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Green spaces suitability analysis for urban resilience using geospatial technology: the case of Jimma city, Oromia, Ethiopia

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Abstract

In recent years, cities have faced significant challenges in terms of security, livability, and sustainability as a result of rapid urbanization and indelible worldwide environmental changes. In this regard, resilience has become a goal for many cities throughout the world, leading to the enhancement of urban ecology. Urban green spaces have been therefore recognized as a successful strategy to build resilience by enhancing the quality of urban settings and endorsing sustainable lifestyles. Thus, this study was aimed at identifying suitable green space sites for urban resilience in Jimma city, Southwest Ethiopia. Geographic information system (GIS)-based multi-criteria land suitability evaluation method was employed for green space suitability analysis by considering ten factors, i.e., soil type, land use land cover, slope, land surface temperature, population density, normalized difference vegetation index, distance from a river, road, existing green area, and protected area. The results of overall suitability revealed that 3.4% of the study area was identified as a highly suitable site for green spaces (S1), 13.8% of the area as a suitable area (S2), and 42.2% as a moderately suitable area (S3) for green space development in Jimma city, while the remaining 35.1% and 5.4% of the study area were less suitable and unsuitable (N1 and N2) for urban greenery development, respectively. Furthermore, the result of the analysis demonstrated that land surface temperature, slope, land use/land cover, and NDVI value were found to be the most important factors for determining a suitable site for urban green space development in this study. Based on the findings of this study, it is possible to infer that the integration of GIS with multi-criteria evaluation (MCE) is a useful and effective method for the evaluation of land suitability for green space development. Hence, the findings of this study assist in amalgamating the appropriate land to be adapted as green spaces in cities, and it will help to form a basis for generating a greener and sustainable city in the future.

Keywords Green space · Jimma city · GIS · Remote sensing · Multi-criteria · Urban resilience

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1 Introduction

There are increasing issues related to environmental problems, notably in the form of global warming, air and water pollution, degradation of soil resources, urban sprawl, excessive noise, and traffic congestion (De Ridder et al., 2015). A similar and critical issue is the growing space of inexperienced land consumption found in most city landscapes around the world. This is becoming an important global concern since more than half of the world's population is currently dwelling in urban areas (UN, 2014). As the world faces increased urbanization and climate change extremes, green space is becoming increasingly scarce, which has been increasing exposure to environmental hazards, such as increasing temperatures, urban heat island effects, heat waves, and fluvial flooding (Woldesemayat & Genovese, 2021). Rapid urbanization in Africa has also resulted in the excessive destruction of urban green spaces. As a consequence, the decline of green spaces in Africa has resulted in them constituting a minor fraction of the total land in numerous urban regions (Senanayake et al., 2013). The overall development of urban green spaces in Africa is hindered by various challenges (Collins, 2014).

As in many other African countries, the situation also occurs in Ethiopia, which is one of the most rapidly urbanizing countries in sub-Saharan Africa where urbanization is mostly driven (Ministry of Urban Development & Housing, 2015). These interventions have alarmed the country into a struggle with urban concerns, unsustainable land use, natural environmental fragmentation, and the loss of green space (Adenew, 2018). Due to this in Ethiopia, most of the urban centers are unable to meet the minimum standard of green space per capita proposed by the World Health Organization (WHO) (MOUDH, 2015). Even the existing urban green space (UGS) components are poorly accessible and not safe (Azagew & Worku, 2020). Moreover, they are not well developed and lack basic facilities, discouraged urban dwellers to utilize those (Hailegiorgis, 2017). Poor enforcement of planning regulations, inadequate legal framework, and lack of financial support was commonly mentioned as driving factors that led to the poor development of UGS components in the urban center of Ethiopia (Girma et al., 2019).

Similarly, the rapid expansion of Jimma city coupled with rapid demographic change and high demand for urban land has resulted in drastic changes in key ecosystems such as natural forests, grasslands, and wetlands (Abraham et al., 2015). Considering the pressures of rapid urbanization and high rates of population growth, there has been a decline in the amount of land available for urban green space development, which has primarily been observed in the last few decades. Besides, the existing recreational space and green area are not balanced with the demand of dwellers and are below standard. The lack of connectivity and multi-functional benefits of the urban green space components in the study area has led to the poor quality. Owing to these various environmental problems, the town has been worsening. (Oromia Urban Planning Institute, 2020). Besides, urbanization-induced green space loss in Jimma city leads to various problems such as ecosystem service declination, ecological disorder, landscape and stream network change (Wakjira & Megersa, 2019). All these point out, the need for the development of green spaces in Jimma city, such as urban parks, gardens, greenways, and others; to sustain the urban environment well-adjusted with disturbances stemming from different sources. Thus, the main motivation behind the initiation of the present research work is to assist the green space development planning process toward environmental resilience in the rapidly urbanizing area of Jimma city by taking green spaces as a good initiative to replace the loss of natural greenery.

Although some studies have been conducted on suitability analysis for green space development in our country, for instance (Abebe & Megento, 2017; Gelan, 2021; Hailemariam, 2021), most of these previous works focused on the some and not all major factors and this has led to an incomprehensive land use plan for green space. There is a need for an analysis that combines these factors dependently for a better assessment of land suitability. In addition to that, they did not considered all known factors including land surface temperature and normalized difference vegetation index (NDVI) in their study. Since one of the most significant roles of green space in urban areas is mitigating heat effects, the land surface temperature is a principal parameter that should be considered in green space planning to identify hot spot areas that require green space. Nonetheless, various researchers that focused on green space suitability analysis overlooked this important parameter in their study. Therefore, this study emphasized on bridging the gap in the existing literature by considering land surface temperature and normalized difference vegetation index (NDVI), which is standardized way to measure healthy vegetation parameters together to determine the suitability of land for green space development. This is due to the fact that land surface temperature (LST) and its relationship with normalized difference vegetation index (NDVI) are significantly considered in environmental study.

2 Materials and methods

2.1 Description of the study area

The study was conducted at Jimma city, which is located in the Jimma zone of Oromia Regional State, South-Western Ethiopia. The city is located 346 km away from the capital city (Addis Ababa) of Ethiopia. Astronomically, it is located between 7° 37′ 20″ and 7° 42′ 40″ North of latitude and 36° 46′ 30″ to 36° 54′ 00″ East of longitude (Fig. 1). It is bordered by Kersa wereda in the east, by Manna wereda in the north, by Manna and Seka Chekorsa in the west, and by Dedo in the south. Currently, the city has been reconstructed into 17 urban kebeles (administrative units) with a total area of 106.34km^2 (Jimma City Profile, 2021).

The topography of Jimma city is divided into escarpment and alluvial plains. Escarpment Zone represents topographically elevated areas and surrounds the city in northwest, north, and east. The alluvial plain zone contains fairly broad valleys and represents lower grounds and elongated low hills. It starts from the foot of the escarpment zone and trends to south-southeast. This zone covers most of the settlement area of city and diminishes into flat further south of the city. The major part of Jimma city, including the central, southern, and western parts, is characterized by flat to gently sloping/undulating topography, while the northern and eastern parts of the city and its peripheries are characterized by hilly/ sloping landscape (Jimma City Profile, 2021).

Elevation within the city ranges from 1670 to 2281 m. Jimma city is characterized by a temperate humid climate that has high precipitation, warm temperature, and long wet period. The mean temperature is between around 12 and 29 °C with a mean daily temperature of 19.5 °C.
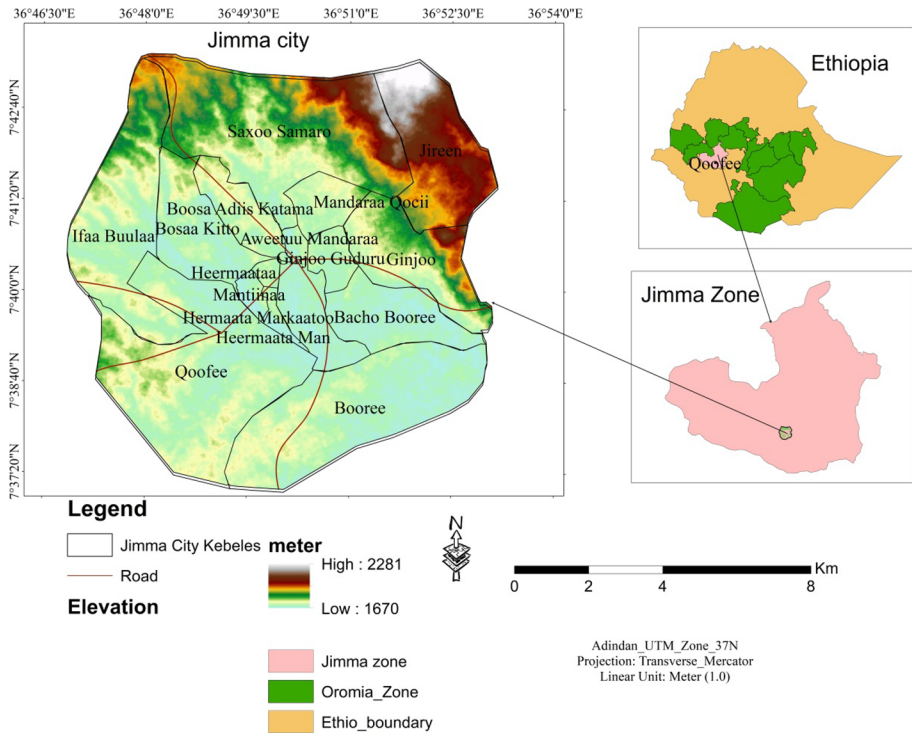
Fig. 1 Location map of the study area

2.2 Methodology of the study

2.2.1 Data types and sources

To achieve the objectives of this study, two types of data were used. These are primary and secondary data. Primary data for this study were collected from various sources. Primary data were collected from protected areas, existing parks, and recreational green areas were collected using handheld GPS. For this study, secondary data embrace geographical data along with remote sensing images, DEM, structural plans, and others. Landsat data (Landsat-8 OLI-TIRS 2021) were freely accessed and downloaded from the online archive of the United States Geological Survey (USGS).

