POSSIBILITY IN IDENTIFYING SUITABLE AREAS FOR URBAN GREEN SPACE DEVELOPMENT USING GIS-BASED MULTI-CRITERIAL ANALYSIS AND AHP WEIGHT METHOD IN DONG HA CITY, VIETNAM

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ABSTRACT

Urban Green Spaces (UGS) is an essential component of the urban environment and provides the community's critical ecosystem services. The administrators face difficulties selecting the multi-level capabilities site for urban green space under the pressures of population growth dynamic, unplanned urban development, and environmental, socio-economic, cultural, and other sociopolitical risks. This study evaluates the possibility of expanding UGS in Dong Ha city using a GIS-based multi-criteria and analytical hierarchy process (AHP). Variables including slope, existing land use/land cover, proximity to the main road, waterbody, pollution sources, park, historic place; land price, population density, and land surface temperature took for suitable analysis. The dasymetric mapping technique utilized for retrieving population density factors demonstrated more accurately for proper evaluation modelling. The findings suggested the spatial distribution of 0.36%, 5.32%, and 23,18% of the area's highly suitable, relative suitable, suitable, respectively. While the most crucial site, 62.03%, is less suitable, and 9.10% is not suitable for UGS development. These research findings could assist the city planner, the government authority, examines the optimal urban green spaces for improving the environmental sustainability in urban areas.

Keywords: Urban Green Spaces, AHP, GIS, Dasymetric, suitable analysis

1. INTRODUCTION

By 2050, 68 per cent of the world's population is projected to be urban and approximates 50 per cent of the level of urbanization in Asia [5]. This unprecedented urban growth leads to post tremendous pressure on natural resources and the ecological environment.

Urban Green Space (UGS) is an essential component of the urban environment and provides the community's critical ecosystem services and the quality of human well-being [2], [4]. Municipal governments in developing countries face difficulties selecting the optimal locations for UGS under the pressures of dynamic population growth, unplanned urban development, and environmental, socio-economic, cultural, and other sociopolitical risks [6]. The suitable land analysis determines the fitness of a given tract of land for a defined use, which is considered vital in UGS planning. The multi-criteria analysis (MCA) with the Analytic Hierarchy Process (AHP) weighting method approach incorporated into GIS-based suitability procedures has been increasingly used in UGS proper evaluation by various parameters such as bio-physical, socio-economic, environmental, policy-related, accessibility factors in decision-making processes [4], [6], [8].

Dong Ha is a young city in Quang Tri province, central Vietnam, facing fast urbanization and the threat of climate change. As a result of the rise of impervious surfaces, green spaces are becoming increasingly limited. Therefore, this study aims to select potential UGS sites to assist in an effective planning process of green areas. A GIS-based multi-criteria and AHP framework was carried out to indicate different parameters for evaluating the possibility of expanding UGS in Dong Ha city. The findings may benefit city planners, real estate developers, and government officials in ensuring the proper land use planning and management of the urban areas.

2. MATERIAL AND METHOD

2.1 Study area

Dong Ha is the capital city of Quang Tri province, central Vietnam. Located between 16°07'53" - 16°52'22" north latitude and 107°04'24" - 107°07'24" east longitude. It has nine wards, with a total natural area of 7,308.53 hectares. As of April 1, 2019, Dong Ha city's population was 95,658 people; after ten years (April 1, 2009 - April 1, 2019), the city's population increased by 14,497 people, an average growth rate of 1.7 people. % five. Some wards have a fast average population growth rate: Dong Luong ward 4.1%; Ward 2 2.2%; Dong Le ward 2.2%; Dong Thanh Ward 2.2%.

