E-NAMTILA Publishing
DYSONA - Applied Science
DAS 6 (2025) 322-333
DOI: 10.30493/DAS.2025.478550

Urban agriculture land suitability assessment using AHP and geospatial analysis in Gondar Zuria, Ethiopia

Mitiku Badasa Moisa [1*]; Shankar Karuppannan [2,3]; Yong Jie Wong [4]; Lina A. Khaddour [5]

1, Department of Earth Science, College of Natural and computational science, Wollega University Nekemte campus, Nekemte, Ethiopia
2, Department of Applied Geology, School of Applied Natural Science, Adama Science and Technology University, Adama, Ethiopia
3, Department of Research Analytics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu, India
4, Department of Bioenvironmental Design, Faculty of Bioenvironmental Sciences, Kyoto University of Advanced Science, Japan
5, School of Computing, Engineering and the Built Environment, Edinburgh Napier University, Edinburgh, UK

E-mail:
mitikubadasa10@gmail.com

Received: 14/09/2024
Acceptance: 09/03/2025
Available Online: 12/03/2025
Published: 01/07/2025

Keywords: Land suitability, AHP, Agriculture, Gondar Zuria

Abstract

In a context of growing population and escalating food demand, urban agriculture emerges as a crucial solution for enhancing food security and promoting ecological sustainability globally. This study aims to analyze land suitability for urban agriculture in Gondar Zuria utilizing Geographic Information System (GIS) and the Analytical Hierarchy Process (AHP). Five characteristics, including land use and land cover, proximity to roads, drainage density, Slope, and soil type, were evaluated to create a potential land suitability map for urban agriculture. The findings indicated that approximately 139 km^2 (47.5%) was highly suitable, 111.9 km^2 (38.2%) was moderately suitable, 17 km^2 (5.8%) was marginally suitable, and 24.9 km^2 (8.5%) was not suitable for urban agriculture in the research region. Future research should investigate further environmental factors, including temperature, precipitation, and altitude, to aid in identifying the most appropriate crop for each zone according to its environmental needs.

1. Introduction

Agriculture constitutes the predominant sector and primary source of livelihood and national income in Ethiopia, accounting for approximately 46% of GDP, 73% of employment, and almost 80% of foreign currency [1]. The productivity of agricultural yields is affected by the appropriateness of land for specific crop species [2]. Land suitability assesses the quantitative and qualitative productivity and appropriateness of an area for a specific crop [3]. In Ethiopia, several significant cereal crops, including Teff, wheat, rice, barley, corn, and rye, are cultivated in diverse agro-ecological zones of the country. It is reported that the production of these crops is increasing due to the increase in cultivated areas in addition to the enhancements in the used agricultural production technologies and inputs [4]. However, there is still a need to develop sophisticated land suitability assessments in order to optimize production, especially in urban areas.

The analysis of land suitability for urban agriculture is essential for designating specific land for particular uses based on its quality, potential, and optimal capacity to mitigate land resource degradation caused by urban expansion and enhance sustainable urban land use planning [5]. Despite the increase in the overall agricultural production, many regions of Ethiopia suffer from extensive agricultural land use without prior assessment of land potential in connection to specific crop types, resulting in significant soil productivity losses and diminished agricultural yields in

DYSONA Applied Science ISSN: 2708-6283

urban areas [6]. Land suitability for urban agriculture necessitates a comprehensive study of ecological criteria such as slope, soil type, texture, drainage, and other pertinent aspects specific to the area [7].

The absence of evidence-based knowledge regarding land suitability for production results in a misalignment between cultivated land and agricultural yield, leading to production losses. Consequently, numerous researchers have undertaken studies to assess land suitability for urban agriculture globally [8][9] and in Ethiopia [10]. However, due to limited study focus in the northern regions of Ethiopia, particularly in Gondar Zuria, there is still a lack of information regarding land suitability in the area. A comprehensive scientific analysis was necessary to address the current challenges and enhance the productivity of the designated agricultural land suitable. In this context, Geographical Information Systems (GIS) and remote sensing are widely employed to assess and determine the suitability of the research region. Therefore, this study sought to address the research gap on urban agriculture land suitability by employing GIS and remote sensing in conjunction with the Analytical Hierarchy Process (AHP) in Gondar Zuria, Northern Ethiopia.

2. Material and Methods

2.1. Description of the study area

The study was carried out in Gondar Zuria, situated in the Amhara National Regional State in the northern region of Ethiopia. Gondar Zuria is located at coordinates ranging from 12°28‘30“ to 12°40‘30’’N and 37°22’30’’ to 37°31’30’’E (Fig. 1). The study area ranges in elevation from 1833 m to 2801 m above sea level, encompassing a total area of 292.8 km^2.

