SITE SUITABILITY ANALYSIS OF LAND FOR URBAN AGRICULTURAL DEVELOPMENT USING GEOSPATIAL TECHNOLOGY: THE CASE OF ADAMA CITY, ETHIOPIA

Hunduma Firdissa Negessa

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

September, 2022

Adama, Ethiopia

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Co- Advisor: Zelalem Biru (PhD)

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DECLARATION

I hereby declare that this Master Thesis entitled "Site Suitability Analysis of Land for Urban Agricultural Development Using Geospatial Technology: The Case of Adama City, Ethiopia" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Hunduma Firdissa Negessa	______________________	_______________
Name of the student	Signature	Date

RECOMMENDATION

We, the advisor(s) of this thesis, hereby certify that we have read the revised version of the thesis entitled "Site Suitability Analysis of Land for Urban Agricultural Development Using Geospatial Technology: The Case of Adama City, Ethiopia" prepared under our guidance by Hunduma Firdissa submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Geo-Informatics Engineering. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Getachew Birhanemeskel (PhD)	____________________	_______________
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Co-Advisor	Signature	Date

APPROVAL SHEET

We, the advisors of the thesis entitled “Site Suitability Analysis of Land for Urban Agricultural Development Using Geospatial Technology: The Case of Adama City, Ethiopia” and developed by Hunduma Firdissa, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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Major Advisor	Signature	Date
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Co-advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Hunduma Firdissa have read and evaluated the thesis entitled ‘’Site Suitability Analysis of Land for Urban Agricultural Development Using Geospatial Technology: The Case of Adama City, Ethiopia” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geo-Informatics 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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LIST OF ACRONYMS

AHP	Analytic Hierarchy Process
ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
CAD	Computer Aided Design
CSA	Central Statistical Agency
DEM	Digital Elevation Model
ETM	Enhanced Thematic Mapper
ERDAS	Earth Resource Data Analysis System
ESRI	Environmental Systems Research Institute
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
LULC	Land Use and Land Cover
LSA	Land Suitability Analysis
FAO	Food and Agricultural Organization
MCA	Multi-criteria Analysis
MCDA	Multi Criteria Decision Analysis
MCDM	Multi-criteria Decision Making
MCE	Multi Criteria Evaluation
RS	Remote Sensing
SDG	Sustainable Development Goals
TIFF	Tagged Image File Format
TM	Thematic mapper
UHI	Urban Heat Island
UN	United Nations
USGS	United States Geological Survey
UTM	Universal Transfer Mercator
WLC	Weighted Linear Combination
WOA	Weighted Overlay Analysis

ABSTRACT

Urbanization and population growth lead to rapid changes in Land use and landcover (LULC) and human population densities. LULC dynamics contribute to agricultural land degradation and biodiversity loss, as well as the displacing of urban greenery. Urban agriculture is one of the best options for mitigating negative environmental effects and is a possible solution to food insecurity by encouraging the urban poor to grow their own fresh foods and to live in a sustainable environment. Land suitability analysis is crucial for the evaluation and grouping of specific areas of land in terms of their suitability for agriculture. Thus, the study demonstrates that analysis of urban LULC changes and other determinant factors for urban agricultural development by the use of geospatial technology based Multi-Criteria Analysis (MCA) techniques for the selection of suitable sites for urban agricultural land using the thematic maps of each criteria, which were prepared and standardized using a pair-wise comparison matrix known as the Analytical Hierarchy Process (AHP). According to obtained results, from the total area of 30963.01ha found in the study area, 5226.87ha (16.88%) was highly suitable, 11804.23ha (37.62%) was moderately suitable, 10802.12ha (34.39%) was less suitable, 2868.68ha (9.26%) was determined as not suitable, and 261.11ha (1.84%) was permanently not suitable for agriculture in the study area. Therefore, the final suitability map provides a better guideline for future urban agricultural land suitability in Adama City. Thus, the study implies an urban agricultural land suitability analysis aimed at identifying environmentally safe and economically feasible sites for future urban agricultural development. The study provides directions for different urban agricultural suitable lands in the study area that would support city planners and policymakers in acting on identified suitable land in the city and also support the government in formulating effective agricultural policies to enhance urban agricultural productivity.

Keywords: Urban agriculture; LULC; land suitability; Geospatial technology; AHP; Adama

CHAPTER-1: INTRODUCTION

1.1 Background of the study

The world has experienced tremendous urbanization and population growth. Urbanization is a global multidimensional process which demonstrates itself through rapidly changing human population densities, land use, and land cover. Land Use and Land Cover (LULC) pattern change, industrialization, and social transformation occur during the urbanization processes. Rapid urbanization, population growth, and land degradation will increase demand for food, fuel, and fiber closer to metropolitan areas in the near future(Smith et al., 2017).

In recent decades, cities around the world, including in developing countries, have been facing rapid urbanization and the expansion of cities (UN-Water, 2015). According to Debela et al., (2020), in 2000, Africa showed a 37.9% urbanization rate, which in 2015 was expected to reach 46.5%, and in 2030 it is expected to further increase to 56.2%. Consequently, studies show that most of the poorest African states have more than half of their urban population below the poverty line (Olivier, 2015). Particularly, for Sub-Saharan countries like Ethiopia, dented by poverty, rapid population growth and environmental degradation.

According to data released by the World Bank, only 19% of the Ethiopian population is settled in urban areas. This number compared to other countries can be said to be at a very minimal stage (Habib Ananya et al., 2012). Despite this, urbanization is growing at a rate of 4.3% per year (P.Z.Mpofu, 2013), and with it, urban poverty has become prevalent. The percentage of urban poor, which was 11% in the year 2000, has increased to 14% (3.2 million) after a decade and in 2011 (Besley, 2015). whereas, Urban agriculture can be a viable source of income, jobs, and the freshest food for the rapidly growing urban poor (Mulugeta, 2013).

The adoption of urban agriculture puts food production and consumption in closer proximity and thus allows cities to attain a higher degree of food self-sufficiency(Habib Ananya et al., 2012). Several advantages have been associated with the development and integration of urban agriculture in cities, including the use of clean and environmentally friendly energy; continued access to healthy food; a reduction in air pollution and soil erosion; and an improvement in food and nutrition security due to an increase in food supply for the urban population (Foster & Rosenzweig, 2008). It is also part of the urban greenery that improves the urban micro-climate, increases biological diversity, and provides aesthetics and recreational for urban areas.

However, urban areas are permeable that cause flooding and runoff. Hence, it reduces runoff water and improves the quality of streams and the environment. In addition, urban agriculture has contributed significantly towards solving waste management problems by converting urban solid waste into productive agricultural inputs such as compost, while treated waste water has been used for irrigation (Gonfa, 2019).

Recently, urban agriculture has become more common in developing countries like Ethiopia. A few years ago, Ethiopia was trying to practice urban agriculture in some cities. Urban agriculture has been practiced in the capital city of Ethiopia, Addis Ababa (Finfinnee). In fact, it has a contribution to national GDP and job opportunities like employment in agriculture, which made up 11.8% (1999) to 13% (2005), and then to 13.5% (2013) of total urban employment. In the same period, although its share has declined from 9% to 7%, employment by urban agricultural activities has increased. When we see its contribution relative to the overall crop production, the shares vary from hardly 0.5% (e.g., in pulses and roots) to 7.9% (e.g., in fruits). The role of urban agriculture in the urban economy can be seen, among many others, in terms of its share of gross domestic product (GDP). On average, between 2010/11 and 2015/16, agriculture contributed to capital. 1.3% of the total GDP of the capital city of Addis Ababa (Yalew, 2020).

Nowadays, urban agriculture has been practicing in major cities of Ethiopia, including Adama, by the initiative "We feed from our backyard". In contrast, to promoting urban agricultural activities in Ethiopia, the cities have wrongly tried to organize agricultural activities under the Bureau of Trade and Industry Development (Tefera, 2010). The case of Adama is also not different from this general picture of Ethiopia as it is part and parcel of the country. Urban agriculture in the city of Adama is the most neglected sector in that there is even no concerned governmental office or individual in the administrative structure of Adama city administration. There is no any written plan or strategy concerning the current and future issues related to this sector. This fact has been resulting in urban agricultural deterioration and environmental degradation (Tefera, 2010).

Land suitability analysis plays a crucial role in the quality of land use and landcover. Consequently, accurate identification of land-use or land-cover categories is a preliminary and crucial step. Land Suitability Analysis (LSA) refers to a procedure or tool used for the identification of the most spatially appropriate pattern for locating current and future specific land uses (Malczewski, 2004). Therefore, LSA is a function of specific requirements, preferences, or predictors of a defined activity (Malczewski, 2006). It 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). This analysis involved considering a wide range of criteria, including accessibility and environmental, physical, and socio-economic factors. In other words, suitability analysis is the process of determining whether a land resource is suitable for some specific uses and determining its suitability level.

A Geographical information system (GIS) is a useful technique to investigate multiple geospatial data with precision and higher flexibility in land suitability analysis (Mendas & Delali, 2012). Therefore, the multicriteria decision making (MCDM) process has been integrated with geospatial techniques in various studies for the potential land use decision-making process to solve complex problems of land management with best alternatives (Mendas & Delali, 2012). Land suitability for agricultural production are frequently assessed using the parameters like; LULC, slope, soil type, surface water (steam/river), distance from road, distance from facility location, distance from residential area, drainage density and population density.

Furthermore, the analytic hierarchy process (AHP) is extensively utilized for multi-criterion decision making of land suitability for various fields (Pramanik, 2016). The analytic hierarchy process was developed by Saaty, (2007), who established a hierarchical model for solving complex problems of land management with the best alternatives (Cengiz & Akbulak, 2009; Malczewski, 2006; Roig-Tierno et al., 2013). As a multicriteria decision-making method, the analytic hierarchy process has been widely used for solving an extensive variety of problems based on complex parameters across various levels where the interaction among parameters is a common characteristic (Pramanik, 2016).

The weighted overlay method (WOM), along with the analytic hierarchy process, provides a very assuring outcome for the site suitability assessment of agricultural land use. Furthermore, this study give attention to the issue of site suitability analysis for urban agricultural development in the urban environment. However, there were no studies conducted in the study area related to site suitability analysis for urban agriculture in the urban environment in the context of LULC dynamics in Ethiopia. Therefore, this study aimed to fill the existing research gap by using geospatial technology and applying GIS-based multicriteria analysis method to examine changes in the LULC patterns particularly on urban agricultural land and identify suitable sites of land for agricultural development in Adama city. Therefore, the main objectives of the study are to identify the suitable lands for urban agricultural development using GIS and analytic hierarchy processes in the study area and to analyze the existing agricultural land for the development of urban agricultural activities.

1.2 Statement of the Problem

In the context of sustainable living, agricultural areas play a major role in the lungs of urban areas (Weerakoon, 2014a). However, it is often affected by the process of land use and land cover (LULC) changes in an urban area. One of the major impacts of LULC change and urbanization is the decline of urban agriculture. Also, urbanization results in the replacement of these green agricultural features such as the built matter for residential, commercial, industry, roadways etc. Along with these structural changes, cities influence the negative consequences, such as loss of fresh vegetables and fruits; nutritional problems; climate change; etc. Although urban agriculture is a relatively simple solution, in many cities, formal recognition and integration of agriculture into city planning and city growth has hardly changed (Priestnall et al., 2020).

Cities face incredible problems associated with food insecurity, environmental pollution, and also problems of unplanned development, high levels of poverty, social vulnerability, poor physical and social environmental quality, and inefficient urban management. Furthermore, the high price of food and the inability of most families/households to buy or provide an adequate amount of nutritious food make them vulnerable to hunger and disease (Habib Ananya et al., 2012).

However, there are abundant agricultural lands, but they cannot be exploited for farming. The suitable land locations for urban agriculture are currently unoccupied or underdeveloped. In Adama, no one has tried to locate the area’s most appropriate for agricultural productivity practice. Furthermore, urban agriculture in Adama has been the subject of a studies, but none of them has focused on identifying appropriate sites for agriculture and how to integrate it with urban land use.

In Adama city, vegetables, fruits, and other cereal crops used by the city population are mostly supplied from surrounding rural areas and distant places. This is because of the low productivity of urban agriculture in the area. Urbanization and agriculture are mostly considered incompatible activities that compete for expensive urban land. In addition, the city does not have proper planned and up-to-date information that gives an impression about the status of urban agriculture, even though there is less implementation of some areas that are allotted for agriculture. These necessitate the need for site suitability analysis of land for urban agricultural development using geospatial technology.

1.3 The Study's Objectives

1.3.1 General objectives

The main objective of this study is to analysis land suitability for urban agricultural development in Adama city using Geospatial technology. To achieve this main objective following specific objectives were outlined.

1.3.2 Specific objectives

The specific objectives of this study are to:

i. Analyze Adama City LULC changes
ii. Determine the main determinants factor of urban agricultural development in Adama;
iii. Evaluate urban agricultural suitability by using the analytical hierarchy process (AHP) based Multi-Criteria Analysis (MCA) methods;
iv. Identify the most suitable site of land for urban agricultural lands in Adama City;

1.4 Research questions

To realize the stated objectives, the study is proposed to answer the following questions:

i. What are the LULC changes in Adama city?
ii. What are the main determinant factors for urban agriculture development in Adama?
iii. How do analytical hierarchy process (AHP) based multi-criteria analysis (MCA) methods help to evaluate urban agriculture suitability?

iv. Which sites of land are most suitable for urban agricultural development in Adama City?

1.5 Significance of the study:

The study of suitability analysis is important for urban and regional planners and decision makers to assess open spaces for urban agriculture. Findings from the study will serve as a working document for Adama city management officials in the identification and selection of suitable sites for urban agriculture in the city. If the proposed site is used as an urban agriculture location with proper management, it will increase the urban food security settings, enhance local productivity, and promote sustainability in response to the pressures of urbanization and climate change by plants. 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 to be conducted in other places.

1.6 The scope of the study

The spatial scope of this study will be limited to Adama City Administration, in Oromia Regional State, Ethiopia. whereas the contextual scope is site suitability analysis for urban agricultural development by using geospatial technology and analytical hierarchy process (AHP) based multi-criteria analysis methods. In order to identify suitable sites for urban agriculture, the criteria considered are LULC (open space), slope, soil type, distance from surface water (stream/river), distance from residential, distance from road, distance from accessibility/facility location, population density, and drainage density.

1.7 Study limitations

As stated earlier above, no study has been conducted yet in this country regarding urban agriculture site selection using geospatial techniques. Thus, the standard distance for factors of proximity analysis is not yet available at the national level and international proximity distance standards were used to reclassify the suitability of factors for a decision system.

CHAPTER-2: LITERATURE REVIEW

2.1 Definition and Concepts of urban agriculture

The definition of urban agriculture given by the United Nations food and agriculture organization (2015) is: "Urban agriculture means economic activities which exactly refers to planting and breeding industry within a big city or around a city circle, taking advantage of the gaps (including cultivated lands, mountainous lands, and the surface of water) among cities, such as the activities of providing fresh agricultural produce, environmental services, tourism and leisure products for cities". Also, urban agriculture is an industry located within (intra-urban) or on the fringe (peri-urban) of a town, a city, or a metropolis that grows and raises, processes, and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products, and services found in and around that urban area, and in turn supplying human and material resources, products, and services largely to that urban area (Adedeji & Ademiluyi, 2009). In theory, urban food production both increases the number of green spaces in urban areas (vacant land and old industrial sites are often used) and enhances biodiversity. In general, then, the concept of UA is closely intertwined with the notions of urban food security, nutrition, and environmental sustainability, but also with ideas of beautification, leisure and exercise, and social interaction.

2.2 Land Use and Land Cover Change

The definition of land use and land cover has been used interchangeably in the land use research community because of the availability of many existing information systems. However, these two terms explain two different issues and meanings. Land cover refers to the observed biophysical cover on the earth's surface including vegetation, bare soil, hard surfaces and water bodies. Whereas land use is the utilization of land cover type by human activities for the purpose of agriculture, forestry, settlement and pasture by altering land surface processes including biogeochemistry, hydrology and biodiversity (Salem et al., 2020).

According to Regasa, (2021) Land use is defined as how the land is utilized by people and their habitats, usually with an accent on the functional role of land for economic activities, whereas land cover is a physical characteristic of the Earth’s surface. Land use and land cover (LULC) dynamics are a well-known, accelerating, and substantial process, mostly driven by human activities, that is contributing significantly to forest fragmentation, land degradation, and biodiversity loss (Regasa, 2021). Land use and land cover changes (LULCCs) analysis is one of the most used techniques to understand how the land has been used in the past years, what types of detections are to be expected in the future, as well as the driving forces and processes. The Earth's surface is experiencing rapid LULC changes as a result of numerous socioeconomic activities and natural phenomena (Cheruto 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. Changes in Land Use and 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 urban agricultural land. LULC change needs global attention for continuous monitoring of the changes. Up-to-date datasets on land use and land cover change provide critical inputs to evaluate complex causes and responses in order to project future trends.

2.3 Types of urban agriculture

Urban agriculture is, essentially, the production of fruits, vegetables, and herbs, as well as livestock raising in an urban environment (Kelly et al., 2011). Urban agriculture has many facets; it can range from community gardens and roof-top gardens, to aquaponics, to vertical farming, and to peri-urban farming. The recent ideological shift in society to move towards greener and more sustainable ways of living has resulted in an increase in urban agriculture.

a) Rooftop Gardens: Rooftop gardens provide a variety of social and environmental benefits. The presence of a rooftop garden on a building increases its value and promotes the concept of urban food production (Xie et al., 2003). The plants being grown in rooftop gardens aid in improving the quality of the surrounding air by reducing carbon dioxide levels (Lovell, 2010a). Furthermore, having a garden on the roof of a building means that the need for internal temperature control is reduced as the garden provides a layer of insulation (Ackerman et al., 2014). The roofs are lined with a drainage layer, followed by a waterproof membrane, and growing medium (Ackerman et al., 2014). When the plants transpire, and the water evaporates from the leaf surface into the surrounding air, the temperature of the immediate environment is reduced (Lovell, 2010a). Canada's National Research Council reported that the rooftop garden at its Ottawa campus reduced the heat entering the building by as much as 85% on hot summer days (Lovell, 2010a).

b) Peri-Urban Farming: Peri-urban farming is the production of food on the outskirts of cities and towns. It can range from small-to large-scale activities, both commercial and non-commercial, and involves horticulture and livestock production, and often operates in a complementary manner to rural agriculture practices (Priestnall et al., 2020). Peri-urban agriculture improves the availability and affordability of nutritious food for urban dwellers, especially those in low socio-economic areas. In developing countries, peri-urban agriculture provides both food and job opportunities for people from low socio-economic backgrounds (Priestnall et al., 2020). In some parts of Africa, over 20,000 people are estimated to be involved in the processing and marketing of peri-urban agriculture (Drechsel et al., 2010). Peri-urban farming provides a number of social benefits for people in low socio-economic areas, ranging from an increased income, a reduction in expenditure on food, and a reduced dependence on imported food, all of which combine to reduce vulnerability in regards to food price fluctuations and availability.

c) Community Gardens: Community Gardens are especially important in developed areas where the garden can be properly maintained. In cases such as these, the garden plays a much more subtle role than trying to solve food insecurity problems; rather, it simply gives the people of the community a direct source of nutritional food, carbon absorption, and a connection to their environment (Priestnall et al., 2020). Community gardens can have quite a dramatic positive effect on the values of land and houses in the surrounding community (Voicu & Been, 2008). One of the biggest problems preventing the establishment of community gardens is the lack of available land or the funds with which to purchase it (Priestnall et al., 2020).

d) Vertical Farming: Vertical farming, the idea of growing food upwards instead of outwards, is a rather recent development, however a farm, only one square block at the base but 30 stories high, could yield as much as 2,400 outdoor acres (Priestnall et al., 2020). Food grown indoors, in a controlled environment, eliminates concerns in regards to flooding and droughts, as well as infectious diseases, and this involves potentially farming upwards to reduce the agricultural land footprint. Green walls can be used as a method for vertical farms as it also uses minimal space and can be practiced on the sides of vertical walls (Priestnall et al., 2020).

