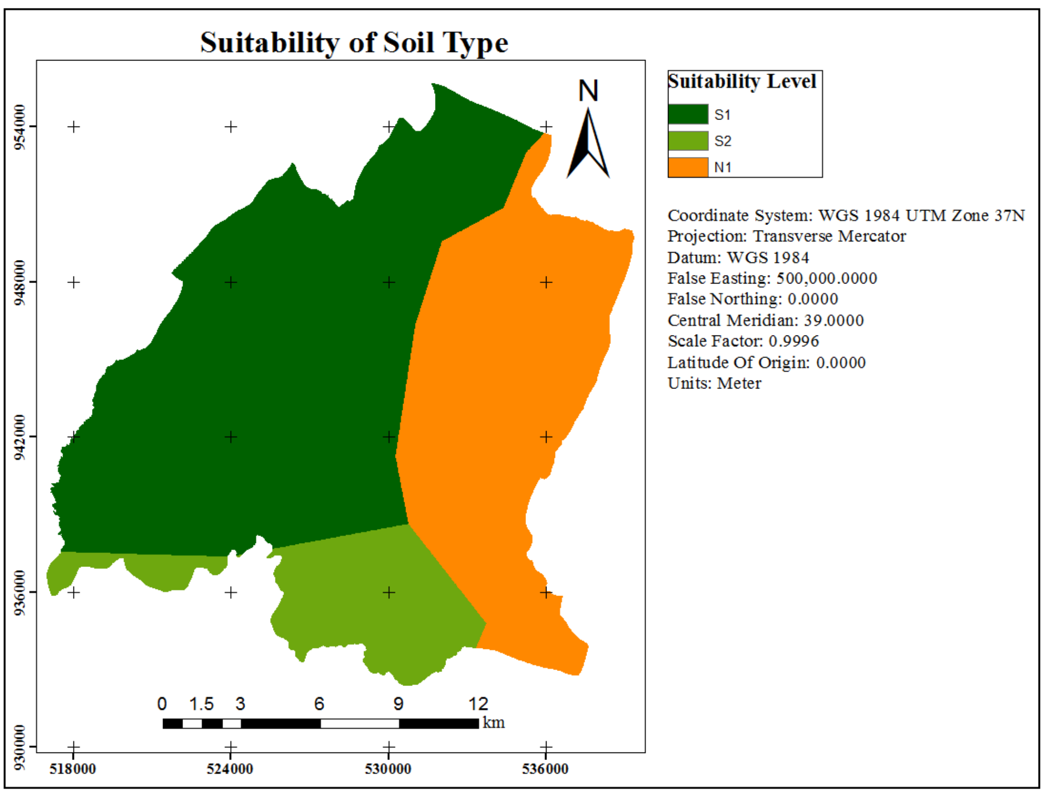


Figure 15: Reclassified soil map (Source: FAO)

4.5.6. Suitability of slope

Earlier studies have shown that low-slope areas are highly suitable for the development of urban green spaces (Yousef and Mohammad, 2014; Abebe and Megento, 2017; Dagistanli et al., 2018; Pareta, 2019) and the aim of building a green space 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 and Mohammad, 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 (moderately suitable) and strongly sloping (less suitable) respectively (Table 17; Figure 16).

Table 17: Reclassified slope and area coverage of suitability levels

Slope (%)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
<5	5	S1	9745.398	31.13
5–10	4	S2	9549.294	30.51
10–15	3	S3	5128.518	16.38
15–30	2	N1	5051.256	16.14
>30	1	N2	1829.748	5.84

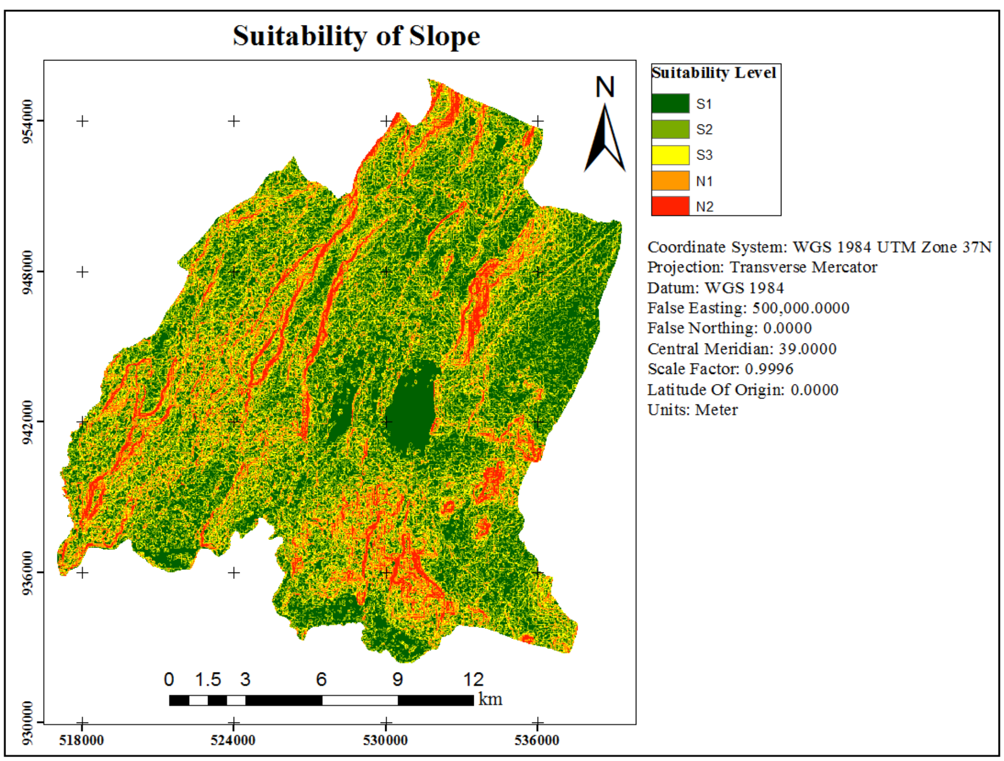


Figure 16: Reclassified slope map

4.5.7. Population density

Population density is one of the socio-economic factors influencing the appropriate selection of green space in urban areas. Some researchers (Ahmed et al., 2011; Heshmat et al., 2013; Elahe et al., 2014; Dagistanli et al., 2018; Pokhrel, 2019) recommend that areas that have high population density are highly suitable for developing green space. 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 and believed to be insufficiently suited to UGSs development (Table 18; Figure 17).

