



**ADDIS ABABA UNIVERSITY**

**College of Technology and Built Environment**

**School of Built Environment**

**Department of Urban and Regional Planning**

**Assessment of Site Suitability for Sustainable Residential Real  
Estate Investment in Addis Ababa: the Case of Lemi-Kura  
Sub-City**

**Author: Kidist Shuma Ayana**

Addis Ababa, Ethiopia  
June, 2025

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Sub-City**

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**A Thesis Submitted to the College of Technology and Built Environment,  
Addis Ababa University, in Partial Fulfillment of the Requirements for  
the Master's Degree in Urban Land and Property Valuation**

Addis Ababa, Ethiopia  
June, 2025

# Declaration

I, the undersigned, declare that this is my original work, has never been presented at this or any other university, and that all the resources and materials used for the dissertation have been duly acknowledged.

**Student Name:** Kidist Shuma Ayana

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## CONFIRMATION

I certify that this is her original work and that it meets the requirements and academic standards of Addis Ababa University. with my approval as the student's supervisor.

**Name:** Dr. Amha Ermias (PhD)

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# Approval Page

This is to certify that the MA thesis prepared by **Kidist Shuma Ayana**, entitled "Assessment of a Site Suitable for Sustainable Residential Real Estate Investment in Addis Ababa: The Case of Lemi-Kura Sub City," is presented in partial fulfillment of the requirements for the master's degree in urban land and property valuation and meets the accepted standards concerning originality and quality.

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# List of Acronyms

<b>ACC</b>	Access to the City Centre	<b>AHP</b>	Analytical Hierarchy Process
<b>AME</b>	Access to Amenity	<b>AMP</b>	Access to Marketplace
<b>AMR</b>	Access to the Main Road	<b>ARA</b>	Land Area
<b>CBD</b>	Central Business District	<b>CI</b>	Consistency Index
<b>CR</b>	Consistency Ratio	<b>DEM</b>	Digital Elevation Model
<b>FAO</b>	Food and Agriculture Organization	<b>FAR</b>	Floor Area Ratio
<b>GCI</b>	Geometric Consistency Index	<b>GEE</b>	Google Earth Engine
<b>GIS</b>	Geographic Information System	<b>GTP</b>	Growth and Transformation Plan
<b>HOP</b>	Proximity to Hospital	<b>HPM</b>	Hedonic Pricing Model
<b>IHDP</b>	Integrated Housing Development Program	<b>LULC</b>	Land Use/Land Cover
<b>MAK</b>	Market Accessibility	<b>MCE</b>	Multi-Criteria Evaluation
<b>MCDM</b>	Multi-Criteria Decision-Making	<b>MRA</b>	Multiple Regression Analysis
<b>MRE</b>	Mean Relative Error	<b>MSI</b>	Multispectral Instrument
<b>NEQ</b>	Neighborhood Quality	<b>NIR</b>	Visible and Near-Infrared
<b>RMLV</b>	Residential Land Value	<b>S2</b>	Sentinel-2
<b>SCA</b>	Sales Comparison Approach	<b>SCH</b>	Proximity to Schools
<b>SDG</b>	Sustainable Development Goals	<b>SRTM</b>	Shuttle Radar Topography Mission
<b>SVM</b>	Support Vector Machine	<b>SWIR</b>	Shortwave Infrared
<b>UN</b>	United Nations	<b>USGS</b>	United States Geological Survey
<b>WHO</b>	World Health Organization		

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# Abstract

This study explores the site suitability for sustainable residential real estate property investment in Addis Ababa, with a specific focus on Lemi-Kura Sub-City. The objective is to identify and map suitable locations for sustainable residential development by integrating Geographic Information System (GIS), the Analytical Hierarchy Process (AHP), and hedonic land value modeling. A geospatial analysis combined with multi-criteria evaluation was undertaken to analyze critical environmental and socio-economic parameters, including land use/land cover, slope, soil, and geology, to establish physical appropriateness. The analysis set the study region into three separate suitability zones for residential development: extremely low, moderate, and very high. Out of the entire area of 78.67 km<sup>2</sup>, about 23.28 km<sup>2</sup> (30.87%) was found to have extremely low suitability, 8.73 km<sup>2</sup> (13.64%) was found to be moderately suitable, and 20.27 km<sup>2</sup> (25.78%) was found to be highly appropriate for building homes. Also, a hedonic pricing model (HPM) was used to measure how property features and location affect the value of residential land. The model construction is based on the Sales Comparison Approach (SCA), employing sample transaction data acquired from various sites in the research area. Based on the model performance, a residential land value map was generated. Finally, the weighted overlay analysis of the physical suitability map and the land value map was done to establish potential zones for residential development. The integrated technique identified that only 8.10% of the land was classified as extremely suitable, 26.51% as moderately suitable, and the rest, 65.39%, as having low suitability for residential use. The integration of GIS, AHP, and HPM generated encouraging results. Future research is encouraged to use sophisticated approaches such as machine learning and deep learning for improved prediction and decision-making.

**Keywords:** Land Value Modelling; Real Estate Development; Residential Site Suitability; Sustainable Housing.

# Chapter 1

## Introduction

### 1.1 Background

According to Kasa et al. (2011), urbanization is the proportionate change in population residing in urban centers and the degree of coverage by urban settlements. Urbanization is said to be among the demographic global trends that have had a shaping impact concerning the built environment (Caprotti et al., 2017). Currently, over 50% of people on the earth reside in urban areas (Ritchie et al., 2024). According to Larsen et al. (2019), the world urban population is expected to be around 68% in 2050. This shows a rapid increase in urban population as compared to 30% of the population of the world in 1950 (Larsen et al., 2019).

Africa is one of the most rapidly urbanizing continents due to the exponential growth of its population (Echendu & Okafor, 2021). According to Angel et al. (2011), the urbanization of the continent is around 43%; however, it's estimated to be 90% in 2050. While the rural population still dominates the continent, as reported by Echendu and Okafor (2021), the urbanization rate is growing faster than any other region in the continent. This rapid urbanization is also occurring at a faster rate in sub-Saharan Africa, which has adequate infrastructure developments (Ritchie et al., 2024). Because of significant economic activities and job opportunities, city centers and sub-city centers were a place to achieve sustainable development in Africa (Echendu & Okafor, 2021).

In Ethiopia, urbanization was around 21.2% in 2019 (UN, 2015). According to Saghir and Santoro (2018), the urban growth rate of sub-Saharan countries is estimated at around 4.1% per year, compared with a global rate of 2.0 percent. Accordingly, Ethiopia is experiencing a comparable urban growth rate of 4.03% per annum (Saghir & Santoro, 2018). Despite the rapid urbanization growth, Ethiopia remains among the list of the least urbanized countries in Africa (Larsen et al., 2019; Saghir & Santoro, 2018). However, based on the report from the World Health Organization in 2022, the urbanization in Ethiopia resulted in strong economic performance over the last 15 years. This makes the country achieve, on average, a 10% annual growth rate, which is one of the highest rates in the world. Urbanization in Ethiopia is mainly due to fast industrialization and rural-urban migration. This resulted in heightened demand for residential housing, mainly in near-urban places and city centers (Peng et al., 2011; Turok et al., 2023).

According to Kitila et al. (2023), the Ethiopian urban population, in 2050 it is pro-

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jected to reach around 33.1%. The population of Addis Ababa, the capital city of Ethiopia, has doubled since 2000, and it is anticipated to redouble by 2035 (Koroso et al., 2021a). The main factor that has driven the Addis Ababa population growth is migration (Wahba Tadros et al., 2021). This will cause informal settlements and unsustainable urban residential housing construction without appropriate planning.

Housing has become an important public issue in almost all societies and is an essential need affecting the well-being of all citizens (Abelti et al., 2001; Yohannes, 2021). In Ethiopia, a shortage of housing is one of the major problems that call for immediate action (Yohannes, 2021). The majority of houses in the country are below qualitative standards and lack adequate space (Charitonidou, 2022). Advance planning in housing is very important, especially in urban areas (Abelti et al., 2001; Yohannes, 2021).

More than 80% of the Ethiopian housing market is owner-occupied (Haile, 2022). Only 39% (1.8 million) of all urban units were owner-occupied (Matsumoto & Crook, 2021). While rental tenure accounts for a small share (15%) of Ethiopia's 19.4 million total housing units, it accounts for 54% of all urban housing units; in the capital city of Addis Ababa, this share is even higher, rising to 61% (Matsumoto & Crook, 2021). The housing quality in Ethiopia is lower compared to the neighboring countries, and the main housing problems in big cities are overcrowding and poor quality (Erkiyhun, 2022). The current urban housing stock in Ethiopia has several characteristics that require urgent attention (Matsumoto & Crook, 2021). These include a historically owner-occupier-dominated housing market, a highly fragmented, closed, and informal rental market; poor-quality housing and overcrowding; and fast-growing, unmet housing demand outpacing the supply of affordable housing (Haile, 2022; Matsumoto & Crook, 2021).

In response, the city has adopted various housing schemes, mostly state-led condominium schemes such as the 20/80 and 40/60 housing schemes, with the aim of providing affordable housing to low- and middle-income families (Charitonidou, 2022). Notwithstanding this, studies have shown that the schemes come with inherent problems, including shortages, delays in construction, and poor service delivery (Erkiyhun, 2022; Yohannes, 2021). In order to supplement government efforts, the private residential sector is gaining momentum with increased investments in high- and mid-income apartment projects (Matsumoto & Crook, 2021). This market-led strategy, though, leaves low-income communities behind, further increasing socio-spatial inequality. The scholars also highlight the need for integrating sustainability, urban commons, and inclusive planning methods to address the spatial as well as social dimensions of housing (Charitonidou, 2022).

Modern urban planning increasingly relies on geospatial analysis to integrate spatial data and support data-driven decision-making processes (Attah et al., 2024). In fast-growing urban cities like Addis Ababa, Geographic Information Systems (GIS) provide essential tools for analyzing spatial relationships between infrastructure and urban development (Yeo et al., 2013). These advanced geospatial science tools enable planners to optimize land allocation processes. Setting appropriate sites for residential, commercial, and industrial developments based on variables like land availability, land price, infrastructure accessibility, and population growth will be made possible by the convergence of geospatial methods and urban land and property value.

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Building a framework for evaluating residential real estate investments using sustainability indicators is the aim of this study. Using geospatial analysis, the study seeks to help Ethiopia’s urban planning strategies with future growth aligned with economic, environmental, and social sustainability goals. This study aims to identify sustainable residential sites using physical and financial factors by considering environmental, physical, and economic perspectives of the study area using geospatial, AHP, and land value modeling approaches by ensuring future development with economic and sustainable goals.

## 1.2 Statement of the Problem

The rapid urbanization and population expansion in Addis Ababa and the surrounding areas have led to an unprecedented demand for residential properties (Spaliviero & Cheru, 2017). This housing demand is not followed by the equivalent increase in orderly planned, appropriate residential zones. The uncontrolled and frequently unplanned growth of the settlements has led to severe housing shortages, inadequate living conditions, and environmental degradation (Abagissa, 2019; Baye et al., 2023). Previous urban development programs have given limited consideration to sustainable housing ideals, and therefore, there is a severe imbalance between housing demand and the supply of basic services, including infrastructure (roads, water, and electricity) and community facilities (green spaces, recreational areas, and public services) (Eshete & Teshome, 2010). With continuous redevelopment, displacement becomes a recurring process, which further increases the social and economic pressure on low- and middle-income families

Although, however, the standards for determining and implementing appropriate places for residences have not been defined properly. There is a lack of holistic consideration of the determinants of physical, economic, environmental, and social sustainability influencing residential real estate development. While some examine each of these determinants separately, few combine them in a geospatial decision-making context (Fikire, 2021; Weldu & Deribew, 2016a).

The research focuses on Lemi Kura Sub-City of Addis Ababa, one of the fastest-growing sub-cities in Addis Ababa with promising real estate development opportunities. Lemi Kura sub-city is relatively newly added sub-city, and much of the area is still in the early stages of development. As a result, it offers a clean slate for both urban planners and investors to shape a modern, well-structured district. It is chosen because as one of the most recently established sub-city, and the sub-city was designed to accommodate the city’s growing population and provide more space for housing and businesses. Unlike some older sub-cities of Addis Ababa, where expansion is limited by existing buildings and roads, Lemi Kura has the opportunity to implement modern urban planning from the start. This means better-designed roads, more green spaces, and efficient public services. It is close to upcoming infrastructure corridors, has current housing pressures and growing developers’ interest, but without evidence-based spatial planning. The area is a microcosm of the general city issues of Addis Ababa—a perfect case study to pilot sustainable residential site suitability.

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Notably, the study also examines if real estate development includes social sustainability principles such as equity, affordability, and community stability that are not typically addressed by existing planning models. Thus, through an AHP-GIS-based multi-criteria decision analysis, the study seeks to determine and rank environmentally and economically sustainable residential development zones in Lemi Kura in relation to more balanced and resilient urban development.

## **1.3 Objectives**

### **1.3.1 General Objective**

The main objective is to assess the site's suitability for sustainable residential real estate investment in Addis Ababa's Lemi-Kura subcity.

### **1.3.2 Specific objectives**

- To identify and map potential areas suitable for sustainable residential real estate development in the study area.
- To develop a multi-criteria decision-making (MCDM) model incorporating key factors influencing site suitability.
- To assess the financial viability of the identified potential residential real estate investment sites.

## **1.4 Research Questions**

1. Which areas within Lemi-Kura subcity are most suitable for sustainable residential real estate investment?
2. What are the key criteria and how can they be integrated into a multi-criteria decision-making model for site suitability analysis?
3. What are the financial returns of investing in sustainable residential real estate in Lemi-Kura?

## **1.5 Significance of the Study**

The long-term viability of urban growth in Addis Ababa is increasingly threatened by a combination of unsustainable development practices, environmental degradation, and severe housing shortage issues exacerbated by the city's rapid urbanization (Worku & Adugna, 2024). This study aims to address the challenges associated with urbanization by ensuring that future developments adhere to sustainability principles. It employs advanced geospatial analysis, multi-criteria decision-making (MCDM), and land value modeling techniques to reduce both the environmental and economic impacts of urban growth, improve housing accessibility, and enhance the overall quality of urban life.

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By offering a systematic, data-driven approach to site selection, this proposed research aims to provide critical insights that will support the Ethiopian government's efforts to close the housing demand-supply gap while minimizing environmental damage. The use of the current state of art technology integration to identify suitable residential sites based on environmental and economic criteria was allowed for the evaluation of multiple factors such as land availability, proximity to infrastructure, and urban land values in a way that is both objective and replicable (Malczewski, 1999). This approach was used to identify areas most suitable for sustainable residential property investment, providing a framework that can be applied not only in Addis Ababa but also in other rapidly growing urban centers in sub-Saharan Africa, where urbanization exceeds infrastructure development (A. Juju et al., 2020).

Moreover, this study contributed to the pool of scientific studies on sustainable urban development, particularly in the developing sub-Saharan parts of Africa, where rapid urbanization poses difficult challenges to city planners and policy makers. The research shall deliver actionable recommendations to stakeholders, including city planners, government, and real estate developers, to make sure that future urban growth is not just environmentally sustainable but also socially equitable and economically viable.

The findings of this study was ultimately guide the planning of urban policies that encourage inclusive growth, decrease inequalities, and support sustainable urbanization. By narrowing the gap between supply and demand for housing in a sustainable manner, the research attempts to continue to ensure that Addis Ababa's urban development is consistent with the principles of sustainable growth and enhancing the level of life of communities while safeguarding the environment for future generations.

## **1.6 Scope of study**

The scope of this thesis is clearly defined by its spatial, thematic, and temporal boundaries. Spatially, the research focuses on Lemi-Kura Sub-City, Addis Ababa, Ethiopia. The study area is characterized by rapid urbanization and significant residential demand resulting from population growth. It encompasses a diverse landscape, including established urban and peri-urban residential zones, extensive mixed-use agricultural lands, and smaller pockets of plantation areas. Thematically, the research addresses the assessment of site suitability for sustainable residential development by integrating geospatial techniques and multi-criteria evaluation to analyze existing land use patterns, environmental factors, and physical constraints relevant to urban planning. Temporally, the study utilizes data collected from 2024 to 2025, for real estate transactions and 2024 for Sentinel-2A satellite imagery data.

## **1.7 Organization of the Thesis**

This research is systematically organized into five coherent chapters, each addressing essential components of the study. The Introduction establishes the research context by examining the rapid urbanization trends in Addis Ababa and outlines the study's objectives, key research questions, problem statement, and the significance of the research.

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The Literature Review provides a comprehensive theoretical framework that informs the study. The Research Methodology presents the scientific foundation of the research, beginning with a detailed characterization of Lemi-Kura Sub-City as the study area and elaborating on the analytical procedures employed. The Results and Discussion chapter interprets the findings by analyzing key determinants of residential suitability and assessing financial viability projections. Finally, the Conclusions and Recommendations chapter synthesizes the major findings, highlights their contributions to urban planning knowledge, and offers evidence-based policy recommendations for municipal authorities along with practical guidelines for urban developers.

# Chapter 2

## Literature Review

### 2.1 Theoretical Literature Review

#### 2.1.1 Global Demographic Transitions

Population growth, population aging, urbanization, and migration are four broad population trends reshaping our world (United Nations, 2024). The changes in size, age structure, and geographic distribution of world populations bring opportunities as well as challenges (United Nations, 2024). The world's population is projected to continue growing in the 50 or 60 years ahead, reaching a peak of around 10.3 billion people during the mid-2080s from 8.2 billion this year (Lam, 2025; United Nations, 2024). After peaking, the global population is projected to start slowly dwindling, falling back to 10.2 billion people towards the end of the century, as seen in Figure 2.1. Africa experienced flood-related hazards over the past 50 years (Hagos et al., 2022).

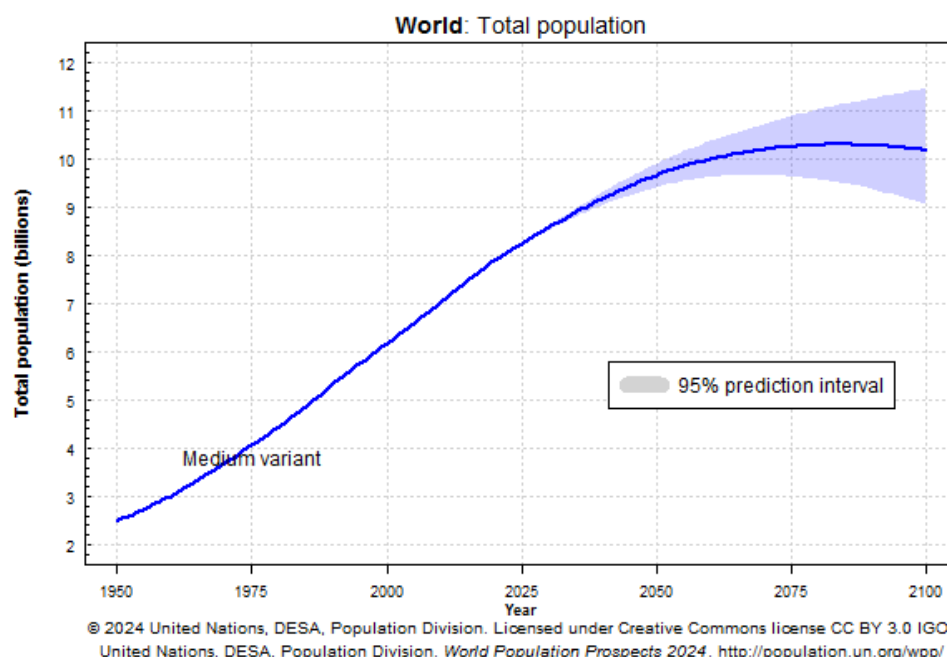


Figure 2.1: World Population Prospects (2024)

Based on the current estimates, the total population size of sub-Saharan Africa in

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2023/24 is approximately 1.222 billion people(United Nations, 2024). It is expected that by 2100, the population would be 292 million smaller under the same scenario.

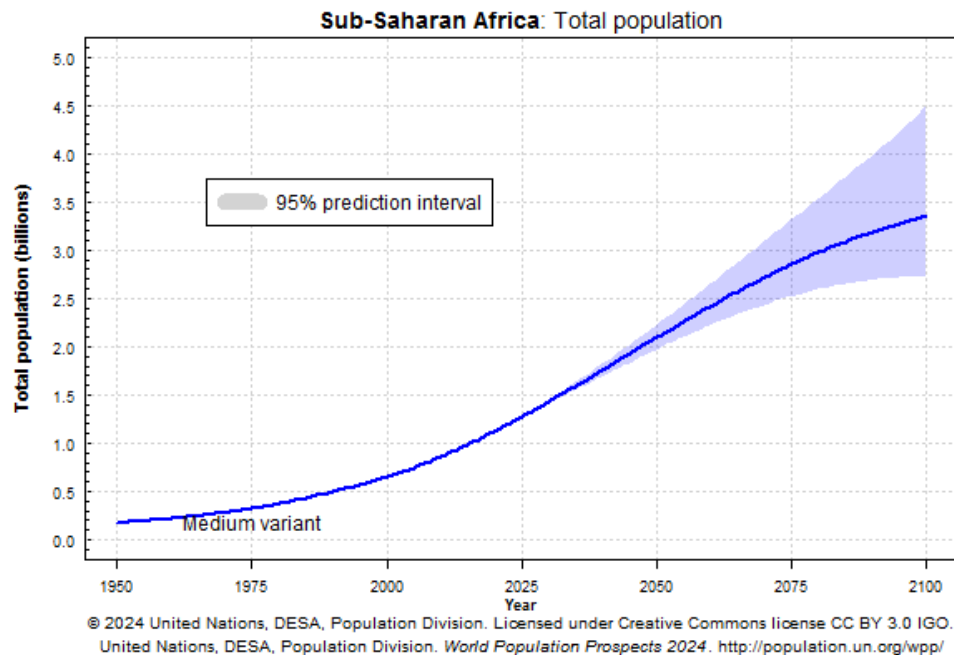


Figure 2.2: Sub-saharan population

## 2.1.2 Ethiopian Urbanization Dynamics

Globally, urban city centers are increasingly becoming the main places of human habitation. The United Nations Sustainable Development Agenda (Nations, 2023) reports that the world population exceeded 8 billion in 2022, with majorities of urban residents(Jaramillo, 2020). Furthermore, in developing countries, approximately 1.1 billion urban residents occupy substandard housing, and this number is expected to grow by an additional 2 billion(Aboulnaga et al., 2021).

Ethiopian demographic studies predict remarkable population expansion between 2007 and 2037(CSA, 2013). According to recent estimates and projections, total population figures lie between 128 and 143 million by 2037, accompanied by urban population growth from 11.9 million to 42.4 million during the same period (Lamson-Hall & Martin, 2022; Lamson-Hall et al., 2019). According to (CSA, 2013), the Ethiopian demography, it predicted a significant population expansion between 2007 and 2037. Based on this, it is expected the urban population to increase in parallel from 11.9 million to 42.4 million during the same period (Lamson-Hall & Martin, 2022; Lamson-Hall et al., 2019). The rapid urban transformation and population growth in Ethiopia have exposed administrative challenges in policy implementation (Lamson-Hall et al., 2019). These inadequate policy enforcement, institutional fragmentation, and planning deficiencies have resulted in community displacements and environmentally unsustainable development patterns in the country(Lamson-Hall & Martin, 2022; Lamson-Hall et al., 2019).

The government-sponsored housing program, including mass condominium projects, aims to address dwelling needs for lower-income groups(K. D. Alemu, 2021). However,

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persistent supply-demand mismatches continue to exacerbate housing accessibility issues (K. D. Alemu, 2021). Harmonizing housing strategies with sustainable urban principles remains challenging, requiring balanced consideration of ecological and social impacts (MEKONNEN, 2017). Ethiopian policymakers have introduced various measures to manage urban growth sustainably (Kassahun & Tiwari, 2012). The capital city features prominently in these efforts through initiatives outlined in the GTP II, which emphasizes sustainable urban expansion, housing provision, and infrastructure enhancement according to the Ethiopian National Planning Commission, 2016).

### 2.1.2.1 Migration Patterns and Drivers

Throughout history, maps have served as a means of displaying geographical data, influencing the many factors. Human mobility patterns in Ethiopia reflect complex interplays of political, economic, and environmental drivers (Kefelegn, 2020). Historical migration trends have been shaped by climatic stressors, conflict, governance challenges, and socioeconomic disparities (Kefelegn, 2020).

### 2.1.3 Sustainable Cities and Urban Development

The United Nations' Sustainable Development Goal 11 (SDG 11) establishes a comprehensive framework for creating inclusive, safe, resilient, and sustainable cities (Nations, 2023). Recent evaluations of global progress reveal that while 150 countries have implemented urban policies aligned with SDG 11 targets, only 23% have measurable outcomes in reducing urban environmental degradation (UN-Habitat, 2023). This implementation gap is particularly evident in rapidly urbanizing African cities like Addis Ababa, where population growth (3.8% annually) outpaces infrastructure development (Economic Commission for Africa, 2022).

Addis Ababa's efforts toward SDG 11 have produced mixed results. The city's 2022 Green Building Proclamation (Authority, 2022) introduced mandatory environmental standards, including 30% green space requirements for new developments. However, compliance monitoring remains weak, with 60% of constructions violating setback regulations and contributing to urban heat island intensification (1.2°C increase since 2015) (M. Tadesse, 2021). This regulatory enforcement challenge mirrors findings from (Abebe & Mulugeta, 2023), who identified a 42% gap between policy formulation and implementation across East African cities. Critical SDG 11 components relevant to residential suitability include:

The UN's recommended "urban footprint" metric (Nations, 2023), analyzing built-up area per capita against service accessibility. This approach addresses Addis Ababa's sprawl patterns, where urban land consumption grows at 5.1% annually compared to 3.8% population growth (Addis Ababa City Plan Preparation Authority, 2023). Following (Kumssa & Jones, 2020), we integrate floodplain buffers (100m minimum) and slope stability thresholds (15° exclusion zones) to operationalize SDG 11's resilience targets. This aligns with Addis Ababa's Climate Resilient Urban Plan (Addis Ababa Environmental Protection Authority, 2021) but extends analysis through GIS-based vulnerability indexing. The model evaluates housing affordability using SDG 11.1 indicators (World

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Bank, 2023), particularly the percentage of households spending  $\geq 30\%$  of income on housing. In Lemi Kura, 58% of residents exceed this threshold (Central Statistical Agency, 2023), highlighting the need for policy interventions.

Comparative studies demonstrate the effectiveness of SDG-aligned planning. (Negash & Yohannes, 2022) documented a 28% improvement in service accessibility in Bahir Dar through similar GIS-AHP integration, while (Mekonnen & Teferi, 2023) showing a 40% reduction in informal settlements in Hawassa using SDG 11 compliance mapping. Our methodology builds on these successes while addressing Addis Ababa's unique challenges of rapid vertical growth and infrastructure deficits.

## **2.1.4 Socio-Economic Factors**

### **2.1.4.1 Population Density and Growth Trends**

According to Immanuel (2023), the current world population is 7.5 billion, with the growth rate of 1.14% per year; about eighty-one percent live in less developed countries. The population growth will have a direct effect on the socio-economic activities of the country. Population growth and economic growth are highly interrelated since they affect each other (K. Alemu, 2020). However, there is no agreement on the impact of such a growing population on economic growth (Immanuel, 2023). Addis Ababa is the hub of political, economic, and cultural centers of Ethiopia (UNDP, 2021). The Ethiopian capital has emerged as a hub of economic activity and urban development, attracting investors seeking opportunities in its increasing property market.

Regarding employment conditions in Ethiopia, among the active population, over 98% were employed in 1984 (K. Alemu, 2014). But in 1994 and 2007, the percentage dropped to 97% and 96.3%, respectively. In the urban area, almost 92% of all economically active people were employed in 1984. However, this number reduced to 78% in 1994 and then to 83% in 2007 (Degu, 2019). Employed people appear to migrate to urban regions in search of better employment and living conditions due to the unfavorable living conditions caused by poor labor productivity and income in rural sections of the nation (K. Alemu, 2014; Degu, 2019).

## **2.2 Conceptual Literature Review**

### **2.2.1 Land Suitability Assessment and Site Selection**

Land is one of the world's land surfaces that human beings have used for different purposes. (Nedd et al., 2021). It can be described by two categories, which include land cover and land use. Land cover refers to the perceived physical features of the land surface, while land use is characterized by activities on the land undertaken by humans (Ullah & Mansourian, 2016). Both land use and land cover are phenomena of importance to urban land use (Ullah & Mansourian, 2016). There is rapid urban expansion with direct environmental consequences if the current urban growth is not planned and managed in a sustainable way (Nedd et al., 2021), because land use planning can have a high contribution towards sustainable urban development (Nedd et al., 2021; Ullah & Mansourian,

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2016).

According to (Fischer & Makowski, 2000), suitability analysis is a very important process in land utilization planning and evaluation. Geospatial-based multi-criteria decision-making (MCDM) techniques have become increasingly popular among urban planners to cope with georeferenced planning problems, including suitability evaluation (Phua & Minowa, 2005). Typically, GIS-based multicriteria decision-making is employed for suitability analysis across various applications related to specific land uses (De Montis et al., 2000; Phua & Minowa, 2005). MCDA techniques facilitate the management of decision problems' multidimensionality through the utilization of multiple factors and criteria (De Montis et al., 2000). Suitability analysis in urban land use planning studies commonly employs multiple characteristics, such as topography, land use and cover (LULC), groundwater potential, geologic hazards, and others.

### **2.2.2 Geospatial Technologies in Urban Development**

Modern GIS platforms enable sophisticated spatial data integration and analysis, supporting comprehensive urban management strategies (Dai et al., 2001). These tools have revolutionized city planning by facilitating evidence-based decision-making for infrastructure development and environmental conservation (Aithal & Ramachandra, 2016). Addis Ababa's growth trajectory necessitates advanced geospatial modeling to predict expansion patterns and optimize service delivery (Koroso et al., 2021b; Tanku, 2024). Spatial analysis applications span land use planning, transportation networks, and site selection processes, incorporating multi-criteria assessment frameworks to balance developmental priorities (Jinollo et al., 2024).

Land suitability assessment evaluates parcel characteristics against intended use requirements (Malczewski, 2004). Residential site selection considers numerous parameters, including safety, accessibility, and livability. Geospatial multi-criteria evaluation techniques have proven effective for both public and private sector location decisions (Yang et al., 2019). Numerous studies demonstrate the efficacy of GIS-AHP integration for residential land use planning, identifying optimal settlement zones through systematic analysis (Long et al., 2007).

### **2.2.3 Analytical Hierarchy Process for Urban Planning**

AHP provides a structured framework for complex decision-making involving multiple competing factors (Hoque et al., 2019). This methodology decomposes problems into hierarchical components, facilitating comparative analysis across diverse criteria. Urban planners employ AHP to evaluate residential location factors such as infrastructure proximity, environmental constraints, and demographic patterns (Guillén-Mena et al., 2023). The technique's quantitative approach enhances transparency in development decisions by assigning measurable weights to evaluation criteria (Guillén-Mena et al., 2023). Essentially, AHP transforms multifaceted problems into simplified hierarchical models incorporating all relevant stakeholders, scenarios, and interrelationships (Adenle et al., 2021; Guillén-Mena et al., 2023). The GIS-AHP integration has gained prominence in land suitability studies, including urban planning applications (Akbulut et al., 2018; Chandio et al., 2011; Fawad et al., 2022).

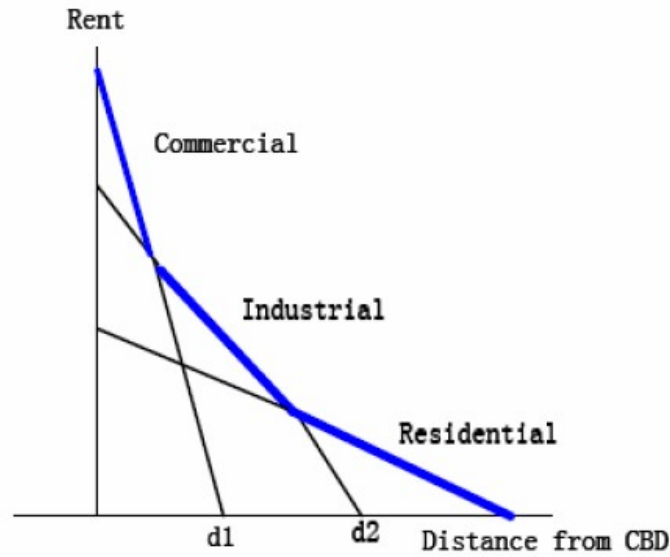


Figure 2.3: The model of urban land market by Alonso (1964). Source from (Liu et al., 2010)

## 2.2.4 Urban land value Models

Urban land is classified into residential, commercial, and industrial land uses. Unlike other commodities, land is not utilized over set or predicted periods of time (Barlowe, 1978). The allocation and use of land resources are affected by the physical and biological, economic, and institutional factors (Liu et al., 2010). In the less developed countries, the requirement for land is affected by accelerated urban and population growth. The value of developed urban land is one of the most important cost features of the worth of a house (Barlowe, 1978; Barnsley et al., 2003). According to Liu et al. (2010), the urban land value has both economic and historic values. The geographical pattern of land value has been investigated by several scholars and researchers; all of these models have indicated a correlation with circumstances of accessibility and land use patterns (Barlowe, 1978).

The analysis of the spatial pattern of residential land values is of vital importance for urban development and land management (Liu et al., 2010). The price of urban land decreases with increasing distance from the city center 2.5. According to Kivell (2002), Industrial activities require proximity to the center for labor availability, transport, and marketing services, but their rent gradient is less steep than commercial uses. Residential activities, the largest land users, desire central locations but cannot outbid commerce and industry, becoming a residual use at the lowest bid-rent curve.

According to (Liu et al., 2010), confirm that residential land values were not only related to exterior attributes, distance, and infrastructure. They also related to the title of registration and land values. Various alternative methods for evaluating and predicting market land prices were the valuation of local government assets. In the following section, we will discuss the different types of property valuation tools in detail.

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#### **2.2.4.1 Sales Comparison Approach (SCA)**

As per Cupal (2016), real estate property is variable in nature, and each unit is distinct with respect to its structure, conditions, investment, and location; therefore, its value is hard to measure. The Sales Comparison Approach (SCA) is a real estate appraisal method that takes into account the value of a property by comparing it with previous sales of comparable properties within the same geographic area (Liu et al., 2010). The sales comparison approach (or market approach) is integrated within the International Valuation Standards (IVS) and also within the European Valuation Standards (EVS) as one of the principal approaches to arrive at a market value (Cupal, 2016).

In the sales comparison approach, there is sometimes a need to allow for differences between the properties to be compared and changes that have later taken place in the market or are structural in character (Cupal, 2016). The approach is often the most direct and efficient means of determining market value, especially for single-family homes in a favorable market (Liu et al., 2010).

#### **2.2.4.2 Cost approach**

The cost approach to property valuation assumes that the cost of capital of acquiring a site and building structures is the maximum cost of the freehold of the property if there existed a market, even when there are no transactions in a market (Connellan & Baldwin, 1993). The cost approach is also known as the contractor's method or the quantity survey approach

parenteliu2010hedonic. The method is particularly relevant to insurance, where site clearance costs can be added to cover the risk of a building being torched by fire and valuing new construction (Connellan & Baldwin, 1993; Liu et al., 2010).

#### **2.2.4.3 Income approach**

The income approach is a comparison technique in which it is supposed that the market value of a land interest is equivalent to the present value of the projected net income derived from the land in the future (Liu et al., 2010). The net income is the gross income minus overhead charges (Cupal, 2016).

### **2.3 Empirical Literature Review**

#### **2.3.1 Geospatial approach to urbanization**

Urbanization is a technologically based process, particularly information and communication technology. Environmentally friendly housing demand is increasing because of the rapid population growth of Ethiopia. Satellite data and geospatial technology have been increasingly applied to site suitability for property in the past few years (Koroso et al., 2021b; Tanku, 2024). These technologies allow decision-makers to collect and analyze spatial data to make informed choices that minimize adverse environmental and community impacts (Al-Shalabi et al., 2006). Global positioning systems (GPS), geospatial technology, and decision-making systems are now part of the digital revolution map of the real estate industry, driving new methods of integration for gathering spatial data and handling property (Naeem et al., 2023). The integrated method utilizes the capabilities

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of Geographic Information Systems (GIS) along with the Analytical Hierarchy Process (AHP) to assess the site qualities, facilitating informed site selection processes (Akbulut et al., 2018; Chandio et al., 2011).

### **2.3.2 Infrastructure and Accessibility in Residential Site Suitability**

The availability and quality of infrastructure play a pivotal role in determining residential site suitability, influencing both livability and long-term urban sustainability. Two critical dimensions emerge from the literature: (1) proximity to roads and essential amenities (2) equity in service distribution. These factors are central to ensuring functional, inclusive neighborhoods and mitigating spatial inequalities in rapidly urbanizing contexts like Addis Ababa.