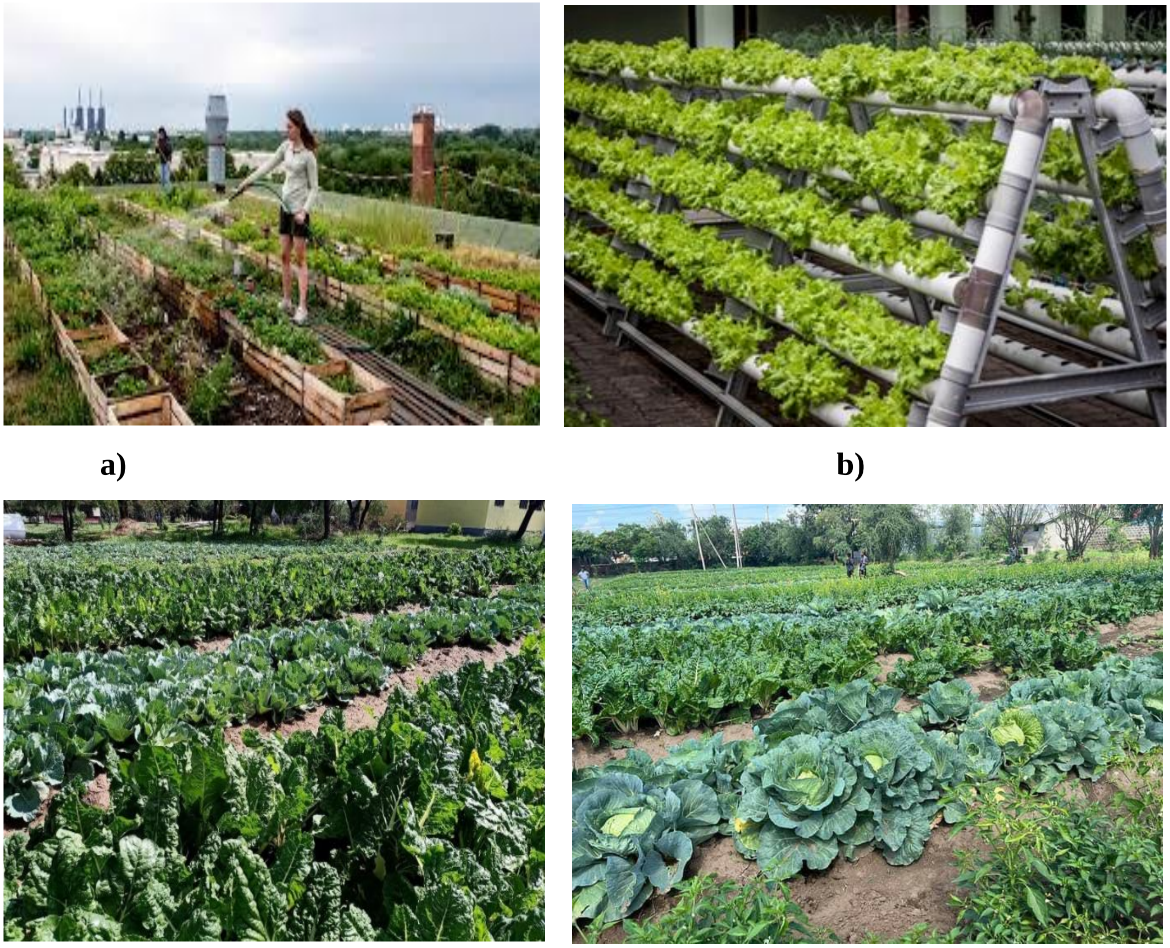
e) Backyard Gardens: This is the cultivation of food on one's own property. Its produce is mostly shared among friends, family, and neighbors as it typically leads to a surplus in the harvest and the food can also be stored and preserved (Orsini & Kahane, 2013). Backyard gardens are beneficial to communities as neighbors can share each other's backyard and employ different methods of farming, leading to better yields (Tirado & Cotter, 2010).

g) Forest gardening: As it pertains to the practice of having gardens grown within an urban forest, however, forest gardening is achieved by having different crops, vegetables, and fruits grown within urban settings (Priestnall et al., 2020). For this reason, forests usually create an environment that is favorable for crop development, and for this reason, they help in ensuring that forests are protected and can make deforestation a non-factor in urban settings. Forest gardening can also be part of afforestation efforts, which encourage the planting of trees as a step towards the fight against global warming in urban areas (Tirado & Cotter, 2010).

h) Greenhouses: it is the practice of agriculture in residential, commercial, and communal urban spaces through the use of greenhouses. They require a substantial amount of land to set up, depending on the crops being planted. Greenhouses give farmers the ability to grow a crop all year round as they provide a controlled environment where the crops can be subjected to specific conditions required for their growth.

i) Green walls: A green wall is the cultivation of vegetation or food crops on the exterior or interior surface of a wall. It does not use up a lot of space as the mechanism used helps to supply the food with adequate water and it uses soil present on the walls. It is a good method for reducing stormwater runoff (Arajo et al., 2018).

j) Animal husbandry: This is the practice of rearing animals for food in urban settings. An urban dweller can choose a location suitable for keeping different types of animals or focus on specific animals such as poultries, goats, rabbits, or sheep. Some cities limit the number of animals one can keep and also the type of animals that can be kept.



a) b)

c) d)

Figure 1: rooftop garden(a); Vertical Farming(b) and Adama Community Gardens (c & d)

Source: a&b (FAO, 2021); c&d (Adama city administration, 2022)

2.4 Benefits of Urban Agriculture

One of the basic functions of urban agriculture is to allow individuals to enjoy environmental horticulture as a hobby, and the other is to produce food and ornamental plants locally for sale to nearby residents. It can act as a multifunctional landscape with a variety of benefits, including the ability to offset many facets of environmental degradation, loss of urban ecosystem and including preventing excessive runoff. Food and ornamental plant production for local consumption can (1) save fossil fuel, labor time, and packaging materials, and thus transportation costs; (2) reduce postharvest losses due to damage during transport; (3) increase job opportunities, which benefits those living in urban areas; and (4) allow residents to enjoy a greater variety of fresh fruit and vegetables (Kozai et al., 2016).

2.4.1 Economic Benefits of Urban Agriculture

Historically as well as today, community development, food security, and economic security are three of the most common reasons for participation in urban agriculture. Urban agriculture not only strengthens social ties and provides healthful sustenance that might otherwise be lacking; it can also contribute to a household's income, offset food expenditures, and create jobs. Food security is affected by both the quantity and quality of food available to a household. Even in locations where urban agriculture does not contribute significantly to employment, food security is of major concern to urban farmers (Nugent, 2002). A perceived or actual need to improve food security and a lack of ability to rely on food from rural areas can result in the use of urban agriculture (Graefe & Schlecht, 2020), which has been shown to improve the quantity and quality of food available to low-income urban households under a variety of conditions (Graefe & Schlecht, 2020; Whittinghill et al., 2013). The extent to which urban agriculture supplements household income is diverse and can be dependent on crop choice and the scale of production. Staples, such as rice, can provide income security for a household (Vagneron, 2006), but vegetables can often command higher market prices and also, animal husbandry can provide high profits (Graefe & Schlecht, 2020) through the sale of dairy products or manure as fertilizer.

2.4.2 Environmental Benefits of Urban Agriculture

Urban agriculture can play an important role in the environmental sustainability of a city (Ackerman et al., 2014). As a form of green infrastructure, urban farms and community food gardens can help reduce urban heat island effects, mitigate urban stormwater impacts, and lower the energy embodied in food transportation (Medeiros & Swatuk, 2013). The Urban Heat Island (UHI), defined as higher mean temperatures in an urban area than in the surrounding rural area (Denes et al., 2019), can lead to urban temperatures between 0.6^0 C and 12^0 C warmer than those of surrounding rural areas (Memon et al., 2011). Increasing the amount of vegetation in an urban area is one of the more popular methods of mitigating the UHI through altering the heat balance of a city (Ackerman et al., 2014). Unfortunately, many urban areas do not have much ground-level land for additional green space, leaving rooftops as an important space for greening and rooftop farms can help reduce local temperatures and, when implemented on a city-wide scale, could result in significant cooling of the urban environment. Urban vegetation, including agricultural space, can also be used in stormwater management.

2.4.3 Social and cultural benefits of urban agriculture

Urban agriculture can be an "agent of change" for communities by providing opportunities for strengthening social bonds, expressing and maintaining cultural heritage, and engaging in activities promoting social and political change (Holland, 2004). Importantly, urban agriculture is seen by many as integral to practicing food justice. By transforming vacant or underutilized properties into productive landscapes that provide places to gather and share knowledge about food, residents not only enhance the beauty of their neighborhood through greening, but they expand their cultural competencies by learning from others.

Urban agricultural activities also provide opportunities for people of all ages to interact, leading to the growth of intergenerational bonds. These opportunities for social interaction are especially important for people who are isolated or from typically segregated groups, such as older people, disabled people, women, people of color, people of different faiths or different educational backgrounds, and people from different socioeconomic classes (Bassarab et al., 2018). The act of getting together for a common purpose fosters a sense of belonging, increases community cohesion, improves quality of life and, importantly, spawns a new generation of engaged citizens (Spanakis & Golden, 2013).

2.5 Trend of urban agriculture

Urban agriculture is considered a recent phenomenon in our modern world; however, it has existed for as long as humans have lived in cities. Agricultural activities have a long history and are related to people's abilities not only to harvest food available in nature, but also to purposefully cultivate and grow it, both plants and livestock. Archaeological evidence suggests that people in different parts of the world (primarily Asia and Africa) started to learn agricultural skills between 10 and 5 thousand years ago (Mannon, 2002). Mesopotamia 3500 BCE, Ancient Egypt 2500 BCE, and Aztec 1100 CE Some ancient civilizations that practiced urban agriculture, where farmers set aside small plots of land for farming within the city’s walls, (Placemaking et al., 2022).

From the 1880s to the early 1900s, allotment gardens were a common way for European cities such as London, Paris, and Stockholm to assist the urban poor in becoming self-sufficient. Poor families were given land to garden in peri-urban areas, or land immediately surrounding a settlement. (Aurora, 2019). Following a long period of industrialization, London became one of them by granting allotments. In addition, public parks were established in the 1920s to provide sufficient quantities of land within the city for citizens to use, typically for a small fee. Furthermore, in the 1800s, Germany began gardening with the aim of preserving green spaces within cities for children to play in nature. During World Wars I and II, this trend became more focused on increasing edible gardens in urbanized areas. (Placemaking et al., 2022).

In Africa, the new national capitals of Côte d'Ivoire, Malawi, and Tanzania are planning for and encouraging Urban Agriculture. The Rwandan government encouraged dooryard gardening and the Bolivian government gave plots to urban schools to produce more food locally. In Nigeria and Zaire, as in China, Japan, Papua New Guinea, and the Philippines, urban farmers have been protected and encouraged through land-use regulations and tax concessions (Lee-smith, 2015).

2.6 Status of Urban Agriculture in Ethiopia

Ethiopia has a long history of famines and food shortfalls that can be traced back to 250 BC. Particularly, since 1959, Ethiopia has remained one of the major food aid recipient countries in the world, as domestic production of food has never been sufficient to meet the food requirements of the national population (Mulugeta, 2013). Indeed, since the 1960s, the number of food insecure households has been increasing, whilst per capita food availability has been decreasing (Resource & Markos, 2020).

Agricultural policy of Ethiopia is mostly rural based favoring rural farmers through extension service, credit, input supply and distribution and land certification system (Abebaw & Akola , 2016). By implementing these productive policies, strategies and programs, remarkable progresses have been made in various sectors in the last two decades (Mulugeta, 2013).

Urban Agriculture practitioners in Ethiopia are for the most part resource-poor, subsistence, and urban poor growing vegetables and raising animals within and/or around city boundaries in uncoordinated manner. The outputs are mostly meant for subsistence purposes, making the sector unable to play a significant role in poverty alleviation, urban greening and waste recycling endeavors. In the current Ethiopian situation, Urban Agriculture has not yet been embedded in the urban planning and developmental strategies though various researchers have recommended for it to be an integral part of the urban system (Mulugeta, 2013). Most of the individuals engaged in Urban Agriculture in the briefly surveyed towns/City (Adama, Addis Ababa, Bishoftu, Burayu, Galan and Sabata) in Ethiopia are the previously rural farmers at fringe zones, long-term residents, females and the youth (Mulugeta, 2013).

Most Urban Agriculture practitioners in Addis Ababa and the small towns in close proximity are low-income earners who practice Urban Agriculture mainly for survival and achieve a combination of nutritional and socioeconomic benefits. The Urban Agriculture consists mostly of dairy farms and vegetable production. Carrots, potatoes, tomatoes, different kinds of cabbage, cauliflower, beetroot, peppers, green beans, cucumbers, lettuce, and celery are widely produced. Moreover, mushrooms, fruits, flowers and seedlings production are newly emerging Urban Agriculture business areas (Gebreegziabher et al., 2010).

2.7 Challenges for urban agriculture

Recently, the local government restricted the use of urban water supply for agriculture in order to conserve water for drinking, washing, and sanitation. Alternative water sources for urban agriculture need to be found, together with methods to prevent water losses and to enhance soil moisture conservation. Some steps have been taken to solve the shortages, such as the micro-jet drip-irrigation systems, which use water more efficiently (Novo & Murphy, 2001). In addition, open land often has extremely hardened soil, is full of gravel, and has low organic matter content. It demands much effort to bring these soils into production, and especially organic matter and compost are needed in large quantities. In some areas with no topsoil, gardeners' plants are in 100% compost. The use of vermiculture is spreading as well. This lack of diversity has been addressed by the popular gardens, and many rare plants are being brought back. This has been largely due to local seed saving, which allows the cultivation of locally-adapted crops and varieties that are suited to the particular conditions of a site (Novo & Murphy, 2001).

However, Challenges of Urban agriculture can be prevented and managed by appropriate urban policy, including provision of adequate extension service to urban farmers. It indicates that extension service and follow up of urban farmers is necessitating in urban area as that of rural area (Abebaw M. & Akola J., 2016).

2.8 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 (Martin & Saha, 2009). The studies by Martin & Saha, (2009) land suitability classification are divided into order, class, sub-class, and unit. Land suitability orders indicate whether the land is assessed as suitable or not suitable for the use under consideration. There are two orders represented in maps, tables, etc. by the symbols S and N, respectively. Order S: suitable land from which sustained use of the type under consideration is expected to benefit, with no unacceptable risk of harm to land resources. Order N is not suitable land, which has qualities that appear to preclude sustained use of the kind under consideration.

Land suitability analysis is one of the important components of spatial data analysis (KGPK Weerakoon, 2014a). It can be described as a process to determine suitability factors for some specific uses in order to determine its suitability level. Land suitability is mostly related to different criteria like physical, socioeconomic, and environmental (KGPK Weerakoon, 2014a).

2.8.1 Land suitability classes

Land suitability classes reflect degrees of suitability. According to (Martin & Saha, 2009) the classes are numbered consecutively, in sequence of decreasing degrees of suitability within the order; Within the order suitable the number of classes is not specified. There might, for example, be only two, S1 and S2 and the number of classes recognized should be kept to the minimum necessary to meet interpretative aims; five should probably be the most ever used; If three Classes are recognized within the Order Suitable, as can often be recommended, the following names and definitions may be appropriate in a qualitative classification: Class S1 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 (Martin & Saha, 2009). Class S2 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 (Martin & Saha, 2009). Class S3 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. Within the order not suitable, there are normally two classes: Class N1 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 and Class N2 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(Martin & Saha, 2009).

2.8.2 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(Martin & Saha, 2009).

2.8.3 Land Suitability Units

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 (Martin & Saha, 2009). The units differ from each other in their production characteristics or in minor aspects of their management requirements, which are often defined as differences in detail of their limitations. Their recognition permits detailed interpretation at the farm planning level and the Suitability units are distinguished by Arabic numbers following a hyphen, e.g., S2e-1, S2e-2 (Ahlqvist, 2008). There is no limit to the number of units recognized within a subclass (Martin & Saha, 2009).

2.9 Application of Geospatial technologies for site suitability analysis

2.9.1 Application of Remote Sensing 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 spaceborne information. Earth observation from airborne platforms has 150 years of history, although the majority of the innovation and development has taken place in the last 30 years (Zubair, 2006). Satellite-based remote sensing provides valuable information that can be used in the assessment of the various aspects of the 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's surface to make the interface of object property and measurement analysis as well as an inventory of the environment and its resources, and it has the unique ability to provide a synoptic view of a large area with the capacity of repetitive coverage. One of the most common applications of remote sensing in site suitability analysis for urban agricultural development is where remote sensing data like satellite images are used for extracting agricultural development criteria (example: land use, land cover, and surface water) with the goal of saving time and cost.

2.9.2 Application of Geographic Information System for site suitability analysis

A Geographic information system (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 also a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. The data types in GIS can be classified into two major groups: spatial and non-spatial data. Non-spatial data are data that describe spatial data in the form of a table. Spatial data are data that have a location value.

According to (Burrough), data in GIS is composed of three dimensions that mean spatial (geographic), time, and attribute. Some people believe that a geographic information system is a system of hardware and software that contributes to analyzing applications or information processing. A GIS is not only a digital store of spatial objectives (areas, points, and lines) but also capable of spatial analysis based on the relations between these objects, including the relationship between objects defined by their location and geometry. It is ideal for preliminary site selection studies because it efficiently stores, retrieves, analyzes, and displays information according to user-defined specifications.

2.9.3 Multicriteria Decision Making Analysis

Multiple-criteria decision-making (MCDM) is a generic term for all methods that exist for helping people make decisions according to their preferences in cases where there is more than one conflicting criterion. Multi-Criteria Decision Analysis (MCDA) is a set of analytical approaches that aid decision-makers in solving complicated problems by utilizing information provided by the decision-makers. Multicriteria decision making (MCDM) has been widely applied for decision-makers that have to deal with complex choices for problems that require the selection of the best alternative according to their preferences from multiple potential candidates (Pavan & Todeschini, 2009).

Multi-criteria analysis (MCA) process provides an optimum solution in which the uncertainties associated with evaluating criteria are ranked on the basis of overall performance of various input with respect to the multiple objectives. In MCA, each and every criterion is given a weightage to represent its genuine importance. The integration of GIS and MCA techniques provides efficient spatial analysis functions. In recent times, GIS-based MCA technique has gained importance because of its capacity to integrate a large quantity of data (Malczewski, 2006).

There are several techniques for multi-criteria decision-making that can be successful based on the many concerns. However, GIS and AHP are the most common for Multi-Criteria Decision Analysis. The Analytic Hierarchy Process (AHP) is a decision-making technique for determining the relative relevance of criteria in a given decision-making situation (Hashemi et al., 2020). AHP provides an effective tool to deal with complex decision-making and unstructured problems (Soltani & Marandi, 2011). The AHP is an iterative technique that consists of a number of stages that can be modified to suit a particular problem (Tsiko & Haile, 2011).

2.10 Analytical Hierarchy Process

The AHP is a powerful and flexible decision-making process to help people set priorities and make the best decisions when both qualitative and quantitative aspects of decisions need to be considered (Saaty, 2004). AHP was developed in the 1970's by Thomas Saaty as the most highly regarded and widely used decision-making theory. The most prominent characteristic of this theory is using the pairwise comparison matrix for value judgement. The criteria pairwise comparison matrix takes the pairwise comparisons as an input and produces the relative weights as an output, and the AHP provides a mathematical method of translating this matrix into a vector of relative weights for the criteria. It is the procedure by which criteria are combined to arrive at a particular evaluation and by which evaluations are compared and acted upon (Yahaya, 2008).

2.11 Criteria of suitability analysis for urban agriculture

Identifying the best criteria is the key for land suitability analysis (Chakma, 2014). The criteria are very significant in the site selection of the identified land use and are used as key drivers in the selection of the geographic location. Significant criteria have been commonly used for developing the framework of the AHP method to identify the best location. On the other hand, selecting criteria may depend on other factors that can influence the selection process, i.e., the availability of data, the extent of the study area, etc. Some of the most significant criteria used for suitability evaluation are accessibility criteria, environmental criteria, physical criteria, and socio-economic criteria (Javadian et al., 2011). Some earlier studies and literature conducted by some researchers used those criteria and sub-criteria for urban agricultural development, such as LULC, slope, soil type, distance from road, distance from river (surface water), community facility locations, distance from residential area, population density, drainage, and distance from market (Ackerman et al., 2014; Habib Ananya et al., 2012; Smith et al., 2017; Sonneveld et al., 2021; Weerakoon, 2014; Whittinghill et al., 2013).

2.12 The significance of urban agriculture

It is estimated that about 800 million people worldwide engage in urban agriculture (Mpofu, 2013). It is thought that globally, urban agriculture produces 15% of all food consumed in urban areas. In Russia, 72% of households are urban farmers; 80,000 in Berlin; 68% in Tanzania; while in China, the 14 largest cities produce 85% or more of vegetables (UN-Water, 2015).

According to the by Gonfa, (2019) Increases in urban agriculture have also been recorded in African cities such as Bissau (Guinea Bissau), Dakar (Senegal), Kumasi (Ghana), Lome (Togo), Nairobi (Kenya), and Dar-es-Salamm (Tanzania) studied by the Food and Agricultural Organization. Thus, urban agriculture is, in most cases, a response by the urban poor to inadequate, unreliable, and irregular access to food and to a lack of purchasing power. Most cities, particularly in developing countries, are unable to generate sufficient income and employment for their rapidly growing populations.

