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; Šarev, 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, & Aydinoglu, 2020). 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; Chandro et al., 2014; Morckel, 2017; Merry et al., 2018; Ustaoglu and Aydinoglu, 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°03'00"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 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.

| 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)                                 |

Determinant 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 scientic 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                 | 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           | Moderaely 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                     | Moderately 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 scales 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 fulfill 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 matrices 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 | 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| 3  | 1   | 3     | 0.3  | 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:

\[ CI = \frac{\lambda_{max} - n}{n - 1} \]

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 (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.
Suitability values of each factors

**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. 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 0.048 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.

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 | (A) | CI | RI  | CF  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|-----|----|-----|-----|
| 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 | 0.1 |
| 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.

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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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**References**

Abebe, M.T., & Megento, T.L. (2016). The city of Addis Ababa from 'Forest city' to 'Urban Heat Island' Assessment of Urban Green Space Dynamics. *Journal of Urban and Environmental Engineering*. 10(2), 254-262.

Abebe, M.T., & Megento, T.L. (2017). Urban green space development using GIS-based multicriteria analysis in Addis Ababa metropolis. *Appl. Geomat*. 9 (4), 247–261.

Abo El Wafa, H., Yeshitela, K., & Pauleit, S. (2018). The use of urban spatial scenario design model as a strategic planning tool for Addis Ababa. *Landscape and Urban Planning*. 180, 308-318. [https://doi.org/10.1016/j.landurbplan.2017.08.004](https://doi.org/10.1016/j.landurbplan.2017.08.004).

Ahmed, I. C., Matori, A., Umar, D. L., & Sabri, S. (2011). GIS-based Land Suitability Analysis Using AHP for Public Parks Planning in Larkana City. *Modern Applied Science*, 5(4), 178-184.

Bagheri, M., Sulaiman, W.N.A., Vagferi, N. (2013). Application of geographic information system technique and analytical hierarchy process model for land-use suitability analysis on coastal area. *J. Coast. Conserv*. 17, 1–10.

Bunruamkaew, K., & Yuji M. (2011). Site Suitability Evaluation for Ecotourism Using GIS & AHP: A Case Study of Surat Thani Province. Thailand. *Procedia Social and Behavioral Sciences*, 21,269–278. doi:10.1016/j.sbspro.2011.07.024.

Chandio, I. A., Matori, A. N., Lawal, D. U., & Sabri, S. (2011). GIS-based land suitability analysis using AHP for public parks planning in Larkana City. *Modern applied science*, 5(4), 177.
Chandio, I.A., Matori, A.N., Yusof, K., Talpur, M.A.H., Aminu, M. (2014). GIS-based land suitability analysis of sustainable hillside development. Procedia Eng. 77, 87–94.

Cho, S. H., Bowker, J. M., & Park, W. M. (2006). Measuring the contribution of water and green space amenities to housing values: An application and comparison of spatially weighted hedonic models. *Journal of agricultural and resource economics*, 485-507.

Cilliers, J. (2009) Future direction in urban planning and space usage compensating urban green spaces. Interdis. Themes J. 1 (1), 1–10.

Crompton, J. L. (2001). Financing and acquiring park and recreational resources. Champaign, IL: Human Kinetics.

Crompton, J. L. (2005). The impact of parks on property values: empirical evidence from the past two decades in the United States. *Managing Leisure*, 10(4), 203-218.

Dagistanli, C., Turan, I. D., & Dengiz, O. (2018). Evaluation of the suitability of sites for outdoor recreation using a multi-criteria assessment model. *Arabian Journal of Geosciences*, 11(17), 492.

Do Carmo Giordano, L., Setti Riedel, P. (2008). Multi-criteria spatial decision analysis for demarcation of greenway: A case study of the city of Rio Claro, Sao Paulo, Brazil. Lands. Urban Plan. 84, 301–311.

Dong, J., Zhuang, D., Xu, X., Ying, L. (2008). Integrated evaluation of urban development suitability based on remote sensing and GIS techniques-a case study in Jingjinji Area, China. Sensors 8 (9), 5975–5986.

Elahe, T., Mobina, J., Marjan, G., Milad, N., & Hooman, B. (2014). Urban park site selection at local scale by using geographic information system (GIS) and analytic hierarchy process. *European Journal of Experimental Biology*. 2014, 4(3): 357-365.

FAO (2006) Guidelines for soil description. Food and Agriculture Organization of the United Nations, Rome.

Fohlmeister S, Pauleit S, Coly A, Touré H, Yeshitela K. (2015) The Way forward: climate resilient cities for Africa’s future. In: Pauleit, S., Coly, A., Fohlmeister, S., Gasparini, P., Jørgensen, G., Kabisch, S., Lindley, S., Simonis, I., Yeshitela, K. (Eds.), Urban Vulnerability and Climate Change in Africa: A Multidisciplinary Approach. Springer, Dordrecht, pp. 369–399.