Table 18: Reclassified population density and area coverage of suitability levels

Population density (pop/ha)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
>80	5	S1	1644.247	5.25
50-80	4	S2	820.223	2.62
20-50	3	S3	2587.729	8.27
5-20	2	N1	2781.405	8.89
<5	1	N2	23470.645	74.97

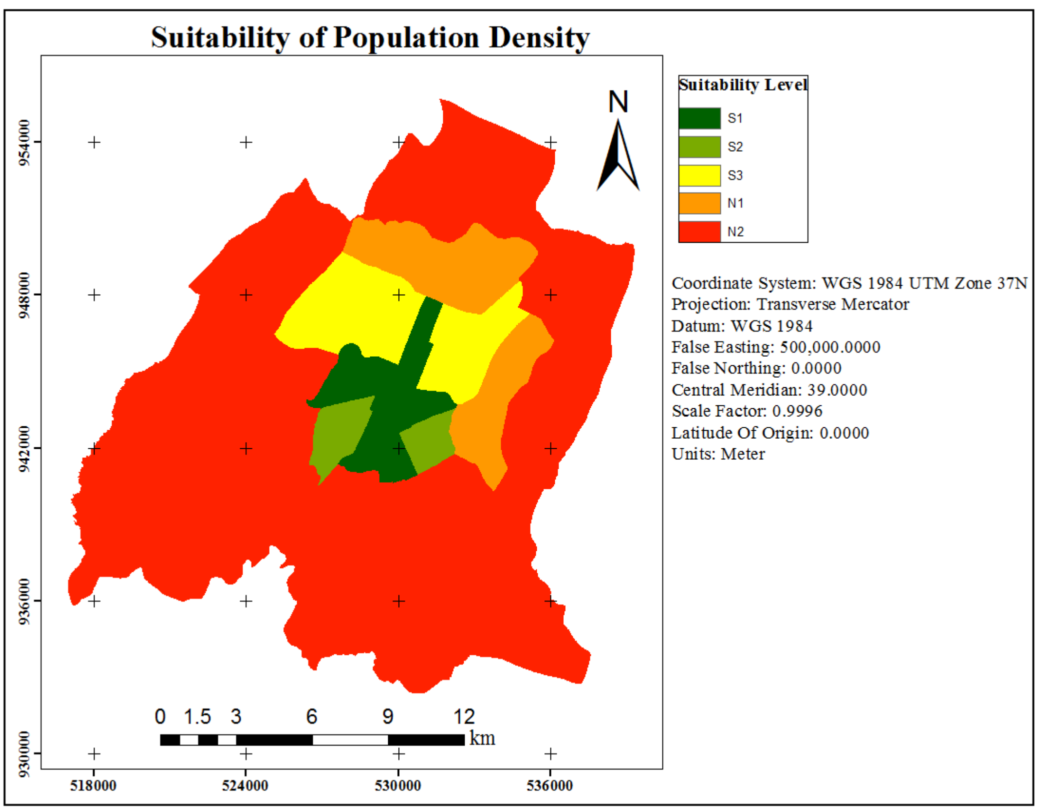


Figure 17: Reclassified population density map

4.5.8. Suitability of distance from facility locations

The facilities location covers the schools, college, major health facilities and hospital's locations that are crucial and important to get all services and meantime need some green spaces nearby such locations. Based on those views the lands which are closer to those facilities are more suitable than farther land (Pokhrel, 2019). Therefore, if distance from the facilities location is less than 400 m, it was considered as highly suitable; 400m – 800m, moderately suitable; 800m-1200m, less suitable; 1200m–1600m, not suitable and >1600m, permanently not suitable for developing green space (Table 19; Figure 18).

Table 19: Reclassified distance from facility locations and area coverage of suitability levels

Distance from facilities location (m)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
<400	5	S1	3366.321	10.75
400–800	4	S2	2913.730	9.31
800–1200	3	S3	2417.016	7.72
1200–1600	2	N1	2449.925	7.83
>1600	1	N2	20157.214	64.39

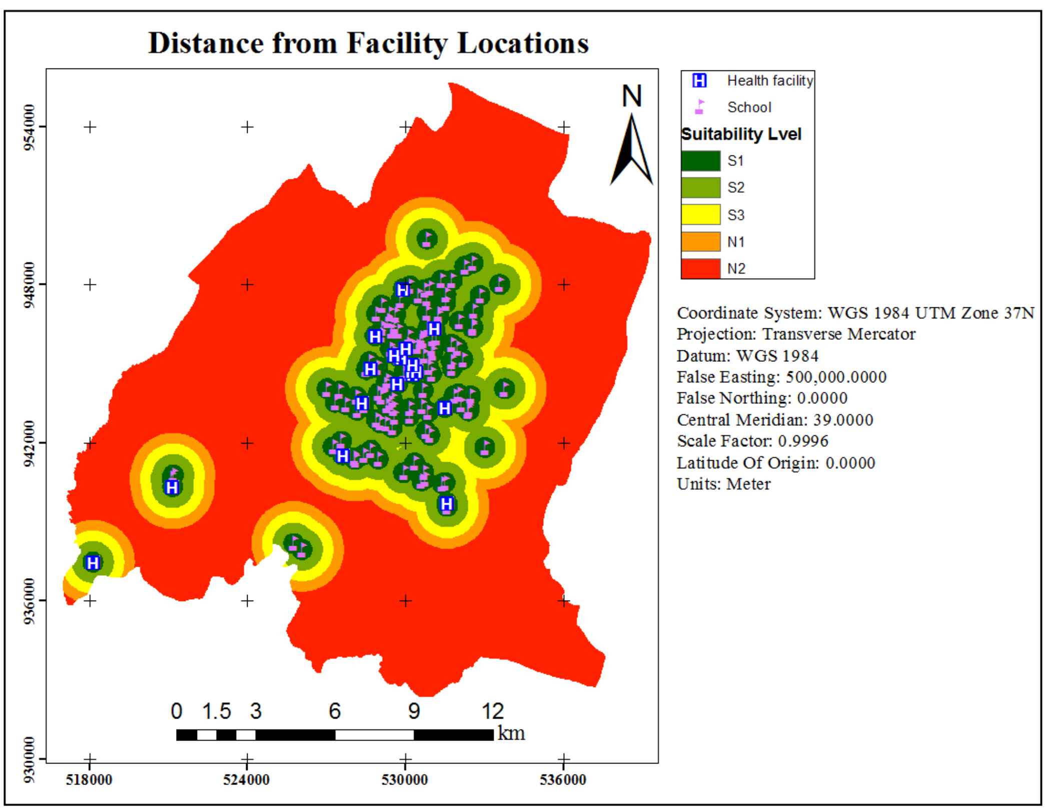


Figure 18: Reclassified facility locations map

4.5.9. Suitability of distance from residential area

Different previous studies carried out by (Zhang et al., 2013; Malmir et al., 2016; Ustaoglu and Aydinoglu, 2020; Gelan, 2021), recommend that green spaces must be accessible to settlement area in urban areas, since they have numerous ecological, social and economic benefits. Distance between settlement areas and green spaces had an adverse impact on users and reported that green spaces such as parks, playground and sport field closest to settlement areas are most popular. Thus, the proximity of green spaces to the settlement area in terms of distance is important to consider. For this study, areas within 500m, 500m to 1000m and 1000 m to 2000 m, distances from the settlement area have been considered as highly suitable, moderately suitable and less suitable respectively (Table 20; Figure 19).