#### **2.3.2.1 Proximity to Roads and Amenities**

Accessibility to transportation networks and public services is a well-established determinant of residential suitability. Empirical studies suggest optimal thresholds for urban livability, including proximity to primary roads ( $\leq 1$  km) and essential services such as healthcare and education facilities ( $\leq 500$  m) (D. e. a. Juju, 2020). These metrics align with transit-oriented development (TOD) principles, which emphasize reducing vehicular dependency by clustering housing near transit corridors (Cervero, 2013). In Lemi Kura, fragmented road networks and uneven service distribution complicate accessibility, necessitating GIS-based network analysis to identify underserved zones. For instance, only 22% of the sub-city's western sectors meet WHO-recommended standards for green space accessibility (Mariam & Kawo, 2019), exacerbating disparities in quality of life.

#### **2.3.2.2 Unequal Service Distribution in Lemi Kura**

The spatial distribution of infrastructure services in Lemi Kura sub-city reveals significant equity challenges that directly impact residential suitability. According to (D. e. a. Juju, 2020), public service coverage in peripheral areas like Lemi Kura, it lags behind central Addis Ababa by a ratio of 3:1, reflecting systematic underinvestment in emerging neighborhoods. This disparity manifests most acutely in three critical sectors: education, healthcare, and transportation infrastructure.

Educational facilities in Lemi Kura remain severely inadequate, with only three public primary schools serving a population of approximately 180,000 residents (Addis Ababa Education Bureau, 2023). This shortage has resulted in overcrowded classrooms where student-teacher ratios regularly exceed 60:1, compromising educational quality. The healthcare situation proves equally concerning, with just one health center operating at 40% of WHO-recommended service standards (Federal Ministry of Health, 2022), forcing residents to travel long distances for basic medical care. Transportation infrastructure presents another major constraint, as 62% of roads in the sub-city remain unpaved (Addis Ababa Roads Bureau, 2023), creating seasonal accessibility problems that particularly affect emergency services and economic activities.

These service gaps disproportionately impact Lemi Kura's low-income residents, who constitute 58% of the sub-city's population living below Addis Ababa's established living

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wage threshold (Central Statistical Agency, 2021). The situation becomes particularly acute in informal settlements concentrated in sectors 3 and 5, where 72% of residents must walk more than one kilometer to access basic services, according to a 2022 sub-city administration report (Lemi Kura Sub-City Administration, 2022). This spatial inequality reinforces cycles of socio-economic marginalization, as limited access to education and healthcare reduces economic mobility while poor transportation infrastructure increases the time and cost of livelihood activities.

Recent policy initiatives, particularly the Integrated Housing Development Program, have sought to solve these disparities using mandatory service provision requirements in new developments (Dubale, 2023). However, implementation in Lemi Kura has faced substantial challenges, with only 35% of planned health facilities and 28% of road projects completed as of 2023, according to city planning authorities (Addis Ababa City Plan Preparation Authority, 2023). Budgetary constraints, protracted land acquisition processes, and competing development priorities among stakeholders have collectively hindered progress. These implementation shortfalls underscore the complex interplay between policy intentions and the real-world realities in rapidly urbanizing contexts.

Our study directly addresses these equity challenges through innovative spatial analysis methods. We incorporate distance-decay models to quantify school and clinic accessibility, develop road network quality indices that account for seasonal variations, and implement population-weighted service demand calculations. This multi-dimensional approach provides a nuanced assessment of service distribution gaps while identifying priority areas for infrastructure investment. The methodology proves particularly valuable in Lemi Kura's context, where conventional planning approaches have struggled to keep pace with explosive urban growth and evolving settlement patterns.

### **2.3.2.3 Flood-related zones**

Since 1981, sub-Saharan countries have been accounting for around 50% of flood-related disaster records (Hagos et al., 2022). Urbanization is triggered by development that leads to making a significant number of people from the rural sector move to urban areas. (Beshir & Song, 2021). This will lead to altering land use and land cover modes of the area by converting the neighborhood's rural land into housing land (Beshir & Song, 2021; Jemberie et al., 2023). According to the definition of Jemberie et al. (2023), flood risk in urban cities, it is mainly brought about by the result of land conversions and urbanization. Similarly, according to Jemberie et al. (2023), flooding threats in contemporary societies have their origins in poor drainage facilities. This will, in turn, lead to calamitous occurrences causing flood deaths and fatal accidents (Jemberie et al., 2023). All the drainage in Addis Ababa is affected by sedimentation and combined design and construction errors (Jemberie et al., 2023). From the assessment of the Addis Ababa Road Authority report submitted in Jemberie et al. (2023), the state of the structures and condition of the drainage facilities in the city is not greater than 50%.

Addis Ababa is vulnerable to riverine as well as flash floods due to extreme rainfall events (De Risi et al., 2020). Additionally, due to the upper catchment activities, the susceptibility to flooding is increased as a result of poor drainage facilities and housing development near riverbanks. According to De Risi et al. (2020), the low-income com-

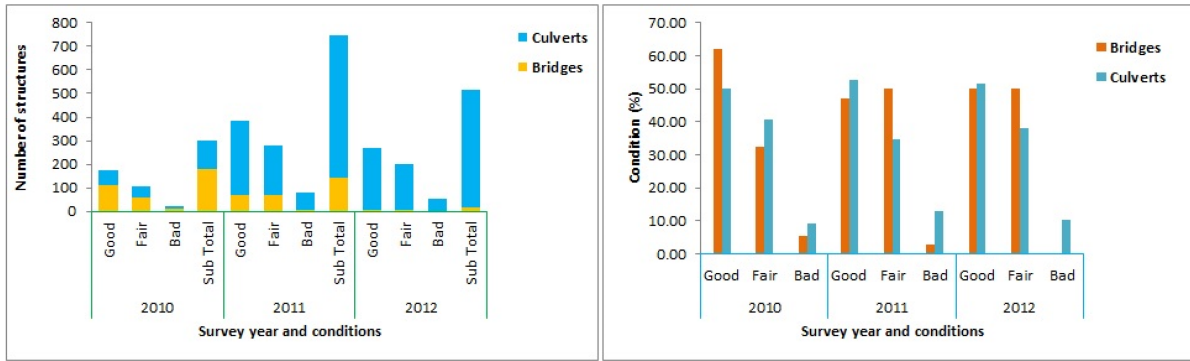


Figure 2.4: Conditions of cross-drainage structures in Addis Ababa from 2011 to 2012 EC. Fully adopted from (Jemberie et al., 2023)

munities were more vulnerable to flood-prone disasters as they were forced to settle near riverine areas.

### 2.3.3 Access to Employment Centers

In Ethiopia, the labor force is growing much more rapidly than the population as a whole because of the young, dominant demographic profile (Kibru, 2012). Over the last two decades, the total labor force of the country has more than doubled (Kibru, 2012). According to (CSA) (2013), the national figure of the unemployment rate in Ethiopia was estimated at 5% of the total labor force. According to (CSA) (2013), Out of the 33,088,792 economically active populations, 1,653,686 were unemployed.

### 2.3.4 Land value in Addis Ababa

According to Mahendra et al. (2022), Land in Ethiopia owned by the government and is leased out to private landowners. In Addis Ababa, there is high demand for land, which offers a great opportunity for revenue generation (Mahendra et al., 2022). In Addis Ababa, the real estate market is directly affected by different factors (Immanuel, 2023). Some of the major factors were economic activities, infrastructure development, and demographic changes were listed as an example (Immanuel, 2023; UNDP, 2021). The rapid population growth with higher urbanization plays a significant role in the real estate investment. Furthermore, the current initiative of Addis Ababa's redevelopment and beautification with infrastructure developments, which include networks, influences the sector (Immanuel, 2023). According to (UNDP, 2021), the urban land value is primarily influenced by the level of infrastructure development, proximity to amenities, and distance from city centers. citepethiopia2021addis. The land value of Addis Ababa is currently concentrated in specific parts of Addis Ababa, as shown in Figure 2.5. Currently, real estate development is concentrated in some parts of the city, as shown in figure 2.5. The real estate price decreases as we go from Bole and Kirkos to the periphery of the city and the lowest price is especially observed in the good and east periphery of Addis Ababa (Immanuel, 2023).

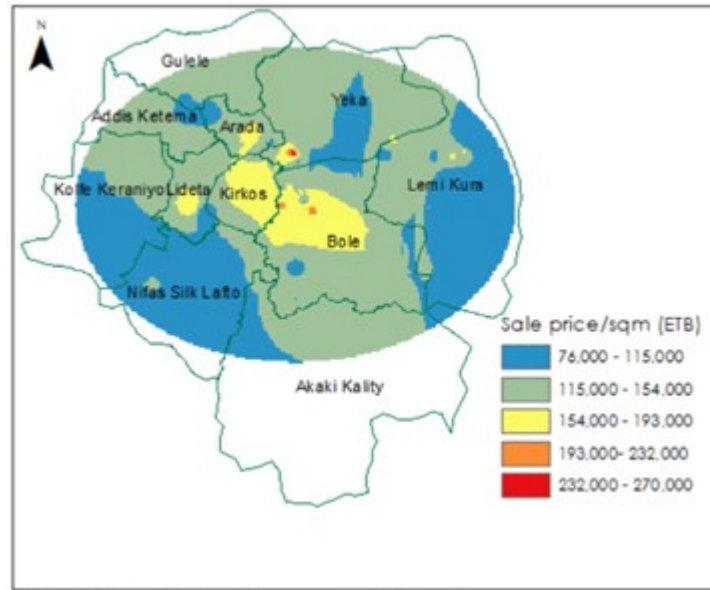


Figure 1: Sale price trend across area (ETB/sqm)

Figure 2.5: Sale price trend across area in addis ababa

# Chapter 3

## Methods

### 3.1 Study Design

The study uses an integrated methodological approach combining Geographic Information Systems, the Analytical Hierarchy Process, and residential land value modeling to identify suitable locations for residential real estate investment in the Lemi Kura Sub-City of Addis Ababa. GIS was used to collect, store, process, and analyze spatial data, including satellite imagery, topographic maps, and land use data, to delineate potential residential real estate development zones. The AHP method was used to support multi-criteria decision-making by assigning relative weights to environmental, social, and economic criteria based on expert evaluations. Residential land value modeling was conducted using both spatial and non-spatial data collected through field surveys and stakeholder interviews. This mixed-methods design allowed the study to address both socio-economic and technical dimensions of residential land suitability analysis.

### 3.2 Description of the Study Area

#### 3.2.1 Study area

The study was conducted in Lemi Kura Sub-City, located in the eastern part of Addis Ababa, Ethiopia. Lemi Kura is one of the eleven administrative divisions of the city and is among the most recently established sub-cities. The area comprises a blend of urban and peri-urban residential zones, alongside extensive mixed-use agricultural lands and a small proportion of plantation areas. Geographically, the study region is bound by the latitude of  $8^{\circ}47'45''$ – $9^{\circ}04'30''$  N and longitude of  $38^{\circ}48'30''$ – $38^{\circ}54'00''$  E, covering a total area of  $62.97\text{ km}^2$  (Fig. 4.8). Lemi Kura was chosen as the research area due to its fast urbanization, various land use patterns, and strategic location as a growing residential and commercial core inside Addis Ababa (Melese, 2004). The sub-city is seeing tremendous development, making it a great place for examining residential suitability and real estate investment possibilities.

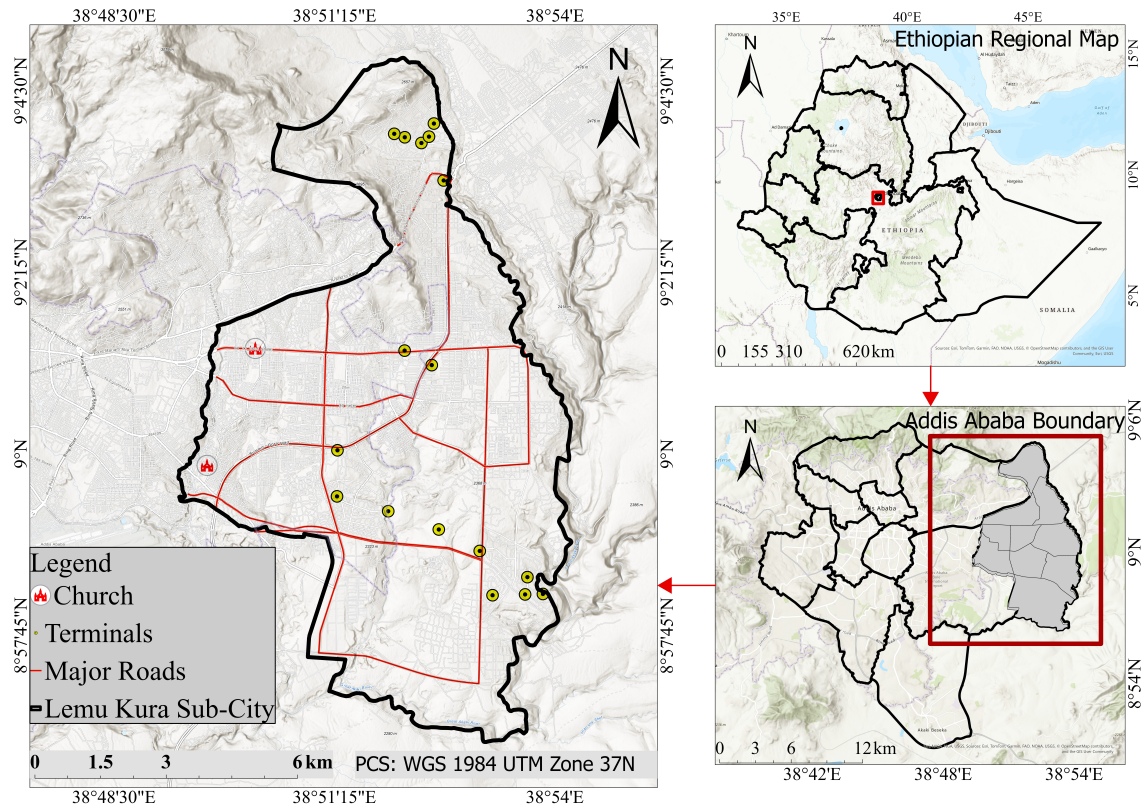


Figure 3.1: Study area

### 3.2.2 Economic Activities

A wide range of economic activities distinguishes Lemi Kura, reflecting the city’s metropolitan and peri-urban characteristics. Commercial and non-commercial operations, manufacturing and small-scale businesses, service industries, real estate, and building are among the most important economic activities(Y. Tadesse, 2021). Construction infrastructure in Lemi Kura is essential infrastructure for its growing population. As the city continues to develop, opportunities for investment and entrepreneurship are likely to expand, attracting both local and foreign investors. With an increasing focus on sustainability and innovation, Lemi Kura is poised to become a hub for diverse industries and a favorable destination for future investments(Y. Tadesse, 2021).

### 3.3 Data Collection Methods

To achieve the study objectives, the study utilized both spatial and non-spatial data types. Spatial data refers to information that has a geographic or locational component, which includes satellite imagery (Sentinel-2A) for land use/land cover (LULC) classification, Digital Elevation Models (DEM) from the SRTM mission for topographic analysis, road networks for accessibility evaluation, and infrastructure data and boundary data, including the sub-city structural plans (district and sub-city levels) for detailed analysis.

Additionally, non-spatial data comprises attribute information that is not inherently

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tied to a specific geographic coordinate, which is vital for socioeconomic and valuation analysis in the sub-city. Expert judgments and qualitative assessments obtained through structured stakeholder interviews were crucial for weighting criteria in the Analytic Hierarchy Process (AHP).

Data were systematically collected, organized, and structured to support the spatial analysis, decision-making, and modeling processes.

### **3.3.1 Primary Data Sources**

#### **3.3.1.1 Remote sensing data**

The primary geospatial datasets that are used in this research work include imageries collected by multispectral Sentinel-2A imagery of 2024 from the Copernicus Data Space Ecosystem<sup>1</sup> and the Shuttle Radar Topography Mission Digital Elevation Model (SRTM-DEM), which was downloaded from the USGS Earth Explorer<sup>2</sup>, providing elevation and slope data. Topographic maps and Google Earth imagery further refine training sites for classification in the study area.

#### **3.3.1.2 Field-Collected Geospatial Data**

Field-based data collection was conducted using handheld GPS devices to collect precise location data, specifically to collect the geographic locations of property houses and different land use types in Lemi-kura sub-city.

#### **3.3.1.3 Property Transaction Records (2024–2025)**

Records of real estate transactions from 2024 to 2025 have been collected from local brokers in Lemi Kura, Addis Ababa, for the Sales Comparison Approach (SCA). Important information like land area, floor area ratio (FAR), and sale prices was included in these records. To aid in the creation of the land value model, the precise geographic locations of the properties were also gathered using handheld GPS devices. A total of 101 property transaction records have been collected from Lemi Kura Sub-city during the field data collection phase. Yeka Abado, Bole Arabasa, Bole Beshale, Hayat Square, Hayat 49, and Semit were among the woredas in the study area from which the transactions were gathered. Mass housing condominium units were the main focus of data collection because other property types were difficult to adjust for in terms of value due to their unpredictability. In order to guarantee consistency and comparability in the analysis, properties with comparatively uniform characteristics were taken into consideration.

#### **3.3.1.4 Stakeholder Interviews**

The research incorporated structured expert interviews as a key component of the site selection process for sustainable housing development in Lemi Kura Sub-City. These interviews were designed to complement the geospatial-AHP analytical framework by

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<sup>1</sup><https://browser.dataspace.copernicus.eu/>

<sup>2</sup><https://earthexplorer.usgs.gov/>

gathering professional assessments regarding the relative significance of different residential suitability factors.

Participants included key stakeholders such as real estate owners, managers, sales professionals, and experts from relevant sectors such as urban planning, cadastral surveying, land administration, and housing development, as well as kebele administrators and woreda-level officials. A purposive sampling approach was adopted to select 15–20 individuals with substantial knowledge of local land dynamics. These participants were identified with the assistance of sub-city authorities to ensure diverse representation and local expertise.

The research team administered individual interviews following a standardized protocol. These sessions specifically examined the comparative significance of various suitability parameters and expert recommendations for ideal residential zones. The gathered responses were systematically processed to generate the pairwise comparison matrices essential for implementing the Analytic Hierarchy Process methodology. Table 3.1 presents a sample that was completed during the interviews.

Table 3.1: Pairwise Comparison Matrix Structure for Real Estate Criteria

Criteria	Comparison Criteria					
	Price	Location	Transport.	Environment	Bldg. Struct.	Pub. Services
Price	1	...	...	...	...	...
Location	...	1	...	...	...	...
Transportation	...	...	1	...	...	...
Environment	...	...	...	1	...	...
Building Structure	...	...	...	...	1	...
Public Services	...	...	...	...	...	1

*Note:* Empty cells (...) indicate required pairwise comparisons using Saaty’s 1–9 scale. Participants compare the row criterion with the column criterion.

These synthesized weights were used as input in ArcGIS Pro to perform a weighted overlay analysis, identifying the most appropriate areas for sustainable residential development in Lemi Kura Sub-City.

This research incorporates the geospatial data collected through systematic ground surveys conducted within the study area. Generally, this study integrates spatial and non-spatial data obtained from Ethiopian governmental institutions, satellite platforms, and field surveys. The spatial data are summarized in Table 3.2, categorized based on their description, source, format, and intended analytical purpose.

### 3.3.2 Secondary Data Sources

In this study, a secondary dataset that included infrastructure layers (such as roads and schools) was collected from the Space Science and Geospatial Institute (SSGI) and the

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Table 3.2: Spatial Data Description for Residential Land Suitability Analysis

Data Description	Source	Format	Purpose
District/Sub-City Boundaries	Addis Ababa Urban Planning & Development Commission	Shapefile	Delineate administrative boundaries for zoning analysis.
Road Networks (2024)	Space Science and Geospatial Institute (SSGI)	Geodatabase	Analyze proximity to infrastructure for hedonic pricing.
Land Use/Land Cover (LULC)	Sentinel-2A (2024) via Copernicus Data Space	Raster (10m)	Classify residential, agricultural, and green zones for suitability analysis.
Elevation & Slope	SRTM DEM (USGS Earth Explorer)	Raster (30m)	Derive topographic constraints.
Population Density (2024)	Central Statistical Agency (CSA)	CSV + Shapefile	Map demand hotspots and project urban growth patterns.

Addis Ababa Urban Planning Office. In addition, exciting writing reports and published and unpublished papers were used for the study.

## 3.4 Data Analysis Methods and Tools

### 3.4.1 Software and tools

This study employs an integrated suite of software tools to address both geospatial analysis and statistical modeling requirements. ArcGIS Pro 3 was used for geospatial data analysis using advanced analytical operations such as proximity analysis, weighted overlay, and suitability mapping using AHP-derived criteria. R statistical software was used for regression analyses for the Hedonic Pricing Model (HPM), quantifying relationships between land values and variables.

### 3.4.2 Sampling Techniques and Sample Size Determination

The study population consists of 42 individuals who are directly or indirectly involved in urban planning and real estate activities in the Lemi Kura subcity. They consist of urban planners, real estate agents and vendors, property valuation specialists, cadastral surveyors, GIS specialists, civil engineers, and sub-city and Wereda-level administrative staff who are highly experienced and skilled professionals. They were deliberately chosen for their job, professional experience, and actual participation in property, land management, and property valuation activities.

Out of the total population, 38 participants were chosen on a purposive and availability random sampling basis. The aim of the method was to incorporate those participants with expertise and knowledge in the area who were also available during the study duration. In balancing professional significance with pragmatic availability, the sampling.

### 3.4.3 Suitability Analysis

In this study, residential site suitability analysis for the study area was assessed through an integrated geospatial modeling approach. The approach incorporates two primary

dimensions: (i) physical suitability analysis based on environmental factors and (ii) residential land value modeling based on socio-economic and proximity factors. The final suitability outcome is derived by combining both dimensions to identify optimal areas for residential development.

### 3.4.4 Physical Suitability Analysis

Physical suitability analysis focuses on evaluating the natural landscape to determine areas that are environmentally appropriate for residential development. The selection of criteria for site suitability analysis was done using different literature reviews Mohamed et al. (2006) and Weldu and Deribew (2016a) and expert knowledge assessed using a structural questionnaire and interviews with real estate developers, urban planners, local government officials, and real estate sales experts. Five key biophysical parameters were considered:

1. **LULC:** To identify existing land uses and exclude incompatible areas such as water bodies and protected lands.
2. **Slope:** Steep areas were considered less suitable due to construction challenges and risks.
3. **Elevation:** Used to exclude extremely high or low areas that may pose environmental or accessibility concerns
4. **Geology:** Influences sunlight exposure and microclimate, with south-facing slopes generally preferred and
5. **Soil:** Soil types were assessed to ensure suitability for construction and infrastructure development.

Table 3.3: Pairwise Comparison Matrix for Environmental Factors in Residential Suitability Analysis

Criteria	Comparison Criteria				
	LULC	Slope	Elevation	Soil	Geology
LULC	1	...	...	...	...
Slope	...	1	...	...	...
Elevation	...	...	1	...	...
Soil	...	...	...	1	...
Geology	...	...	...	...	1

*Note:* Values indicated by "..." should be filled based on expert evaluation using Saaty's 1–9 preference scale.

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### 3.4.5 Geographical Information System

The combination of Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP), an established Multi-Criteria Decision Making (MCDM) technique, significantly strengthened the site evaluation framework. This integrated methodology facilitates comprehensive assessment of potential development locations through quantitative analysis of both geospatial and attribute-based factors. The research will employ this combined approach to establish a rigorous, evidence-based selection process for identifying optimal residential investment sites in Lemi Kura sub-city, ensuring methodological transparency and reproducibility.

#### 3.4.5.1 Land use land cover mapping

As mentioned by Reis (2008), image classification involves categorizing image pixels into distinct groups, known as classes, based on shared spectral characteristics. The output of this process is a “thematic map,” which generally represents land cover or land use patterns. For the residential housing suitability assessment, a supervised classification approach is employed. Specifically, the maximum likelihood classification algorithm is applied to identify three primary land cover classes: agricultural land, forested areas, and urban or settlement zones. The urban/built-up category encompasses residential, commercial, and mixed-use zones, as well as rural settlements, bare lands, and open grasslands Table 3.4. A detailed description of the identified land use and land cover classes is provided in

Table 3.4: Land-use class

Land-use Class	Description
Agricultural land	Including crop fields, fallow land, sandy, bare, grassland and bare soil
Builtup	Including urban and rural settlements and asphalted roads.
Forest	Economic forests such as eucalyptus other natural forests.

#### 3.4.5.2 Derivation of Slope and Elevation

A Digital Elevation Model (DEM) constitutes a gridded numerical representation of terrain morphology, encoding height values relative to a specified reference surface across a geographic area (Croneborg et al., 2020). These models exclusively capture bare earth topography, deliberately excluding anthropogenic features, vegetation canopy, and other above-surface elements. For this study, key topographic derivatives, including slope gradient and elevation characteristics, were computed from 30m resolution SRTM data using ArcGIS Pro’s geospatial processing capabilities. The analytical workflow incorporated an essential preprocessing step of depression filling, wherein elevation artifacts were hydrologically corrected by adjusting cell values to their respective pour points through specialized surface analysis algorithms.

#### 3.4.5.3 Derivation of Soil and Geology

Soil and geological conditions play a critical role in determining the suitability of land for residential development. In this study, soil data were obtained from the FAO soil type

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database. Areas dominated by clay or waterlogged soils were considered less suitable due to potential structural and drainage issues, while well-drained loamy or sandy soils were generally preferred.

The geological data were used to assess subsurface conditions, including bedrock type and geological stability, which directly affect the risk of ground movement. The dataset was derived from the geological map of Ethiopia obtained from the Space Science and Geoinformation Institute (SSGI). Regions underlain by stable lithologies such as granite or basalt were deemed more favorable, whereas zones with highly fractured or unconsolidated materials were assigned lower suitability scores.

#### 3.4.5.4 Reclassification

The ArcGIS Pro software was used to pre-process the data. The various spatial layers were reclassified based on standard suitability ranges and expert-based scores to ensure comparability across criteria. The reclassification followed the scheme below:

#### A. 3.4.6 Slope Analysis for Residential Suitability

Topographic gradient represents a fundamental consideration when evaluating land for housing development. Excessive inclinations may complicate building processes, elevate geological instability risks, and necessitate greater infrastructure expenditures. Based on this, the slope values were categorized into three distinct classes reflecting terrain steepness:

- **0–5%:** These areas were considered the most ideal for residential use, as the slopes are suitable for residential development (Al-Shalabi et al., 2006). They are relatively flat, which allows for easier construction and lower infrastructure costs.
- **5–15%:** Moderately suitable for residential development. These areas may require more engineering considerations, such as terracing or slope stabilization.
- **Greater than 15°:** Unsuitable for residential development. Steep slopes in this range pose significant challenges for construction due to instability, erosion, and increased construction costs ((Al-Shalabi et al., 2006)).

The derived slope classification scheme serves as a critical input for evaluating residential development potential across the study area. This systematic categorization facilitates informed land-use decisions by identifying optimal construction zones based on terrain characteristics.

- B. Land Use/Land Cover:** The reclassification of LULC types into suitability scores follows a systematic workflow to align land cover characteristics with residential development constraints. LULC classes are categorized based on local planning guidelines and the Ethiopian Urban Land Proclamation (No. 818/2014). Each LULC type is assigned a suitability score. See Table 3.5.

Table 3.5: LULC Reclassification Scheme for Residential Suitability

LULC Type	Suitability	Rationale
Agricultural Land	Unrestricted	Convertible with rezoning; moderate priority due to soil fertility preservation.
Built-Up Area	Restricted	Limited space; high redevelopment costs (Malczewski, 2004).
Industrial Land	Restricted	Pollution risks; requires buffer zones (Habitat, 2018).
Military Compound	Restricted	Legally prohibited for civilian use.
Green Area and parks	Restricted	Protected under urban green space policies and Public recreational use.
Bare Land	Unrestricted	Ideal for development due to minimal environmental constraints.
Grassland	Unrestricted	Suitable for development with minimal impact on the environment.
Shrubland	Unrestricted	Easily convertible for residential use with moderate environmental impact.

### 3.4.7 Physical Suitability Model Analysis

This research adopts a combined geospatial and multi-criteria decision analysis approach to evaluate suitable areas for sustainable residential real estate development in Lemi Kura, a sub-city within Addis Ababa. Utilizing Geographic Information System (GIS) as an advanced spatial analysis tool, the study effectively collected, analyzed, and mapped georeferenced data encompassing key environmental, infrastructural, and socio-economic factors critical to urban land-use planning.

To navigate the complexities of competing priorities in urban development, the Analytical Hierarchy Process (AHP) was employed to hierarchically structure and assign weights to each criterion based on the priorities established by stakeholders and experts. This approach ensures a robust and transparent ranking of factors for the physical suitability analysis of site selection. Subsequently, the weighted criteria underwent a GIS-based weighted overlay analysis, which involved synthesizing raster and vector data layers to produce a composite suitability map. This map categorizes zones into distinct classifications (e.g., high, moderate, and low suitability) for residential investment, effectively balancing developmental feasibility with physical sustainability.

### 3.4.8 Residential land value modeling

The residential land value modeling using multiple regression analysis has improved site suitability analysis. This approach facilitates the systematic selection of suitable investment locations by quantifying various spatial and non-spatial variables. By employing these methods, the study offers a data-driven, transparent, and repeatable framework for identifying optimal sites for sustainable residential real estate development in the Lemi Kura sub-city, based on assessments of financial viability. This framework not only enhances decision-making by investors but also contributes towards overall development

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and planning strategies within the region. By including these advanced analytical techniques, stakeholders can more effectively match residential development with community needs and environmental sustainability goals.

Additionally, this study incorporates a residential land value model that combines the sales comparison approach (SCA) with multiple regression analysis (MRA). This dual-method framework quantifies variations in land value by considering property attributes, locational factors, and regulatory conditions, thereby enriching the geospatial suitability analysis with insights driven by market dynamics. This approach provides a more of how different factors interact to influence real estate markets. By leveraging these insights, policymakers and developers can make informed decisions that promote sustainable growth and reflect the unique characteristics of the region.

### 3.4.9 Hedonic Pricing Model via Multiple Regression Analysis (MRA)

Hedonic regression is commonly applied to address complexities related to property valuation, particularly for residential buildings, which exhibit considerable variability in their features (Wikipedia, n.d.). Since the value of individual building characteristics is not directly observable, it becomes necessary to break down a property into its constituent attributes—such as building type, number of bedrooms and floors, lot size, and proximity to urban centers, schools, amenities, and healthcare facilities. Hedonic pricing models facilitate the estimation of the impact each of these factors has on the overall market price by analyzing them individually and determining their respective contributions to property value (Ai, 2005; Monson, 2009).

The Sales Comparison Approach (SCA) was used to collect and analyze the recent transactions of comparable properties in Lemi Kura and adjacent sub-cities, adjusting prices based on both qualitative and quantitative differences. Using the SCA approach, physical attributes, location factors, and environmental factors were considered.

For this study, actual land price is considered a dependent variable. Different independent variables were identified through a literature review, leading to the selection of the following variables for analysis: proximity to the city center, subcity center, schools, health centers, major roads, and views of amenities. Residential land value was modeled by examining the proximity to socioeconomic and infrastructural amenities, which significantly influence demand and desirability. The following criteria were used:

1. **Distance to City-Center and sub-city center:** According to Suparmono (2012), there is a direct correlation between the location factors of parcels of land and the land price. Areas closer to the central business district and sub-city typically have higher value (Ai, 2005; Barbatei, 2020). In this study, the sample of residential buildings, the city business center (CBD) and sub-city center are considered as origins, and major nearby roads have been linked to destination points. To calculate distances from each residential property point to the closest major road, an ArcGIS Pro Near Tool proximity tool was used.

- 
2. **Proximity to School and Health center:** Properties located near high-quality schools and health centers are more desirable for residential land development (Ai, 2005). The availability of these amenities significantly influences individual property prices, with closer proximity typically leading to higher valuations. It is believed that being close to a hospital will make treatment facilities more accessible. (Ai, 2005; Barbatei, 2020). The same methods used for proximity to the CBD, the ArcGIS Pro proximity tool, were used for calculating the proximity of each sample from schools and health centers.
  3. **Access to major roads and bus stops:** Improves connectivity and convenience. Properties with direct access to arterial roads, highways, or bus stops significantly increase prices due to reduced travel times and improved accessibility to commercial centers, employment hubs, and essential services (Ai, 2005). Proximity to the main road and bus stop significantly affects land prices (Barbatei, 2020). The ArcGIS Pro proximity tool was used for calculating the proximity of each sample to major roads and transport.
  4. **Proximity to parks and recreational areas:** Access to green spaces, playgrounds, and recreational facilities significantly enhances residential attractiveness and improves quality of life, leading to premium land valuations (Troy & Grove, 2008). Studies demonstrate that properties within 300-500 meters of urban parks command price premiums of 5-15%, with effects being strongest in densely populated areas (Wolch et al., 2014). The ArcGIS Pro proximity tool was used for calculating the proximity of each sample from access proximity to parks and recreational areas.

These parameters were spatially analyzed and combined into a Residential Land Value Index and applied to estimate residential land value (RMLV) per square meter, expressed as:

$$\text{Price}_i = f(\text{Structural Attributes}, \text{Locational Attributes})$$

$$\text{RMLV} = \beta_0 + \beta_1(\text{ARA}) + \beta_2(\text{FAR}) + \beta_4(\text{SCH}) + \dots + \beta_{15}(\text{ACS}) \quad (3.1)$$

where ARA is Land area, FAR is Floor area ratio, NEQ is Neighborhood quality, SCH/HOP is Proximity to schools, hospitals, parks, AME is amenity access, MAK is market activity and accessibility.

The model is calibrated using R statistical software, with stepwise variable selection to optimise predictive accuracy.

### 3.4.10 Integrating Residential Land Value Modeling into Geospatial Suitability Analysis

Regression outputs are spatialized in ArcGIS Pro to generate residential land value heatmaps. These layers are overlaid with suitability criteria (slope, LULC, flood zones) to identify high-value zones aligned with environmental and infrastructural constraints. Combines land value heatmaps with suitability criteria (slope, flood zones) using equation:

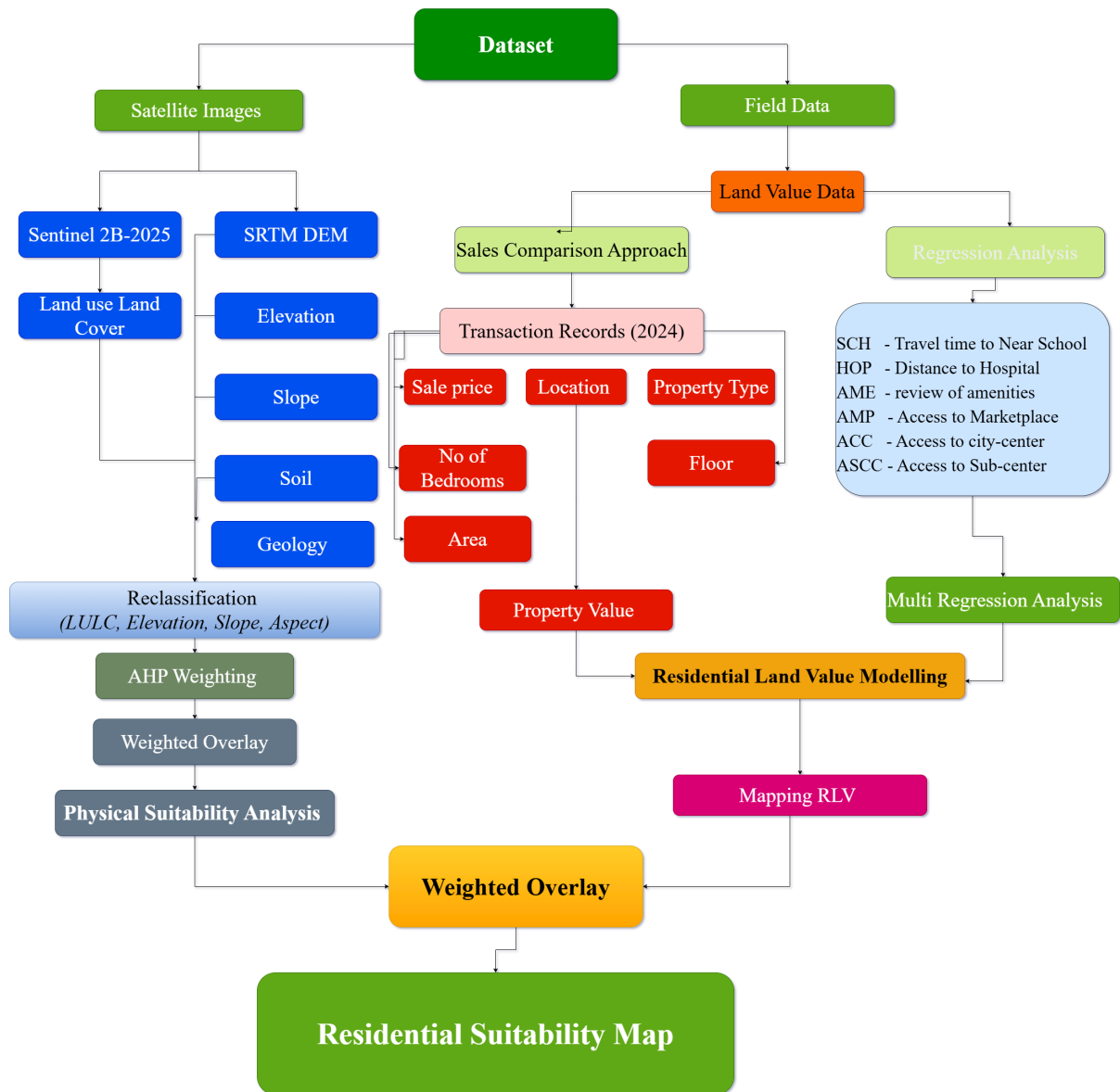


Figure 3.2: Methodological Framework

$$\text{Suitability Score} = \sum_{i=1}^n w_i \cdot x_i \quad (3.2)$$

where:  $w_i$ : AHP-derived weights,  $x_i$ : Normalized criteria scores (1–9).