Gashu, K & Gebre-Egziabher, T. (2018). Spatiotemporal trends of urban land use/land cover and green infrastructure change in two Ethiopian cities: Bahir Dar and Hawassa. *Environmental Systems Research*. 7(1), 8. https://doi.org/10.1186/s40068-018-0111-3.

Giles-Corti, B., Broomhall, M.H., Knuiman, M., Collins, C., Douglas, K, Ng, K, Lange, A. and Donovan, R.J. (2005). Increasing walking: how important is distance to, attractiveness, and size of public open space? *American Journal of Preventive Medicine*, 28(2), pp. 169-176.

Gill, S. E., Handley, J. F., Ennos, A. R., and Pauleit, S. (2000). Adapting cities to climate change: The role of the green infrastructure. *Built Environ.,* 33 (1), 115–133.

Girma, Y., Terefe, H., Pauleit, S., & Kindu, M. (2018). Urban green infrastructure planning in Ethiopia: The case of emerging towns of Oromia special zone surrounding Finfinne. *Journal of Urban Management*. https://doi.org/10.1016/j.jum.2018.09.004.

Girma, Y., Terefe, H., Pauleit, S., & Kindu, M. (2019). Urban Green Spaces Supply in Rapidly Urbanizing Countries: The Case of Sebeta Town, Ethiopia. *Remote Sensing Applications: Society and Environment*. 13, 138-149. https://doi.org/10.1016/j.rase.2018.10.019.

Gul, A., Orucu, M. K., & Karaca, O. (2006). An approach for recreation suitability analysis to recreation planning in Gölcük Nature Park. *Environmental management*, 37(5), 606-625.

Haase, D., and Nuissl, H. (2007). Does urban sprawl drive changes in the water balance and policy? The case of Leipzig (Germany) 1870–2003. *Landscape Urban Plann.,* 80 (1–2 ), 1–13.

Hamada, S., and Ohta, T. (2010). Seasonal variations in the cooling effect of urban green areas on surrounding urban areas. *Urban For. Urban Greening*, 9 (1), 15–24.

Heshmat, P, Rahim, M., Hassan, A., Javad, S., & Omid, K. (2013). Site selection for local forest park using analytic hierarchy process and geographic information system (case study: Badreh County) . *International Research Journal of Applied and Basic Sciences*, 6 (7), 930-935.

Jabir. K., & Arun Das.S. (2014). Evaluation of Recreational Site Selection and the Prospects of Recreational. *International Journal of Environmental Sciences.* 3.1. 17-21.

Jiang H., & Eastman JR. (2000). Application of fuzzy measures in multi-criteria evaluation in GIS. *Int J Geogr Inform Sci* 14:173–184.

Jones M, Kimberlee R, Deave T, et al. (2013). The role of community centre-based arts, leisure and social activities in promoting adult well-being and healthy lifestyles. Int J Environ Res Publ Health 10:1948–62. 10.3390/ijerph10051948.

Kienast, F., Degenhardt, B., Weilenmann, B., Wager, Y., Buchecker, M. (2012). GIS-assisted mapping of landscape suitability for nearby recreation. Landsca. Urban Plan. 105 (4), 385–399.
Kuldeep, P. (2013). Remote Sensing and GIS Based Site Suitability Analysis For Tourism Development. *International Journal of Advanced Research in Engineering and Applied Sciences*, 2(5), 43-56.

Kumar, M., Shaikh, V.R. (2012). Site suitability analysis for urban development using GIS based multicriteria evaluation technique. *J. Indian Soc. Remote. Sens.* 41, 417–424.

Kuruneri-Chitepo C, Shackleton CM. (2011). The distribution, abundance and composition of street trees in selected towns of the Eastern Cape, South Africa. *Urban For. Urban*. 10 (3), 247–254. [https://doi.org/10.1016/j.ufug.2011.06.001](https://doi.org/10.1016/j.ufug.2011.06.001).

La Rosa, D., Privitera, R. (2013). Characterisation of non-urbanized areas for land-use planning of agricultural and green infrastructure in urban contexts. *Landsc. Urban Plan.* 109 (1), 94–106.

Lamson-Hall, P., Angel, S., DeGroot, D., Martin, R., & Tafesse, T. (2018). A new plan for African cities: The Ethiopia Urban Expansion Initiative. *Urban Studies*, 004209801875760.doi:10.1177/004209801875760.

