GIS-BASED SUITABILITY ANALYSIS FOR POTENTIAL LOCATIONS OF PARKS IN MIRPUR AREA OF DHAKA, BANGLADESH

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ABSTRACT

Identification of urban open spaces is an important step to enhance the livability of a city. These free access zones have the prospect of positively influencing both the physical and mental prosperities of their users. Moreover, further conversion of the potential open spaces to green spaces could lead to the satisfaction of several sustainable development goals, focusing on overall well-being, sustainability, climate action, life and land. In the past, many literatures indicated towards accessibility of greenspaces using various methods of calculations and decision-making processes. Also, the use of crowdsourcing information and surveying were proposed in the identification of greenspaces which were resource intensive in terms of funding, manpower and time duration. To the best of our knowledge, no scientific work covered the recognition of open spaces in Dhaka using Geographic Information System (GIS). In this study,several conditioning factors (or parameters) were used to detect open spaces suitable for parks in the Mirpur area of Dhaka, Bangladesh. Information pertaining to land-use/land-cover, household population, existing road networks, existing buildings and existing open spaces were obtained from the Capital Development Authority of Bangladesh (Rajdhani Unnayan Kartipakkha). By using the Overlay Analysis (weighted sum) in ArcGIS Pro, these five factors were individually categorized and then ranked in terms of their relationship to the suitability of parks. Then, the Weighted Sum Overlay method was used to obtain the suitability map. Results showed that the most suitable area for open space had a coverage of around 0.50 km^2. Whereas the next best appropriate open lands had 4.33 km^2 of area. Collectively, the combined areas could satisfy the need for green spaces of the residents. However, most of the areas were clustered at the southern, eastern, and northwestern portion of Mirpur.

Keywords: *Geographic information system, suitability analysis, land-use/land-cover, green space, sustainability.*

1. INTRODUCTION

Access to open or green urban spaces is essential for people to link with the nature, thereby nurturing both the physical and mental health. Also, the use of green spaces fosters social bonding. Green urban areas have become an important element for discussion as they actively combat detrimental climatic changes (Cetin, 2015),(Stessens et al., 2017). Due to the unplanned and rapid expansion of urban areas, the existence of green zones is threatened and they continue to decline both in number and quality to satisfy per capita demand for open spaces. The disorganized city development is mainly contributed due to the increase in population, industrial establishments, and the overall rise in construction based activities (Abebe & Megento, 2017). Therefore, it has become imperative that green spaces are put under major focus in order to properly integrate and sustain them in urban settings. Many past research works focused on the accessibility and quality of green zones. For instance, Cetin assessed the distribution and number of green spaces in Kutahya and also evaluated their size and per capita rates. Under the study, around 167 parks were digitized and categorized according to their areas as small or large. It was found that parks covered the place with a total area of around 614.3 m^2. All these findings accounted for an integrated green space system for sustainability (Cetin, 2015). Stessens et al. utilized GIS based tools to evaluate the accessibility and quality of urban green spaces in Brussels using several indicators (e.g., naturalness, biodiversity, quietness, and spaciousness). Results revealed that equal sized populations had low, medium, and high access to green spaces. Also, more than half the population under the urban blocks managed to avail green spaces with below average quality, necessitating further development (Stessens et al., 2017). Abebe & Megento conducted land suitability analysis using GIS for determining urban green spaces, employing multi-criteria analysis methods. Finally, the study identified green areas with less, moderate and high suitability (Abebe & Megento, 2017). Hsu et al. employed GIS techniques to evaluate greenspace accessibility in Adelaide, Melbourne, Sydney, and Brisbane of Australia. For the study, 2017 Australian census data was used. Results showed that there was a significant spatial inequality in the access and locations of parks or green spaces and accessibility was greatly differentiated within each of the considered metropolitan areas and it was also varied from city to city. Finally, the investigation was promoted to conduct future planning of justified urban areas absent of disparities for greenspace allocations (Hsu et al., 2022). Puttinaovarat & Horkaew conducted green space area management using crowdsourcing data, GIS and artificial intelligence in the form of a geospatial platform. Basically, user-submitted data were verified using artificial intelligence. The outcomes indicated that the identification of green spaces in terms of classification and analysis by the combination of human driven data with software caused the resulting accuracies to be 93.50% and 97.50% respectively. This geospatial system was deemed to be a feasible solution for the governmental entities for the proper urban planning (Puttinaovarat & Horkaew, 2022). Bosch et al. developed and examined an urban green space indicator for public health. The indicator for green space accessibility was defined by a segment of urban population residing at a certain distance from green space boundary. Additional parameters included various population data, maximum distance to green spaces, minimum green space size, etc. It was found that increasing green space size coupled with decreasing distance to green space lowered the indicator value. Also, a default accessibility indicator option resulting from a maximum distance of 300 m to green space boundary with a minimum green space size of 1 hectare was recommended for sustainable public health (Bosch et al., 2016). Dinda et al. assessed the loss of urban green space (UGS) with the change in land-use/land-cover and predicted the future loss of UGS in Kolkata. Multi-temporal Landsat satellite images were used coupled with three land classification algorithms. The study found that built-up area was increased significantly and would end up covering about 84% of the total area in the future. Also, the coverage for vegetation and grassland decreased for the considered years (Dinda et al., 2021). Stessens et al. attempted to relate various features of urban green spaces and recognized the quality of green spaces by blending survey works with GIS-based spatial metrics. The different characteristics when assessing the qualities for green spaces observed by the residents were quietness, spaciousness, cleanliness, maintenance, and safety. GIS-based evaluations were finally conducted on the aforementioned parameters (i.e., naturalness, quietness and spaciousness) in terms of biological value, land cover, green space shape and size. A decent correlation was obtained between the GIS-derived variables and end-users' perceptions of green space qualities (Stessens et al., 2020). Vilcea and Șoșea emphasized on the fact that urban population faces both physical and mental stresses due to the lack of exercise and socializations coupled with subjugation to various types of environmental pollutions (i.e., air, water, sound, thermal, visual, etc.). Therefore, access to green spaces such as parks could potentially alleviate the dilemmas. In the study, Craiova, Romania was selected to determine accessibility to green space as this specific area was constantly under development for urban spaces with reduction in urban green areas. GIS based analysis was performed to figure out green spaces within the city with suggestions made to improve available green areas for the inhabitants. Results also showed locations and number of parks correlated with population density. Finally, data indicated uneven distribution of parks and approach to green spaces (Vîlcea & Șoșea, 2020).