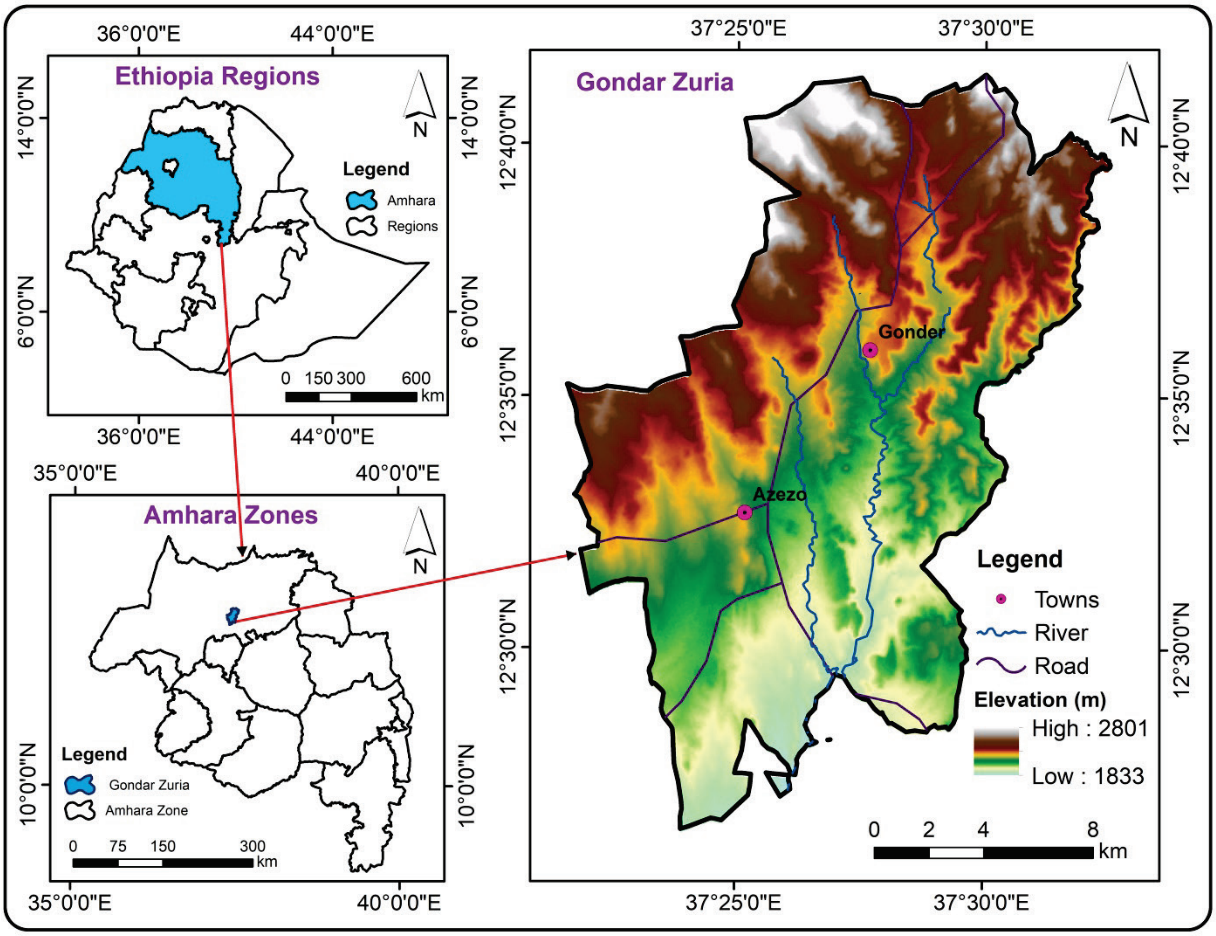

Figure 1. Location of the study area

2.2. Data sources and descriptions

Various geospatial types of data were utilized for the analysis of land suitability in urban agriculture. A cloud-free satellite image from Landsat OLI/TIRS 2023 was obtained during the dry season from the USGS website for the purpose of classifying land use and land cover types. In a similar manner, data from the Ministry of Water and Irrigation Engineering was utilized to provide information on soil types. The road infrastructure data was clipped using GIS data from 2014, while the STRM DEM was obtained from the United States Geological Survey to create the surface slope (Table 1).

Additional materials and software, including Handheld GPS, ArcGIS 10.3, ERDAS 2015, Arc SWAT 10.3, and IDRISI Selva 17, were utilized to analyze and visualize land suitability for urban agriculture in the study.

Table 1. Data sources and description

Data	Data types	Resolution (m)	Sources
Landsat OLI/TIRS	Land use land cover	30	USGS
STRM DEM	Slope, Drainage network	30	USGS
Soil data	Soil types	30	Ministry of water and irrigation engineering (MoWIE)
Infrastructure data	Roads	30	Ethiopian mapping agency (EMA)

2.3. Analysis methodology

The assessment of land suitability for urban agriculture in the designated area was conducted utilizing geospatial technology by integrating key parameters within GIS frameworks.

The process of rasterization was executed to convert vector data into raster format, facilitating the necessary weighted overlay analysis. The final parameter overlay analysis classified the study area into four land classes: highly suitable, moderately suitable, marginally suitable, and not suitable (Table 2).