By synthesizing econometric precision with geospatial granularity, this methodology offers a replicable framework for sustainable urban planning in rapidly growing cities. It not only identifies optimal residential sites but also quantifies their socioeconomic and environmental trade-offs, empowering policymakers to navigate the complexities of 21st-century urbanization. The overall methodological framework is shown in Figure 3.2.

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### 3.4.11 Accuracy Assessment

Upon completing the weighted overlay analysis, the resultant suitability map will undergo validation using both field surveys and high-resolution satellite data from Google Earth. The validation approach will include a ground verification trip to visit a few sites labeled as “highly suitable” and a few labeled as “unsuitable” or low-suitability by the model. On the ground, conditions will be assessed to determine if the highly suitable sites are indeed open for development and serviced by infrastructure. Similarly, the low-suitability sites will be evaluated to verify if they present issues such as being flood-prone or far from essential infrastructure.

In addition to field surveys, the draft suitability map will be presented to expert stakeholders (real estate developers, urban planners, local officials, etc.) through follow-up interviews. The data from both the field validation and stakeholder feedback will be used to make necessary improvements, enhancing the model’s accuracy, relevance, and applicability.

# Chapter 4

## Result and Decisions

### 4.1 Response Rate

This study sent 38 questionnaires to Lemi Kura subcity real estate and urban planners. From the distributed questionnaires, 34 were answered and returned, for an 89.47% response rate. Strong participant involvement and the fact that the obtained response rate much exceeds the criterion for excellence help to confirm the validity and dependability of the results. This significant level of participation guarantees that the collected information effectively reflects the target population of real estate professionals, a site suitable for the objectives of the study.

### 4.2 Demographic and Social Factors

According to the above analysis of questionnaire responses of 38 selected participants of Lemi Kura sub-city, most respondents had their origin as urban planning professionals (39.5%), real estate developers (31.6%), and local government administrators from higher officials down to coordinator level (18.4%), then a smaller fraction from other professions related to surveyors and GIS professionals (10.5%). This professional report indicates a significant level of those directly involved in land use, development planning, and property management in Lemi Kura Sub-city.

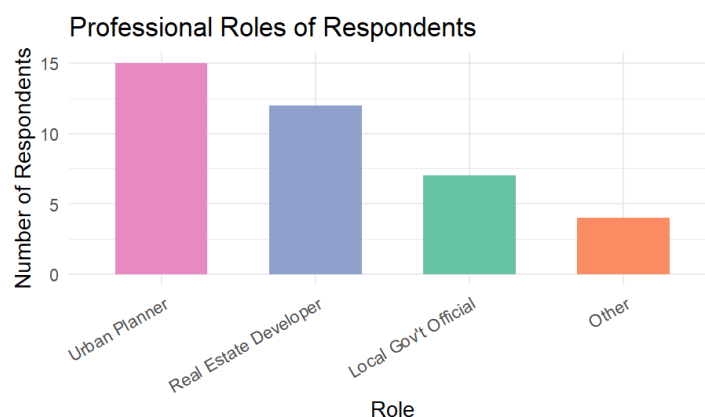


Figure 4.1: Professional roles of respondents

As for population trend, the majority of the respondents (68.4%) perceived the growth in population in Lemi Kura to be very rapid, while another 21.1% described it as being moderate. Some perceived it as slow (7.9%) or that there was no growth at all (2.6%). These responses confirm that the sub-city is experiencing rapid demographic changes, likely due to urban expansion and continuous basic infrastructure development in the sub-city that absorbs some of individuals' concerns and results in increased housing needs.

Population Growth Perception

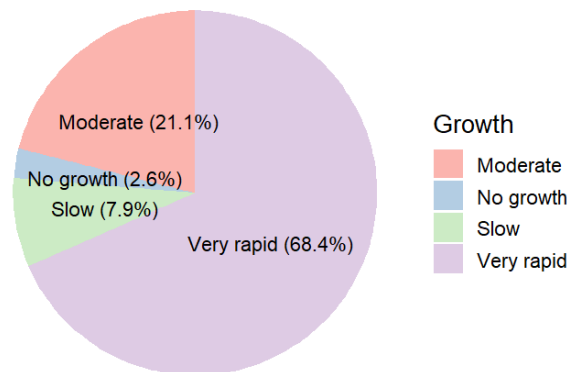


Figure 4.2: Perception of Population Growth

When asked about the demand and supply relationship for housing, 78.9% of the respondents responded that demand is greater than supply, reflecting a significant pressure on the housing market. A comparatively smaller percentage of 13.2% opined that supply is equal to demand, while 7.9% were unclear. This reflects that available urban infrastructure may be behind in containing residential demands.

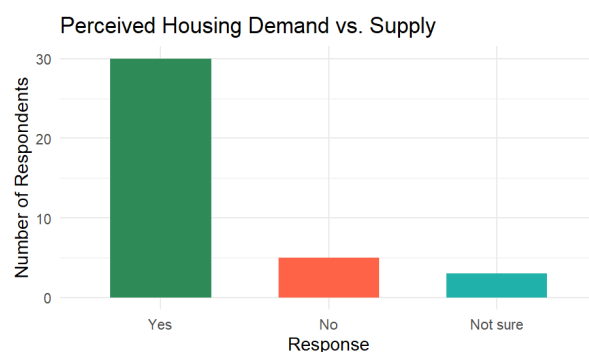


Figure 4.3: Housing Demand vs Supply

In terms of migration trends, over half the respondents (57.9%) viewed rural-to-urban movement as the primary contributor to population growth in Lemi Kura. Internal movement from other sub-cities also counted significantly (28.9%), while international movement (5.3%) and other unspecified factors (7.9%) played lesser roles. This is indicative of broader urbanization trends within Addis Ababa, where sub-cities at the periphery are likely to attract new residents due to land availability and development opportunities.

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## Migration Source to Lemi Kura

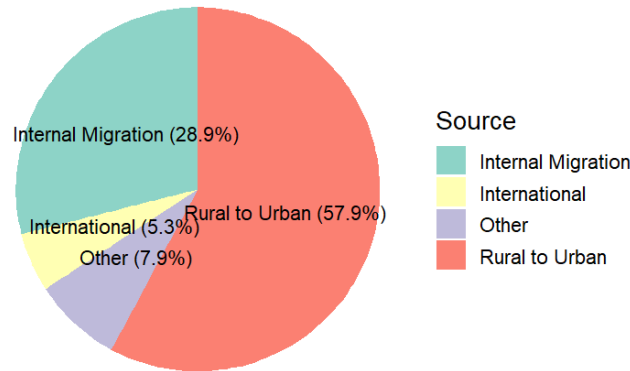


Figure 4.4: Migration Source

The following graphs visually represent the above observations and affirm that Lemi Kura is a rapidly emerging urban area propelled by professionally led development and population transformation, particularly rural and internal migration

## 4.3 Environmental Factors

### 4.3.1 Importance of Topography in Real estate Site Selection

Based on the analysis from the questionnaire, the majority of respondents (52.63%) rated topographic factors such as slope, elevation, and aspect as playing an important role in real estate site suitability analysis. An additional 31.58% of respondents considered it "important," indicating that over 84% of the participants agreed on the significance of topographic features in the site selection criteria. This suggests that elevation and terrain conditions are central to both the feasibility and safety of real estate development in Lemi Kura, especially given risks of landslides or drainage issues in sloped areas.

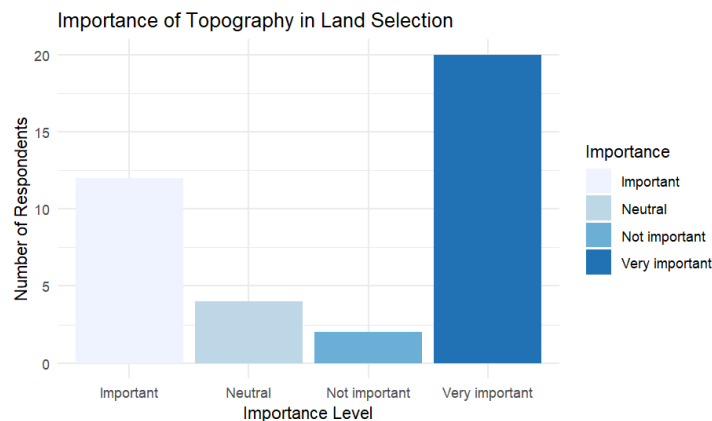


Figure 4.5: Topography Importance

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### **4.3.2 Environmental Factors Prioritized in Real Estate Investment**

As described by the analysis result shown in the following figure, participants cited soil quality and stability (30 times) and water quality and availability (28 times) as the most critical environmental concerns when determining future residential real estate locations. They were followed by natural disaster hazard (26) and proximity to green space (24). These factors pose physical land stability and resource availability (like pure water) as primary concerns, along with ecological amenities and risks of hazards. Interestingly, air quality and biodiversity were also listed but considered to be secondary priorities.

### **4.3.3 Environmental Concerns and Awareness of Protected Areas in Lemi Kura**

The majority of respondents (25 out of 38) stated that they were "very concerned" about the environmental impacts of urban expansion in Lemi Kura, which suggests a high degree of environmental awareness among stakeholders. This degree of concern justifies the necessity of introducing sustainability and mitigation measures into any proposal for housing or infrastructure development.

Additionally, more than half of the respondents (22 of 38) acknowledged the presence of protected areas—such as forests and wetlands—that limit development within the sub-city. This acknowledgment underscores the necessity to integrate environmental regulations and protection zones into the urban development plan. However, 10 respondents stated no knowledge of such protected areas, and 6 were unsure, pointing to a lack of awareness or communication between professionals and administrators.

## **4.4 Infrastructure and Accessibility**

### **4.4.1 4.1 Assessment of Current Transportation Infrastructure**

The research shows that the majority of respondents rated transport infrastructure in Lemi Kura Sub-city as good, implying that there are adequate road networks and effective public transport services. This is an implication that mobility systems existing in place are well positioned to support large-scale residential development within the sub-city. Efficient transportation networks are not only crucial in enhancing land suitability but also in encouraging planned urban development, particularly in peripheral suburbs.

### **4.4.2 Proximity of Key Infrastructure to Potential Development Sites**

Most interviewees indicated potential residential areas. However, the sub-city lacks basic water supply infrastructure. This feedback spatially targeted infrastructure investment. It also suggests that developers can expect higher costs and logistical challenges if developments are situated in less-serviced areas.

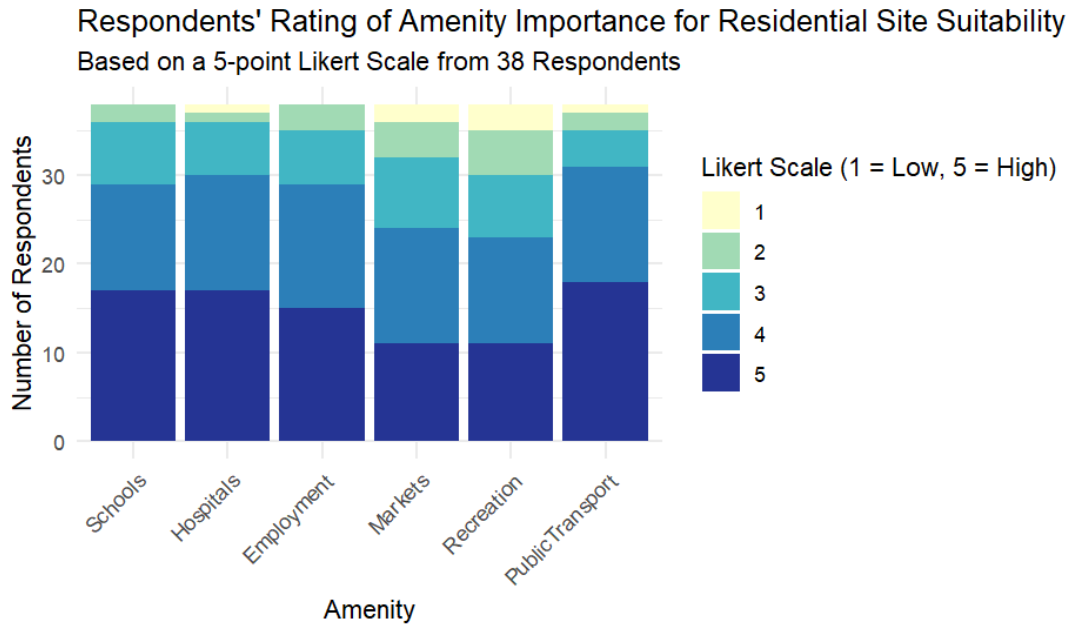


Figure 4.6: Rating of amenity importance for residential site suitability

#### 4.4.3 Importance of Amenity Proximity in Site Suitability

Respondents were asked to rate the importance of proximity to key amenities using a 5-point Likert scale (1 = Not important, 5 = Very important). The results show the same pattern across the answers: schools, hospitals, and employment centers were rated highly, with over 76% of respondents scoring 4 or 5. This suggests that these amenities are widely regarded as key factors in determining residential site feasibility.

Markets and shopping centers and recreational facilities, while still considered important, had relatively slightly medium ratings, with about 60–65% of the respondents giving them a rating of 4 or 5. The findings emphasize that functional accessibility to social infrastructure remains a key problem in urban residential planning. These facilities must thus be given high weight in site suitability models, especially when applying multi-criteria decision-making approaches like AHP.

A vast majority of the respondents also underscored the availability of public transport as an important factor in choosing residential areas. Out of 38 responses using a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree), 81.6% of the respondents marked this factor at either 4 or 5, indicating strong agreement. Its mean rating of 4.3 indicated a clear preference for residential areas with effective and available public transport facilities.

These results highlight the necessity to align urban development plans with transit-oriented development (TOD) plans. The integration of transport infrastructure into housing planning not only raises the level of accessibility but also results in higher land values and encourages compact, sustainable urban growth, particularly in rapidly developing cities like Lemi Kura Sub-city.

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## 4.5 Physical-based land suitability analysis

The analysis of residential site suitability for real estate investment was done using 5 biophysical variables, which include land use and land cover, slope, elevation, soil, and geology. The detail is described in the following sections. The analysis aims to identify optimal locations for potential development by evaluating how each of these variables influences residential desirability and environmental sustainability. By systematically assessing these factors, we can help investors seeking to make informed decisions in the real estate market.

## 4.6 Land Use/Land Cover (LULC) Classification

Based on the results of classification conducted in Lemi Kura Subcity, agricultural land occupies the largest portion of the study area, covering approximately 44.41% of the total area, followed closely by built-up areas at 43.94%, while forest cover accounts for only 11.62% (Figure 4.7).

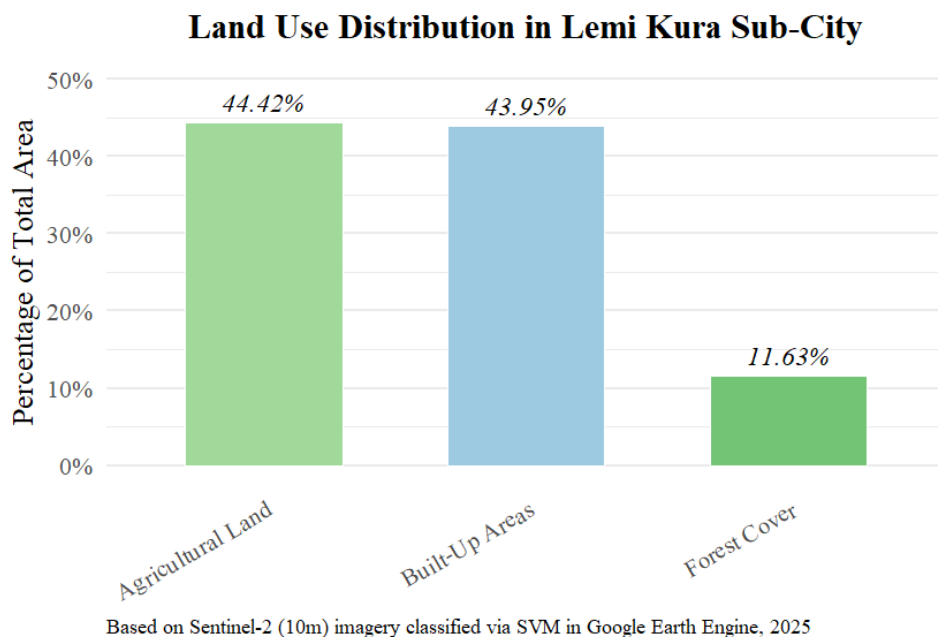


Figure 4.7: Land use distribution of Lemi Kura Subcity

As Addis Ababa grows, peripheral sub-cities like Lemi Kura are becoming hotspots for residential investment nowadays. Due to this, bare land, shrubland, grassland areas, and farmland, which fall under the agricultural land category, are often less intensively used or fallow, making them more feasible and cost-effective for urban development compared to built-up or ecologically sensitive areas.

Unlike built-up zones, which are already saturated and require significant redevelopment costs, or forest lands, which have ecological and regulatory constraints, these agricultural subtypes are generally characterized by favorable terrain, accessibility, and

fewer environmental limitations.

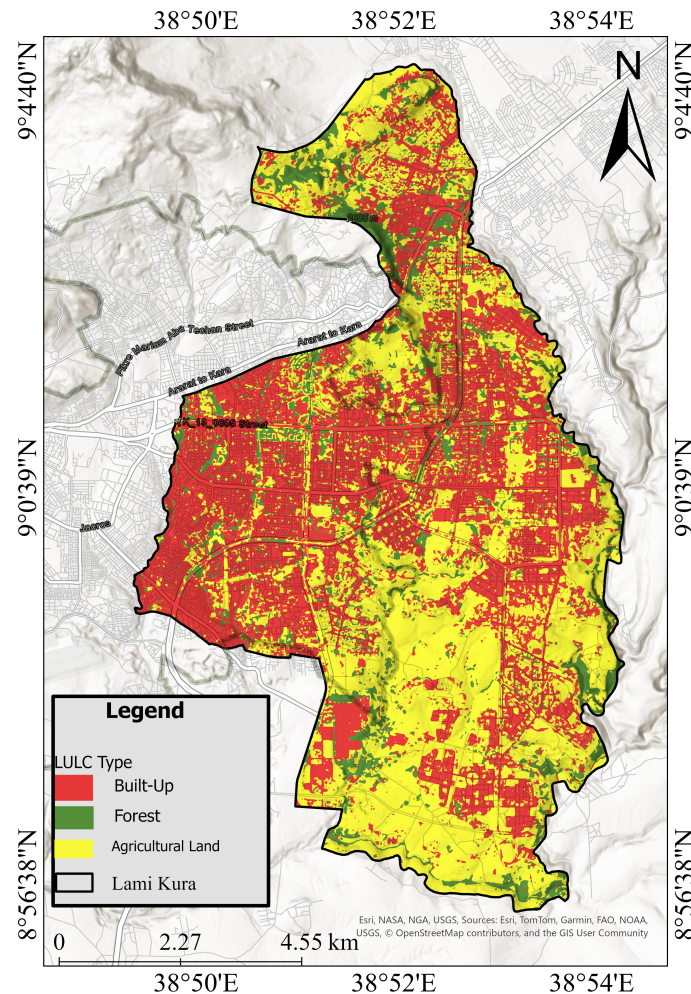


Figure 4.8: Land use/land cover map of Lemi Kura Subcity (Year = 2025)

The land use/land cover (LULC) classification for Lemi Kura Sub-City, performed using Sentinel-2 satellite imagery (10-meter resolution) and the maximum likelihood classification algorithm on the ArcGIS Pro software, was assessed through a confusion matrix derived from independent validation points. The evaluation demonstrated high classification performance, achieving an overall accuracy of 94%

In summary, the geospatial analysis reveals that agricultural land—particularly in the form of bareland, grassland, and shrubland—offers significant potential for sustainable residential development in Lemi Kura Sub-City. With proper planning, infrastructure investment, and environmental consideration, these areas can contribute to addressing the city’s growing housing demand without compromising ecological integrity.

## 4.7 Topographic Factors

Topographical features significantly influence urban planning decisions, with elevation and slope gradient representing the most critical geographical determinants (Guo et al.,

2020). A comprehensive analysis of these terrain characteristics is vital for fostering sustainable urban growth, reducing environmental risks, and enhancing living conditions. Elevation emerges as one of the most significant topographic variables in residential suitability assessments. Areas with lower elevations face substantially higher flood risks, resulting in both

### 4.7.1 Elevation analysis

The study area’s elevation analysis shows a distinct suitability pattern for urban residential development in the study area. Highly suitable zones, covering the largest portion (44%), are predominantly located in the western direction. Moderately suitable areas account for approximately 41% of the study area, primarily concentrated in the central and northeast part of Lemi Kura subcity. In contrast, unsuitable elevation zones constitute 15% of the area, mostly in the western direction, possibly due to extreme slopes or low-lying flood-prone terrain. Based on this analysis, the elevation of the subcity is most favorable for urban expansion and shows suitable conditions for residential housing construction.

Table 4.1: Elevation Reclassification for Residential Site Selection

<b>Elevation Range (m)</b>	<b>Suitability Class</b>	<b>Area (km<sup>2</sup>)</b>	<b>Percentage (%)</b>
< 2350.0	Highly Suitable	36.86	46.86
2350.0–2450.0	Moderately Suitable	32.90	41.83
2450.0–2727.0	Low Suitable	8.91	11.32
<b>Total</b>		<b>78.67</b>	<b>100.00</b>

High-elevation areas cost a lot to the government, particularly supplying the mountain areas with facilities like roads, water supply, and electricity, which are much more costly in comparison with the flat areas (Al-Shalabi et al., 2006; Jha et al., 2012). In addition, slope gradient significantly impacts construction feasibility and safety. Steep slopes are susceptible to landslides and soil erosion, making them less ideal for residential development without proper engineering interventions (COROMINAS et al., 2008; Fell et al., 2008). Topographical factors, elevation, and slope play a fundamental role in urban residential site selection. Proper consideration of these elements can enhance disaster resilience, reduce construction costs, and improve living conditions (COROMINAS et al., 2008; Fell et al., 2008). The classified elevation map based on suitability ranges is shown in Figure 4.26.

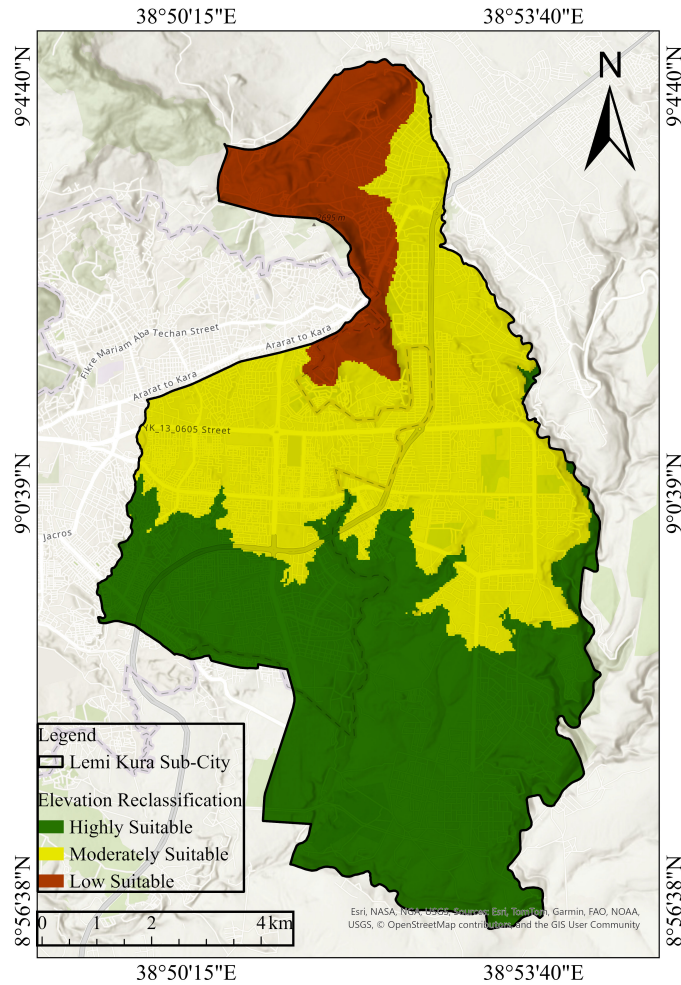


Figure 4.9: Reclassified elevation map

Elevation variations influence microclimate conditions, infrastructure accessibility, and construction processes. When properly incorporated into site selection criteria, these geographical characteristics can yield significant benefits. Different papers demonstrate that topography-based planning enhances community disaster resilience by avoiding geohazard zones (Fell et al., 2008), reduces construction costs through minimized earthworks and foundation requirements (Jha et al., 2012), improves overall living conditions through better natural drainage and ventilation, and minimizes environmental impact by preserving natural landforms and reducing cut-and-fill operations (COROMINAS et al., 2008). This multidimensional value proposition explains why modern urban planning frameworks increasingly prioritize topographic analysis during the preliminary site assessment phase, particularly in regions with complex terrain. This focus on topographic analysis allows for more informed decision-making, ensuring that developments are both sustainable and resilient to potential geohazards. As urban areas continue to expand, the integration of such analytical methods will be crucial in fostering safer and more livable communities. Communities that prioritize topographic analysis can better mitigate risks associated with landslides, flooding, and other environmental challenges. By leveraging advanced modeling techniques and data-driven approaches, urban planners can create more adaptive infrastructures that enhance public safety and promote long-term sustainability.

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## 4.7.2 Slope analysis

A Digital Elevation Model (DEM) represents the three-dimensional surface of the Earth, from which critical terrain features such as slope and contour lines can be derived. Among these, slope is the most influential factor in residential site suitability analysis due to its direct impact on construction feasibility and safety. Urban areas typically exhibit diverse topographic relief and population distribution patterns. Historically, urban expansion has predominantly occurred in lowland areas with gentle slopes (Guo et al., 2020).

However, recent developments in Addis Ababa have witnessed residential construction extending into steeper slopes and narrow valleys (Guo et al., 2020; Weldu & Deribew, 2016b), increasing risks of slope instability and debris flows that threaten lives and property (Asrat et al., 2025; Guo et al., 2020). Urban planning best practices suggest ideal slopes between 2% and 15% for residential development (Weldu & Deribew, 2016b), as steeper gradients significantly raise construction costs and geohazard risks. Using ArcGIS Pro’s raster calculator, we classified the study area’s slopes into three categories (Table 4.2) based on their development suitability.

Slope areas that exceed 10% are categorized as unsuitable for residential construction (Cullingworth & Cullingworth, 2002). The maximum slope within the study area is 87.83%, placing it in this high-risk category. Conversely, slopes below 10% present optimal conditions for development, balancing construction feasibility with safety considerations. The spatial distribution of slope suitability is visualized in Figure 4.10.

The reclassification results (Table 4.2) demonstrate that the study area predominantly consists of semi-flat terrain suitable for residential development, particularly in central and northern regions. Slope gradients range from 0% to 87.83%, categorized as:

- Highly suitable (0% to 5%): Covering 34.20% of the area, concentrated in eastern and western flat zones
- Moderately suitable (5% to 15%): The largest category at 52.47%, widely distributed
- Unsuitable (> 15%): Comprising 13.33%, primarily in northern steep zones

Table 4.2: Slope Suitability Classification

Suitability Class	Slope Range (%)	Area (km <sup>2</sup> )	Percentage (%)
Highly Suitable	0–5	26.38	34.20
Moderately Suitable	5–15	40.5	52.47
Unsuitable	> 15	10.29	13.33
<b>Total</b>		<b>78.26</b>	<b>100.00</b>

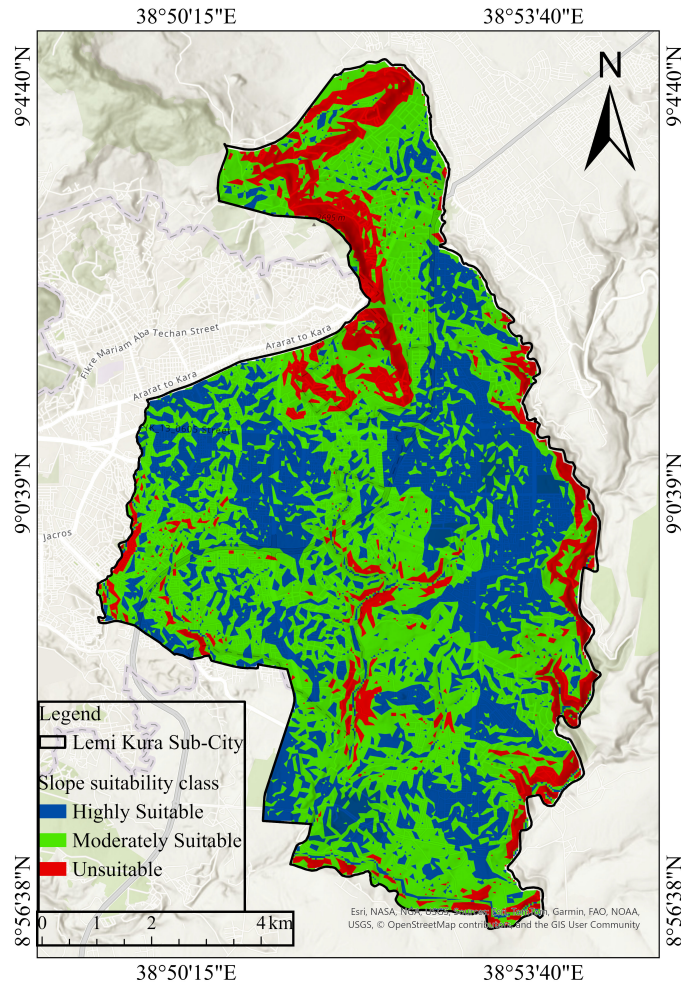


Figure 4.10: Reclassified Slope

## 4.8 Environmental Factors

For this study, soil and geological data were acquired from the Space Science and Geospatial Institute and the FAO soil database, respectively. The analysis focused on identifying soil types and geological formations that either support or constrain residential development.

### 4.8.1 Soil

The FAO Soil Classification System analysis revealed three dominant soil types covering the study area (Figure 4.11). As shown in Table 4.3, Pellic Vertisols constitute the majority at 50.94%, followed by Eutric Nitisols at about 32.30%, and Chromic Luvisols at around 16.75% or 13.18 km<sup>2</sup>. Each soil type presents distinct geotechnical properties influencing residential development potential.

Table 4.3: Soil Type Distribution and Suitability Classification

Soil Type	Suitability Rank	Area (km <sup>2</sup> )	Percentage (%)
Pellic Vertisols	Low Suitability	40.077	50.94
Eutric Nitosols	Moderately Suitable	25.413	32.30
Chromic Luvisols	Highly Suitable	13.180	16.75
<b>Total</b>		<b>78.67</b>	<b>100.00</b>

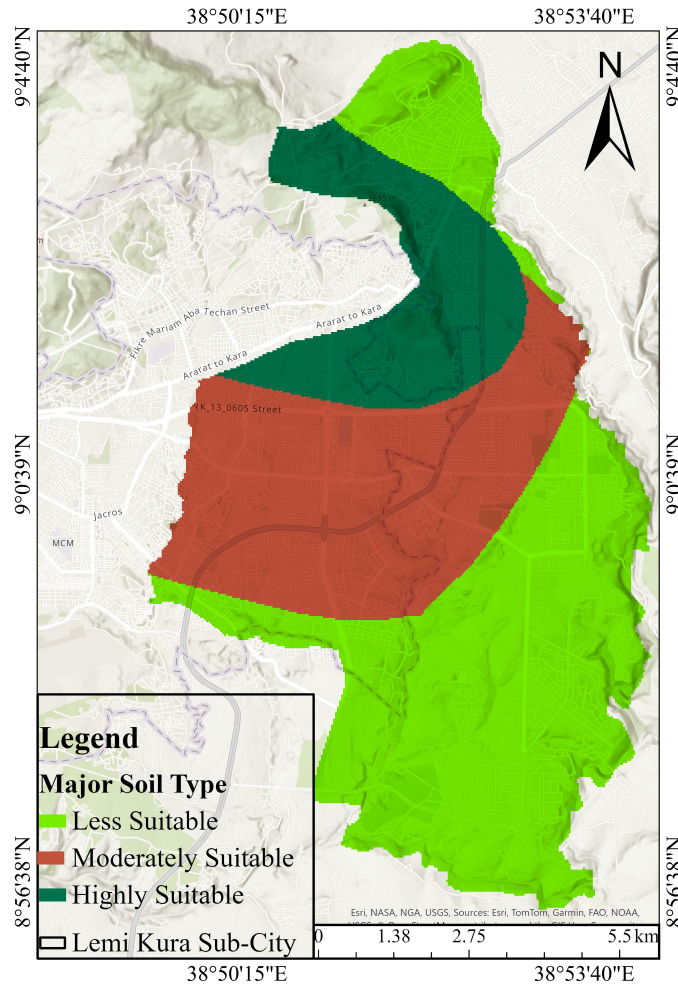


Figure 4.11: Soil Map

Vertisols, covering 50.94% of the area, demonstrate challenging engineering properties due to their high smectite clay content. According to, Sharma (2006), these expansive soils require stabilization measures for safe construction, Jha et al. (2012) noting they increase infrastructure costs by 25-40% compared to stable soils. This significant increase in costs can be attributed to the need for specialized foundations, drainage systems, and ongoing maintenance to mitigate the adverse effects of soil movement. Consequently, understanding the properties and behavior of Vertisols is crucial for engineers and urban planners working in affected regions.

Eutric Nitosols (32.30% coverage) offer moderate suitability with better drainage

(permeability  $10^{-5}$ – $10^{-6}$  m/s) and bearing capacity (150-200 kPa) as documented in Information (2003). Chromic Luvisols, while only 16.75% of the area, represent the most favorable substrates for foundation support without major modifications (WRB, 2015). This makes them ideal for construction projects where stability is paramount.

As urban development continues to expand in these regions, careful consideration of soil types will be essential to ensure the longevity and safety of infrastructures. Infrastructure projects must also factor in potential environmental impacts and soil conservation practices, which can be influenced by the choice of materials and construction techniques. By prioritizing the use of suitable soil types, developers can enhance the resilience of structures while minimizing ecological disturbances.

## 4.8.2 Geology

The study area’s geological framework comprises three principal formations that present both opportunities and challenges for urban development. These Middle to Late Cenozoic volcanic units exhibit distinct geotechnical properties that significantly influence land use planning and construction feasibility. The study area’s geological composition, as mapped in Figure 4.12, comprises three principal formations that significantly influence land use planning (Table 4.4). These Middle to Late Cenozoic volcanic units exhibit distinct engineering geological properties relevant for residential development.