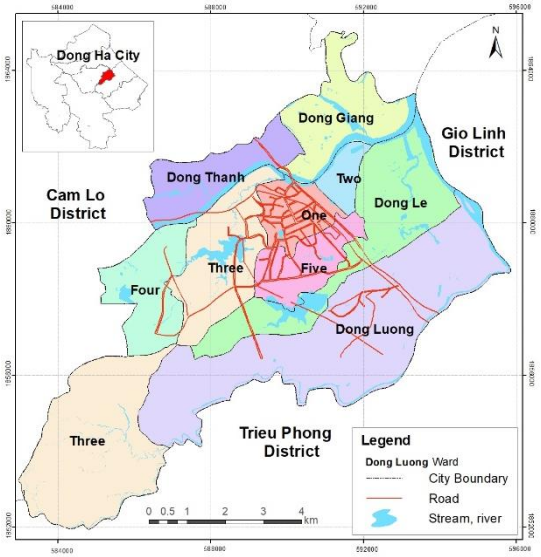

Figure 1: Map of the study area

2.2 Materials

The spatial and non-spatial data were gathered from various government departments and authorities such as the Department of Natural Resources & Environment (DONRE), Department of Statistic (DS), People's Committee of Quang Tri Province (PC). The collected data showed in table 1.

Table 1. Data collection for analysis

Data	Sources	Type	Year	Resolution /Scale	Purpose
Landuse map	DONRE	Vector	2020	1:10.000	Proximity analysis
Topographic map			2015	1:10.000	Slope
Master plan and land use planning			2030	1:10.000	Reference
Land price information	PC	Excel	2020 - 2024	Ward level	Landprice
Population census	DS	Excel	2020	Ward level	Population density analysis
Landsat 8 TIRS	UGSS	Raster	2020	30 x30 m	Land surface temperature analysis

3. METHODOLOGY

3.1 Determination of criteria

The criteria that affect selecting suitable UGS vary from researcher to researcher and are grouped into some dimensions, i.e., physical, socio-economic, environmental, accessibility [4], [9], [12]. Based on the synthesizing literature review, expert consultation, and study area condition, the optimized UGS suitability evaluation criteria were adopted, including ten measures in table 2. The level of suitability for urban green space development is defined by the Food and Agricultural Organization and classed in each sub-criteria as follows: Highly suitable (S1), relatively suitable (S2), suitable (S3), less suitable (S4), and Unsuitable (N) for urban green space corresponding to the score of 5, 4, 3, 2, 1, respectively [1] (Table 2).

3.2 GIS-based multi-criteria analysis and AHP framework for suitable analysis

GIS-based analysis was conducted to derive the selecting criteria map indicating in table 2. Population density mapping at a finer scale and higher resolution can play an essential role in understanding urban spatial features, especially in analysis for urban green space. Therefore, dasymetric mapping effectively helps allocate population data to more delicate spatial units with ancillary data [11]. Dasymetric mapping technique was utilized for extracting the population density through spatial analysis, population distribution over a given territory based on the weighting of each land-use/surface cover category to distribute population data shown on the map more accurately in geographical space [3],[10]. The slope criteria map was derived by interpolation from the elevation data of the topographic map. Land surface temperature criteria were obtained from an algorithm from Landsat 8 TIRS. The proximity analysis was established with the different distances for the pollution sources, road, waterbody, historic place, park criteria. The land price information is joined with the administrative unit for deriving the land price criteria.

Table 2. The criteria for site selection and suitable analysis of urban green space