Table 2. Rating parameters for agricultural land suitability analysis

Parameters	Classification criteria and scale				
	Unit	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
LULC	Class	agricultural land,	Grassland	Bareland	Built up area, vegetation, water body
Soil types	Name	Eutric Fluvisols, Chromic Luvisols	Eutric Vertisols,	Eutric Leptosols	Urban
Drainage density	Km/km^2	>1.43	0.83-1.43	0.29 – 0.83	0-0.29
Road	km	0 – 1.3	1.3 – 2.7	2.7 – 4.5	>4.5
Slope	percent	0-10	10-37	37-47	>47

The analytical hierarchy process (AHP) method was employed to determine the weighted importance value of each parameter within IDRISI Selva 17 software, facilitating a comparison of the percent influence of each parameter for suitability analysis. A pairwise comparison matrix was created to assess the weight and relative importance of each factor by normalizing the eigenvector of the factors based on their cumulative total [11]. The factor's weight was divided by the number of classes to determine the breakdown of the classes and equal interval ranging techniques were employed to allocate the total weights of the elements across the different degrees of appropriateness classes [12] (Table 3).

Table 3. Relative importance factors value (Adapted from [12])

Intensity of importance	Definitions	Explanations
1	Equal importance	Both factors contribute equally to the objective
3	Somewhat more important	There is a slight favor of one factor over the other
5	Much more important	There is a strong favor of one factor over the other
7	Very much more important	There is a very strong favor of one factor over the other (Its importance is demonstrated in practice)
9	Absolutely more important	The evidence favoring one factor over the other is the highest possible validity
2,4, 6,8	Intermediate values	When compromise is needed

2.4. Physical land suitability for urban agriculture in Gondar Zuria

2.4.1. Soil types

The suitability of the land for agriculture can be influenced by the soil types present in the study area. This indicates that different soil types could categorize the study area into distinct land suitability classes. The soil type data acquired from the Ministry of Water and Irrigation Engineering was clipped to the study area to determine the soil types relevant to the research area. Moreover, the soil data has been transformed into raster format with a spatial resolution of 30m for the purpose of overlay analysis.

2.4.2. Drainage density

The drainage network served as a crucial element in the mapping of urban agriculture [13], derived from the digital elevation model of the study area using Arc SWAT software. The calculation of drainage density was performed utilizing the drainage network within the ArcGIS environment through the application of line density analysis. The data is presented in km/km^2 and categorized into intervals: greater than 1.43 km/km^2, 0.83 to 1.43 km/km^2, 0.29 to 0.83 km/km^2, and less than 0.29 km/km^2. Areas with high drainage density demonstrate excellent potential for urban agriculture, while those with low drainage density are less suitable for agricultural land in the study region [14]. The following formula [15] establishes drainage densities for each grid square:

$$DD = \Sigma \frac{LWS}{AWS}$$

Where DD is drainage density, AWS is an area of the watershed, and LWS is the total length of streams in the watershed

2.4.3. Proximity to road

Road accessibility enables farm owners to efficiently transport their produced yield from the farmland to the market center, as well as delivering necessary inputs to the farming site without encountering difficulties. Therefore, the suitability of land for agricultural purposes is influenced by its closeness to the road. The proximity to the road increases the suitability for farming sites, and the opposite holds true as well. Previous studies indicate that agricultural site suitability classes based on road proximity are categorized as follows: distances of 0-1.3 km are highly suitable, 1.3 to 2.7 km are moderately suitable, 2.7 to 4.5 km are marginally suitable, and distances greater than 4.5 km are deemed not suitable [16].

2.4.4. Slope

The suitability of land for urban agricultural may be influenced by the slope of the study area. A flat and gentle slope is more suitable for agricultural activities compared to steep slopes. Moreover, areas with poor slope management exhibits increased risks of land erodibility, leading to a decline in production yield. Earlier studies focused on categorizing land suitability for agricultural purposes according to slope ranges of 0 to 10%, 10 to 37%, 37 to 47%, and greater than 47%, designating these as highly suitable, moderately suitable, marginally suitable, and unsuitable land forms, respectively [17].

2.4.5. Land use and land cover (LULC)

Landsat 8 OLI from 2023 was utilized to classify land use and land cover types in the study area through a supervised classification method employing the maximum likelihood algorithm. The study area comprised various land cover types, including agricultural land, grassland, built-up areas, vegetation, bare land, and water bodies. The classified land cover types exhibit varying suitability classes for urban agricultural activities. Agricultural land and grassland are usually moderately to highly suitable for staple crops (such as maize [18]) cultivation.

2.5. Criteria weight estimation by pairwise comparison

The analytical hierarchy process (AHP) of multi-criteria evaluation (MCE) analysis methods was utilized, employing a scale from 1 to 9 to determine the criteria weight for assessing land suitability for urban agriculture [19] (Table 4).