The Ntb formation (transitional/alkaline basalts, covering approximately 12% of the study area, consists of transitional and alkaline basalts characterized by well-developed columnar jointing with average spacing of 0.5-1.2 meters. These rocks demonstrate high compressive strength, making them mechanically competent for foundation support. Nn Formation (Pyroclastic Series) Dominating 65% of the terrain, the Nn pyroclastic series presents the most complex geotechnical environment and PNa Formation (Transitional Basalts) The PNa formation’s subalkaline basalts 23% coverage offer relatively favorable construction conditions

Table 4.4: Geological Formation Distribution in Study Area

<b>Geological Formation</b>	<b>Suitability Class</b>	<b>Area (km<sup>2</sup>)</b>	<b>Percentage (%)</b>
Nn Pyroclastic Series	Low Suitable	51.81	65.85
Ntb Alkaline Basalts	Moderately Suitable	0.54	0.69
PNa Transitional Basalts	Highly Suitable	26.32	33.45
<b>Total</b>		<b>78.67</b>	<b>100.00</b>

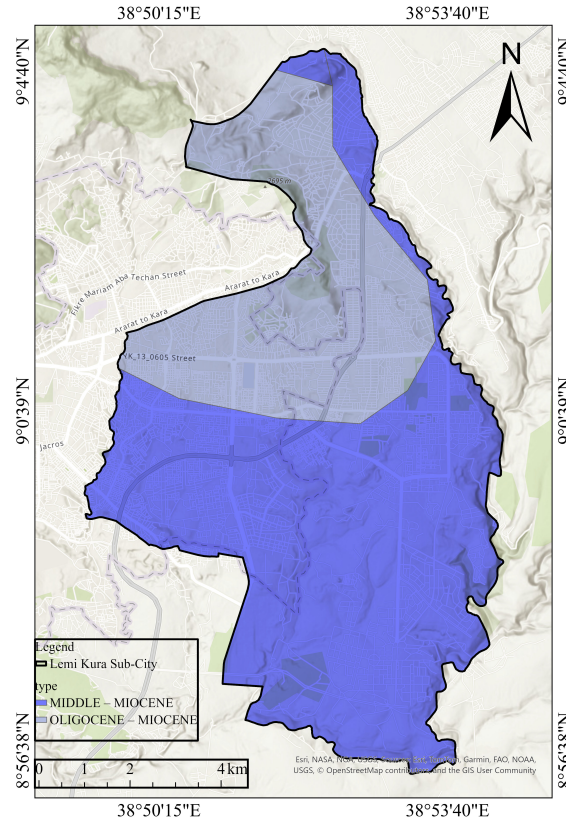


Figure 4.12: Geological Map

## 4.9 AHP Analysis

The weighting of suitability criteria played a pivotal role in the analysis, as it fundamentally influenced the validity of the resulting suitability map. To establish objective weight assignments, we employed Saaty’s 9-point scale (Saaty, 1980) for pairwise comparison of criteria (e.g., evaluating slope importance relative to soil type). These comparative judgments were analyzed using the BPSMSG AHPcalc tool (Goepel, 2018), which implements the Analytic Hierarchy Process (AHP) through geometric mean calculations. The methodology ensured rigorous weight derivation while maintaining consistency ( $CR \leq 0.1$ ), thereby reducing subjective bias in the prioritization of factors affecting residential suitability.

To address potential discrepancies among stakeholders, consensus was quantified using Shannon entropy (Goepel, 2013), measuring the dispersion of expert opinions across the decision group. During data collection, 15 domain experts (e.g., urban planners, environmental scientists) participated in structured interviews, ranking criteria based on local conditions. Their inputs were aggregated into a unified weight set, reconciling conflicts through iterative feedback—a technique adapted from the Delphi method.

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## 4.10 Computed Layer Weights

This research employed the Analytic Hierarchy Process (AHP) to systematically evaluate five critical physical determinants of residential suitability: (1) Land Use/Land Cover (LULC), (2) Elevation, (3) Slope, (4) Soil Characteristics, and (5) Geology. The weighting analysis incorporated inputs from 15 domain experts representing diverse professional backgrounds, including urban planning, land administration, real estate management, cadastral services, and local governance. Through structured pairwise comparisons, we derived normalized weight percentages for each criterion along with corresponding uncertainty measures, which quantify the dispersion in expert judgments. The resulting weights reflect both the collective expertise and the inherent variability in professional perspectives across these disciplines.

The AHP results, summarized in Table 4.5, reveal a clear prioritization of physical factors relevant to residential development planning. LULC and elevation emerged as the most influential factors, indicating their dominant role in shaping spatial suitability for housing development.

Table 4.5: AHP Results (Weight  $\pm$  Uncertainty)

Rank	Criterion	Weight	%	Uncertainty	( $\pm$ )	%
1	Land Use/Land Cover (LULC)	27.8	%	5.0		%
2	Elevation	26.5	%	4.0		%
3	Slope	16.8	%	3.2		%
4	Soil Characteristics	15.8	%	2.3		%
5	Geology	13.0	%	2.2		%

The analysis shows that LULC and elevation together contribute more than 54% of the total decision weight, emphasizing their critical influence in determining suitable residential areas within Addis Ababa's diverse physical landscape. Despite some variation in expert input (with uncertainty ranging from  $\pm 2.2\%$  to  $\pm 5.0\%$ ), the overall consistency of judgments was within acceptable limits. The AHP computation yielded a principal eigenvalue ( $\lambda_{\max}$ ) of 5.057, with a Consistency Index (CI) of 0.014 and a Consistency Ratio (CR) of 1.3%. Since the CR is well below the standard 10% threshold, this confirms that the pairwise comparisons among the five criteria were logically coherent and reliable.

### 4.10.1 Consistency Validation of AHP Pairwise Comparisons

The reliability of the Analytic Hierarchy Process (AHP) results depends fundamentally on the consistency of the pairwise comparison judgments. The resulting CR of 1.3% is well below the critical threshold of 10% (Saaty, 1980), confirming that our expert judgments maintain satisfactory logical consistency and the weight derivation process is mathematically valid.

Furthermore, the Geometric Consistency Index (GCI) was calculated as 0.05, and the Psi value was 20.0%, both of which support the conclusion that the consensus among the

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15 participants was reasonable. The mean relative error (MRE) of 16.8% with an estimated MRE of 16.9% indicates a moderate spread in expert evaluations but remains within an acceptable range for decision-making contexts involving human judgment. These consistency and validation metrics collectively ensure the robustness and credibility of the computed weights and confirm the soundness of the AHP methodology applied in this study.

Specifically, LULC was rated as the most important factor ( $27.8\% \pm 5.0\%$ ), reflecting considerations such as zoning policies, land accessibility, and potential for land use conversion. Elevation followed closely ( $26.5\% \pm 4.0\%$ ), underscoring its role in climate suitability and construction feasibility in a topographically complex setting. Slope ( $16.8\% \pm 3.2\%$ ) ranked third, as steep gradients pose challenges for infrastructure and increase erosion risks. Soil characteristics ( $15.8\% \pm 2.3\%$ ) were also significant, influencing foundation stability and drainage. Geology ( $13.0\% \pm 2.2\%$ ) was rated lowest but still contributes to structural safety and subsurface assessments, particularly related to groundwater and seismic risks.

## 4.11 Mapping of Physical Residential Suitability Map

The residential suitability map was generated by integrating five weighted criteria layers within a Geographic Information System (GIS) framework. Based on the Analytic Hierarchy Process (AHP) derived weights, each factor, including Land Use/Land Cover (LULC), elevation, slope, soil characteristics, and geology, was reclassified and assigned its respective importance value. The weighted overlay analysis was then performed to combine these layers.

The combination of AHP with GIS significantly enhanced the analysis by allowing the AHP-derived weights to be applied directly to spatial datasets. For example, areas vulnerable to flooding and debris flow were assigned lower suitability scores when overlaid with highly weighted criteria such as elevation and slope. This blended approach merging expert judgment through AHP with spatial data in GIS proved especially valuable for tackling complex, multi-criteria decisions involving raster-based inputs. It offers a transparent and structured way to transform subjective preferences into objective, spatially explicit outcomes. Similar methods have shown strong results in applications like flood risk assessment (Malczewski, 2011) and renewable energy site selection (Azizi et al., 2022), reinforcing its effectiveness in sustainable land-use planning.

The residential site suitability analysis resulted in a classified map delineating three distinct suitability zones across the study area: very low suitability, moderate suitability, and very high suitability potential for residential development in the study area. Out of the total area of 78.67 km<sup>2</sup>, approximately 23.28 km<sup>2</sup> (30.87%) was identified as having very low suitability, while 8.73 km<sup>2</sup> (13.64%) was categorized as having moderate suitability. A significant portion, 23.28 km<sup>2</sup> (25.78%), fell under the moderately suitable category, indicating areas with some development potential but possible constraints.

These findings offer valuable insights for urban planners, real estate developers, and policymakers, guiding future land use decisions, zoning regulations, and infrastructure

Table 4.6: Residential Suitability by Physical Criteria in Lemi Kura

Rank	Suitability Class	Area (km <sup>2</sup> )	Percentage%
1	Highly Suitable	20.28	25.78 %
2	Low Suitable	24.28	30.87 %
3	Moderately Suitable	10.73	13.64 %
<b>Total (Accounted Area)</b>		<b>55.29</b>	<b>70.29 %</b>

planning. The classified suitability map was presented in Figure 4.13, which illustrates the spatial distribution of residential suitability across the Lemi Kura Sub-City, enabling an informed understanding of where sustainable development should be prioritized.

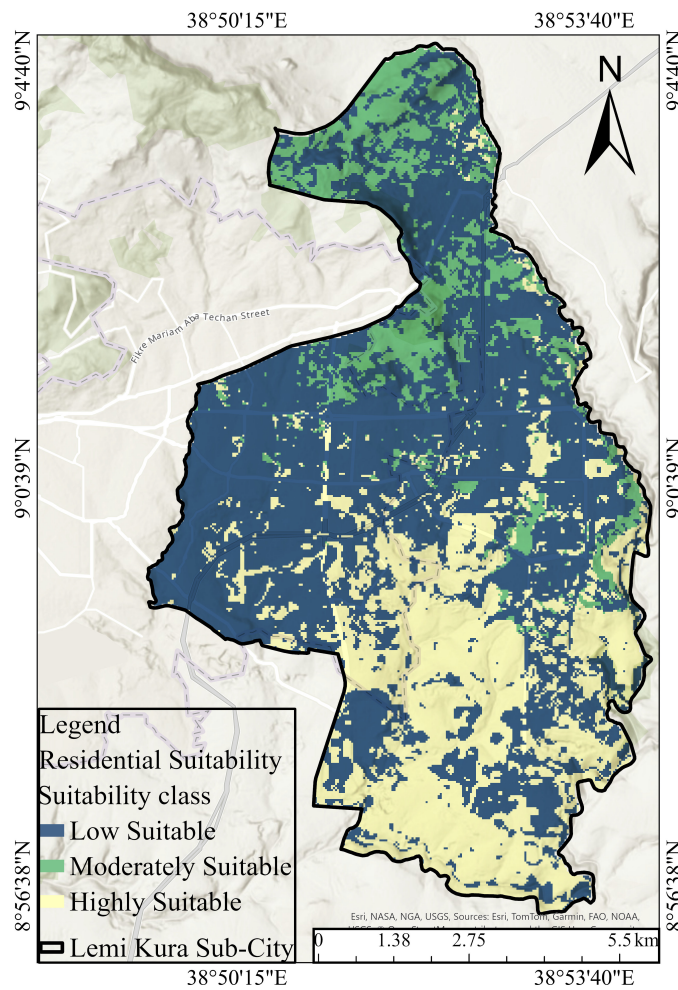


Figure 4.13: Residential Suitability Map Based on Physical Criteria

## 4.12 Residential land value modeling

The integration of Geographic Information Systems (GIS), the Analytical Hierarchy Process (AHP), and residential land value modeling using multiple regression analysis has improved site suitability analysis. The residential land value modeling was developed

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using a geospatial and sales comparison approach (SCA).

Prior to data collection, a dual-method approach combining comprehensive literature review and Analytic Hierarchy Process (AHP) was implemented to identify the most influential variables for land value modeling in the study area. The AHP results, presented in Table 4.7, revealed two distinct categories of significant determinants: (1) property-specific characteristics, including market price, built-up area, floor level, number of rooms, and property type; and (2) accessibility metrics comprising distance to schools (DIST\_SCH), distance to health centers (DIST\_HC), access to main roads (AMR), proximity to city center (ACC), distance to sub-city center (ASCC), and accessibility to marketplaces (AMP). Additionally, categorical variables distinguishing between fully furnished and unfurnished properties were identified as influential factors in the valuation model.

Table 4.7: AHP Weights and Percentages Based on Expert Judgement

Criteria	Weight	Percent (%)
Price	0.1687	16.87
Location	0.3614	36.14
Transport	0.2312	23.12
Environment	0.0690	6.90
Bldg. Struct.	0.1016	10.16
Pub. Services	0.0680	6.80

The AHP results presented in Table 4.7 demonstrate that three primary factors significantly influence potential homebuyers' decisions: location attributes, transportation accessibility, and property pricing. Furthermore, the analysis reveals that secondary considerations, including building structural characteristics, availability of public services and amenities, and environmental quality, collectively contribute to residential property selection. These findings align with established real estate valuation theories, which emphasize the multidimensional nature of housing purchase decisions.

The data are classified into dependent and independent variables to determine the relative influence of independent variables on land market sales prices. The dependent variable is price, while independent variables include property characteristics (area, floor, room, type), accessibility measures (DIST\_SCH, DIST\_HC, AMR, ACC, ASCC, AMP), and categorical distinctions (type).

For the land value modeling, a total of 101 residential prices were collected from 2024 to 2025 in the Lemi Kura subcity. The property prices were obtained using the sales comparison approach (SCA). To ensure realistic results, only condominium sales prices from 12 woredas in Lemi Kura sub-city were included. Data on price, area, floor number, and type were gathered during field data collection. Proximity variables were calculated using the ArcGIS Pro Proximity tool, specifically the Near tool. Finally, the attribute data were exported in Excel format, and simple multiple linear regression analyses were performed using R statistical software. Additionally, the data used in this study were categorized into spatial data and non-spatial data, which are shown in the following table 4.8.

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Table 4.8: Classification of Variables Used for Land Value Modeling

Variable	Spatial	Non-Spatial	Dependent	Independent
Market Price (Price)		✓	✓	
Area		✓		✓
Floor		✓		✓
Number of Rooms		✓		✓
Type (Furnished/Unfurnished)		✓		✓
DIST_SCH	✓			✓
DIST_HC	✓			✓
AMR	✓			✓
ACC	✓			✓
ASCC	✓			✓
AMP	✓			✓

The non-spatial data describe the real land price and are collected through interviews with experts and local sales about the residential land value in the land market.

### 4.13 Influence factors of residential land value

Estimation of the actual residential land value is one of the complicated tasks for which it is not possible to determine the exact value. However, it's possible to predict the land value by developing a model using multiple valuation variables. The dependent and independent land valuation model was selected for the model development, which uses both spatial and non-spatial datasets. These used variables are price, area, floor, number of rooms, type, proximity to (school, health centers), and access to (main road, city center, subcity center, and marketplace).

In reality, it is close to impossible to calculate an exact value of a land parcel, but asset value estimation is feasible. To estimate the value, some land valuation factors, which influence the total perceived value of a land parcel, were selected and spatially examined employing the developed model. From among the land valuation factors being considered for comparison with benchmark price and expert opinion, the majority influence factors can be identified. And such influence factors are non-spatial fieldwork and spatial fieldwork. In this section, the majority of independent variables will be described and measured.

#### 4.13.1 Proximity to city centre

Several studies include explicit variables describing urban characteristics in the residential location choice (Schirmer et al., 2014). The distance from the residential house to the main city center significantly affects the land value. According to Ai (2005) explains land prices in residential areas mainly depend on the relation to transportation costs and distance from the city center and subcenters.

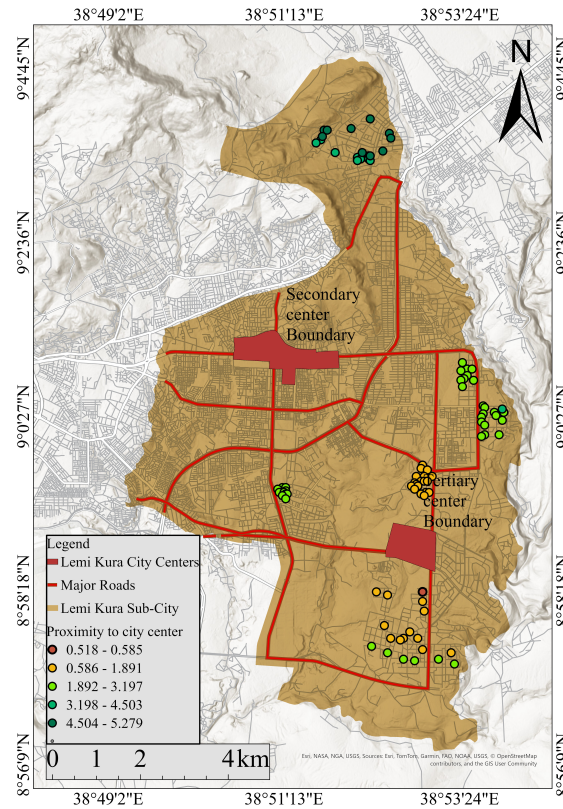


Figure 4.14: Accessibility to city center (ACC)

The city center serves as the primary, most important, and often historical core of business and employment areas. In the study area, two main city centers were identified. The city center was derived from the structural plan of Addis Ababa Administrative City (Figure 1). This framework outlines key zones for commercial activities, cultural landmarks, and public services, which collectively enhance the urban experience. Additionally, these city centers play a crucial role in the growth trajectory of the sub-city, making them vital for residents.

The accessibility to Lemi Kura city center is calculated for each sample using the ArcGIS Pro proximity tool. From this map, it shows the grade of the accessibility to the city center, ranging from 0.5 km to 5 km. The accessibility to Lemi Kura city center is calculated for each sample using the ArcGIS Pro proximity tool. From this map, it shows the grade of the accessibility to the city center ranges from 0.5 km to 5 km. The accessibility to the city center is shown in the figure below, figure 4.14.

#### 4.13.2 Proximity to Sub-city center

The same procedure as the measurement of accessibility to the city center has been used to measure the least distance of each sample to the subcenter. The sub-city center data was extracted from the structural plan of Addis Ababa. Sub-city centers were used as they are defined as places planned and designated for commercial use. Additionally, it is described as an area with a higher level of employment and activities than neighboring areas.

The distance to the Lemi Kura sub-city center is calculated for each sample using the ArcGIS Pro proximity tool near tool. From this map, it shows the grade of the distances to the sub-city center, ranging from 0.131 km to 2.2 km. The accessibility to the city center is shown in the figure below, figure 4.14.

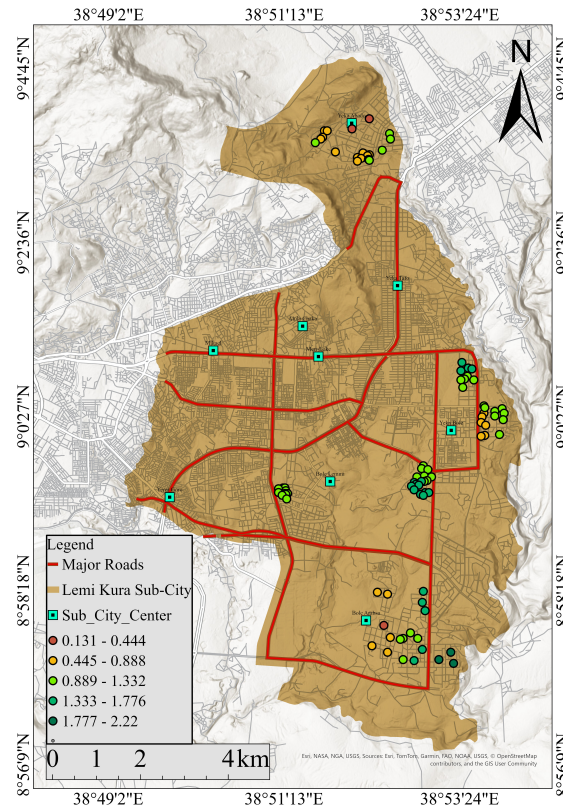


Figure 4.15: Accessibility to Sub-city center (ASCC1)

### 4.13.3 Distance to main road

Based on the analytic hierarchy process (AHP) analysis, accessibility to the major roads and crucial pricing factors significantly influenced land valuation in the study area. GIS-based analysis was employed to quantify this relationship, with road proximity metrics calculated using ArcGIS Pro proximity tools. The dataset includes all sampled variables, measuring Euclidean distances to the nearest arterial roads. The land price value is estimated to increase with nearness to the main road. Based on the analysis, the distance of this variable ranges from 0.025 km (near the main road) to 1.6 km (far from the main road).

### 4.13.4 Distance to school

The proximity to educational institutions was incorporated as one factor in the land value modeling. The availability of schools near to the property affects the choice of the land. The same as proximity to the city center, ArcGIS Pro proximity tools were used

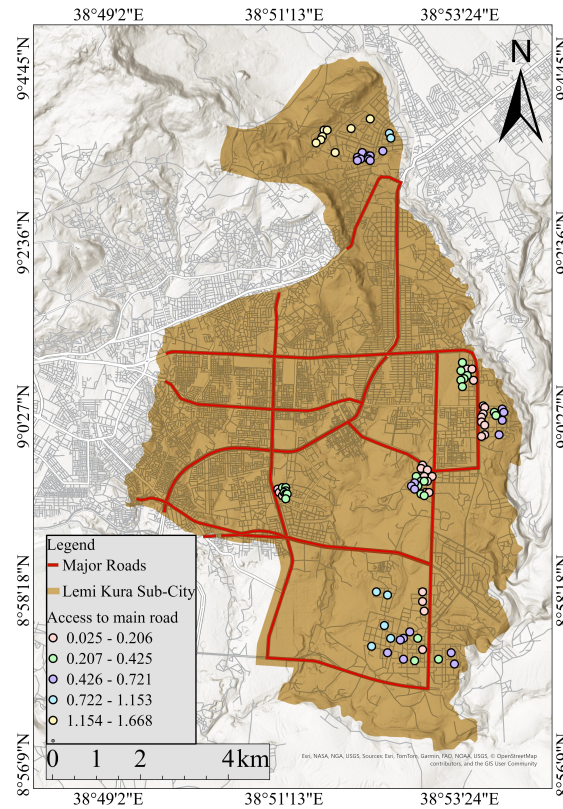


Figure 4.16: Accessibility to main road (ASCC1)

to identify the nearest schools to the sample variables using the proximity near tool in the GIS environment. The minimum observed distance from the sample variables to the nearest school is 0.5 km and the maximum observed distance is around 5.5km.

#### 4.13.5 Distance to Health Center

Healthcare facility proximity was operationalized as a critical determinant in the land valuation model, incorporating both clinics and hospitals as key amenity variables. The analysis, conducted using ArcGIS Pro's network analysis tools, revealed a substantial variation in access distances ranging from 0.55 km (optimal proximity) to 5.5 km (maximum observed distance).

#### 4.13.6 Distance to market place

The model incorporated distance to markets accessibility in addition to the above factors. These variables were analyzed using Euclidean distance measurements, calculated from each sample parcel centroid to the nearest corresponding facility using the ArcGIS proximity tool. Based on the analysis, with results showing market accessibility ranging from 0.6 to 5.0 km.

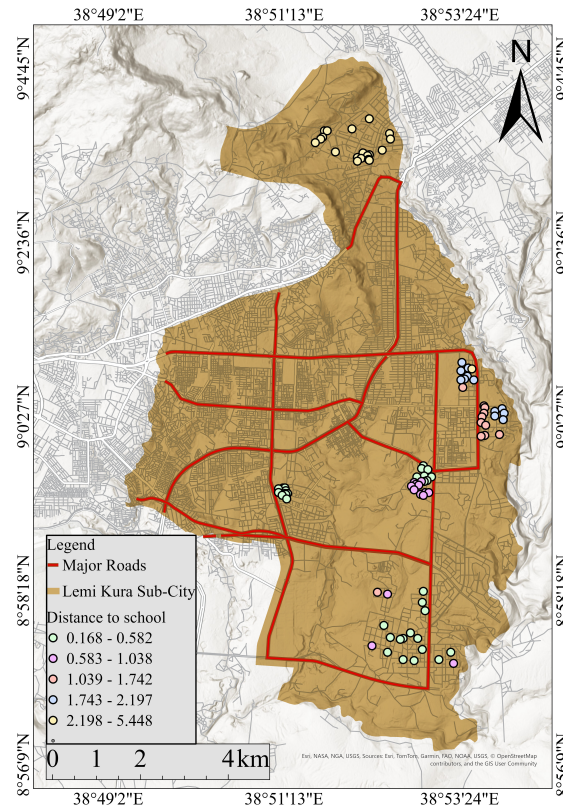


Figure 4.17: Distance to school (SCH)

## 4.14 Development of model

The land valuation model for Lemi Kura was developed through systematic geospatial data analysis and advanced GIS processing techniques. This approach addresses critical technical challenges in property assessment within the study area by employing state-of-the-art geographic analysis tools to transform raw valuation data into actionable insights. The integrated model incorporates spatial attributes, market accessibility and road network connectivity, amenity proximity to educational institutions and health center facilities and urban centrality. Relative position to Lemi Kura’s central business district and major employment hubs.

In addition to this, the location, price, number of rooms, floor, and type of property from the sales comparison approach were also included in the development of the land valuation model. This geospatial integrated approach effectively bridges the gap between conventional appraisal methods and modern data-driven valuation techniques.

In the model development, the influence factors that can potentially determine the price of land value changes were used. A hedonic regression is used to estimate a land price equation for residential land use. The ArcGIS Pro and R statistical software package was used for data analysis and model calibration.

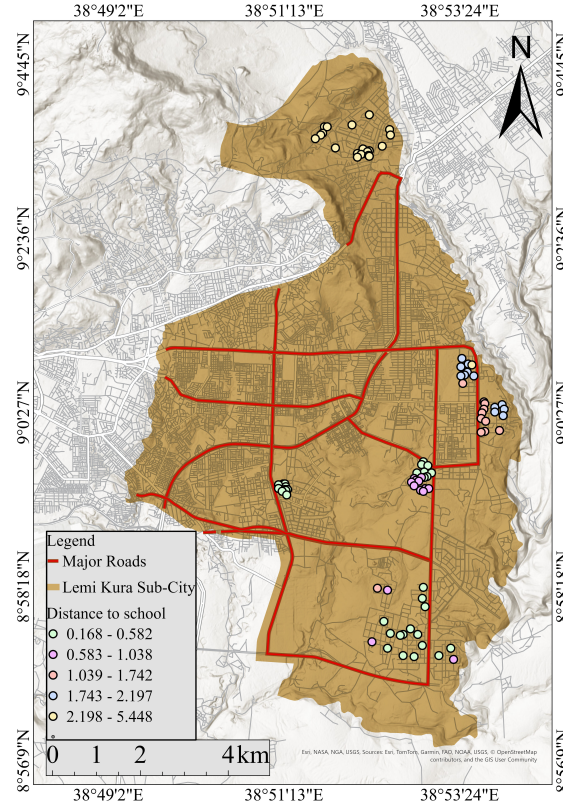


Figure 4.18: Distance to health center (HC)

#### 4.14.1 Correlation matrix

According to Zou et al. (2003), the objective of correlation analysis is to measure and explain the magnitude of a linear or nonlinear relationship between two continuous variables. Pearson correlation coefficient (PCC) is a statistical parameter that measures the magnitude and direction of a linear relationship between any random variables (Benesty et al., 2008). The values of the correlation coefficient range from -1 to 1. The sign of the correlation coefficient indicates the direction of the relationship (positive or negative)(Benesty et al., 2008; Zou et al., 2003).

The analysis utilized Pearson's product-moment correlation through R's `cor.test()` function (Zou et al., 2003).

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}} \quad (4.1)$$

Where:

- $r$  = Correlation coefficient (-1 to +1)
- $X_i, Y_i$  = Paired observations
- $\bar{X}, \bar{Y}$  = Variable means

This study uses a Pearson correlation coefficient to quantify relationships between dependent land price and the independent nine quantitative variables across 101 sample

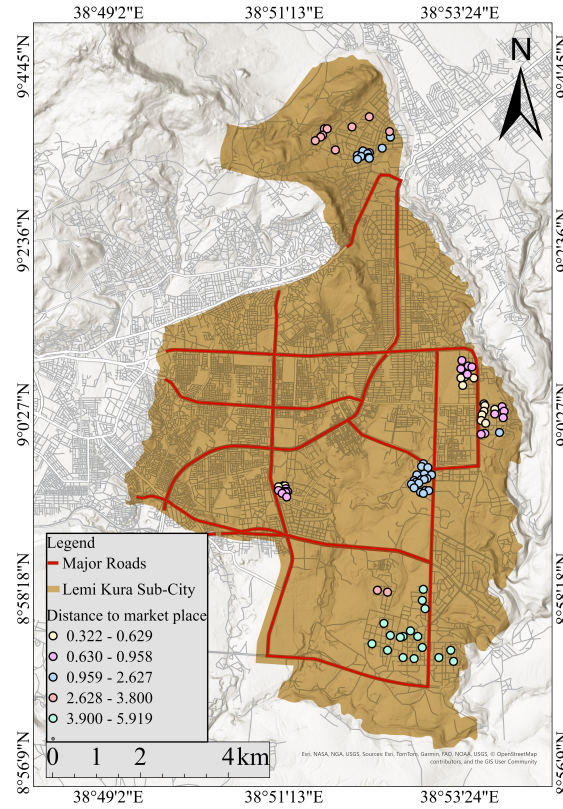


Figure 4.19: Access to market place(AMP)

parcels in Lemi Kura sub-city. One variable was systematically removed from the correlation coefficient analysis, which is the property type variable, as it is a categorical data type. The nonparametric Pearson’s correlation coefficient matrix of both dependent and independent variables was calculated and the correlation coefficient of each variable was identified as shown in (Table 4.9), which indicates a rank-order correlation coefficient.

Table 4.9: Pearson Correlation Matrix among Selected Variables

Variable	Price	Area	Floor	Room	DIST_SCH	DIST_HC	AMP	ASCC	AMR	ACC
Price	1.000	0.805	0.158	0.460	-0.257	0.218	0.105	-0.416	0.105	-0.381
Area	0.805	1.000	0.304	0.577	-0.036	0.244	-0.201	-0.226	0.156	-0.191
Floor	0.158	0.304	1.000	0.266	-0.153	0.383	-0.112	-0.157	0.166	-0.090
Room	0.460	0.577	0.266	1.000	-0.203	0.323	-0.238	-0.287	0.245	-0.207
DIST_SCH	-0.257	-0.036	-0.153	-0.203	1.000	0.091	0.630	0.890	-0.434	-0.102
DIST_HC	0.218	0.244	0.383	0.323	0.091	1.000	-0.166	0.195	0.015	-0.474
AMP	-0.381	-0.201	-0.112	-0.238	0.630	-0.166	1.000	0.550	-0.450	0.358
ASCC	-0.416	-0.226	-0.157	-0.287	0.890	0.195	0.550	1.000	-0.471	-0.213
AMR	0.105	0.156	0.166	0.245	-0.434	0.015	-0.450	-0.471	1.000	0.073
ACC	-0.316	-0.191	-0.090	-0.207	-0.102	-0.474	0.358	-0.213	0.073	1.000

Based on the results from the correlation coefficient analysis of the sample data, the area shows the strongest positive correlation with the dependent variable, property price, with a correlation coefficient of (+0.805). This indicates that a larger property area size is a significant determinant of property value. The analysis also reveals a moderate positive correlation between room and price, with a correlation coefficient of (+0.460).

This correlation shows the price of property increases as the number of rooms increases. In contrast, distance from the health center, access from the sub-city center and floor shows a weaker positive association.

Additionally, moderate negative correlation was observed in the correlation analysis. Access to the city center (ACC), access to the main road (AMR), and access to the marketplace (AMP) show correlation coefficients of -0.316, -0.381, and -0.105, respectively, which indicates that the price of a property decreases as the distance from the access to the city center, main road, and marketplace significantly reduces property value. This shows property with nearby facilities to the property is more preferred based on the analysis of the data.

Generally, based on the analysis, the correlation matrix (Table ??) shows significant relationships between land price and various spatial factors in Lemi Kura sub-city. Figure 4.21 visually represents these relationships, showing only statistically significant correlations ( $p < 0.05$ ).

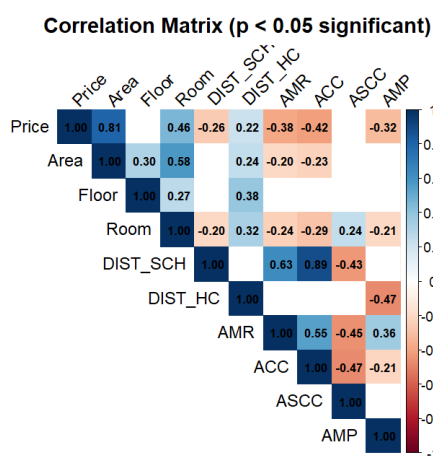


Figure 4.20: Correlation Matrix of All Variables. Blue indicates positive correlations, and red shows negative relationships (all  $p < 0.05$ ).

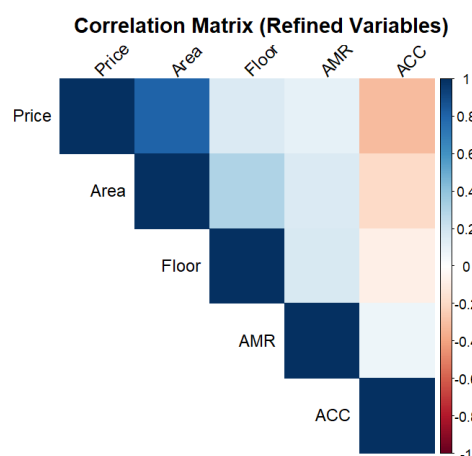


Figure 4.21: Correlation Matrix of Top 4 Variables with Price. Blue indicates positive correlations, and red shows negative relationships (all  $p < 0.05$ ).

The correlation analysis shows a significant pattern in the relationships between land valuation variables. The strong correlations to land price were identified in the correlation matrix analysis, which included the strongest positive relationship to price ( $r = 0.8055$ ), followed by number of room count ( $r = 0.459$ ). The access to the city center (ACC), the main road (AMR) and the marketplace (AMP) shows a moderate negative correlation to the price variable with a correlation coefficient of ( $r = -0.415, r = -0.381, r = -0.316$ ) respectively. Table 4.10 presents the top five variables most strongly correlated with residential property price, ranked by the absolute value of their Pearson correlation coefficients. Among them, area and number of rooms show strong positive correlations, while ACC, AMR, and AMP exhibit moderate negative associations with price, all statistically significant at  $p < 0.001$ .

The correlations demonstrate proportional relationships, with the area, room, and access to the city center with price representing a particularly strong association. In another way, distance to school (Dist\_SCH), distance to health center (Dist\_HC) and access

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Table 4.10: Top Variables Correlated with Property Price

Variable	Description	Correlation Coefficient	p-value
Area	Property size (in m <sup>2</sup> )	0.8055	$3.17 \times 10^{-24}$
Room	Number of rooms	0.4595	$1.34 \times 10^{-6}$
ACC	Access to city center	-0.4158	$1.53 \times 10^{-5}$
AMR	Access to main road	-0.3814	$8.33 \times 10^{-5}$
AMP	Access to market	-0.3160	$1.28 \times 10^{-3}$

to sub-city center (ASCC) correlation analysis indicate the absence of meaningful linear relationships between these variables with a correlation coefficient of ( $r = -0. -0.257, r = -0. -0.218, r = -0. -0.105$ ) respectively.

The strongest correlation between parcel area and price explains approximately higher shared variance ( $r^2 = 0.805^2$ ), while weaker associations like access to the subcity center ( $r^2 = -0.105^2$ ) contribute minimally to the overall explanatory power. These findings are strategic variable selection in subsequent modeling phases to balance predictive accuracy with model parsimony.

In (Table 4.9), several predictor variables in the analysis show a mutual association. The accessibility measures of room and area exhibit a particularly strong correlation ( $r = 0.577$ ). Similarly, access to the city center (ACC) and access to the main road (AMR) both correlate highly with distance to school (DIST SCH) ( $r = 0.890$ ) and ( $r = 0.630$ ) respectively). According to Ai (2005), multicollinearity occurs where the independent variables are highly correlated; however, the correlation coefficient is a dimensionless percentage, indicating only whether two variables are linearly related.

Additionally, during the sales comparison method-based data collection, the property condition (fully furnished and moderately furnished) characteristics were also considered and collected for each sample. Fully furnished is described as a completely furnished property, which includes kitchen cabinets, standard interior design, and other accessories that are not used, and moderately furnished is a property where used materials and old. As this independent variable is categorical, it's not included in the Pearson's correlation analysis. However, based on the ANOVA analysis, significant valuation differences between fully furnished and moderately furnished residential properties in Lemi Kura were observed. The boxplot visualization (Figure 4.22) reveals significant valuation differences between fully furnished and moderately furnished residential properties.



Figure 4.22: Distribution of land prices (\$/m<sup>2</sup>) by property type in Lemi Kura.

## 4.15 Model development using Hedonic regression model

This study uses hedonic price modeling to develop residential property values in Lemi Kura sub-city, Addis Ababa. The hedonic price model is used in different studies to develop land value models (Liu et al., 2010; Metzner & Kindt, 2018). The hedonic regression model was first introduced by Court (1939). Later the hedonic model was formalized by Rosen (1974), which posits that the price of a differentiated good, such as real estate, can be decomposed into the implicit prices of its constituent characteristics.