Table 20: Reclassified distance from residential area and area coverage of suitability levels

Distance from residential area (m)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
<500	5	S1	12609.880	40.28
500–1000	4	S2	3304.301	10.55
1000–2000	3	S3	5896.489	18.84
2000–3000	2	N1	4397.972	14.05
>3000	1	N2	5095.565	16.28

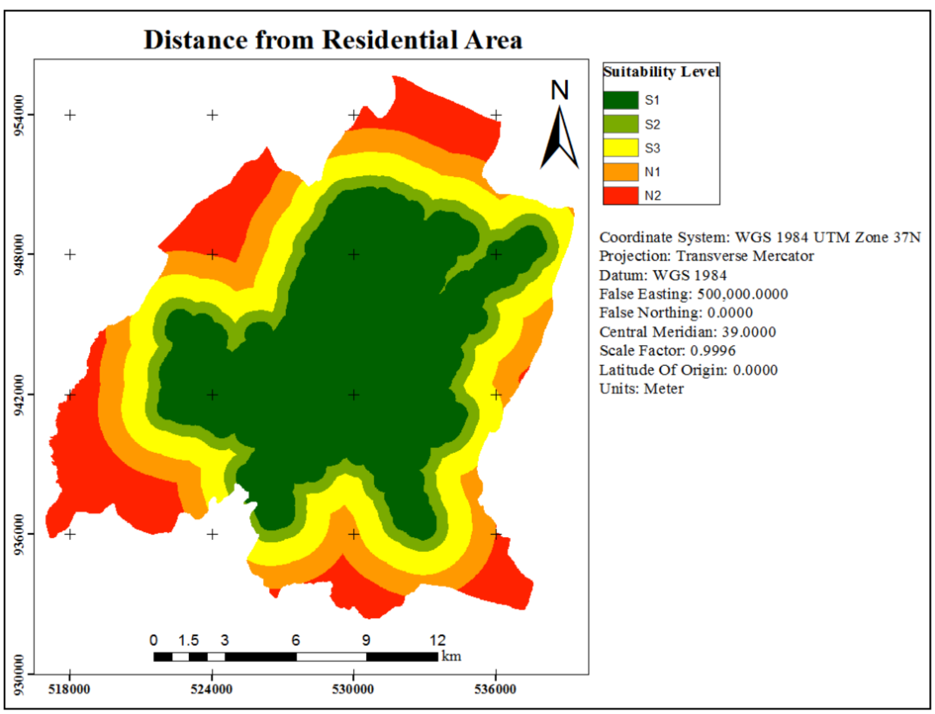


Figure 19: Reclassified residential area map

4.6. AHP Weight Derivation

Analytical Hierarchy Process (AHP) pairwise comparison matrix was created and criteria weights were calculated for each factor by comparing factors on a scale from 1 to 9. The reclassified input datasets were assigned a weight value to express the importance or preference of each criterion to the other criteria for suitable site selection for green space (Table 20).

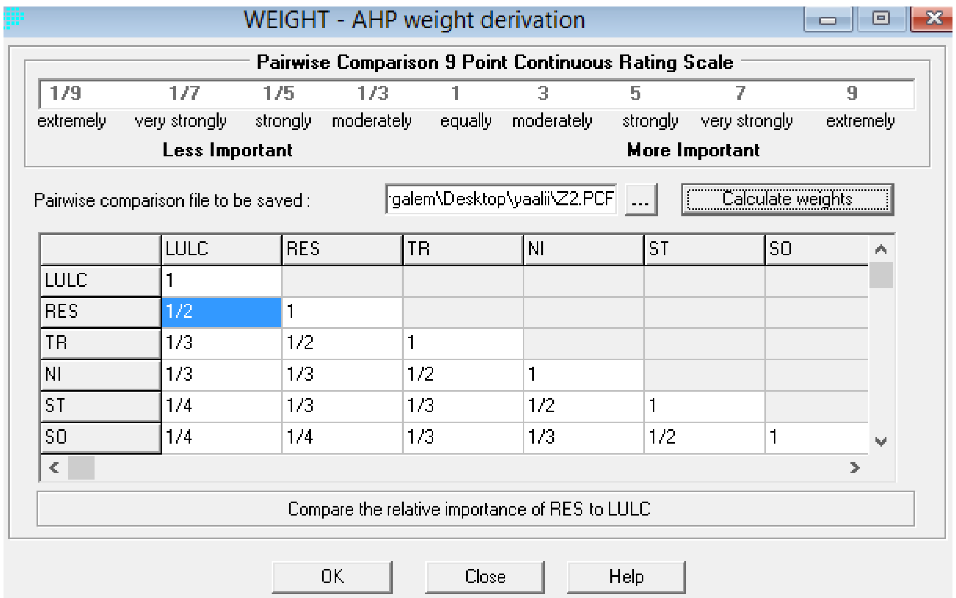


Figure 20: Pairwise comparison matrix

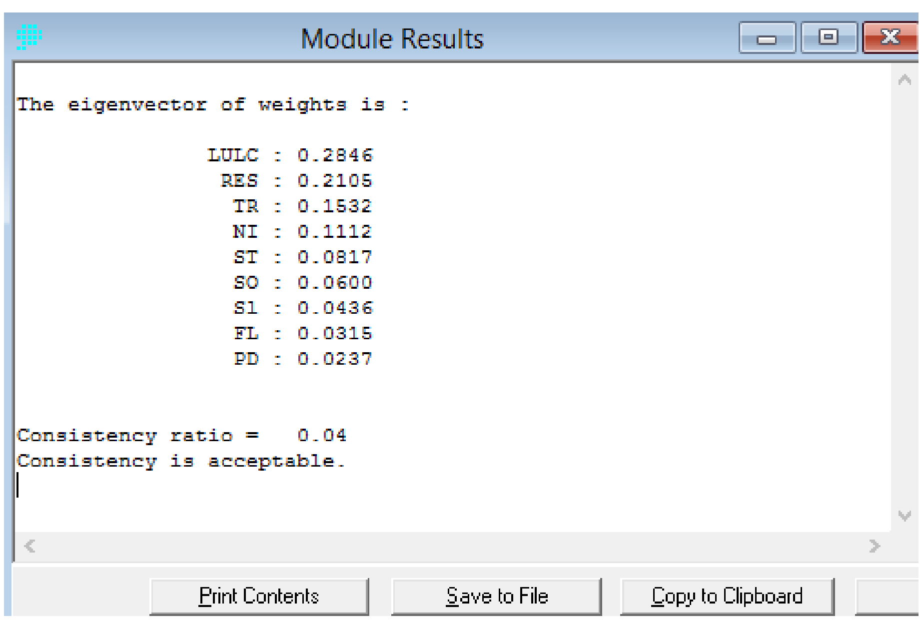


Figure 21: Eigenvector of the pair wise comparison matrix

Table 21: Pairwise comparison matrix

Criteria	LULC	RES	TR	NI	ST	SO	SL	FL	PD	Weight
LULC	1	2	3	3	4	4	6	6	7	29
RES	1/2	1	2	3	3	4	4	6	6	21
TR	1/3	1/2	1	2	3	3	4	4	6	15
NI	1/3	1/3	1/2	1	2	3	3	4	4	11
ST	1/4	1/3	1/3	1/2	1	2	3	3	4	8
SO	1/4	1/4	1/3	1/3	1/2	1	2	3	3	6
SL	1/6	1/4	1/4	1/3	1/3	1/2	1	2	3	4
FL	1/6	1/6	1/4	1/4	1/3	1/3	1/2	1	2	3
PD	1/7	1/6	1/6	1/4	1/4	1/3	1/3	1/2	1	3

Note: LULC = Land use/ land cover, RES = Residential area, TR = Transportations, NI = Noise Influence, ST = Stream, SO = Soil type, SL = Slope, FL = Facility locations, PD = population density