Table 4. AHP Pairwise comparison matrix of parameter selected for this study

Factors	LULC	Slope	Drainage density	Road	Soil type
LULC	1	2	9	9	9
Slope	1/2	1	7	7	7
Drainage density	1/9	1/7	1	3	3
Road	1/9	1/7	1/3	1	3
Soil type	1/9	1/7	1/3	1/3	1
Sum	1.83	3.42	17.66	20.33	23

The pairwise comparison of each targeted parameter was conducted using the provided intensity of the parameter's important value to reclassify and weight all parameters based on their relative importance and degree of influence in determining the potential for urban agriculture in the study area [11][20].

The acceptability and clarity of the parameters' pairwise comparison was assessed based on the calculated value of the consistency ratio (CR). The calculated value of CR must be less than 10% to be deemed acceptable [21]. The calculated suitability for urban agriculture land in the CR was 0.03, indicating it is below 10%. The parameters for pairwise comparison consistence ratio were established as the ratio of the consistency index (CI) to the random consistency index:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}$$

Where CI is consistency index and RI is random consistency index.

Consistency index is the measure of parameters consistency as the degree of consistency by using the following formula:

$$\mathrm{CI} = \frac{\lambda\, max - n}{n - 1}$$

In this context, n represents the number of parameters, while λ max denotes the principal eigenvalue of these parameters. This value can be determined by multiplying the total horizontal summation of the given intensity importance values with the normalized principal eigenvector values of the parameters. The normalized principal eigenvector was derived by averaging the normalized relative weights of the parameters.

The random consistency index represents a fixed value assigned to each targeted parameter according to their intensity importance scale (Table 5).

Table 5. Random index value table

Intensity importance	1	2	3	4	5	6	7	8	9	10
Constant number	0.00	0.00	0.58	0.90	1.12	1	1.32	1.41	1.45	1.49

2.6. Weighted overlay analysis

The weighted overlay tool facilitates multiple steps in the overall analysis process within a unified framework, enabling the prioritization of suitability modeling or optimal site selection [22]. This ultimately results in a standardized scale for evaluating appropriateness or preference.

The final assessment of land suitability for urban agriculture was conducted using a weighted overlay analysis based on various parameters in the study area. As outlined by [23], the calculation of land suitability was conducted in the following manner:

$$S = \Sigma \mathrm{Wi} \times \mathrm{Xi}$$

3. Results and Discussion

3.1. Land use and land cover (LULC) type suitability

The land use land cover (LULC) types of the study area were classified into: vegetation cover, grassland, bare land, agricultural land, built up area and water body. The presence of various land cover types creates an opportunity to the occurrences of different land suitability classes for urban agriculture activities. According to [24], agricultural land and grassland were considered as highly suitable and moderately suitable; bare land and built up area were classified as marginally suitable and not suitable for urban agriculture activities. The results of the current study revealed that, agricultural land was the most dominating LULC category with an area of 212.6 km^2 (72.6%). On the other hand, built up and vegetation zones covered an area of 20.6 km^2 (7%) and 13.9 km^2 (4.7%), respectively (Table 6).

Table 6. LULC types and area coverage

LULC Types	Area (km^2)	Area (%)
Agricultural land	212.6	72.6
Bare land	8.2	2.8
Built up area	20.6	7.0
Grassland	37.1	12.7
Vegetation	13.9	4.7
Wetland	0.5	0.2

Most of study area, except for the central built up zone, was covered with agricultural land and grassland which are highly or moderately suitable for agricultural applications (Fig. 2 A).

3.2. Soil suitability

Four soil types were identified in the study area: Chromic Luvisols, Eutric Fluvisols, Eutric Leptosols, and Eutric Vertisols. Eutric Leptosols, a moderately suitable agricultural soil, constituted the predominant soil type, covered 68% of the area. On the other hand, Chromic Luvisols, a highly suitable agricultural soil, comprised 14.4% of the area (Table 7) (Fig. 2 B). Moreover, the southwestern and central regions of the study area are characterized by Eutric Fluvisols and are classified as moderately suitable for urban agriculture. The classification employed for soil type suitability was grounded in prior research, which underscored that soil type is a critical determinant of land suitability for urban agriculture [25][26].

Table 7. Soil type and area coverage

Soil types	Area (km^2)	Area (%)
Chromic Luvisols	42.3	14.4
Eutric Fluvisols	13.9	4.7
Eutric Leptosols	199.2	68.0
Eutric Vertisols	33.2	11.3
Urban	4.3	1.5

3.3. Drainage density

The drainage density was expressed in km/km^2 and characterized as the total length of all the streams divided by the total area of the drainage basin. High drainage density is considered highly suitable for agriculture and vice versa [27-29]. Higher drainage density values were observed toward the central parts of the study area, whereas eastern and western parts were characterized by low drainage density values (Fig. 2 C).

