



# Urban green space suitability analysis using geospatial techniques: a case study of Addis Ababa, Ethiopia

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## ABSTRACT

Urban green space (UGS) is crucial in providing ecosystem services and optimizing the health of urban residents. This study aimed at identifying suitable sites for UGS development using geospatial techniques in Addis Ababa City. In the present study, an analytical hierarchical process with Geographic Information Systems based multi-criteria evaluation process was used for identifying suitable sites for UGS development. Eight parameters namely land use land cover types, Normalized Difference Vegetation Index, population density, soil types, slope, elevation, road and rivers were used. Results show that about 1 km<sup>2</sup> (0.2%) and 67.4 km<sup>2</sup> (12.8%) are categorized as highly suitable and moderately suitable sites for UGS, respectively. About 247.2 km<sup>2</sup> (46.9%) of the area was marginally suitable and 205.2 km<sup>2</sup> (38.9%) was currently not suitable, while 6.2 km<sup>2</sup> (1.2%) was permanently not suitable. The evaluation of UGS development support policy makers to identify the importance of open green space for environmental quality and quality of life in urban center.

## ARTICLE HISTORY

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## KEYWORDS

Analytical hierarchical process; geospatial techniques; multi criteria evaluation; Addis Ababa City

## 1. Introduction

Urban green space (UGS) is considered as a lung for city dwellers and essential for promoting sustainable development and enhancing the quality of life of residents (Cicea and Pirlogea 2011; Yang et al. 2022; Anteneh et al. 2023). The UGS have a huge potential to regulate the city microclimate (Alkama and Cescatti 2016; Li et al. 2021; Pamukcu-Albers

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et al. 2021), minimize the risk of urban flooding (Kim et al. 2016; Liu et al. 2023; Pei et al. 2023), absorbs pollutants and release oxygen (Haq 2011; Li et al. 2018). Other studies highlight the importance of UGS for quality life and behavior in cities (M'likiugu et al. 2012; Orsi 2018; Gelan 2021; Li et al. 2021). The UGS is crucial to minimize the problem of heat waves, floods, waste water pollution, landslides, coastal erosion, and air pollution (Contesse et al. 2018; Yin et al. 2022; Zhao et al. 2022; Zhu et al. 2022). It is clear that UGS can make a significant contribution to carbon sequestration and improves sustainable conservation of biodiversity. By increasing urban green infrastructure can mitigate urban heat island effects and heat wave, and improve urban comfort for the residents (Hansen et al. 2015; De Haas et al. 2021; Li et al. 2023; Yang et al. 2023; Yin et al. 2023). Due to human activity, the urban heat island effect manifests in towns and cities. A study by Li et al. (2023) documented that the urban heat island effect can be mitigated by green spaces in cities, which also reduce the effects of pollution. Despite the role of UGS in climate change mitigation and environmental health, little attention was given in most of sub-Saharan African countries (Mensah 2014; Yang et al. 2022a).

In developing countries like Ethiopia, there is a tendency of increasing trend of environmental pollutions and climate change in large cities due to the increasing number of constructions and expansions of small-scale industries (Tarekegn and Gulilat 2018). In spite of the role of green space for urban thermal comfort level, the share of UGS that can moderate the urban microclimate is remain limited in big city like Addis Ababa. In addition, the availability of green space in the city has significantly declined due to the need for more space for different factories, construction of large buildings for commercial and residential purposes as well as the construction of illegal houses. These problems hinder the city administrations to meet the minimum standard of urban green area components per person is ( $9\text{ m}^2$ ), which proposed by World Health Organization (Girma et al. 2019; Yang et al. 2022b; Li et al. 2023).

Land suitability analysis is vital in UGS planning as it gives room for choosing the most suitable site (Sahabo and Mohammed 2016; Guo and Zhong 2022). Multi-criteria analysis integrated with the Geographical Information System (GIS) have been increasingly used for site suitability analysis (Uy and Nakagoshi 2008; Van Berkel et al. 2014; Ustaoglu and Aydinoglu 2020). The analytical hierarchical process (AHP) method is one of the most widely used multi-criteria decision-making (MCDM) techniques (Kordi and Brandt 2012). It is the best and efficient method methods to extract weights of different factors.

The structural land use plan of Addis Ababa city indicates that the minimum standard for urban green space area is 30% of the total land area (Azagew and Worku 2020). A study by Gebeyehu (2014) at Gulele sub city of Addis Ababa indicates the UGS is below standard. The low standard of UGS is the cumulative impacts of the declining of urban green areas and the increasing of built-up area and expansion of transportation infrastructures. Lack of reserved areas for green space, weak urban policy, limited number of parks, and lack of urban agroforestry contributes for the declining of urban green space (Mao et al. 2022; Wang et al. 2022). Recent studies by Woldeamayrat and Genovese (2021) indicate that public access to greenspace in Addis Ababa city was substantial declined as a result of city expansions and road infrastructures. Moreover, the ecological, educational, economic and social roles of urban green areas are getting less attention.

Urban green space development policies are clearly stated and have a strong constitutional foundation. Nevertheless, it is considered that the Growth and Transformation Program 2010–2015 (GTPI), Growth and Transformation Program 2016–2020 (GTPII), and Climate Resilient Green Economy (CRGE) are some of the initiatives promoting the

importance's of UGS (Gebrehiwot et al. 2014). These initiatives lack a comprehensive understanding of urban green development and implementation, focusing instead on broad green development and conservation (Eshetu et al. 2021). To provide shading, reduce runoff, mitigate the urban heat island effect, and sequester carbon, street tree plantings are recommended in the Green Infrastructure Based Landscape Design Supporting Manual, which was developed in 2011 (Ayele et al. 2022). The regulations and rules created by the relevant organizations are ambiguous, and law enforcement rarely applies to green environments.

The UGS played a crucial role in maintaining a health urban environment. A significant warming has been observed in Addis Ababa city as vegetation cover declines (Warkaye et al. 2018). In spite of this problem, little efforts have been conducted to minimize the potential impacts of UGS depletion. Previous studies have been conducted on UGS development in Ethiopia (Abebe and Megento 2017; Teferi and Abraha 2018; Gelan 2021; Worku et al. 2021). Other scholars investigate the impacts of urban LULC change on heat island and Urban thermal comfort level Addis Ababa city (Moisa and Gemedda 2021; Moisa and Gemedda 2022; Moisa et al. 2022a). Even though UGS plays a crucial role to minimize the impacts of urban land use and land cover (LULC) changes on urban heat island, the importance of UGS to mitigate urban climate change is less emphasized. Therefore, this study is aimed to fill the existing research gap by evaluating UGS suitability in Addis Ababa city by using geospatial techniques. The findings of this study are crucial for city land use planning and decision support for the development of UGS development.