Urban farmers usually specialize in the production of perishable and high-value agricultural products such as vegetables, milk and milk products, eggs, and meat. In terms of the Gross Domestic Product (GDP), urban agriculture contributed 2% in Shanghai (China), and 4% in Lima (Peru) (Veenhuizen, 2006). In six East and Southern African countries, the number of people obtaining part of their food from urban agriculture is expected to rise from about 25 million to 40 million by 2020 (Lee-smith, 2015).

In addition, urban agriculture has contributed significantly towards solving waste management problems by converting urban solid waste into productive agricultural inputs such as compost, while treated waste water has been used for irrigation. Urban agriculture is also part of the urban greenery that improves the urban micro-climate, increases biological diversity, and enhances the aesthetics and recreational functions of urban areas.

2.13 Research Empirical studies

Urban agriculture has been studied by many scholars around the world. Several authors have stated that urban agricultural practices and strategies differ depending on climate, geography, cultural preference, and local demand (Lovell, 2010b; Specht et al., 2014). Badami & Ramankutty (2014) analysis shows that Urban Agriculture is feasible in terms of urban land availability to grow the basic daily vegetable intake for the urban poor in the high-income countries.

The research results of Abebaw M. & Akola J (2016) clearly showed that the contribution of urban agriculture is multifarious, and have great importance in urban greening, fight against poverty through the supply of food products to the poor populations, food security attainment and job creation (Abebaw M. & Akola J., 2016). Resource & Markos (2020) witness Urban Agriculture is important for its productive acreage but it is more important from the perspective of transforming urban dwellers from being consumers into a community of co-producers and participating in Urban Agriculture.

Different scholars and institutions agree that urban agriculture contributes a lot to food security and poverty alleviation in the cities/towns of Ethiopia. Most of studies in Ethiopia on urban agriculture is don't focus on land suitability that result for sustainability and multifunctionality of urban agriculture for urban residents. However, none Still can't try to analysis suitability of land to locate urban agriculture. Assessing the role of urban agriculture in attaining urban food security with special reference to smallholders in Adama City (Tefera, 2010) was the best example.

This paper benefited from parallel work on a global assessment of urban agriculture conducted by the following scholars: (Habib Ananya et al., 2012; Pramanik, 2016; Smith et al., 2017; Sonneveld et al., 2021; Weerakoon, 2014b) etc. After reviewing literatures, the research gaps were identified. The major difference between their analysis and present research is that, specifically, researchers haven't evaluated LULC that can determine the land function of the study area, and also many researchers haven't used the more specific criteria for identifying more suitable areas. In fact, in Ethiopia, none of them evaluated urban agriculture land suitability, considering the existing agricultural lands to be (the most suitable) for urban agriculture. Regarding Adama, it has been studied, but no one has focused on identifying an appropriate site for agricultural land and how to integrate it with urban land use.

Therefore, the study was conducted to develop a site suitability to find appropriate locations to implement and evaluate the urban agricultural land suitability and availability of land for urban agriculture under different scenarios in Adama City.

2.14 Conceptual Framework Nowadays,

The suitable site selection process for urban agriculture considers four parameters such as accessibility, physical, environmental and socio-economic (Mishra et al., 2015). Accessibility analysis encompasses any spatial analysis of the area, like proximity to roads and railways, different services, dangerousness of the location, and natural features. Physical features deal with features and attributes of the land surface. For example, LULC, soil moisture, soil type, slope, elevation, and topography are important parameters in the suitable site selection process. Environmental parameters are important for suitability analysis, such as streams, existing urban agriculture, etc. Socio-economic is another significant parameter for suitability analysis, such as LULC and population density. Urban agriculture is increasingly gaining attention as a source of multiple benefits (Wise S. et al., 2010; Byrne JA. et al., 2015). Urban agriculture is based on local initiatives and there is a direct relationship between activities, output, and the needs of the local population (Chaudhuri, 2015). Self-reliance through conservation of energy, self-help housing, social services, treatment of waste, and usage of unused resources are all measures to help promote self-reliance. Urban agriculture is considered part of subsistence agriculture. This form of production includes agriculture; the construction and maintenance of houses; the collection of water and firewood; health care; recreation; and transport and it is thought that urban agriculture can play a crucial role in the production of food for Third World cities with regard to the urban poor (Chaudhuri, 2015) and can provide better environmental conditions. This is done by analyzing the suitability of land for agriculture. Generally, there are many determinant factors (main factors and sub-factors) that affect urban agriculture development. Accessibility, physical, environmental, and socioeconomic factors are all important. The below figure illustrates the conceptual framework for demonstrating urban agriculture's suitable site selection parameters and the benefit or contribution of urban agriculture for urban ecosystems.

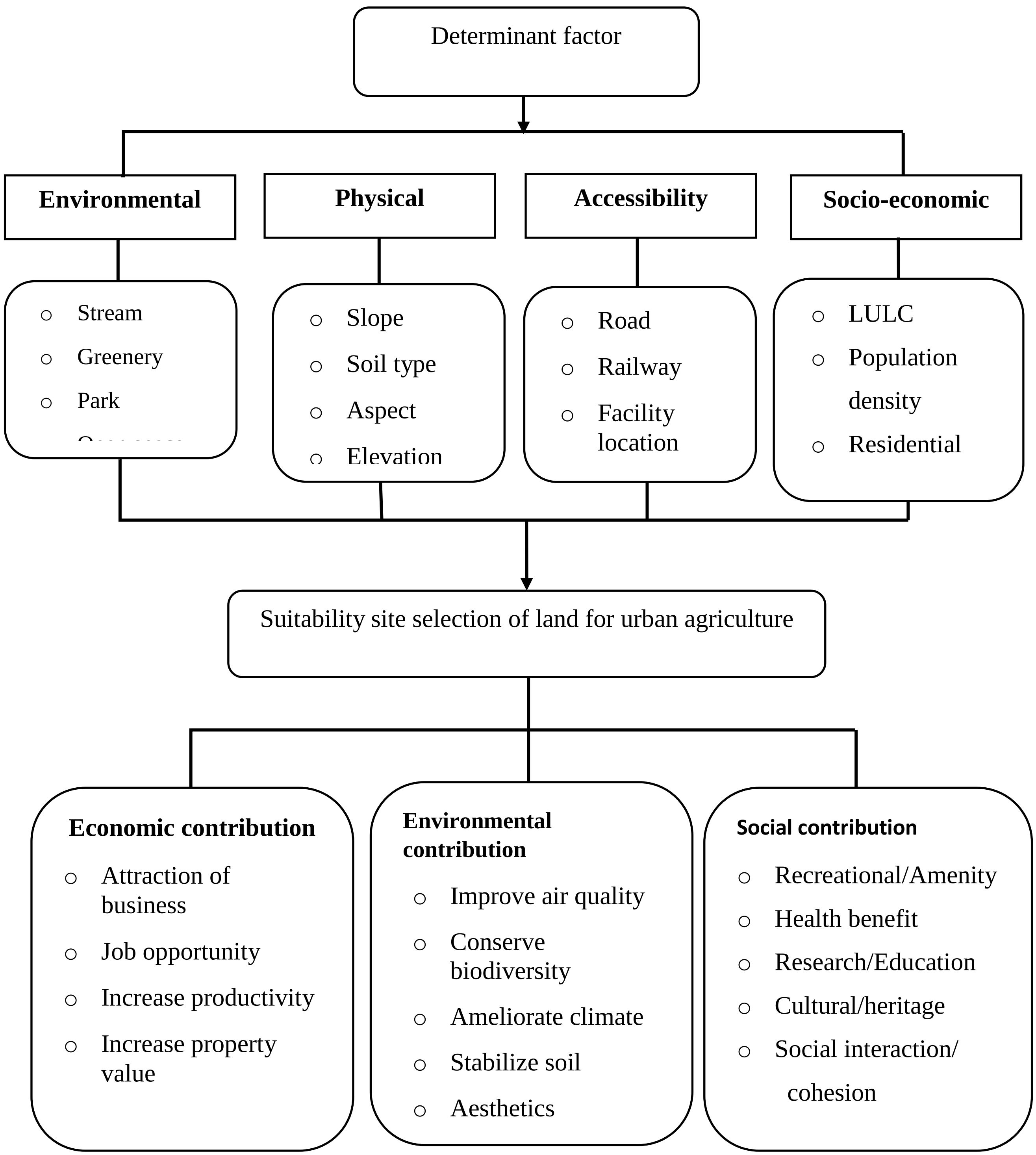


Figure 2: Conceptual framework for the study

Source: (Mensah, 2014) and modified by the author

CHAPTER- 3: MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Geographic Location

Adama is a city in central Oromia Region, Ethiopia. Adama city is located at nodal point along the railway line that stretched from Port of Djibouti to Finfinne/ Addis Ababa in the heart of Rift Valley with incomparable opportunities for tourism, conference, industrial and trade of development in the region. It is located at 8.54°N 39.27°E at an elevation of 1712 meters, 99 km southeast of Finfinne/Addis Ababa. The city sits between the base of an escarpment to the west, and the Great Rift Valley to the east. The city is also situated north of prominent Awash River that has been the most utilized river for irrigation in the country and the source of city's potable water (Adama City Municipality Office [ACMO], 2018).

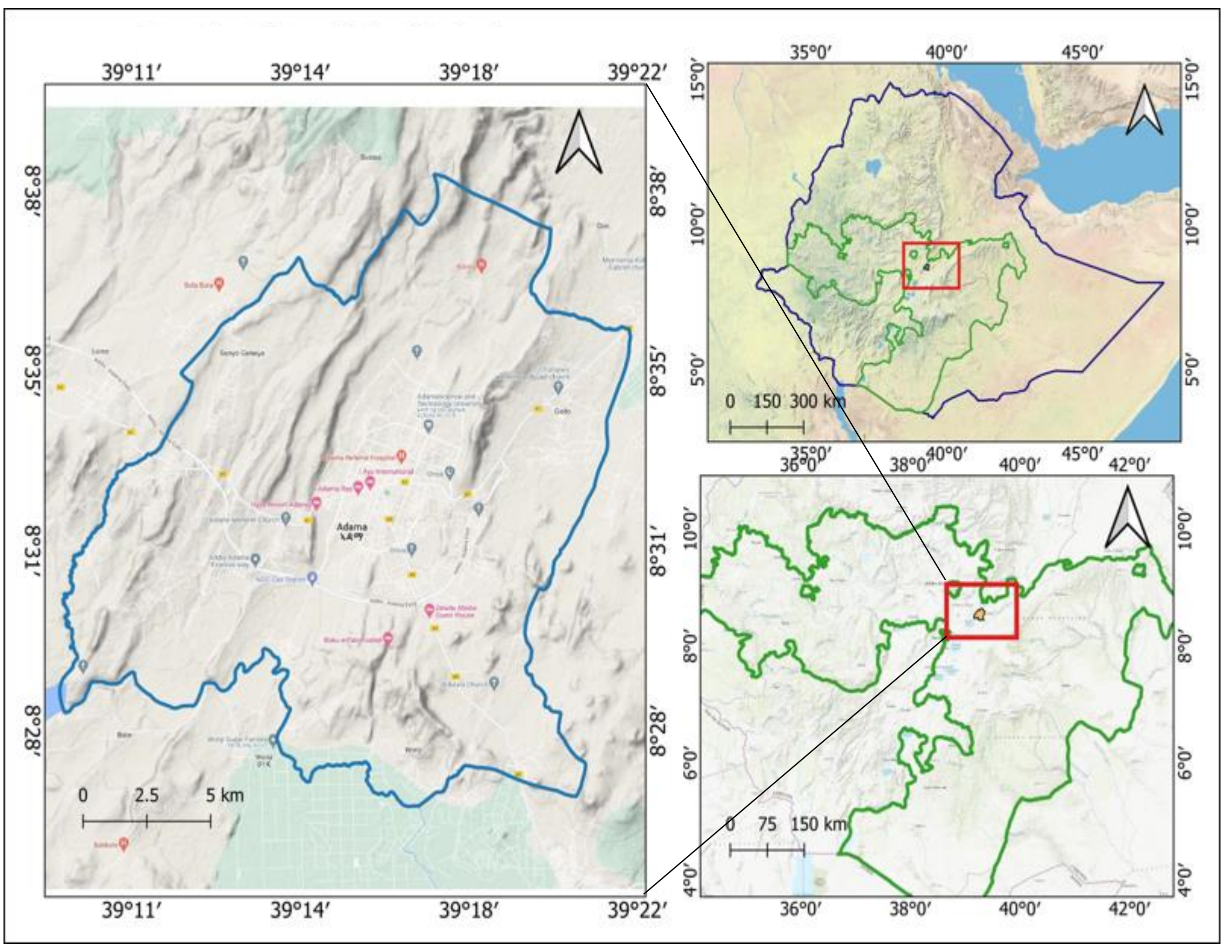


Figure 3: location map of the study area

3.1.2 Demography /population

Demographically, Adama is the most rapidly growing city both in terms of population and physical areas in the region starting from the outset of its establishment due to ongoing urban spread out, natural growth of population and high level of rural urban migrations. According to the last three consecutive censuses conducted in the country showed large increase of population in the city. So that 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 that distributed over land areas 133.6 km^2 were inhabited in Adama. Based on this the population of Adama city including four suburban Genda's under the city administration in 2016 (2009 E.C) was 391,597 of whom male 193,992 and female 197,605 (ACMO, 2018).

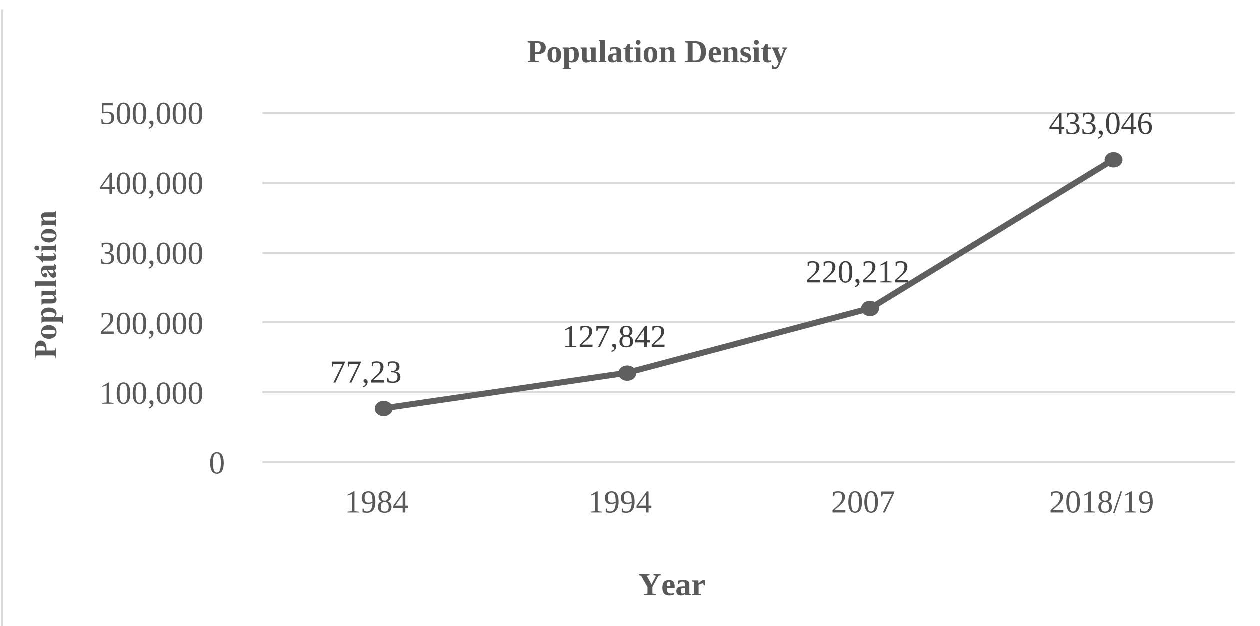


Figure 4: Population of Adama city from 1984 to 2018/19(CSA, 2018/19 projected)

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

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 city are uneven as elsewhere in the country. The pattern of spatial distribution of population shows difference among different quarters of the city. The density of population varies from area to area. The central parts of the city have high population density in comparison with the urban expansion areas. The urban Ganda/kebeles with the biggest population is Irreecha (09), whereas, the urban Ganda/kebele with the least population is Boku Shenan. Badhatu (07) and Gurmu (06) are the first and the second dense urban ganda/kebele respectively (Socioeconomic profile of Adama, 2020).

Sex Ratio

The majority of the residents of the city 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. It also points out the name given for kebeles, before 2017 the name of 14 kebeles (which listed in figure 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).

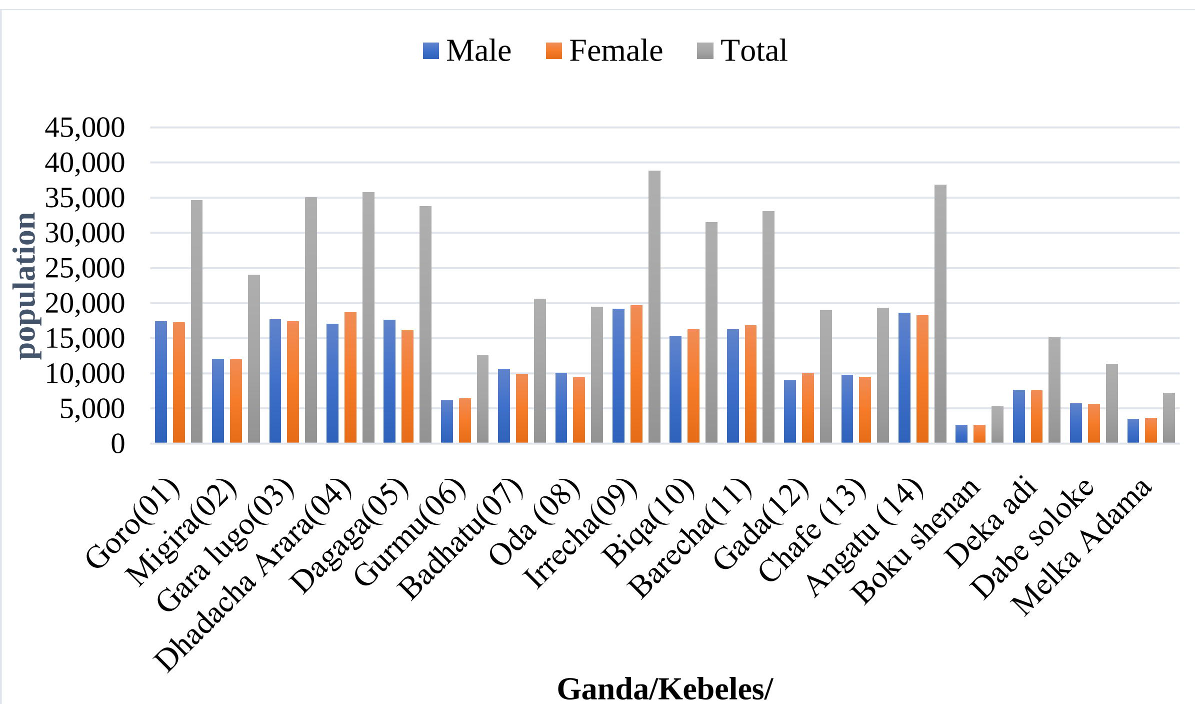


Figure 5: Population of Adama city at kebele level (CSA, 2018/19)

Source: (*Socio-Economic Profile of Adama*, 2020)

3.1.3 Climate

The city 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 trends of rainfall and temperature during the consecutive past five years the maximum average and minimum average annual temperature was 29.4^0c and 15.8^0c 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).

3.1.4 Soil Type

Adama city is covered by three kind of major soil type which are eutric fluvisols, haphlic phaeozomes and haplic luvisosls. According to Food and Agricultural organization FAO (2001), the physical and hydrological characteristics of these soil are defined as follow: -

Eutric fluvisols: - Most Fluvisols are wet in all or part of the profile due to stagnating groundwater and/or flood water from rivers or tides. Their texture can vary from coarse sand in levee soils to heavy clays in basin areas.

Haphlic phaeozems: - Phaeozems are porous, well-aerated soils with moderate to strong, very stable, crumb to blocky structures. Phaeozems with clay accumulation have even better water storage properties than other Phaeozems but may still be short of water in the dry season.

Haplic luvisols: - Luvisols have favorable physical properties; they have granular or crumb surface soils that are porous and well aerated. They have a higher clay content in the sub soil than in the top soil, as a result of pedogenetic processes (especially clay migration) leading to an argic sub soil horizon.