Previous research showed that most of the scientific works in urban planning were concerned with the accessibility and quality of urban green extents by considering parameters chiefly focused on their different features. However, most of the studies were conducted for developed countries where urban expansions were booming. In addition, almost all the papers focused on the reachability and the standard of the already existing open spaces in the urban settings and not taking into consideration the creation of new green zones in terms of their suitability by considering different spatial and non-spatial factors. Therefore, the objective of this research is to perform a suitability analysis for potential locations for green spaces in the Mirpur area of Dhaka, Bangladesh by accounting for land-use/land-cover, household population, existing roads, existing buildings, and present open spaces. Also, the locations for future green zones are ranked in terms of 8 classes with the lowest being least and the highest being most appropriate for allocating green areas. For the endeavour, Geographic Information System (GIS) is chiefly used.

2. METHODOLOGY

2.1 Study Area

From Dhaka North City Corporation (DNCC) Layer, Wards were selected which only covered Mirpur area (Figure 1), by using select by attribute function. Mirpur was based on 02 (two) zones which were zone 2 and zone 4. Zone 2 had Wards 2, 3, 4, 5, 6, 7, 8 and 15. Whereas, Zone 4 had Wards 9, 10, 11, 12, 13, 14 and 16 (*Dhaka City Corporation*, 2021). Based on DNCC Mirpur layer, LULC (Land Use Land Cover) layer for Mirpur area was collected, designating 08 distinctive classes for lands (Table 1). Buildings, Roads and existing open spaces under DNCC were further processed in such a fashion as to only use the buildings and roads covering Mirpur area for suitability analysis.