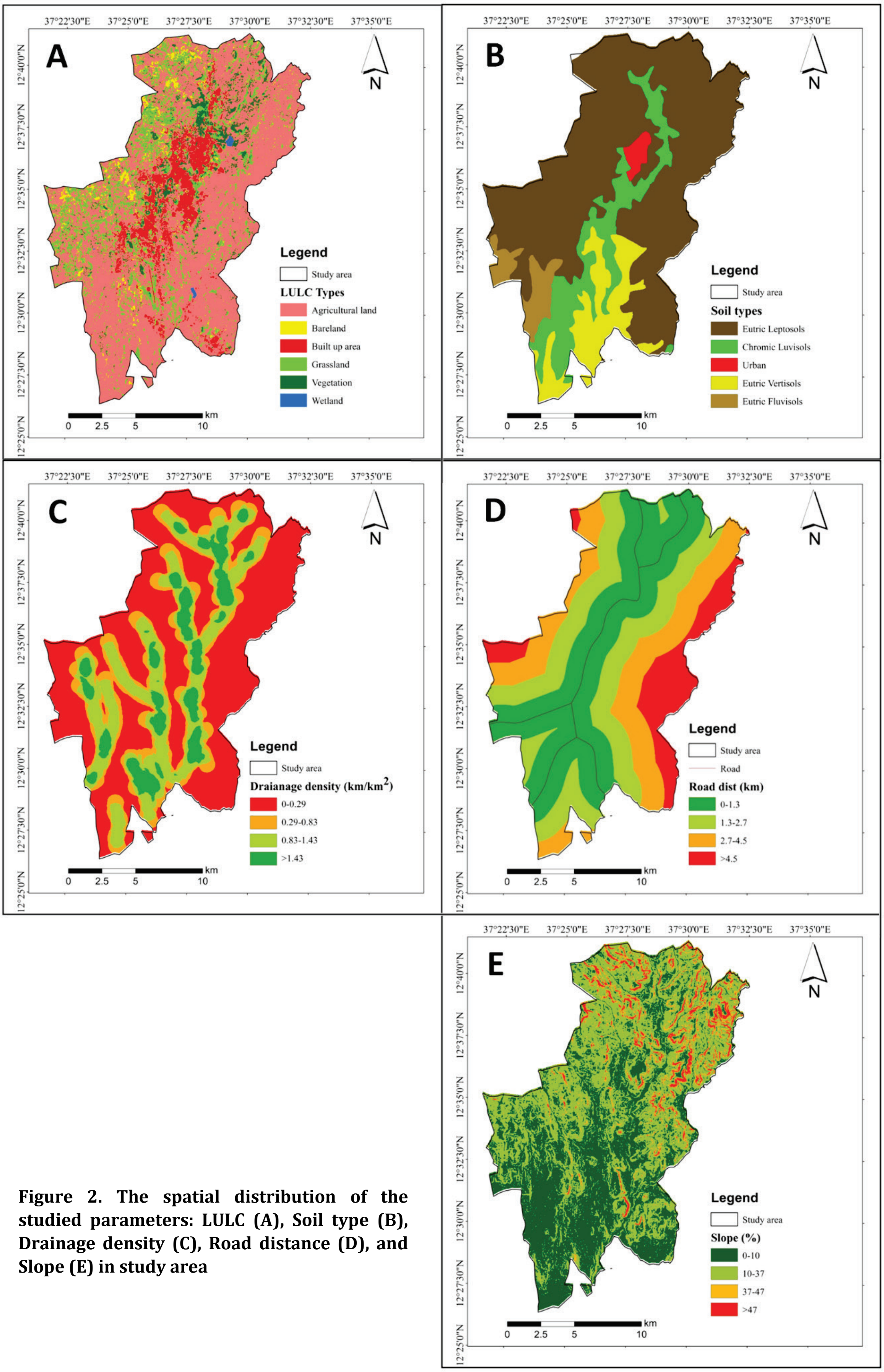

Figure 2. The spatial distribution of the studied parameters: LULC (A), Soil type (B), Drainage density (C), Road distance (D), and Slope (E) in study area

3.4. Road proximity

The availability and proximity of nearby roads is necessary for transporting required resource during farming and selling the products after harvest. Regardless of their fertility, lands with poor access to road networks have less agricultural suitability due to poor access. The current road proximity mapping showed that central and southern parts of Gondar Zuria region were dominated with highly suitable and moderately suitable lands, while eastern and western parts of study area were occupied by marginally suitable and not suitable land for urban agriculture (Fig. 2 D).

3.5. Slope suitability

Land suitability for urban agriculture site selection is influenced by the steepness of the land surface. An area with a steep slope is more susceptible for surface soil erosion, which reduces its suitability status for farming purposes [8]. According to slope degree, the current results identified highly suitable (0-10%), moderately suitable (10-37%), marginally (37-47%) and not suitable land form with slope greater than 47% in Gondar Zuria region. Spatially, some of the southern and central parts were highly suitable and moderately suitable while some eastern and south northern parts of study area were marginally suitable and not suitable for urban agriculture (Fig. 2 E).

