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# GIS-based multi-criteria analysis for sustainable urban green spaces planning in emerging towns of Ethiopia: the case of Sululta town

Eshetu Gelan\*

## Abstract

**Background:** Urban green spaces are important components, contributing in different ways to the quality of human well-being. In the planning and management of urban centres, attention to the appropriate site selection of urban green spaces with regard to the importance that these spaces have from the perspectives of ecology, socioeconomic, mentality, etc., is an inevitable requirement. In present decades, land suitability mapping methods and GIS have been used to support urban green space planners in developed countries; however, its application and practices are limited in developing countries, like Ethiopia. Therefore, the aim of this study has to select potential sites for green spaces in Sululta town that assist an effective planning process of green areas in a sustainable way.

**Methods:** In this study, GIS-based Multi-criteria analysis (MCA) has been adopted to select suitable sites for urban green spaces. Existing land use, proximity to settlement, road and water body, population density, land ownership, topography, and scenic attractiveness were recognized as the key factor affecting urban green land suitability.

**Results:** The results showed that 13.6%, 34%, 28%, and 18.9% of the study area are highly suitable, suitable, moderately suitable, and poorly suitable, respectively, for urban green spaces development. Furthermore, out of the total area of the study town 5.5% of the landmass is not suitable for urban green spaces development.

**Conclusions:** Therefore, the application of GIS-based MCA has provided an effective methodology to solve a complex decisional problem in urban green spaces site selection in the study town and urban planning all over the country.

**Keywords:** Sululta, GIS, Multi-criteria analysis, Analytical hierarch process, Urban green spaces

## Introduction

With more than 50% of the global population now living in urban areas, the world has experienced unprecedented urban growth in recent decades (Wu 2014). The global urban population is projected to be 6.3 billion by 2050, almost double the global population of 3.5 billion urban dwellers in 2010 (SCBD 2012). This rapid urbanization has posed greater pressure on natural resources and the

environment (Rees and Wackernagel 1996; Shi 2002) and the amount of land exploited for infrastructure development and buildings has increased at the expense of urban green spaces (Sandstrom 2002).

Urban green spaces are of crucial importance, especially in an urbanized world, as they are the key providers of ecosystem services and improve the quality of life of urban residents. For instance, by increasing water infiltration, it promotes the regulation of ecosystem services (Haase and Nuissl 2007; Pauleit and Duhme 2000) and has positive impacts on microclimate regulation (Gill et al. 2000; Hamada and Ohta 2010). It also provides

\*Correspondence: eshetu.tgelan@gmail.com  
Department of Architecture, School of Civil Engineering and Architecture, Adama Science and Technology University (ASTU), Adama, Ethiopia

benefits to city residents, such as exercise, socialization, interaction with nature and connection with places of rich cultural heritage (Crompton 2005; Cho et al. 2006; Sarev 2011). It is important to understand in this sense that green spaces are main components of urban environments (Tratalos et al. 2007) not only for their recreation but also for social contributions (Jones et al. 2013), health (Kimberlee et al. 2011) and environmental outcomes (Patel et al. 2009).

Despite the numerous aforementioned benefits, urban green spaces are unable to provide urban dwellers with the desirable facilities due to increased urbanization and unplanned urban growth (Wright and Nebel 2002), lack of proper site selection and planning and lack of attention to population thresholds (Ahmadi et al. 2016). As a result, both quality and quantity of urban green spaces are adversely affected and do not deliver what urban centres demand from urban green spaces as a living organism (Crompton 2001). Therefore, by taking into consideration environmental and social-economic factors, well planned, and well-designed green spaces within the reach of the community are mandatory in order to maximize the value that green spaces bring to urban residents and their environment in a sustainable way (Giles-Corti et al. 2005).

Land suitability analysis is vital in urban green spaces planning as it gives room for choosing the most suitable site from among various alternatives (Sahabo and Mohammed 2016). For suitable site selection, the multi-criteria analysis (MCA) approach that is integrated with the Geographical Information System (GIS) has been increasingly used (Uy and Nakagoshi 2008; Van Berkel et al. 2014; Ustaoglu, and Aydinoglu 2020). In order to determine different land problems considering the alternatives, MCA focuses on various parameters such as biophysical, socio-economic and policy-related factors in decision-making processes (Pramanik, 2016).

The MCA methods have been widely applied in both developed and developing countries to select agricultural sites, industrial sites, residential areas, landfill sites, wind farms, disaster area, health centres, and education centres (Rikalovic et al. 2014; Rahmati et al. 2016; Marsh et al. 2016; Demesouka et al. 2016; Vasileiou et al. 2017). However, the MCA methodology has not commonly used in developing countries such as Ethiopia to select suitable site for urban green spaces development and using MCA in urban planning, as decision-making tools are not practiced.

In parts of Europe, North America and Asia, MCA approach that is integrated with the GIS to identify suitable site for urban green spaces has been receiving more attention and it is considered as one of the essential tools for urban green spaces planning (Nowak et al.

2003; Ustaoglu and Aydinoglu 2020). In order to specifically analyse the characteristics of green areas and possible sites suitable for green spaces in either the European or overseas context, numerous studies were conducted (Kienast et al. 2012; La Rosa and Privitera 2013; Chandio et al. 2014; Morckel 2017; Merry et al. 2018; Ustaoglu and Aydinoglu 2020). However, in developing countries, while some green spaces studies have been performed, the available studies have concentrated largely on the evaluation of urban green spaces with less emphasis on the study of the suitability analysis for green spaces site selection. For instances, the studies in sub-Saharan African countries are primarily related to street trees' abundance and composition (Kurunerichitepo and Shackleton 2011), green space degradation (Mensah 2014), green space extent (McConnachie et al. 2008; McConnachie and Shackleton 2010) and planning aspects (Cilliers 2009; Fohlmeister et al. 2015).