Criteria	Description	Level of suitability				
		S1 (5)	S2 (4)	S3 (3)	S4 (2)	1 (N)
Slope (%) - SL	The areas with low slopes are highly suitable for developing UGS	0-5	5-10	10-15	15-30	>30
Proximity to waterbody (m) - PW	The closer to waterbody gets more preferences, contributing to maintaining the area's environmental health.	0-20	20-40	40-60	60-80	>80
Proximity to road (m) - PR	The UGS site is preferable when it is located at a suitable distance from roads to easily access transportation, enhance the possibility of monitoring, and maintain their security for citizens.	0-25	25-50	50-75	75-100	>100
Proximity to pollution source (km) - PPo	Noisy areas are not suitable for UGS like the factory area because of high sound pollution and smoke.	>20	15-20	10-15	5-10	0-5
Proximity to history place (km) - PH	The development of UGS must ensure that there is no encroachment on the relic.	0-0,5	0,5-1	1-1,5	1,5-2	>2 and the historic areas
Proximity to park (km) - PPa	The area farthest from the existing park requires green space due to the lack of green space or vegetation, balancing the number of green spaces and gardens between the regions.	>3	2-3	1-2	0,5-1	<0,5
Existing land use - LU	The capacity of land use type can be changeable into UGS	Bare land	Green Space	Forest	Agriculture	Construction land
Population density (people/ha)- PD	The areas closer to residential areas are highly suitable for developing green space.	>100	50-100	20-50	S4: 5-20;	<5
Land price (1.000 VND/m^2) - LP	The areas with the lower price will be priority than those areas with the higher price for UGS development	<3.000	3.000-6.000	6.000-9.000	9000-1.5000	> 1.5000
Land surface temperature (˚C) - LST	UGS is considered an appropriate way to reduce urban heat; Areas with high temperatures will be prioritized to develop UGS	>34	32 - 34	30-32	28-30	<28

The MCA with the AHP method is an effective tool for dealing with the complex decision-making process. Based on pairwise comparisons to rank the selected criteria. The AHP weighted score for each criterion is determined based on its importance to the development of UGS. Questionnaires for each measure have been prepared. The requirements are weighted by consulting ten experts in land use or urban planning fields based on their desired priorities following Saaty's 9 point scale. The formula checked the consistency check of the pairwise comparison matrix: RC = IC/IR (1) to ensure the result meets the requirement

(RC < 0.1). 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 [7]. The MCA has incorporated ArcGIS 10.4 to select an appropriate location for the development of UGS.

In potential UGS suitable analysis, each criterion (vector layer) was normalized by turning it into a raster layer with a resolution of 30 × 30 m. The weighted linear combination technique was adopted to aggregate the standardized layers using the formulation to derive the potential land suitable map for urban green space development [2], [4]:

$$S = \sum_{i=1}^{n} W_i X_i \quad (2)$$

where S is the total value of the UGS suitability evaluation, n is the total criteria number; W_i is the combined weight result of criteria i, and X_i is the suitability value for standards i. Figure 2 depicts the framework of GIS-based multi-criteria analysis and the AHP weight method to select the suitable places for urban green space in Dong Ha city.