The above AHP result shows that the derived factors have a different degree of influence on urban green spaces. As it is evident from (Table 21; figure 21), the weight assigned to the factors reveals the relative importance of each parameter in exposing an area to urban green spaces evaluation. As a result, shows land use/land cover with the weight of 29 has the highest priority, 21, 15, 11, 8, 6, 4, 3 and 3 was obtained as a weight value for the distance from residential area, distance from roads/transportation, distance from factory/noise influence, distance from the stream, suitability of soil type, suitability of slope, distance from facility locations and population density respectively with 0.04 of consistency ratio (Figure 21). Consistency ratio of 0.1 or less is acceptable to continue the AHP analysis (Saaty, 2008). In this study, consistency ratio (CR) of conducted AHP comparisons has obtained 0.04, which is smaller than 0.1 therefore the comparisons can be acceptable. Based on the result of this study, AHP is a highly effective instrument for determining factor weights and is more helpful than alternative approaches since the inconsistency of the factor weight's pair-wise comparison matrix can be calculated and controlled by the Consistency Ratio (CR). In various studies (Kumar and Shaikh, 2012; Bagheri et al., 2013; Romano et al., 2015; Abebe and Megento, 2017; Pokhrel, 2019; Ustaoglu and Aydinoglu, 2020), this has been confirmed.

4.7. Weighted Overlay Analysis

After weighting the parameter, as regards the relative importance of each parameter as well as suitability index, all the reclassified parameters were overlaid in order to select suitable sites for green space development using the weighted overlay tool or a raster calculator in ArcGIS and final urban green spaces suitability map was prepared (Figure 22).

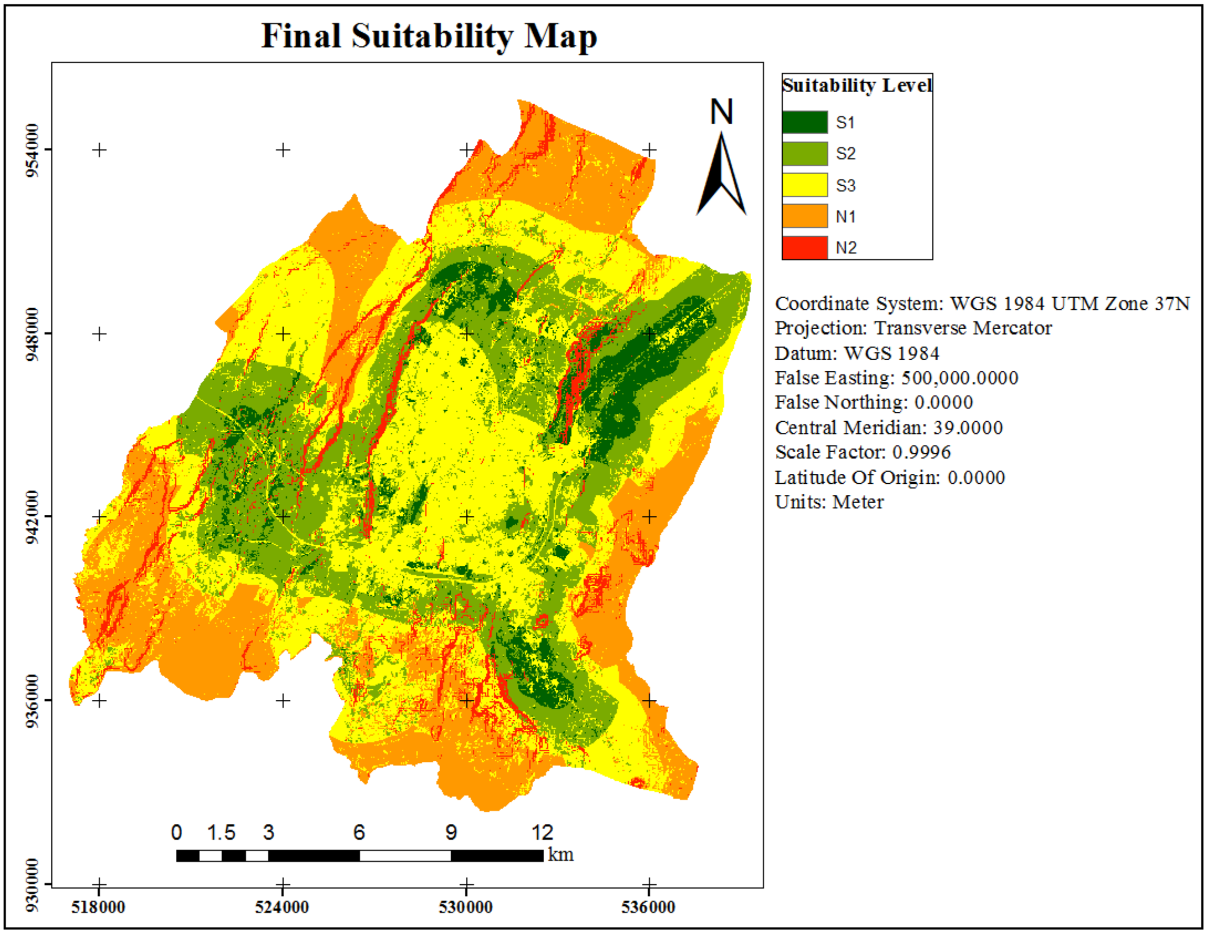


Figure 22: Final suitability map

According to GIS-based multi-criteria analysis, the result obtained from the overall suitability map shows 2000.805 and 7953.809 hectares are highly suitable and moderately suitable for green space development. The large area is less suitable for green space development in the existing situation which covers 36.42% (11402.344 ha) of the area. The remaining 26.07% and 5.71% are not suitable and permanently unsuitable for green space development respectively (Table 22). In the land use plan, the selected areas are mostly categorized as Shrub and bushes, bare land and farm land.

Table 22: Final suitability area and percent of total area coverage

Level of Suitability	Area (ha.)	Percent of total area (%)
S1	2000.805	6.39
S2	7953.809	25.41
S3	11402.344	36.42
N1	8159.420	26.07
N2	1787.837	5.71

4.8. Validation of the result

It is essential that the results should be validated; this was done with sensitivity analysis and field verification. Validation helps to assess the reliability of the output and is usually assessed by ground truth verification and sensitivity analysis (Abebe and Megento, 2017).

4.8.1. Sensitivity analysis

Sensitivity Analysis (SA) determines the reliability of the model through assessment of uncertainties in the reproduction results (Chen et al., 2009). It is well-known that SA is crucial to the validation and calibration of numerical models. SA can be used as a tool to check the robustness of the final outcome against slight changes in the input data. Thus, SA can help reduce uncertainty in how a MCDM method operates and the stability of its outputs by illustrating the impact of introducing small changes to specific input parameters on evaluation outcomes (Crosetto et al., 2000).

In this study SA was carried out by changing the weight values of each input criteria in four scenarios (Table 23 and Figure 24). The weight value for each criterion was calculated using a pairwise comparison matrix of AHP with a consistency ratio of less than 0.1 as provided by Saaty (2008).