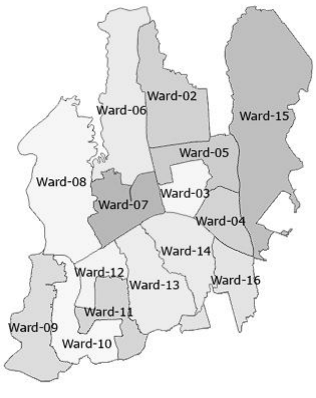

Figure 1: Respective wards covering Mirpur area of Dhaka city

2.2 LULC for Mirpur Area

Mirpur LULC (Figure 2) was already a raster layer with eight classes and it needed reclassification only. Based on the judgement and reasoning, the following suitability criteria were provided for each LULC type. There was a total of 8 (Eight) suitability values (based on the LULC categories), 1 being the least suitable area and 8 being the most suitable area. From the table, it is observed that most waterbodies in Mirpur area were situated in lowlands and were retention ponds. So, they were not ideal for identifying potential locations for green spaces such as parks. Trees were found to be in botanical garden and national zoo. So, new open spaces should be situated outside of those locations. Land cover belonging to grasslands were highly sought after to establish green spaces. Flooded vegetation and crops were not deemed appropriate to place park locations because they needed further expansions in the future. Scrabs/Shrubs on the other hand seemed to exude the same level of importance as grass, thereby warranting a similar suitability score (Table 1).

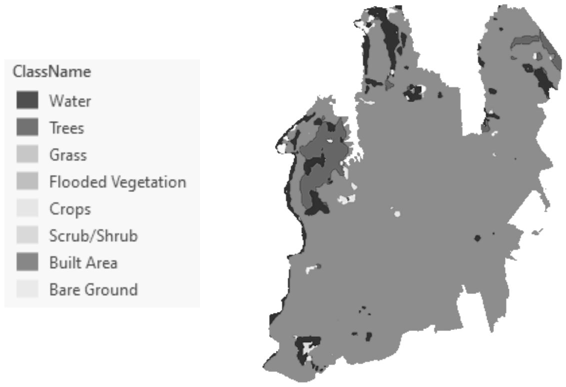

Figure 2: Mirpur LULC Layer with classifications

Table 1: Suitablity values for land use types

Land Use Feature	Suitability Value	Reasoning
Water	3	Retention ponds or low land area. Not very suitable for parks.
Trees	4	Mostly belonging to botanical garden and national zoo.
Grass	7	Highly suitable area to establish parks.
Flooded Vegetation	2	Not formal water bodies. Containing hyacinth plants.
Crops	1	Areas nearest to crops are needed to be used for additional farmlands.
Scrab/Shrub	6	Similar to Grass.
Built Area	8	Not enough open spaces. These needs to be imposed.
Bare Ground	5	Could be potential locations but needs lots of financial budgeting to establish green space.

2.3 Household Population for Mirpur Area

From Mirpur buildings layer, household population was determined by using the column containing the number of dwelling units under each building referred as “Dw_Unit”. From that information, another column named “HH_POP” was prepared. Since there was no population data present in the existing database due to the unavailability of updated population census, it was assumed that average household members in a single dwelling unit was 4.35 according to BBS-2011(*Bangladesh Population and Housing Census 2011, National Volume-3: Urban Area Report*, 2014). Then, by using the field called “HH_POP” in the attribute table, field calculation was conducted, multiplying all values under “Dw_Unit” (i.e., Dwelling Unit) with 4.35 provided potential numbers of residential members in those units under each of the buildings in Mirpur who would be occupying the free spaces.

Mirpur buildings polygon layer (containing household population data) was converted to point layer (Figure 3) by using Feature to Point geoprocessing analysis tool. The point layer was further rasterized and reclassified in such a manner that class with the highest population value was the most suitable for designating green spaces and class with the least population count would end up being least suitable for the allocation of free zones.

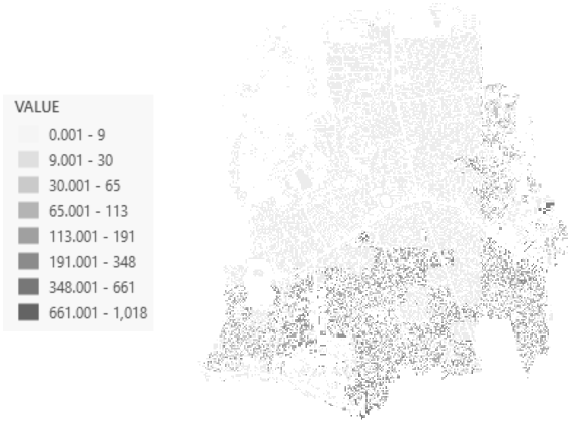

Figure 3: Mirpur housing population classification

2.4 Road Network for Mirpur Area

Euclidean distance of existing Mirpur Road network layer (Figure 4) was obtained and the resulting computation was reclassified in a way which dictated the suitability of unused spaces to be the most if they existed closer to the roads and least if they were away from the roads.