Secondary data were also acquired from reliable internet sources, journals, published and unpublished government institutions manuals, and reports (Table 1).

2.2.2 Software packages used

Different software packages were used for data preprocessing, preparation, analysis, and output generation. These are ArcGIS 10.3, ERDAS Imagine 2015, IDRISI Selva 17.0 and Arc SWAT.. ArcGIS 10.3 was applied for proximity and overlay analysis and database creation. ERDAS Imagine 2015 was also used for image classification. The IDRISI Selva 17.0

Table 1 Data types, sources, and purposes

Data types	Source	Definition
Population data	Municipality of the city and Central Statistics Authority	For suitability analysis
Land sat image	USGS	For LU/LC, LST, NDVI analysis
Structural plan	Jimma city land administration and use office	To generate road network
Administrative boundary	Jimma city municipality	To subset/extract the area of the study
DEM data	ASTER Global DEM website	To extract slope, stream network suitability analysis
GPS data	Field survey	Ground verification
Soil data	FAO digital soil map	For Suitability assessment
Revised structural plan	Plan commission	For reviewing issues dealing about Green Space system in Jimma city

software was used for the weighting of different factor maps using the analytical hierarchy process (AHP) method and for calculating the consistency ratio and Arc SWAT used to generate stream network of the study area. Each software package is explained in detail in the table in terms of its application for the study (Table 2).

2.2.3 Method of data processing and analysis

For urban green spaces planning, there were no universally agreed criteria and factors (Jabir & Arun, 2014). For that reason, criteria were selected using literature reviews, relevance within the biophysical and existing socio-economic situation in the city, and availability of data. Evaluation factors were designated from environmental, accessibility, physical, and socio-economic aspects. Accordingly, for this study, criteria's considered for suitability evaluation were slope, soil, population density, distance from protected area and major institutions, proximity to the road, existing land use, distance from the water body, and distance from existing green amenities, NDVI value, and land surface temperature.

I.   Preparation of thematic maps for criteria

Following the identification of criteria, the raw data needed for the preparation of the study area thematic layer were gathered. Then, the preparation of criteria maps focused on processing the raw data to generate the thematic layers. Accordingly, ten thematic layer were developed for the study area. These thematic layers were produced using a variety of processing methods. The following section goes into the details of each thematic layers preparation.

Buffering is a spatial analysis tool used to produce areas within a particular distance based on a specified standard for selecting urban greenery sites (Stessens et al. 2017). To analyze the suitability of Green space site distance from road and river, geo-processing operation such as buffering was done with specified distance-based literature values mainly used in the green space site selection process. Also, to evaluate the suitability of urban green space distance from protected areas and existing green amenities, the collected GPS coordinates of those areas were imported into ArcGIS software and multiple ring buffer using analysis tools (proximity) was done. After buffering operation, they were converted into raster format to make them ready for reclassification (Nkeki. 2016).

On the other hand, shuttle radar topography mission, digital elevation model (SRTM DEM) with 30 m*30 m resolution was used to derive and prepare the slope and stream map of the study area. The analysis of slope was based on the surface analyst of the Arc GIS spatial analyst toolbox, and the land use land cover (LULC) factor analysis was based

Table 2 Software packages used for this study	Software	Applications
	ArcGIS10.3	Proximity analysis, reclassification, weighted overlay, NDVI mapping, LST mapping, data visualization and map layout
	IDRISI Selva 17.0	Weighting of factors
	ERDAS Imagine 2015	Image classification
	Arc SWAT	To generate stream network of the study area
	Google earth pro	Used as a base map in visual image interpretation and for the purpose of ground truthing and validation of suitability map

on the acquisition of Landsat images. This was followed by image analysis for specifying the LULC classes of the study area based on the GPS points for classification. A population density map was also generated from the input population data by computing population density using a field calculator in the Arc GIS environment (Hailemariam, 2021).The soil map of the study area was prepared by extraction from the FAO digital soil map of Ethiopia.

Normalized difference vegetation index (NDVI) map of the study area was produced through raster calculator in ArcGIS 10.3. As earlier stated to derive the NDVI map from Landsat-8 OLI-TIRS 2021 image, the following equation was used.

$$NDVI = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4} \tag{1}$$

Land surface temperature retrieval: LST can be calculated through thermal infrared remote sensing data (Suresh et al., 2016).The land surface temperature of the study area was estimated using the Landsat 8 thermal bands by applying a set of equations through a raster calculator in ArcGIS 10.3. The first step to computing LST was the conversion of the digital number into radiance for the TM sensor. Thus, from the metadata file, the digital number of the TM sensor was converted into a radiance value using the following equation (USGS, 2019):

$$L\lambda = \frac{LMAX\lambda - LMIN\lambda}{QCALMAX - QCALMIN} \times (DN - QCALMIN) + LMIN\lambda \tag{2}$$

where $L\lambda$ = spectral radiance at the sensor's aperture in watts/(meter squared × ster × μm), QCAL = the quantized calibrated pixel value in DN, LMINλ = the spectral radiance that is scaled to QCALMIN in watts/(meter squared * ster * μm), LMAXλ = the spectral radiance that is scaled to QCALMAX in watts/(meter squared * ster * μm), QCALMIN = the minimum quantized calibrated pixel value (corresponding to LMINλ) in DN, QCALMAX = the maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN.

IRS thermal bands (Band 10 and Band 11) data were converted to top of the atmosphere (TOA) spectral radiance using the radiance rescaling factors provided in the metadata file (USGS, 2019). Hence, the digital number for Landsat 8 imagery of thermal band was used to generate radiance using the equation below:

$$L\lambda = (ML \times QCal) + AL \tag{3}$$

where $L\lambda$ is the TOA spectral radiance at the sensor's aperture, ML is the band-specific multiplicative rescaling factor from the metadata, Qcal is the quantized and calibrated standard product pixel values (DN), AL is the band-specific additive rescaling factor from the metadata.

Then, the brightness temperature (BT) can be expressed as (Jesus & Santana, 2017).

$$BT = \frac{K2}{\ln\left(\frac{K1}{L\lambda} + 1\right)} - 273.15 \tag{4}$$

where BT is the satellite brightness temperature [Celsius], $K2$ is the calibration constant 2 [Kelvin], the band-specific thermal conversion constant from the metadata, $K1$ is the calibration constant 1 [Kelvin], the band-specific thermal conversion constant from the metadata. NDVI data were used to calculate the proportion vegetation (PV), which can be expressed as follows (USGS, 2019):

$$PV = \left[\frac{NDVI - NDVImin}{NDVImax - NDVImin} \right]^2 \tag{5}$$

where NDVI min was retrieved from the NDVI minimum value, which is -1, and NDVI max, retrieved from the NDVI maximum value, which is 1.

After calculating the PV, the land surface emissivity (LSE) was calculated via the following formula (Jesus & Santana, 2017):

$$LS\varepsilon = 0.004 \times PV + 0.986. \tag{6}$$

Lastly, LST was calculated by taking the average of two thermal bands (band 10 and 11) from Landsat 8 OLI/ TIRS and can be expressed as follows (Jesus & Santana, 2017):

$$LST = \frac{TB}{1(\lambda\ TB/P)\ In\varepsilon} \tag{7}$$

where *LST*: land surface temperature (in Kelvin), *TB*: radiant surface temperature (in Kelvin), λ: the wavelength of emitted radiance (11.5 µm), ρ: h×c/σ (1.438×10⁻² mK), h: is Planck's constant (6.26×10⁻³⁴ J s), c: is the velocity of light (2.998×10⁸ m/s) σ: is Stefan Boltzmann's constant (1.38×10⁻²³ J K⁻¹) and, ε: island surface emissivity.