Table 23: Weight value (%) for each input criteria in four scenarios

Criteria	Scenario (%)			
	1	**2**	**3**	**4**
LULC	29	35	24	31
Distance from residential area	21	10	18	11
Distance from transportations	15	14	14	22
Distance from noise influence	11	7	7	5
Distance from stream	8	4	4	3
Soil type	6	13	9	15
Slope	4	9	12	7
Distance from facility locations	3	5	5	4
Population density	3	3	7	2
Consistency ratio	4	5	4	3
Total suitable area (%)	31	25	31	32

Scenario 1 was selected as the base scenario which covers 31% of the total area in order to compare the effect of changes in weight value among four scenarios. As the LULC in scenario 2 increases, total suitable size decreases from 31% to 25%. In scenario 3, with an increase in the Soil type, slope, distance facility locations and population density the total suitable area was again 31% of the total area. Therefore, in scenario 3, the weights, Consistency ratio and total suitable area are most likely similar to scenario 1. However, in scenario 4, the lowest weight value was assigned to distance from stream, distance from facility locations and population density then, the total suitable area increased to 32% of the total area. Finally, from the sensitivity analysis scenario 1 was selected as a best suitability scenario by comparing consistency ratio, weight values of each input criteria and total suitable area of each scenario.

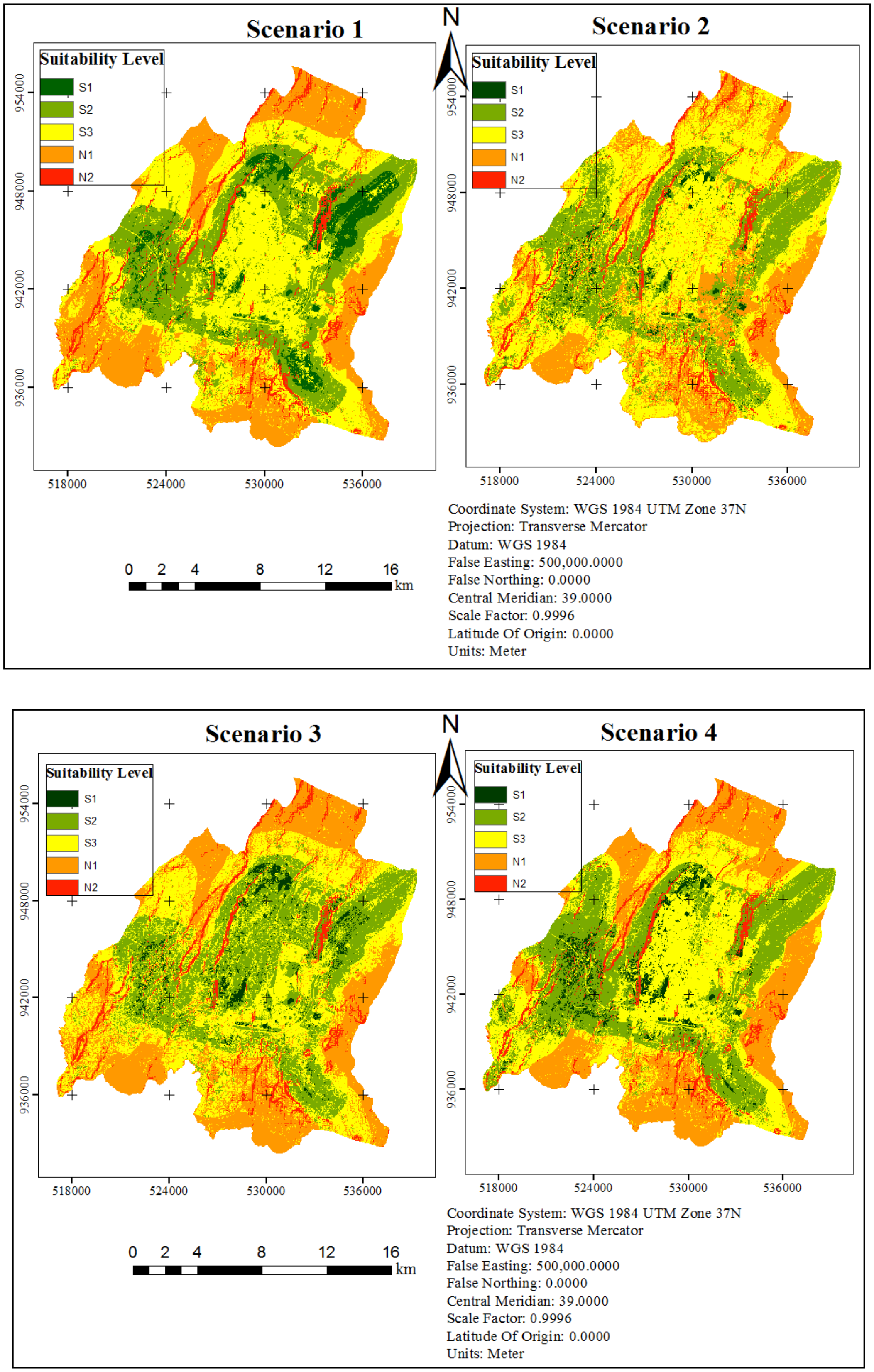


Figure 23: Sensitivity analysis map of four scenarios

4.8.2. Field verification

Field verification is visiting the location and comparing results to your observations. Remote Sensing often calls this process "ground-truthing". Field verification was made to assess the ground truth of the suitable area using GIS-MCA techniques with reference to the Sole and Danbela recreational & botanic garden are among the best suitable sites, and in the north-eastern part of the Town following roads to Dire Dawa also suitable site for green space development.