## 2. Methods and materials

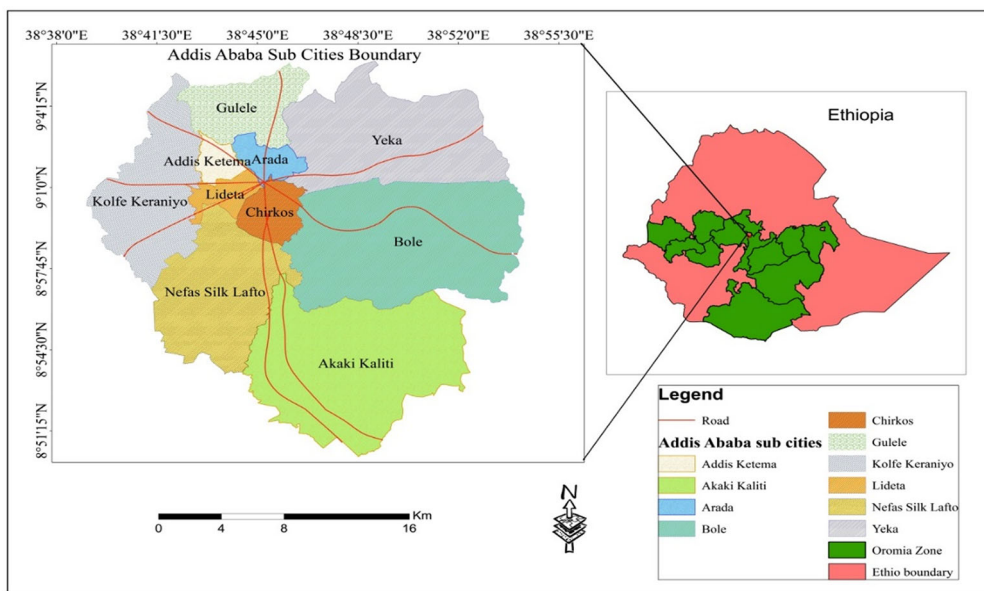
### 2.1. Descriptions of the study area

Addis Ababa is the capital of Ethiopia. It is located in the heart of the country surrounded by Oromia Special Zones and covers an area about 527 km<sup>2</sup>. The city lies to the north of the equator between 8°51'15" and 9°4'15"N latitude and 38°38'0" and 38°55'30"E longitude (Figure 1). The city has been considered as the center of social, economic and political for the country. Addis Ababa city has an estimated population of 4, 592,000 with annual growth rate of 4% [Central Statistical Agency (CSA), 2019]. The city population is projected to reach seven million population by the year 2039 (Arsiso et al. 2017).

The mean minimum and maximum temperature at Bole Sub-city of Addis Ababa varied between 7.66°C to 11.61°C, and 22.65°C to 24.54°C, respectively (Alemu and Dioha 2020). The city of Addis Ababa experienced flash floods as a result of poor drainage system, rapid housing development along the river banks (Birhanu et al. 2016). Due to the declining of UGS and increasing of impervious surfaces the land surface temperature and urban heat islands are significantly increasing over the past decades (Moisa and Gemedda 2022).

#### 2.1.1. Land use land cover change of Addis Ababa

The LULC of Addis Ababa city was classified into five major classes. From the calculated Landsat images results show that the built-up area was the most dominant LULC classes over the past three decades. Due to rapid human population growth and growing demands for residential and commercial buildings aggravated the conversion of LULC around the periphery of the city. The built-up area increased substantial, while agriculture, vegetation and grassland were dramatically decreased between the 1990 and 2020



**Figure 1.** Map of the study area.  
 "Source: Author's own conception."

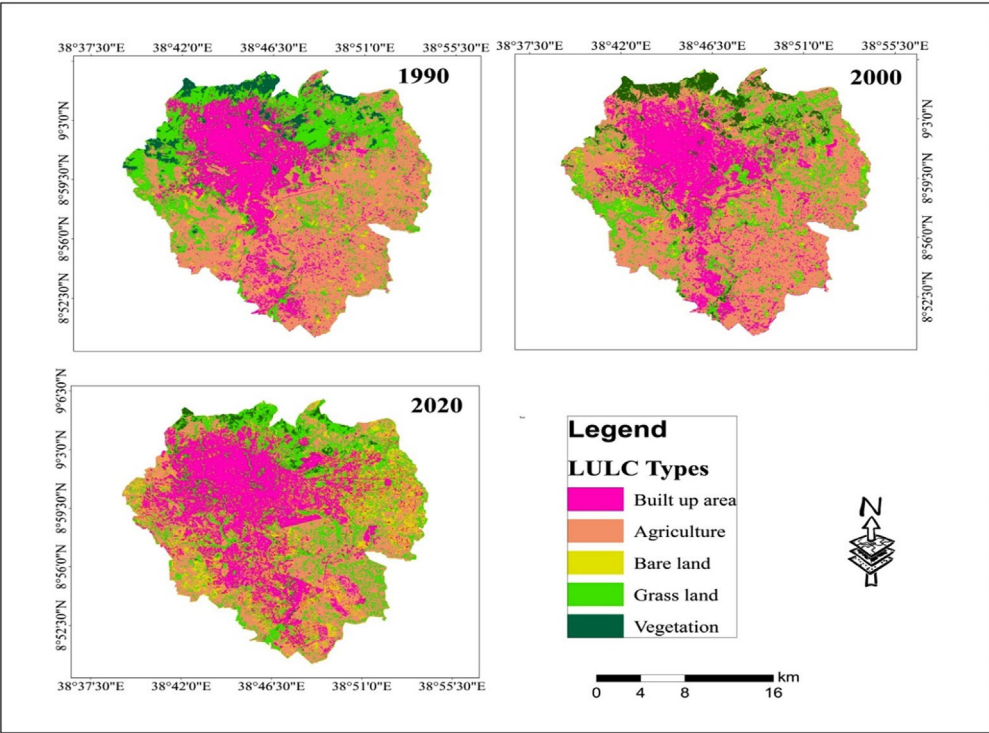
(Figure 2). A study by Nor et al. (2017) confirmed that rapid urbanization has had a significant impact on UGS development. To overcome such problems, effective strategies are required to achieve the sustainable development.

## 2.2. Data sources

Landsat 8 OLI/TIRS of 30-meter resolution, DEM were downloaded from the USGS website (<https://www.usgs.gov/> accessed on July 1,2021). Soil types, population density, road networks and drainage network of the study area were obtained from Ministry of agriculture, CSA and Addis Ababa city land administration (Table 1). The LULC types, Normalized Difference Vegetation Index (NDVI), population density, soil types, slope, elevation, road and rivers were identified as the main attributes for the evaluation of UGS development suitability analysis, which was selected based on the existing scientific literatures.