This situation also occurs in the case of Ethiopia, which is one of the fastest growing countries in sub-Saharan Africa (Lamson-Hall et al. 2018), and studies have focused on the impacts of urban growth on green space (Abebe and Megento 2016; Gashu and Gebre-Egziabher 2018; Abo El Wafa et al. 2018), climate change adaptation (Lindley et al. 2015), the development of functional green infrastructure and ecosystem service (Woldegerima et al. 2017), planning aspect (Girma et al. 2019), green spaces depletion (Girma et al., 2019a) and utilization pattern (Yeshewazerf 2017; Molla et al. 2017; Girma et al. 2019b). However, the topic of suitability analysis for green space in the urban environment by using methods such as GIS-based Multi-criteria analysis has not discussed in these studies. This study therefore aimed to fill the existing research gap by applying GIS-based Multi-criteria analysis method to identify suitable sites for urban green space development in Sululta town.

## Materials and methods

### Description of the study area

Sululta town is located in Sululta district of the previous North Shewa administrative zone of Oromia region, currently under Oromia special zone surrounding Finfinne. It is situated very close to the district capital town Chanco and Addis Ababa, which are far about 15 and 23 km in the north and south direction, respectively. Astronomically, the study area is located between 9° 30' 00" N to 9° 12' 15" N latitude and 38° 42' 0" E to 38° 46' 45" E longitude. The administrative area of the town is about 4471 hectares. Sululta has the same general climatologically characteristics as that of Addis Ababa. Globally it is a part of tropical humid climatic region, which is characterized by warm temperature and high rainfall. The soils of the zone are basically derived from mesozoic

sedimentary and volcanic rocks. The major soil types of Sululta area are Chromic Luvisols (Fig. 1).

**Methods**

Urban green spaces have continuously played a significant role in enhancing the quality of life of urban inhabitants and in supporting urban metabolism. However, urban green spaces have experienced a physical and social decline, while its heterogeneity and richness is often neglected and its contribution to the well-being of a community ignored within current urban planning instruments in Sululta town (Girma et al. 2019; Girma et al. 2019a). Under this circumstance, GIS-based multi-criteria land suitability analysis is becoming critical in determining the land resource that is suitable for urban green spaces (Cetin 2015). Continued development and refinement of suitability analysis, particularly with GIS technology, can enable urban planners to create a suitable urban green spaces system in the urban environment (Manlum 2003).

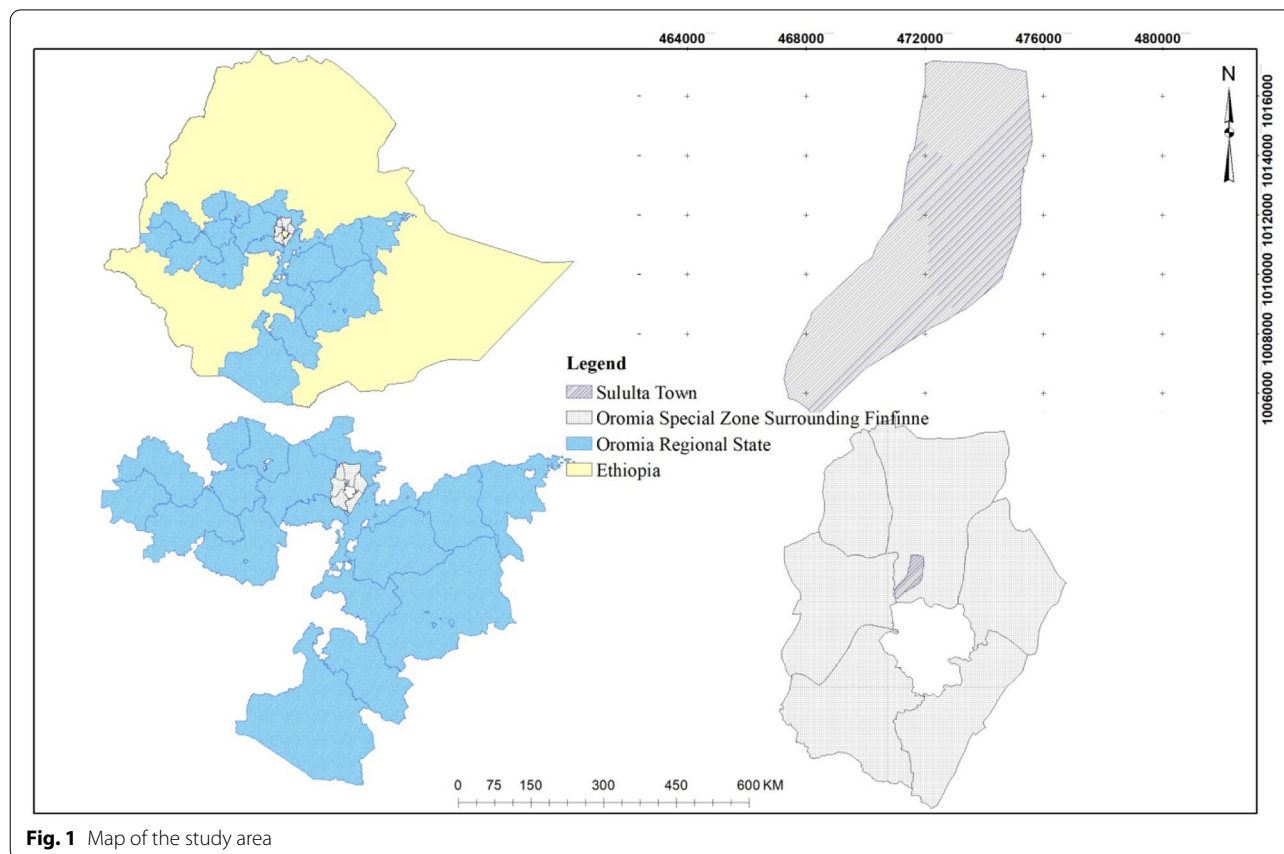
Several literatures have stated that MCA components are used in only a few GIS programs (e.g. IDRISI and ILWIS) to select appropriate places for different functions (Lesslie et al. 2008; Chen et al. 2001; Ozturk and

Batuk 2011). MCA has not yet been implemented in the standard functions, according to the literatures, while ArcGIS is one of the most popular GIS applications. In this study, MCA has incorporated ArcGIS 10.2 as a method to select an appropriate location for the development of urban green space.