II.   Data conversion and reclassification

All the thematic layers were processed to map suitable green space locations in Jimma city. Since the units of each thematic factor are different, combining and fusing the thematic factors is not applicable. Thus, criteria maps were first geo-referenced and converted into raster format, and then all the thematic layers were standardized by reclassifying each into five classes through the natural breaks (Jenks) technique. To assign a rating (score) for each criterion, a review of previous scientific experimental research findings and literature on parameters was undertaken. Based on FAO (1976) land suitability classification, the datasets were reclassified from highly suitable (S1) to unsuitable (N2), where S1 represents the highly suitable, S2 suitable, S3 moderately suitable, N1 less suitable, and N2 represents unsuitable conditions for green space site selection in Jimma city (Table 3).

III.   Analytic hierarchy process

The analytic hierarchy process (AHP) method is one of the most commonly used multi-criteria decision-making (MCDM) techniques that combine the qualitative and quantitative analysis of complex systems (Kordi & Brand, 2012). It is considered one of the most efficient methods of extracting the weights of different factors. A pair-wise comparison matrix is a rating of the relative importance of two factors regarding the suitability of the land (Rediet et al., 2020). To compute the weights for the criteria, a pairwise comparison matrix (PWCM) was constructed. The weighting process was done by referring different literatures and similar case studies. In this process, each factor was compared with the other factors, relative to its importance, on a scale from 1 to 9, where a higher number indicated that the chosen factor was more important than the other factors to which it was compared to (Table 4). The influence of each factor relative to the other factor was determined and weight for the criteria's were assigned based on multi-criteria evaluation in the AHP procedure developed by Saaty, (1980) using pairwise comparison matrix. This was done by using IDRISI Selva software decision support (weight) module (Table 4).

Table 3 Suitability class and definition

Suitability class	Value	Definitions
Not suitable	1	This is attributed to sites with characteristics imposing certain constraints, which cannot be overcome or technically excluded for development
Less suitable	2	A level for sites with characteristics imposing constraints, which can be overcome, but by massive investment
Moderately suitable	3	This is for factors with many criterion indicators. It denotes site with constraints but where the Investment is higher than in suitable class
Suitable	4	Sites with characteristics, which can be overcome by moderate investment
Highly suitable	5	Areas with characteristics imposing no significant constraints for development

Table 4 Satya's rating scale. *Source*: Saaty (1980)

The intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favor one over the other
5	Much more important	Experience and judgment strongly favor one over the other
7	Very much more important	Experience and judgment very strongly favor one over the other
9	Absolutely more important	its importance the evidence favoring one over the Other is the highest possible validity
2, 4, 6, 8	Intermediate values	This is demonstrated in practice when compromise is needed

It should be noted that for preventing bias thought criteria weighting, the Consistency Ratio was used (CR). Consistency for a comparison matrix was measured by calculating the consistency index (CI) (Eq. 8).

The consistency check formula is:

$$C.I = \frac{\lambda \max - n}{n - 1} \tag{8}$$

$$C.R. = \frac{C.I.}{R.I.} \tag{9}$$

where n = the number of items being compared in the matrix, λ max = the largest eigenvalue, RI = random consistency index.

This consistency index was then compared to a random index (*RI*). The RI is the average *CI* of randomly generated reciprocal matrices using the scale 1/9, 1/8... 8,9. According to Sat (1980), if consistency ratio is less than 0.10, it is within acceptable limit. Thus, in this study, CR < 0.1, the consistency check result was acceptable, and the weight distribution was reasonable (Table 5).

IV. Weighted overlay analysis

The weighted overlay was used for applying a common measurement scale of values to different inputs to create an integrated analysis. In this study, after weighing criteria regarding their importance for land suitability analysis, all criteria maps were overlaid using a suitability index. Using the ArcGIS weighted overlay analysis tool, overall land suitability was assessed spatially and a final suitability map was generated by aggregating the output from AHP. It can be expressed as:

$$\text{Weighted overlay} = \sum Ci * Wn \tag{10}$$

Table 5 Random consistency index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

where *Ci* is the criteria (*i*) that were reclassified and *Wn* is the amount of weighted data (*n*).

3 Result and discussions

3.1 Suitability analysis for urban green spaces development in Jimma city

3.1.1 Factors for urban green space development

The site selection process for urban green space involves various social, environmental, and economic aspects. To achieve the objectives of the study, different factors that would affect the suitability analysis of green space were considered and the analysis was made by using the GIS-based multi-criteria land suitability evaluation method. Accordingly, Land use/land cover, soil type, slope, proximity from road, proximity from rivers/streams, proximity to protected areas, population density, NDVI, land surface temperature, existing park, were considered as criteria for green space suitable site analysis in Jimma city.

3.1.1.1 Land use/land cover Land use is the most important parameter for urban land suitability analysis as the distribution of various land-use types gives considerable constraints to urban green space development. In this regard, the existing land use system is important in showing the spatial distribution, characteristics, and feasibility of the land for urban green space development. A land-use map of the study area was made from Landsat OLI/TIRS data in 2021 using a maximum likelihood algorithm. Five different classes of land use and land cover were identified, which include dense vegetation, sparse vegetation, built-up areas, agricultural land, and open space (Fig. 2).

Several studies (Ahmed & Ugai, 2011; Pokhrel, 2019; Abebe & Megento, 2017; Elahe et al., 2014; Pantlone, 2010) have considered land use as a parameter for green space suitability analysis. Earlier studies conducted by (Manlun, 2003; Ahmed & Ugai, 2011; Heshmat et al., 2013) demonstrated that open space and vegetated areas are the best places for the development of greenery in urban areas. In view of that, during reclassification, the highest value was given to bare land, while the lowest value was assigned to highly built-up areas. Hence, open space, vegetation, agricultural land, and build-up were ranked as highly suitable, suitable, moderately suitable, and unsuitable for green space site selection in the study area, respectively.

As it is indicated in Table 6, about 41.7%, 24.4%, and 8.2% were moderately suitable, suitable, and highly suitable for greenery development, respectively, from a land use and land cover point of view. This is due to the fact that open space has low economic value. It was chosen as a highly suitable land-use type in comparison to other land-use classes. Likewise, existing vegetation and agricultural lands may have enough open area to be used as an alternative for green space development. The remaining 25.8% of the study areas are unsuitable for urban green space this was mainly due to that the area was occupied by buildup areas. To enhance the compatibility with existing land use system, built up- area were taken as unsuitable for green space site selection process. Therefore, the central parts of the city are not suitable for urban green space since most of the city built ups are concentrated at the center of the city.

3.1.1.2 Slope The slope is another important factor that influences the evaluation of green space. It significantly affects storm water capacity and flows as well as soil ero-
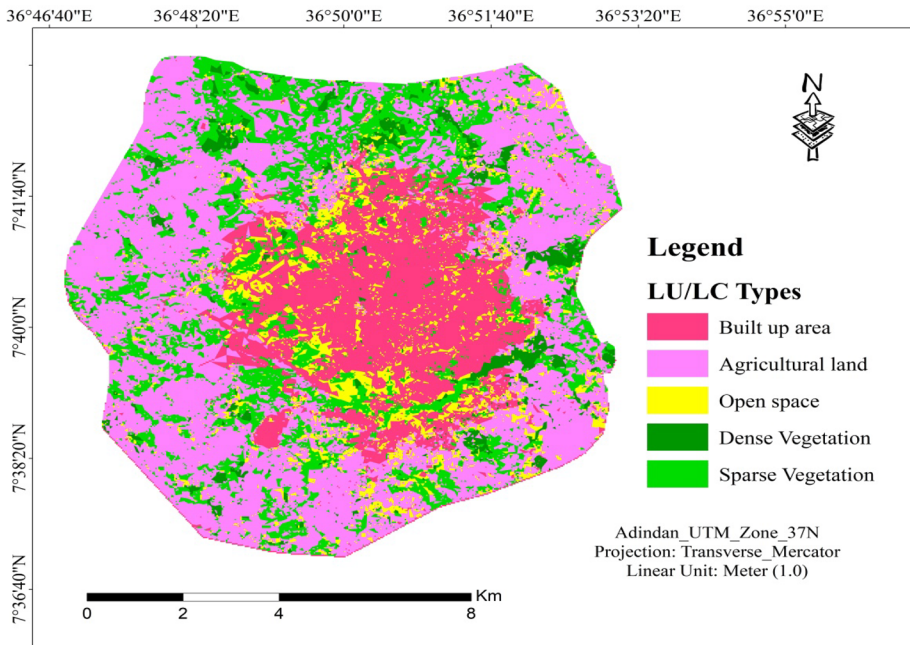
Fig. 2 LULC map of the study area