## 2.3. Data analysis

Suitability analysis of UGS of the study area was determined by using GIS and multi criteria evaluation (MCE). For this study, eight parameters mainly slope, LULC types, NDVI, population density, soil types, altitude (elevation), river and road data were produced in ArcGIS environment to evaluate land suitability for UGS development (Figure 3). All parameters were reclassified and weighted based on the relative importance and degree of influence (Table 2) using a pairwise comparison matrix (Saaty 1980; Kordi and Brandt 2012; Girma et al. 2020). Finally, the relative importance of each parameter was calculated by normalizing the eigenvector of the factors (Camiz and Pillar 2018). With the support of a pairwise comparison matrix, each factor was compared with the other factors, relative to its importance, on a scale from 1/9 to 9 as proposed by Saaty (2002) (Table 3). The pairwise comparison matrix method uses people and expert preferences



**Figure 2.** Map of land cover changes in last few decades.  
"Source: Author's own conception."

**Table 1.** Data types and sources and purpose.

Data Types	Sources
Population data	Municipality of the city and Central Statistics Authority
Landsat 8 OLI/TIRS image	USGS
Structural plan	Addis Ababa city land administration and land use office
DEM data	ASTER Global DEM website
GPS data	Field Survey
Soil data	Ministry of Agriculture

(Morales and de Vries 2021) for comparing the classes and make matrix table. The consistency ratio (CR) and consistency index (CI) for criteria are calculates as shown in Eq. 1 and Equation 2.

The consistency check formula is:

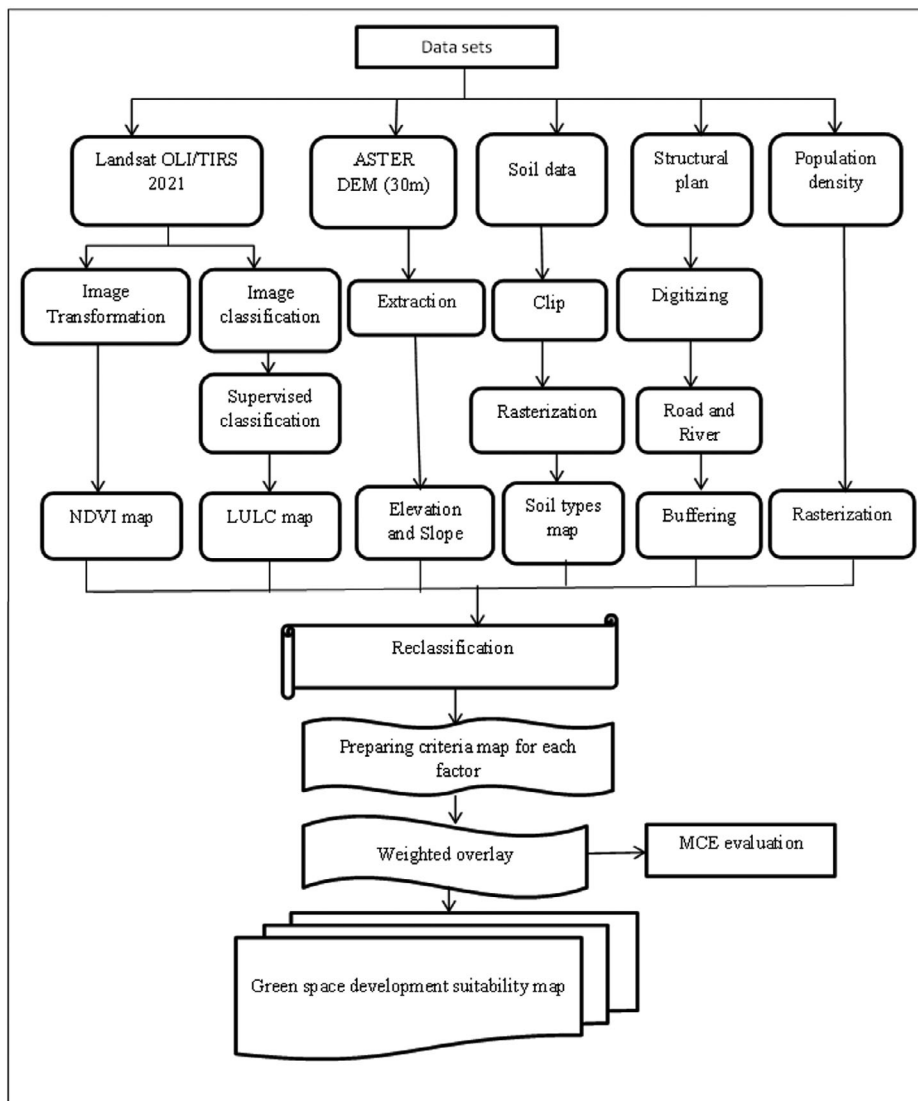
$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{Eq 1}$$

where:  $\lambda_{max}$  is the largest Eigen value of the pairwise comparison matrix and n is the number of classes.

Then, CR taken by the following formula (Eq 2) (Saaty 1980)

$$CR = \frac{CI}{RI} \tag{Eq 2}$$

where: RI is the ratio index/average value of CI for random matrices.



**Figure 3.** Methodological flow chart of the study.  
 "Source: Author's own conception."

### 2.3.1. Weighted overlay analysis

After weighing of criteria regarding their importance for green space suitability analysis, all criteria maps were overlaid using suitability index (Gelan 2021). Overall urban green area was generated by aggregating the output from AHP following Kahsay et al. (2018) using equation (Eq 3).

$$SI = \sum Wi * Xi \quad (\text{Eq 3})$$

where SI = Suitability Index, Wi = weight of factor I, and Xi = normalized criterion score of factors. Finally, the weight was assigned based on their degree of influence.

**Table 2.** Relative importance factors value (Adapted from Saat's 1980).

Intensity of importance	Definitions	Explanations
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favour one over the other
5	Much more important	Experience and judgment strongly favour one over the other
7	Very much more important	Experience and judgment very strongly favour one over the other. Its importance is demonstrated in practice
9	Absolutely more important	The evidence favouring one over the other is the highest possible validity
2,4,6,8	Intermediate values	When compromise is needed

**Table 3.** Pair wise comparison matrix of parameter selected for this study.

Factors	Pop density	NDVI	Road	LULC	Slope	Elevation	River	Soil types
Pop density	1	2	2	2	2	3	3	4
NDVI	1/2	1	2	2	2	3	3	4
Road	1/2	1/2	1	2	2	2	3	3
LU/LC	1/2	1/2	1/2	1	2	2	3	3
Slope	1/2	1/2	1/2	1/2	1	2	2	3
Elevation	1/3	1/3	1/2	1/2	1/2	1	2	3
River	1/3	1/3	1/3	1/3	1/2	1/2	1	2
Soil types	1/4	1/4	1/3	1/3	1/3	1/3	1/2	1
$\Sigma=$	4.42	7.07	8.95	10.5	/11.98	15.56	19.36	22.16