Therefore, this study proposed the application of GIS-based multi-criteria suitability analysis using analytical hierarchy process (AHP) to support the decision-making process on selecting an appropriate site for development urban green spaces. This approach will be used as a basis for the town's administration and the planning authority to identify an appropriate and potential site for providing suitable, sufficient and accessible urban green spaces to the urban dwellers. Moreover, it will be used as a benchmark to guide the sustainable land use decision in the study area.

In this study, to select a suitable site for urban green spaces using GIS-based multi-criteria analysis the following five main steps were used:

- Spatial and non-spatial data collection
- Determination and rating of criteria and sub-criterion



**Fig. 1** Map of the study area

- Criteria standardization and factor map generation
- Determination of weighting for factors and
- Weighted overlay analysis.

### ***Spatial and non-spatial data collection***

The primary data from the field survey were collected through interviews undertaken with different experts in the related field of study for identifying factors that are important for urban green spaces site selection. Various spatial data were also obtained from different secondary sources (Table 1). The data were analysed in ArcGIS 10.2 and ERDAS Imagine 2010 for further analysis and mapping purposes.

### ***Determination and rating of criteria and sub-criteria***

In AHP process selection of criteria and their sub-criteria is a crucial stage as selection of criteria influences the judgment by segregating one criterion from other and at the same time, by giving more importance to one criterion over other (Ullah 2014). For urban green space planning, there were no universally agreed criteria and factors (Jabir and Arun 2014). Therefore, by synthesizing literature review, personal experiences, experts opinions and previous related studies conducted by different researchers (Manlun 2003; Uy and Nakagoshi 2008; Pantalone 2010; Ahmed et al. 2011; Kuldeep 2013; Heshmat et al. 2013; Elahe et al. 2014; Yousef et al. 2014; Abebe and Megento 2017; Li et al. 2018; Dagistanli et al. 2018; Ustaoglu and Aydinoglu 2020) 12 factors were considered for selection of suitable site for development of urban green spaces (Table 2). In this study, scientific standards review and personal experiences were used to ensure the reliability of the experts' opinions.

Besides identifying appropriate criteria and sub-criteria to select a suitable site for urban green spaces the rating has been assigned for each factor. In order to assign a rating (score) for each criterion and sub-criteria, review of previous scientific experimental research findings and literature on parameters were undertaken. Furthermore, reviews were consolidated through consultations and discussion with experienced experts and researchers from various disciplines. Rating of factors has usually made in terms of five classes: highly suitable, suitable, moderately suitable, poorly suitable, and not suitable (FAO 2006).

### ***Criteria standardization and factors map generation***

In GIS-based multi-criteria decision-making analysis, there is a need to standardize the data in order to integrate the data measured in different units and mapped in different scale of measurement such as ordinal, interval, nominal and ratio scales (Pereira and Duckstein 1993).

Even though there are different methods that can be used to standardize criterion maps, linear scale transformation is the most frequently used technique (Malczewski 2003). For criterion standardization in this study, all the vector maps of the criterion were converted to raster data formats. Afterward using the Spatial Analyst tool in ArcMap the raster maps were reclassified into five classes with the values that range from 1 to 5, where the value of 5 was taken as highly suitable while that of 1 was unsuitable for all factors considered. This approach will enable all measurements to have an equivalent value before any weights were applied. However, it was important to note that there were some variables that did not fulfil the whole range of the criteria. Once all the criteria maps were standardized, a weight of each criteria map was calculated using AHP.

### ***Estimating weight for factors and sub-factors***

One component of GIS-Based multi-criteria decision-making analysis is assigning criteria weights for each factor maps. The purpose of weighing in this process is to express the importance or preference of each factor relative to another factor effect on urban green spaces. In this study, the AHP using pairwise comparison matrixes were used to calculate weights for the criteria maps. AHP is a widely used method in multi-criteria decision-making analysis and was introduced by Saaty (1980). In this study, the AHP was carried out in three steps. Firstly, pair-wise comparison of criteria was performed and results were put into a comparison matrix. A Pair-wise comparison is performed in the 9-degree preferences scale, which is suggested by Saaty (1980), each higher level of scale shows higher importance than the previous lower level (Table 3).

According to Saaty (1980), the values in the matrix need to be consistent, which means that if  $x$  is compared to  $y$ , it receives a score of 9 (strong importance),  $y$  to  $x$  should score 1/9 (little importance) and something compared to itself gets the score of 1 (equal importance). Experts are asked to rank the value of criterion map for pairwise matrix on a saaty's scale. Moreover, the pairwise comparison matrices (Annexe 1) were developed by taking into account the information provided by the relevant literature (Uy and Nakagoshi 2008; Pantalone 2010; Elahe et al. 2014; Yousef et al. 2014; Abebe and Megento 2017; Dagistanli et al. 2018; Ustaoglu and Aydinoglu 2020).

The second step was calculating criterion weights, the weights are calculated by normalizing the eigenvector associated with the maximum eigenvalue of the (reciprocal) ratio matrix. In this study the computation of the criterion weights involves the following operations: (a) summing the values in each column of the pairwise comparison matrix (Annexe 1); (b) dividing each element



in the matrix by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix, (Annexe 1)), and (c) computing the average of the elements in each row of the normalized matrix, that is, dividing the sum of normalized scores for each row by 12 (the number of criteria).

Once the pair-wise comparison was filled and the weight of the factor was determined, a consistency ratio (CR) was calculated to identify inconsistencies and develop the best-fit weights in the complete pair-wise comparison matrix. A consistency ratio was calculated for each pairwise comparison matrix to verify the degree of credibility of the relative weights, by using the following formula (Bunruamkaew and Yuji 2001).

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

where CR=Consistency ratio, CI=referred to as consistency index, RI=is the random inconsistency index whose value depends on the number (n) of factors being compared; as illustrated in Table 4 (Saaty 1980).

The consistency index (CI) was calculated by the following formula:

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

where n=the number of items being compared in the matrix,  $\lambda_{\max}$ =Average value of the consistency vector.