Table 6 Land use/land covers suitability level with their respective area coverage

Land use land cover	Suitability class	Value	Area (km^2)	Area (%)
Open space	High suitable	5	8.6	8.2
Vegetation	Suitable	4	25.6	24.4
Agriculture	Moderately suitable	3	43.8	41.7
Built up are	Unsuitable	1	27.1	25.8

sion potentials. Green spaces are essential on steep slopes to minimize damaging runoff or to reduce the severity of flooding events in urban and peri-urban environments by increasing soil infiltration. Previous studies conducted by (Heshmat et al., 2013; Li et al., 2018; Ziyari & Sattari, 2014) suggested that the Land that has a slope of less than 5% is, considered as flat and is un suitable, likewise, the Land that has a slope 5–10% is gentle slopes and these slopes are, considered as less suitable for the urban green space development. Based on FAO (2007), the slope value 0 to 0.2% is considered as flat and up to 5 gently slope. 5–10% and 10–15% are called sloping and strongly sloping, respectively. Whereas 15–30% and above 30% are moderately steep and steep, respectively. Based on this assertion, In this study, the Areas with a slope of < 5% were considered as potentially un suitable, and the suitability was increased with the increase of slope, where sites with a slope greater than 30% were ranked as highly suitable, whereas slope ranges between 30–15, 15–10, and 10–5 were reclassified as suitable, moderately suitable, less suitable for urban greenery development, respectively.

Table 7 Reclassified slope and area coverage of suitability levels

S/No	Slope interval (%)	Area (Km^2)	Area (%)
1	< 5	10.4	9.9
2	5–10	23.9	22.8
3	10–15	23.9	22.7
4	15–30	37.8	36.0
5	> 30	9.0	8.6
	Total	105.1	100.0
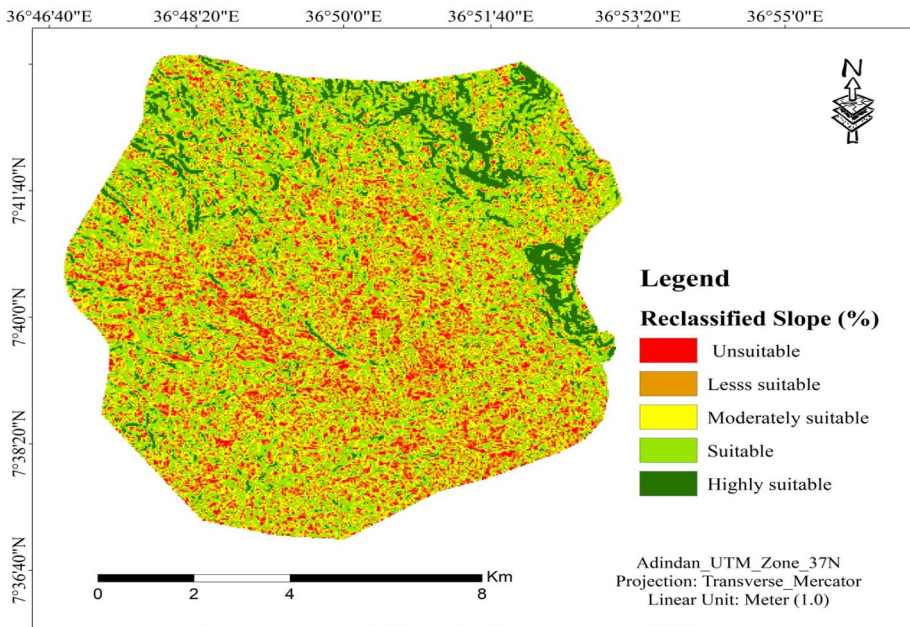
Fig. 3 Reclassified slope suitability map

As outlined in Table 7, about 8.6% of the extent of the study area was highly suitable and 36.0% of the area is suitable, whereas, 22.7%, 22.8%, and 9.9% of the study area were reclassified as, moderately suitable, less suitable and unsuitable for green space suitability evaluation, respectively (Fig. 3).

3.1.1.3 Normalized vegetation index (NDVI) NDVI analysis outcomes revealed that the urban green space of Jimma city is not planned efficiently. This unequal spreading of urban green space can therefore diminish the species productivity, and outward and inward urban growth may lead to habitat loss in the urban ecology. The normalized difference vegetation index (NDVI) can reflect the vegetation coverage and plant habitat; the higher the NDVI vegetation status of the environment is, the better the level of green space adaptability and the higher the score.

Previous studies conducted by Li et al. (2018) revealed NDVI as one significant parameter for green space suitability evaluation in their analysis. This factor of

suitability has taken to recognize landscape cover level of contribution in protecting and enhancing the natural ecosystem and the environment. As a result, the area having a high NDVI value was considered as a potential place to rehabilitate the city and it ranked as highly suitable in terms of environmental protection benefit. Accordingly, in this study, the areas with high NDVI value were the highest weighted, while areas with low NDVI value were assigned with lower values, so the area having greater NDVI value was considered as highly suitable for green space development. The majority of land patches that marked in green color, as seen on the map below, have potential in terms of environmental protection. The NDVI map shows that the central areas, specially marked with red, are not suitable in terms of this factor.

Table 8 demonstrates that about 10% of the study area was classified as highly suitable (S1) for green space development. NDVI values of healthy green vegetation tend to have positive values ranging from 0.3 to 0.8 due to its spectral characteristics (Senanayake et al., 2013). This reflects that the area has promising potential for future vegetation growth and vitality level. In addition, about 24.5%, 32.9%, and 24.0%of the study area were found to be suitable (S2), moderately suitable (S3), and less suitable (N1) for greenery establishment, respectively. The remaining 8.6% of the study area was classified as unsuitable class for green space site selection process (Fig. 4).

3.1.1.4 Land surface temperature Green spaces are one of the most crucial approaches to mitigate urban heat and are needed for effective climate change adaptation in urban areas. As a result, land surface temperature (LST) was selected and taken into consideration as a parameter in this study to designate hot spot areas that would benefit from green infrastructure through regulating urban heat effects. The land surface temperature was derived from Landsat imagery (OLI/TIRS). LST was estimated using the conversion of radiance to satellite brightness temperature and spectral emissivity.

As it can be seen from Fig. 5, in 2021, the maximum temperature was recorded (36.3 °C) with a minimum temperature value of (15.4 °C).

In this study, high suitability values correspond mainly to areas with higher percentages of paved surfaces, with less vegetation or fewer water elements to regulate the urban heat effect (Apud et al., 2020). According to Apud et al. (2020), the area that has a high land surface temperature requires sufficient green space to sustain the city ecosystem.

Based on this clue, an area having a land surface temperature value greater than 27.1 was considered highly suitable for green spaces because of their potential to deliver climate resilience benefits; while an area having a land surface temperature

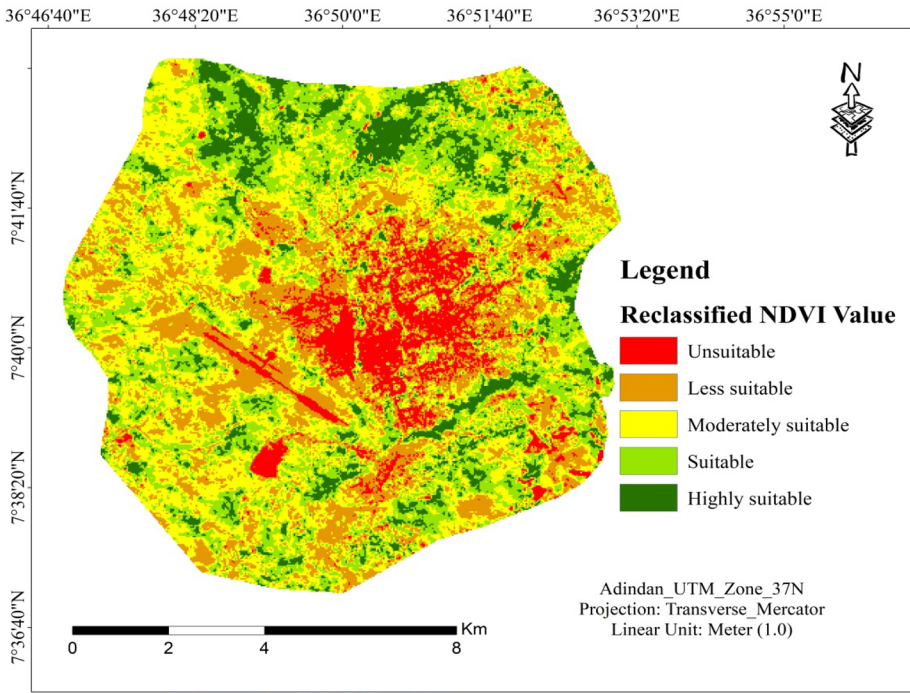| Table 8 Reclassified NDVI value and area coverage of suitability levels	NDVI value	Suitability class	Value	Area (km^2)	Area (%)
	> 0.32	Highly suitable	5	10.5	10.0
	0.27–0.32	Suitable	4	25.7	24.5
	0.22–0.27	Moderately suitable	3	34.6	32.9
	0.167–0.22	Less suitable	2	25.2	24.0
	< 0.167	Unsuitable	1	9.0	8.6
	Total			105.1	100.0