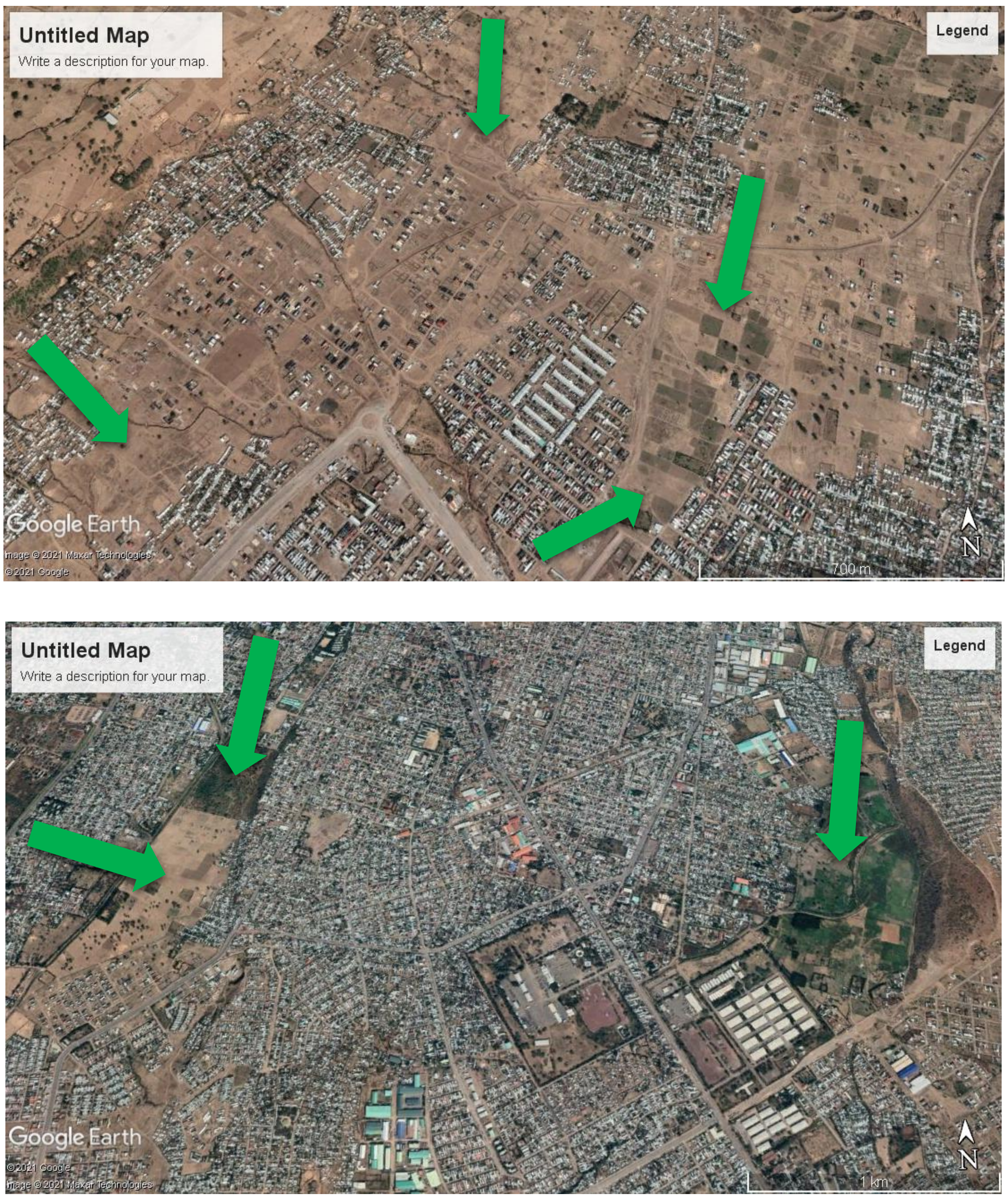


Figure 24: Selected areas for green space development

The LULC of the selected areas are mostly categorized under bare land, Shrub and bushes and some part of farm land are relatively suitable for green space development. With respect to the distance from residential area, transportations, noise influence, stream, slope, facility locations, soil and population, the selected areas are identified as suitable sites for green space development (Figure 24).

4.9. Comparison of proposed structural plan green area Vs. MoUDH (2015) Standard

Proposed structural plan (2017) green area was extracted from the proposed structural plan (2017) of the Town in the ArcGIS environment. In the proposed structural plan (2017), 5496 ha (17%) of the study area was proposed for open spaces, botanical garden, mountain green frame, road side green, parks, Zoo, urban agriculture and horticulture and sport field (proposed structural plan (2017) of the Adama). But this is not enough for green spaces because the Ethiopian Planning Strategy and Urban Land Management Plan allocated 30% of the land for green areas (MoUDH, 2015).

4.10. Comparison of suitability scenario map Vs. proposed structural plan green area

The best suitability scenario was selected by sensitivity analysis. After the best suitability scenario was selected it is possible to compare it with the proposed structural plan (2017) of the Town. Comparison of proposed structural plan (2017) in the study area was conducted by considering the locational aspects of the UGS in the suitability map. Figure 26 shows the comparison between the best suitability scenario and the proposed structure plan (2017) of Adama Town.

The extracted proposed structural plan (2017) green area was overlayed on the best suitability scenario UGS map of the town in the ArcGIS environment. After each suitability level was clipped from best suitability scenario then intersected with proposed structural plan green area. From the result, 230.903 ha (0.71%) of the Town, green area is located in a highly suitable area, 1189.091 ha (3.74%) of the study area, green area is located in a moderately suitable area and 1653.924 ha (5.20%) of the study area, green area is located in less suitable. Whereas the rest 1555.257 ha (4.64%) and 854.655 ha (2.71%) of, green area are relatively located in not suitable area and unsuitable areas respectively. From the comparison of suitability scenario map Vs. proposed structural plan (2017) green area, the majority of proposed structural plan (2017) green area were in the less suitable and not suitable domain of the study area.

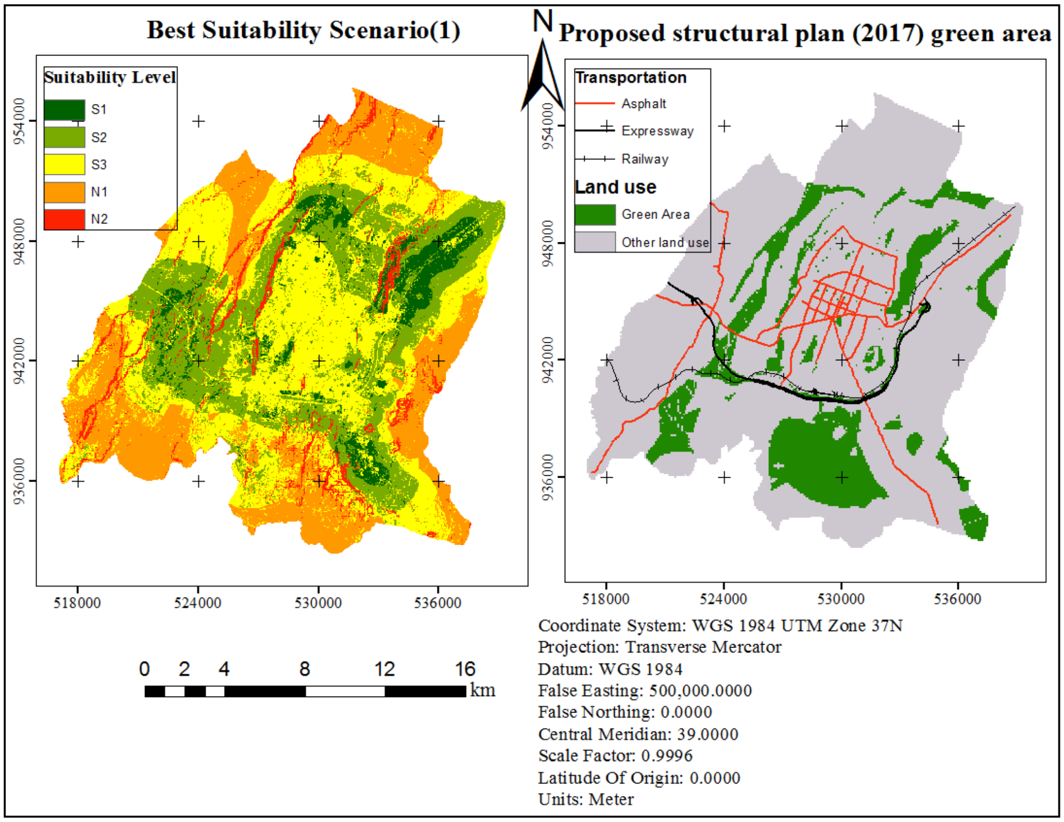


Figure 25: Comparison between suitability scenario and proposed structure plan (2017)

