GIS-Based Multi-criteria Analysis for Sustainable Urban Green Spaces Planning in Emerging Towns of Ethiopia: The Case of Sululta Town

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Research

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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 possible 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.

Result

Based on GIS-based MCA, 13.6%, 34%, 28%, and 18.9% of the study area are highly suitable, suitable, moderately suitable, and poorly suitable, respectively. Furthermore, based on the suitability analysis out of the total area of the study town 5.5% of the landmass is not suitable for green spaces.

Conclusion

Therefore, the application of this tool has provided an effective methodology to solve a complex decisional problem in green spaces site selection in the study town and urban planning all over the country.

Introduction

In the past and present decades, the world has experienced unprecedented urban growth, with more than 50% of the global population living in urban areas now (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 (Secretariat of the Convention on Biological Diversity, (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 limited 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 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. 2010), 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., 2012). 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, & Mohammed, 2016). For suitable urban green space 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, & Aydınoglu, A2020). In order to determine different land problems considering the alternatives, MCE focuses on various parameters such as bio-physical, socio-economic and policy-related factors in decision-making processes (Pramanik, 2016).

In parts of Europe, North America and Asia, MCA approach that is integrated with the GIS to identify suitable site for urban green spaces have 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 Aydınoglu, 2020). However; in developing countries, while some green space studies have been performed, the available studies have concentrated largely on the assessment of urban green spaces with less emphasis on the study of the suitability analysis for green space site selection. For instances, the studies in sub-Saharan African countries are primarily related to street trees' abundance and composition (Kuruneri-Chitepo 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 & Megento, 2016; Gashu & 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., 2018), green spaces depletion (Girma et al., 2019) and utilization pattern (Yeshewazerf, 2017; Molla et al., 2017). However, the topic of suitability analysis for green space in the urban environment has not discussed in these studies. This study therefore aimed to fill the existing research gap by using GIS-based Multi-criteria analysis 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 Chancho 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 $9^0$30'00"N to 9^0 12'15"N latitude and $38^0$42'0"E to $38^0$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 Suluta area are Chromic Luvisols.

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., 2018; Girma et al., 2019). 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). 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-criteria
- Criteria standardization and factor map generation
- Determination of weighting for factors and
- Weighted overlay analysis

Spatial and non-spatial data collection

Firstly, 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. Secondly, various spatial data were obtained from different sources (Table 1). The data were analysed in ArcGIS 10.2 and ERDAS Imagine 2010 for further analysis and mapping purposes.

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	DEM	U.S. Geological Survey(USGS)

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).

Besides identifying appropriate criteria and sub-criteria to select a suitable site for urban green spaces the rating has been assigned for each factors. 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).

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

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

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 et al, 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 Analytical Hierarchy Process (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).

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

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 (Table 4) 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).

Table 4 Pair wise comparison matrix

Factors	ELU	VC	RT	PR	PS	PD	LO	S	E	PWS	FPA	V
ELU	1	1	3	0.3	0.1	0.3	1	0.14	0.3	3	1	1
VC	1	1	3	0.2	0.14	0.2	0.3	0.3	1	0.3	5	3
RT	0.3	0.3	1	0.2	0.1	0.2	0.3	0.2	0.3	1	0.3	1
PR	3	5	5	1	0.2	0.14	3	1	1	5	7	5
PS	9	7	9	5	1	0.2	5	3	5	5	3	7
PD	3	5	5	7	5	1	7	1	3	7	5	3
LO	1	3	3	0.3	0.2	0.14	1	0.3	1	3	0.3	3
S	7	3	5	1	0.3	1	3	1	3	5	5	3
E	3	1	3	1	0.2	0.3	1	0.3	1	3	1	3
PWS	0.3	3	1	0.2	0.2	0.14	0.3	0.2	0.3	1	3	0.2
FPA	1	0.2	3	0.14	0.3	0.2	3	0.2	1	0.3	1	1
V	1	0.3	1	0.2	0.14	0.3	0.3	0.3	0.3	3	1	1

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 and V **=** Visibility (scenic attractiveness),

The second step was calculating criterion weights, in this case, values from each column were summed and every element in the matrix was divided by the sum of the respective column. The new matrix is called normalized pair-wise comparison matrix (Table 4). Finally, an average from the elements from each row of the normalized matrix was calculated. 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 5 (Saaty, 1980).