In the model development, a multiple linear regression model was employed to establish the relationship between the dependent variable and its various independent variables. The modeling process involved several stages, including model development using all potential variables, assessment of multicollinearity, model refinement, and comparison. These stages are discussed in detail in the section below.

### 4.15.1 Model Building and Refinement Outcomes

The first model was developed based on all potential predictors. The initial full model incorporated all predictor variables. For the full model, both the linear regression model is estimated using ordinary least squares (OLS) and the variance inflation factor (VIF) generated to identify potential multicollinearity and model biases. Table 4.11 and Ta-

ble 4.12 show the ordinary least squares (OLS) regression results and variance inflation factors (VIF), respectively, for all variables in the full model.

Table 4.11: Model A (All Variables) Summary with Significance Levels

Variable	Estimate	Std. Error	t-Value	p-Value	Significance
(Intercept)	4,491,502	576,836	7.79	1.12e-11	***
Area	65,152	5,007	13.00	2.14e-22	***
Floor	-102,754	38,274	-2.68	8.64e-03	**
Room	-212,127	133,074	-1.59	1.14e-01	ns
DIST_SCH	-1,301	86,388	-0.02	9.88e-01	ns
DIST_HC	77,561	73,323	1.06	2.93e-01	ns
AMR	-559,814	179,227	-3.12	2.40e-03	**
ACC	-188,894	44,198	-4.27	4.77e-05	***
ASCC	-370,031	112,528	-3.29	1.44e-03	**
AMP	-63,515	217,301	-0.29	7.71e-01	ns
Type2	-562,530	110,720	-5.08	2.02e-06	***

**Significance codes:** \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ , ns = not significant

Table 4.12: Variance Inflation Factors (VIF) for Model A and Multicollinearity Assessment

Variable	VIF	Multicollinearity Status
Area	1.985	Low
Floor	1.349	Low
Room	1.791	Low
DIST_SCH	<b>7.680</b>	<b>High (Potential Issue)</b>
DIST_HC	1.844	Low
AMR	1.470	Low
ACC	1.935	Low
ASCC	<b>8.519</b>	<b>High (Potential Issue)</b>
AMP	2.767	Moderate
Type	1.116	Low

Based on the analysis of p-values and Variance Inflation Factors (VIF), model refinement was considered to improve the hedonic price model's robustness and interpretability. Specifically, the variables DIST SCH and ASCC were candidates for removal due to their high multicollinearity, as indicated by elevated VIF values, with DIST SCH also demonstrating a lack of statistical significance. Additionally, variables such as Room, DIST HC, and AMP showed non-significant p-values and were therefore considered for exclusion to streamline the model without compromising explanatory power. This refinement aims to reduce redundancy and potential multicollinearity issues, ultimately enhancing model reliability.

The model was refined by removing 5 independent variables from the model. Room, distance to school, distance to health center, and accessibility to the main road were removed from the refined model due to their non-significance ( $p > 0.05$ ) and high VIF values. The distance to school (SCH) and access to the city center (ASCC) were removed due to their high VIF value.

Table 4.13: Full Model Regression Results for Land Value Model

Term	Estimate	Std. Error	Statistic	p-value	Significance
(Intercept)	4,036,929	122,329	33.0	$4.60 \times 10^{-52}$	***
Area	59,548	1,059	56.2	$6.73 \times 10^{-72}$	***
Floor	-65,852	8,110	-8.12	$2.31 \times 10^{-12}$	***
Room	-5,985	28,178	-0.212	$8.32 \times 10^{-1}$	
Type2	-499,284	23,612	-21.1	$1.12 \times 10^{-36}$	***
DIST_SCH	-26,738	18,343	-1.46	$1.48 \times 10^{-1}$	
DIST_HC	4,316	15,511	0.278	$7.81 \times 10^{-1}$	
AMR	-2,109	45,983	-0.046	$9.64 \times 10^{-1}$	
ACC	-283,618	23,890	-11.9	$4.08 \times 10^{-20}$	***
ASCC	-445,993	37,960	-11.7	$7.25 \times 10^{-20}$	***
AMP	-223,333	9,351	-23.9	$1.01 \times 10^{-40}$	***

A refined hedonic pricing model was developed using the top five independent predictor variables identified through correlation analysis. The model includes the variables area, floor, AMR (access to main road), ACC (accessibility to city center), and property type. The results of the regression are presented in Table 4.14. These variables were selected to improve model interpretability while maintaining predictive strength. Table 4.14 presents the estimated coefficients and statistical significance levels for each variable in the refined hedonic pricing model.

Table 4.14: Model B (Refined) Linear Regression Results

Variable	Estimate	Std. Error	t-Statistic	p-Value	Significance
Intercept	3,035,836	468,027	4.35	3.43e-05	***
Area	67,599	4,883	13.80	1.64e-24	***
Floor	-75,136	44,298	-2.05	5.31e-02	.
AMR	9,720	192,526	2.34	4.60e-01	**
ACC	-138,910	41,317	-3.36	1.12e-03	**
Type2	-679,420	134,134	-5.07	2.00e-06	***

Significance codes: \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ , .  $p < 0.1$

According to the model analysis, the intercept is estimated at 3,035,836 ETB and is statistically significant at the 0.1% level. This value theoretically represents the base price of a residential property when all independent variables are equal to zero. The r-square values of the model show the predicted price of the property indicates 0.788 correlation with the actual values. This shows a strong, positive correlation was observed using the refined model as shown in the following figure 4.26.

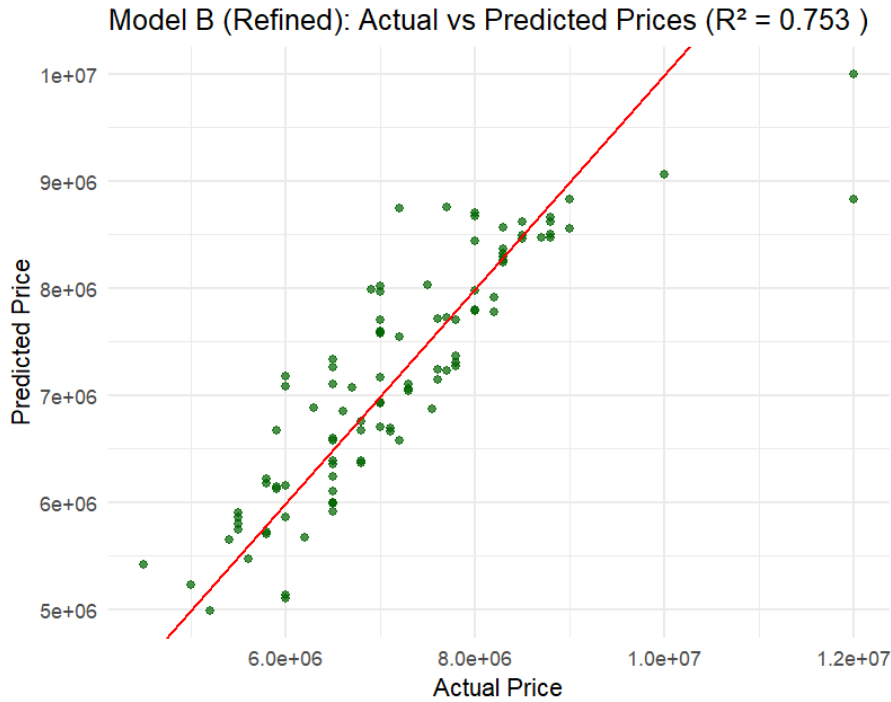


Figure 4.23: Actual vs Predicted property value prediction

#### 4.15.2 Final Model Interpretation

The final refined model (Table 4.14) offers insights into the key drivers of property prices. These drivers include factors such as area, floor, property condition, and access to the marketplace, which collectively affect land value trends in the study area. Understanding these elements will empower stakeholders to make informed decisions about property investments and pricing strategies. By using this model, investors can identify profitable opportunities and adjust their approaches based on real-time market dynamics. Additionally, policymakers can utilize these insights to create regulations that promote sustainable development and equitable access to housing.

The estimated equation of the final hedonic model is:

$$\text{Price} = \beta_0 + \beta_1 \text{Area} + \beta_2 \text{Floor} + \beta_3 \text{AMR} + \beta_4 \text{ACC} + \beta_5 \text{Type}_2 \quad (4.2)$$

Coefficient	Value
$\beta_0$ (Intercept)	3,035,836.13
$\beta_1$ (Area)	67,599.05
$\beta_2$ (Floor)	-75,135.58
$\beta_3$ (AMR)	9,719.77
$\beta_4$ (ACC)	-138,909.87
$\beta_5$ (Type <sub>2</sub> )	-679,420.28

Each coefficient represents the marginal implicit price of the corresponding characteristic, holding all other characteristics constant.

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Based on the hedonic pricing model, it reveals the coefficient for the area variable is 67,599 ETB, which is positive and highly significant ( $p < 0.001$ ). This suggests that, holding other factors constant, each additional square meter or kare of each property area increases the predicted market value by approximately 67,599 ETB. This result aligns with standard economic principles of real estate valuation, where larger properties are generally more valuable. It also reflects buyer preferences in the local market that favor more spacious housing.

$$\frac{\partial \text{Price}}{\partial \text{Area}} = 67,599 \text{ birr/kare} \quad (4.3)$$

In addition, in the model, when the property found on a higher floor is associated with a decrease of approximately 6-75,135.58 birr in price. This finding suggests a preference among residents for lower-floor properties within the study area. This indicates a tendency for higher-floor units to be slightly less valuable than those on lower floors, potentially due to reduced convenience, especially in buildings lacking elevator access. Although the effect is not strongly significant, it provides some empirical support for the hypothesis that floor level may influence perceived housing quality or accessibility in the study area.

The coefficient for AMR is estimated at 9,720 ETB; however, it is not statistically significant ( $p = 0.960$ ). This result indicates that access to market roads does not have a consistent or reliable impact on property prices within the study context. It is possible that market road proximity is already captured by other accessibility-related variables or that local buyers do not prioritize it as a key factor in residential decision-making in the study area.

The refined hedonic price model indicates that non-furnished properties are associated with a decrease in price of approximately 679,420.28 ETB compared to furnished properties. This result suggests a strong influence of furnishing status on property price. The coefficient for type being negative confirms that furnished properties generally command higher prices in the market, consistent with buyers' preference for move-in-ready units.

$$\Delta \text{Price}_{\text{Furnishing}} = \beta_{\text{Moderate}} = -679,420.28 \text{ birr} \quad (4.4)$$

The variable ACC shows a negative and statistically significant association with property prices, with a coefficient of -138,910 ETB ( $p = 0.001$ ). This finding suggests that property at a distance from the city center may be associated with a decrease in property value.

Based on the analysis, as the distance from the major road (AMR) increases, it is directly associated with a decrease of approximately 228,120 birr in price. This is also highly significant ( $p < 0.001$ ), emphasizing the premium placed on properties with better access to public transportation.

## 4.16 Potential Land suitability Map

The predicted land values from the hedonic model were exported to ArcGIS Pro for spatial analysis. Using geostatistical interpolation, an inverse distance weighting (IDW)

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approach was applied to generate a continuous land value surface across the study area.

The interpolated land values were normalized to a standardized 1–5 scale using the following transformation (Hu et al., 2013) :

$$\text{Normalized Value} = 4 \times \left( \frac{V_i - V_{\min}}{V_{\max} - V_{\min}} \right) + 1 \quad (4.5)$$

where:

- $V_i$  represents the original land value estimate
- $V_{\min}$  denotes the minimum observed land value
- $V_{\max}$  indicates the maximum observed land value

Through stakeholder interviews and expert consultations, a weighted overlay scheme was established with physical suitability factors of 60% weight and land value considerations of 40% weight. The integrated analysis produced a residential suitability map that was subsequently classified into three distinct suitability categories (Figure 4.24):

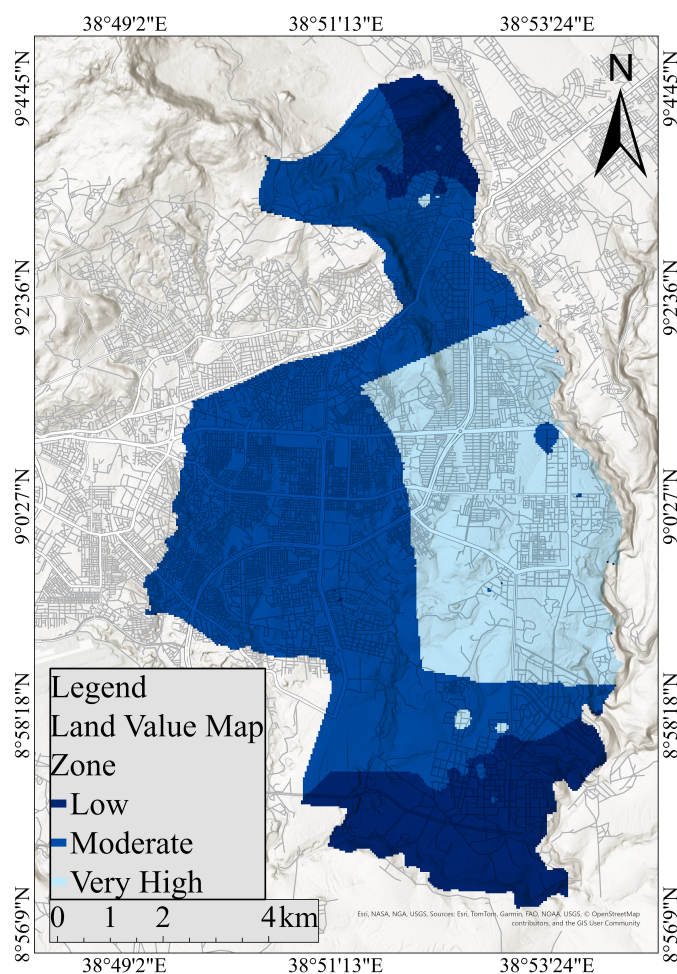


Figure 4.24: Residential suitability classification showing three zones: (1) High, (2) Moderate, and (3) Low suitability areas

The comprehensive suitability analysis identified three distinct residential development zones in Lemi Kura sub-city. Using weighted overlay techniques combining physical suitability (60% weight) and land value factors (40% weight). The comprehensive residential site suitability analysis identifies a potential residential land suitability based on the physical and economic factors. The classification was carried out by dividing the study area into three major suitability classes: highly suitable, moderately suitable, and low suitable.

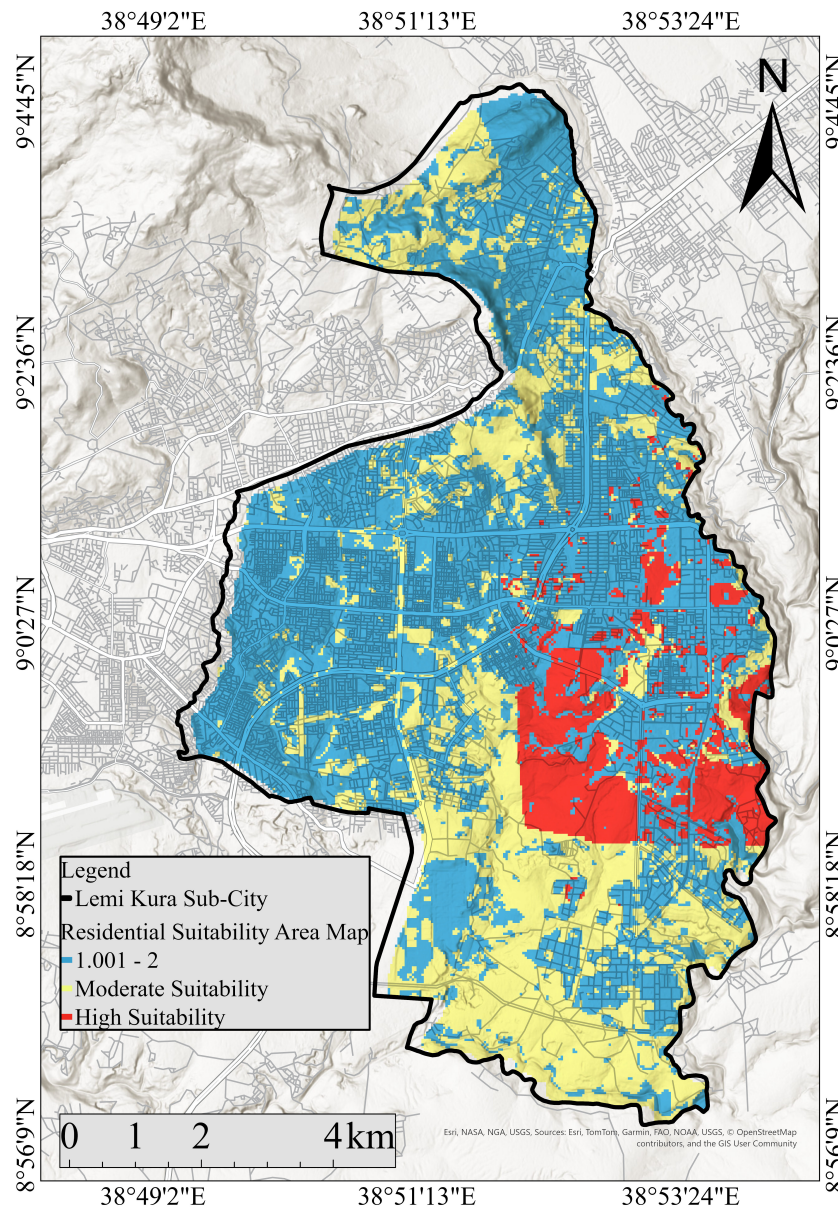


Figure 4.25: Real estate suitability map of Lemi-kura Sub-city

The residential site suitability classification reveals a significant disparity in the distribution of residential potential across the study area. Only a small portion, approximately 6.98 km<sup>2</sup> or 8.10%, of the land is classified as highly suitable for residential use. suggests limited availability of prime land that meets the highest suitability criteria, possibly due

to constraints such as terrain, accessibility, or infrastructure. Meanwhile, a moderate proportion 22.83 km<sup>2</sup>, equivalent to 26.51% falls under the **moderately suitable** category. These areas may support residential development with certain improvements or planning considerations, such as infrastructure upgrades or service provision.

The majority of the land, 45.21 km<sup>2</sup> or 65.39%, is classified as low suitable. This indicates that most of the land may not be ideal for residential development under current conditions and may require substantial investment or should be reserved for other land uses. This uneven distribution emphasizes the need for informed spatial planning and investment prioritization to ensure sustainable urban expansion and efficient land use management.

Table 4.15: Suitability Class Distribution

Suitability Class	Area (km <sup>2</sup> )	Percentage	Development Potential
High	6.98	8.10%	Immediate development
Moderate	22.83	26.51%	Conditional development
Low	45.21	65.39%	Restricted development

## 4.17 Comparison of Final Residential Suitability Map with Existing Structural Plan

The resulting residential suitability map, derived from a combination of physical and economic factors, identifies the most suitable locations for residential developments. However, when compared with the updated structure plan of Lemi Kura sub-city developed by the Addis Ababa City Plan Commission, various inconsistencies were identified. The result adds valuable insight into potential inefficiencies in existing land use planning and future policy action to ensure sustainable city growth.

Based on the comparison analysis, the existing mixed residential built-up in the study area lies within medium and low suitability zones of the area. This shows the residential expansion in the Lemi Kura subcity has been driven by unplanned urban growth structure. This will result in poor accessibility, topographical restraints, an environmentally unsound situation, and lower economic hub proximity in the study area.

The structural design shows that several industrial areas have been positioned adjacent to residential neighborhoods and water bodies. This goes against established environmental and public health standards, which generally recommend buffer zones between residential neighborhoods and industries. Being adjacent to rivers also discredits the matter of water pollution and destruction of habitats. Such an environmental use is highly hazardous to environmental sustainability and people's health.

Additionally, based on the analysis of the structural plan of Lemi-Kura sub-city, the siting of solid waste disposal sites along and even on riverbanks revealed there are serious deficiencies in the structural plan, which is an indicator of serious planning deficiencies. The areas are rated to have low and medium suitability in the final map primarily due

to environmental concerns and flooding hazard risk. It violates basic urban sanitation and environmental requirements and compromises the long-term ecological integrity of the area.

Finally, spatial incompatibility of suitability categories and the current structural plan of the study area demonstrates the need for a data-driven-based planning strategy. Redevelopment and prospective urban expansion need to be guided by suitability model-based analysis to ensure environmental preservation and public security of health.

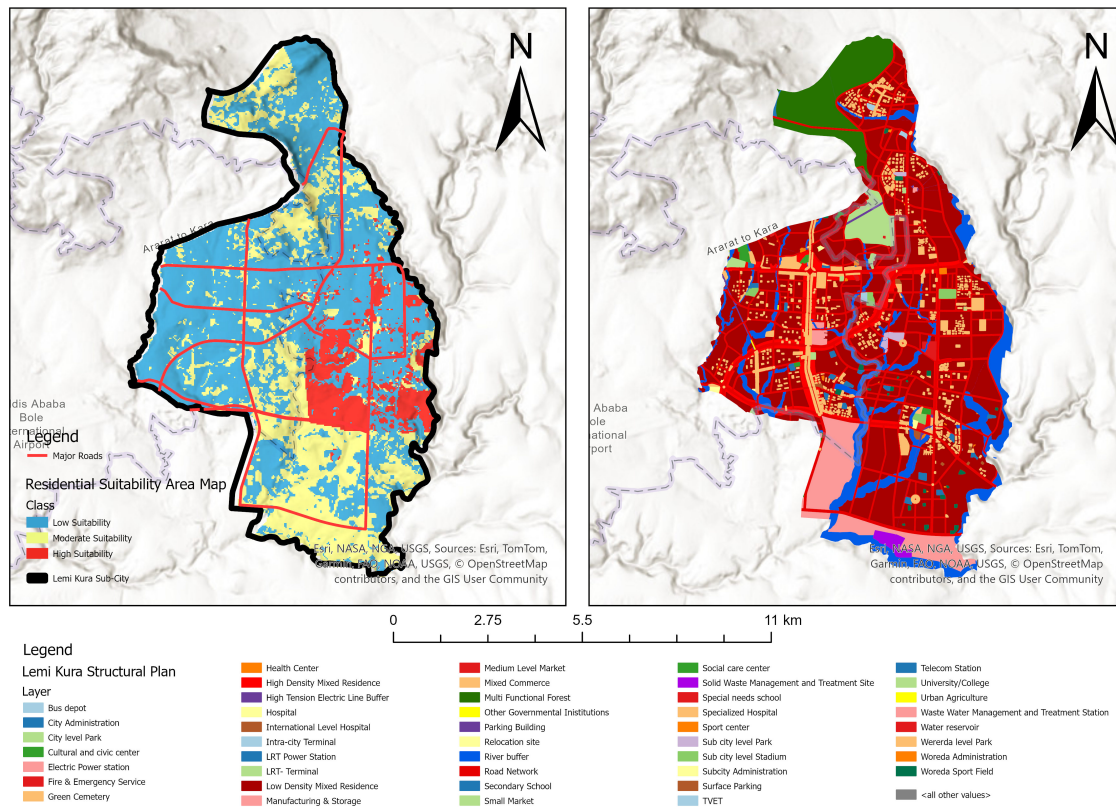


Figure 4.26: Comparison of Final Residential Suitability Map with Existing Structural Plan

In conclusion, the analysis reveals a wide disconnect between common land use practices and recommendations for suitability-based planning. Filling this gap will be crucial to the development of sustainable, effective, and equitable urban expansion in Lemi Kura sub-city.

# Chapter 5

## Conclusion and Recommendations

### 5.1 Conclusion

This study comprehensively assessed the real estate investment site suitability analysis of a residential area in Lemi Kura Sub-city, Addis Ababa, through the integration of stakeholder views together with a Geographic Information System (GIS), Analytic Hierarchy Process (AHP) approach, and hedonic land value modelling.

The high survey response rate of 89.47% reflected active participant involvement, which set the reliability of the data obtained from urban planners, real estate developers, and local government administrators. The result of the analysis showed that Lemi Kura Sub-city is rapidly undergoing demographic transformation, characterized by a very rapid population increase perception of 68.4% and an evident housing demand-supply gap, with 78.9% of the respondents testifying to demand outpacing supply. Rural-to-urban migration was offered as the primary driver for such growth, accounting for 57.9% of observed population growth, all factors with direct significance on land value dynamics.

Topographic conditions, particularly slope and elevation, were also recognized as being critical in site suitability, with over 84% of the respondents validating their importance. Such physical features are essential determinants of developable land. Environmental concerns, specifically soil stability and quality, water supply, and natural disaster hazard, were recognized as a priority for future residential development. These must be incorporated into land value models because natural hazard and resource availability are key drivers of land desirability and long-term economic viability. Besides, the assessment of accessibility and infrastructure further asserted the importance of well-developed transportation networks and being near amenities like schools, hospitals, and job hubs, with over 76% of respondents rating these as highly important. The strong support for accessibility of public transport (81.6%) underscored the need for coordinating urban growth with transit-oriented planning, which significantly enhances land value within accessible areas.

The physical suitability analysis, conducted using Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP), assessed factors such as Land Use/Land Cover (LULC), slope, elevation (DEM), soil, and geology. Among these factors, LULC and elevation emerged as the most influential, contributing 27.8% and 26.5%, respectively, to the overall decision-making weight. The analysis revealed that out of the total

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area of 78.67 km<sup>2</sup>, approximately 23.28 km<sup>2</sup> (30.87%) was identified as having very low suitability, while 8.73 km<sup>2</sup> (13.64%) was categorized as low suitability. A significant portion, 20.36 km<sup>2</sup> (25.78%), was classified as moderately suitable—indicating some physical constraints that would require careful planning and intervention.

In parallel, the economic suitability of land was evaluated using a hedonic pricing model to estimate residential land value. The model showed that land area was a significant factor influencing property value, with larger plots contributing to higher values. Proximity to city centers, sub-city hubs, and major roads also had a substantial positive effect on land values. Additionally, housing conditions played a key role: fully furnished properties commanded, on average, about 679,420.28 Ethiopian birr more than moderately furnished properties.

When integrating both physical and economic factors, the final residential site suitability classification revealed a notable disparity in the distribution of development potential across the study area. Only a small portion, 8.10%, was classified as highly suitable for residential use. This suggests that prime land meeting both physical and economic criteria is limited, likely due to constraints related to terrain, accessibility, or infrastructure. A moderate proportion, 26.51%, was categorized as moderately suitable, indicating areas that may support residential development if infrastructure improvements and planning measures are implemented. The majority of the land, 65.39%, was deemed to have low suitability, meaning it is less favorable for development under current conditions and may require substantial investment or be reserved for alternative land uses.

In terms of economic analysis of the land value, the study utilized a hedonic regression pricing model to examine residential land value. Based on the developed model, area is one of the significant variables that increase the property value. Proximity to city centers, sub-city hubs, and major roads also significantly increased land values. Moreover, housing conditions played a key role in pricing, with fully furnished properties commanding a substantial premium on average, about 492,577 Ethiopian birr more than their moderately furnished counterparts.

In conclusion, this study presents a replicable and practical methodology for guiding sustainable residential planning in rapidly urbanizing contexts. Its integration of spatial data, environmental assessment, and economic modeling contributes to informed decision-making that promotes sustainable growth, environmental stewardship, and social equity.

## 5.2 Recommendations

Land valuation should be systematically and regularly updated to reflect real market dynamics and development trends. This will improve benchmark pricing and enable more informed land-use planning decisions. The spatial comparison between the refined residential suitability map and the existing structural plan of Lemi Kura sub-city has identified significant spatial discrepancies, requiring immediate planning and policy-level intervention. The following recommendations are based on empirical findings through the hedonic pricing model, spatial suitability analysis, and land use conflicts identified from the updated structural plan of Lemi-Kura Sub-city:

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- Based on the analysis, it's highly recommended that the sub-city and Addis Ababa planning commission should undertake a comprehensive review of the structure plan to align with the model-based suitability classification for future residential, industrial, and infrastructural development. The completed model integrates both physical constraints and economic land values, resulting in a more realistic identification of real estate development areas. Continued development in unsuitable areas reduces housing quality and increases urban vulnerability to natural and environmental-related health issues.
  - During the comparison of the identified site with the existing structural plan, solid waste disposal sites were located near riverbanks, which are highly vulnerable hydrological zones, which is not recommended in line with national environmental policy and WHO standards. The suitability map classifies these zones as low and medium suitability due to flood risk and ecological sensitivity. The continued use of these zones for waste disposal not only violates concepts of sustainable urban planning but also poses long-term threats to water quality, public health, and ecosystem services. Based on this, it's highly recommended to relocate the waste disposal site from its existing location to another suitable site based on site suitability analysis methods.
  - The structure plan proposes industrial land use in proximity to residential suburbs and riverbanks, which are economically less attractive and environmentally sensitive and it shows that these proximities increase exposure to toxins and reduce quality of life. As a result, it's highly important to enact strict zoning laws that enforce spatial separation between industrial areas and residential zones, especially along rivers and ecologically important corridors.
  - Finally, establishing an urban planning policy mandating the integration of GIS-based suitability models and market data into all future structural and zoning plans will improve the standard of living, preserve ecologically important areas and promote sustainable residential living standards in the study area.

# Bibliography

- Abagissa, J. (2019). Informal settlements in addis ababa: Extent, challenges and measures taken. *Journal of Public Administration, Finance and Law*, (15), 7–30.
- Abebe, S., & Mulugeta, D. (2023). Policy implementation gaps in east africa. *Urban Governance*, 3(1), 112–125.
- Abelti, G., Brazzoduro, M., & Gebremedhin, B. (2001, October). *Housing conditions and demand for housing in urban ethiopia: In-depth studies from the 1994 population and housing census in ethiopia* [Italian Multi-Bi Research Project ETH/92/P01]. Central Statistical Authority (CSA), Addis Ababa; Institute for Population Research – National Research Council (Irp-Cnr), Rome.
- Aboulnaga, M. M., Badran, M. F., Barakat, M. M., Aboulnaga, M. M., Badran, M. F., & Barakat, M. M. (2021). Global informal settlements and urban slums in cities and the coverage. *Resilience of informal areas in megacities–magnitude, challenges, and policies: Strategic environmental assessment and upgrading guidelines to attain sustainable development goals*, 1–51.
- Addis Ababa City Plan Preparation Authority. (2023). *Annual implementation progress report* (tech. rep.). AACPPA. Addis Ababa, Ethiopia.
- Addis Ababa Education Bureau. (2023). *Addis ababa education bureau annual report* (tech. rep.). AAEB. Addis Ababa, Ethiopia.
- Addis Ababa Environmental Protection Authority. (2021). *Climate resilient urban plan* (tech. rep.). AAEP.A.
- Addis Ababa Roads Bureau. (2023). *Road infrastructure status report* (tech. rep.). AARB. Addis Ababa, Ethiopia.
- Adenle, Y. A., Chan, E. H., Sun, Y., & Chau, C. (2021). Assessing the relative importance of sustainability indicators for smart campuses: A case of higher education institutions in nigeria. *Environmental and Sustainability Indicators*, 9, 100092.
- Ai, P. (2005). Residential land value modelling. *Faculty of Geo-Information Science and Earth Observation of the University of Twente. 2005.[An electronic resource]. Access mode: [https://www. itc. nl/library/papers\\_2005/msc/upla/ai\\_ping. pdf](https://www.itc.nl/library/papers_2005/msc/upla/ai_ping.pdf) ( : 29.12. 2017), free. Heading from the screen.*
- Aithal, B. H., & Ramachandra, T. (2016). Visualization of urban growth pattern in chennai using geoinformatics and spatial metrics. *Journal of the Indian Society of Remote Sensing*, 44, 617–633.
- Akbulut, A., Ozcevik, O., & Carton, L. (2018). Evaluating suitability of a gis–ahp combined method for sustainable urban and environmental planning in beykoz district, istanbul. *International Journal of Sustainable Development and Planning*, 13(8), 1103–1115.
- Alemu, K. (2014). *Impact of population growth on the ethiopian economic performance*. LAP LAMBERT Academic Publishing.