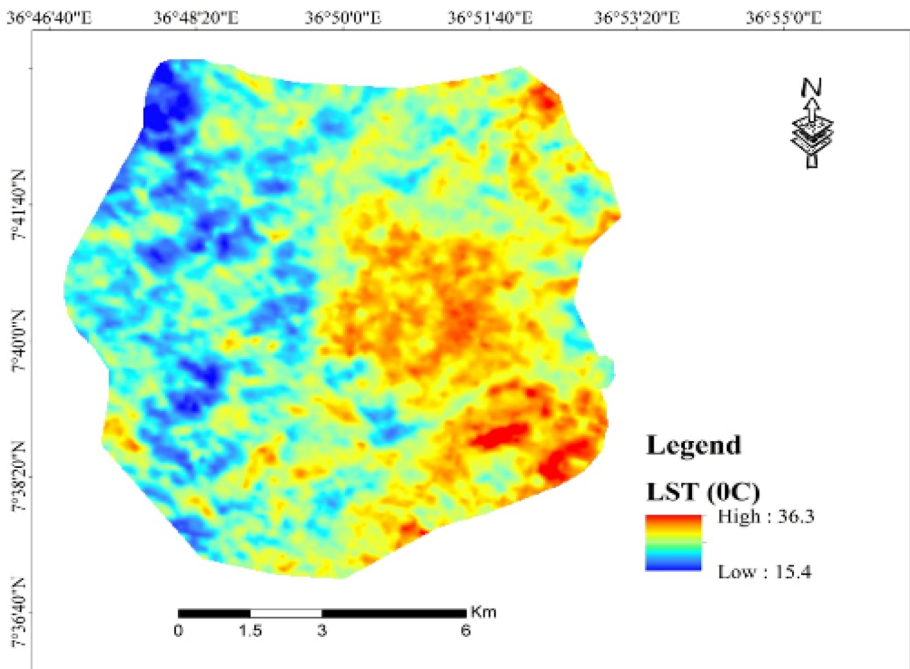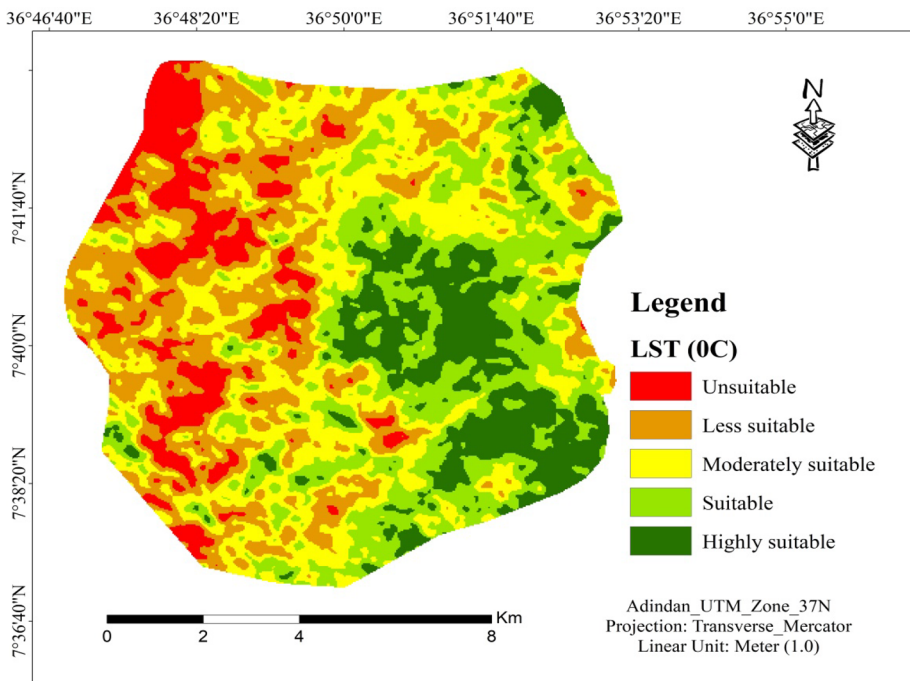**Fig. 4** Reclassified NDVI suitability map

Fig. 5 LST map of Jimma city

Table 9 Reclassified LST and area coverage of suitability levels

LST(0C)	Suitability class	Value	Area (km²)	Area (%)
<17.5	Unsuitable	1	11.0	10.5
17.5–20.8	Less suitable	2	24.9	23.7
20.8–23.8	Moderately suitable	3	29.4	28.0
23.8–27.1	Suitable	4	24.6	23.4
>27.1	Highly suitable	5	15.2	14.4
Total			105.1	100

**Fig. 6** Reclassified land surface temperature map

value of less than 17.5 was ranked as unsuitable for urban greenery site selection. In the study area, LST values between 23.8 and 27.1, 20.8 and 23.8, and 17.5–20.8 were considered suitable, moderately suitable, and less suitable for greenery establishments, respectively.

Table 9 demonstrates that about14.4% and10.5% of the study area were classified as highly suitable (S1) and unsuitable for green space development, respectively. In addition, about 23.7%, 28.0 and 23.7% of the study area were found to be suitable (S2), moderately suitable (S3), and less suitable (N1) for greenery establishment, respectively. From (Fig. 6), central and eastern parts of the study area were highly suitable for urban green spaces development.

Table 10 Reclassified distance from parks and area coverage of suitability levels

Existing green amenities	Suitability class	Value	Area (km²)	Area (%)
>4000	Highly suitable	5	17.4	16.6
3000–4000	Suitable	4	23.8	22.6
2000–3000	Moderately suitable	3	24.3	23.1
1000–2000	Less suitable	2	22.4	21.3
<1000	Unsuitable	1	17.2	16.4
Total			105.1	100

3.1.1.5 Existing green spaces As presented in Table 10, 16.6% of the study areas were highly suitable for green space development because these areas are located far from existing green amenities/parks. This enables the city residents to get a sufficient number of accessible recreational parks within walking distance. Likewise, 22.6% and 23.1% of the study areas were suitable and moderately suitable, respectively. The remaining 21.3% and 16.4% of the study area were less suitable and unsuitable for green space development. As shown in Fig. 7, the central and some northeastern parts of the study area are not suitable for urban green spaces. This is due to the fact that better access to park service is more commonly observed in these parts of the city. Conversely, the northern, southern, and western parts of the study area were highly suitable for urban green spaces.
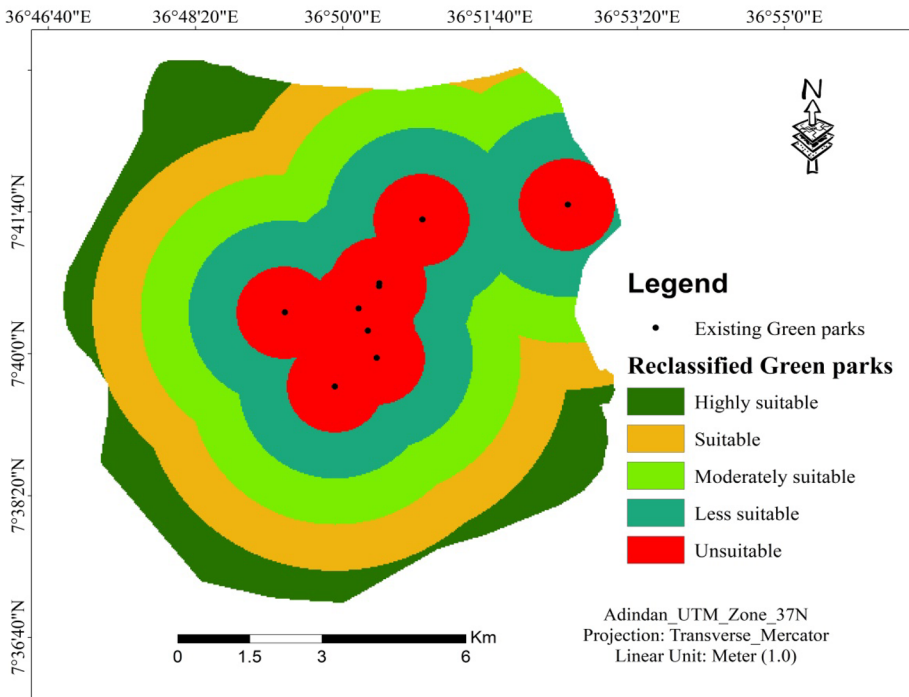
Fig. 7 Reclassified green parks suitability map

The finding indicates that available urban green spaces such as recreational parks are insufficient in Jimma city. Individuals do not have the same access to recreational green space within the walking distance and its distribution is not even. Thus, it is necessary to precisely localize city amenity green space or keep their interval to make equal spatial distribution and this will help to secure the development of green spaces or vegetation to new areas. For the development of green spaces the area which is farthest from the existing green area highly requires green space (Pantlone, 2010). Different studies that focused on green space suitability have also identified similar findings (Pokhrel, 2019; Abebe & Megento, 2017; and Manlun, 2003) that distance from the existing green space including parks is an important parameter for green space suitability analysis to make urban park service areas accessible to the city population.