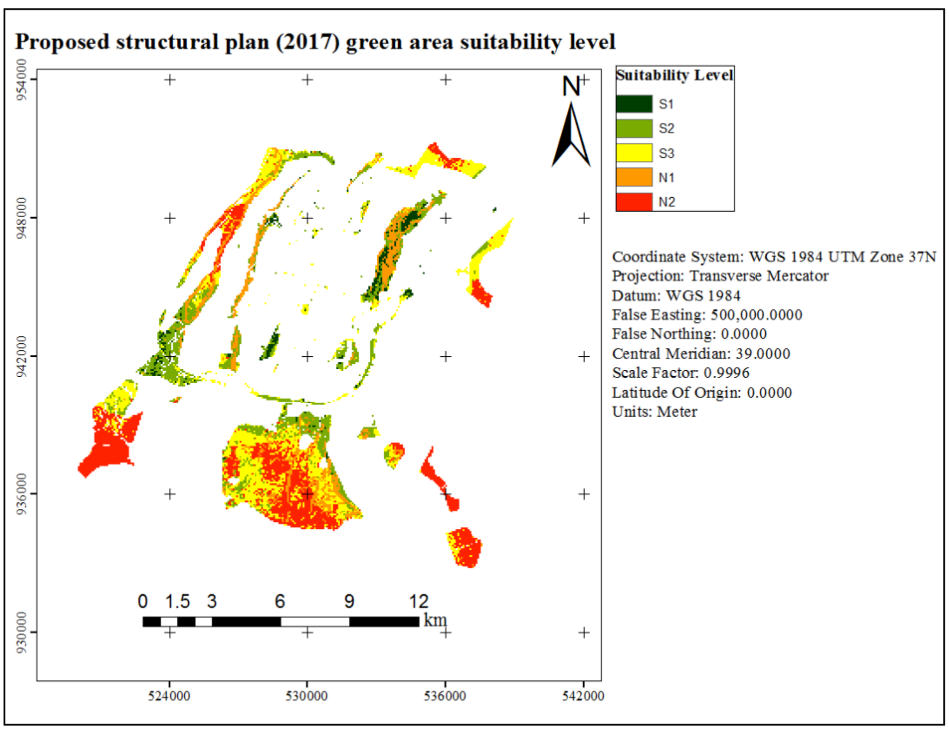


Figure 26: Proposed structural plan (2017) green area suitability level

4.11. Discussion

The world has experienced tremendous urbanization and population growth. Land use and land cover (LULC) pattern change, industrialization and social transformation occur during the urbanization processes. One of the major impacts of urbanization is a shrinking of urban green spaces, through the development of infrastructures and various development projects. Urban green space (UGS) plays a vital role in the mitigation of negative impacts of urbanization, but it is often abominably affected by the process of land use land cover (LULC) changes in an urban area (Dinda et al., 2021).

The study area practiced descending trends in most of the LULC classes during the study period namely, bare land and shrub and bushes, whereas farm land showed a minor loss and water body showed a minor increment, while built-up is the only LULC class that showed greater expansion along the past three decades. The most common understanding of the use of change analysis is to provide relevant data on changes concerning extent, trend, location and how the change was distributed spatially. Hence, the study is important to indicate the trend of LULC change particularly green space pertaining to analysis land suitability for urban green space development.

The LULC changes practiced across Adama Town showed spatial decline of different LULC classes due to corresponding horizontal expansion of urban area as well conversion of LULC classes due to increment of built-up areas within the study area. Results from the LULC maps derived in the years 1991, 2006 and 2021 has revealed that the study area has undergone tremendous change in the past thirty years (1991-2021). During this period, the built-up areas increased from 948.796 ha (3.03%) in 1991 to 5983.908 ha (19.12%) in 2021, whereas the shrub and bushes, were decreased from 2832.216 ha (9.05%) in 1991 to 1992.234 ha (6.36 %) in 2021. The marked increment of built-up area in the study area is a result of a conversion of others LULC classes primarily the shrub and bushes and farm land classes.

The result indicated that over the past 30 years built-up area showed continuous increment, whereas shrub and bushes showed continuous decline. So those areas, which are close to built-up and urban centers, were subjected to significant loss of shrub and bushes (greeneries) in the last three decades. In agreement with the present study, earlier studies have shown that LULC change has negative impact on the green spaces. For example, Eyob (2008) reported that, a rapid and unplanned expansion and commercial development, along with population pressure, has negative impact on the green spaces. Similarly, Mensah (2014) argued that urbanization has a negative impact on the natural environment by encroaching green spaces in many cities. This reduction of green spaces has indicated that the Adama Town administration has a problem of proper planning and implementation to keep the Town green with the exception of the establishment of a few roadside trees in the Town. Therefore, suitability analysis for urban green space development within the Town are mandatory in order to maximize both quality and quantity of urban green spaces that bring value to urban dwellers and their environment in a sustainable way.

There are many determinant factors (main factors and sub factors) that affect urban green space development. Main factors are accessibility, physical, environmental and socio-economic factors. Therefore, the current study used nine site selection criterion including environmental criteria (stream/river), accessibility criteria (road and railway), physical criteria (slope and soil types) and the Socio-economic criteria like LULC, population density, noise influence, distance from residential area and distance from facility locations are the main determinant criterion used to select suitable site for urban green space development. The final map has shown that, 6.39%, 25.41%, and 36.42% of the study area has been identified as highly suitable, moderately suitable, and less suitable for green space development respectively.

Accordingly, understanding changes in the 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.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The urban areas in Adama Town have expanded dramatically, while green areas have been declining. Those areas, which are close to built-up and urban centers, were subjected to significant loss of shrub and bushes (greeneries) in the last three decades. The green spaces in the urban areas have been declining faster and faster so that a large section of the general public does not have access to such green spaces. As the green spaces are the significant components of the urban landscape and provide multiple benefits as composite functions that include environmental, socio-cultural and economic benefits. Unplanned expansion and development have been leading the Town to the multiple risk hotspot area from various environmental, social and disaster perspectives. In this situation urban green spaces are considered as an important natural contributor that supplies numerous ecosystem services for human kind living in Town and can be a significant part for sustainable development.

The analysis demonstrated that the rapid urbanization in Adama Town has given little room for green space development. In the proposed structural plan (2017), 5496 ha (17%) of the study area was proposed for open spaces, botanical garden, mountain green frame, road side green, parks, Zoo, urban agriculture and horticulture and sport. But this is not enough for green spaces because the Ethiopian Planning Strategy and Urban Land Management Plan allocated 30% of the land for green areas (MoUDH, 2015).

Land suitability analysis is a critical element in determining suitable areas for green space development. Proposing suitable sites for green space development using suitability analysis involves multi-criteria analysis steps. The GIS-based multi-criteria analysis performed in this study found that, in the current situation, the larger land mass 31.80% (highly suitable 6.39% and moderately suitable 25.41%) of the Town is suitable for urban green spaces development. Consequently, the Town has great potential to develop adequate urban green spaces.

As demonstrated in this study geospatial technology can play a crucial role in urban green space planning and help to get up-to-date information about the urban land use and AHP based multi criteria analysis (MCA) methods has been shown to be a flexible and realistic tool for selecting suitable areas for urban green spaces in the study area.

5.2. Recommendation

The findings of this particular study have shown that Geospatial technologies and GIS-based multi-criteria analysis (MCA) are important tools for studies of LULC change and suitability analysis for UGS development.