Li, Z., Fan, Z., Shen, S. (2018). Urban green space suitability evaluation based on the AHPCV combined weight method: a case study of Fuping County, China. *Sustainability* 10, 2656.

Lindley, S. J., Gill, S. E., Cavan, G., Yeshitela, K., Nebebe, A., Woldegerima, T., & Abo-El Wafa, H. (2015). Green infrastructure for climate adaptation in African cities. S. Pauleit, et al (Eds.), 2015 Urban Vulnerability and Climate Change in Africa, Springer International Publishing Switzerland, A Multidisciplinary Approach. Future City 4 (2015) [http://link.springer.com/chapter/10.1007%2F978-3-319-03982-4_4](http://link.springer.com/chapter/10.1007%2F978-3-319-03982-4_4).

Mahdavi, A., Niknejad, M. (2014). Site suitability evaluation for ecotourism using MCDM methods and GIS: case study-Lorestan province, Iran. *J. Biodivers. Environ. Sci.* 4 (6), 425–437.

Mahmoud, A. H. A., & El-Sayed, M. A. (2011). Development of sustainable urban green areas in Egyptian new cities: The case of El-Sadat City. *Landscape and Urban Planning*, 101(2), 157-170.

Malczewski, J. (2003). *GIS-based land-use suitability analysis: a critical Overview*, Progress in Planning 62: 3 – 65.

Malmir, M., Zarkesh, M.M.K., Monavari, S.M., Jozi, S.A., Sharifi, E. (2016). Analysis of land suitability for urban development in Ahwaz County in southwestern Iran using fuzzy logic and analytic network process (ANP). *Environ. Monit. Assess.* 188, 447.

Manlun, Y. (2003). *Suitability Analysis of Urban Green Space System Based on GIS*. ITC.

McConnachie MM, Shackleton CM. (2010) Public green space inequality in small towns in South Africa. *Habitat Int.* 34, 244–248. [https://doi.org/10.1016/j.habitatint.2009.09.009](https://doi.org/10.1016/j.habitatint.2009.09.009).

McConnachie, M.M., Shackleton, C.M., McGregor, G.K. (2008). The extent of public green space and alien plant species in 10 small towns of the sub-tropical Thicket biome, South Africa. *Urban For. Urban Green.* 7 (1), 1–13.

Mensah, C. A. (2014). Urban green spaces in Africa: nature and challenges. *International Journal of Ecosystem*, 4(1), 1-11.

Merry, K., Bettinger, P., Siry, J., Bowker, J.M., Weaver, S., Ucar, Z. (2018). Mapping potential motorised sightseeing recreation supply across broad privately-owned landscapes of the Southern United States. *Landsc. Res.* 43 (5), 721–734.

Molla, M. B., Ikporukpo, C.O., and Olatubara, C.O. (2017). Socio-economic characteristics and utilization of urban green infrastructure in Southern Ethiopia. *International Journal of Development Research*, 7, (12), 18010-18020.

Morckel, V. (2017). Using suitability analysis to select and prioritize naturalization efforts in legacy cities: an example from Flint, Michigan. *Urban For. Urban Green.* 27, 343–351.

Nowak, D.J., Crane, D.E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environ. Pollut.* 116, 381–389.

Nur D. B. (2017): An approach to determining forest areas with recreational potential: The case of forest areas around main transportation roads in the Maçka Region of Trabzon, Turkey, *Journal of Sustainable Forestry*, DOI: 10.1080/10549811.2017.1406374.

Pantalone, S. (2010). Creating the Urban Forest: Suitability Analysis for Green Space in the City of Boston. USGS Land Cover Institute, Tufts University.

Patel, V., Goel, D. S., & Desai, R. (2009). Scaling up services for mental and neurological disorders in low-resource settings. *International Health*, 1(1), 37–44. [https://doi.org/10.1016/j.inhe.2009.02.002](https://doi.org/10.1016/j.inhe.2009.02.002).

Pauleit, S., and Duhme, F. (2000). Assessing the environmental performance of land cover types for urban planning. *Landscape Urban Plann.*, 52 (1), 1–20.

Peng, J., Ma, J., Du, Y., Zhang, L., Hu, X. (2016). Ecological suitability evaluation for mountainous area development based on conceptual model of landscape structure, function, and dynamics. *Ecol. Indic.* 61 (2), 500–511.
Pereira, J.M.C. and Duckstein, L. (1993). A multiple criteria decision-making approach to GIS based land suitability evaluation. *International Journal of Geographical Information Science* 7: 407 – 424.

Piran, H., Maleknia, R., Akbari, H., Soosani, J., Karami, O. (2013). Site selection for local forest park using analytic hierarchy process and geographic information system (case study: Badreh County). *Int. Res. J. Appl. Basic Sci.* 6 (7), 930–935.