3.1.1.6 Protected area and major institutions As shown in Table 11, the result of proximity analysis revealed that nearly 11.10% of the area is highly suitable in terms of proximity to protected areas and major institutions parameter. Also, about 12.4% and 12.6% of the area are found to be suitable (S2) and moderately (S3) suitable for green space development, respectively, whereas 13.8% and 50.1% of the study area are less suitable (N1 and unsuitable (N2) for the establishment of urban greenery, respectively.

Developing green spaces closer to those areas could help to preserve and maintain the ecological values of such places (Manlun, 2003).The foremost ambition of establishing greenery near to those areas is to safeguard their proximity and high compatibility with each other while creating a healthy environment for employees and visitor revitalization at these centers.

Major government or religious institutions like health facilities locations, churches, or police stations; are crucial to getting all services and meantime need some green space spaces nearby such locations. Pokhrel (2019) indicated that establishing green space near to these sites could keep the ecological benefits and give environmental services to all service users, as well as provide shelter during an emergency (Fig. 8).

3.1.1.7 Suitability of UGS distance from the roads Roadside green space has a wide range of socioeconomic and environmental benefits. Green areas near the roads are key aspects of urban ecosystems since they are effective instruments for reducing air and noise pollution, providing shade, and keeping the road cool for road users, all of which improve the quality of life and improve the attractiveness and welfare of cities. The number of automobiles in city traffic and the surrounding area contributes to traffic-related air and noise pollution.

Table 11 Reclassified protected area and area coverage of suitability levels

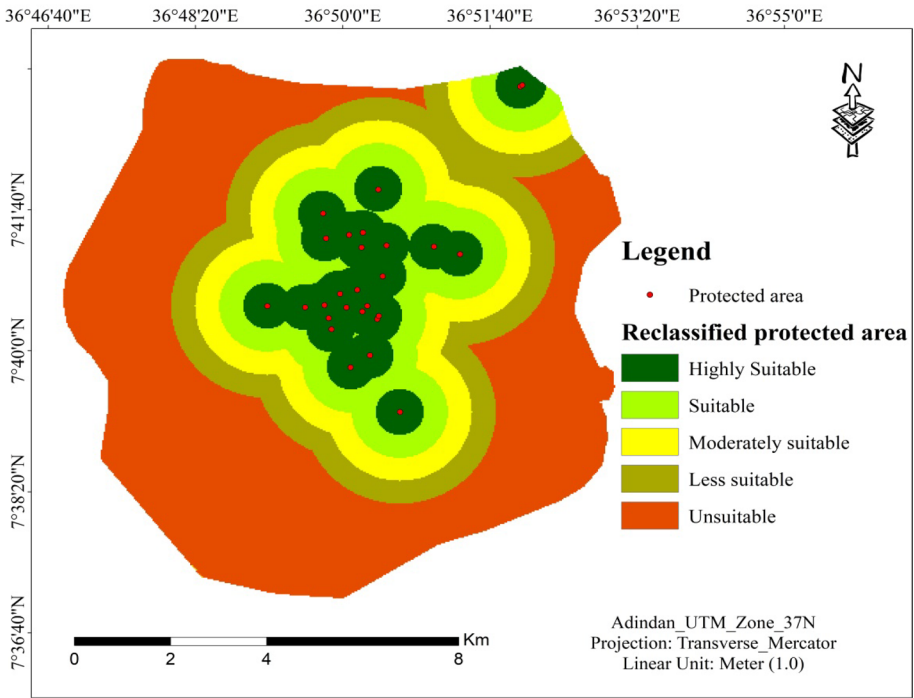| Protected area and major institutions	Suitability class	Value	Area (km^2)	Area (%)
<500	Highly suitable	5	11.6	11.1
500–1000	Suitable	4	13.1	12.4
1000–1500	Moderately suitable	3	13.2	12.6
1500–2000	Less suitable	2	14.5	13.8
>2000	Unsuitable	1	52.7	50.1
Total			105.1	100.0

Fig. 8 Reclassified protected area and major institutions suitability map

This adversely affects environmental quality and emphasizes the importance of planning green space development near the road (Ozturk, & Bozdogan, 2015).

An earlier study carried out by (Pantlone, 2010; Pokhrel, 2019; and Li et al., 2018), considered road as an important factor for suitability analysis. A recent study accompanied by Elahe et al. (2014) and Chandio et al. (2011) found that the urban greenery site is desirable if it is situated at a standard distance from roads. As a result, the proximity of the main road has been taken into account as one part of infrastructural facilities when determining suitable sites for urban greenery development. Hence, the green space site is unsuitable if the distance from roads is greater than 2000 m. Distance from the road between 500–1000, 1000–1500, and 1500–2000 was ranked as suitable, moderately suitable, and less suitable for green space suitability evaluation, respectively, while distance less than 500 m from the road, considered as highly suitable for greenery development (Fig. 9).

3.1.1.8 Suitability of UGS distance from the water body Green space is an important tool for achieving and maintaining healthy water ecosystems, and it provides numerous benefits to the water sector, including water flow regulation, water storage for later use, water purification and provisioning, species protection, biodiversity enhancement, climate change mitigation and adaptation, and disaster reduction through flood prevention and mitigation. Moreover, water-related green space initiatives have the potential to save money by avoiding the costs of delivering similar services, such as alleviating demand on wastewater treatment plants or ensuring a sufficient water supply. Additional benefits of green spaces are also linked to preserving the biodiversity of the aquatic ecosystem (Caparros et al., 2020).
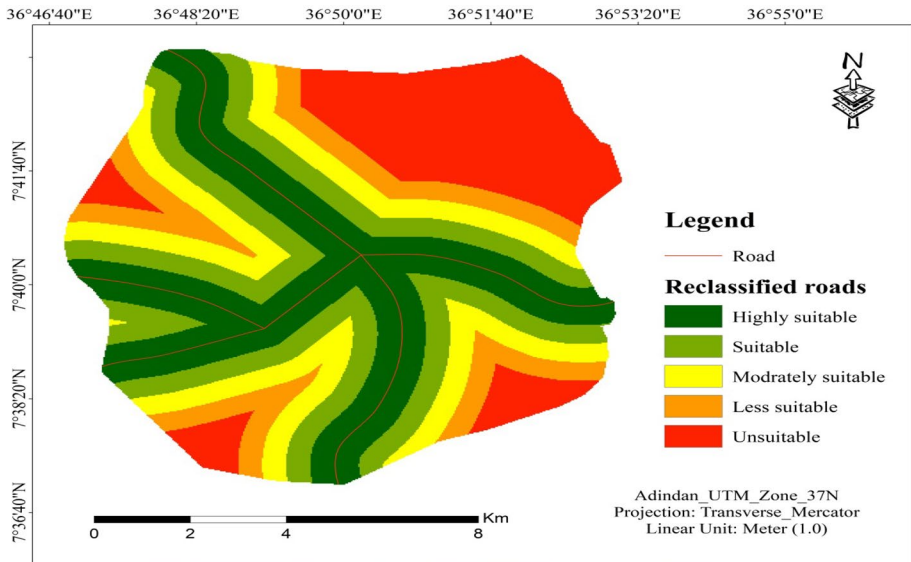
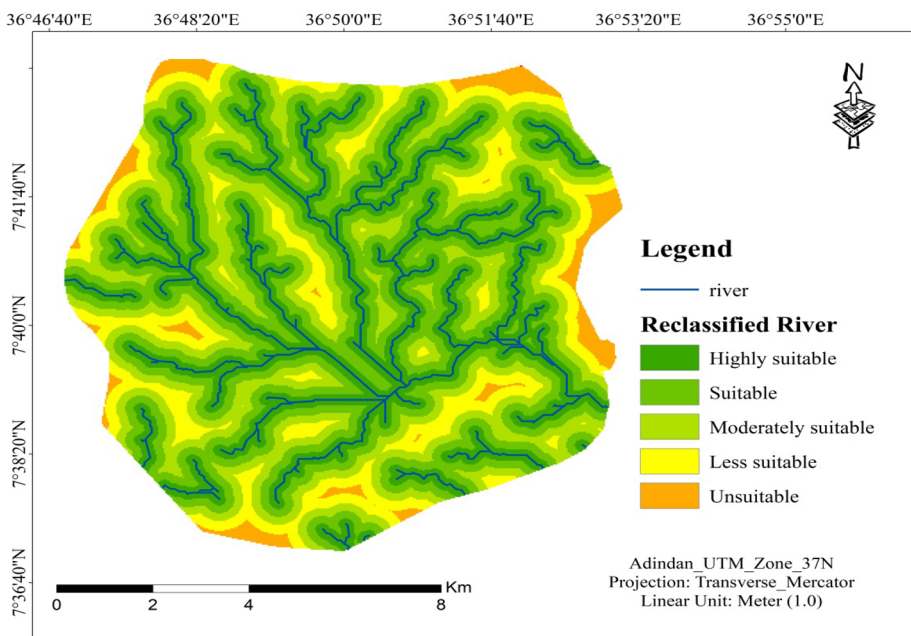**Fig. 9** Reclassified distance from road suitability map