### 3. Result and discussions

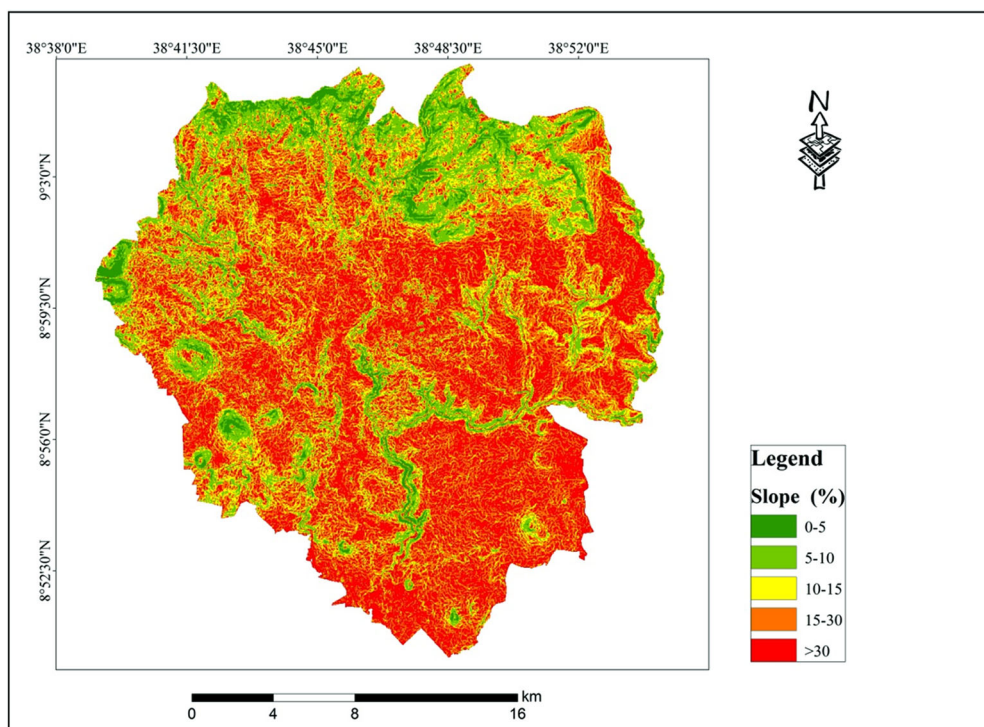
#### 3.1. Parameters used for urban green space development suitability analysis

The determinant evaluation for UGS suitability analysis was performed based on eight factors. These factors include slope, LULC, elevation, NDVI, population density, soil type, roads, and streams. Taking all these factors into consideration, we have been able to evaluate land suitability for UGS development. Based on geographical location and other parameters we used eight factors to evaluate the suitability of UGS. The results of this study are important not only for city administration, but also for citizens to enjoy fresh air. The UGS make the city residents more resilient to climate extremes like drought, flood and heat waves. The provision of UGS indicates the accessibility to fresh air that can support city administration and planners to improve the well-being of the city population and maintaining the urban thermal comfort level. Orsi (2018) conclude that the distribution and accessibility of urban green areas can determine the quality of life in cities.

##### 3.1.1. Slope

Slope is one the key parameters that determine UGS suitability analysis. For instance, growth and development of green vegetation can affect by slope. The slope factor reveals the amount to which the ground is sloped. The areas captured with gentle (low) slopes are highly suitable for UGS development. Slope based land suitability for UGS was classified into highly suitable, moderately suitable, marginally suitable, currently not suitable and permanently not suitable. Increasing the slope related with decreasing land suitability for UGS and vice versa (Teferi and Abraha 2018, Gelan 2021). The slope area less than 5% is, considered as flat and it is highly suitable, slope 5–10% is gentle slopes and these





**Figure 4.** Slope map of the study area.  
 "Source: Author's own conception."

slopes are, considered as suitable for the UGS development (Figure 4). The results show that 29.3% of slope is highly suitable, while 3.3% of slope is permanently not suitable for UGS (Table 4).

### 3.1.2. Land use and land cover

Since Addis Ababa city is experiencing rapid urbanization with high population growth rate. There is a mismatch between demand of land and supply for house construction, which may force some people to buys and sells land illegally in and around the periphery of the city. This illegal land sales remains the key problems not only in urban centers but also in the countryside (Holden and Bezu 2016). A study conducted by Abebe et al. (2019) at Jimma city found that the low economic class was more involved in illegal house construction than the wealthy. The LULC is another factor used for UGS development. The LULC of the Addis Ababa city were produced from Landsat images of the study area and classified into five classes. These classes are agriculture, bare land, built up area, grassland and vegetation (Table 5; Figure 5). According to Abebe and Megento (2017) and Girma et al. (2019) suggested that vegetation, bare land and grassland are the best area for UGS development. This is because it does not take much to turn a barren and grassy area into a green space. It is too costly to covert the built-up area into UGS. In addition, urban land with vegetation cover was more appropriate for UGS development in the study area (Azagew and Worku 2020). Besides, costly it may result to conflict between the city administration and residents. Therefore, it is better if the city administration considers the issue of UGS development in urban planning.

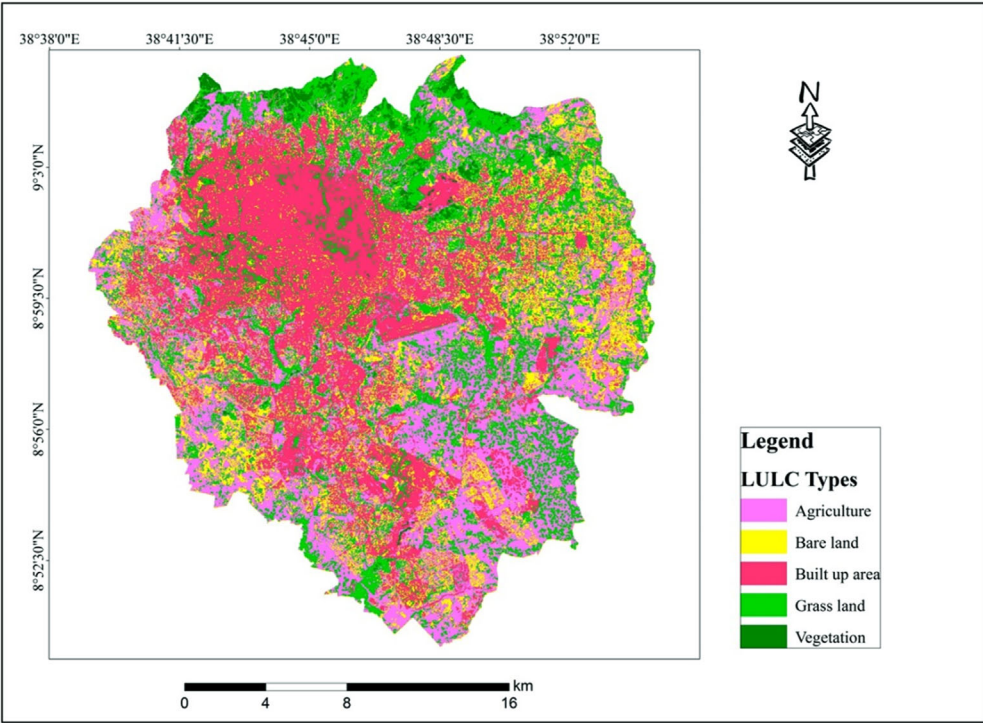


**Table 4.** Slope category and their suitability level.

Slope (%)	Suitability level	Value	Area (km <sup>2</sup> )	Area (%)
<5	S1	5	154.3	29.3
5-10	S2	4	182.0	34.5
10-15	S3	3	87.4	16.6
15-30	N1	2	85.7	16.3
>30	N2	1	17.6	3.3
			527.0	100