3.2 Data Collection and the Sources

This study included both spatial and non-spatial data from actual fieldwork and secondary (Ancillary) data. The following table describes types of data in the study, formats and where the data gathered from.

Table 1: Data's and their source

No.	Data Required	Data Source	Data Type	Year	Resolution	Data Format
1	Structure Plan	Municipality	Secondary	Recent	-	CAD (.dwg)
2	Population	CSA	Secondary	2018/19	-	-
3	DEM	Free ASTER	Secondary	2022	10m	Raster (.tiff)
4	Landsat 5 TM			2002	30m	
	Landsat 7 ETM+	USGS	Secondary	2012	30m	Raster (.tiff)
	Sentinel-2A			2022	10m	
5	Road network	Google Earth	Secondary	2022	-	Kml (.kml)
6	Stream	DEM	Secondary	-	-	Raster (.tiff)
7	Soil type	FAO	Secondary	-	-	Shapefile(.shp)
8	Facility location	Handled GPS	Primary	2022	3m	point

3.3 Materials Used

Geographic information systems (GIS) and multi-criteria decision-making (MCDM) techniques have been used in solving site selection problems. The site selection process for urban agriculture development involves various socio-cultural, technological, environmental, and economic aspects. GIS-MCDA 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). GIS-MCDA provides a flexible tool that is able to handle and bring together a wide range of variables assessed in different ways and thus offers useful assistance to the decision maker in pointing at suitable locations (Taha & Daim, 2013).

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

To achieve the objective of this study, different types of software were used. Software is a program that is used for the collection, organization, analysis, interpretation, and presentation of data. The following table describes the types of software that were used in the study, their versions, and their purposes.

Table 2: Software used and their purpose

No.	Software Name	Version	Purpose
1	ArcGIS	10.8	For storing, managing, processing, analysis spatial information and thematic map preparation.
2	ERDAS Imagine	2015	For processing and analysis satellite images
3	Microsoft Word and Excel	2019	Integrating attribute data and compositing final thesis
4	IDRISI	32	To assign weight for each factor
5	Google Earth	7.3	For Random point collection and accuracy assessment

3.4 Data Processing and Analysis Methods

After the data was collected from various sources, both quantitative and qualitative form, these are processed using different techniques and then data was analyzed by using different software like Arc GIS 10.8, IDRISI, and ERDAS IMAGINE 2015. After completion of data processing, data was analyzed following different methods. ArcGIS, ERDAS and Microsoft Excel have been used for data analysis in order to achieve the objective. This thesis was performed for LULC dynamics, which were analyzed using ERDAS IMAGINE 2015 and land suitability analysis for urban agricultural development in Adama city using geospatial technology.

The Remote Sensing and Geographic Information System have proved to be very important in assessing and analyzing land use and land cover changes. The temporal information on land use and land cover helps identify the areas of change in a region. The quantitative analysis and identifying the characteristics and processes of surface changes can be analyzed from the different periods of remote sensing data. Image classification was done in order to assign different spectral signatures from the Landsat datasets to different LULC. The LULC classification includes Built up area, Water bodies, Farm land, vegetation areas and bare land. The supervised classification was carried out using the Maximum Likelihood (Gadrani et al., 2018).

GIS-based multi-criteria land suitability analysis is becoming critical in determining the land resource that is suitable for urban agriculture. In order to identify suitable sites of land for urban agriculture development, different criteria will be considered such as LULC, soil type, slope, stream/river, road, drainage, residential area, population density, and facility location. Then MCA has incorporated ArcGIS as a method to select suitable locations for urban agricultural development. Furthermore, application of GIS-based multi-criteria suitability analysis using the analytical hierarchy process (AHP) to support the decision-making process on selecting an appropriate site depending on the criteria.

3.5 Analyzing Adama city LULC changes

This research seeks to analysis of LULC over the period 2002–2022, as the basis for identifying quantitatively and spatially changes between LULC classes. ERDAS IMAGINE 2015 software was used in image processing and classifying LULC maps. A supervised classification technique was conducted for the image classification process to represent five land use land cover (LULC) types: builtup/urban land, farm land, water body, bareland and vegetation. Maximum likelihood was applied for the classification process. The total accuracy was estimated by producing an error classification matrix for each LULC map.

3.5.1 Image Pre-Processing

After data collection, the study undergoes the processes of manipulating, sorting, and preprocessing collected data to analysis the LULC dynamics of the study area. The satellite images of 2002, 2012 and 2022 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 illumination variance through radiometric calibration procedures.

3.5.2 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. It is a technique to identify different features such as urban area/Builtup, vegetation 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 2002, 2012 and 2022 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, vegetation, farm land, bare land and water body.

3.5.3 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 (van Vliet et al., 2011). Therefore, the assessment of the accuracy of mapping generated from remote sensing data is a critical and essential step in the classification process (Tahri et al., 2021). The error matrix is the most common tool in terms of determining the accuracy of the classification results. User accuracy, producer accuracy, overall accuracy, and Kappa statistics were then derived from the error matrices for LULC classes. According to van Vliet et al., (2011), 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 a required component of most image analysis.

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. The producer's accuracy was calculated by 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:

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

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:

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

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.

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

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

Kappa Coefficient: The Kappa coefficient can be used as another measure of agreement or accuracy. The major diagonals and the chance agreement were used to measure the agreement or accuracy between the remote sensing derived classification map and the reference data. 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. The divided the possible ranges for kappa into three groups: a value greater than 0.80 (i.e., 80% and above) represents strong agreement; a value between 0.40 and 0.80 (i.e., 40%–80%) represents moderate agreement; and a value of 0.40 (i.e., 40% and below) represents poor agreement.

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

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

Omission Error: Errors of omission refer to reference sites that were left out (or omitted) from the correct class in the classified map. The real land cover type was left out or omitted from the classified map. Error of omission is sometimes also referred to as a Type I error. An error of omission in one category will be counted as an error in commission in another category. Omission errors are calculated by reviewing the reference sites for incorrect classifications in columns for each class and adding together the incorrect classifications and dividing them by the total number of reference sites for each class. A separate omission error is generally calculated for each class.

Commission Error: Commission errors are calculated by reviewing the classified sites for incorrect classifications by going across the rows for each class and adding together the incorrect classifications and dividing them by the total number of classified sites for each class.

3.5.4 LULC Change Detection analysis

Post-classification comparison approach was employed for detection of land use and land cover changes by comparing independently produced thematic maps for 2002, 2012 and 2022. Then, the classified land use and land cover maps were compared to show the changes between each year, i.e., 2002–2012, 2012–2022 and 2002–2022 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:

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

$$\text{Total LULC change} = \text{Area}_{\textit{final year}} - \text{Area}_{\textit{initial year}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (5)}$$

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

Percentage LULC change were calculated using the following equation:

$$\text{Percentage LULC change} = \frac{(\text{Area}_{\textit{final year}} - \text{Area}_{\textit{initial year}})}{\text{Area}_{\textit{initial year}}} * 100 \quad \ldots\ldots\ldots \text{Equation (6)}$$

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

3.6 Determining determinant factors contributing for urban agriculture

According to the studies by Jabir (2014), there were no universally agreed criteria or factors for urban agricultural development. Land suitability analysis for the selection of suitable sites for urban agricultural development in Adama city was carried out based on the following factors: distance from roads, LULC, population density, soil type, slope, distance from facility locations, distance from residential areas, drainage, and distance from stream were often used for agricultural land suitability assessment.

(a) Land Use/Land Cover: Land use land cover of the study area was acquired from USGS sentinel-2A of 2022 and it has its own influence on land suitability analysis for agricultural crop production.

(b) Soil type: The type of soil is one of the most important factors for agricultural land suitability. Soil behavior helps to estimate the soil performance for agricultural production. Thus, when deciding on the suitability of land for agricultural production, it is necessary to know the soil types (Bozdağ et al., 2016). Three soil types are situated in the study: which are eutric fluvisols, haphlic phaeozomes and haplic luvisosls. Alluvial soils contain rich nutrients for crops and are rich in organic matter content. Drain ability is used to describe the relative rapidity and extent of removal of water in the soil, which is dependent upon the soil permeability. The soil has a significant impact on the amount of recharge, which can infiltrate into the groundwater and hence, influences the ability of contaminants to move vertically into the vadose zone (Ohri & Singh, 2010).

(c) Population Factor: Densely populated urban areas, particularly in low and middle-income countries, are particularly vulnerable to the effects of environmental and climate change. Where there are dense concentrations of households and economic activities, the effects of climate change can affect large numbers of people and have a major impact on urban economies, even if they affect only relatively small land areas (Dodman, 2009). Population density is measured by dividing a given population by a given area. Therefore, it is important to consider the population density of a given area in order to select a sustainable agriculture area. Areas with low population density are the ideal planning locations for agricultural development.

d) Topographic factors: The topography category comprises three criteria: aspect, slope, and elevation. These criteria affect agricultural land suitability and must be considered in agricultural land selection.

Aspect: Plants need sun exposure at certain intervals in order to maintain their physiological activities. The duration of this need varies according to the species of plant. Plants generally exhibit optimum growth in the southern and western aspects that receive sunlight for a substantial portion of the day (Yavuz, 2016). Therefore, aspect is taken into consideration as an assessment criterion for selecting the land to be used for urban agricultural development

Slope: The soil formation is closely related to geomorphologic properties. Slope degree is the main factor determining erosion control. The amount of materials carried away with erosion increases with the growing degree of slope. An increase in slope degree slows down the development of soils and decreases soil depth and fertility(Yavuz, 2016). Furthermore, slope affects agricultural production negatively by restricting machinery and management applications such as soil tillage, irrigation, and drainage.

Elevation: Elevation is an important factor affecting agricultural land suitability due to its role in temperature changes, thus in variation of plant cover. The periods of vegetation and bloom are delayed by 4–6 days for every increase of 100m in elevation on the mountains. This fact negatively affects the plant variety to be selected for agricultural production.

3.7 Suitability Evaluations using AHP based multi-criteria analysis (MCA) methods

In this study, to select a suitable site for urban agriculture using GIS-based multi-criteria analysis. The main aim of GIS based Multi-Criteria Analysis (MCA) was to produce a map showing suitable sites for urban agricultural development in Adama city.

3.7.1 Standardize the factors/criterion scores

All of the selected criteria are in different units, so to execute the Weighted Overlay Method they require conversion into the same units and hence require a standardized value (Pramanik, 2016). Standardization techniques convert measurements to uniform units, and the resulting score loses dimension as well as measurement unit for all criteria (Pramanik, 2016). The vector layer of all criteria maps was converted to a raster layer and the weighted overlay model was developed. After that, all raster layers were reclassified and used as the input data for the weighted overlay method, which finally created the suitability map for agriculture. 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 on different scales of measurement such as ordinal, interval, nominal, and ratio scales (Pavan & Todeschini, 2009). Even though there are different methods that can be used to standardize criteria, linear scale transformation is the most frequently used technique (Malczewski, 2004). 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 (Martin & Saha, 2009), land suitability classification, the datasets were reclassified from highly suitable (S1) to permanently unsuitable (N2), where S1, S2, S3, N1 and N2 represent the highly suitable, moderately suitable, less suitable, not suitable and permanently unsuitable conditions for urban agricultural development, respectively.

3.7.2 Defining weights/ Determine the weight of each factor

Assigning criteria weights to 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 another factor's effect on urban agricultural development. There are several methods available to determine the weight, like the 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 to each factor.

In this study, to select a suitable site for urban agricultural development, the AHP was carried out using the following three steps Pair-wise comparison of criteria, calculating criterion weights and Calculating consistency ratio (CR).

Pair-wise comparison of criteria

According to Flitter et al. (2013), a pairwise comparison is another method for weighing many factors. It is based on the Analytic Hierarchy Process (AHP), a well-known decision-making framework created by an American mathematics professor in the 1960s (1980). This strategy allows you to focus on simply comparing two criteria at a time. As a result, when dealing with a large number of classes, the effort required to compare each criterion with each other grows rapidly (to be exact, with n criteria, there are n (n-1)/2 comparisons). However, as a method, their accuracy and dependability are also very diverse.

Furthermore, the three techniques have different underlying scales. They range from ordinal (weighting by ranking) to interval (weighting by rating), to a ratio scale (pairwise comparison). Wrong weights lead to incorrect suitability analysis conclusions and, as a result, incorrect judgments (Flitter et al., 2013). As a result, the focus of this thesis is to analysis land suitability in order to make the best possible urban agriculture site suitability decision.

Table 3: 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 favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another.
7	Demonstrated importance	An Activity is strongly favored and its dominance is demonstrated in practice.
9	Extreme Importance	The evidence favoring 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.

Source: Saaty (2007)

According to (Saaty, 2007), 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).

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.

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:

A pairwise comparison matrix will be constructed, where each criterion is compared with the other criteria, relative to its importance, on a scale from 1 to 9 (Saaty, 2004). Following computation of the pairwise matrix, relative weights will be computed using the (Saaty, 2007) approach, and the degree of consistency will be used in developing the ratings estimated by consistency ratio index (CR) as follows:

$$CR = \frac{CI}{RI} \qquad \text{………………..…………………………………. Equation (7)}$$

$$CI = \frac{\lambda\, max - n}{n-1} \qquad \text{……………..……………………..………………… Equation (8)}$$

Table 4: Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54

Source: Saaty (2004)

3.7.3 Aggregate the criteria

According to Malczewski, (2003), GIS can be used not only for automatically producing maps, but it is unique in its capacity for integration and spatial analysis of multi-source data sets. These data are manipulated and analyzed to obtain useful information for a particular application such as land suitability analysis. Once the criteria maps are developed, the aggregation stage is undertaken to combine the information from the various factors. In the context of GIS, three decision rules i.e., Boolean overlay, weighted overlay and ordered weighted averaging are common for MCE (Malczewski, 2000; Jiang and Eastman, 2000; Malczewski, 2003). The type of aggregation used is a weighted overlay. The evaluation is simply the multiplication of all the images. However, the study adopts the weighted overlay technique for developing the suitability maps for each land-use type and vector overlay analysis for deriving a composite suitable land allocation map. 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 urban agriculture. This can be done by using the following formula to derive the intended map (i.e., urban agricultural suitability map for Adama city).

The AHP, pairwise comparison matrix estimates the weights of each criterion (wi). Pairwise comparison matrixes involve the comparison of all possible pairs of criteria in order to estimate which of them are from a higher priority. (Saaty, 2007) suggests a scale from 1 to 9 in which value 1 indicates that the criteria are equally essential and value 9 means that the considered criterion is superior to the other criteria. The land suitability classes were assigned score 5, 4, 3, 2 and 1, respectively. The classes with higher scores are highly suitable for crop production and by applying these scores, the estimated suitability classes and all thematic maps were reclassified (Natsagdorj et al., 2020).

$$\mathrm{LS} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{Wi} * \mathrm{Xi} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{Equation (9)}$$

Where, LS indicates the total land suitability score, Wi denotes the weight of the selected land suitability criteria, xi indicates the assigned sub-criteria score of i land suitability criteria, and n denotes the total number of land capability criteria (Cengiz & Akbulak, 2009)

3.7.4 Validate/verify the result

To recommend the best site suitability for urban agriculture; validating the results with the exists one. 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. The studies by Abebe & Megento, (2017), sensitivity analysis was performed by changing the weight of criteria and field surveys were conducted for ground truth verification.

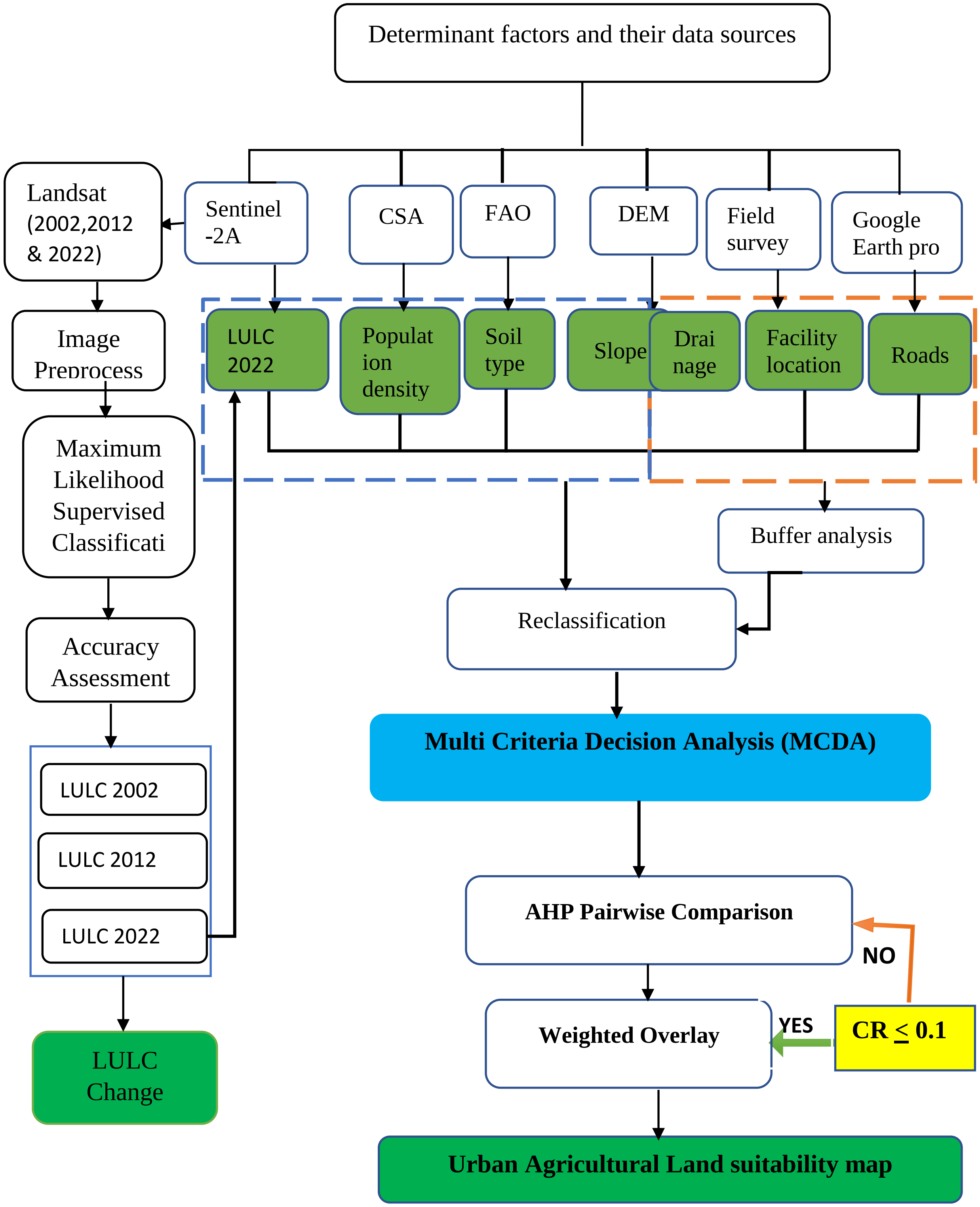


Figure 6: Technological Scheme of the Study

CHAPTER- 4: RESULT AND DISCUSSION

This chapter based on the data gathered, data analysis performed and LULC maps developed from 2002, 2012 and 2022 years, presented in the following Figure 7 and Figure 9, shows the statistical change analysis of LULC over the study period (2002–2022), or about 20 decades. While this thesis aimed to implement a land suitability analysis to identify available areas for urban agriculture practices using an expert knowledge approach and a data-driven approach, it also aimed to compare the results obtained from both approaches. In this context, the results of the procedure carried out in the expert knowledge approach using the MCA-AHP method and including a spatial sensitivity analysis developed to evaluate the robustness of the model implemented Finally, maps of suitability analysis of land for urban agricultural development were created for each suitability criterion, and the final composite map was produced by weighted overlaying of the individual maps. Reclassified criterion, standardization score, area coverage of suitability levels and weights of each factor.

In this regard, the parameters considered in this study were LULC, slope, soil type, river/stream, existing built-up area/residential, road, drainage density, facility location and population density. Finally, based on (Martin & Saha, 2009) classification, all those parameters were internally classified into five classes; highly suitable(S1), moderately suitable(S2), marginal/less suitable(S3), not suitable(N1) and permanently not suitable(N2) with values ranging from 5 to 1, where 5 denotes the highly suitable and 1 denotes the permanently not suitable for all factors and constraints considered.

4.1 Analysis of Adama City LULC Change

4.1.1 Land Use and Land Cover Classification

To accomplish the objectives of the study, the LULC of the study area was first classified from Landsat satellite images of 2002, 2012 and 2022 to compute the LULC change trend of Adama city. The images were interpreted or classified into five LULC classes, namely: built-up, vegetation, farmland, bare land, and water bodies. The LULC maps are generated after running a maximum likelihood supervised classification in ERDAS IMAGINE software. The results showed that, over the study period (2002–2022), the dominant land cover type in the study area was farm land, ranging between 67.80% and 76.32% of the total area.