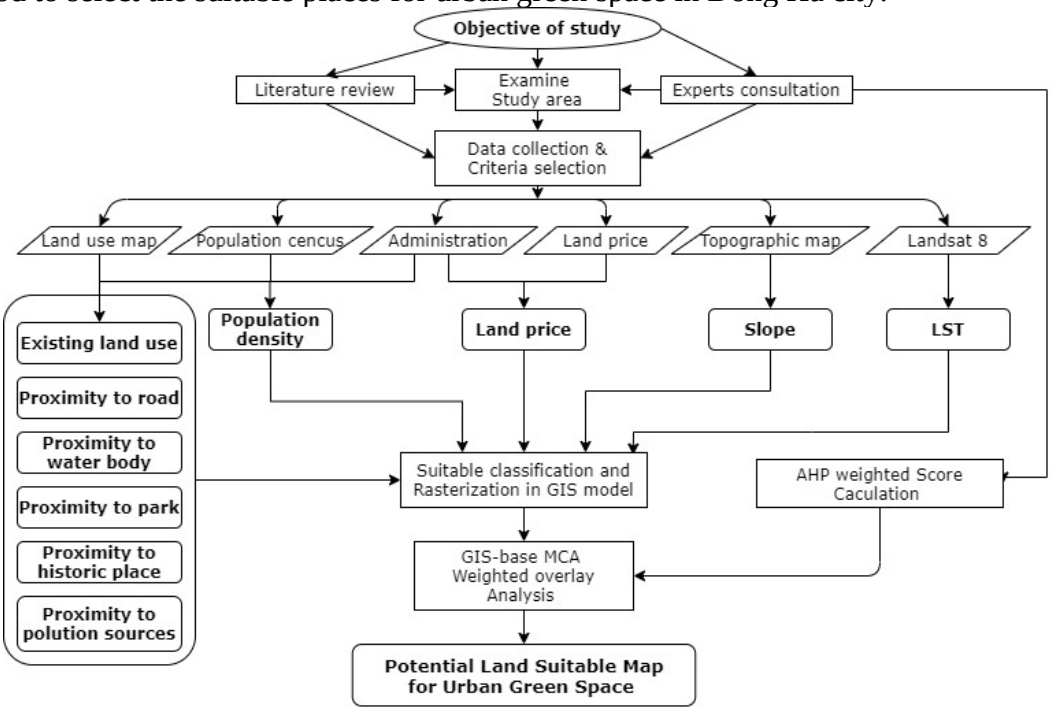

Figure 2. Flow chart of GIS-based multi-criteria analysis and AHP weight method to select the suitable places for urban green space

4. RESULT AND DISCUSSION

4.1 Mapping and weighting each criterion

The results of computing AHP weights for each criterion by comparing the pairs of evaluation criteria according to the importance scale, with the consistency coefficient CR = 8.9%, satisfying the condition AHP analysis. The degree of influence on UGS varies depending on the criterion. The indicators that greatly influence UGS expansion are land surface temperature and population density with weights of 0.29 and 0.23, respectively. Meanwhile, the slope criteria and land price indicators have negligible influence on UGS expansion with the weight of 0.02 and 0.01, respectively, reflecting the reality with special conditions in the study area. The suitable thematic maps for ten criteria were done under the GIS platform in raster format for further appropriate analysis (Figure 4). Previous studies commonly derived the population density criteria under traditional density techniques of Choropleth [2], [3]. This method depicted the population distribution homogeneously throughout each administrative

boundary unit and significantly affected further spatial data analysis. In this paper, the Dasymetric mapping map technique was adopted for making population density maps because of its ability to distribute population data shown on the map more accurately in geographical space (Figure 4-PD).