**Table 5.** LULC types and areal coverage of the study area.

LULC Types	Level of suitability	Value	Area (km <sup>2</sup> )	Area (%)
Agriculture	S3	3	155.6	29.5
Bare land	S1	5	80.3	15.2
Built up area	N2	1	168.3	31.9
Grass land	S1	5	113.7	21.6
Vegetation	S2	4	9.2	1.7
Total			527.0	100



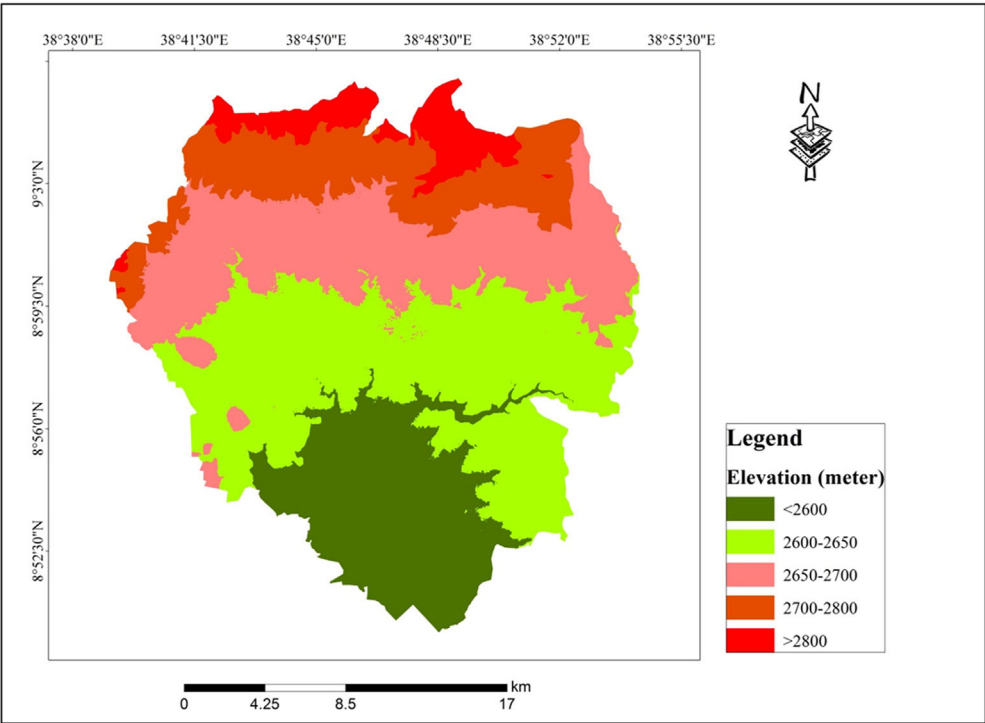
**Figure 5.** LULC map of the study area.  
"Source: Author's own conception."

**3.1.3. Elevation**

Elevation is the key factors to determine UGS development (Mahmoud and El-Sayed 2011). According to Gelan (2021) confirmed that the area of low elevation was more suitable for UGS development. The green space area has the capacity to minimize susceptible to storm water accumulation and flooding. Kim et al. (2016) highlights the importance of

**Table 6.** Elevation and their suitability level.

Elevation (m)	Level of suitability	Value	Area (km <sup>2</sup> )	Area (%)
<2600	S1	5	30.6	5.8
2600-2650	S2	4	76.4	14.5
2650-2700	S3	3	134.5	25.5
2700-2800	N1	2	184.2	34.9
>2800	N2	1	101.3	19.2
Total			527.0	100.0



**Figure 6.** Elevation map of the study area.  
“Source: Author’s own conception.”

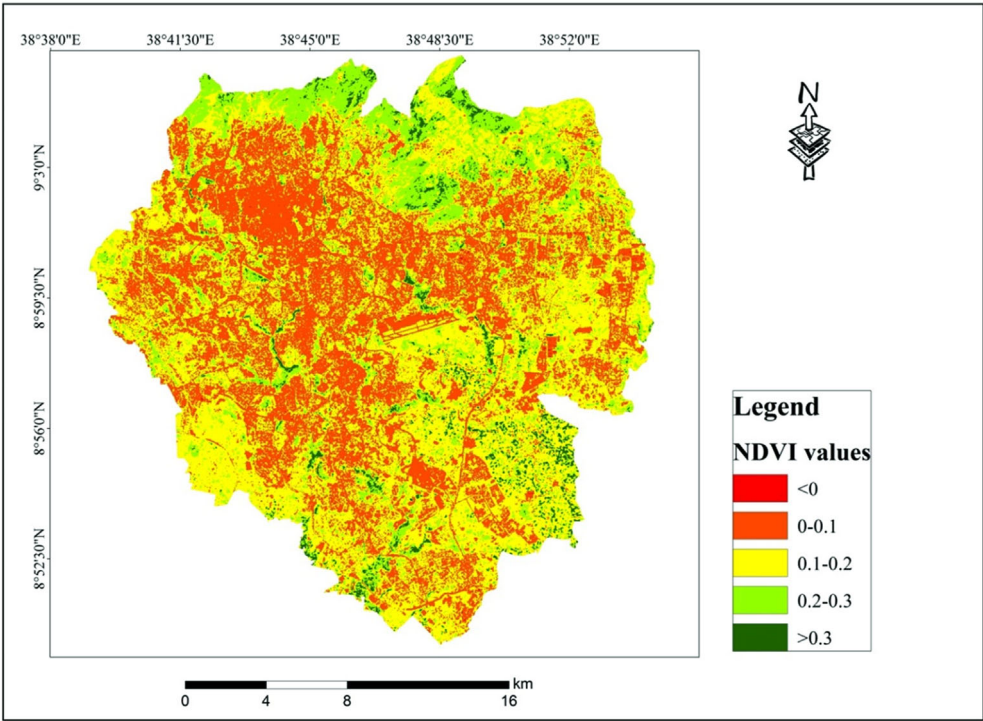
UGS in flood risk minimization and management. In the present study, we classified elevation of the study area as highly suitable (<2600 m), moderately suitable (2600–2650 m), marginally suitable (2650–2700 m), currently not suitable (2700–2800 m), and permanently not suitable (>2800 m) for UGS development (Table 6; Figure 6). This classification of elevation for UGS development was more consistence with previous studies (Girma et al. 2019).