Figure 4: Mirpur road network layer

2.5 Existing Buildings for Mirpur Area

Similarly, Euclidean distance of the existing buildings (Figure 5) as a point layer was determined and it was reclassified in such a fashion that green areas closer to the buildings were the most suitable and spaces away from the establishments were the least favourable.

Figure 5: Mirpur building layer

2.6 Existing Open Spaces in Mirpur Area

Some features of existing open space layer (Figure 6) were not properly enclosed with polyline. Those were rectified prior to their conversion to polygons and then to points. After that, from the resulting point layer, Euclidean distance layer was computed and areas further away from the present open space points were considered to be most suitable and extents closest to the points were thought to be least appropriate.

Figure 6: Mirpur open space layer

3. OVERLAY ANALYSIS USING WEIGHTED SUM METHOD

Total Green Space suitability was carried out based on reclassified LULC, Household Population, Existing Roads, Existing Buildings & Existing Open Space. The weighted percentage for each parameter was chosen based on personal opinion and judgement. This could vary from individual to individual. For instance, LULC was given a weightage of 25% due to the allocation of new green spaces was based on appropriate land-covers. For household populations, an importance of only 10% was provided because most buildings in the Mirpur area had a smaller number of stories and each unit had lower counts of people. As previously mentioned, the creation of new open spaces was desired closer to major road networks. Therefore, it proved to be as significant as LULC. New open spaces close to existing buildings were thought to be the most crucial factor in the suitability analysis. So, it was given a weight allocation of 30%. Already situated open spaces were either privately or institutionally owned. Therefore, access to these areas by the general population was restricted in most cases. Consequently, this aspect did not carry significant impact when allocating areas for future green spaces (Table 2).

Table 2: Weighted allocation of the suitability criteria

Criteria	% Weight Allocation	Remarks
LULC	25	Green spaces within land use types were desired.
Household Population	10	Most population in a single building was moderate to less due to structures having low number of stories and dwelling units.
Existing Roads	25	New open spaces nearby major road networks were sought after.
Existing Buildings	30	Crucial for identifying open space for park establishment within existing buildings.
Existing Open Space	10	Existing open spaces were either privately or institutionally owned with restrictive access for general public at all times.

Then, by combining all the reclassified raster layers with their weight allocation in percentage, overlay analysis by using weighted sum method was conducted to obtain a single raster, representing the suitable locations for situating parks. Then, this raster was again reclassified according to the suitability numbers ranging from 1 being the least suitable to 8 being the most suitable. Lastly, GCS (Geographic Coordinate System) of the reclassed weighted raster layer was converted to PCS (Projected Coordinate System) to obtain the suitable areas for the suitability weighted raster layer. For the PCS, Gulshan 303 Bangladesh Transverse Mercator was found to be appropriate.

4. RESULTS AND DISCUSSIONS

Under the histogram depicting the distribution of the household population with respect to cell counts, it is evident that most of the buildings in Mirpur area were occupied by approximately 10 people. The distribution of household population in Mirpur area was skewed (i.e., not symmetrical). This was attributed to the presence of underdeveloped areas with residents (e.g., slums). Also, most buildings had multiple uses types. So, only the members under the residential dwelling units were considered when accounting for a specific building. Furthermore, the default bin numbers for the histogram was reduced to declutter excessive data within the chart and ensure legibility (Figure 7).