- 
- Alemu, K. D. (2021). Assessment of housing demand and feasibility of establishing real estate business in ethiopia. *Journal of Land Management and Appraisal*, 8(2), 28–38.
- Alemu, K. (2020). The impact of population growth on economic growth: Evidence from ethiopia using ardl approach. *Journal of Economics and Sustainable Development*, 11(3), 19–33.
- Al-Shalabi, M. A., Mansor, S. B., Ahmed, N. B., & Shiriff, R. (2006). Gis based multicriteria approaches to housing site suitability assessment. *XXIII FIG congress, shaping the change, Munich, Germany, October*, 8–13.
- Angel, S., Parent, J., Civco, D. L., Blei, A., & Potere, D. (2011). The dimensions of global urban expansion: Estimates and projections for all countries, 2000–2050. *Progress in planning*, 75(2), 53–107.
- Asrat, Z. E., Wubie, A. M., & Walelegn, M. W. (2025). Review on land suitability assessment and site selection for housing development. *Survey Review*, 57(401), 180–185.
- Attah, R. U., Gil-Ozoudeh, I., Garba, B., & Iwuanyanwu, O. (2024). Leveraging geographic information systems and data analytics for enhanced public sector decision-making and urban planning. *Magna Sci Adv Res Rev*, 12(2), 152–63.
- Authority, A. A. E. P. (2022). *Addis ababa green building guidelines* (tech. rep.). AAEP.
- Azizi, A., Malekmohammadi, B., Jafari, H. R., & Nasiri, H. (2022). Gis-based multicriteria decision analysis for wind and solar energy site selection: A systematic review. *Renewable and Sustainable Energy Reviews*, 156, 111988. <https://doi.org/10.1016/j.rser.2021.111988>
- Barbatei, I. (2020). The impact of distance to city center on housing prices. *Journal of Architecture, Urbanism and Heritage*, 3(1), 73–79.
- Barlowe, R. (1978). *Land resource economics. the economics of real estate*.
- Barnsley, M. J., Møller-Jensen, L., & Barr, S. L. (2003). Inferring urban land use by spatial and structural pattern recognition. *Remote Sensing and Urban Analysis: GISDATA 9*, 102.
- Baye, F., Adugna, D., & Mulugeta, S. (2023). Administrative failures contributing to the proliferation and growth of informal settlements in ethiopia: The case of woldia township. *Heliyon*, 9(3).
- Benesty, J., Chen, J., & Huang, Y. (2008). On the importance of the pearson correlation coefficient in noise reduction. *IEEE Transactions on Audio, Speech, and Language Processing*, 16(4), 757–765.
- Beshir, A. A., & Song, J. (2021). Urbanization and its impact on flood hazard: The case of addis ababa, ethiopia. *Natural Hazards*, 109(1), 1167–1190.
- Caprotti, F., Cowley, R., Datta, A., Broto, V. C., Gao, E., Georgeson, L., Herrick, C., Odendaal, N., & Joss, S. (2017). The new urban agenda: Key opportunities and challenges for policy and practice. *Urban research & practice*, 10(3), 367–378.
- Central Statistical Agency. (2021). *Addis ababa living standards survey* (tech. rep.). CSA. Addis Ababa, Ethiopia.
- Central Statistical Agency. (2023). *Addis ababa housing survey* (tech. rep.). CSA.
- Cervero, R. (2013). *Urban transport and land use planning: A synthesis of global knowledge*. Elsevier.
- Chandio, I. A., Matori, A.-N., Lawal, D. U., & Sabri, S. (2011). Gis-based land suitability analysis using ahp for public parks planning in larkana city. *Modern applied science*, 5(4), 177.
-

- 
- Charitonidou, M. (2022). Housing programs for the poor in addis ababa: Urban commons as a bridge between spatial and social. *Journal of Urban History*, 48(6), 1345–1364. <https://doi.org/10.1177/00961442211029903>
- Connellan, O., & Baldwin, R. (1993). The cost approach to valuation. *Journal of Property Valuation and Investment*, 11(1), 50–56.
- COROMINAS, J., LEROI, E., & SAVAGE, W. Z. (2008). Landslide susceptibility, hazard and risk zoning for land use planning. *Engineering geology*, 102(3-4).
- Court, A. (1939). *Hedonic price indexes with automotive examples*.
- Croneborg, L., Saito, K., Matera, M., McKeown, D., & van Aardt, J. (2020). Digital elevation models: A guidance note on how digital elevation models are created and used-includes key definitions, sample terms of reference, and how best to plan a dem-mission.
- (CSA), C. S. A. (2013). Ethiopian housing market and land use trends: Policy challenges and solutions. *Ethiopian Development Review*, 12(2), 75–95.
- CSA, E. (2013). Populaion projection for ethiopia: 2007-2035 central statistitcal agency. *Addis Ababa, Ethiopia*.
- Cullingworth, J. B., & Cullingworth, J. B. (2002). *The political culture of planning: American land use planning in comparative perspective*. Routledge.
- Cupal, M. (2016). Price adjustments of price-setting factors under sales comparison approach (sca). *Global Journal of Business, Economics and Management: Current Issues*, 6(2), 164–170.
- Dai, F., Lee, C., & Zhang, X. (2001). Gis-based geo-environmental evaluation for urban land-use planning: A case study. *Engineering geology*, 61(4), 257–271.
- De Montis, A., De Toro, P., Droste-Franke, B., Omann, I., Stagl, S., et al. (2000). Criteria for quality assessment of meda methods. *3rd Biennial conference of the European society for ecological economics, Vienna*, 3–6.
- De Risi, R., Jalayer, F., De Paola, F., Carozza, S., Yonas, N., Giugni, M., & Gasparini, P. (2020). From flood risk mapping toward reducing vulnerability: The case of addis ababa. *Natural Hazards*, 100, 387–415.
- Degu, A. A. (2019). The nexus between population and economic growth in ethiopia: An empirical inquiry. *International Journal of Business and Economic Sciences Applied Research (IJBESAR)*, 12(3), 43–50.
- Dubale, K. (2023). *Urban zoning laws in ethiopia*. Addis Ababa University Press.
- Echendu, A. J., & Okafor, P. C. C. (2021). Smart city technology: A potential solution to africa’s growing population and rapid urbanization? *Development Studies Research*, 8(1), 82–93.
- Economic Commission for Africa. (2022). *African urbanization trends*. UNECA.
- Erkiyhun, D. (2022). *Practices and problems of condominium housing construction projects: The case of lideta sub-city housing construction development projects in addis ababa* [Doctoral dissertation]. St. Mary’s University.
- Eshete, Z. S., & Teshome, K. (2010). Performance, challenges, and prospects of real estate financing in addis ababa. *Available at SSRN 2335525*.
- Fawad, M., Ullah, F., Irshad, M., Shah, W., Mahmood, Q., & Ahmad, I. (2022). Marble waste site suitability assessment using the gis-based ahp model. *Environmental Science and Pollution Research*, 29(19), 28386–28401.
- Federal Ministry of Health. (2022). *Health facility mapping report*. FMOH. Addis Ababa, Ethiopia.
-

- 
- Fell, R., Corominas, J., Bonnard, C., Cascini, L., Leroi, E., Savage, W. Z., on Landslides, J.-1. J. T. C., Slopes, E., et al. (2008). Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. *Engineering geology*, *102*(3-4), 85–98.
- Fikire, A. H. (2021). Determinants of urban housing choice in debre berhan town, north shewa zone, amhara region, ethiopia. *Cogent Economics & Finance*, *9*(1), 1885196.
- Fischer, G., & Makowski, M. (2000). Land use planning. *Model-Based Decision Support Methodology with Environmental Applications*, 333–365.
- Goepel, K. D. (2013). Implementing the analytic hierarchy process as a standard method for multi-criteria decision making in corporate enterprises. *Proceedings of the International Symposium on the Analytic Hierarchy Process (ISAHP)*. [https://bpmsg.com/academic/ahp\\_template.php](https://bpmsg.com/academic/ahp_template.php)
- Goepel, K. D. (2018). BPMSG AHPcalc: Analytic hierarchy process (ahp) software [Version: 2018-09-15]. <https://bpmsg.com/ahp/ahp-calc.php>
- Guillén-Mena, V., Quesada-Molina, F., Astudillo-Cordero, S., Lema, M., & Ortiz-Fernández, J. (2023). Lessons learned from a study based on the ahp method for the assessment of sustainability in neighborhoods. *MethodsX*, *11*, 102440.
- Guo, P., Zhang, F., Wang, H., & Qin, F. (2020). Suitability evaluation and layout optimization of the spatial distribution of rural residential areas. *Sustainability*, *12*(6), 2409.
- Habitat, U. (2018). Urban planning for city leaders. a handbook for kenya.
- Hagos, Y. G., Andualem, T. G., Yibeltal, M., & Mengie, M. A. (2022). Flood hazard assessment and mapping using gis integrated with multi-criteria decision analysis in upper awash river basin, ethiopia. *Applied Water Science*, *12*(7), 148.
- Haile, M. (2022). *Title of the report or publication* (tech. rep.) (Please update with exact title). Ethiopian Economics Association (EEA). Addis Ababa, Ethiopia.
- Hoque, M. A.-A., Tasfia, S., Ahmed, N., & Pradhan, B. (2019). Assessing spatial flood vulnerability at kalapara upazila in bangladesh using an analytic hierarchy process. *Sensors*, *19*(6), 1302.
- Hu, S., Cheng, Q., Wang, L., & Xu, D. (2013). Modeling land price distribution using multifractal idw interpolation and fractal filtering method. *Landscape and Urban Planning*, *110*, 25–35.
- Immanuel, T. (2023). *Determinants of commercial real estate performance: The case of addis ababa, ethiopia* [Doctoral dissertation, Thesis], <https://uir.unisa.ac.za/handle/10500/30218>.
- Information, I. -. W. S. (2003). Soil classification and mapping [Available at <https://www.isric.org>].
- Jaramillo, L. G. (2020). Make cities and human settlements inclusive, safe, resilient and sustainable. In *Mining, materials, and the sustainable development goals (sdgs)* (pp. 99–116). CRC Press.
- Jemberie, M. A., Melesse, A. M., & Abate, B. (2023). Urban drainage: The challenges and failure assessment using ahp, addis ababa, ethiopia. *Water*, *15*(5), 957.
- Jha, A. K., Bloch, R., & Lamond, J. (2012). *Cities and flooding: A guide to integrated urban flood risk management for the 21st century*. World Bank Publications.
- Jinollo, G. T., Workalemahu, L., & Adugna, D. (2024). Spatial distribution of urban land-use in addis ababa, ethiopia. *Urban, Planning and Transport Research*, *12*(1), 2307364.
-

- 
- Juju, A., Ali, M., & Tsegaye, D. (2020). Urbanization and infrastructure development in sub-saharan africa: The case of rapidly growing cities. *Urban Development and Planning Journal*, 34(7), 501–520.
- Juju, D. e. a. (2020). Infrastructure equity in african cities. *Cities*, 97, 102531.
- Kasa, L., Zeleke, G., Alemu, D., Hagos, F., & Heinimann, A. (2011). Impact of urbanization of addis abeba city on peri-urban environment and livelihoods. *Sekota Dry land Agricultural Research Centre of Amhara Regional Agricultural Research Institute: Addis Ababa, Ethiopia*.
- Kassahun, S., & Tiwari, A. (2012). Urban development in ethiopia: Challenges and policy responses. *The IUP journal of Governance and public policy*, 7(1), 59–65.
- Kefelegn, H. (2020). Determinants of youths rural to urban migration in ethiopia (case of addis ababa). *Academic Journal of Research and Scientific Publishing— Vol*, 2(15), 1.
- Kibru, M. (2012). Employment challenges in ethiopia. *Addis Ababa University, Ethiopia*.
- Kitila, A. W., Akmel Yesuf, A., & Woldemikael, S. M. (2023). Drivers and prospects of over-urbanization of addis ababa, ethiopia. *International Planning Studies*, 28(2), 162–177.
- Kivell, P. (2002). *Land and the city: Patterns and processes of urban change*. Routledge.
- Koroso, N. H., Lengoiboni, M., & Zevenbergen, J. A. (2021a). Urbanization and urban land use efficiency: Evidence from regional and addis ababa satellite cities, ethiopia. *Habitat International*, 117, 102437. <https://doi.org/https://doi.org/10.1016/j.habitatint.2021.102437>
- Koroso, N. H., Lengoiboni, M., & Zevenbergen, J. A. (2021b). Urbanization and urban land use efficiency: Evidence from regional and addis ababa satellite cities, ethiopia. *Habitat International*, 117, 102437.
- Kumssa, A., & Jones, J. (2020). *Urban resilience in africa*. Routledge.
- Lam, D. (2025). The next 2 billion: Can the world support 10 billion people? *Population and Development Review*, 51(1), 63–102.
- Lamson-Hall, P., Angel, S., DeGroot, D., Martin, R., & Tafesse, T. (2019). A new plan for african cities: The ethiopia urban expansion initiative. *Urban Studies*, 56(6), 1234–1249.
- Lamson-Hall, P., & Martin, R. (2022). The ethiopia urban expansion initiative and knowledge exchange. *Buildings & Cities*, 3(1).
- Larsen, L., Yeshitela, K., Mulatu, T., Seifu, S., & Desta, H. (2019). The impact of rapid urbanization and public housing development on urban form and density in addis ababa, ethiopia. *Land*, 8(4), 66.
- Lemi Kura Sub-City Administration. (2022). *Lemi kura sub-city socioeconomic profile* (tech. rep.). LKSA. Addis Ababa, Ethiopia.
- Liu, Y., Zheng, B., Turkstra, J., & Huang, L. (2010). A hedonic model comparison for residential land value analysis. *International journal of applied earth observation and geoinformation*, 12, S181–S193.
- Long, H., Heilig, G. K., Li, X., & Zhang, M. (2007). Socio-economic development and land-use change: Analysis of rural housing land transition in the transect of the yangtse river, china. *Land Use Policy*, 24(1), 141–153.
- Mahendra, A., King, R., Gray, E., Hart, M., Azeredo, L., Betti, L., Prakash, S., Deb, A., Ashebir, E., & Ibrahim, A. (2022). *Urban land value capture in são paulo, addis ababa, and hyderabad: Differing interpretations, equity impacts, and enabling conditions*. Lincoln Institute of Land Policy.
-

- 
- Malczewski, J. (1999). *Gis and multicriteria decision analysis*. John Wiley & Sons.
- Malczewski, J. (2004). Gis-based land-use suitability analysis: A critical overview. *Progress in planning*, 62(1), 3–65.
- Malczewski, J. (2011). Gis-based multicriteria decision analysis: A survey of the literature. *International Journal of Geographical Information Science*, 20(7), 703–726. <https://doi.org/10.1080/13658810600661508>
- Mariam, L., & Kawo, N. (2019). Accessibility metrics for urban services. *Ethiopian Journal of Development Research*, 41(2), 45–67.
- Matsumoto, T., & Crook, J. (2021). *Sustainable and inclusive housing in Ethiopia: A policy assessment*. Coalition for Urban Transitions.
- Mekonnen, D., & Teferi, S. (2023). Informal settlement reduction strategies. *Journal of African Cities*, 5(2), 201–215.
- MEKONNEN, E. (2017). Assessment of affordability of condominium houses: The case of addis ababa housing construction project office at tuledimitu site.
- Melese, M. (2004). City expansion, squatter settlements and policy implications in addis ababa: The case of kolfe keranio sub-city. *Ethiopian Journal of the Social Sciences and Humanities*, 2(2), 50–79.
- Metzner, S., & Kindt, A. (2018). Determination of the parameters of automated valuation models for the hedonic property valuation of residential properties: A literature-based approach. *International Journal of Housing Markets and Analysis*, 11(1), 73–100.
- Mohamed, A., MANSOR, S. B., AHMED, N. B., & SHIRIFF, R. (2006). Gis-based multicriteria approaches to housing site suitability assessment. *FIG CONGRESS*, 0–0.
- Monson, M. (2009). Valuation using hedonic pricing models.
- Naeem, N., Rana, I. A., & Nasir, A. R. (2023). Digital real estate: A review of the technologies and tools transforming the industry and society. *Smart Construction and Sustainable Cities*, 1(1), 15.
- Nations, U. (2023). The sustainable development goals report 2023.
- Nedd, R., Light, K., Owens, M., James, N., Johnson, E., & Anandhi, A. (2021). A synthesis of land use/land cover studies: Definitions, classification systems, meta-studies, challenges and knowledge gaps on a global landscape. *Land*, 10(9), 994.
- Negash, T., & Yohannes, K. (2022). Sdg implementation in bahir dar. *Ethiopian Urban Studies*, 8, 77–92.
- Peng, X., Chen, X., & Cheng, Y. (2011). Urbanization and its consequences. *Paris, France: Eolss Publishers*, 2(5754), 1–16.
- Phua, M.-H., & Minowa, M. (2005). A gis-based multi-criteria decision making approach to forest conservation planning at a landscape scale: A case study in the kinabalu area, sabah, malaysia. *Landscape and urban planning*, 71(2-4), 207–222.
- Reis, S. (2008). Analyzing land use/land cover changes using remote sensing and gis in rize, north-east turkey. *Sensors*, 8(10), 6188–6202.
- Ritchie, H., Samborska, V., & Roser, M. (2024). Urbanization. *Our world in data*.
- Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of political economy*, 82(1), 34–55.
- Saaty, T. L. (1980). The analytic hierarchy process (ahp). *The Journal of the Operational Research Society*, 41(11), 1073–1076.
-

- 
- Saghir, J., & Santoro, J. (2018). Urbanization in sub-saharan africa. *Meeting Challenges by Bridging Stakeholders*. Washington, DC, USA: Center for Strategic & International Studies.
- Schirmer, P. M., Van Eggermond, M. A., & Axhausen, K. W. (2014). The role of location in residential location choice models: A review of literature. *Journal of Transport and Land Use*, 7(2), 3–21.
- Sharma, H. (2006). *Soil mechanics and foundations* (6th). Pearson Education.
- Spaliviero, M., & Cheru, F. (2017). The state of addis ababa 2017: The addis ababa we want. *The State of Addis Ababa 2017: The Addis Ababa We Want*.
- Suparmono, S. (2012). Accessibility to center business district and land price. *Economic Journal of Emerging Markets*, 143–152.
- Tadesse, M. (2021). *Urban heat island effects in african cities* [Doctoral dissertation, Addis Ababa University].
- Tadesse, Y. (2021, October). *Urban expansion and the changing socio-economic life of the surrounding rural community: The case of woreda 03 lami kura sub-city, addis ababa city administration* [Doctoral dissertation, Addis Ababa University] [PhD Thesis]. <http://etd.aau.edu.et/handle/12345678/29285>
- Tanku, M. (2024). Rethinking urban spatial planning and industrial development approaches in ethiopia: Bridging gaps for better outcomes. *Frontiers of Urban and Rural Planning*, 2(1), 17.
- Troy, A., & Grove, J. M. (2008). Property values, parks, and crime: A hedonic analysis in baltimore, md. *Landscape and Urban Planning*, 87(3), 233–245.
- Turok, I., Scheba, A., & Visagie, J. (2023). Rethinking urbanization and economic development: A synopsis.
- Ullah, K. M., & Mansourian, A. (2016). Evaluation of land suitability for urban land-use planning: Case study d haka city. *Transactions in GIS*, 20(1), 20–37.
- UN, D. (2015). World urbanization prospects: The 2014 revision. *United Nations Department of Economics and Social Affairs, Population Division: New York, NY, USA*, 41, 3.
- UNDP. (2021). Addis ababa. *Communications, London*.
- UN-Habitat. (2023). *Global urban monitoring framework* (tech. rep.). United Nations.
- United Nations. (2024). *World population prospects 2024: Summary of results* (Technical Report No. UN DESA/POP/2024/TR/NO. 9) (Suggested citation: United Nations (2024). World Population Prospects 2024: Summary of Results. UN DESA/POP/2024/TR/9. New York: United Nations.). United Nations, Department of Economic and Social Affairs, Population Division. New York.
- Wahba Tadros, S., Wellenstein, A., Das, M., Palmarini, N., D'Aoust, O., Singh, G., Restrepo Cadavid, P., Goga, S., Terraza, H., Lakovits, C., et al. (2021). Demographic trends and urbanization. *World Bank Group: Washington, DC, USA*. Available online: <http://documents.worldbank.org/curated/en/260581617988607640/Demographic-Trends-and-Urbanization> (accessed on 29 September 2022).
- Weldu, W. G., & Deribew, I. A. (2016a). Identification of potential sites for housing development using gis based multi-criteria evaluation in dire dawa city, ethiopia. *International journal of sciences: basic and applied research*, 28(3), 34–49.
- Weldu, W. G., & Deribew, I. A. (2016b). Identification of potential sites for housing development using gis based multi-criteria evaluation in dire dawa city, ethiopia. *International journal of sciences: basic and applied research*, 28(3), 34–49.
-

- 
- Wikipedia. (n.d.). Hedonic regression – Wikipedia, the free encyclopedia [[Online; accessed 17-May-2025]]. [https://en.wikipedia.org/wiki/Hedonic\\_regression](https://en.wikipedia.org/wiki/Hedonic_regression)
- Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities ‘just green enough’. *Landscape and Urban Planning*, *125*, 234–244.
- Worku, D., & Adugna, G. (2024). Urbanization and housing challenges in addis ababa: A sustainable development approach. *Ethiopian Journal of Urban Studies*, *18*(1), 23–45.
- World Bank. (2023). *Affordable housing indicators*. Urban Development Unit.
- WRB, I. W. G. (2015). *World reference base for soil resources 2014*. FAO.
- Yang, H., Li, Y., Zhang, Z., Xu, Z., & Huang, X. (2019). Gis-based multi-criteria assessment and seasonal impact on plantation forest landscape visual sensitivity. *Forests*, *10*(4), 297.
- Yeo, I.-A., Yoon, S.-H., & Yee, J.-J. (2013). Development of an environment and energy geographical information system (e-gis) construction model to support environmentally friendly urban planning. *Applied Energy*, *104*, 723–739.
- Yohannes, H. (2021). *Assessment on factors influencing shortage of 20/80 housing supply: Case study of bole subcity housing project office* [Doctoral dissertation]. St. Mary’s University.
- Zou, K. H., Tuncali, K., & Silverman, S. G. (2003). Correlation and simple linear regression. *Radiology*, *227*(3), 617–628.

# Appendix 1: Publishable Manuscript

# Assessment of Site Suitability for Sustainable Residential Real Estate Investment in Addis Ababa: The Case of Lemi-Kura Sub-City

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## Abstract

This study explores the site suitability for sustainable residential real estate property investment in Addis Ababa, with a specific focus on Lemi-Kura Sub-City. The objective is to identify and map suitable locations for sustainable residential development by integrating Geographic Information System (GIS), the Analytical Hierarchy Process (AHP), and hedonic land value modeling. A geospatial analysis combined with multi-criteria evaluation was undertaken to analyze critical environmental and socio-economic parameters, including land use/land cover, slope, soil, and geology, to establish physical appropriateness. The analysis set the study region into three separate suitability zones for residential development: extremely low, moderate, and very high. Out of the entire area of 78.67 km<sup>2</sup>, about 23.28 km<sup>2</sup> (30.87%) was found to have extremely low suitability, 8.73 km<sup>2</sup> (13.64%) was found to be moderately suitable, and 20.27 km<sup>2</sup> (25.78%) was found to be highly appropriate for building homes. Also, a hedonic pricing model (HPM) was used to measure how property features and location affect the value of residential land. The model construction is based on the Sales Comparison Approach (SCA), employing sample transaction data acquired from various sites in the research area. Based on the model performance, a residential land value map was generated. Finally, the weighted overlay analysis of the physical suitability map and the land value map was done to establish potential zones for residential development. The integrated technique identified that only 8.10% of the land was classified as extremely suitable, 26.51% as moderately suitable, and the rest, 65.39%, as having low suitability for residential use. The integration of GIS, AHP, and HPM generated encouraging results. Future research is encouraged to use sophisticated approaches such as machine learning and deep learning for improved prediction and decision-making.

**Keywords:** Residential site suitability, geospatial analysis, hedonic pricing model, AHP, sustainable housing, multi-criteria evaluation.

*Keywords:* Ethiopia, urbanization, drivers, impacts

## 1. Introduction

35 Urbanization represents a fundamental demographic shift reshaping built environments globally, with over half the world’s population now residing in urban areas (Ritchie et al., 2024). Africa’s rapid urbanization—projected to reach 90% by 2050—is particularly pronounced in Ethiopia, where urban growth exceeds global averages at 4.03% annually (Echendu & Okafor, 2021; Saghir & Santoro, 2018). Addis Ababa epitomizes this transition, with its population doubling since 2000 and projected to redouble by 2035 (Koroso et al., 2021). This accelerated growth has precipitated severe housing deficits, where 80% of Ethiopia’s housing market is owner-occupied yet characterized by substandard quality and overcrowding (Erkiyhun, 2022; Haile, 2022).

45 Despite government initiatives like condominium schemes (e.g., 20/80 and 40/60 models) and private sector involvement, housing delivery remains inadequate and socially exclusionary (Charitonidou, 2022; Matsumoto & Crook, 2021). Critical gaps persist in holistic planning frameworks that integrate environmental, economic, and social sustainability dimensions (Fikire, 2021). This study addresses these deficiencies by developing a geospatial multi-criteria decision model combining Analytic Hierarchy Process (AHP), land value modeling, and GIS analysis to identify sustainable residential investment sites in Addis Ababa’s Lemi-Kura sub-city.

55 Our integrated methodology evaluates physical constraints (land availability, slope), economic viability (land values, infrastructure proximity), and environmental factors to optimize site selection. The framework advances evidence-based urban planning in rapidly developing contexts while balancing investor returns with community needs (Attah et al., 2024; Malczewski, 1999). By bridging theoretical sustainability principles with practical investment analytics, this research contributes actionable insights for equitable urban expansion in sub-Saharan Africa’s dynamic housing markets.

## 2. Methodology

### 65 3. Study Area

The research was conducted in Lemi Kura Sub-City, one of the eleven administrative divisions in the eastern part of Addis Ababa, Ethiopia. This sub-city is characterized by rapid urbanization and diverse land use patterns, including urban and peri-urban residential zones, extensive mixed-use agricultural lands, and some plantation areas. Geographically, Lemi Kura is situated between approximately  $8^{\circ}47'45''$ – $9^{\circ}04'30''$  N latitude and  $38^{\circ}48'30''$ – $38^{\circ}54'00''$  E longitude, covering an area of  $62.97 \text{ km}^2$ . Its strategic location and ongoing development make it an ideal setting for examining residential suitability and real estate investment potential.

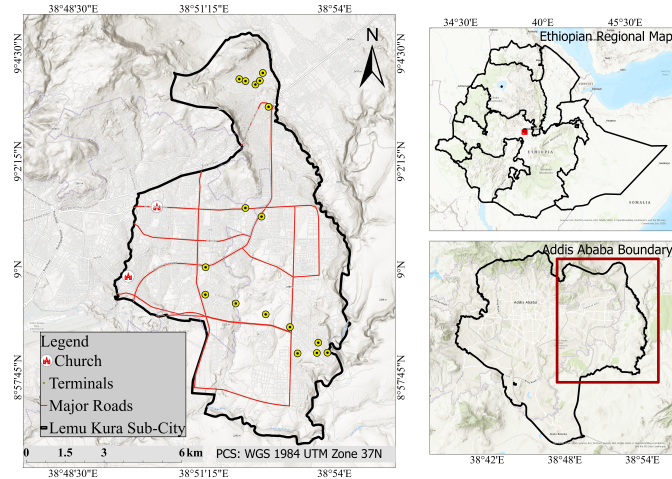


Figure 1: Study area map of Lemi Kura subcity.

#### 75 4. Data Sources and Types

This study integrated both spatial and non-spatial data to support residential land suitability analysis in Lemi Kura Sub-City. Spatial data included Sentinel-2A imagery (2024) for land use/land cover (LULC) classification, Shuttle Radar Topography Mission (SRTM) DEM for elevation and slope extraction, road network layers, and administrative boundary shapefiles. These datasets were acquired from platforms such as Copernicus, USGS Earth Explorer, and Ethiopian government institutions (e.g., SSGI and Addis Ababa Urban Planning Office). Additionally, spatial data were collected in the field using handheld GPS units to record property locations and land use types.

Non-spatial data encompassed socioeconomic attributes, expert opinions, and property transaction records (2024–2025). A total of 101 real estate transactions were gathered from specific woredas such as Yeka Abado and Hayat Square. Structured interviews were conducted with 15–20 purposefully selected stakeholders—including urban planners, real estate professionals, and local administrators—to derive pairwise comparisons for AHP analysis. This qualitative input was instrumental in developing a weighted criteria matrix for spatial modeling. Secondary sources also included planning reports and relevant literature.

#### 5. Analytical Tools and Sampling Approach

ArcGIS Pro 3 was used for spatial data processing, including proximity and weighted overlay analyses based on AHP-derived weights. R software supported statistical modeling using the Hedonic Pricing Model (HPM) to estimate land value based on key variables. Spatial datasets were organized in various formats

such as shapefiles, rasters, and geodatabases depending on their purpose—e.g., elevation for terrain analysis, LULC classification, and infrastructure evaluation.

100 The study population consisted of 42 professionals involved in land and property management. From this, 38 participants were selected through purposive and availability-based sampling to ensure the inclusion of individuals with practical and professional expertise. This approach balanced the need for domain-specific knowledge with accessibility during the study period.

## 105 6. Integrated Residential Suitability Assessment

This study employed a geospatially integrated modeling framework to evaluate residential site suitability in Lemi Kura Sub-City, combining biophysical and socio-economic perspectives. The assessment was structured into two major components: (i) physical suitability analysis based on environmental constraints and (ii) land value modeling incorporating socio-economic and proximity-based factors. The synthesis of these dimensions provided a robust spatial decision support framework for identifying optimal residential development zones.

110 The physical suitability component focused on environmental variables essential to construction feasibility and long-term habitability. Drawing from literature and expert consultation, five key criteria were prioritized: land use/land cover (LULC), slope, elevation, geology, and soil type. These criteria were structured using the Analytic Hierarchy Process (AHP), enabling pairwise comparison matrices (e.g., Table ??) to weight each factor's relative importance. Spatial data inputs—such as Sentinel-2A imagery and SRTM DEM—were processed in 120 ArcGIS Pro to generate classified thematic maps and topographic derivatives including slope gradients and elevation ranges.

## 7. Geospatial Methods and Analytical Tools

The study integrated Geographic Information Systems (GIS) with AHP, a Multi-Criteria Decision-Making (MCDM) approach, to enable transparent, replicable spatial modeling. Land use/land cover mapping was conducted using a supervised classification algorithm—Maximum Likelihood Classifier—applied to Sentinel-2A imagery. The classification delineated three major land cover categories: agricultural land, built-up areas, and forested zones (Table ??). These thematic layers were instrumental in excluding incompatible land uses and delineating potential zones for residential investment.

130 Topographic analysis was performed using 30m SRTM DEM data. Slope and elevation layers were derived using hydrologically corrected DEMs through pre-processing steps such as depression filling. These topographic variables served as critical inputs in the physical suitability index, accounting for construction feasibility, risk factors, and environmental performance.

This methodological framework—grounded in expert-driven weighting, empirical classification, and elevation modeling—supports a comprehensive and systematic evaluation of residential development potential, offering scalable applicability to other urban contexts in Ethiopia and beyond.

## 140 8. Results

### 9. Response Rate

Of the 38 questionnaires distributed to professionals involved in real estate and urban planning in Lemi Kura Sub-City, 34 were completed and returned, resulting in a high response rate of 89.47%. This substantial level of participation enhances the reliability of the findings and reflects strong engagement from stakeholders directly involved in land development and planning.

### 10. Demographic and Social Characteristics of Respondents

Respondents predominantly represented urban planning professionals (39.5%), followed by real estate developers (31.6%) and local government administrators (18.4%), with a minority comprising GIS experts and surveyors (10.5%). This professional composition ensures that the views captured are grounded in relevant experience and institutional knowledge.

Regarding perceived population dynamics, 68.4% of respondents observed rapid population growth in Lemi Kura, attributed to ongoing urban expansion and infrastructure improvements. Another 21.1% considered the growth moderate, while only a small fraction indicated slow or no growth.

The majority (78.9%) of respondents believed that housing demand exceeded supply, highlighting growing pressure on residential infrastructure. Only 13.2% reported demand-supply equilibrium, and 7.9% were uncertain—indicating a significant housing gap in the sub-city.

Migration trends were identified as a key driver of demographic change. Rural-to-urban migration was cited by 57.9% of participants as the dominant source of population increase, followed by internal migration from other sub-cities (28.9%). International migration and other sources played marginal roles.

### 165 11. Environmental Factors in Site Selection

#### 11.1. Topographic Considerations

Topographic attributes—specifically slope, elevation, and aspect—were widely recognized as important in residential site selection. Over 84% of participants ranked these features as either "very important" or "important." This consensus underscores the need to consider terrain-related risks, such as landslides or drainage challenges, in planning and zoning processes.

#### 11.2. Prioritized Environmental Criteria

Soil quality and stability emerged as the most frequently cited environmental criterion (cited by 30 respondents), followed by water quality and availability (28), natural disaster risk (26), and access to green spaces (24). While air quality and biodiversity were also mentioned, they ranked lower in priority. These results indicate that respondents place higher value on geophysical safety, natural resource availability, and ecological amenities.

### 11.3. Environmental Awareness and Protected Areas

180 A substantial proportion of respondents (25 out of 38) expressed strong concern about the environmental implications of ongoing urban expansion. This reflects a shared recognition of the need for sustainable development frameworks in Lemi Kura.

185 Moreover, 57.9% of participants acknowledged the existence of protected areas—such as wetlands and forests—that impose constraints on urban development. However, approximately 42.1% either denied knowledge or were unsure of such areas, indicating gaps in communication or awareness regarding environmental regulations and conservation zones.

190 These findings collectively reinforce the necessity of integrating geospatial and ecological considerations into urban planning efforts to ensure sustainable residential development in Lemi Kura.

## 12. Mapping of Physical Residential Suitability

195 A residential suitability map was developed using GIS and Analytic Hierarchy Process (AHP) by integrating five weighted criteria: land use/land cover, elevation, slope, soil, and geology. Each criterion was reclassified and weighted based on expert judgment through AHP, and a weighted overlay analysis was performed.

200 This integration of GIS and AHP enabled the translation of expert preferences into spatially explicit outputs, enhancing decision-making for complex site suitability problems. Similar methods have been effective in flood risk and renewable energy site analyses (Azizi et al., 2022; Malczewski, 2011).

205 The final map delineated three suitability zones across Lemi Kura Sub-City: highly suitable (25.78%), moderately suitable (13.64%), and low suitability (30.87%). These insights are essential for guiding sustainable residential planning and zoning in the area.

Table 1: Residential Suitability by Physical Criteria in Lemi Kura

Rank	Suitability Class	Area (km <sup>2</sup> )	Percentage%
1	Highly Suitable	20.28	25.78 %
2	Low Suitable	24.28	30.87 %
3	Moderately Suitable	10.73	13.64 %
<b>Total (Accounted Area)</b>		<b>55.29</b>	<b>70.29 %</b>

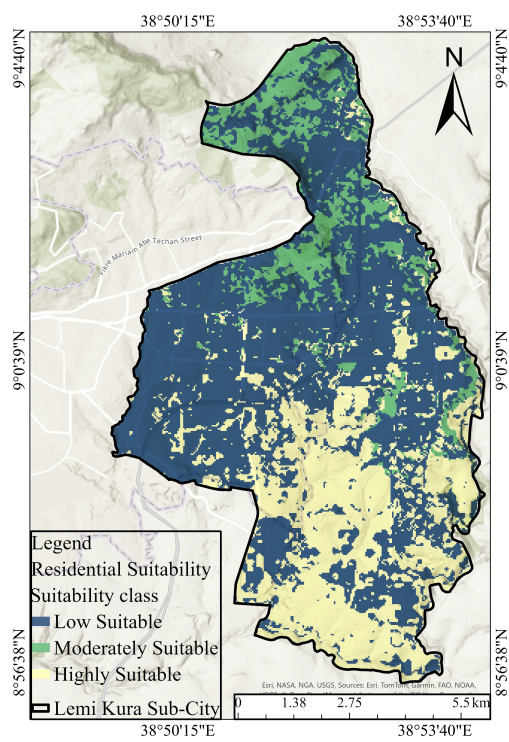


Figure 2: Residential Suitability Map Based on Physical Criteria

210 **13. Development of the Model**

The land valuation model for Lemi Kura was developed using systematic geospatial data analysis combined with advanced GIS processing techniques. This integrated approach addresses key technical challenges in property assessment within the study area by leveraging state-of-the-art spatial analysis tools to transform raw valuation data into actionable insights. The model incorporates spatial attributes such as market accessibility, road network connectivity, proximity to amenities like educational institutions and health centers, and urban centrality relative to Lemi Kura’s central business district and major employment hubs.

215 Additionally, property-specific variables including location, price, number of rooms, floor level, and property type from the sales comparison approach were incorporated. This geospatially integrated method bridges conventional appraisal techniques with modern data-driven valuation models.

A hedonic regression was employed to estimate land price, with ArcGIS Pro and R software used for data processing, analysis, and model calibration.

220 *13.1. Correlation Matrix*

Correlation analysis measures the magnitude and direction of relationships between continuous variables (Zou et al., 2003). The Pearson correlation coefficient (PCC) quantifies the linear association between variables, ranging from -1 (perfect negative) to +1 (perfect positive) (Benesty et al., 2008).

225 Pearson’s product-moment correlation was computed using R’s `cor.test()` function, as shown in Equation 1:

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}} \quad (1)$$

where  $r$  is the correlation coefficient,  $X_i$  and  $Y_i$  are paired observations, and  $\bar{X}$  and  $\bar{Y}$  are the means of the variables.

235 The analysis included 101 sample parcels from Lemi Kura sub-city. Due to its categorical nature, property type was excluded from the Pearson correlation analysis. Table 2 presents the correlation matrix among the dependent variable (land price) and nine quantitative independent variables.

Table 2: Pearson Correlation Matrix Among Variables

Variable	Price	Area	Floor	Room	DIST_SCH	DIST_HC	AMP	ASCC	AMR	ACC
Price	1.000	0.805	0.158	0.460	-0.257	0.218	0.105	-0.416	0.105	-0.381
Area	0.805	1.000	0.304	0.577	-0.036	0.244	-0.201	-0.226	0.156	-0.191
Floor	0.158	0.304	1.000	0.266	-0.153	0.383	-0.112	-0.157	0.166	-0.090
Room	0.460	0.577	0.266	1.000	-0.203	0.323	-0.238	-0.287	0.245	-0.207
DIST_SCH	-0.257	-0.036	-0.153	-0.203	1.000	0.091	0.630	0.890	-0.434	-0.102
DIST_HC	0.218	0.244	0.383	0.323	0.091	1.000	-0.166	0.195	0.015	-0.474
AMP	-0.381	-0.201	-0.112	-0.238	0.630	-0.166	1.000	0.550	-0.450	0.358
ASCC	-0.416	-0.226	-0.157	-0.287	0.890	0.195	0.550	1.000	-0.471	-0.213
AMR	0.105	0.156	0.166	0.245	-0.434	0.015	-0.450	-0.471	1.000	0.073
ACC	-0.316	-0.191	-0.090	-0.207	-0.102	-0.474	0.358	-0.213	0.073	1.000

240 The strongest positive correlation with land price is property area ( $r = +0.805$ ), indicating larger properties command higher prices. The number of rooms also correlates moderately positively with price ( $r = +0.460$ ). Floor level, distance from the health center, and access to the sub-city center show weaker positive associations.

245 Negative correlations were found for access to the city center (ACC,  $r = -0.316$ ), main road (AMR,  $r = -0.381$ ), and market (AMP,  $r = -0.105$ ), suggesting prices decrease as distances to these amenities increase, highlighting their importance in property valuation.

Table 3 lists the top five variables ranked by the absolute value of their correlation with price, all statistically significant at  $p < 0.001$ .

Table 3: Top Variables Correlated with Property Price

Variable	Description	Correlation Coefficient	p-value
Area	Property size (m <sup>2</sup> )	0.8055	$3.17 \times 10^{-24}$
Room	Number of rooms	0.4595	$1.34 \times 10^{-6}$
ACC	Access to city center	-0.4158	$1.53 \times 10^{-5}$
AMR	Access to main road	-0.3814	$8.33 \times 10^{-5}$
AMP	Access to market	-0.3160	$1.28 \times 10^{-3}$

250 Other variables such as distance to school (DIST\_SCH), distance to health center (DIST\_HC), and access to sub-city center (ASCC) exhibit weak or no meaningful linear relationships with land price.

255 The correlation matrix also reveals multicollinearity among some independent variables, for example, strong correlations between access to city center and distance to school ( $r = 0.890$ ) and between room count and area ( $r = 0.577$ ). While correlation does not imply causation, these insights inform variable selection for subsequent regression modeling (Ai, 2005).

260 In addition to quantitative variables, property condition (fully furnished vs. moderately furnished) was considered. Due to its categorical nature, it was excluded from correlation analysis. However, ANOVA tests revealed significant valuation differences between these categories (Figure 3).

#### 14. Model Development Using Hedonic Regression Model

265 This study employs a hedonic price modeling approach to estimate residential property values in Lemi Kura sub-city, Addis Ababa. The hedonic pricing model has been widely used in various studies to develop land value models (Liu et al., 2010; Metzner & Kindt, 2018). Originally introduced by Court (1939) and later formalized by Rosen (1974), this model posits that the price of a differentiated good—such as real estate—can be decomposed into the implicit prices of its constituent characteristics.

270



Figure 3: Distribution of land prices (\$/m<sup>2</sup>) by property furnishing status in Lemi Kura.