Pramanik, M. K. (2016). Site suitability analysis for agricultural land use of Darjeeling district using AHP and GIS techniques. *Modeling Earth Systems and Environment*, 2(2), 56. doi:10.1007/s40808-016-0116-8.

Rees, W., Wackernagel, M. (1996). Urban ecological footprints: Why cities cannot be sustainable—And why they are a key to sustainability. *Manag. Urban Sustain.* 16, 223–248.

Rehnuma, M., Yusof, M. J. M., & Bakar, S. A. (2007). Emerging Green Spaces In North Of Dhaka: Suitability Analysis In A Dense Urban Settlement.

Romano, G., Dal Sasso, P., Liuzzi, G.T., Gentile, F. (2015). Multi-criteria decision analysis for land suitability mapping in a rural area of Southern Italy. *Land Use Policy* 48, 131–143.

Saaty, T. (1980). *The Analytical Hierarchy Process*. McGraw-Hill International, New York.

Sahabo, A. A., & Mohammed, A. B. (2016). A GIS Based Multi-Criteria Analysis For Siting Recreational Parks In Yola-North Local Government. *International Journal of Applied Science and Engineering Research*, 5(1), 20-29.

Sandstrom, U.G. (2002). Green Infrastructure Planning in Urban Sweden. *Plan. Pract. Res.* 17, 373–385.

Schipperijn J, Ekholm O, Stigsdotter U K, Toftager M, Bentsen P, Kamper-Jørgensen F and Randrup TB. (2010). Factors influencing the use of green space: results from a Danish national representative survey. *Landscape and Urban Planning* 95 130–7.

Secretariat of the Convention on Biological Diversity, (SCBD) (2012). *Cities and Biodiversity Outlook*.

Shi, L. (2002). Suitability Analysis and Decision Making Using GIS, Spatial Modeling.

Tratalos, J., R. Fuller, P. Warren, R. Davies & K. Gaston. (2007). Urban form, biodiversity potential and ecosystem services. *Landscape and Urban Planning* 83(4): 308-317.

Tudes, S., Yigiter, N.D. (2010). Preperation of land use planning model using GIS based on E. Ustaoglu and A.C. Aydinoglu Urban Forestry & Urban Greening 47 (2020) 126542 AHP: case study Adana-Turkey. *Bull. Eng. Geol. Environ.* 69 (2), 235–245.

Ullah, K. M. (2014). Urban land-use planning using Geographical Information System and Analytical Hierarchy Process: case study Dhaka city. *LUMA-GIS Thesis*.

Ustaoglu, E., & Aydinoglu, A. C. (2020). Site suitability analysis for green space development of Pendik district (Turkey). *Urban Forestry & Urban Greening*, 47, 126542.

Uy, P. D., & Nakagoshi, N. (2008). Application of land suitability analysis and landscape ecology to urban greenspace planning in Hanoi, Vietnam. *Urban Forestry & Urban Greening*, 7(1), 25-40.

Van Berkel, D.B., Munroe, D.K., Gallemora, C. (2014). Spatial analysis of land suitability, hot-tub cabins and forest tourism in Appalachian Ohio. *Appl. Geogr.* 54, 139–148.

Wang, A., & Chan, E. (2019). Institutional factors affecting urban green space provision—from a local government revenue perspective. *Journal of Environmental Planning and Management*, 62(13), 2313-2329.

Woldegerima, T., Yeshitela, K., Lindley, S. (2016). Characterizing the urban environment through urban morphology types (UMTs) mapping and land surface cover analysis: the case of Addis Ababa, Ethiopia. *Urban Ecosystem*, 20,245–263.

Wright, R.T., & Nebel B.J. (2002). *Environmental Science: Towards A Sustainable Future*. New Jersey. Pearson Education Inc.

Wu, J. (2014). Urban ecology and sustainability: The state-of-the-science and future directions. *Landsc. Urban Plan.* 125, 209–221.

Yeshewazerf, G. H. (2017). Recreational parks: practices and challenges in Hawassa City. *Journal of Tourism and Hospitality*, 6(3). doi: 10.4172/2167-0269.1000284.

Yousef, A. Z., & Mohammad, H. S. (2014). Site Selection and prioritize urban parks and green spaces (case study: District 22 of Tehran Municipality). *Technical Journal of Engineering and Applied Sciences*, 4(4), 230-243.

Zhang, X., Fang, C., Wang, Z., Ma, H. (2013). Urban construction land suitability evaluation based on improved multi-criteria evaluation based on GIS (MCE-GIS): Case of New Hefei City, China. *Chin. Geogr. Sci.* 23 (6), 740–753.