**3.1.4. Normalized difference vegetation Index (NDVI)**

Normalized Difference Vegetation Index (NDVI) is other parameters to determine the green space suitable area and can inform the current environmental conditions, as well as future opportunities of UGS development suitable area (Wang et al. 2022). From the calculated data, NDVI greater than 0.3 is highly suitable for UGS development, whereas, NDVI values less than 0 is permanently not suitable for suitability analysis of UGS development (Table 7; Figure 7). The UGS can improve urban resiliency to climate extremes

**Table 7.** NDVI Values and their suitability.

Vegetation cover	Level of suitability	Value	Area_km <sup>2</sup>	Area (%)
NDVI > 0.3	S1	5	1.4	0.3
0.2 < NDVI < 0.3	S2	4	179.2	34.0
0.1 < NDVI < 0.2	S3	3	254.3	48.2
0 < NDVI < 0.1	N1	2	78.0	14.8
NDVI < 0	N2	1	14.2	2.7
Total			527.0	100.0



**Figure 7.** NDVI map of the study area.  
"Source: Author's own conception."

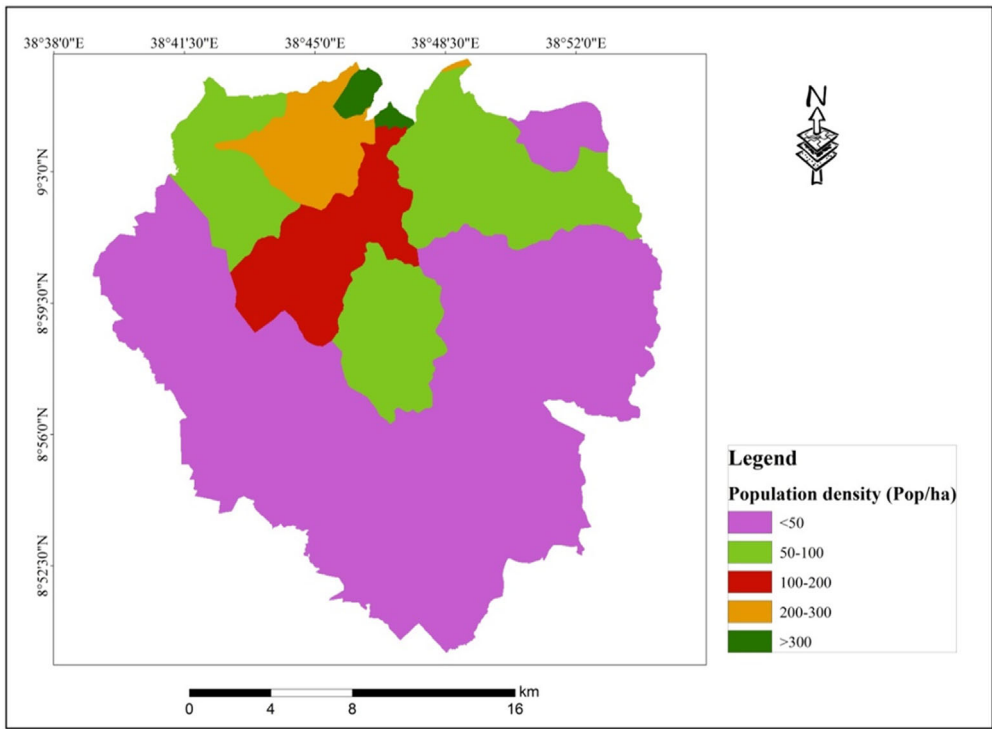
like heat waves and maintain sustainability of cities in addition to ecological and economic contributions (Kim et al. 2016). Study by Moisa et al. (2022b) over Jimma city in southwestern parts of Ethiopia confirmed that vegetation coverage, open and green space area played a crucial role in urban thermal environment. The classification of NDVI for this study was based the classification of (Abebe and Megento 2017) which have been conducted in Bole sub city of Addis Ababa.

**3.1.5. Population density**

Population density is another crucial factor for the analysis of green space development (Gelan 2021). Highly populated area was more related with dense built-up area with highly vulnerable for heat stress from urban heat island and heat wave in the study area (Li et al. 2020). Hence, highly populated areas are highly suitable for HGS development and vice versa (Abebe and Megento 2017). From the calculated result, population density >300pop/ha highly suitable and <50 pop/ha permanently not suitable for UGS

**Table 8.** Population density and suitability level.

Population density (pop/ha)	Level of suitability	Value
>300	S1	5
200-300	S2	4
100-200	S3	3
50-100	N1	2
<50	N2	1



**Figure 8.** Population density of the study area.  
"Source: Author's own conception."

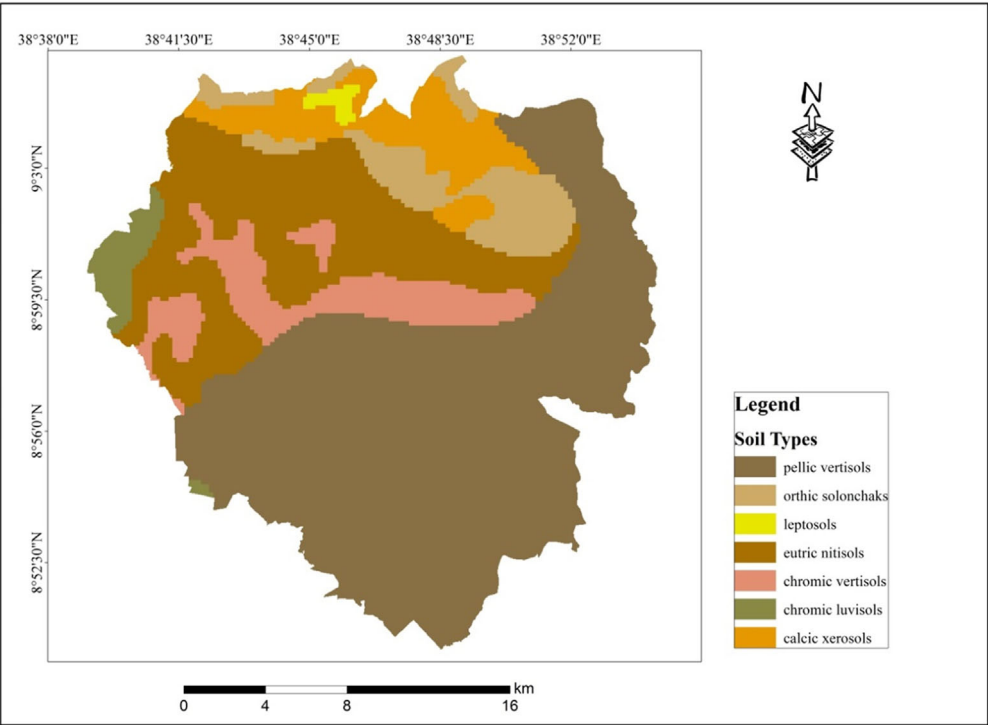
development (Table 8; Figure 8). Previous study by Tarekegn and Gulilat (2018) reported that the city of Addis Ababa experiencing a higher population growth driven by rural to urban migration. According to Central Statistical Agency (CSA)) (2007) report the population growth rate of Addis Ababa city was about 2.1%.

**3.1.6. Soil types**

According to Abebe and Megento (2017) suggested that, chromic vertisols and chromic luvisols are considered as suitable soil as it is deep soil and contain 45% clay or more clay which is high natural fertility. Moreover, the black or dark colors of soils as indicators of good soils (fertile soils) are reflections of the high amounts of organic matter contents in the soils (FAO 1984; He et al. 2021; Zhang et al. 2021). Orthic solonchaks consider unsuitable compared to clay soil (Cheng and Fu 2022). About 56.3 km<sup>2</sup> captured by chromic vertisols and chromic luvisols were highly suitable for urban green development (Table 9; Figure 9).