#### Weighted overlay analysis

Once the criteria maps and weights have been developed and established, a decision rule of multi-criteria analysis was used. As pointed by Jiang and Eastman (2000) and Malczewski (2003) there are three common decision rules in multi-criteria analysis namely weighted linear overlay, Boolean overlay and ordered averaging. The weighted linear combination technique was applied to aggregate the standardized layers in this study. In weighted linear combination procedure, factors and parameters ( $X_i$ ) are multiplied by the weight of the suitability parameters ( $W_i$ ) to get composited weights and then summed. This can be expressed by using the following formula to derive the intended map i.e. urban green spaces suitability map for the towns.

$$S = \sum_{i=1}^n (W_i X_i)$$

where S=total suitability score,  $W_i$ =weight of the selected suitability criteria layer,  $X_i$ =assigned sub criteria score of suitability criteria layer i, n=total number of suitability criteria layer.

## Result and discussion

### AHP weights

The result of AHP shows that the derived factors have a different degree of influence on urban green spaces. As it is evident from Table 5, the weight assigned to the factors reveals the relative importance of each parameter in exposing an area to urban green spaces evaluation. As a result shows, an area with high population density with the normalized weight of 0.22 has the highest priority. Proximity to settlement area with the weight of 0.21 is in the second priority. Slope with a normal weight of 0.13 has the third priority. Proximity to the road with a normal weight of 0/10 is in the fourth priority. Elevation with normal weight of 0/059 is of the fifth priority. The area with vegetation cover with normal weight of 0/048 is the next priority. The flood-prone area with the normal weight of 0/04 is in the low priority. Proximity to water sources, visibility and existing land with almost similar weight of 0/032, 0/032 and 0/039, respectively, have relatively lowest priority (Table 5). These imply that the higher the weight in the percentage of a factor, the more influence it has in suitable site selection for urban green spaces.

Saaty (2008) has shown that Consistency ratio of 0.1 or less is acceptable to continue the AHP analysis. But if it's larger than 0.10, then there are inconsistencies in the evaluation process, and the AHP method may not yield a meaningful result. In this study, consistency ratio or CR of conducted comparisons has obtained 0.09, which is smaller than 0.1 and therefore the comparisons can be acceptable. The computation of consistency ratio is given in Table 5, below.

Based on the result of this study, AHP is a highly efficient instrument for determining factor weights and is more beneficial than alternative approaches since the inconsistency of the factor weights' pair-wise comparison matrix can be calculated and controlled by the Consistency Ratio (CR). In various studies (Dong et al. 2008; Tudes and Yigiter 2010; Kumar and Shaikh 2012; Bagheri et al. 2013; Romano et al. 2015; Abebe and Megento 2017; Ustaoglu and Aydinoglu 2020), this has been confirmed.

### Suitability values of each factors

Studies have shown that current land use must be considered when choosing suitable sites for the development of urban green spaces and have identified the suitability of different land uses based on their use type (Uy and Nakagoshi 2008; Zhang et al. 2013; Malmir et al. 2016; Abebe and Megento 2017; Dagistanli et al. 2018). Open spaces and forest land were considered to be highly suitable for urban green spaces in this study, based on knowledge obtained from the analysis of literature and expert

opinion. To rehabilitate the quarry area they are considered as suitable for urban green spaces. Additional, in this study, existing building area and water body has considered as moderately suitable for urban green spaces. In this study, agriculture is regarded as poorly suited to urban green spaces (Fig. 2i; Table 2).

Various researchers have shown that low-slope areas are highly suitable for the development of urban green spaces (Heshmat et al. 2013; Mahdavi and Niknejad, 2014; Pramanik, 2016; Abebe and Megento, 2017; Dagistanli et al. 2018) and 0–10 slope areas are suitable for urban green spaces such as open spaces and parks. This study therefore considered the lower slope land to be more suitable than the higher slope land and area with slope of 0–5%, 5–10%, 10–15% and 15–20% has considered as highly suitable, suitable, moderately suitable, and poorly suitable, respectively, for identify suitable site for urban green spaces development. Area with the slope greater than 20% considered as unsuitable for developing urban green spaces in this study (Fig. 2d; Table 2).

In selecting suitable sites for urban green spaces, elevation have also significant role and should be considered as the major factor (Gül et al. 2006; Mahmoud and El-Sayed 2011; Li et al. 2018; Dagistanli et al. 2018). Based on the information acquired from literature review and expert opinion, in this study the elevations between 2550 and 2600m, 2600–26500m, 2650–2700m and 2700–2800m were considered as highly suitable, suitable, moderately suitable and poorly suitable, respectively. In this analysis, areas with elevations greater than 2800 m were considered to be unsuitable for the development of urban green spaces (Fig. 2h; Table 2).