3.6. Final Land suitability for urban agriculture in Gondar Zuria

The normalized AHP pairwise comparison matrix for five infrastructural, ecological, and biophysical data interpretations (Table 8) was utilized for assessing the suitability classes of Gondar Zuria area for urban agricultural. Using the weights derived from Table 8, the following suitability (S) equation was formulated and executed within the Raster Calculator in a GIS framework to generate the possible land suitability map for urban agriculture in Gondar Zuria (Fig. 3):

$$S = (0.495 \times \text{LULC}) + (0.322 \times \text{Slope}) + (0.087 \times \text{Drainage Density}) + (0.06 \times \text{Road Proximity}) + (0.036 \times \text{Soil Type})$$

Table 8. Normalized AHP pairwise comparison matrix and computation of criterion weightage

Factors	LULC	Slope	Drainage density	Road	Soil types	Weight
LULC	0.546	0.585	0.510	0.443	0.391	0.495
Slope	0.273	0.292	0.396	0.344	0.304	0.322
Drainage density	0.060	0.041	0.057	0.148	0.130	0.087
Road	0.060	0.041	0.019	0.049	0.130	0.060
Soil types	0.060	0.041	0.019	0.016	0.043	0.036

Consistency Ratio (CR) = 8.31

The findings indicated land classifications of high suitability at 139 km^2 (47.5%), moderately suitability at 111.9 km^2 (38.2%), marginally suitable at 17 km^2 (5.8%), and not suitable at 24.9 km^2 (8.5%) within the study region (Table 9). Highly suitable land classes emerged from the integration of lower slopes, elevated drainage density, proximity to roads, grassland and agricultural land cover types, and suitable physical soil types within the study area. The inverse of all those qualities also renders them unsuitable for urban agriculture in Gondar Zuria. Consequently, the southern, eastern, and certain northern regions of the research area were highly suitable for agricultural activities, whereas the central regions, characterized by restrictive characteristics, were unsuitable for urban agriculture (Fig. 3).

Table 9. Suitability classes and area coverage

Suitability classes	Area (km^2)	Area (%)
Highly suitable	139.0	47.5
Moderately suitable	111.9	38.2
Marginally suitable	17.0	5.8
Not suitable	24.9	8.5