Fig. 10 Reclassified distance from river suitability map

According to this notion, distances from existing water resources were taken as one of the factors influencing Jimma city suitability for green space development (Fig. 10). The most suitable location for green space establishment is near water resources such as

Table 12 Reclassified population density and area coverage of suitability levels

S/No	Pop dens (pop/ha)	Area (km²)	Area (%)
5	> 80	1	0.9
4	50–80	20	19
3	20–50	84	79.9
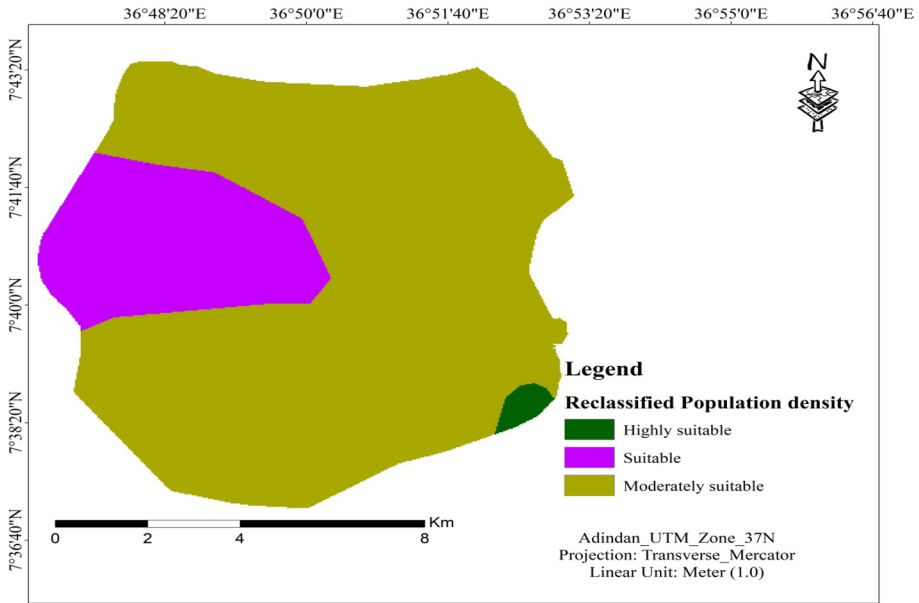
**Fig. 11** Reclassified population density suitability map

reservoirs, ponds, lakes, and rivers, as water is a crucial component for urban green space development (Heshmat et al., 2013).

3.1.1.9 Population density For the evaluation of green spaces, population density is one of the vital socioeconomic factors, as green spaces deliver positive health, social, and environmental outcomes by upgrading the environmental quality of densely populated areas and making cities more livable and enjoyable. Earlier studies carried out by (Abebe and Megento, 2017; Elahe et al., 2014; Pantalone, 2010; Piran et al., 2013) suggested that developing green space near densely populated areas could provide various benefits. Metropolitan (2019) also stated that areas with a high population density and a larger citizen population require access to open green spaces. Therefore, based on this idea, in this study, highly populated areas were taken as a priority for green space development to intensify open green areas in highly populated areas. With respect to population density, suitable and moderately suitable areas cover 19% and 79.9% of the total area, respectively (Table 12) (Fig. 11).

3.1.1.10 Soil types As illustrated in Table 13, the majority of soil in the study area is dominated by eutric fluvisols (52.7%), which are found in the northeastern and southern parts of the city, followed by dystric nitisols (42.3%), which are overriding in the northern part

Table 13 Reclassified soil types and area coverage of suitability classes

Soil types	Suitability class	Value	Area (km^2)	Area (%)
Dystric nitisols	Highly suitable	5	44.5	42.3
Dystric fluvisols	Suitable	4	1.5	1.4
Chromic vertisols	Moderately suitable	3	3.8	3.6
Eutric fluvisols	Less suitable	2	55.4	52.7
Total			105.1	100.0
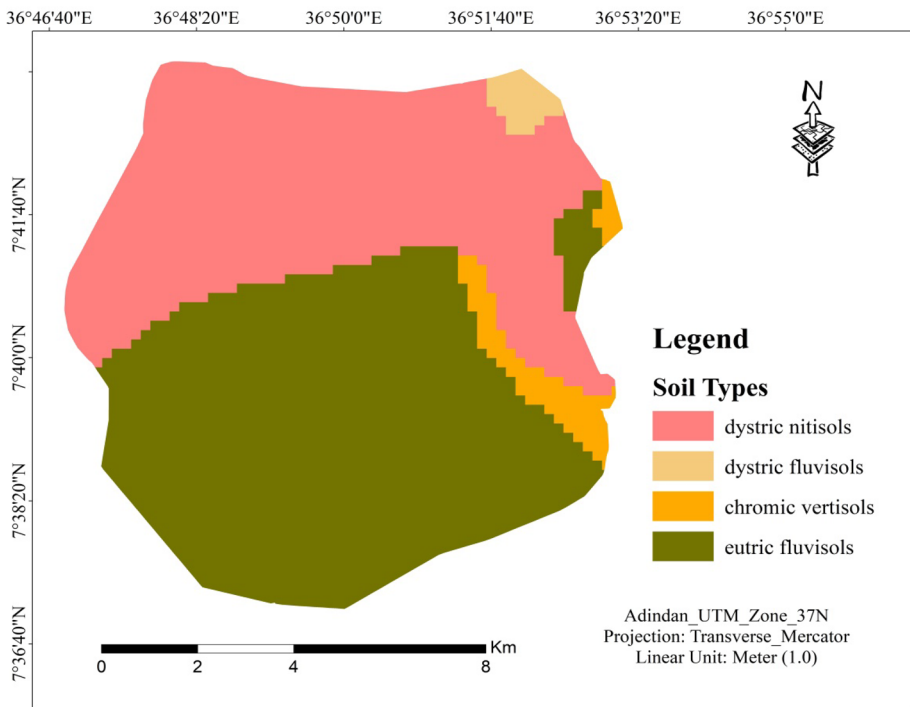
Fig. 12 Soil type suitability map

of the city. The rest of the city is covered by chromic vertisols (3.6%) and dystric fluvisols (1.4%), which are predominantly found in the eastern and northeastern parts of the study area, respectively (Fig. 12).

Eutric fluvisols were considered unsuitable as compared to other types as they have the least content of clay and saline, a low water holding capacity, and high hydraulic conductivity (Abebe & Megento, 2017). On the other hand, dystric nitisols are highly fertile; hence, they were considered highly suitable for green space development.

Moreover, the finding indicates that understanding what type of soil is present at selected site is one important aspect in deciding which part of the city is best suited to greenery development. As most urban soils are not real soils in the scientific sense, they lack the structure and profile of natural soils found in rural and natural settings. They are made up of a variety of materials that have accumulated over time as a result of

human activity. They may be deficient in structure, nutrition, and organic matters, has high acidity or alkalinity, or have been contaminated by salt spreading or other human activities. As a result, it is important to identify the soil type of the area for better greenery development. According to the extracted digital soil data, the study area has four major soil classes based on the FAO/UNESCO soil classification system. They are eutric fluvisols, dystric nitisols, chromic vertisols, and dystric fluvisols.

3.1.2 Pairwise comparison matrix result

After reclassification of each parameter was undertaken, this stage was done to establish a set of weights for each of the factors. The selected parameters or factors considered in this study have different degrees of importance. Hence, the importance level of each criterion relative to the other criteria was identified to pinpoint the influence of each factor relative to the other factors for the green space suitable site selection process. The weight for each criterion was determined based on the multi-criteria evaluation technique in the APH procedure developed by Saaty (1980). A pairwise comparison technique was used in the AHP weight module to calculate weights and their consistency ratio to select suitable sites for urban green space development in the study area. As a result, the relative weight of each criterion was assigned, and the consistency ratio was calculated to determine the consistency of judgment. According to the study results, the consistency ratio was 0.04, which is less than 0.1 and acceptable (Saaty, 1980). Factors and weights are summarized in Table 14.