One of the results noticed in this study was the major LULC changes caused by rapid expansion of built-up areas, while green areas have been declining. Therefore, a proper planning should be implemented by considering urban green space development and the Town development plan should focus on a vertical built up expansions rather than horizontal expansions. The Town municipality/administration and beautification office need to respect the national standard of green space coverage of the Town; update the LULC using geospatial technologies and formulate guidelines to develop and manage the UGS in the context of GIS based multi-criteria decision-making processes.

Furthermore, the town administration should encourage the community and stakeholders so as to develop and maintain a community garden. The up-to-date information of the green space coverage should also be continuously studied and implemented with the appropriate measure. More research needs to be conducted in this regard for enhancing and improving both quality and quantity of urban green spaces at national level.

In this study, Landsat imageries were used for LULC change studies, Landsat imageries were of 30 m resolution which are not high resolution so, as a result some LULC type was generalized by other LULC types and some errors were also incurred in image classification. Therefore, future studies should consider using high resolution images such as QuickBird and IKONOS so as to overcome the problem. High resolution satellite images are important in producing high quality and more accurate results.

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APPENDICES

Appendix I: Coordinates of factory locations

Name of Factories	Easting	Northing
Tyre Process	520164.364	938995.743
National Cement Factory	520267.993	939519.751
Steel Factory	520856.326	940080.342
Mixing Plant	524981.718	942735.904
Adama Roof Factory	527182.377	940506.7
Adama Roof Factory	526964.756	940673.057
Adama Roof Factory	527106.728	940867.57
Ayinarge Flour Factory	526958.164	940947.574
ACOS Ethiopia	527044.947	941099.842
T.M Food Complex	527147.937	941205.08
Industrial Park	533494.362	940934.8
Beza Mar	530450.795	941960.687
Family Flour Factory	530781.256	942489.643
Oxygen, Nitrogen gas Plant	528374.839	943561.099
BEKAS Chemical Manufacturing	527345.019	944369.291
Tractor Factory	527922.275	944392.133
Turkey Textile Industry	528068.484	945740.082

Appendix II: Coordinates 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

Appendix III: Coordinates of School locations

Name of schools	Easting	Northing
New Vision KG School	527267.231	941848.621
Green Hill school	531793.698	944831.181
Qobo Luto Temsea Elementery School	521188.997	940774.857
Qobo Luto Temsea Elementery School	521138.726	940655.265
Melka Hidda School	525768.943	938180.93
KG School	526085.65	937949.155
Preparatory	531603.547	939584.318
Private School	531419.264	940447.523
Fekir KG School	531523.51	940493.296
Burka primary and Secondary School	530635.884	940552.086
Yomada KG School	530749.192	940614.991
Birra Academy School	530710.827	940874.283
Yalewet School	529949.196	940864.653
Dana School	530372.52	941236.773
Goyas School	529641.343	529641.343
Kidus Kuran School	528985.175	941390.232
Elementry School	528429.549	941539.193
Lugo Primary School	528712.654	941709.849
Elementry School	528106.457	941365.238
Elementry School	528065.49	941438.792
Oda School	527587.95	942062.614
Elementry School	533036.446	941824.358
Kena KG School	532408.747	943216.254
Kena KG School	532449.758	943267.319
Akber Academic School	532129.241	943448.823
Solomon KG and School	531871.854	943792.518
Yasmin Elementry School	532027.429	943851.255
Egziabeher Ab church school	532494.455	943783.229

Dabe Soloke Primary school	533788.301	944046.65
Catholic primary school	529515.845	942585.177
KG school	529282.945	942730.831
Abuna Georgorios KG school	529063.142	942759.009
Gary primary school	528911.125	942881.538
Adama Boset Elementary school	529604.112	942995.06
Fekir KG School	530942.841	942287.893
progress Academy	530791.393	942454.74
School	530168.298	943006.706
school	530167.008	943297.98
Exa Academy	530637.978	943383.716
primary school	530879.196	943165.682
Adama no 4 school	530692.047	943982.365
St.Joseph KG School	529558.475	943316.297
Haylig KG school	529328.779	943429.913
Haylig KG school	529431.305	943525.957
Rift Valley University Collage	529090.521	943762.495
Nafyad KG School	529005.325	943889.496
Unity Academy	528178.324	943229.932
Holly angels' school	528431.134	943411.304
Galila school	528149.881	943757.645
Dambela Elementary school	527764.779	943449.14
KG School	527350.219	943537.802
Private School	527041.952	944052.063
KG School	529255.501	944216.766
primary school	529315.649	944365.727
Adama no 3 school	528531.687	944779.536
Kidus Kuran School	528965.34	944880.674
Daga adi school	528657.06	945073.979
Royal Collage	529960.004	944666.784

Harambe Collage	530514.042	944791.429
kening school	531004.171	944623.591
Birayit mayindis School KG-10	530891.326	944863.734
Abuna Georgorios school	531766.781	945078.602
Day_star Academy	532197.523	945171.63
Family School	531980.829	945603.166
Catholic elementary school	531770.749	945741.279
Awash primary and secondary school	531049.141	945423.955
Awash primary and secondary school	531023.476	945578.736
Chefik primary school	530743.414	945310.051
Eba primary school	531191.487	946001.144
Holly angels Elementary school	531072.266	945953.625
KG School	529765.001	945249.215
KG School	529564.027	945412.353
Hunde Gudina primary school	529448.801	945557.08
Geladios TVET	530276.949	945661.679
Elementry School no 2	530122.961	945722.004
TVET(Garment)	530475.717	945666.243
Midland school	530565.213	945865.144
Hayu Borifan School	530675.676	945873.743
KG School	530621.437	945996.774
Elementary school	530149.436	946040.761
Dasangam School	530887.36	946389.747
Makobili School	529095.995	946084.418
Abdi boru school	529145.252	946349.795
Barnabas school	529496.707	946250.135
Abnezer KG school	529738.537	946236.377
Holly savior school	529598.572	946411.267
Adama youth Academy	529332.731	946653.097
Abebe Lefire Academy	529435.919	946884.872

Nowzer Academy	529640.575	946865.557
Star Academy	528925.272	946891.222
Nigat Elemntary school	529120.601	947216.793
Almaz KG school	529835.705	947401.373
Wisdom school	530837.288	946948.255
KG School	531275.13	946781.567
Nafyad School no 2	531283.067	946913.859
Kamara school no2	532561.801	946358.815
School	532595.787	946996.585
KG School	532856.082	947583.263
Daga Adi Primary school	533602.804	948009.904
KG School	531553.337	947306.614
Hamara Noha Academy	531561.539	947636.285
Abuna Georgorios school	530837.902	947469.73
KG School	530498.441	947576.489
Hawi Academy	530189.936	947945.319
Excel School	530759.321	947821.6
Oda primary school	530961.992	947868.696
Guda Miju School	531367.07	948162.251
Ambassador School	531794.638	948163.31
Bole Primary School	532270.955	948691.221
Daga Adi Primary school	532584.222	948820.073
Sekekelo Primary School	530840.438	949734.933
ASTU	532058.589	946602.255
Unity University	527518.368	943965.353
St. Joseph School	529517.332	943638.653