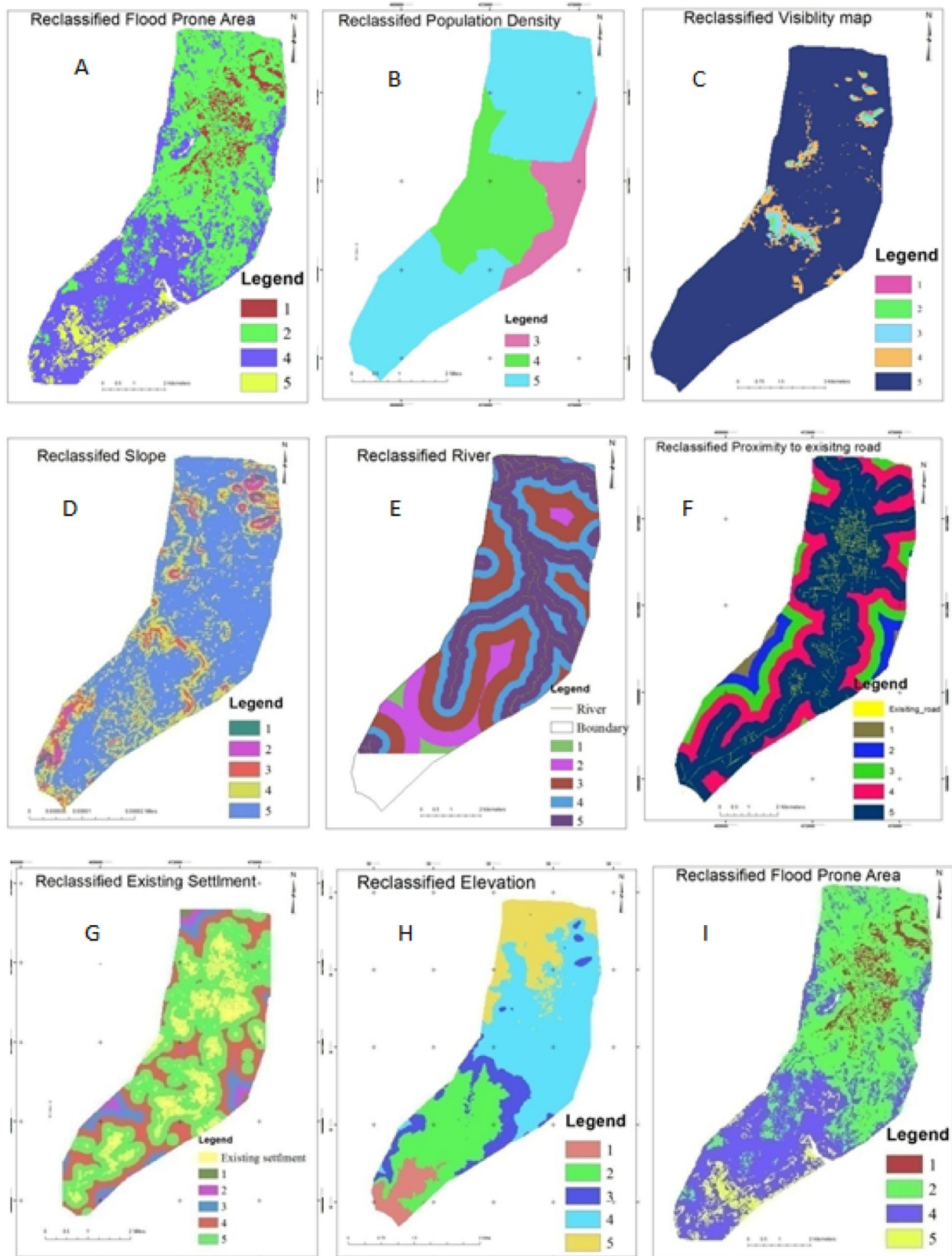
In any geographic analysis, proximity is always significant. Green spaces must be accessible to settlement areas in urban areas, since they have numerous ecological, social and economic benefits (Zhang et al. 2013; Malmir et al. 2016; Ustaoglu and Aydinoglu 2020). Hornsten and Fredman (2000) argued that a significant distance between settlement areas and green spaces had an adverse impact on users and reported that green spaces such as playground, parks and sport field closest to settlement areas are most popular. Therefore, the proximity of green spaces to the settlement area in terms of distance is very important to consider. In this research, the proximity of the settlement area has taken as a criterion. Based on this, areas that have identified within 500 m distances from the settlement area has considered as highly suitable by making Euclidian distances and the area with distances from 500 m to 1000 m has been considered suitable (Fig. 2g; Table 2). In addition, the area with distances of 1000 m to 2000 m, 2000 m to 3000 m and greater than 3000 m form settlement area has considered

to be moderately appropriate, poorly suited and unsuitable for the development of urban green spaces.

The road proximity also plays a vital role in providing convenient and feasible routes to the local population to reach local green areas in their surroundings (Bunruamkaew and Murayama 2011; Kienast et al. 2012; Morckel 2017). Elahe et al. (2014) and Ahmed et al. (2011) indicated that if it is situated at an acceptable distance from roads in order to access transport, the green space site is preferable. As a result, the road network proximity has been given due consideration as one aspect of infrastructural facilities in the mapping suitable site for urban green areas. Based on this, by making Euclidian distances, areas within the 400 m radius of the road network has considered as highly suitable, area within the 400 m–800 m range was considered suitable, and area within the 800 m–1000 m range was considered as moderately suitable. In addition, the area between 1000 m and 1500 m has considered as poorly suitable and the area more than 1500 m from the road network has considered as not suitable (Fig. 2f; Table 2). Studies have also shown that the types of roads have an effect on the selection of suitable urban green spaces (Gül et al. 2006; 2011). Research conducted by Gül et al. (2006) and Chandio et al., (2011) found that areas with access to major roads are highly appropriate for the development of urban green spaces than areas with access to local roads such as gravel-soil roads, forest soil roads. Therefore, arterial and collector roads are considered to be highly suitable in this study for the selection of suitable locations for urban green spaces, as these types of roads are highly distributed in the town. In addition, main roads and local roads are regarded as suitable and moderately suitable, respectively (Fig. 2j; Table 2).

Manlun (2003), Heshmat et al. (2013), Kuldeep (2013) and Abebe and Megento (2017) have noted that for the development of green space, lands closest to rivers, lakes and reservoirs are highly suitable. Therefore, on the basis of this claim, the distance less than 250 m from the river considered to be highly suitable and between 250 m and 500 m is considered as suitable in this study. Moreover, distances between 500 m and 1000 m and 1000 m to 1500 m is considered as moderately suitable and poorly suitable for urban green spaces, respectively. Whereas distance greater that 1500 m relatively considered as totally unsuitable (Fig. 2e; Table 2).