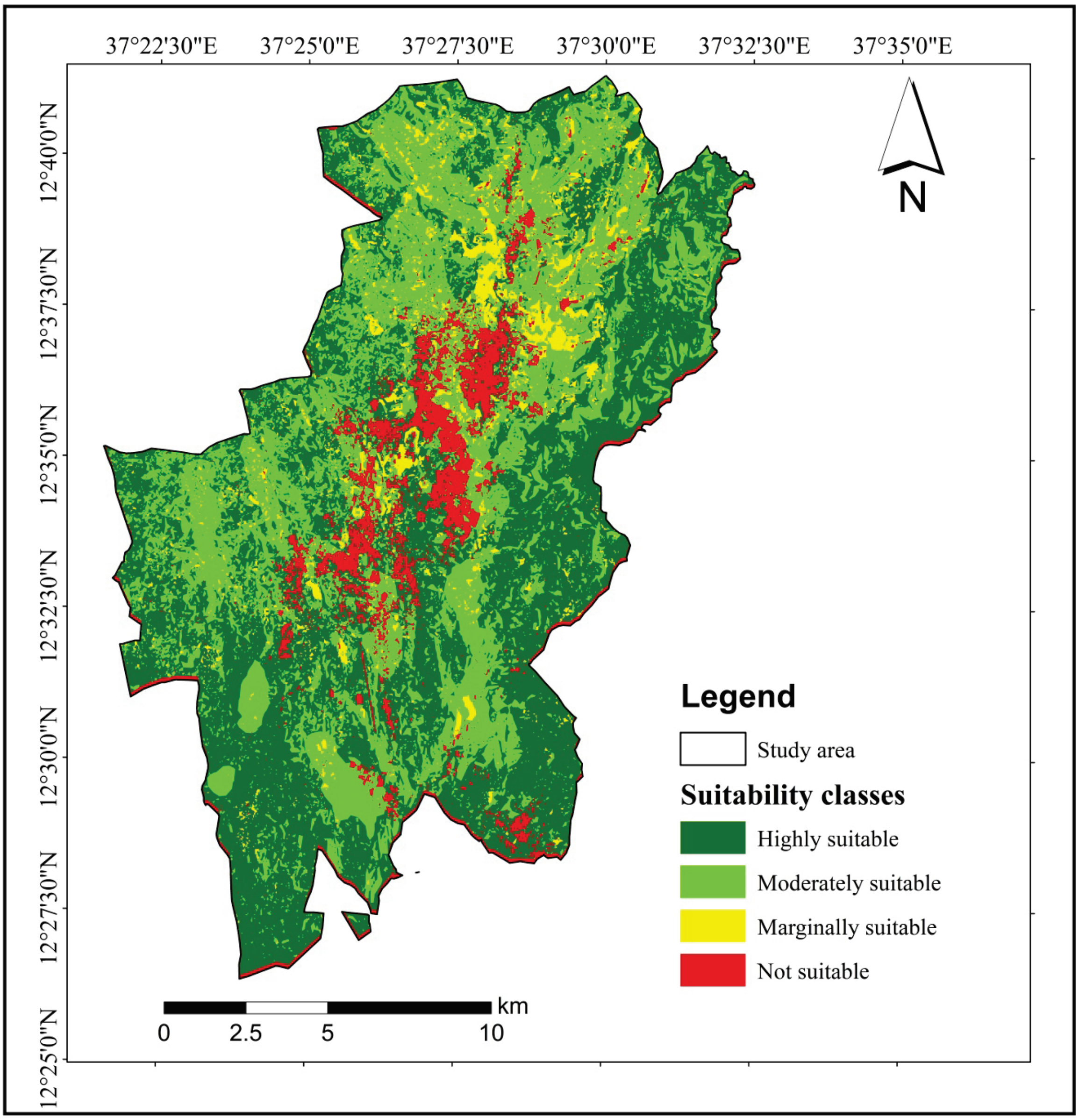

Figure 3. Potential land suitability map for urban agriculture of Gondar Zuria

The generated suitability map (Fig. 3) presents significant vital metrics for the study area's population, particularly concerning the management of critical issues such as agricultural land in urban settings to meet the rising food demand [30][31]. Furthermore, the findings of this evaluation align with the objectives of holistic sustainable development in urban regions concerning the attainment of food security, ecosystem sustainability, and the alleviation of agriculture's adverse effects [32]. Engaging local agricultural communities in the agricultural planning process is advisable to strengthen their participation in sustainable agricultural development. The study additionally fosters innovation in urban agriculture by advocating for sustainable and smart agricultural approaches. These strategies can decrease the consumption of natural resources, including water and fertilizers, thereby mitigating environmental impacts and conserving resources for future generations. Moreover, the presented framework can include more environmental factors such as temperature, humidity, elevation, and water availability to be applied on the national level assisting agricultural policy recommendations toward specific crops and agricultural activities.

4. Conclusions

This study utilized GIS and AHP methods to analyze and overlay many environmental parameters in order to assess site suitability for urban agriculture. The findings indicated that the majority of the research area was classified as either highly suitable (47.5%) or moderately suitable (38.2%) for urban agriculture. The identification of land suitability classes is crucial for implementing optimal urban land resource management strategies. This discovery offers insights for farmers to exploit sites with significant agricultural potential. Subsequent research may explore additional elements, including soil physical and chemical characteristics, precipitation, temperature, and elevation, to identify the most suitable crop for each zone.

5. Acknowledgments

The authors acknowledge Wollega University Nekemte Campus College of Natural and Computational Science, Department of Earth Science for the existing facilities to conduct this study.

Conflict of interest statement

The authors declared no conflict of interest.

Funding statement

The authors declared that no funding was received in relation to this manuscript

Data availability statement

The authors declared that all the used data and data sources are included in the manuscript.

References

1. Amsalu A. Institutional context for soil resources management in Ethiopia: a Review. Addis Ababa, Ethiopia. 2015.
2. Sengupta S, Mohinuddin S, Arif M, Sengupta B, Zhang W. Assessment of agricultural land suitability using GIS and fuzzy analytical hierarchy process approach in Ranchi District, India. Geocarto Int. 2022;37(26):13337-68. DOI
3. Viana CM, Freire D, Abrantes P, Rocha J, Pereira P. Agricultural land systems importance for supporting food security and sustainable development goals: A systematic review. Sci. Total Environ. 2022;806:150718. DOI
4. Bezabih G, Wale M, Satheesh N, Fanta SW, Atlabachew M. Forecasting cereal crops production using time series analysis in Ethiopia. J. Saudi Soc. Agric. Sci. 2023;22(8):546-59. DOI
5. Bamrungkhul S, Tanaka T. The assessment of land suitability for urban development in the anticipated rapid urbanization area from the Belt and Road Initiative: A case study of Nong Khai City, Thailand. Sustain. Cities Soc. 2022;83:103988. DOI
6. Ebrahim E, Mohamed A. A GIS based land suitability analysis for sustainable agricultural planning in Gelda catchment, Northwest Highlands of Ethiopia. J. Geogr. Reg. Plan. 2017;10(5):77–91. DOI
7. Aleminew A, Alemayehu M. Soil Fertility Depletion and Its Management Options under Crop Production Perspectives in Ethiopia: A Review. Agric. Rev. 2020;41(2):91-105. DOI
8. Ahmed R, Mohammad SM, Coalee UM, Mahmud KH. A GIS and remote sensing based multicriteria analysis for identifying potential agricultural land: A case study on Savar Upazila, Bangladesh. Bangladesh Rural Dev. Stud. 2023;26(1):13-26.
9. Olaniyi AO, Ajiboye AJ, Abdullah AM, Ramli MF, Sood AM. Agricultural land use suitability assessment in Malaysia. Bulg. J. Agric. Sci. 2015;21(3):560-72.