To achieve this goal, the land use and land cover map of the study area were reclassified and ranked as per their suitability order. Accordingly, farmland, vegetation, and barren land are highly suitable, moderately suitable, and less suitable, respectively. Thus, built-up areas are considered as not suitable and waterbodies are permanently not suitable for the suitability of land for agriculture development.

4.1.2 Accuracy Assessment of the Classification

The accuracy assessment in this study revealed the overall accuracies of 91.27%, 94.96%, and 91.3% with the Kappa statistics of 0.890, 0.937, and 0.888 were calculated for the three reference years 2002, 2012 and 2022 respectively. This indicates that all classifications are in an acceptable range because the overall accuracy of each year was greater than 85% and a kappa coefficient greater than 0.80 represents strong agreement is an indicator for strong accuracy. Results of users' accuracy in this study showed that in 2010 the maximum class accuracy was for bare land and agriculture (100%) and the minimum was for vegetation (90%).

Table 5: Error matrix of classification for 2002

		Reference Data						
	Classified LULC	Water body	Built-up	Barel and	Vegetation	Agriculture	Total row	User accuracy%
classified samples maps	Waterbody	17	0	0	2	1	20	85.00
	Built-up	0	28	0	1	1	31	90.32
	Bare land	0	0	21	0	1	22	95.45
	Vegetation	1	0	0	27	0	28	96.43
	Agriculture	0	1	2	0	22	25	88.00
	Total column	18	29	23	30	25	115	
	Producer accuracy%	94.44	96.55	91.30	90.00	88.00		
	Overall accuracy = 91.27							
	Koppa coefficient = 0.890							

Table 6: Error matrixes of classification for 2012

	Reference Data							
	Classified LULC	Water body	Built Up	Bare land	Vegetation	agriculture	Total row	User accuracy%
classified samples maps	Waterbody	20	0	0	1	1	22	90.90
	Built-up	0	29	0	0	1	30	96.67
	Bare land	0	0	21	0	0	21	100.00
	Vegetation	0	0	1	18	1	20	90.00
	Agriculture	0	0	0	0	25	25	100.00
	Total column	20	29	22	19	29	113	
	Producer accuracy %	100%	100%	95.50	94.74	86.21		
	Overall accuracy = 94.96							
	Koppa Coefficient =0.937							

Table 7: Error matrix of classification for 2022

	Reference Data							
	Classified LULC	Water body	Built-up	Bare land	vegetation	Agriculture	Total Row	User accuracy%
classified samples maps	Waterbody	14	0	0	1	1	16	87.5
	Built-up	0	21	0	0	2	23	91.3
	Bare land	0	0	12	1	1	14	85.7
	Vegetation	0	0	0	20	2	22	90.9
	Agriculture	0	0	0	1	27	28	96.43
	Total Column	14	21	12	23	33	94	
	Producer accuracy %	100%	100%	100%	90.9%	81.81%		
	Overall Accuracy = 91.3%							
	Koppa Coefficient = 0.888							

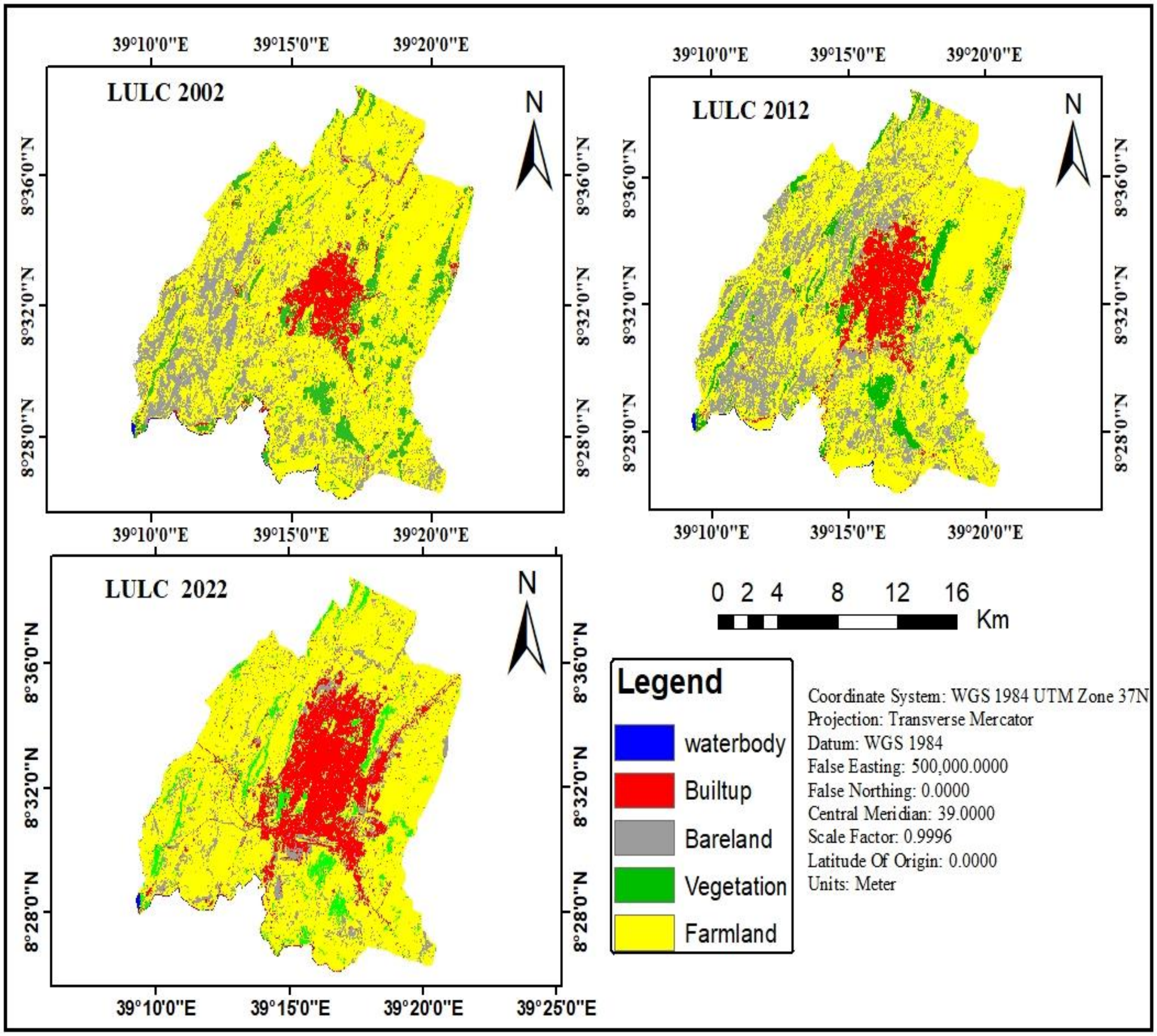


Figure 7: LULC map of study area in 2002, 2012 and 2022

In this study, three LULC maps were produced for the study period (Figure 7), and the spatiotemporal LULC dynamic process was analyzed (Tables below). Based on the LULC classification, over the past two decades, LULCs in study areas such as farmland were in continuous decline, while vegetation, bare land classes, and water bodies showed small declines. In general, out of the five LULC classes identified in the study area, only built-up showed continuous increment over the past 20 years. The extent of change within the study area of the individual LULC categories in hectares (ha) and the percentage (%) they occupied for 2002, 2012 and 2022 are presented below.

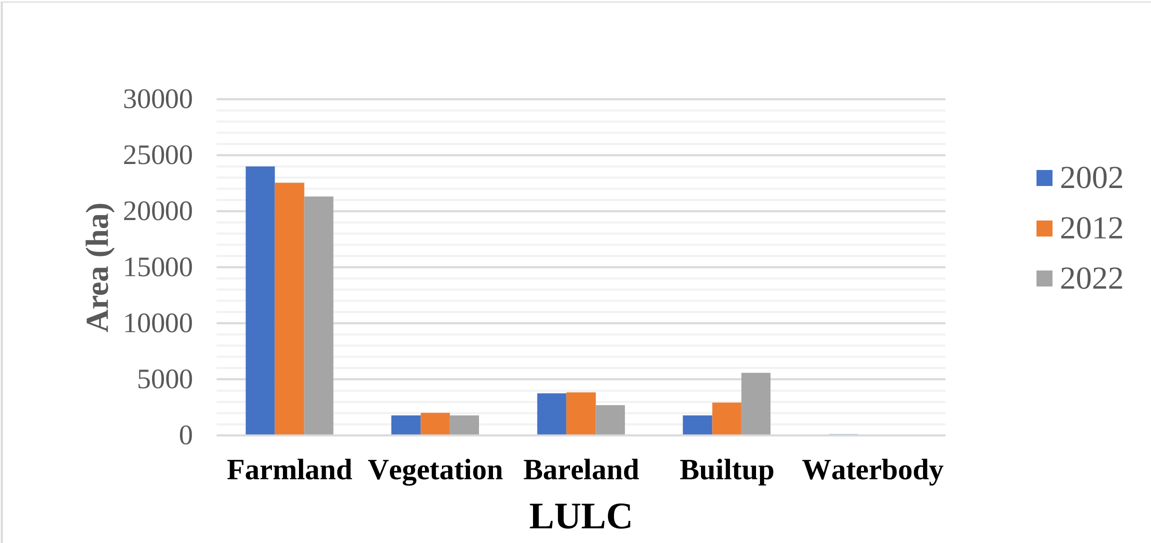


Figure 8: Change Trends of LULC from 2002-2022

4.1.3 LULC Change Detection analysis

In 2002, the study area was dominated by farmland, covering 76.32% of the area, followed by bare land, covering 11.94% of the area. Built-up, vegetation, and water bodies shared 5.66%, 5.72%, and 0.36% of the total area, respectively. In 2012, farmland, bare land, and vegetation covered 71.69%, 12.26%, and 6.44% of the total area, respectively. The remaining parts of the area were covered with built-up (9.36%) and water bodies (0.25%). In 2022, built-up area increased by 17.72%) and farmland area decreased by 67.80%. The remaining (14.48%) was the share of other LULC classes.

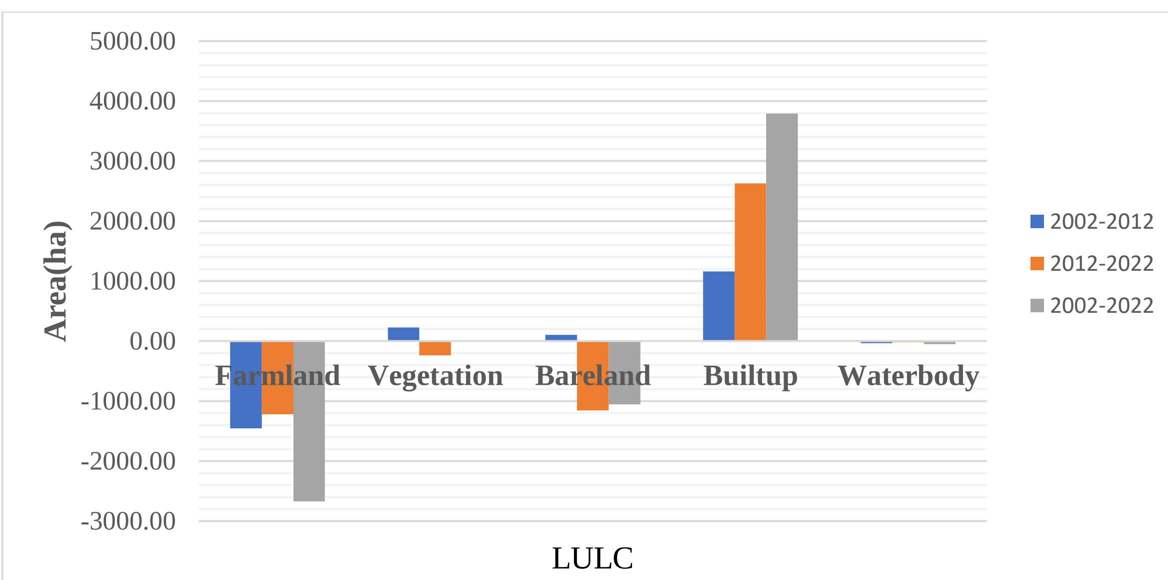


Figure 9: LULC Change detection analysis from 2002-2022

The information summarized in figure 10 shows the spatial extents, percentage changes over time, as well as the annual average growth of the five LULC classes (farmland, bare land, built-up, vegetation, and waterbody) in Adama city between 2002 and 2022. Besides, table 9 demonstrates the spatio-temporal variations of the proportions of each class that occurred over the span of 20 years. Overall, the results show the extensive LULC changes in Adama city over the study period. Farm land was the dominant class at the beginning of the study period, but declined with the continuous increase of built-up area. The rate of annual builtup change is greater by far than the rest of the land use classes. The coverage of farmland was slightly more than 76.32% of the total area at the beginning of the study timeframe. In the following 10 years, it moderately decreased to about 71.69%; consecutively, it dramatically dropped to nearly 9% in the final year. By contrast, the proportion of built-up was 5.55% in 2002, and in the consecutive 10 years it moderately increased to 9%, and rapidly increased to nearly 18% in the final years.

Generally, the decreased trends were observed in the farm land and bare land LULC classes during the study period. Only one of the five LULC classes identified in the study area increased during the study period. Figure 10 depicts the minimal decrease in water bodies over the last 20 years.

4.4 The factors contributed for urban agriculture land suitability

This study aims to analyze land suitability areas for urban agriculture development. AHP values have been prepared by integrating the suitability ranking of parameters/factors and their corresponding AHP values for the analysis of land suitability of the study area for urban agriculture. From the final ranking collected from the secondary source, the final suitability has been prepared. The result of suitability analysis for all the nine suitability parameters, along with the final suitability to promote urban agriculture within an area, is very crucial to judge the suitability of that area for urban agriculture. A suitability map has been prepared for the study area as the output of the suitability analysis. The major affecting factors have been considered for a land suitability map for urban agriculture development. Land use and landcover, soil type, slope, distance from a road, water river/stream, residential area, facility location, drainage, and population density parameters have been analyzed differently. The result of each factor suitability analysis has been discussed here.

4.4.1 Land Use/ Land cover (LULC) suitability

To identify LULC suitability, land uses has been classified according to the suitability of Urban Agriculture. Land-use types are relevant indicators that contribute to the assessment of land suitability (Sonneveld et al., 2021). In this study there were Five land use types were identified: bare land, farmland, built-up areas, vegetation, and water bodies. Zolekar (2018) argued that LULC plays an important role in environmental assessment related to environmental issues and themes and It also indicates the distribution and characteristics of land like settlement, road, agriculture land, fallow land, barren land, rocky land, vegetation cover. Farm lands are considered as highly suitable for urban agriculture (Habib Ananya et al., 2012). Water bodies are also used for aquaculture, So in case of land use suitability classification, water bodies and flood flow zones are considered as highly suitable for agricultural use (Habib Ananya et al., 2012). In contrast this research aquaculture is not considered, it considered on urban farming.

According to Zolekar (2018) Fallow land has potential for agriculture, but is not presently used under for it, this class of land has been classified as marginally suitable for agriculture. Some classes like settlement, barren land, water bodies, and rocky land are permanently not suitable for agriculture. Most of the area under dense forest in the study region is environmentally protected zone and not permissible for agriculture activity. Therefore, this class of land has also been classified as not suitable.

However, based on knowledge obtained from the analysis of literature, farmland and bare land were considered to be highly suitable and moderately suitable for urban agriculture development respectively. Additionally, in this study vegetation, Built-up area and water body were considered as less suitable, not suitable and permanently unsuitable conditions for agricultural development respectively.

Table 8: Reclassified LULC and area coverage of suitability levels

LULC type	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
Farmland	5	S1	21185	67.67
Bare land	4	S2	2700.37	8.63
Vegetation	3	S3	1788.62	5.71
Built-up	2	N1	5571.52	17.80
Waterbody	1	N2	62.17	0.20

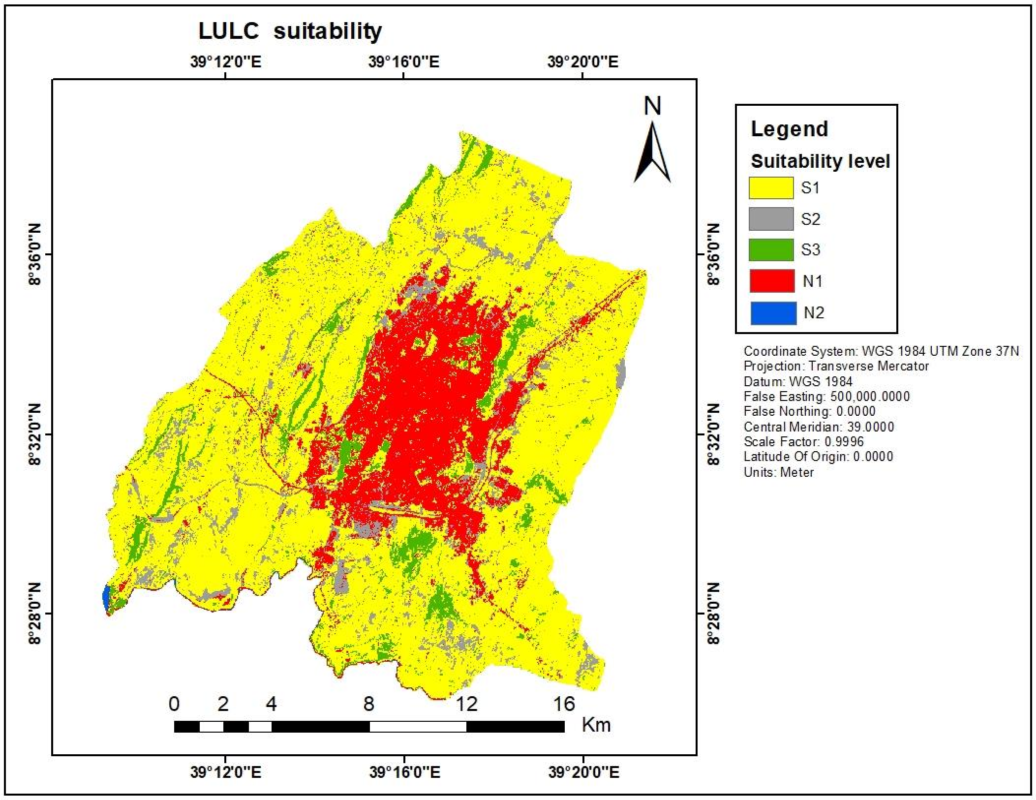


Figure 10: Existing land use and land cover suitability map

4.4.2 Slope suitability

The slope analysis is useful for detecting the potential sites for agriculture and watershed management (Bandyopadhyay et al., 2009). The slope map clearly indicates that maximum wards of the city have gentle slope of less than 3° (Parry et al., 2018). If the slope is gentle, the area can be mountainous or hilly (>20%), and it is not suitable for farming purposes (College, 2015). The study (Yavuz, 2016) argued that the slope of the land surface for agricultural land suitability with a 0–2 % was evaluated as highly suitable; 2–4 % was evaluated as moderately suitable; 4–8 % was evaluated as marginally suitable, and 8 % was evaluated as unsuitable. S3 lands account for 28% and are related with slightly sloping to strongly sloping (6–16%) terrain N1 lands are likely to be defined by steep slopes (16–30%) and higher erosion risk, and N2 lands include the areas where adverse terrain or poor soil quality place severe constraints on cultivation. In contrast, if the slope is flat or <5%, the land is recommended as suitable for agriculture. The slope of the land surface for agricultural land suitability with a 0–2 %, highly suitable; 2–5 %, moderately suitable; 5–10 % less suitable; 10–20 % was evaluated as not suitable and >20 % was evaluated as permanently not suitable as stated in table 9.