Flood-prone areas have also introduced as parameters for the study of suitability. Studies found that the area within the lower flood-prone area has more suitable than the land with higher flood-prone area for urban green spaces development and they indicated that urban green spaces must be free from flood prone area as most



**Fig. 2** Factor map to make suitability analysis for urban green space

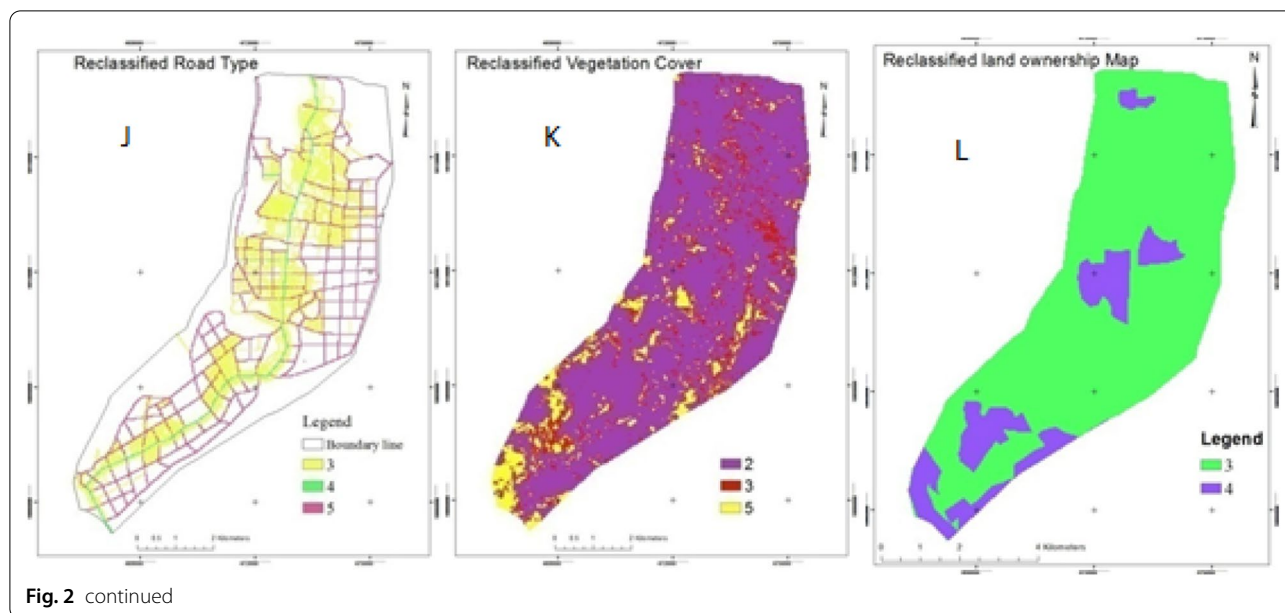


Fig. 2 continued

**Table 1** List of data and their original sources

S/N	Data	Sources
1	Road network	Municipalities of the town and field survey
2	Boundary map	Municipalities of the town
3	Structural plan	Municipalities of the town and Oromia Urban Planning Institute
4	Residential areas	Municipalities of the town and field Survey
5	Existing land use map	Municipalities of the town, Google earth image and field survey
6	Population data	Municipalities of the town and central statistics authority
7	Landsat 8 OLI	National Aeronautics and Space Administration(NASA)
8	Digital Elevation Model (DEM)	U.S. Geological Survey(USGS)

as possible (Piran et al. 2013; Peng et al. 2016). Based on the information obtained from the literature review and expert opinion, high flood risk areas has considered as unsuitable for the development of urban green spaces in this study, and low and medium flood risk areas are considered as highly and moderately suitable (Fig. 2a; Table 2).

Urban green space suitability assessment is directly or indirectly correlated with different socio-economic factors. Population density is known to be one of the socio-economic factors influencing the appropriate selection of green space in urban areas. Places with a higher number of people with crowded places near the high population density required access to the open green spaces (Schipperijn et al. 2010). Some researchers (Gül et al. 2006; Pantalone 2010; Ahmed et al. 2011; Heshmat et al. 2013; Elahe et al. 2014; Dagistanli et al. 2018) recommend that areas that have high population density are highly suitable for developing green space. On the basis of this claim,

the study area is densely populated in the northwest, north, south and southeast, and it is considered as highly suitable for the development of urban green space. The eastern portion is sparsely populated and believed to be insufficiently suited to urban green spaces development. As it has a medium population density, the central and western parts of the town has considered as moderately suitable for urban green spaces development (Fig. 2b; Table 2).

Environmental criteria are the most significant and important criteria for the evaluation of urban green spaces in any locality. Factor like vegetation cover plays an important role (Gül et al. 2006; Mahmoud, & El-Sayed 2011; Li et al. 2018; Dagistanli et al. 2018). Based on the information obtained from the literature review and expert opinion, in this study area with high vegetation cover has considered as highly suitable for urban green space development. Moreover, area with medium



**Table 2 Criteria and sub-criteria for suitability analysis**

Criteria	Sub-criteria	Standardization Score	Factor suitability rating
Existing Land Use (ELU)	Open space	5	Highly suitable
	Flower farm	1	Unsuitable
	Swampy area	1	Unsuitable
	Field croup	2	Poorly suitable
	Water body	3	Moderately suitable
	Forest land	5	Highly suitable
	Building area	3	Moderately suitable
	Quarry site	4	Suitable
Vegetation Cover (VC)	High vegetation cover	5	Highly suitable
	Medium vegetation cover	3	Moderately suitable
	Low vegetation cover	2	Poorly suitable
Road Type (RT)	Main road	4	Suitable
	Arterial road	5	Highly suitable
	Collector road	5	Highly suitable
	Local road	3	Moderately suitable
Proximity to Road (PR)	0–400m	5	Highly suitable
	400–800m	4	Suitable
	800–1000m	3	Moderate suitable
	1000–1500m	2	Poorly suitable
	> 1500	1	Unsuitable
Proximity to Settlement area (PS)	< 500 m	5	Highly suitable
	500 m–1000 m	4	Suitable
	1000 m–2000 m	3	Moderately suitable
	2000 m–3000 m	2	Poorly suitable
	> 3000 m	1	Unsuitable
Population Density (PD)	High	5	Highly suitable
	Medium	4	Suitable
	Low	3	Moderately suitable
Land Ownership (LO)	Public	5	Highly suitable
	Private	3	Moderately suitable
Slope (S)	0–5%	5	Highly suitable
	5–10%	4	Suitable
	10–15%	3	Moderately suitable
	15–20%	2	Poorly suitable
	> 20%	1	Unsuitable
Elevation (E)	2550–2600m	5	Highly suitable
	2600–2650m	4	Suitable
	2650–2700m	3	Moderately suitable
	2750–2800m	2	Poorly suitable
	> 2800 m	1	Unsuitable
Proximity to Water sources (PWS)	0–250m	5	Highly suitable
	250–500m	4	Suitable
	500–1000m	3	Moderately suitable
	1000 m–1500 m	2	Poorly suitable
	> 1500 m	1	Unsuitable
Flood Prone Area (FPA)	High	1	Unsuitable
	Medium	3	Moderate suitable
	Low	5	Highly suitable