For the model development, a multiple linear regression framework was employed to establish the relationship between the dependent variable (property price) and various independent variables representing property attributes and accessibility factors. The modeling process included several stages: initial model development using all potential predictors, assessment of multicollinearity, model refinement, and performance comparison. The details of these stages follow below.

#### 14.1. Model Building and Refinement Outcomes

The initial full model included all considered predictor variables. Ordinary Least Squares (OLS) regression was used to estimate the model parameters, and the Variance Inflation Factor (VIF) was calculated to detect potential multicollinearity issues. Table 4 summarizes the OLS regression results, while Table 5 presents the VIF scores for all variables in the full model.

Based on both p-values and VIF values, model refinement was necessary to improve the model's robustness and interpretability. Variables DIST\_SCH and ASCC were identified for removal due to their high multicollinearity (high VIF) and, in the case of DIST\_SCH, a lack of statistical significance. Other variables with non-significant p-values—Room, DIST\_HC, and AMP—were also considered for exclusion to simplify the model while preserving explanatory power. This step reduces redundancy and mitigates multicollinearity, enhancing the re-

Table 4: Model A (All Variables) Summary with Significance Levels

Variable	Estimate	Std. Error	t-Value	p-Value	Significance
(Intercept)	4,491,502	576,836	7.79	1.12e-11	***
Area	65,152	5,007	13.00	2.14e-22	***
Floor	-102,754	38,274	-2.68	8.64e-03	**
red!20 Room	-212,127	133,074	-1.59	1.14e-01	ns
red!20 DIST_SCH	-1,301	86,388	-0.02	9.88e-01	ns
red!20 DIST_HC	77,561	73,323	1.06	2.93e-01	ns
AMR	-559,814	179,227	-3.12	2.40e-03	**
ACC	-188,894	44,198	-4.27	4.77e-05	***
ASCC	-370,031	112,528	-3.29	1.44e-03	**
red!20 AMP	-63,515	217,301	-0.29	7.71e-01	ns
Type2	-562,530	110,720	-5.08	2.02e-06	***

**Significance codes:** \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ , ns = not significant

Table 5: Variance Inflation Factors (VIF) for Model A and Multicollinearity Assessment

Variable	VIF	Multicollinearity Status
Area	1.985	Low
Floor	1.349	Low
Room	1.791	Low
red!20 DIST_SCH	<b>7.680</b>	<b>High (Potential Issue)</b>
DIST_HC	1.844	Low
AMR	1.470	Low
ACC	1.935	Low
red!20 ASCC	<b>8.519</b>	<b>High (Potential Issue)</b>
AMP	2.767	Moderate
Type	1.116	Low

liability of the final model.

295 Accordingly, the refined model excluded five variables: Room, DIST\_SCH, DIST\_HC, AMP, and ASCC. Table 6 shows the regression results after refinement.

Table 6: Regression Results of the Refined Full Model

Term	Estimate	Std. Error	t-Statistic	p-value	Significance
(Intercept)	4,036,929	122,329	33.0	$4.60 \times 10^{-52}$	***
Area	59,548	1,059	56.2	$6.73 \times 10^{-72}$	***
Floor	-65,852	8,110	-8.12	$2.31 \times 10^{-12}$	***
Type2	-499,284	23,612	-21.1	$1.12 \times 10^{-36}$	***
ACC	-283,618	23,890	-11.9	$4.08 \times 10^{-20}$	***

300 A further refined hedonic price model was developed focusing on the top five independent predictors identified through correlation and multicollinearity analysis: Area, Floor, AMR (access to main road), ACC (accessibility to city center), and Property Type. Table 7 presents the results for this final model. These variables balance interpretability with predictive strength.

Table 7: Model B (Refined) Linear Regression Results

Variable	Estimate	Std. Error	t-Statistic	p-Value	Significance
Intercept	3,035,836	468,027	6.48	3.43e-05	***
Area	67,599	4,883	13.85	1.64e-24	***
Floor	-75,136	44,298	-1.70	8.9e-02	. *
AMR	9,720	192,526	0.05	0.960	ns
ACC	-138,910	41,317	-3.36	1.12e-03	**
Type2	-679,420	134,134	-5.07	2.00e-06	***

Significance codes: \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ , .  $p < 0.1$ , ns = not significant

305 The refined model explains approximately 78.8% of the variance in property prices ( $R^2 = 0.788$ ), indicating a strong positive correlation between predicted and actual values, as visualized in Figure 4.

#### 14.2. Final Model Interpretation

310 The final hedonic pricing model (Table 7) highlights the key determinants of property prices in the study area: property area, floor level, accessibility to main roads and city center, and property furnishing status. These variables collectively shape land value trends in Lemi Kura sub-city and provide stakeholders with actionable insights for investment and policy decisions.

315

The estimated regression equation is:

$$\text{Price} = \beta_0 + \beta_1 \times \text{Area} + \beta_2 \times \text{Floor} + \beta_3 \times \text{AMR} + \beta_4 \times \text{ACC} + \beta_5 \times \text{Type}_2 \quad (2)$$

with coefficients summarized below:

Interpretation of key coefficients:

- **Area:** The coefficient of 67,599 ETB per square meter indicates that, all else equal, each additional square meter increases the property value by about 67,599 ETB. This aligns with common real estate market behavior where larger properties command higher prices:

$$\frac{\partial \text{Price}}{\partial \text{Area}} = 67,599 \text{ birr/m}^2$$

- **Floor:** A negative coefficient (-75,136 ETB) suggests that properties located on higher floors tend to have lower values compared to those on lower floors, potentially reflecting local preferences or lack of elevator facilities.
- **AMR (Access to Main Road):** Although the coefficient is positive (9,720 ETB), it is not statistically significant ( $p = 0.960$ ), suggesting no consistent impact on property price within the study area.
- **ACC (Access to City Center):** This variable shows a significant negative effect (-138,910 ETB,  $p = 0.001$ ), indicating that properties farther from the city center tend to have lower prices.
- **Type<sub>2</sub> (Furnishing Status):** The large negative coefficient (-679,420 ETB) for non-furnished properties confirms that furnishing strongly influences property prices, with furnished units being valued higher.

In summary, the refined hedonic model captures the complex interplay of physical property attributes and accessibility factors influencing residential property values in Lemi Kura. These insights can guide investors, developers, and policymakers in making informed decisions that promote sustainable urban development and efficient real estate markets.

## 15. Potential Land Suitability Map

The predicted land values from the hedonic model were exported to ArcGIS Pro for spatial analysis. Using geostatistical interpolation, an Inverse Distance Weighting (IDW) approach was applied to generate a continuous land value surface across the study area.

The interpolated land values were normalized to a standardized 1–5 scale using the following transformation (Hu et al., 2013):

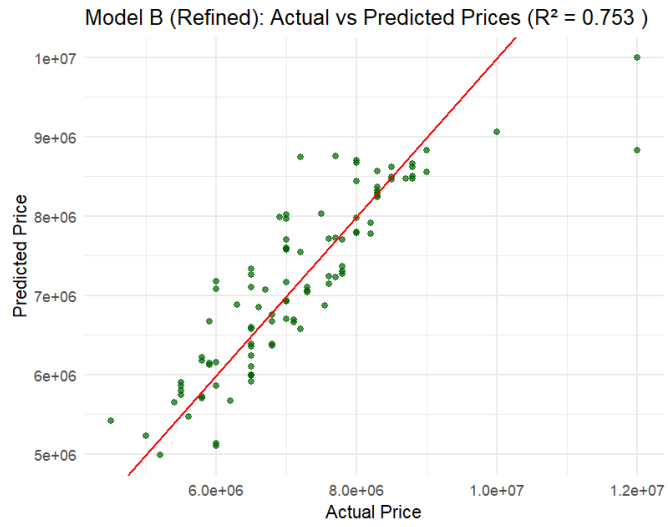


Figure 4: Actual vs. Predicted Property Values

Coefficient	Value
$\beta_0$ (Intercept)	3,035,836.13
$\beta_1$ (Area)	67,599.05
$\beta_2$ (Floor)	-75,135.58
$\beta_3$ (AMR)	9,719.77
$\beta_4$ (ACC)	-138,909.87
$\beta_5$ (Type <sub>2</sub> )	-679,420.28

$$\text{Normalized Value} = 4 \times \left( \frac{V_i - V_{\min}}{V_{\max} - V_{\min}} \right) + 1 \quad (3)$$

where:

- $V_i$  represents the original land value estimate,
- 350 •  $V_{\min}$  denotes the minimum observed land value,
- $V_{\max}$  indicates the maximum observed land value.

Through stakeholder interviews and expert consultations, a weighted overlay scheme was established assigning 60% weight to physical suitability factors and 40% weight to land value considerations. The integrated analysis produced a residential suitability map, which was subsequently classified into three distinct suitability categories (Figure 5):

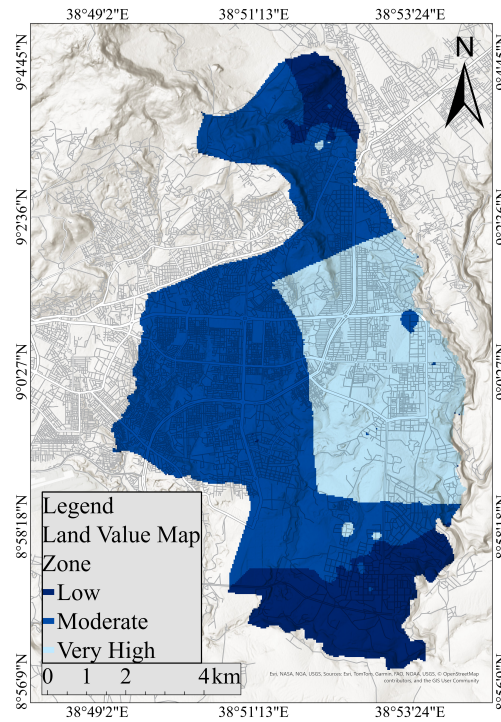


Figure 5: Residential suitability classification showing three zones: (1) High, (2) Moderate, and (3) Low suitability areas

The comprehensive suitability analysis identified three distinct residential development zones in Lemi Kura sub-city by combining physical suitability (60%

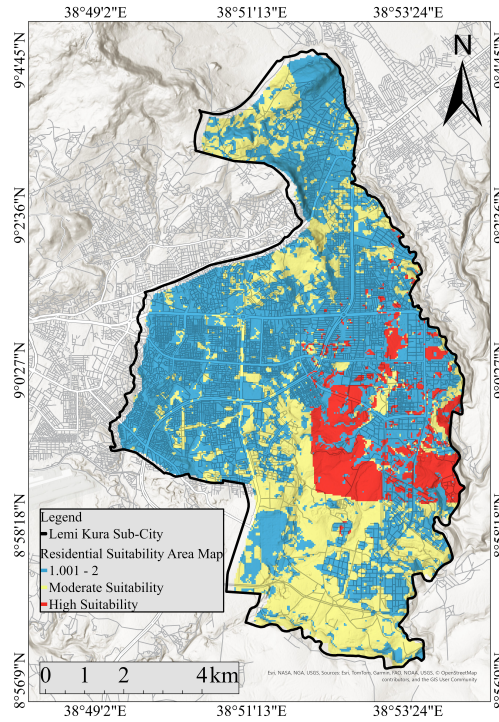


Figure 6: Real estate suitability map of Lemi Kura Sub-city

weight) and land value factors (40% weight). The study area was classified into three major suitability classes: highly suitable, moderately suitable, and low suitability.

The residential site suitability classification reveals a significant disparity in the distribution of residential potential across the study area. Only a small portion, approximately 6.98 km<sup>2</sup> (8.10%), is classified as highly suitable for residential use, suggesting limited availability of prime land that meets the highest suitability criteria, possibly due to constraints such as terrain, accessibility, or infrastructure. Meanwhile, a moderate proportion, 22.83 km<sup>2</sup> (26.51%), falls under the **moderately suitable** category. These areas may support residential development with certain improvements or planning considerations, such as infrastructure upgrades or enhanced service provision.

The majority of the land, 45.21 km<sup>2</sup> (65.39%), is classified as **low suitability**. This indicates that most of the land may not be ideal for residential development under current conditions and may require substantial investment or be reserved for other land uses. This uneven distribution emphasizes the need for informed spatial planning and investment prioritization to ensure sustainable

urban expansion and efficient land use management.

Table 8: Suitability Class Distribution

Suitability Class	Area (km <sup>2</sup> )	Percentage	Development Potential
High	6.98	8.10%	Immediate development
Moderate	22.83	26.51%	Conditional development
Low	45.21	65.39%	Restricted development

## 16. Comparison of Final Residential Suitability Map with Existing Structural Plan

380 The residential suitability map, derived from a combination of physical and economic factors, identifies the most suitable locations for residential development. However, comparison with the updated structure plan of Lemi Kura sub-city developed by the Addis Ababa City Plan Commission reveals various inconsistencies. These findings highlight potential inefficiencies in existing land use planning and point to the need for future policy actions to ensure sustainable city growth.

390 The analysis shows that existing mixed residential built-up areas lie predominantly within medium and low suitability zones, indicating that residential expansion in Lemi Kura sub-city has been driven by unplanned urban growth. This pattern is likely to result in poor accessibility, topographical constraints, environmentally unsound conditions, and limited proximity to economic hubs.

395 The structural plan also places several industrial areas adjacent to residential neighborhoods and water bodies, contravening environmental and public health standards that recommend buffer zones between such land uses. Proximity to rivers raises concerns about water pollution and habitat destruction, posing significant risks to environmental sustainability and public health.

400 Moreover, the structural plan locates solid waste disposal sites along and even on riverbanks, highlighting serious planning deficiencies. These areas, rated as low and medium suitability in the final map, are vulnerable to flooding and environmental hazards. This placement violates urban sanitation standards and threatens the long-term ecological integrity of the region.

405 Overall, the spatial mismatch between the suitability classification and the current structural plan underscores the need for data-driven planning strategies. Future redevelopment and urban expansion should be guided by suitability model-based analyses to ensure environmental preservation and public health protection.

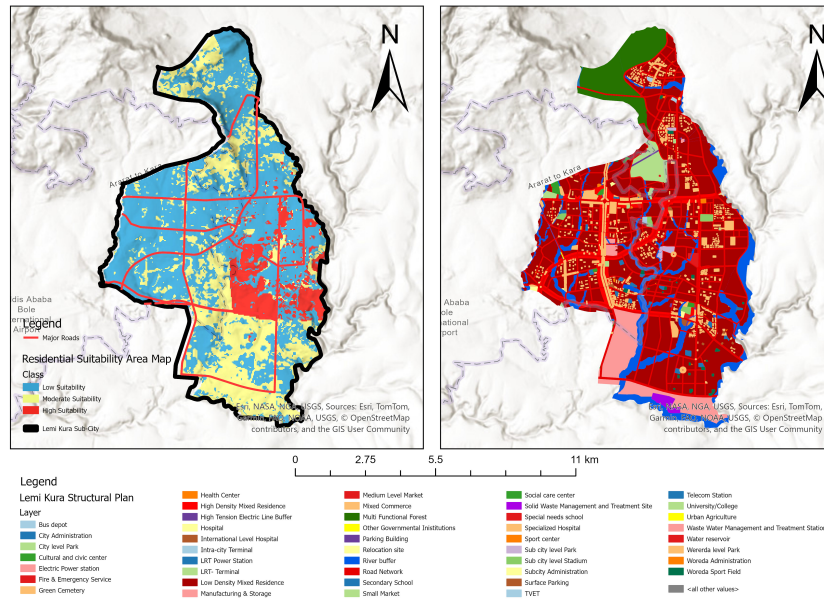


Figure 7: Comparison of Final Residential Suitability Map with Existing Structural Plan

In conclusion, the analysis reveals a significant disconnect between existing land use practices and suitability-based planning recommendations. Bridging this gap is essential for achieving sustainable, effective, and equitable urban growth in Lemi Kura sub-city. Conclusion and Recommendations

## 415 17. Conclusion

This study comprehensively assessed residential real estate investment site suitability in Lemi Kura Sub-city, Addis Ababa, integrating stakeholder perspectives with Geographic Information System (GIS) analysis, the Analytic Hierarchy Process (AHP), and hedonic land value modeling.

420 A high survey response rate of 89.47% demonstrated active participation from urban planners, real estate developers, and local government officials, strengthening the reliability of the data. The analysis revealed rapid demographic transformation in the sub-city, with 68.4% of respondents perceiving significant population growth and 78.9% identifying a demand-supply gap in housing. Rural-to-urban migration was cited as the primary driver of growth  
425 (57.9%). These factors directly influence land value dynamics.

Topographic conditions, especially slope and elevation, were confirmed as  
430 critical for site suitability, with over 84% of respondents validating their impor-

tance. Environmental factors including soil stability, water supply, and natural disaster hazards were prioritized for future residential development, emphasizing their role in land desirability and long-term economic viability. Accessibility to transport infrastructure and proximity to amenities like schools, hospitals, and job centers were also highly rated (over 76%), with strong support for public transport accessibility (81.6%), underscoring the importance of transit-oriented planning.

Physical suitability analysis using GIS and AHP considered factors such as Land Use/Land Cover (LULC), slope, elevation, soil, and geology. LULC and elevation contributed most significantly to the decision weights (27.8% and 26.5%, respectively). Out of 78.67 km<sup>2</sup>, approximately 23.28 km<sup>2</sup> (30.87%) was classified as very low suitability, 8.73 km<sup>2</sup> (13.64%) as low suitability, and 20.36 km<sup>2</sup> (25.78%) as moderately suitable, indicating physical constraints requiring careful planning.

Economic suitability was evaluated via a hedonic pricing model estimating residential land values. The model showed that land area, proximity to city centers, sub-city hubs, and major roads positively influenced land values. Housing conditions were also significant; fully furnished properties commanded an average premium of about 679,420.28 Ethiopian birr compared to moderately furnished ones.

Combining physical and economic factors, the final site suitability classification indicated that only 8.10% of the land is highly suitable for residential development, 26.51% is moderately suitable, and 65.39% is of low suitability. This highlights the limited availability of prime land and the need for infrastructure improvements in moderately suitable areas.

In summary, this study offers a replicable, practical methodology that integrates spatial, environmental, and economic data to support sustainable residential planning in rapidly urbanizing settings. It provides a foundation for informed decision-making that promotes balanced growth, environmental stewardship, and social equity.

## 18. Recommendations

To enhance urban planning and sustainable development in Lemi Kura Sub-city, the following recommendations are made based on the hedonic pricing model, spatial suitability analysis, and identified land use conflicts:

- The sub-city and Addis Ababa City Planning Commission should undertake a comprehensive review and update of the structural plan to align with the model-based suitability classification. Integrating physical constraints and economic land value data will improve the realism and sustainability of future residential, industrial, and infrastructure developments.

Continuing development in unsuitable areas risks housing quality and increases urban vulnerability to natural and environmental hazards.

- Solid waste disposal sites currently located near riverbanks should be re-located based on site suitability analysis to avoid flood-prone and ecologically sensitive areas. Maintaining waste sites in these zones violates national environmental policies and WHO standards, posing serious threats to water quality, public health, and ecosystem services.
- Industrial land uses sited near residential neighborhoods and riverbanks pose significant environmental and health risks. Strict zoning regulations must be enacted to enforce spatial separation between industrial and residential areas, particularly along ecologically important corridors and water bodies.
- Urban planning policy should mandate the integration of GIS-based suitability models and market data into all future structural and zoning plans. This approach will help improve living standards, preserve ecologically valuable areas, and promote sustainable residential development.

## References

- Ai, P. (2005). Residential land value modelling. *Faculty of Geo-Information Science and Earth Observation of the University of Twente*. 2005. [An electronic resource]. Access mode: [https://www.itc.nl/library/papers\\_2005/msc/upla/ai\\_ping.pdf](https://www.itc.nl/library/papers_2005/msc/upla/ai_ping.pdf) ( : 29.12. 2017), free. Heading from the screen.
- Attah, R. U., Gil-Ozoudeh, I., Garba, B., & Iwuanyanwu, O. (2024). Leveraging geographic information systems and data analytics for enhanced public sector decision-making and urban planning. *Magna Sci Adv Res Rev*, 12(2), 152–63.
- Azizi, A., Malekmohammadi, B., Jafari, H. R., & Nasiri, H. (2022). Gis-based multi-criteria decision analysis for wind and solar energy site selection: A systematic review. *Renewable and Sustainable Energy Reviews*, 156, 111988. <https://doi.org/10.1016/j.rser.2021.111988>
- Benesty, J., Chen, J., & Huang, Y. (2008). On the importance of the pearson correlation coefficient in noise reduction. *IEEE Transactions on Audio, Speech, and Language Processing*, 16(4), 757–765.
- Charitonidou, M. (2022). Housing programs for the poor in addis ababa: Urban commons as a bridge between spatial and social. *Journal of Urban History*, 48(6), 1345–1364. <https://doi.org/10.1177/00961442211029903>
- Court, A. (1939). *Hedonic price indexes with automotive examples*.
- Echendu, A. J., & Okafor, P. C. C. (2021). Smart city technology: A potential solution to africa’s growing population and rapid urbanization? *Development Studies Research*, 8(1), 82–93.

- Erkiyhun, D. (2022). *Practices and problems of condominium housing construction projects: The case of lideta sub-city housing construction development projects in addis ababa* [Doctoral dissertation]. St. Mary's University.
- 515 Fikire, A. H. (2021). Determinants of urban housing choice in debre berhan town, north shewa zone, amhara region, ethiopia. *Cogent Economics & Finance*, 9(1), 1885196.
- 520 Haile, M. (2022). *Title of the report or publication* (tech. rep.) (Please update with exact title). Ethiopian Economics Association (EEA). Addis Ababa, Ethiopia.
- Hu, S., Cheng, Q., Wang, L., & Xu, D. (2013). Modeling land price distribution using multifractal idw interpolation and fractal filtering method. *Landscape and Urban Planning*, 110, 25–35.
- 525 Koroso, N. H., Lengoiboni, M., & Zevenbergen, J. A. (2021). Urbanization and urban land use efficiency: Evidence from regional and addis ababa satellite cities, ethiopia. *Habitat International*, 117, 102437. <https://doi.org/https://doi.org/10.1016/j.habitatint.2021.102437>
- 530 Liu, Y., Zheng, B., Turkstra, J., & Huang, L. (2010). A hedonic model comparison for residential land value analysis. *International journal of applied earth observation and geoinformation*, 12, S181–S193.
- Malczewski, J. (1999). *Gis and multicriteria decision analysis*. John wiley & sons.
- 535 Malczewski, J. (2011). Gis-based multicriteria decision analysis: A survey of the literature. *International Journal of Geographical Information Science*, 20(7), 703–726. <https://doi.org/10.1080/13658810600661508>
- Matsumoto, T., & Crook, J. (2021). *Sustainable and inclusive housing in ethiopia: A policy assessment*. Coalition for Urban Transitions.
- 540 Metzner, S., & Kindt, A. (2018). Determination of the parameters of automated valuation models for the hedonic property valuation of residential properties: A literature-based approach. *International Journal of Housing Markets and Analysis*, 11(1), 73–100.
- Ritchie, H., Samborska, V., & Roser, M. (2024). Urbanization. *Our world in data*.
- 545 Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of political economy*, 82(1), 34–55.
- Saghir, J., & Santoro, J. (2018). Urbanization in sub-saharan africa. *Meeting Challenges by Bridging Stakeholders*. Washington, DC, USA: Center for Strategic & International Studies.
- 550 Zou, K. H., Tuncali, K., & Silverman, S. G. (2003). Correlation and simple linear regression. *Radiology*, 227(3), 617–628.

## Appendix 2: Data Collection Tool

## Addis Ababa University

This questionnaire aims to gather essential insights from key stakeholders involved in urban development and real estate investments in Addis Ababa Lemi Kura sub-city, Ethiopia. The information collected will be used to assess the suitability of potential sites for sustainable residential real estate development, utilising geospatial analysis tools, including Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP).

Please answer the following questions based on your knowledge and experience in urban development, real estate, infrastructure, and sustainability in Addis Ababa, Lemi Kura sub-city.

**We appreciate your time and effort in contributing to this vital research.**

### Section 1: General Information

1. Name of Respondent (optional): \_\_\_\_\_
2. Position/Title: \_\_\_\_\_
3. Organisation/Agency: \_\_\_\_\_
4. Years of Experience in Real Estate Development/Urban Planning: \_\_\_\_\_

### Section 2: Demographic and Social Factors

1. What is your role in the development process? (Check all that apply)
  - Real Estate Developer
  - Urban Planner
  - Local Government Official
  - Other (please specify): \_\_\_\_\_
2. How do you perceive the current population growth in Lemi Kura sub-city?
  - Very rapid
  - Moderate
  - Slow
  - No growth
3. Do you believe housing demand in Addis Ababa Lemi Kura sub-city exceeds the available supply?
  - Yes
  - No
  - Not sure

4. What is the primary migration source into Addis Ababa, specifically to Lemi Kura Sub-city?

- Rural to urban migration
- Internal migration from other cities
- International migration
- Other (please specify): \_\_\_\_\_

**Section 3: Environmental Factors**

1. How important is the topography (e.g., slope, elevation, and aspect) when selecting land for residential development?

- Very important
- Important
- Neutral
- Not important

2. Which environmental factors should be prioritised when selecting a residential real estate investment site? (Rank the following from most important to least important)

- Soil quality and stability
- Natural disaster risks (e.g., floods, landslides)
- Proximity to green spaces and parks
- Biodiversity and wildlife habitats
- Air quality
- Water quality and availability

3. How concerned are you about the environmental impact of urban expansion in Lemi Kura sub-city?

- Very concerned
- Somewhat concerned
- Not concerned
- Not sure

4. Are any protected areas (e.g., forests, wetlands) in Lemi Kura Sub-city that restrict development?

- Yes, there are protected areas
- No, there are no protected areas
- Not sure

#### **Section 4: Infrastructure and Accessibility**

1. How would you rate the current transportation infrastructure (roads, public transport) in the Lemi Kura sub-city?

- Excellent
- Good
- Fair
- Poor

2. What is the proximity of key infrastructure (e.g., roads, public transport, electricity, water supply) to potential development sites?

- Very close
- Somewhat close
- Distant
- Very distant

3. How important is proximity to the following amenities in determining site suitability for residential development? **(Rate each on a scale from 1 = Not important to 5 = Very important)**

- Schools: 1 2 3 4 5
- Hospitals/Health Centres: 1 2 3 4 5
- Shopping centres/Markets: 1 2 3 4 5
- Recreational facilities (parks, gyms, etc.): 1 2 3 4 5
- Employment centres: 1 2 3 4 5

4. Is the availability of public transportation a critical factor when selecting sites for residential development?

- Yes, it is critical
- Somewhat important
- Not important

#### **Section 5: Socioeconomic and Market Factors**

1. What is the general trend of property values in Lemi Kura sub-city over the past 5 years?

- Increased significantly
- Increased moderately
- Stayed the same
- Decreased

2. What is the current demand for residential housing in Lemi Kura sub-city?

- High demand
- Moderate demand
- Low demand

3. How would you rate housing affordability for middle- and low-income families in the sub-City?

- Affordable
- Somewhat affordable
- Not Affordable

4. What residential real estate development type is in highest demand in Lemi Kura sub-city?

- Low-income housing
- Middle-income housing
- Luxury housing
- Mixed-use developments (residential and commercial)
- Other (please specify): \_\_\_\_\_

5. Are there any significant economic or employment opportunities in Lemi Kura sub-city that could affect housing demand?

- Yes, there are several opportunities
- Yes, but limited opportunities
- No, there are no significant opportunities

#### **Section 6: Legal, Regulatory, and Policy Factors**

1. How familiar are you with the current zoning regulations in Lemi Kura sub-city?

- Very familiar
- Somewhat familiar
- Not familiar

2. Are there any legal barriers (e.g., land tenure security, property rights) that could affect residential real estate development in Lemi Kura sub-city?

- Yes
- No
- Not sure

3. How would you assess the enforcement of land use regulations in Lemi Kura sub-city?

- Strong enforcement
- Moderate enforcement
- Weak enforcement
- Not sure

4. Do you think government policies currently support sustainable real estate development?

- Yes, policies are well-aligned with sustainability
- No, policies need improvement
- Not sure

**Section 7: Sustainability Considerations**

1. How important is environmental sustainability in site selection for residential real estate development in Lemi Kura sub-city?

- Very important
- Somewhat important
- Not important

2. Which sustainable development features would you prioritise for residential developments in Lemi Kura sub-city? (Check all that apply.)

- Energy-efficient buildings
- Rainwater harvesting
- Green spaces and parks
- Sustainable waste management systems
- Proximity to public transportation

3. What challenges do you foresee in implementing sustainable residential developments in Lemi Kura sub-city?

- Limited land availability
- High construction costs
- Lack of infrastructure
- Government regulations and policies
- Community resistance
- Other (please specify): \_\_\_\_\_

**Section 8: Final Comments and Recommendations**

1. What are the main challenges to sustainable residential real estate development in Lemi Kura sub-city?  
(Open-ended response)

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2. Do you have any recommendations for improving site selection and sustainable real estate development planning in Lemi Kura sub-city? (Open-ended response)

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**Thank you for your time and valuable insights! Your responses will significantly contribute to assessing the site's suitability for sustainable residential real estate investment in the Lemi Kura sub-city, Addis Ababa.**

## Appendix 3: Predicted Land Value

Id	X_Coord	Y_Coord	Property_	Price	Area	Floor	Room	Type	DIST_SCH
1	38.86505	9.062925	2	5470000	70.75	4	2	1	4.382128
2	38.86835	9.067739	2	5400000	70.75	1	2	2	5.026141
3	38.87171	9.062171	2	5500000	64	2	2	1	4.732908
4	38.87207	9.062343	2	5.00E+06	64	2	2	2	4.764701
5	38.87183	9.061538	2	8.00E+06	106	2	3	1	4.672238
6	38.87208	9.061268	2	6600000	86	3	3	1	4.654349
7	38.87467	9.063288	2	7.00E+06	103	4	3	2	4.97068
8	38.87627	9.066798	2	4800000	70.75	4	2	2	5.38762
9	38.87645	9.065703	2	5.00E+06	64	2	2	1	5.268384
10	38.86261	9.067413	2	7.00E+06	103	4	3	2	4.664589
11	38.86237	9.066014	2	5340000	64	2	2	1	4.516836
12	38.86194	9.065552	2	6350000	83	2	3	1	4.448772
13	38.86332	9.067413	2	7.00E+06	103	4	3	2	4.702338
14	38.86079	9.064859	2	7.00E+06	103	4	3	2	4.32126
15	38.87201	9.069824	2	6500000	83	2	2	1	5.448412
16	38.87027	9.061695	2	7540000	106	3	3	2	4.6291
17	38.8696	9.06109	2	8170000	106	2	3	1	4.530859
18	38.86944	9.061932	2	6750000	83	1	2	1	4.58957
19	38.87066	9.062819	2	6500000	83	3	2	1	4.751512
20	38.89962	9.010085	4	8.00E+06	101	4	3	1	2.006673
21	38.89962	9.010085	4	7600000	101	4	3	2	2.006673
22	38.89798	9.009547	4	7.00E+06	86	8	3	1	1.822825
23	38.89986	9.009252	4	8100000	107	9	3	1	1.981508
24	38.89568	9.009123	4	8370000	101	5	4	1	1.590553
25	38.89603	9.010354	4	6850000	83	3	3	2	1.706151
26	38.89573	9.010778	4	7260000	83	5	3	1	1.712674
27	38.89533	9.008417	4	8300000	101	7	3	1	1.513058
28	38.89606	9.006775	4	7150000	86	3	3	2	1.482601
29	38.89599	9.004722	4	8140000	94	5	3	1	1.381309
30	38.89513	9.004452	4	7500000	94	5	3	2	1.281873
31	38.89968	9.007802	4	7150000	86	5	3	1	1.888958
32	38.89809	9.008636	4	7900000	101	7	3	1	1.779454
33	38.89514	9.007262	4	8790000	101	4	3	1	1.423367
34	38.8989	9.004774	4	7100000	83	5	3	1	1.685522
35	38.86998	9.019987	1	9450000	110	4	3	1	0.371986
36	38.86998	9.019987	1	9600000	110	4	3	1	0.371986
37	38.86998	9.019987	1	9985885	110	1	3	1	0.371986
38	38.86998	9.019987	1	10867376	125	2	3	1	0.371986
39	38.8807	8.994157	4	6800000	83	4	3	2	0.784803
40	38.88185	8.99617	4	8500000	107	5	3	1	0.529013
41	38.8807	8.994157	4	8650000	103	3	3	1	0.784803
42	38.8807	8.994157	4	8300000	103	6	3	1	0.784803
43	38.88274	8.997736	4	7300000	83	4	3	1	0.32982
44	38.88319	8.998438	4	8.00E+06	107	5	3	2	0.238319
45	38.8841	8.997637	4	8100000	103	4	3	2	0.298198
46	38.88349	8.996313	4	8300000	103	5	3	1	0.451443

47	38.88393	8.995251	4	8300000	105	4	3	1	0.562521
48	38.88325	8.992364	4	7800000	94	5	3	1	0.887301
49	38.88258	8.992544	4	8500000	103	3	3	1	0.879569
50	38.88363	8.992905	4	8300000	103	5	3	1	0.823521
51	38.88438	8.992905	4	8.00E+06	103	3	3	2	0.821088
52	38.88279	8.995235	4	6800000	83	4	3	2	0.585173
53	38.88346	8.99521	4	7300000	94	5	3	2	0.57246
54	38.88128	8.993499	4	7300000	83	4	3	1	0.821623
55	38.88219	8.994325	4	8500000	103	2	4	1	0.700645
56	38.88177	8.994577	4	7700000	94	5	3	1	0.690865
57	38.88129	8.994908	4	8800000	105	3	3	1	0.680995
58	38.885	8.996084	4	8800000	105	3	3	1	0.477167
59	38.87895	8.962779	2	6500000	76	2	2	1	0.199888
60	38.87895	8.962779	2	6.00E+06	71	4	2	1	0.199888
61	38.87895	8.962779	2	6300000	86	4	3	1	0.199888
62	38.87254	8.961309	2	6500000	76	2	2	1	0.608809
63	38.87587	8.959989	2	5100000	71	5	2	2	0.276734
64	38.87645	8.962991	2	6200000	86	5	3	2	0.267538
65	38.87848	8.962658	2	5850000	76	2	3	2	0.167903
66	38.88198	8.962916	2	5900000	71	3	3	1	0.468693
67	38.88301	8.960645	2	6.00E+06	86	3	3	2	0.470764
68	38.88135	8.95822	2	6300000	83	2	3	1	0.486579
69	38.87898	8.958527	2	5200000	71	6	2	2	0.310916
70	38.88951	8.95772	2	5900000	86	5	3	1	0.709552
71	38.88636	8.958471	2	5400000	76	2	2	1	0.53563
72	38.88352	8.968494	2	5500000	71	5	2	2	0.212708
73	38.88054	8.964055	2	5900000	86	5	3	2	0.40883
74	38.87511	8.965421	2	6500000	71	3	3	1	0.570527
75	38.88886	8.959916	2	5800000	86	3	3	2	0.466249
76	38.87577	8.971937	2	7400000	86	2	3	1	0.828344
77	38.87362	8.972406	2	6500000	71	3	3	1	1.053582
78	38.88298	8.970342	2	7300000	94	3	3	1	0.33616
79	38.8832	8.972472	2	6800000	83	5	3	1	0.567598
80	38.85386	8.992234	2	6500000	71	1	2	2	0.485174
81	38.85386	8.992234	2	7.00E+06	86	2	3	2	0.485174
82	38.85386	8.992234	2	6600000	70.7	2	2	1	0.485174
83	38.85319	8.993699	2	6700000	71	1	3	1	0.540636
84	38.85408	8.99391	2	5900000	70	4	3	2	0.445206
85	38.85461	8.993857	2	6850000	70.7	2	2	1	0.386244
86	38.85473	8.993206	2	6500000	71	1	2	2	0.371888
87	38.85327	8.992843	2	7.00E+06	86	2	3	2	0.534933
88	38.85515	8.992681	2	5950000	70.7	4	2	2	0.334918
89	38.85484	8.991556	2	6850000	71	1	3	1	0.397516
90	38.85471	8.992482	2	6100000	70	4	3	2	0.387456
91	38.85446	8.992761	2	6750000	70.7	2	2	1	0.407659
92	38.89124	9.019667	2	5300000	64	2	2	2	2.02946
93	38.89124	9.019683	4	7550000	94	4	3	1	2.029147

94	38.89106	9.017983	4	6700000	86	3	5	2	2.003512
95	38.89176	9.016308	4	8250000	103	3	3	1	1.924976
96	38.89368	9.016111	4	7500000	103	3	3	2	2.030686
97	38.8923	9.016875	4	7300000	83	4	3	1	2.010204
98	38.89244	9.018462	4	8.00E+06	103	3	3	1	2.154627
99	38.89098	9.015995	4	7800000	94	4	3	1	1.850238
100	38.8914	9.014534	4	7400000	83	4	3	1	1.740868
101	38.89325	9.018394	4	7600000	101	5	3	2	2.20789