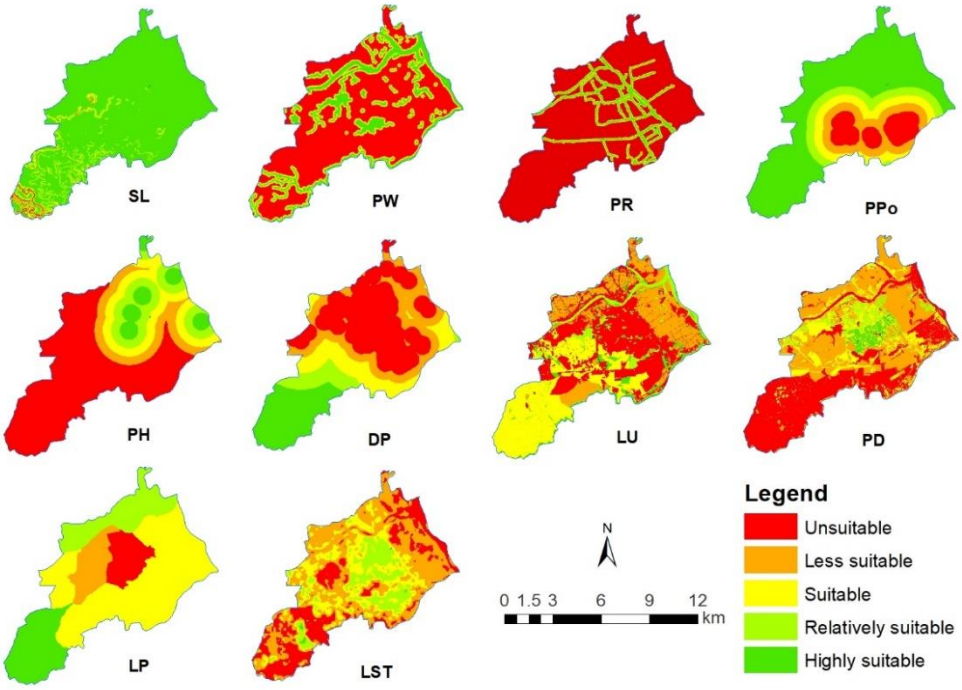

Figure 4. Suitability level of each criterion for urban green space development

4.2 The potential suitable land for expanding urban green space

A comprehensive overlay analysis was performed on each criterion following the AHP weighted score to derive the potentially suitable land for UGS development in Dong Ha city. The proper level was defined in 5 grades as highly suitable, relative suitable, suitable, less suitable, and unsuitable (Figure 5).

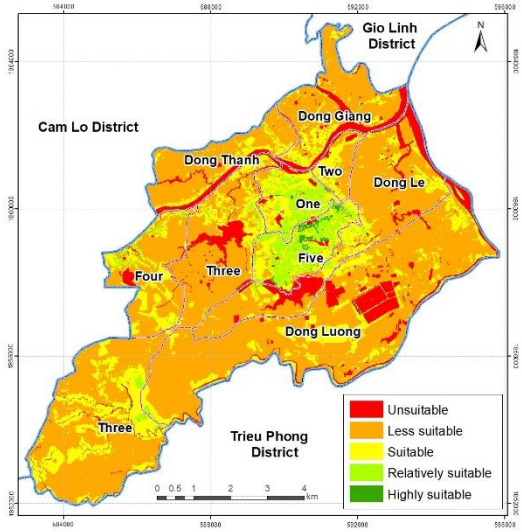

Figure 5. Final suitability map for urban green space development

The results show that UGS suitability is concentrated in Ward 5, which covers a small area of 26.67 ha and accounts for 0.36% of the entire region. Most of the sites have high population density, building land with high temperatures, and high road density, which are ideal for UGS expansion. The analysis findings also show that the terrain slope is relatively flat adjacent to historical-cultural monuments. The relative suitability area is 388.62 ha, representing 5.32% of the total area, distributed mainly in wards 1 and 5. It belongs to the wards with high population density, high land price, and elevated green area coverage, such as wards 1 and 2. The suitability area encompasses 1,694.07 ha, or 23.18% of the total land area, and is primarily located in the city centre, encompassing wards 1, 2, 5, and Dong Luong and along the river. These areas contain many people and a lot of heat, but the rest of the conditions aren't ideal for UGS development. The location with the degree of unsuitability occupies the highest area of 4,533.72ha, accounting for 62.03% of the total area. These locations are primarily agricultural

land, with relatively low density of main roads and low population density. In particular, the place to the southwest of the city is mainly suitable for low-density forest development. The location is not ideal, with 665.42 ha, accounting for 9.10% of the city area, particularly water surface land, parkland, and relic area.

5. CONCLUSION

In this study, the suitable region for urban green space development in Dong Ha city was determined using an integrated GIS-based multi-criteria with AHP weighted technique, which can aid in selecting suitable land for urban green space planning and development. The model of suitability assessment was established based on a weighted linear combination technique including ten criteria empowering various dimensions of physical, socio-economic, accessibility, environment for UGS development. The dasymetric mapping technique was utilized for retrieving population density factors demonstrated more accurately for suitable evaluation modelling. The suitability analysis results indicated the possibility of identifying the proper UGS development with suitable, relative appropriate and highly ideal for the areas located in the core city and the southwest of the town. These findings also meet Quang Tri Province's planning orientation on expanding the urban space and establishing new residential areas for economic development to the west and south. The open green space spread from the core city to the surrounding areas. Moreover, the findings provide a framework of GIS-based multi-criteria analysis and AHP weighted method in UGS development for Dong Ha city planning green spaces in the backdrop of climate change challenges in recent years.

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