**Table 2 (continued)**

Criteria	Sub-criteria	Standardization Score	Factor suitability rating
Visibility (scenic attractiveness) (V)	High	5	Highly suitable
	Medium	3	Moderately suitable
	Low	2	Poorly suitable

**Table 3 Fundament scale used in Pair-wise comparison**

Intensity of importance's	Qualitative definition
1	Equal importance
2	Equally or slightly more important
3	Slightly more important
4	Slightly to much more important
5	Much more important
6	Much to far more important
7	Far more important
8	Far more important to extremely more important
9	Extremely more important

and low vegetation cover has considered as moderately and poorly suitable, respectively (Fig. 2k; Table 2).

The availability of land is often considered as significant factor in the selection of appropriate sites for urban green spaces. Studies have shown that public land is highly

suitable for urban green space development as compared to private land (Chandio et al. 2011). The study undertaken by Wang and Chan (2019) suggest that the situation with initial public land ownership status backed up by regulatory instruments is more advantageous for providing urban green spaces than that with the initial private land ownership status relying on market-based instruments. On the basis of this claim, in this study public land is considered as highly suitable and private land has considered as moderately suitable for selecting optimal location for urban green spaces in the town (Fig. 2g, i Table 2).

In this study, as suggested by Gül et al. (2006) and Nur (2017), scenic beauty is also considered to decide the best or potentially acceptable sites for urban green space development. Based on the information obtained from the literature review and expert opinion, in this study area with high, moderate and low scenic attractiveness has considered as highly, moderately and poorly suitable

**Table 4 Random inconsistency index**

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

**Table 5 Computation of the factor weight and estimates of consistency ratio**

Factors	ELU	VC	RT	PR	PS	PD	LO	S	E	PWS	FPA	V	Weight	(λ)	CI	RI	CR
ELU	0.032	0.033	0.071	0.02	0.014	0.078	0.039	0.017	0.019	0.08	0.03	0.03	0.039	13.6	0.14	1.53	0.09
VC	0.032	0.033	0.071	0.012	0.018	0.047	0.013	0.04	0.057	0.009	0.15	0.09	0.048				
RT	0.010	0.011	0.023	0.012	0.014	0.047	0.013	0.024	0.019	0.027	0.01	0.03	0.02				
PR	0.09	0.167	0.119	0.06	0.025	0.03	0.118	0.12	0.057	0.13	0.214	0.16	0.1				
PS	0.29	0.234	0.214	0.3	0.125	0.047	0.19	0.37	0.28	0.13	0.09	0.22	0.21				
PD	0.09	0.167	0.119	0.4	0.62	0.23	0.27	0.12	0.173	0.19	0.15	0.096	0.22				
LO	0.03	0.1	0.071	0.02	0.025	0.03	0.039	0.041	0.057	0.081	0.01	0.096	0.05				
S	0.22	0.1	0.119	0.06	0.048	0.23	0.118	0.123	0.173	0.13	0.15	0.096	0.13				
E	0.09	0.033	0.071	0.06	0.025	0.07	0.039	0.041	0.057	0.081	0.03	0.096	0.059				
PWS	0.010	0.1	0.023	0.012	0.025	0.03	0.013	0.024	0.019	0.027	0.09	0.006	0.032				
FPA	0.03	0.006	0.071	0.008	0.042	0.047	0.118	0.024	0.057	0.009	0.03	0.032	0.04				
V	0.03	0.011	0.023	0.012	0.017	0.078	0.013	0.041	0.019	0.081	0.03	0.032	0.032				

ELU Existing Land Use, VC Vegetation Cover, RT Road Type, PR Proximity to Road, PS Proximity to Settlement area, PD Population Density, LO Land Ownership, S Slope, E Elevation, PWS Proximity to Water sources, FPA Flood Prone Area, V Visibility (scenic attractiveness), CI consistency index, RI random inconsistency, CR consistency ratio

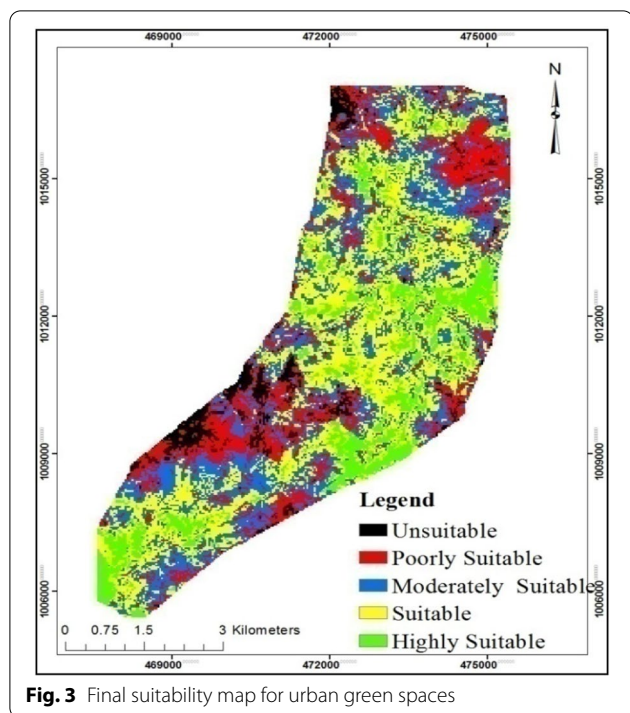


Fig. 3 Final suitability map for urban green spaces

**Table 6 Area cover of classified land suitability map for Sululta town**

Class	Area (ha)	%
Highly suitable	610.7	13.6
Suitable	1523.9	34
Moderately suitable	1276.6	28
Poorly suitable	813	18.9
Unsuitable	246.7	5.5

for appropriate site selection of urban green space development, respectively.