Table 5 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

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

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

Where;

n= the number of items being compared in the matrix

λ_{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 (Xi) are multiplied by the weight of the suitability parameters (Wi) 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.

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

Where;

S= total suitability score

Wi = weight of the selected suitability criteria layer,

Xi = 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 6, 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. Slop 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 6). 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 6, 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.

Table 6 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.[illegible]
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 and **CR**= Consistency ratio

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, & 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 (Figure 2I and 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 (Figure 2D and Table 2).

In selecting suitable sites for urban green spaces, elevation have also significant role and should be considered as the major factor (Gul et al. 2006; Mahmoud, & El-Sayed, 2011; Li et al. 2018; Dagistanli, et.al. 2018). Based on the information acquired from literature review and expert opinion, the elevations between 2550-2600m, 2600-26500m, 2650-2700m and 2700-2800m in this study area 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 (Figure 2H and 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). 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 was taken as a criterion. Based on this, those areas that have been identified within 500m distances from the settlement area have been considered as highly suitable by making Euclidian distances and the area with distances from 500m to 1000m has been considered suitable (Figure 2G and Table 2). In addition, the area with distances of 1000m to 2000m, 2000m to 3000m and greater than 3000m form settlement area was 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 of suitability maps 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 400m-800 m range was considered suitable, and area within the 800m-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 (Figure 2F and Table 2). Studies have also shown that the types of roads have an effect on the selection of suitable urban green spaces (Gul, et.al. 2006; 2011). Research conducted by Gul, 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 (Figure 2J and 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 500m to 1000m and 1000m to 1500m is considered as moderately suitable and poorly suitable for urban green spaces, respectively. Whereas distance greater that 1500m relatively considered as totally unsuitable (Figure 2E and Table 2).

Flood-prone areas have also been 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 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 (Figure 2A and 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 (Gul,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 is considered to be highly suitable for the development of urban green space. The eastern portion is sparsely populated and believed to be insufficiently suited to urban green areas. 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 (Figure 2B and 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 (Gul,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 and low vegetation cover has considered as moderately and poorly suitable, respectively (Figure 2k and 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 & 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 (Figure 2L Table 2).

In this study, as suggested by Gul, 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 for appropriate site selection of urban green space development, respectively.

Final Suability 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.

Based on table 7, 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 (7), out of the total area 18.9% (813ha) 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.

Table 7 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

In general, 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. There are similar studies in the literature proposed GIS based multi criteria analysis for land uses planning both in developed and developing countries (Do Carmo Giordano & Setti Riedel, 2008; Uy & Nakagoshi, 2008; Chandio et al. 2011; Abebe & Megento 2017; Ustaoglu, & Aydinoglu, 2020).

Conclusion

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%), Slop (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.

Abbreviations

AHP: Analytical Hierarchy Process; CR=Consistency ratio; CI= consistency index; RI = random inconsistency index; GIS: Geographic Information System; MCA: Multi-criteria analysis (MCA); SCBD: Secretariat of the Convention on Biological Diversity