The weighting results indicated that land surface temperature, slope weight of 30%, 25%, 15% and 11%, respectively, while soil type, proximity to rivers and distance from the road, population density, distance from protected areas, and existing parks were found to be the least important criteria identified in this study with eigen vector weights of 1%, 2%, 3%, 4%, 5%, and 8%, respectively.

Table 14 Pairwise comparison matrix

Factors	LST	SL	LULC	NDVI	GP	PA	PD	RO	RI	ST	Weight	Weight(%)
LST	1										0.2969	30
SL	0.5	1									0.2154	21
LULC	0.33	0.5	1								0.1535	15
NDVI	0.25	0.33	0.5	1							0.1085	11
GP	0.2	0.25	0.33	0.5	1						0.0761	8
PA	0.16	0.2	0.25	0.33	0.5	1					0.0529	5
PD	0.14	0.16	0.2	0.25	0.33	0.5	1				0.0370	4
RO	0.12	0.14	0.16	0.2	0.25	0.33	0.5	1			0.0262	3
RI	0.11	0.12	0.14	0.16	0.2	0.25	0.33	0.5	1		0.0190	2
ST	0.1	0.11	0.12	0.14	0.16	0.2	0.25	0.33	0.5	1	0.0145	1
Total											1.00	100

Consistency ratio = 0.04 < 0.1 → Acceptable

LST Land surface temperature, *SL* Slope, *LUlC* Land-use/land-cover, *NDVI* Normalized vegetation index, *GP* Green parks, *PA* Protected area, *PD* Population density, *RO* Road, *RI* River, *ST* Soil type

Table 15 Magnitude and percentage of areas shown in the overall suitability map

Suitability classes	Area (km^2)	Area (%)
Highly suitable	3.6	3.4
Suitable	14.5	13.8
Moderately suitable	44.4	42.2
Less suitable	36.9	35.1
Unsuitable	5.7	5.4
Total	105.1	100.0
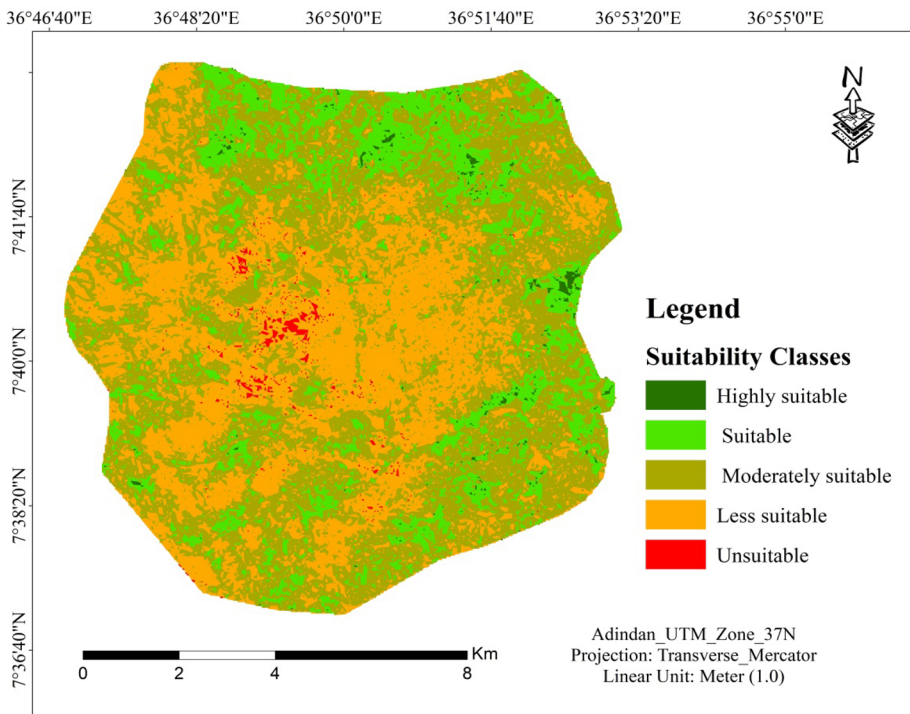
Fig. 13 Green space suitability map

3.1.3 Green space suitability map of Jimma city

The reclassified thematic maps/layers of each factor were weighted using the weights derived from the AHP process. The weighted maps/layers were overlaid by using the weighted overlay spatial analyst tools. Lastly, an overall suitability map was prepared. The results of the weighted overlay analysis in Table 15 revealed that 3.4% of the study area was identified as a highly suitable place for green space (S1), 13.8% of the area as a suitable area (S2), and 42.2% as a moderately suitable area (S3) for green space development in Jimma city, whereas the remaining 35.1% and 5.4% of the study area were less suitable and unsuitable (N1 and N2) for greenery establishment, respectively. According to the

overall suitability map (Fig. 13), some northern and south eastern parts of the study area were found to be the most suitable areas for green space. While most central parts of the study area were less suitable for urban greenery development due to their inability to fulfill the criteria. Thus, it is possible to conclude that the city has promising potential for the development of various urban green space components, such as playgrounds, sports fields, parks, and others, since more than half of the land in the study area falls under the highly suitable, suitable, and moderately suitable classes for the development of urban greenery. Table 15 illustrates the percentage and magnitude of areas shown in the final suitability map.

These study findings are in agreement with those of Abebe and Megento (2017). They considered LULC, population density, distance from the road, distance from the stream, distance from the historical place, noise influence, and distance from the existing park, slope, and soil type as parameters for green space suitability analysis in Addis Ababa city. They revealed a nearly similar result in their findings, with 4.2% and 4.0% of the study area being highly suitable and unsuitable for green space development, respectively.

In the same manner, the research conducted by Gelan (2020) in Sululta town resulted in comparatively approximate results as the findings of this study, where the moderately suitable area covers an area of 34% of Sululta town. On the other hand 5.5% of the study area was identified as unsuitable for urban greenery site selection. Pokhrel (2019) also used GIS-based MCDA in land suitability analysis for urban green space development. Pokhrel focused on planning green space in a compact city and confirmed that the combination of MCDA and GIS in land-use decision support systems reduces the time needed for green space suitability analysis. The conclusion of this study is also agreed with Pokhrel's finding.

Likewise, Ustaoglu and Aydinoglu (2020) conducted a site suitability analysis of greenery development in the Pendik district of Turkey. As compared to this study, they considered accessibility, blue and green amenities, and land use/cover as the important factors for selecting urban green space suitability, and they stated that conducting suitability analysis for green space through GIS-based multi-criteria analysis is crucial for optimal land use planning and decision support. Although factors differ from study to study, in general, the findings of this study and the results of the previous research work point out a shared point that the integrated AHP and GIS approach can serve as a powerful suitability analysis and evaluation tool for green space development in urban areas.

4 Conclusion

Urban green spaces are an essential component of the urban landscape as they contribute to mitigating climate change impacts and provide several benefits for cities. In the meantime, the city's unplanned development has resulted in various environmental problems that reduce the quality of urban settings. Realizing resilient urban development is therefore becoming a multifaceted issue. In this regard, urban green spaces are important natural contributors that provide a variety of ecosystem services to people living in cities and can play an important role in achieving sustainable development goals.

This study applied GIS-based multi-criteria decision analysis in the city of Jimma to assess land suitability conditions for green space development with ten criteria referring to environmental, social, and economic aspects. Based on the findings of the study, land surface temperature, slope, land use, land cover, and NDVI value are dominant factors

that influence urban greenery site selection, while soil, proximity to the river, and distance from the road, population density, proximity to protected areas, and existing parks were found to be the least important criteria identified in this study. Also, the results of overall suitability revealed that 3.4% of the study area was identified as a highly suitable place for green space (S1), 13.8% of the area as a suitable area (S2), and 42.2% as a moderately suitable area (S3) for green space development in Jimma city, whereas the remaining 35.1% and 5.4% of the study area were less suitable and unsuitable (N1 and N2) for urban greenery establishment, respectively. Accordingly, the evaluation of the land suitability of the study area indicates that the study area has a promising potential for green space development. Thus, site selection for urban green space development using appropriate analytical tools is substantial to identify the potential and appropriate land uses to enhance the integrity and sustain the ecosystem services of urban green space. In light of the present finding, GIS-based multi-criteria analysis can offer valuable information and spatial data for green space suitability analysis and planning which will help policy and planning authorities for site selection of green areas. Besides, the result of this study can influence policy assessments, assist local governments and environmental agencies in monitoring urban green space dynamics from time to time and advance environmentally sustainable urban development and forming resilient cities.

Data availability Available in the manuscript.

Declarations

Conflict of interest The author declare that they have no conflict of interest.

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