**Final suitability analysis for urban green spaces**

After weighting the criteria, as regards the relative importance of each criterion as well as suitability index, all the criterion maps were overlaid and final urban green spaces suitability map was prepared. According to GIS-based multi-criteria analysis, the final suitability maps have five classes for the study town that are highly suitable, suitable, moderately suitable, poorly suitable and unsuitable. Suitability maps of Sululta towns are demonstrated in Fig. 3.

According to the overall suitability map, southern, central and south eastern part of the study area is more adequate for urban green space such as playground, sport field, parks and the like development purposes. It is

because the lands mass in this area are fall in suitable and highly suitable classes.

Based on Table 6, out of the total area of the Sululta, town, about 13.6% (610.7 ha) area fall under the highly suitable category. The suitable area covers an area of 34% (1523.9 ha) of Sululta town. The area which is shaded by blue colour covers 28% (1276.6 ha) of Sululta town representing the moderately suitable class. Moreover, based on the Table 6, out of the total area 18.9% (813 ha) of Sululta towns have been covered by poorly suitable class. Out of the total area 5.5% of Sululta towns land mass is not suitable for urban green spaces.

The final suitability maps show a series of spaces following a pattern and connectivity. These can be adapted to form the urban green spaces system, complete with corridors and hubs within the study area. This can increase opportunities for residents and biodiversity to enjoy the nature and benefits of urban green spaces. Moreover, as the maps show the town have a high potential for developing the urban green spaces such as playground, sport field, parks and the like as more than half of the town’s lands mass are suitable. Therefore, the planning authority and the towns’ administration can take this approach as a benchmark to provide suitable, accessible, interconnected and sufficient urban green spaces in town under study.

Literature shows that many studies have used multi-criteria analysis based on GIS for land use planning in different countries. Ustaoglu and Aydinoglu (2020), for example, performed a site suitability study for the development of green space in the Pendik district of Turkey. Similar to this study, they considered geophysical factors, accessibility, blue and green amenities, settlement centres and land use/cover as the key factors affecting urban green land suitability and they also concluded that undertaking suitability analysis for green space through GIS based multi criteria analysis is mandatory for optimising land use planning and decision support. Giordano and Riedel (2008) conducted land suitability assessment of greenways in the city of Rio Claro, Brazil. They combined the AHP method with GIS for the analysis of land suitability, similar to this study. Uy and Nakagoshi (2008) used the ecological threshold factor approach and GIS in Hanoi, Vietnam, for land suitability study for green areas. Their research considered the concepts of landscape-ecology in the organisation of urban green spaces. Chandio et al. (2011) used GIS-integrated AHP strategy to evaluate factors such as land availability, land price/value, accessibility and socio-economic factors for the development of public parks in Larkana City, Pakistan. Similar to this study, Abebe and Megento (2017) also considered land use/cover, density, road network and river as the

main factor undertake to site suitability analysis of urban green space development for the city of Addis Ababa.

In general, the factors used in this study to select suitable site for urban green spaces such as parks, play grounds and sport field development is compliant with different studies undertaken in different part of the world. Moreover, similar to studies conducted by Giordano and Riedel (2008), Uy and Nakagoshi (2008), Chandio et al. (2011), Abebe and Megento (2017) and Ustaoglu and Aydinoglu (2020) the methodology applied in this study provide a base for future studies focusing on land suitability assessments. GIS-based multi criteria analysis suitability assessment technique can be utilised to produce land suitability maps regarding other land uses such as industrial, residential, landfill, urban land, water management and forest development. Moreover, the methodologies are complementary with the other green land assessment methods, such as landscape metrics analysis, landscape connectivity analysis, accessibility and network analysis and therefore can be used in green spaces planning to specify and quantify the suitable sites in line with the other approaches.

## Conclusions

In this study, GIS-based multi-criteria analysis has been used to support the site selection process for the development of urban green spaces. The study results are very significant in evaluating the feasibility of the use of GIS-based multi-criteria analysis for the development of urban green space. Since, by using appropriate analytical methods, the evaluation of urban green space is necessary to recognize their potential and to better select the most suitable land uses to improve their integrity and maintain the benefits obtained from them.

In the present study, the sub-criteria for site suitability for urban green spaces in order of importance were area with high population density (22%), Proximity to settlement area (21%), Slope (13%), Proximity to the road (10%), elevation (5.9%), vegetation cover (4.8%), Proximity to water sources, visibility and existing land (3.2%) and flood prone area (4%). The GIS-based multi-criteria analysis performed in this study found that, in the current situation, the larger land mass (47%) of the town is suitable for developing urban green spaces. The town, therefore, has great potential to develop adequate urban green spaces.

GIS technologies can play a crucial role in urban green space planning, as shown in this study, and AHP has been shown to be a flexible and realistic tool for selecting areas for urban green spaces in the study area. This can be attributed to participation of experts in the determination of the criteria and sub criteria using AHP. Furthermore, GIS may be used to support spatial decision-making, as it

has excellent spatial problem solving capabilities. Therefore, this study can provide a framework for the planning process using GIS and AHP for Ethiopian County planning and the results can be useful in the planning of urban green space and future land use planning in study town.

Finally, future research should focus on assessing the suitable site selection for each urban green spaces component such as park, playground, sport field, and the like, independently. In this study, the same criteria and sub criteria were considered to select suitable site for all components of urban green space. Therefore, considering criteria and sub criteria for each component separately are necessary in order to provide a complete understanding of urban green space suitability analysis.

### Acknowledgements

The author wishes to thank Sululta town municipality experts who participated in ranking the value of criterion map for pairwise matrix.

### Authors' contributions

The author collected, analysed, interpreted the data and prepared the manuscript. The author read and approved the final manuscript.

### Funding

The research has not received any fund from public or private entities.

### Availability of data and materials

All data generated or analysed during this study are included in this published article.

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

The author declares no competing interests.

Received: 5 December 2020 Accepted: 23 January 2021

Published online: 06 February 2021

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