10. Kahsay A, Haile M, Gebresamuel G, Mohammed M. GIS-based multi-criteria model for land suitability evaluation of rainfed teff crop production in degraded semi-arid highlands of Northern Ethiopia. Model. Earth Syst. Environ. 2018;4(4):1467–86. DOI

11. Wind Y, Saaty TL. Marketing applications of the analytic hierarchy process. Manag. Sci. 1980;26(7):641-58.

12. Saaty TL. The analytic hierarchy process (AHP). J. Oper. Res. Soc. 1980;41(11):1073-6.

13. Ibrahim-Bathis K, Ahmed SA. Rainfall-runoff modelling of Doddahalla watershed—an application of HEC-HMS and SCN-CN in ungauged agricultural watershed. Arab. J. Geosci. 2016;9(3). DOI

14. Kadam AK, Umrikar BN, Sankhua RN. Assessment of recharge potential zones for groundwater development and management using geospatial and MCDA technologies in semiarid region of Western India. SN Appl. Sci. 2020;2(2). DOI

15. Selvam S, Magesh NS, Chidambaram S, Rajamanickam M, Sashikkumar MC. A GIS based identification of groundwater recharge potential zones using RS and IF technique: a case study in Ottapidaram taluk, Tuticorin district, Tamil Nadu. Environ. Earth Sci. 2014;73(7):3785–99. DOI

16. Assoma AA. Adaptation and Change in Enset Ecology and Farming Among the Kore of Southwestern Ethiopia. Washington State Univ. 2017.

17. Bahir AL, Ahmed MA, Antille DL. Land suitability evaluation to optimize land management of small-scale farms in the Gerado catchment, North-Eastern Ethiopia. Trop. Agric. 2015;92(1):49-68.

18. Bonfante A, Monaco E, Alfieri SM, De Lorenzi F, Manna P, Basile A, Bouma J. Climate change effects on the suitability of an agricultural area to maize cultivation: application of a new hybrid land evaluation system. In Advances in Agronomy. 2015;133:33-69. DOI

19. Saaty TL. Decision making with the analytic hierarchy process. Int. J. Serv. Sci. 2008;1(1):83-98.

20. Singh AK, Rahman B, Thakur R. Assessment of Land Suitability and Irrigation Potential for Improving Cropping Intensity and Ensuring Food Security in North East India. J. Indian Soc. Soil Sci. 2019;67(3):281. DOI

21. Yalew SG, van Griensven A, Mul ML, van der Zaag P. Land suitability analysis for agriculture in the Abbay basin using remote sensing, GIS and AHP techniques. Model. Earth Syst. Environ. 2016;2(2). DOI

22. Iqbal AB, Rahman MM, Mondal DR, Khandaker NR, Khan HM, Ahsan GU, et al. Assessment of Bangladesh groundwater for drinking and irrigation using weighted overlay analysis. Groundw. Sustain. Dev. 2020;10:100312. DOI

23. Debesa G, Gebre SL, Melese A, Regassa A, Teka S. GIS and remote sensing-based physical land suitability analysis for major cereal crops in Dabo Hana district, South-West Ethiopia. Cogent Food Agric. 2020;6(1):1780100. DOI

24. Sishah S. Suitability Analysis for Moringa Oleifera Tree Production in Ethiopia-A Spatial Modelling Approach. Preprints. 2020.

25. Kazemi F, Hosseinpour N. GIS-based land-use suitability analysis for urban agriculture development based on pollution distributions. Land Use Policy. 2022;123:106426. DOI

26. Bhat SA, Hussain I, Huang NF. Soil suitability classification for crop selection in precision agriculture using GBRT-based hybrid DNN surrogate models. Ecol. Inform. 2023;75:102109. DOI

27. Kumari A, Tiwary P, Upadhyaya A, Jeet P. Morphometric analysis using geospatial techniques to infer hydrologic behaviour of Waghadi Watershed, Maharashtra, India. Indian J. Ecol. 2023;50(2):532-8. DOI

28. Yuan N, Li Y, Xiong Y, Xu B, Liu F, Fu H. Scale Effects on the Reduction of Drainage Water and Nitrogen and Phosphorus Loads in Hilly Irrigation Areas. Agronomy. 2023;13(8):2083. DOI

29. Zhou C, Tan X, Liu Y, Shi F. Quantifying the migration rate of drainage divides from high-resolution topographic data. Earth Surf. Dyn. 2024;12(2):433–48. DOI

30. Koroso NH, Zevenbergen JA. Urban land management under rapid urbanization: Exploring the link between urban land policies and urban land use efficiency in Ethiopia. Cities. 2024;153:105269. DOI

31. Wang X, Song X, Wang Y, Xu H, Ma Z. Understanding the distribution patterns and underlying mechanisms of non-grain use of cultivated land in rural China. J. Rural Stud. 2024;106:103223. DOI

32. Zhao Q, Yu L, Chen X. Land system science and its contributions to sustainable development goals: A systematic review. Land Use Policy. 2024;143:107221. DOI