Table 9: Reclassified slope and area coverage of suitability levels

Slope (%)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
<2	5	S1	10473.25	33.45
2 - 5	4	S2	12604.68	40.26
5 - 10	3	S3	5356.48	17.11
10 - 20	2	N1	1692.3	5.41
>20	1	N2	1181.01	3.77

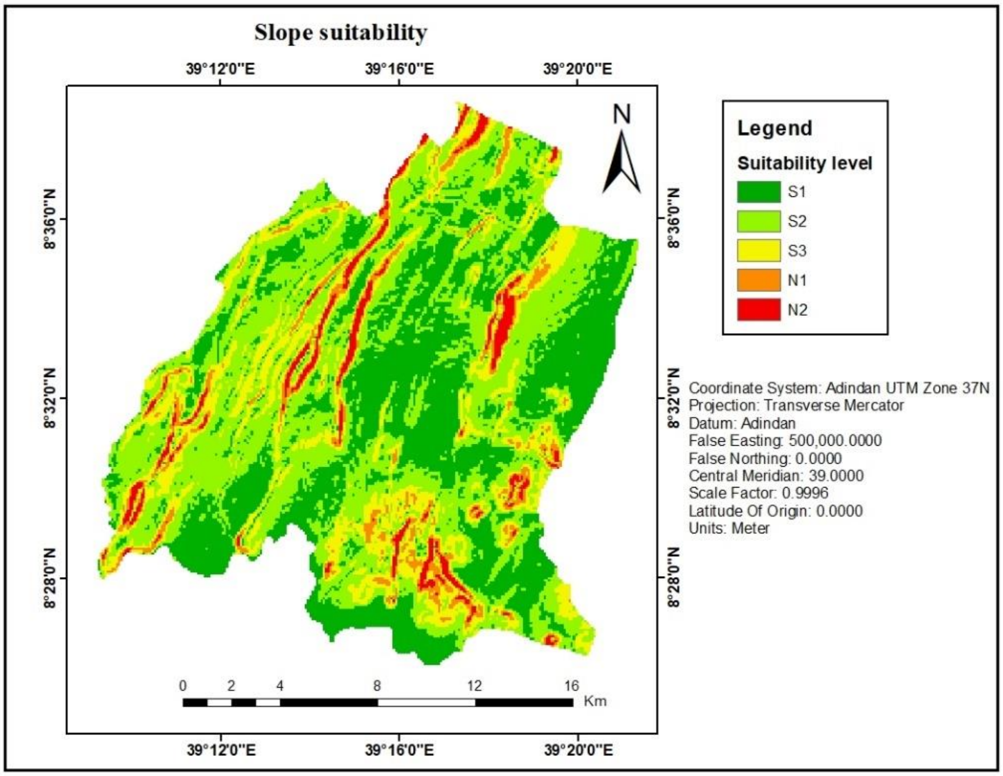


Figure 11: Reclassified slope suitability map

4.4.3 Distance to Road suitability

Proximity to roads is one of the criteria that should be considered from economic and social points of view during urban agricultural site selection processes. However, proximity to a road network is recommended for urban land use as well as for agricultural land due to high transportation costs. Low accessibility zones face higher cost of travel, both financially and in terms of the time taken to travel, which render market gardening products and agricultural commodities unprofitable and hence, the size of the market and proximity to access road influence food crop production (Abdullah, 2017).

For implementation of an urban food production system first were located within 400 meters of a major highway in order to adequately access the necessary inputs required (Smith et al., 2017). Therefore, to minimize such problems, the land selected must be sited very close to roads. Proximity to roads was reclassified based on the fact that very distant sites are not suitable. Accordingly, sites 0-300, 300-600, and 600-900 are highly suitable, moderate, and less suitable, whereas 900–1200 and more than 1200 m from existing roads were excluded. But more weight was assigned to suitable areas (Puntsag et al., 2014).

Table 10:Reclassified distance from road and area coverage of suitability levels

Distance from Road (m)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
<300	5	S1	7753.2	24.76
300 - 600	4	S2	4311.27	13.77
600 - 900	3	S3	3039.46	9.71
1200 -1500	2	N1	2299.49	7.34
>1500	1	N2	13904.29	44.41

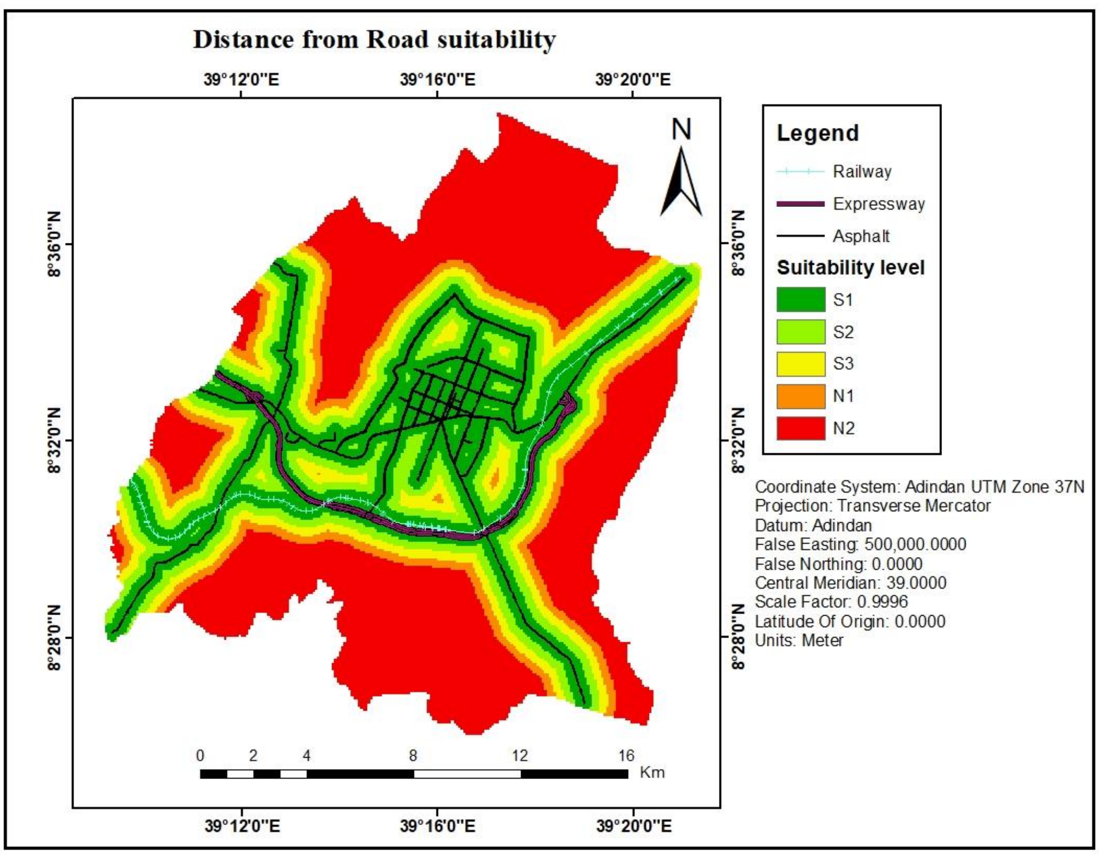


Figure 12: Reclassified road suitability map

4.4.4 Suitability of distance from the stream/waterbody

Agricultural processes and urban areas are based on water. According the study (Pramanik, 2016) the distance from river 0–500m was used as a minimum distance from a water source that urban agricultural land can use. Accordingly, analysis tools were used to prepare multiple polygons around each stream and river within the following distances: 0-250m is highly suitable, 250-500 is suitable, and 500-750, 600-800, and >800m respectively, less suitable, not suitable, and permanently not suitable. The proximity map was reclassified into five classes, and weights were calculated using data analysis. Accordingly, more weight was assigned to more suitable areas (0–250m) to minimize the effect of water, a 1000 m buffer area was used.

Table 11: 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	5824.23	18.60
250 - 500	4	S2	6253.57	19.97
500 - 750	3	S3	4568.52	14.59
750 - 1000	2	N1	3530.36	11.28
>1000	1	N2	11131.03	35.55

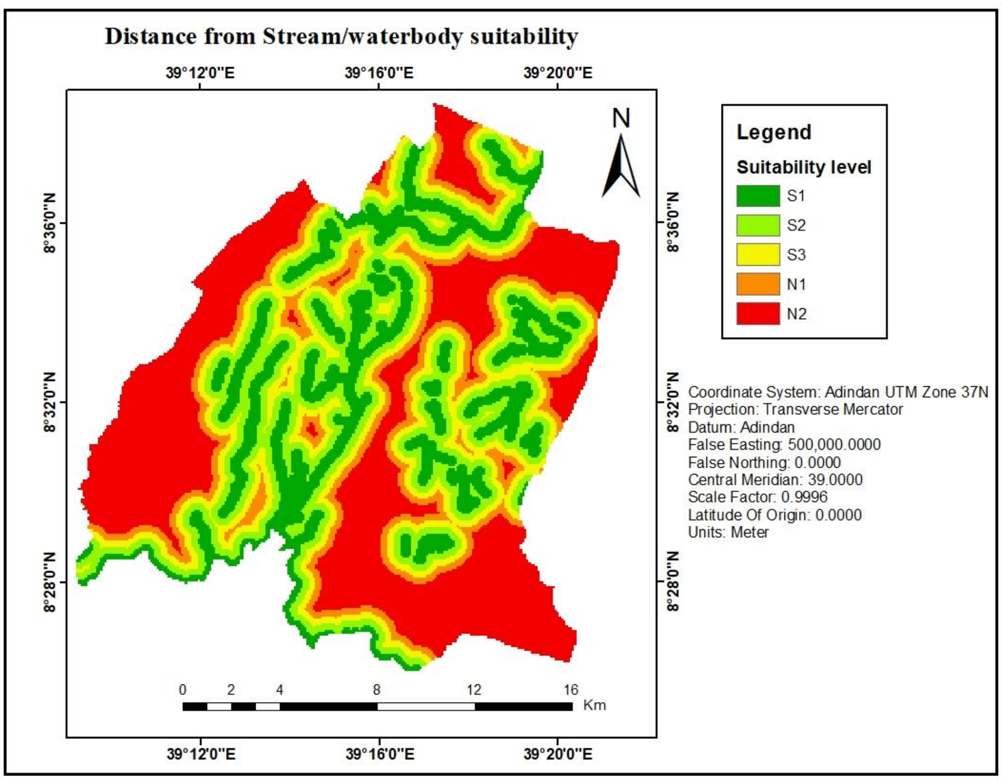


Figure 13: Reclassified distance from stream suitability map

4.4.5 Soil type suitability

The type of soil is one of the most important factors for agricultural land suitability (Yavuz, 2016). Soil behavior helps to estimate the soil performance for agricultural production. Thus, when deciding on the suitability of land for agricultural production, it is necessary to know the soil types (Yavuz, 2016). Three soil types are situated in the study: Eutric Cambisols, Haplic Xerosols and Lithosols. Therefore, Eutric Cambisols soils are assigned as ‘‘highly suitable’’ for agriculture. Eutric Cambisols soil; therefore, this type has very high calcium content (Yavuz, 2016). Chemical and biological activities slowdown in this soil type when they remain dry for long periods in summer (Yavuz, 2016).

Table 12: 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	17202.71	54.95
Haplic Xerosols	4	S2	3988.68	12.74
Lithosols	2	N1	10116.33	32.31

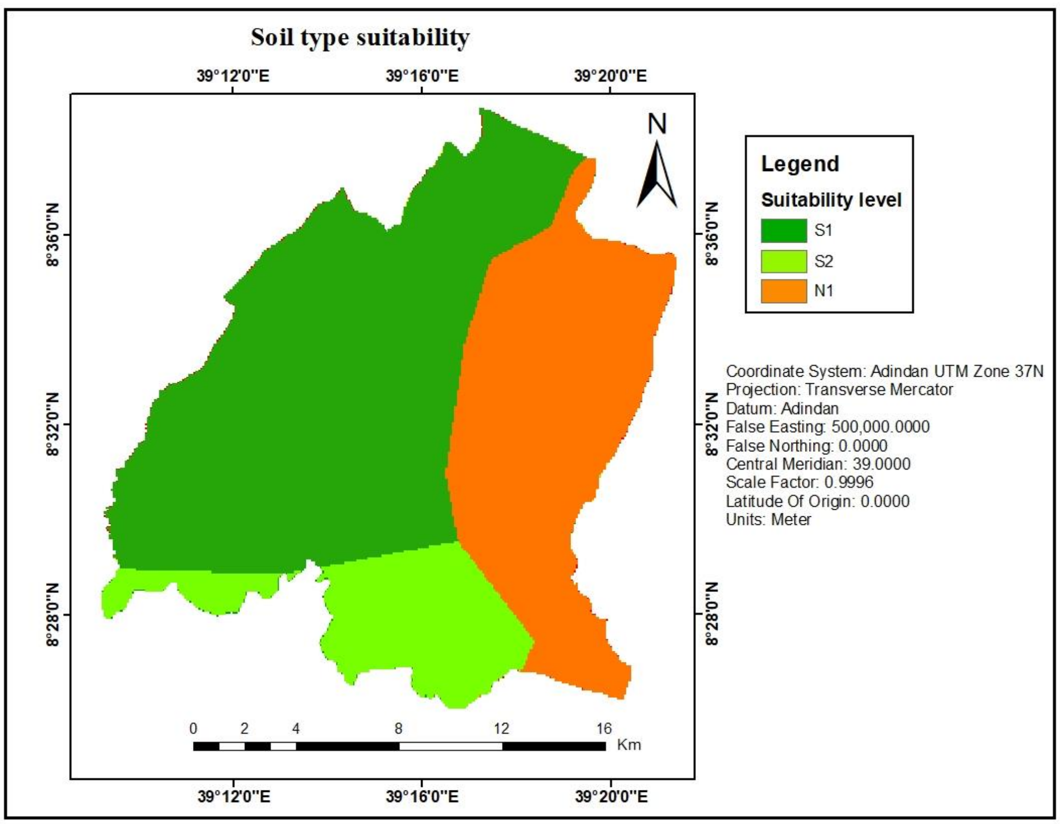


Figure 14: Reclassified soil suitability map source: FAO

4.4.6 Drainage suitability

Drainage density indicates the closeness of the spacing of channels to each other. It has a relationship with the suitability of land for agriculture. The more the drainage density indicates, the more agricultural suitability and vice versa. However, for irrigation systems, drainage has a great role in agricultural suitability. Therefore, this research considered land suitability analysis for agricultural development. The drainage of the study area was delineated from the stream feature of the DEM data. Finally, it was converted to drainage density by line density in ArcGIS software and reclassified into five categories.

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

Distance from Drainage (m)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
<400	5	S1	6828.9	21.81
400 - 800	4	S2	4557.59	14.56
1200 - 1500	3	S3	5246.56	16.76
1500 -1800	2	N1	4466.88	14.27
>1800	1	N2	9187.79	29.35

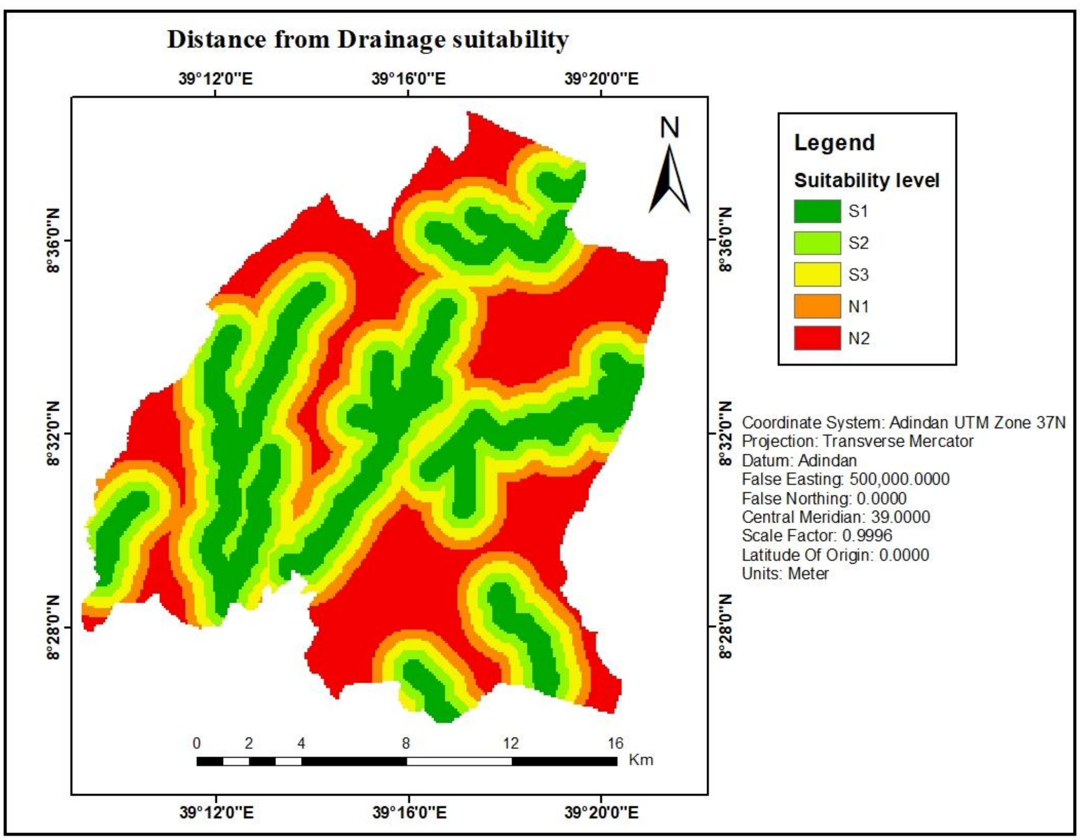


Figure 15:Reclassified Drainage density suitability map

4.4.7 Population density suitability

There are no agricultural areas in some neighborhoods, indicating that urban development has rapidly increased and that the population in rural areas has started to replace the population in urban areas (Ergen & Kentel, 2016). The relationship shows that the increase in the urban population leads to the destruction of urban agricultural areas. If urban agricultural areas and the increase in population cannot be balanced, the urban agricultural areas will be destroyed or eliminated by urban development. However, agricultural areas have decreased due to the increase in urban populations.

Table 14: Reclassified population density and area coverage of suitability levels

Population density (pop/ha)	Standardization Score/Value	Level of suitability	Area (ha.)	Area cover in (%)
<5	5	S1	18572.14	59.32%
5- 20	4	S2	1080.47	3.45%
20 - 40	3	S3	6961.73	22.24%
40 - 80	2	N1	4245.55	13.56%
>80	1	N2	447.83	1.43%

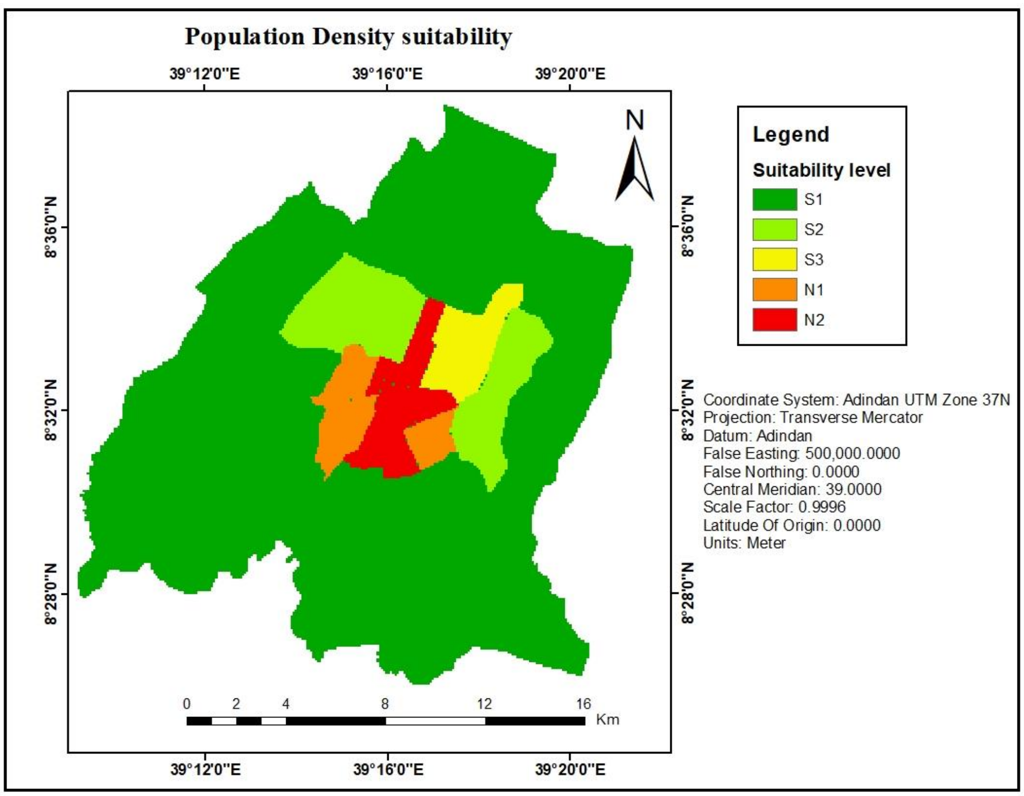


Figure 16: Reclassified population density suitability map

4.4.8 Residential area Suitability

The inclusion of agricultural practices in residential areas is more effective for the residents. However, the low-density residential areas are important for agricultural activities that contribute to the country's well-being, especially in the urban areas. Therefore, urban agriculture must be accessible to settlement areas in urban areas since it has numerous ecological, social, and economic benefits. The distance between settlement areas and agricultural land had an adverse impact on residents and that urban agriculture, such as backyards, gardens, and land closest to settlement areas, is the most popular. Thus, the proximity of agricultural land to the settlement area in terms of distance is considered as follows:

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

Distance from Residential (m)	Standardization Score/Value	Level of suitability	Area (ha)	Area cover in (%)
>800	5	S1	20582.96	65.74
600 - 800	4	S2	1620.11	5.17
400 - 600	3	S3	1934.62	6.18
200 - 400	2	N1	3013.17	9.62
< 200	1	N2	4156.86	13.28

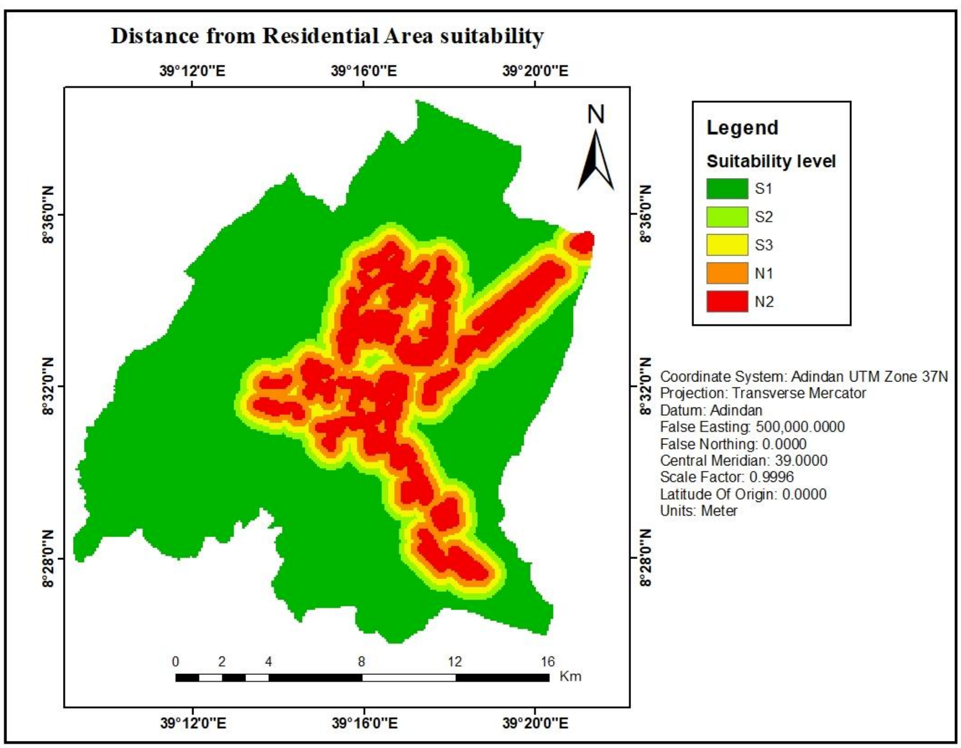


Figure 17: Reclassified residential area suitability map

4.4.9 Suitability of distance from facility locations

The facility location covers the schools, colleges, major health facilities, and hospital locations that are crucial and important to get all services and, in the meantime, some agriculture near such locations. The proximity of urban agriculture to facility locations is important for the purpose of education, food security, social interaction, and environmental sustainability. Based on those views, the lands that are closer to those facilities are more suitable than further lands (Pokhrel, 2019).

Table 16: Reclassified distance from facility and area coverage of suitability levels

Distance from facility location (m)	Standardization Score/Value	Level of suitability	Area (ha)	Area cover in (%)
<300	5	S1	2446.77	7.82
300 - 600	4	S2	2591.84	8.28
900 - 1200	3	S3	1970.91	6.30
1200 - 1500	2	N1	1753.22	5.60
>1500	1	N2	22544.98	72.01

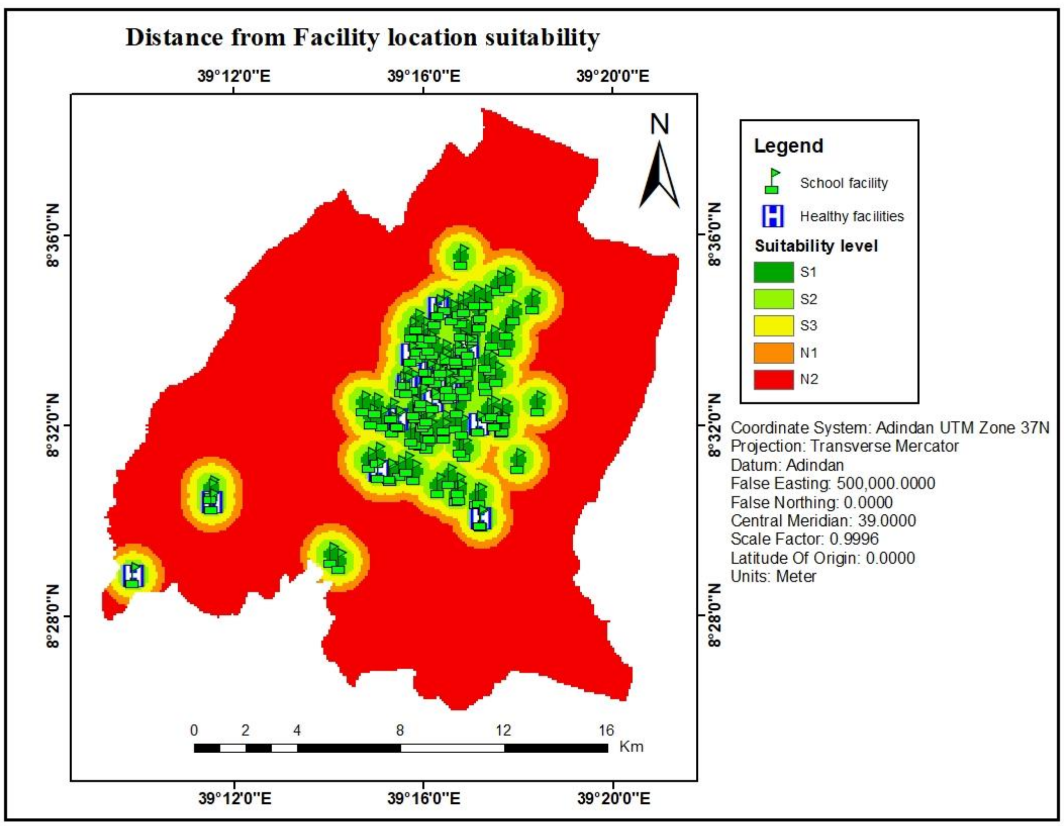


Figure 18: Reclassified facility location suitability map

4.5 Suitability Evaluations for urban Agricultural development

After all parameters were prepared in raster format, the overlay analysis was performed using the weighted overlay tool in the GIS spatial analysis extension by considering the weight of parameters. A suitability map has been prepared by integrating the suitability ranking of parameters and corresponding AHP values. The suitability map shows the suitability of the study area for urban agriculture. The result of suitability analysis for all the nine suitability parameters along with each suitability. This issue is critical, so experts' opinions are crucial in the defining scales applied to input layers and weights given to factors in the AHP process.

4.5.1 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 urban agriculture.

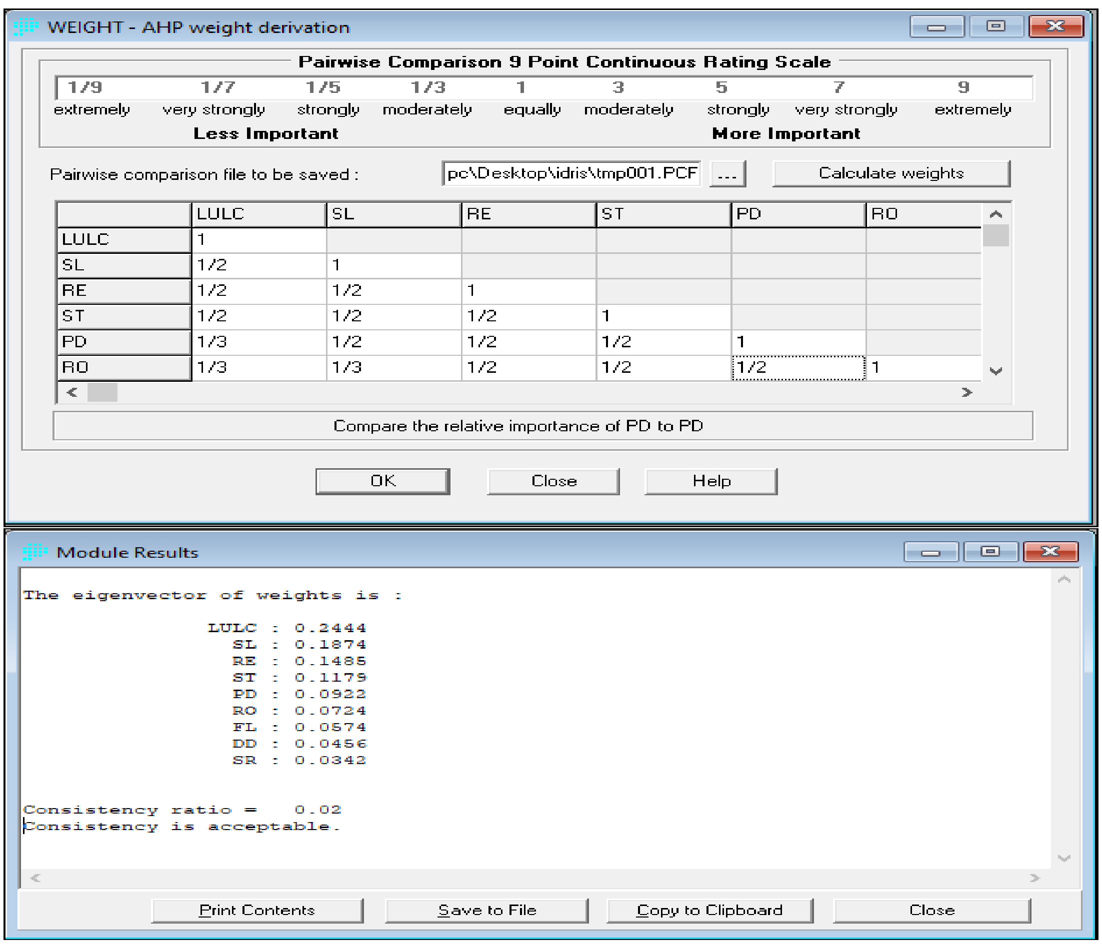


Figure 19: AHP Weight derivation map for each factors/ criterion.

4.5.2 Weighted Overlay Analysis

An overlay analysis is needed in order to combine each raster, give a final ranking, and determine the suitability for urban garden placement (Wahlmeier, 2017).

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 urban agricultural development using the weighted overlay tool or a raster calculator in ArcGIS and urban agricultural land suitability map was prepared.

The main use of AHP is ranking and prioritization of parameters. Priority framework quality affects the effectiveness of available sources which are the essential judgment from the decision maker (Andi et al., 2017). Furthermore, the experts usually use their experiential judgment when making the decision. Each of the expert participants determined the weight to the design factors and gave the weights depend on the parameters of the factors. The computation of weights for parameters using Analytical Hierarchical Process (AHP) involves three main steps.
The steps followed to calculate the weight of parameters used in this study are detailed as below

Table 17: Pairwise comparison matrix and weight of factors

Criteria	LULC	SL	RE	ST	PD	RO	FL	DD	SR	weights
LULC	1	2	2	2	3	3	4	4	6	28.56
SL	1/2	1	2	2	2	3	3	4	4	20.83
RE	1/2	1/2	1	2	2	2	3	3	4	14.93
ST	1/2	1/2	1/2	1	2	2	2	3	3	11.33
PD	1/3	1/2	1/2	1/2	1	2	2	2	3	8.58
RO	1/3	1/3	1/2	1/2	1/2	1	2	2	2	6.52
FL	1/4	1/3	1/3	1/2	1/2	1/2	1	2	2	4.94
DD	1/4	1/4	1/3	1/3	1/2	1/2	1/2	1	2	3.52
SR	1/6	1/4	1/4	1/3	1/3	1/2	1/2	1/2	1	2.78

Note: LULC = Land use/ land cover, RA = Residential area, RO= roads DD= Drainage Density, SR = Stream, ST = Soil type, SL = Slope, FL = Facility locations, PD = population density

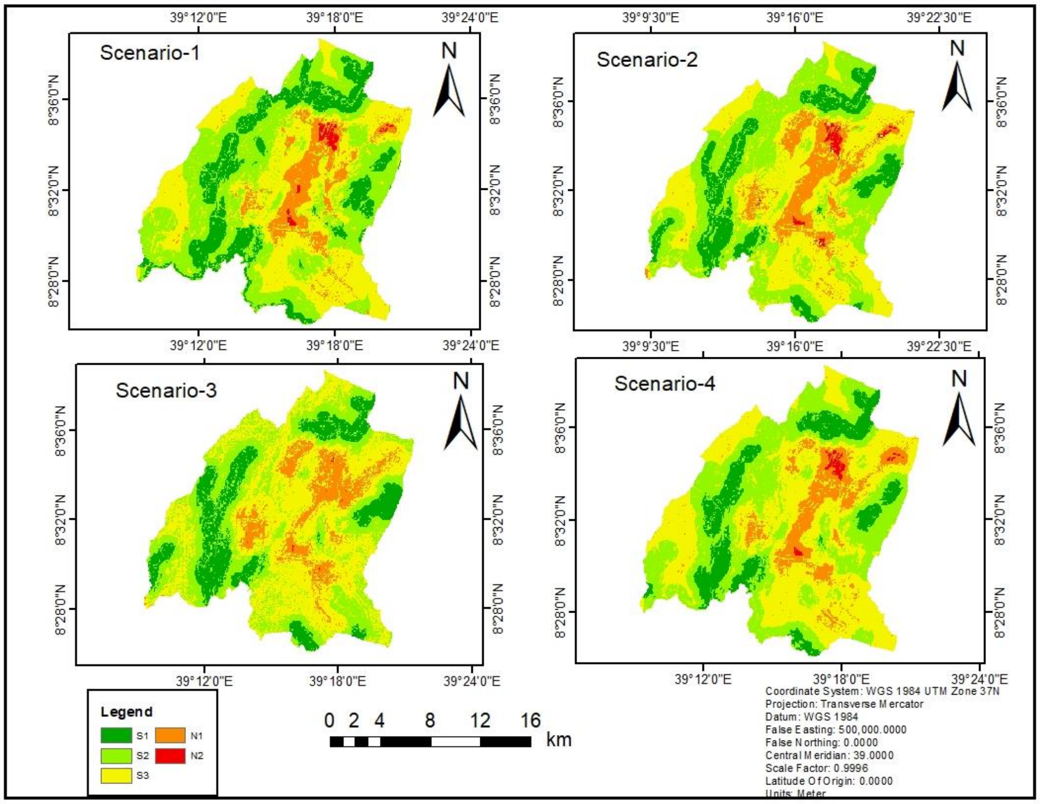


Figure 20: Sensitivity analysis map of four scenarios

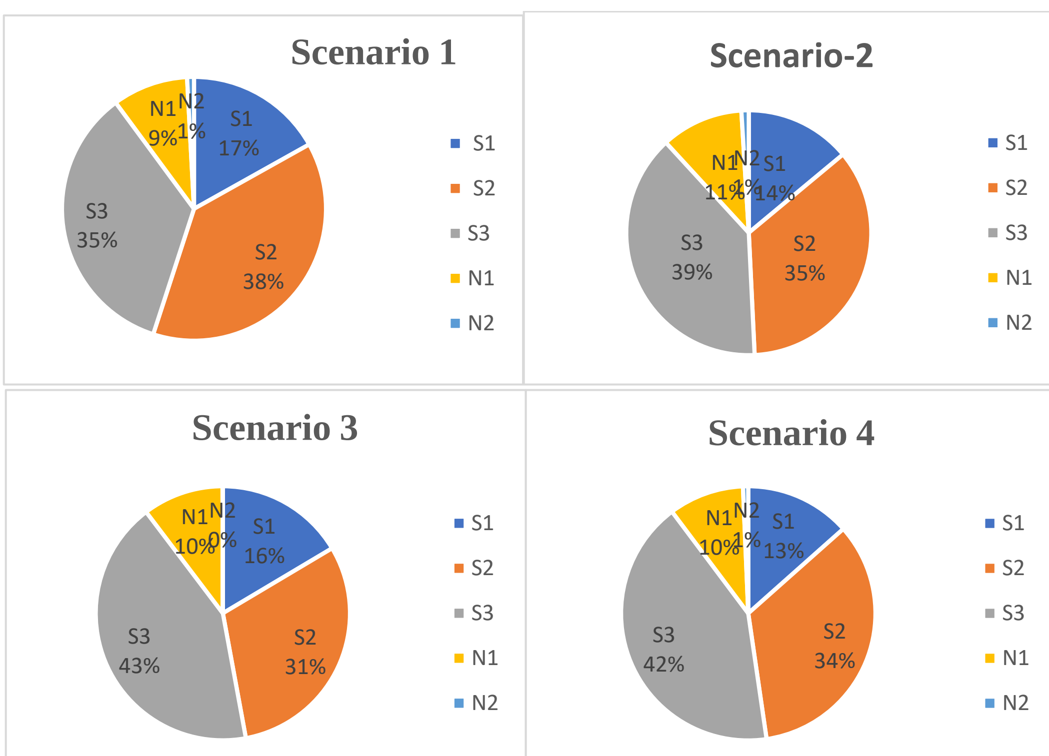


Figure 21: Overall scenarios of land classes for urban agriculture

Table 18: Analysis of four scenarios

Criteria	Scenario %			
	1	**2**	**3**	**4**
LULC	29	35	7	31
Slope	21	10	18	11
Soil type	15	14	24	22
Population density	11	7	12	5
Distance from stream	8	4	4	3
Distance from road	6	13	9	15
Distance from residential area	4	9	7	7
Distance from drainage	3	5	5	4
Distance from facility locations	3	3	14	2
Total suitable area (%)	17	14	16	13

Scenario 1 was selected as the base scenario which covers 17% 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 17% to 14%. In scenario 3, with an increase in the Soil type, slope, distance facility locations and population density the total suitable area was again 16% 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 decreased to 13% of the total area.

4.6 Final Urban Agricultural Development Site Suitability Analysis

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. According to GIS-based multi-criteria analysis, the result obtained from the overall suitability map shows 5226.87ha (16.88%), 11804.23ha (37.62%) and 10802.12ha (34.39%) are highly suitable, moderately suitable and less suitable of land for urban agricultural development respectively. The remaining 2868.68ha (9.26%) and 261.11ha (1.84%) are not suitable and permanently unsuitable for urban agricultural development respectively (Table 19). In the land use plan, the selected areas are mostly categorized as existing agricultural land, vegetation, and bare land.

Table 19: land suitability level for urban agriculture

Level of Suitability	Area (ha.)	Percent of total area (%)
S1	5295.79	16.92
S2	11873.23	37.92
S3	10871.12	34.72
N1	2937.47	9.38
N2	330.11	1.05

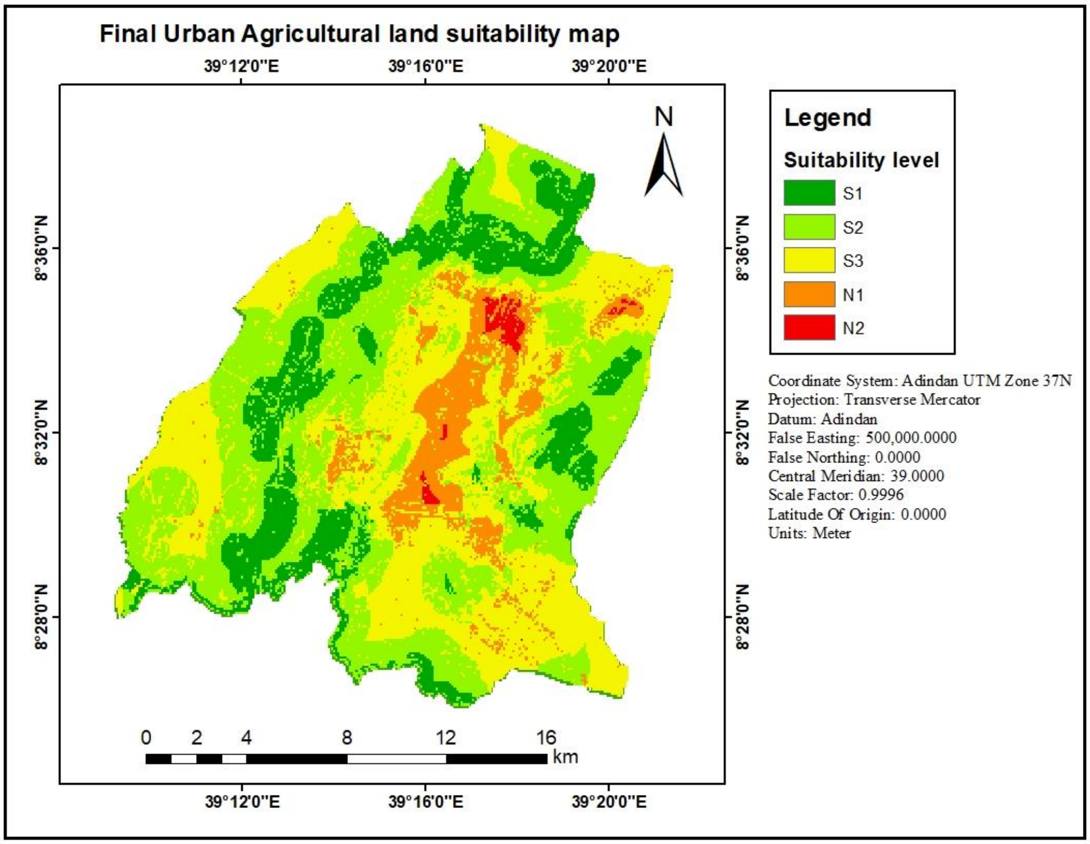


Figure 22: Final land suitability map of urban agriculture

4.6.1 Validation of the result

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

This is useful in situations such as where uncertainties exist in the definition of the importance of different factors (Yahaya, 2008). Thus, SA can help reduce uncertainty in how a MCA 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).