**Table 9.** Soil types and suitability level.

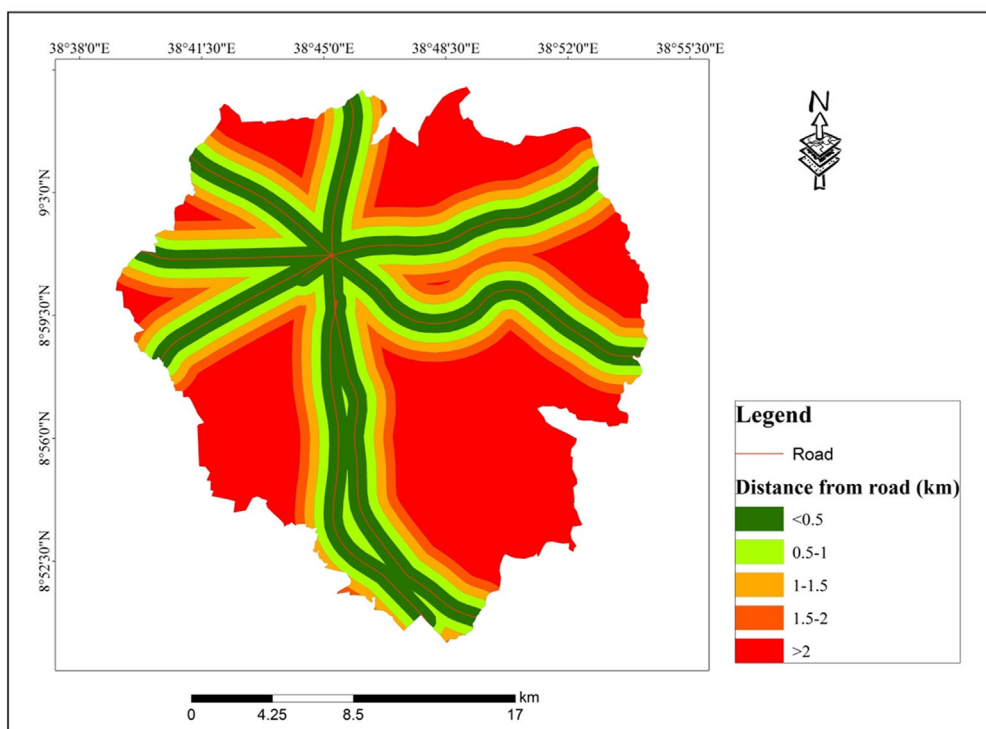
Soil Types	Suitability level	Value	Area (km <sup>2</sup> )	Area (%)
calcic xerosols	S3	2	39.3	7.5
chromic luvisols	S1	5	11.7	2.2
chromic vertisols	S1	5	44.6	8.5
eutric nitisols	S3	2	111.6	21.2
leptosols	S2	4	2.8	0.5
orthic solonchaks	N1	1	38.4	7.3
pellic vertisols	S2	4	278.6	52.9
Total			527.0	100



**Figure 9.** Soil types of the study area.  
"Source: Author's own conception."

**3.1.7. Roads**

Proximity the roads to green space is one of the key parameters that determine the effectiveness and the likelihood of monitoring and maintenance of UGS development. As distance of UGS away from the road, acceptability of urban land for urban green space becomes decreased. Accessibility as an important factor for suitability urban green space analysis (Yang et al. 2009; Kumar and Biswas 2013). Tahmasebi et al. (2014) and Chandio et al. (2011) confirmed that the green space area is better when it is located at a suitable distance from roads. Accordingly, the green space site is unsuitable if distance from roads is greater than 2km. The distance starting from 0.5–1km is considered as moderately suitable and distance less than 0.5 km, is highly suitable (Figure 10). Several studies have demonstrated the important influence that green spaces have on human health. Green spaces help individuals live longer, enhance air quality, and reduce traffic noise and city temperatures (Schindler et al. 2022).



**Figure 10.** Distance from roads map.  
 "Source: Author's own conception."

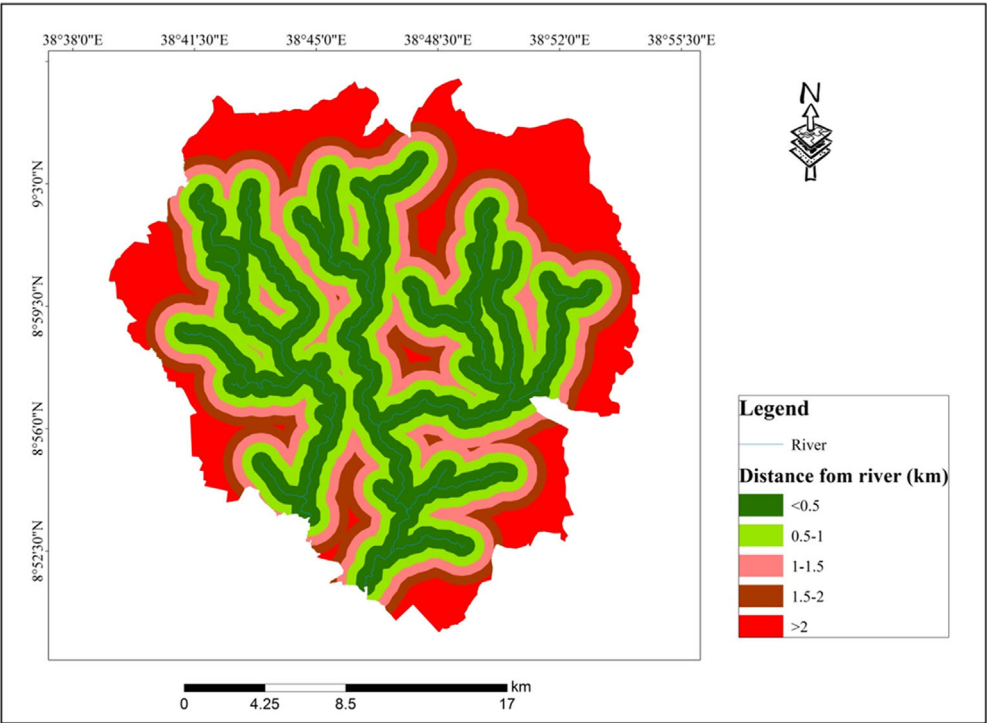
### 3.1.8. Stream (Rivers)

Water body was more suitable for vegetation growth, flourished with denser oxygen levels, fewer contents of carbon dioxide and conducive environments for human recreational site. The urban area closer to streams/rivers is more suitable UGS development and used to maintain the environmental health of the area (Pareta 2013). Lands closest to water resources like rivers, lakes and reservoirs are highly suitable for green space development. Therefore, from calculated data, the distance from the river is  $< 0.5$  km, the area is highly suitable and in between 0.5 km-1 km moderately suitable (Figure 11).