DIST_HC	AMR	ACC	ASCC	AMP	fit	lwr	upr	Prediction	Percentage
0.575693	1.154663	4.288137	0.754096	2.628963	5661249	5577947	5744550	-191249	-3.49632
0.158	1.278587	4.91209	0.129692	2.968429	5472056	5352243	5591868	-72055.7	-1.33436
0.55054	0.560694	4.488315	0.832446	2.27286	5410729	5322686	5498773	89270.51	1.6231
0.558105	0.557531	4.51319	0.833888	2.281935	4880944	4794103	4967784	119056.1	2.381122
0.480267	0.495595	4.421188	0.900914	2.202007	8033045	7933236	8132854	-33044.8	-0.41306
0.443246	0.455414	4.395958	0.939689	2.166219	6686266	6615111	6757421	-86266	-1.30706
0.664232	0.597258	4.66921	0.933106	2.336674	7007593	6909712	7105475	-7593.34	-0.10848
0.327216	0.996081	5.086623	0.90235	2.712671	4790271	4695392	4885150	9729.34	0.202695
0.449028	0.876502	4.97379	0.959794	2.591219	5115016	5016351	5213682	-115016	-2.30033
0.702701	1.668379	4.688904	0.651186	3.192874	6946333	6838755	7053910	53667.26	0.766675
0.721154	1.59072	4.532689	0.729333	3.07236	5262726	5171981	5353470	77274.43	1.447087
0.773995	1.600127	4.471597	0.795464	3.054511	6437442	6356810	6518074	-87442.2	-1.37704
0.625747	1.610522	4.708202	0.57607	3.155249	6987619	6877932	7097306	12380.83	0.176869
0.910809	1.665894	4.368765	0.942907	3.061436	6929517	6831775	7027258	70483.08	1.006901
0.459853	1.34615	5.279337	0.416458	3.09325	6364469	6260285	6468654	135530.9	2.08509
0.543729	0.62308	4.384126	0.825531	2.267967	7453497	7354429	7552564	86503.46	1.147261
0.571121	0.629709	4.292025	0.875793	2.22998	8080874	7983416	8178332	89126.03	1.090894
0.500391	0.705135	4.368435	0.78114	2.323214	6744734	6659495	6829973	5266.328	0.07802
0.442462	0.685582	4.514892	0.720433	2.373022	6525583	6451001	6600165	-25583.1	-0.39359
2.849058	0.56793	3.199737	1.266091	0.756083	8071112	8003131	8139093	-71112.1	-0.8889
2.849058	0.56793	3.199737	1.266091	0.756083	7552169	7474381	7629958	47830.58	0.62935
2.669903	0.386616	3.063625	1.076422	0.593328	6931370	6809993	7052748	68629.61	0.980423
2.815588	0.593414	3.131703	1.258557	0.801265	7980983	7845206	8116760	119017.2	1.469348
2.446423	0.133712	2.914422	0.828081	0.385871	8378824	8304932	8452716	-8824.13	-0.10543
2.566436	0.173236	3.054581	0.930433	0.362781	6836770	6763855	6909686	13229.71	0.193134
2.575292	0.141034	3.08505	0.931047	0.321857	7163396	7087509	7239283	96603.92	1.330632
2.366296	0.094711	2.827595	0.759972	0.409347	8244469	8140541	8348396	55531.3	0.669052
2.316014	0.172508	2.695226	0.785961	0.600516	7157976	7081584	7234367	-7975.58	-0.11155
2.184363	0.163371	2.489337	0.77677	0.791932	8010108	7937792	8082424	129891.8	1.595722
2.087797	0.068067	2.41972	0.687998	0.783217	7561248	7472755	7649741	-61248	-0.81664
2.671322	0.572112	2.982977	1.198351	0.839657	7124564	7056914	7192214	25435.96	0.355748
2.618442	0.398474	2.979848	1.05268	0.64242	7990420	7895251	8085590	-90420.1	-1.14456
2.26849	0.072284	2.70218	0.698137	0.500001	8583040	8507886	8658193	206960.1	2.354495
2.327773	0.482571	2.652548	1.093279	0.970963	7066865	7000194	7133536	33134.66	0.466685
0.809419	0.118421	0.470898	0.940743	2.503029	9266962	9177980	9355943	183038.1	1.936911
0.809419	0.118421	0.470898	0.940743	2.503029	9266962	9177980	9355943	333038.1	3.469147
0.809419	0.118421	0.470898	0.940743	2.503029	9554651	9438468	9670835	431233.7	4.318433
0.809419	0.118421	0.470898	0.940743	2.503029	10394284	10266383	10522185	473091.7	4.353321
0.189595	0.509571	0.895847	1.566027	2.304174	6652238	6570766	6733710	147761.7	2.172966
0.364992	0.31571	1.138516	1.311927	2.049856	8684588	8618558	8750618	-184588	-2.17162
0.189595	0.509571	0.895847	1.566027	2.304174	8514450	8440356	8588544	135550.2	1.567055
0.189595	0.509571	0.895847	1.566027	2.304174	8226760	8147167	8306354	73239.62	0.882405
0.547413	0.116782	1.327434	1.114559	1.852067	7370907	7310635	7431179	-70907.1	-0.97133
0.63579	0.025158	1.412961	1.023458	1.760755	8293737	8208299	8379175	-293737	-3.67171
0.660244	0.04619	1.345224	1.039185	1.776484	8150111	8070838	8229385	-50111.3	-0.61866
0.53368	0.205264	1.188858	1.198905	1.935633	8503865	8441266	8566465	-203865	-2.45621

0.548753	0.158559	1.08301	1.279759	2.012018	8698961	8637303	8760619	-398961	-4.80676
0.521256	0.22287	0.755304	1.601531	2.329278	7782270	7710944	7853596	17730.09	0.227309
0.447142	0.296655	0.760758	1.61378	2.34574	8523475	8446122	8600829	-23475.3	-0.27618
0.537143	0.182846	0.82215	1.530007	2.256884	8375898	8306530	8445267	-75898.5	-0.91444
0.615362	0.100888	0.837979	1.500335	2.221348	8067258	7978906	8155609	-67257.6	-0.84072
0.424134	0.284754	1.056957	1.340947	2.077802	6769379	6695035	6843724	30620.6	0.450303
0.496154	0.210924	1.068395	1.307481	2.042013	7381468	7306445	7456490	-81467.8	-1.116
0.272231	0.443242	0.836804	1.590809	2.328444	7171686	7099232	7244139	128314.4	1.757732
0.350631	0.346511	0.945598	1.460814	2.197752	8673444	8591668	8755220	-173444	-2.04051
0.304621	0.393345	0.964102	1.461332	2.199224	7817891	7753847	7881934	-117891	-1.53105
0.255619	0.448029	0.9897	1.461055	2.199218	8687672	8616192	8759152	112328.4	1.276459
0.682603	0.044864	1.195876	1.14793	1.875634	8858419	8790980	8925858	-58418.7	-0.66385
0.463249	0.600543	1.68344	0.932152	4.901925	6393006	6311000	6475013	106993.7	1.646056
0.463249	0.600543	1.68344	0.932152	4.901925	5889370	5801623	5977118	110629.7	1.843828
0.463249	0.600543	1.68344	0.932152	4.901925	6824900	6747384	6902415	-524900	-8.33174
1.186189	0.723024	2.047259	0.592286	4.641163	6512275	6418617	6605932	-12274.6	-0.18884
0.888567	0.680629	2.087893	0.877466	4.976868	5155442	5054196	5256689	-55442.4	-1.08711
0.731753	0.875798	1.753877	0.683271	4.727703	6356353	6252477	6460229	-156353	-2.52182
0.516929	0.652262	1.713515	0.892179	4.88275	5889483	5798406	5980560	-39483.1	-0.67493
0.144743	0.268653	1.562469	1.23356	5.090497	5824780	5742140	5907419	75220.42	1.274922
0.330255	0.149095	1.784185	1.4365	5.357855	6003251	5910638	6095863	-3250.61	-0.05418
0.627928	0.3255	2.083025	1.431709	5.465483	6312439	6219115	6405762	-12438.5	-0.19744
0.721889	0.585837	2.124879	1.219047	5.293251	4797831	4685108	4910555	402168.8	7.734014
0.809621	0.572675	2.126516	2.220005	5.919213	5685908	5529785	5842032	214091.6	3.628671
0.674787	0.224442	2.002335	1.873991	5.775461	5601529	5475666	5727392	-201529	-3.73202
0.539668	0.114126	0.923009	1.353642	4.74349	5338428	5237690	5439166	161572.1	2.937675
0.282759	0.429296	1.491758	1.045785	4.893855	6214914	6124278	6305550	-314914	-5.33753
0.898406	1.030245	1.5508	0.429733	4.421835	6398754	6285986	6511521	101246.2	1.557633
0.55683	0.495263	1.874463	2.057572	5.681969	5578707	5441225	5716188	221293.1	3.815399
0.87278	0.949458	0.84217	0.768741	3.886393	7608055	7516772	7699337	-208055	-2.81155
0.988664	0.917643	0.820116	0.694988	3.698101	6665693	6563717	6767670	-165693	-2.54913
0.741895	0.177955	0.747027	1.344801	4.558442	7587895	7513004	7662786	-287895	-3.94376
0.614385	0.159456	0.517149	1.457545	4.405982	6761359	6677624	6845094	38640.98	0.56825
0.226994	0.152634	2.533988	1.151283	0.737252	6245871	6149119	6342623	254129.2	3.90968
0.226994	0.152634	2.533988	1.151283	0.737252	7085504	7008121	7162886	-85503.5	-1.22148
0.226994	0.152634	2.533988	1.151283	0.737252	6650206	6569130	6731283	-50206.5	-0.7607
0.285503	0.127781	2.376129	1.190069	0.569703	6834637	6740293	6928982	-134637	-2.00951
0.200469	0.227974	2.347678	1.090268	0.558316	6028818	5940581	6117055	-128818	-2.18336
0.146437	0.282593	2.350327	1.032857	0.578908	6807113	6723359	6890868	42886.6	0.626082
0.109642	0.274396	2.421583	1.032713	0.651526	6363023	6264998	6461048	136977.2	2.107342
0.270873	0.109809	2.470198	1.197349	0.664687	7099203	7019998	7178409	-99203.5	-1.41719
0.079359	0.303028	2.477072	1.000952	0.721262	6038880	5954038	6123722	-88880.1	-1.49378
0.198898	0.234404	2.492001	1.074001	0.830773	6796220	6707102	6885338	53780	0.785109
0.131586	0.250352	2.501576	1.053564	0.728193	5958648	5873614	6043683	141351.7	2.31724
0.144546	0.232129	2.472266	1.072618	0.691434	6721223	6639966	6802480	28776.97	0.426325
2.582417	0.278541	2.803838	1.566196	0.956797	5361856	5252631	5471080	-61856	-1.16709
2.580752	0.276776	2.803435	1.567846	0.958594	7558923	7481937	7635910	-8923.34	-0.11819

2.721963	0.356963	2.782094	1.379313	0.779091	6782818	6707265	6858370	-82817.6	-1.23608
2.79217	0.289939	2.867784	1.213921	0.581415	8465915	8396334	8535495	-215915	-2.61715
2.886097	0.078618	3.080393	1.263525	0.555677	7859247	7774515	7943979	-359247	-4.78996
2.876504	0.22946	2.923059	1.290287	0.634687	7053139	6986036	7120242	246861.2	3.38166
2.768164	0.199794	2.932623	1.46326	0.808699	8263593	8182485	8344700	-263593	-3.29491
2.719963	0.375657	2.785857	1.161384	0.572029	7864229	7806697	7921760	-64228.5	-0.82344
2.603863	0.330632	2.852234	1.0144	0.404755	7271672	7207181	7336162	128328.2	1.734165
2.829647	0.112331	3.022169	1.481829	0.801402	7391540	7303334	7479745	208460.1	2.742896

Within\_95CI

No

Yes

No

No

Yes

No

Yes

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Yes

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Yes

Yes

No

Yes

Yes

Yes

Yes

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## Appendix 4: AHP Process (Multiple Input Summary Sheet)

### AHP Analytic Hierarchy Process (EVM multiple inputs)

K. D. Goepel Version 07.07.2022 Free web based AHP software on: <https://bpmsg.com>

**Only input data in the light green fields and worksheets!**

n=  Number of criteria (2 to 10) Scale:  AHP 1-9  
 N=  Number of Participants (1 to 20) α:  Consensus:   
 p=  selected Participant (0=consol.) 2 7 Consolidated

**Objective** To Assess the Site Suitability area for Sustainable Residential Real Estate Property Investment in

**Author** Kidist Shuma

**Date**  Thresh:  Iterations: 6 EVM check: 8.0E-10

Table	Criterion	Comment	Weights	+/-
1	LULC		27.8%	5.0%
2	Elevation		26.5%	4.0%
3	Slope		16.8%	3.2%
4	Soil		15.8%	2.3%
5	Geology		13.0%	2.2%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
10		question section ("+" in row 66)	0.0%	0.0%

<b>Result</b>	<b>Eigenvalue</b>	Lambda: <b>5.057</b>	MRE: 16.8%
	<b>Consistency Ratio</b>	0.37 GCI: <b>0.05</b> Psi: <b>20.0%</b> CR: <b>1.3%</b>	

Matrix	LULC	Elevation	Slope	Soil	Geology	0	0	0	0	0	normalized principal Eigenvector
LULC	1	1 1/4	2	1 1/2	1 5/7	-	-	-	-	-	27.83%
Elevation	4/5	1	2	1 4/5	1 6/7	-	-	-	-	-	26.54%
Slope	1/2	1/2	1	1 2/7	1 5/9	-	-	-	-	-	16.83%
Soil	2/3	5/9	7/9	1	1 3/7	-	-	-	-	-	15.84%
Geology	3/5	1/2	2/3	5/7	1	-	-	-	-	-	12.96%
0	-	-	-	-	-	1	-	-	-	-	0.00%
0	-	-	-	-	-	-	1	-	-	-	0.00%
0	-	-	-	-	-	-	-	1	-	-	0.00%
0	-	-	-	-	-	-	-	-	1	-	0.00%
0	-	-	-	-	-	-	-	-	-	1	0.00%

# AHP Analytic Hierarchy Process (10x10 Matrix)

Power Method (Dominant Eigenvalue)

5

1	1.00	1.24	2.00	1.53	1.71	-	-	-	-	-
2	0.81	1.00	1.94	1.80	1.85	-	-	-	-	-
3	0.50	0.52	1.00	1.29	1.56	-	-	-	-	-
4	0.65	0.55	0.77	1.00	1.42	-	-	-	-	-
5	0.58	0.54	0.64	0.70	1.00	-	-	-	-	-
6	-	-	-	-	-	1.00	-	-	-	-
7	-	-	-	-	-	-	1.00	-	-	-
8	-	-	-	-	-	-	-	1.00	-	-
9	-	-	-	-	-	-	-	-	1.00	-
10	-	-	-	-	-	-	-	-	-	1.00
Sum (col)	3.5458	3.847	6.3531	6.3335	7.5394	0	0	0	0	0

Iterations

0	20
0.75	5.06
0.74	4.82
0.49	3.06
0.44	2.88
0.35	2.35
0.10	0.00
0.10	0.00
0.10	0.00
0.10	0.00
0.10	0.00

Scaling

1.00	1.00
0.99	0.95
0.65	0.60
0.59	0.57
0.46	0.47
0.13	0.00
0.13	0.00
0.13	0.00
0.13	0.00
0.13	0.00
4.36	3.59

0.28	0.32	0.31	0.24	0.23	-	-	-	-	-
0.23	0.26	0.31	0.28	0.25	-	-	-	-	-
0.14	0.13	0.16	0.20	0.21	-	-	-	-	-
0.18	0.14	0.12	0.16	0.19	-	-	-	-	-
0.16	0.14	0.10	0.11	0.13	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Normalization

0.2293	0.27829
0.2269	0.265406
0.1492	0.168313
0.1349	0.15844
0.1064	0.129552
0.0307	3.02E-16
0.0307	3.02E-16
0.0307	3.02E-16
0.0307	3.02E-16
0.0307	3.02E-16
0.0307	3.02E-16

Check 8E-10

I\*I

5.0573										
	5.0573									
		5.0573								
			5.0573							
				5.0573						
					5.0573					
						5.0573				
							5.0573			
								5.0573		
									5.0573	

Eigenvalue: 5.057326

err: 1.0E-08 1.58E-29

Iterations: 6.0E+00 2.96E-30

check: 8.02E-10 2.59E-30

1.11E-30

9.98E-31

6.04E-31

1.5E-30

1.5E-30

1.5E-30

1.5E-30

1.5E-30

A-I\*I

-4.0573	1.24	2.00	1.53	1.71	-	-	-	-	-
0.81	-4.0573	1.94	1.80	1.85	-	-	-	-	-
0.50	0.52	-4.0573	1.29	1.56	-	-	-	-	-
0.65	0.55	0.77	-4.06	1.42	-	-	-	-	-
0.58	0.54	0.64	0.70	-4.06	-	-	-	-	-
-	-	-	-	-	-4.06	-	-	-	-
-	-	-	-	-	-	-4.06	-	-	-
-	-	-	-	-	-	-	-4.0573	-	-
-	-	-	-	-	-	-	-	-4.0573	-
-	-	-	-	-	-	-	-	-	-4.0573

(A-I\*I)x

3E-14	3E-14	3E-14	3E-14	3E-14	3E-14	3E-14	3E-14	3E-14	3E-14	3E-14
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Convergence

1.E-02

1.E-09

1.E-16

**AHP**  
bpmmsg.com  
**Analytic Hierarchy Process**  
Multiple Input Summary Sheet

Consolidated = Weighted geometric mean off participants

15 = k number of participants  
5 = n number of criteria

C Consolidated										
	1	2	3	4	5	6	7	8	9	10
1		1.236	1.998	1.532	1.714	0	0	0	0	0
2	0.809		1.94	1.803	1.849	0	0	0	0	0
3	0.5	0.515		1.294	1.557	0	0	0	0	0
4	0.653	0.555	0.773		1.42	0	0	0	0	0
5	0.584	0.541	0.642	0.704		0	0	0	0	0
6	0	0	0	0	0		0	0	0	0
7	0	0	0	0	0	0		0	0	0
8	0	0	0	0	0	0	0		0	0
9	0	0	0	0	0	0	0	0		0
10	0	0	0	0	0	0	0	0	0	

1 Participant 1										
	1	2	3	4	5	6	7	8	9	10
1	1	3	5	4	4	0	0	0	0	0
2	1/3	1	3	2	4	0	0	0	0	0
3	1/5	1/3	1	1	2	0	0	0	0	0
4	1/4	1/2	1	1	3	0	0	0	0	0
5	1/4	1/4	1/2	1/3	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

2 Participant 2										
	1	2	3	4	5	6	7	8	9	10
1	1	2	4	3	4	0	0	0	0	0
2	1/2	1	2	2	3	0	0	0	0	0
3	1/4	1/2	1	2	2	0	0	0	0	0
4	1/3	1/2	1/2	1	2	0	0	0	0	0
5	1/4	1/3	1/2	1/2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

3 Participant 3										
	1	2	3	4	5	6	7	8	9	10
1	1	3	5	4	5	0	0	0	0	0
2	1/3	1	3	3	4	0	0	0	0	0
3	1/5	1/3	1	1	2	0	0	0	0	0
4	1/4	1/3	1	1	2	0	0	0	0	0
5	1/5	1/4	1/2	1/2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

4 Participant 4										
	1	2	3	4	5	6	7	8	9	10
1	1	2	3	3	3	0	0	0	0	0
2	1/2	1	2	2	1	0	0	0	0	0
3	1/3	1/2	1	2	2	0	0	0	0	0
4	1/3	1/2	1/2	1	1	0	0	0	0	0
5	1/3	1	1/2	1	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

5 Participant 5										
	1	2	3	4	5	6	7	8	9	10
1	1	1/2	2	1/3	1/2	0	0	0	0	0
2	2	1	3	2	2	0	0	0	0	0
3	1/2	1/3	1	1/2	1	0	0	0	0	0
4	3	1/2	2	1	1	0	0	0	0	0
5	2	1/2	1	1	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

6 Participant 6										
	1	2	3	4	5	6	7	8	9	10
1	1	2	4	3	4	0	0	0	0	0
2	1/2	1	2	2	3	0	0	0	0	0
3	1/4	1/2	1	2	2	0	0	0	0	0
4	1/3	1/2	1/2	1	1	0	0	0	0	0
5	1/4	1/3	1/2	1	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

7 Participant 7										
	1	2	3	4	5	6	7	8	9	10
1	1	3	6	5	8	0	0	0	0	0
2	1/3	1	2	3	7	0	0	0	0	0
3	1/6	1/2	1	2	4	0	0	0	0	0
4	1/5	1/3	1/2	1	2	0	0	0	0	0
5	1/8	1/7	1/4	1/2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

8 Participant 8										
	1	2	3	4	5	6	7	8	9	10
1	1	1/2	1/3	1/2	1/4	0	0	0	0	0
2	2	1	1/2	2	1/3	0	0	0	0	0
3	3	2	1	2	1	0	0	0	0	0
4	2	1/2	1/2	1	1/2	0	0	0	0	0
5	4	3	1	2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

9 Participant 9										
	1	2	3	4	5	6	7	8	9	10
1	1	1	2	2	3	0	0	0	0	0
2	1	1	2	2	3	0	0	0	0	0
3	1/2	1/2	1	1	2	0	0	0	0	0
4	1/2	1/2	1	1	2	0	0	0	0	0
5	1/3	1/3	1/2	1/2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

10 Participant 10										
	1	2	3	4	5	6	7	8	9	10
1	1	3	3	4	2	0	0	0	0	0
2	1/3	1	2	2	1	0	0	0	0	0
3	1/3	1/2	1	2	1	0	0	0	0	0
4	1/4	1/2	1/2	1	1/2	0	0	0	0	0
5	1/2	1	1	2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

11 Participant 11										
	1	2	3	4	5	6	7	8	9	10
1	1	4	6	5	7	0	0	0	0	0
2	1/4	1	4	3	5	0	0	0	0	0
3	1/6	1/4	1	2	3	0	0	0	0	0
4	1/5	1/3	1/2	1	2	0	0	0	0	0
5	1/7	1/5	1/3	1/2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

# Appendix 5: R Statistical Script for Hedonic Land Value Modeling

```

# INSTALL AND LOAD PACKAGES -----
rm(list = ls())

library(car)    # For vif() and regression diagnostics
library(ggplot2) # For custom visualization
library(gridExtra) # For arranging multiple plots
library(GGally) # For ggpairs (correlation matrix)
library(dplyr)  # For data manipulation
library(corrplot) # For visualizing correlations
library(data.table) # For efficient data handling
library(writexl) # For exporting to Excel
library(broom)   # For tidy model outputs
library(performance) # For model performance metrics
library(ggpubr)  # For publication-ready plots

# LOAD AND EXPLORE DATA -----
# Load the dataset
data <- read.csv("C:/MinteGIS/Ko Research/Multi Regression/ArcGIS Excel_Final.csv")

# View basic structure of the data
cat("Data Structure:\n")
str(data)

# Check for missing values
cat("\nMissing values in each column:\n")
print(colSums(is.na(data)))

# DATA PREPARATION -----
# Convert categorical variables to factors
data$Type <- as.factor(data$Type)

# Remove unused columns (all NA columns)
data <- data %>% select(-X, -X.1)

# EXPLORATORY DATA ANALYSIS -----
# 1. Correlation Analysis with significance stars
numeric_vars <- na.omit(data[c("Price", "Area", "Floor", "Room", "DIST_SCH",
                              "DIST_HC", "AMR", "ACC", "ASCC", "AMP")])

```

```

cor_matrix <- cor(numeric_vars)

# Calculate p-values for correlations
cor.mtest <- function(mat, conf.level = 0.95) {
  mat <- as.matrix(mat)
  n <- ncol(mat)
  p.mat <- matrix(NA, n, n)
  diag(p.mat) <- 0
  for (i in 1:(n - 1)) {
    for (j in (i + 1):n) {
      tmp <- cor.test(mat[, i], mat[, j], conf.level = conf.level)
      p.mat[i, j] <- p.mat[j, i] <- tmp$p.value
    }
  }
  colnames(p.mat) <- rownames(p.mat) <- colnames(mat)
  p.mat
}
p.mat <- cor.mtest(numeric_vars)

cat("\nCorrelation with Price (sorted) with p-values:\n")
cor_with_p <- data.frame(
  Variable = names(cor_matrix["Price", ]),
  Correlation = cor_matrix["Price", ],
  p_value = p.mat["Price", ]
) %>% arrange(desc(abs(Correlation)))
print(cor_with_p)

corrplot_corr <- corrplot(cor_matrix, method = "color", type = "upper",
  tl.col = "black", tl.srt = 45,
  p.mat = p.mat, sig.level = 0.05, insig = "blank",
  addCoef.col = "black", number.cex = 0.6,
  title = "Correlation Matrix (p < 0.05 significant)",
  mar = c(0, 0, 2, 0)) # Adjust margins within corrplot

# Option 1: ANOVA (If Type Has Multiple Levels)
anova_result <- aov(Price ~ Type, data = data)
summary(anova_result)
ggplot(data, aes(x = Type, y = Price, fill = Type)) +
  geom_boxplot() +

```

```
labs(title = "Price Distribution by Type") +  
theme_minimal()
```

```
# 2. Enhanced visualization of relationships with Price
```

```
top_vars <- names(sort(abs(cor_matrix["Price", ]), decreasing = TRUE))[2:6]
```

```
plot_list <- list()
```

```
for (var in top_vars) {
```

```
  p <- ggplot(data, aes_string(x = var, y = "Price")) +
```

```
    geom_point(alpha = 0.6, color = "steelblue") +
```

```
    geom_smooth(method = "lm", color = "red", se = TRUE) +
```

```
    stat_cor(method = "pearson", label.x.npc = "left", label.y.npc = "top") +
```

```
    labs(title = paste("Price vs", var, "with Correlation Coefficient"),
```

```
          x = var, y = "Price") +
```

```
    theme_minimal() +
```

```
    theme(plot.title = element_text(size = 10))
```

```
  plot_list[[var]] <- p
```

```
}
```

```
# Display all plots in a grid with title
```

```
price_scatter_grid <- grid.arrange(grobs = plot_list, ncol = 2,
```

```
                                   top = "Top 5 Variables Correlated with Price")
```

```
print(price_scatter_grid) # Print the arranged plot
```

```
# Save the scatter plot grid
```

```
ggsave("price_scatter_grid.png", plot = price_scatter_grid, width = 10, height = 8, units = "in",  
        dpi = 300)
```

```
cat("\nScatter plots of top correlated variables with Price saved as price_scatter_grid.png\n")
```

```
# MODEL BUILDING -----
```

```
# Full model with all potential predictors
```

```
full_model <- lm(Price ~ Area + Floor + Room + Type + DIST_SCH + DIST_HC + AMR +  
ACC + ASCC + AMP,
```

```
    data = data)
```

```
# Enhanced model summary with tidy output
```

```
cat("\nFull Model Summary with Significance Stars:\n")
```

```
full_model_summary_tidy <- tidy(full_model) %>%
```

```
  mutate(significance = case_when(
```

```

    p.value < 0.001 ~ "****",
    p.value < 0.01 ~ "***",
    p.value < 0.05 ~ "**",
    p.value < 0.1 ~ ".",
    TRUE ~ ""
  ))
print(full_model_summary_tidy)

# Check for multicollinearity with interpretation
cat("\nVariance Inflation Factors (VIF) with Interpretation:\n")
vif_values <- vif(full_model)
vif_df <- data.frame(
  Variable = names(vif_values),
  VIF = vif_values,
  Interpretation = ifelse(vif_values > 5, "High Multicollinearity", "Acceptable")
)
print(vif_df)

# MODEL REFINEMENT -----
# Remove insignificant variables (p > 0.05)
refined_model <- update(full_model, . ~ . - Room - DIST_SCH - DIST_HC - AMR)

# Enhanced refined model summary
cat("\nRefined Model Summary with Confidence Intervals:\n")
refined_summary_tidy <- tidy(refined_model, conf.int = TRUE) %>%
  mutate(significance = case_when(
    p.value < 0.001 ~ "****",
    p.value < 0.01 ~ "***",
    p.value < 0.05 ~ "**",
    p.value < 0.1 ~ ".",
    TRUE ~ ""
  ))
print(refined_summary_tidy)

# Check log transformation
log_model <- update(refined_model, log(Price) ~ .)

# FINAL MODEL SELECTION -----
model_comparison <- compare_performance(
  full_model, refined_model, log_model,

```

```

  metrics = c("AIC", "BIC", "R2", "R2_adj", "RMSE")
)

cat("\nComprehensive Model Comparison:\n")
print(model_comparison)

# Select final model based on AIC and adjusted R-squared
final_model <- refined_model # Based on the output, refined model has better AIC and similar
R2_adj

# Visual model comparison
model_comp_plot <- plot(model_comparison) +
  labs(title = "Model Comparison Metrics") +
  theme_minimal()
print(model_comp_plot)

# Save model comparison plot
ggsave("model_comparison.png", plot = model_comp_plot, width = 8, height = 6, units = "in",
dpi = 300)
cat("\nModel comparison plot saved as model_comparison.png\n")

# FINAL MODEL DETAILS -----
cat("\nFinal Model Equation with Standard Errors:\n")
final_summary <- tidy(final_model) %>%
  mutate(term = ifelse(term == "(Intercept)", "Intercept", term))
equation <- paste0("Price = ",
  round(final_summary$estimate[1], 2),
  " (SE = ", round(final_summary$std.error[1], 2), ")")
for (i in 2:nrow(final_summary)) {
  equation <- paste0(equation, " + ",
    round(final_summary$estimate[i], 2),
    " (SE = ", round(final_summary$std.error[i], 2), ")*",
    final_summary$term[i])
}
cat(equation, "\n")

# PREDICTIONS AND EXPORT -----
# Calculate predictions and confidence intervals
predictions <- predict(final_model, newdata = data, interval = "confidence")
data <- cbind(data, predictions)

```

```

# Calculate errors
data <- data %>%
  mutate(
    Prediction_Error = Price - fit,
    Percentage_Error = (Prediction_Error / Price) * 100,
    Within_95CI = ifelse(Price >= lwr & Price <= upr, "Yes", "No")
  )

# Save the updated dataset with all statistics
output_csv_path <- "C:/MinteGIS/Ko Research/Multi Regression/Kidist_final.csv"
write.csv(data, file = output_csv_path, row.names = FALSE)

cat("\nDataset with predictions and statistics saved to:\n")
cat("CSV:", output_csv_path, "\n")

# ENHANCED VISUALIZATION -----
# Actual vs Predicted plot with confidence intervals
p1 <- ggplot(data, aes(x = Price, y = fit)) +
  geom_point(aes(color = Within_95CI), alpha = 0.6) +
  geom_errorbar(aes(ymin = lwr, ymax = upr), alpha = 0.2) +
  geom_abline(intercept = 0, slope = 1, color = "red") +
  scale_color_manual(values = c("Yes" = "steelblue", "No" = "red")) +
  labs(title = "Actual vs Predicted Prices with 95% CI",
       x = "Actual Price", y = "Predicted Price",
       color = "Within 95% CI?") +
  theme_minimal() +
  theme(legend.position = "bottom")
print(p1)
ggsave("actual_vs_predicted.png", plot = p1, width = 8, height = 6, units = "in", dpi = 300)
cat("\nActual vs Predicted prices plot saved as actual_vs_predicted.png\n")

# Residuals plot with density
p2 <- ggplot(data, aes(x = fit, y = Prediction_Error)) +
  geom_point(alpha = 0.6, color = "steelblue") +
  geom_hline(yintercept = 0, color = "red") +
  geom_smooth(se = FALSE, color = "darkgreen") +
  labs(title = "Residual Analysis",
       x = "Predicted Price", y = "Prediction Error") +
  theme_minimal()

```

```

print(p2)
ggsave("residuals_vs_predicted.png", plot = p2, width = 8, height = 6, units = "in", dpi = 300)
cat("\nResiduals vs Predicted prices plot saved as residuals_vs_predicted.png\n")

# Error distribution plot
p3 <- ggplot(data, aes(x = Percentage_Error)) +
  geom_histogram(aes(y = ..density..), bins = 30, fill = "steelblue", alpha = 0.7) +
  geom_density(color = "red") +
  labs(title = "Percentage Error Distribution",
       x = "Percentage Error", y = "Density") +
  theme_minimal()
print(p3)
ggsave("percentage_error_distribution.png", plot = p3, width = 8, height = 6, units = "in", dpi =
300)
cat("\nPercentage error distribution plot saved as percentage_error_distribution.png\n")

# Combine all diagnostic plots
diagnostic_plots <- grid.arrange(p1, p2, p3, ncol = 2,
                                top = "Model Diagnostic Plots")
print(diagnostic_plots)
ggsave("model_diagnostics.png", plot = diagnostic_plots, width = 12, height = 10, units = "in",
dpi = 300)
cat("\nCombined model diagnostic plots saved as model_diagnostics.png\n")

# COMPREHENSIVE MODEL PERFORMANCE ASSESSMENT -----
valid_data <- data[complete.cases(data$fit), ]

# Calculate all relevant metrics
metrics <- data.frame(
  Observations = nrow(valid_data),
  RMSE = sqrt(mean((valid_data$Price - valid_data$fit)^2)),
  MAE = mean(abs(valid_data$Price - valid_data$fit)),
  MAPE = mean(abs(valid_data$Percentage_Error)),
  MPE = mean(valid_data$Percentage_Error),
  R2 = summary(final_model)$r.squared,
  Adj_R2 = summary(final_model)$adj.r.squared,
  Within_95CI = mean(valid_data$Within_95CI == "Yes") * 100,
  F_Statistic = summary(final_model)$fstatistic[1],
  F_p_value = pf(summary(final_model)$fstatistic[1],
                 summary(final_model)$fstatistic[2],

```

```

summary(final_model)$statistic[3],
lower.tail = FALSE)
)

cat("\nComprehensive Model Performance Metrics:\n")
print(t(metrics))

# Normality test for residuals
cat("\nNormality Tests for Residuals:\n")
shapiro_test <- shapiro.test(resid(final_model))
print(shapiro_test)

# Statistical Sound Analysis
cat("\nSTATISTICAL SOUND ANALYSIS:\n")
cat("=====\n")

cat("\n1. Model Fit:\n")
cat("R-squared (R²):", round(metrics$R2, 3), ". This indicates that approximately",
round(metrics$R2 * 100, 1), "% of the variance in Price is explained by the final model.\n")
cat("Adjusted R-squared:", round(metrics$Adj_R2, 3), ". This is a more conservative measure of
model fit, adjusted for the number of predictors. The value is similar to R-squared, suggesting
the model is not overly complex.\n")

cat("\n2. Prediction Accuracy:\n")
cat("Root Mean Squared Error (RMSE):", round(metrics$RMSE, 2), ". This represents the
average magnitude of the errors between predicted and actual prices. Lower values are better.\n")
cat("Mean Absolute Error (MAE):", round(metrics$MAE, 2), ". This is another measure of the
average error magnitude, less sensitive to outliers than RMSE.\n")
cat("Mean Absolute Percentage Error (MAPE):", round(metrics$MAPE, 2), "%. On average, the
model's predictions are off by about", round(metrics$MAPE, 2), "%.\n")
cat("Mean Percentage Error (MPE):", round(metrics$MPE, 2), "%. This indicates a slight
tendency for the model to underpredict (negative value).\n")
cat("Percentage of Actual Prices within 95% Confidence Interval:", round(metrics$Within_95CI,
2), "%. Ideally, this value should be close to 95%.\n")

cat("\n3. Overall Model Significance:\n")
cat("F-statistic:", round(metrics$F_Statistic, 2), ", p-value:", format.pval(metrics$F_p_value), ".
The highly significant p-value indicates that the overall regression model is statistically
significant, meaning that at least one of the predictors has a significant impact on Price.\n")

```

```
cat("\n4. Residual Analysis (Normality):\n")
cat("Shapiro-Wilk Test for Normality of Residuals: W =", round(shapiro_test$statistic, 3), ", p-
value =", format.pval(shapiro_test$p.value), ".\n")
if (shapiro_test$p.value > 0.05) {
  cat("The p-value is greater than 0.05, suggesting that we do not have strong evidence to reject
the null hypothesis that the residuals are normally distributed. This is a desirable property for
linear regression models.\n")
} else {
  cat("The p-value is less than 0.05, suggesting that we reject the null hypothesis and there is
evidence that the residuals are not normally distributed. This might warrant further investigation
or consideration of alternative modeling techniques.\n")
}

cat("\nFINAL MODEL REPORT\n")
cat("=====\n")
cat("Selected Model: Refined Linear Model\n")
```