4.6.2 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 Dhaka Adi, in northern part Adama city called bole sub city and around Awash river are among the best suitable sites, and in the western part of the city also suitable site for urban agricultural development. Validation of the land suitability results is challenging due to unavailability of widely distributed. The proposed was based on both indigenous knowledge and empirical evidence, presuming that land characteristics have the largest influence on agriculture though other factors clearly do also influence farmers crop choices and land allocation.

Figure 23: Selected areas for urban agricultural development

Source: Google Earth 2022

As it is shown in figure 23, S1 represent highly suitable area for agriculture. The LULC of the selected areas is mostly categorized under existing agriculture, vegetation, and bare lands, and hence, they are relatively suitable for urban agricultural development. The selected areas are identified as suitable sites for urban agricultural development based on identified factors. From the map shown in Figure 24, the existing coverage of agricultural land in the city is 20347.49ha, which is allotted for agricultural practices.

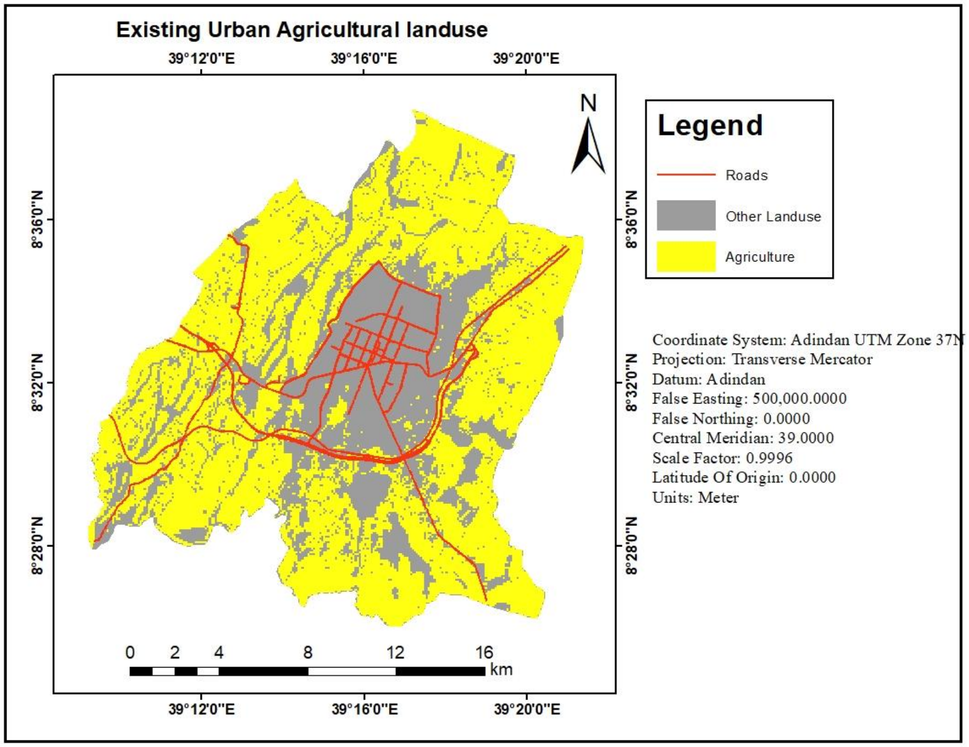


Figure 24: Existing urban agricultural land use map

From the comparison of suitability scenario map Vs. proposed structural plan (2017) Agricultural land, Comparison of existing land use map and final land suitability map. According to the site suitability the extracted proposed structural plan (2017) Agricultural area was overlayered on the best suitability scenario Urban Agricultural map of the city in the ArcGIS environment.

4.7 Comparison of suitability scenario map Vs. Existing urban agricultural land

Comparison of proposed structural plan (2017) in the study area was conducted by considering the locational aspects of the Urban Agricultural land in the suitability map. Figure 25 shows the comparison between the suitability scenario and the proposed structure plan (2017) of Adama city. The best suitability scenario was selected by analysis verified field. After the best suitability scenario was selected it is possible to compare it with the proposed structural plan (2017) of the city. The overlay done between the GIS-based suitability map and based suitability map gives the suitable land which is available for agriculture. The final results showed that the total area of suitable land which is available for agriculture was 4407.59ha (21.90%) of Agricultural land is located in a highly suitable area, 8841.37ha (43.94%) of Agricultural land is located in a moderately suitable area and 6211.73ha (30.87%) of Agricultural land is located in less suitable.

Whereas the rest 599.33ha (2.98%) and 61.93ha (0.31%) of, Agricultural land is relatively located in not suitable and permanently not suitable areas respectively. The existing site is suitable for agricultural land; high and moderately suitable land is 13248.96; highly suitable land for urban agricultural practice in Adama city is approximately 4407.59; and is functional for agricultural development. However, Agricultural land were dominated in the moderate suitable and less suitable of the study area.

Table 20: Comparison of suitability scenario map and Existing urban agricultural land

Total Area (ha)	Area (%)	Suitability level
4407.59	21.90	S1
8841.37	43.94	S2
6211.73	30.87	S3
599.33	2.98	N1
61.93	0.31	N2

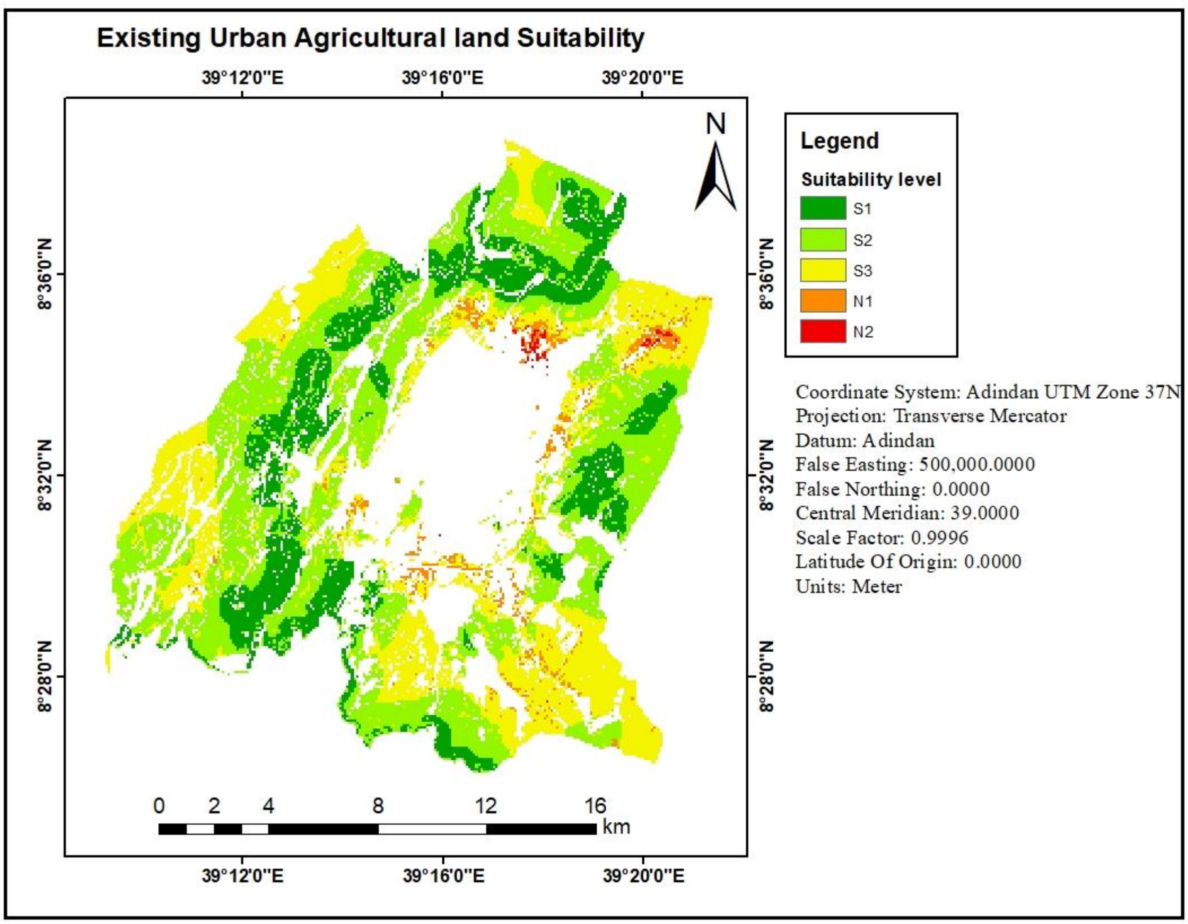


Figure 25: Comparison selected land suitability and existing land suitability maps

4.8 Discussion

This study offers interesting insights to identify the suitable lands for urban agricultural development using geospatial integrated with GIS and analytic hierarchy processes in the study area and to analyze the existing agricultural land for the development of urban agricultural activities. Therefore, this study used site selection criteria and determinant factors (main factors and sub-factors) that affect urban agriculture. The main factors are accessibility, physical, environmental, and socio-economic factors. In reality, land suitability for agriculture should also consider social aspects (Widiatmaka et al., 2016).

In a study of the Analysis of Land Use and Land Cover Changes of Blantyre City in Urban Areas Using Remote Sensing, witnessed LULC changes, the conversion of agricultural land, forest land, and bare land into a builtup area (Gondwe et al., 2021). Land use and land cover (LULC) dynamics are a well-known, accelerating, and substantial process, mostly driven by human activities, that is contributing significantly to agricultural land degradation, forest fragmentation, and biodiversity loss by the increment of urbanization (Yalew, 2020). In this study, most LULC classes in the study area experienced descending trends; specifically, bare land, vegetation, and waterbodies experienced minor losses; urban/built-up is the only LULC class that experienced greater expansion over the past two decades, and farmland is the inverse.

LULC analysis indicates the spatial distribution and characteristics of land like agricultural land, plantation, settlement, fallow land, barren land, mixed trees, built-up land, forest, wastelands, water bodies by Zolekar & Bhagat (2015) in their study discussing the Multi-criteria land suitability analysis for agriculture in the hilly zone: Remote sensing and GIS approach. Knowing the existing LULC is useful for analysis of urban agricultural land suitability. Furthermore, the study is important to indicate the trend of LULC change, particularly in urban agriculture, pertaining to the analysis of land suitability for urban agricultural development.

The LULC changes practiced across Adama city showed spatial decline of different LULC classes due to corresponding horizontal urban expansion as well as conversion of LULC classes to different land uses, also due to the increment of urban/built-up areas within the study area. This study confirms since it found that an area with water bodies or builtup reduces suitability, while an agglomeration or cultivated areas indicate a higher probability for developing urban agriculture.

This study's results show that a greater distance reduces the likelihood of higher suitability for urban agriculture, the increased distance to the stream/waterbody improved the suitability of land, while it had been assumed that suitable areas would be closer to the waterbody, which increases access to a reliable source. The finding corroborated by Pramanik (2016), who found high slopes (3–89^0) with higher intensity of gully erosion and lower drainage availability of the study area were efficient factors, resulting in a smaller area or lower rate of highly suitable agricultural land in the Darjeeling district. Wahlmeier (2017) argued that for an urban garden, ideally a flat to low slope is needed for a likely higher crop yield, although there exist other variables that could contribute to a less than ideal garden yield (e.g. water and wind movement, nutrient flow, water depth, soil type, etc.) and he looked for slopes of less than 10 degrees.

The accessibility valuation was set by giving out higher scores to lands that were closer to the road; this was for reasons of ease of access, including better access to agricultural inputs and production transport (Widiatmaka et al., 2016). Indeed, the findings of (Habib Ananya et al., 2012; Sonneveld et al., 2021) show a shorter distance to roads as an important factor for higher land suitability. Because of the low transportation costs and less time-consuming nature, most of the cultivators prefer this mode of transport, especially for perishable products (Majumdar, 2020). Smith et al. (2017) found that for the implementation of an urban food production system, it must first be located within 400 meters of a major highway in order to adequately access the necessary inputs. This research also argued that the greater the average physical distance, the higher the cost of transport, reducing profitability and a greater distance may increase commuting time, thereby reducing the time spent on agricultural activities. An additional operation to determine the 1000m range from schools with demand and accessible areas where utilities are not limiting factors was performed (Smith et al., 2017).

Therefore, newly proposed urban agricultural development sites are at safer allowable LULC, existing urban agriculture area, soil fertility, proximity to road, proximity to stream/river, existing facility/school, and health care center. Thus, the appropriate urban agricultural development location of Adama city was generated by considering physical, environmental, economic, and socially acceptable. Therefore, analyzed land suitability for urban agricultural development within the city is mandatory in order to maximize both the quality and quantity of fruits and vegetables, in addition to urban greenery, that bring value to urban dwellers and make the environment more sustainable.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusions

Rapid urban expansion has posed serious questions about agricultural land and environmental sustainability in Adama City. The urban periphery has mostly been subjected to a significant loss of agricultural land in the last two decades. The amount of agricultural land in urban areas has been declining at such a rapid rate that urban agriculture is no longer viable. Land use and land cover (LULC) dynamics are well known to significantly contribute to agricultural land degradation and biodiversity loss by the increment of urban dynamics. The analyzed land suitability was multifunctional for the greenery as well as significant components of the urban landscape and provided multiple benefits, like environmental, socio-cultural, and economic benefits, and also provided useful information for urban planning policies and decision-makers geared to achieving multifunctional and sustainable land use for green spaces and productivity.

Land suitability analysis is a critical element in determining suitable areas for agricultural development. It has been determined that geospatial technologies and multi-criteria Analysis (MCA) with the integration of GIS and AHP is particularly helpful for identifying agriculturally acceptable lands. The GIS-based land suitability analysis based on critical factors was conducted to find the most suitable areas for sustainable urban agricultural development in Adama city.

To achieve the aim of this study, nine criteria were considered (LULC (open space), slope, soil type, distance from surface water (stream/river), distance from residential, distance from road, distance from accessibility/facility location, population density, and drainage density were selected parameters and analyzed Using AHP with WLC in a GIS. Then, the areas classified for future agricultural production suitability indexes were highly suitable, moderately suitable, marginally suitable, not suitable, and permanently not suitable. Highly suitable areas have the greatest potential for future agricultural activities and should be prioritized. The GIS-based multi-criteria analysis performed in this study found that, in the current situation, 16.88%, highly suitable land for urban agriculture activities, 37.62% moderately suitable, and 34.39% less suitable; 9.26% not suitable, and 1.84% permanently not suitable. To conclude, the most suitable areas for urban agriculture practices are mostly located in the southern (near Awash river), northwest, southwest, and rarely western parts of the city.

5.2 Recommendations

Based on the findings of this study the following Recommendations are drawn:

- The findings of this study will be beneficial to various parties. From the finding, planners, decision-makers, and developers can identify and recognize that where is optimal land for future agricultural practice to keep land suitable while utilizing the land type properly.
- This suitability study map shows that the area where land utilization urban agriculture, however, Further study focusses on urban agriculture for environmental sustainability analysis that benefit multifunctional.
- Field verification is needed before the final decision is made using the results of the study. However, Areas identified as less suitable, not suitable, and permanently unsuitable in the study are located far from rivers, near urban/builtup areas, on steep slopes, and with less soil fertility. Thus, those areas will be used for other urban land uses (if not occupied by other urban infrastructures).
- Furthermore, the city administration should encourage the community and stakeholders so as to enhance the practice urban agriculture and maintain a community garden. The up-to-date information of the urban agricultural 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 agriculture at national level.
- The land use, land cover, and existing agricultural land maps used in this study were mapped from free Landsat images of 30m resolution. Therefore, further study should be recommended to use 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 for generating LULC and existing agricultural land.
- Further studies are necessary about the planning of future urban agricultural practices to identify the suitability of identified sites for multiple purposes (aesthetic, greenery, research center, and other purposes) and for sustainable life in the city.

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APPENDIX

Appendix I: Area and percentage of the LULC units for 2002, 2012 and 2022

LULC type	**2002**		**2012**		**2022**	
	Area(ha)	Area (%)	Area(ha)	Area (%)	Area(ha)	Area (%)
Farmland	23999.84	76.32	22544.26	71.69	21325.43	67.80
Vegetation	1798.02	5.72	2024.96	6.44	1788.51	5.69
Bareland	3754.73	11.94	3856.94	12.26	2700.07	8.59
Builtup	1781.40	5.66	2942.02	9.36	5571.52	17.72
Waterbody	113.70	0.36	79.52	0.25	62.17	0.20
Total	31447.70	100	31447.70	100	31447.70	100

Appendix II: LULC detection analysis Area and percentage of the for 2002-2022

LULC type	**2002 -2012**		**2002 -2022**		**2012 - 2022**	
	Changes (Δ/ha)	Area (%)	Changes (Δ/ha)	Area (%)	Changes (Δ/ha)	Area (%)
Farmland	-1455.59	-6.06	-2674.41	-11.14	-1218.83	-5.41
Vegetation	226.94	12.62	-9.51	-0.53	-236.45	-11.68
Bareland	102.21	2.72	-1054.66	-28.09	-1156.87	-29.99
Builtup	1160.62	65.15	3790.12	212.76	2629.50	89.38
Waterbody	-34.18	-30.06	-51.53	-45.32	-17.35	-21.82

Appendix III: Rain fall and temperature data of Adama (2005-2012 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 (^{0}C)	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 (^{0}C)	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 (^{0}C)	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 (^{0}C)	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 (^{0}C)	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 (^{0}C)	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 (^{0}C)	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 (^{0}C)	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
2010	T RF (mm)	0	13	0	108.2	42.4	107.6	221.3	179.8	51.2	1.2	18.8	1.5	64.2
	M Max (ºC)	26.7	29.5	30	29.8	29.9	28.8	27.2	27.2	28.8	29.3	28.1	27.3	28.6
	M Min (ºC)	12.5	15.2	16.2	16	17.0	17.5	16.2	16.4	15.5	15.7	15.3	14.4	16.7
2011	T RF (mm)	0	0	64.4	111.6	64	112.8	317.6	141.1	283.9	23.4	93.6	16.6	103.3
	M Max (ºC)	28.6	30.6	31.7	31.2	31.5	29.9	27.4	26.9	27.2	26.9	27.3	25.3	28.9
	M Min (ºC)	13.2	16.6	17.8	17.6	17.4	17.6	16	16.6	16.2	14.6	15.1	14	17.2
2012	T RF (mm)	0	1.1	68.7	76.4	52.2	103.3	344	307.5	62.8	8.1	4.5	8.5	88
	M Max (ºC)	26.4	28.8	31.5	30.6	31.1	29.3	26.3	26.7	27.9	28.9	27.6	26.8	28.5
	M Min (ºC)	13.7	16.1	17.1	17.2	17.2	17.6	16.1	16.3	16.6	15.6	15.2	13.8	17.2

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)

Appendix IV: Projected Population by sex, sex ratio and Population density

Ganda	Male	Female	Total	Ratio to total pop	Total area in hectare	Population density/ ha	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		

Appendix V: Coordinates of School locations

Name of schools	Easting	Northing
New Vision KG School	527267.231	941848.621
Green Hill school	531793.698	944831.181
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

Appendix VI: Coordinates of School 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