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

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

Competing interests

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Author contributions

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

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Figures

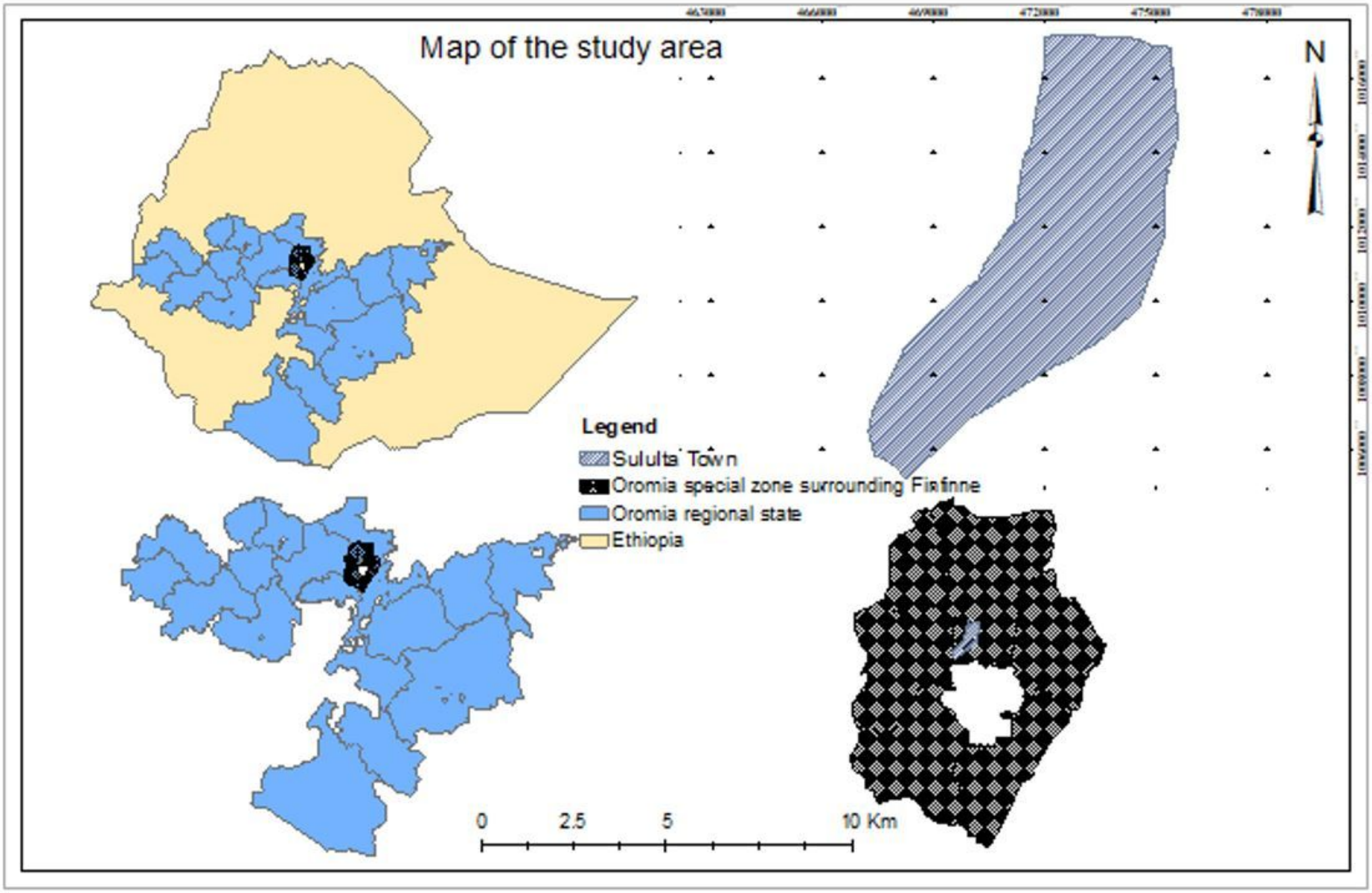

Figure 1

Map of the study area

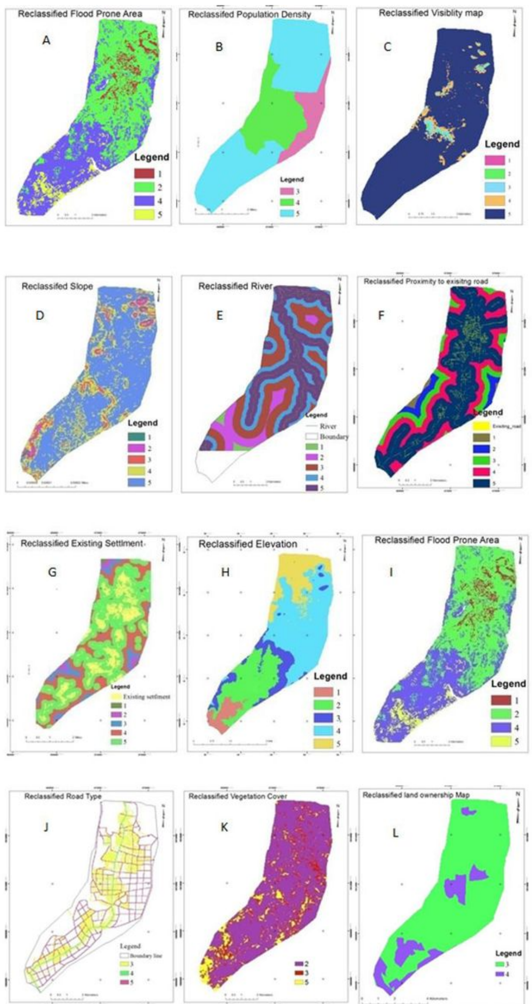

Figure 2

Factor map to make suitability analysis for urban green space

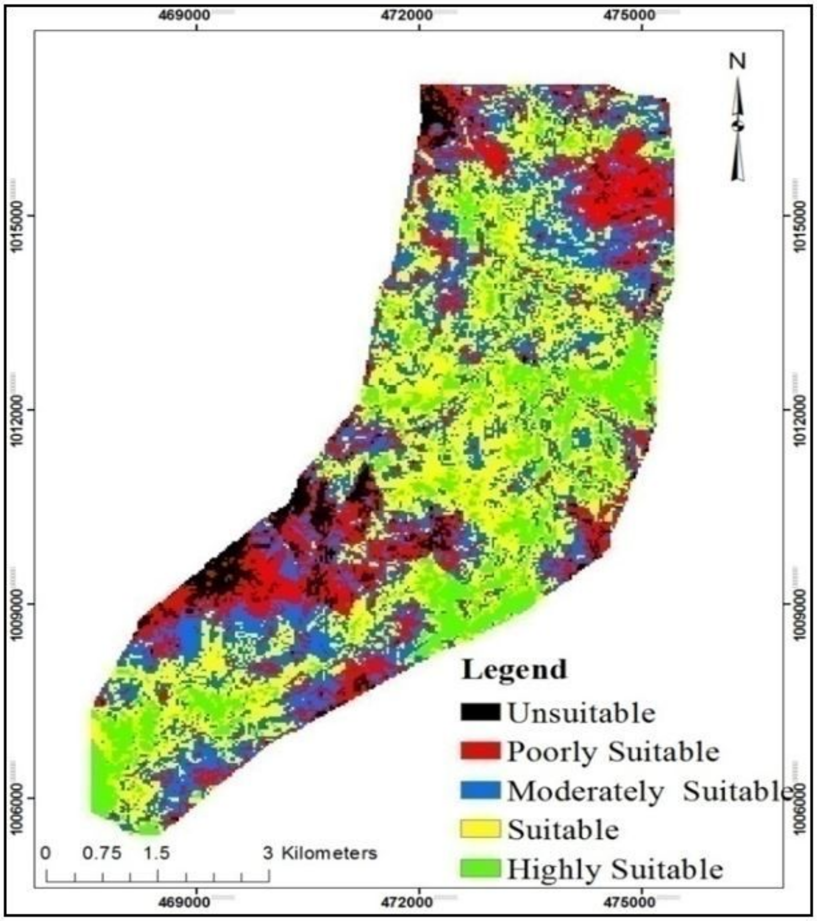

Figure 3

Final suitability map for urban green spaces