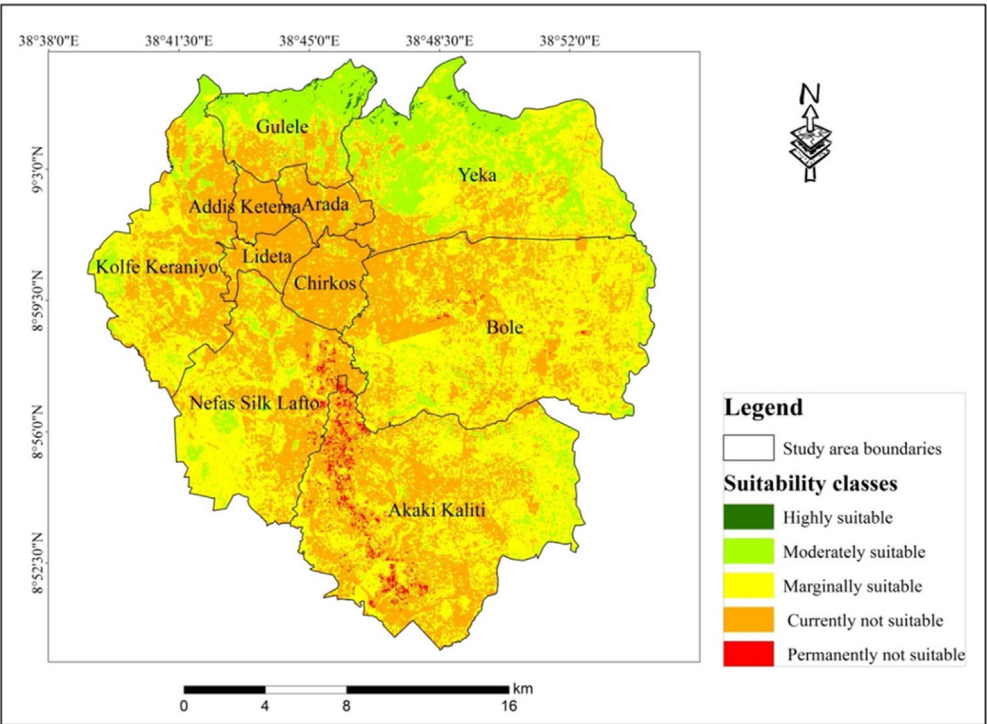
## 3.2. Suitable area for urban green space development of Addis Ababa city

The result of this study, combined from eight (8) factors, UGS development of Addis Ababa city was analyzed. Final land suitability map of urban green development of the study area was produced. The Northern part of the study area, Gulele and Yeka, sub cities were highly suitable and moderately suitable are available, respectively. Eastern and central parts of the area were dominated by marginally suitable, currently not suitable and permanently not suitable (Figure 12). The results show that about  $1 \text{ km}^2$  (0.2%) occupied by high suitable and  $67.4 \text{ km}^2$  (12.8%) was dominated by moderately suitable in the study area. In addition, marginally suitable occupies about  $247.2 \text{ km}^2$  (46.9%), lastly, currently not suitable and permanently not suitable occupies about 38.9% and 1.2%, respectively (Table 10). The results of this finding it in line with the goal of Ethiopia's Environmental Policy, established in 1997, is to plan and develop green spaces inside metropolitan areas that offer recreational opportunities for cities dwellers and improve urban microclimates.





**Figure 11.** Distance from River map.  
"Source: Author's own conception."



**Figure 12.** Suitable area for urban green space development map.  
"Source: Author's own conception."

**Table 10.** Suitability classes and the corresponding area coverage.

Suitability classes	Area (Km <sup>2</sup> )	Area (%)
Highly suitable	1.0	0.2
Moderately suitable	67.4	12.8
Marginally suitable	247.2	46.9
Currently not suitable	205.2	38.9
Permanently not suitable	6.2	1.2
Total	527.0	100.0

In addition, the goal of the 2015-developed urban greenery and beautification policy is to provide green spaces that combat environmental degradation, pollution, and urban flooding while also promoting environmental sustainability (Girma et al. 2019). Similarly, establishing ecologically sound, aesthetically pleasing, and socially beneficial green spaces in cities is one of the goals of Ethiopia's national urban green infrastructure standard, which was developed in 2015. Another goal is to provide suitable, sufficient, and ecologically viable green spaces to meet the community's recreational, social, economic, and environmental needs (Eshetu et al. 2021). The results of this research paper provide direction for the community in Addis Ababa to organize them to planting and maintaining trees to earn personal income from the city administration office and improve their own livelihoods. Consequently, urban planners used this result to create effective design for effective UGS development strategies.

#### 4. Conclusion

The UGS are crucial elements of the city's framework that improve the welfare and lifestyles of its residents. Beside this importance, the status of UGS is being decreased and eradicated due to rapid human population development, native and exotic trees that were planted to beautify the urban environment and required urgent scientific investigation for the future management action. This study evaluates UGS suitability of Addis Ababa city by using the integration of analytical hierarchical process and GIS based multi-criteria evaluation. The LULC types, NDVI, population density, soil type, slope, elevation, road and rivers were used as the key parameters determining UGS development. The UGS suitability analysis is crucial for city administration to design effective strategies to maintain the urban thermal environment in one hand, and minimizing the possible occurrence of climate extremes in the other hand. Green urban area can enhance the quality of urban residents through providing social, economic aesthetics values beside climate change regulations. The vast majority of the urban residents have less access to nearby public urban green open space due to lack of sufficient information about the advantage of green space development for their livelihoods. Urban green spaces are important to provide multiple benefits through acting as a lung of cities, improve the physical, psychological stress relief center and improve social harmony through social interaction and recreation. Thus, UGS development is an essential not optional for mega cities like Addis Ababa. The UGS are considered as an important natural donor that supplies numerous ecosystem services and thus stakeholders should give high priority for this sector.

An integrated analytical hierarchical process and GIS might be an effective tool for evaluation of UGS suitability analysis. These integrated approaches allow considering multi factors to understand the importance of different factors for suitability analysis. From the final result of land suitability classes for UGS development, marginally suitable and currently not suitable classes were dominating than highly suitable and moderately

suitable classes in the study area. This implies that, rapid urban expansion from informal urban settlement with a little attention of UGS in the Addis Ababa city. Urban planners, decision makers, environment and climate change resilience specialists, natural resource managers and others concerned bodies must provide a crucial responsibility for the conservation and protection of UGS to ensure sustainable urban development in the city. Further studies which considers socio economic data, high resolution satellite images like aerial photography and quick bird are required to forward feasible policymakers for UGS development of Addis Ababa city.

## Consent for publication

The authors agreed to publish this manuscript for publication.

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## Disclosure statement

No potential conflict of interest was reported by the authors.

## Author contributions

MBM involved in conceptualization, data collection, software, visualization, data analysis and developing original draft of the manuscript. BBO, KTD and MEF participated in methodology, data analysis and manuscript edition. MMG and DOG contributed in conceptualization, validation of results, review and edition of the final manuscript. All authors read and approved the final manuscript.

## Availability of data

Available in this manuscript.

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