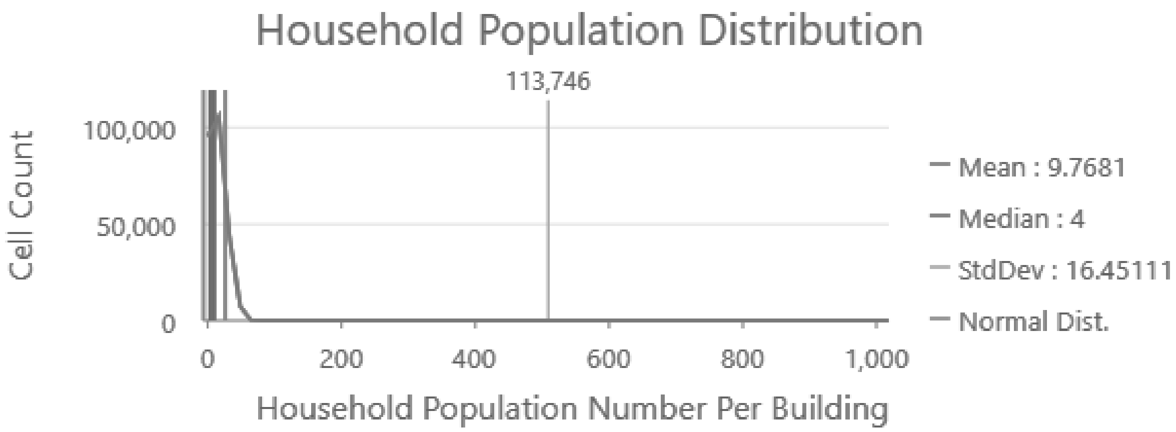

Figure 7: Household population distribution

Under the properties of the terminal layer (i.e., suitability analysis layer), it was found that each cell size was 26.6 by 26.6 m. So, the total area of each cell was 707.56 m^2. Cell count under each class of suitability category (i.e., 1 being the least suitable and 8 being the most suitable) multiplied by the individual cell area provided the area in m^2 of each feasible zone. From the table, it could be

elucidated that the most suitable area for establishing green space (e.g., park) was 503075.20 m^2 or 0.50 km^2 (under suitability value = 8). Whereas the next best suitable area for green space (i.e., 7) was 4328145.00 m2 or 4.33 km^2 (Table 3). According to City Corporation Act 2009 (City Corporation Act, 2009), 0.1 acre (i.e., 0.004 km^2) free space is required per 1000 people. In Mirpur area, around 1,111,082.00 residents existed based on additional statistics resulting from household population distribution (Figure 7). So, for the stated number of residents, around 4.44 km^2 of free space is required. Analysis revealed that the current available free zones had a collective highly suitable area of around 4.83 km^2 which was appreciable and around 8.71% more than the recommendation. Furthermore, the most suitable area with class value of 8 was mostly scattered and clustered at the southern portion of the overlay map. Also, a dense congregation of the areas was found at the eastern portion of the map. Unfortunately, access to these locations could be availed by mostly the residents occupying the southern and eastern parts of the Mirpur area. Therefore, the next most appropriate areas with a suitability value of 7 was considered alongside the best ones as they spanned out from the north-western part of Mirpur and spiraled in such a manner as to reach the eastern corner in a substantially concentrated fashion. When considering the south side, almost all the areas had suitability value of 7, reaching both south-western and south-eastern corners. There seemed to be the presence of prominent locations for establishing parks at the west side as well, but it had lower area counts compared to all the other dimensions. Potential Park locations with suitability value of 7 could be readily accessible by all the inhabitants in Mirpur area of Dhaka, Bangladesh. As discussed earlier, based on the multi-criteria analysis and the generated comprehensive suitability map, the factors depended on the most feasible areas for situating parks are locations close to significant household populations, free spaces that are closest to the existing major roads, zones nearest to the existing buildings and unused spaces away from existing recreational establishments. Also, based on the map, the most suitable locations (i.e., suitability value of 8) for establishing parks are found in the south, east and north-western parts of Mirpur area. However, in order to satisfy the required size and accessibility of the proposed free spaces, the next best suitable areas (i.e., with suitability value of 7) are also needed to be considered that cover most of the southern parts of Mirpur area and also connect the north to the east side through the central zone (
Figure **8**).

Table 3: Suitable area under each suitability class

Suitability Values	**Cell Counts**	**Area (m^2)**
1	7	4952.92
2	13	9198.28
3	34	24057.04
4	46	32547.76
5	3189	2256409
6	3607	2552169
7	6117	4328145
8	711	503075.2

From the suitability analysis to identify potential locations to develop green zones, built area was found to be the most dominant compared to all other land cover classes in terms of both its cell counts and the possible area coverage. Household population distribution was severely distorted towards the left side, showcasing a mean population of 10 per building. Overall, the most suitable and second-most suitable areas fulfilled adequate requirements for the total estimated inhabitants in Mirpur area of Dhaka, Bangladesh. As previously mentioned, most of the existing works covered accessibility and quality of greenspaces by only focusing on the existing open zones (Cetin, 2015), (Stessens et al., 2017) and (Hsu et al., 2022). However, this particular effort developed the spatial allocation of green spaces by conducting suitability analysis using multi-criteria which seemed to resemble the works produced by Abebe & Megento, but they used different criteria for assessment for a different location and they used three types of descriptive suitability estimation instead of eight suitability classes (derived from LULC map layer) used in this paper (Abebe & Megento, 2017).

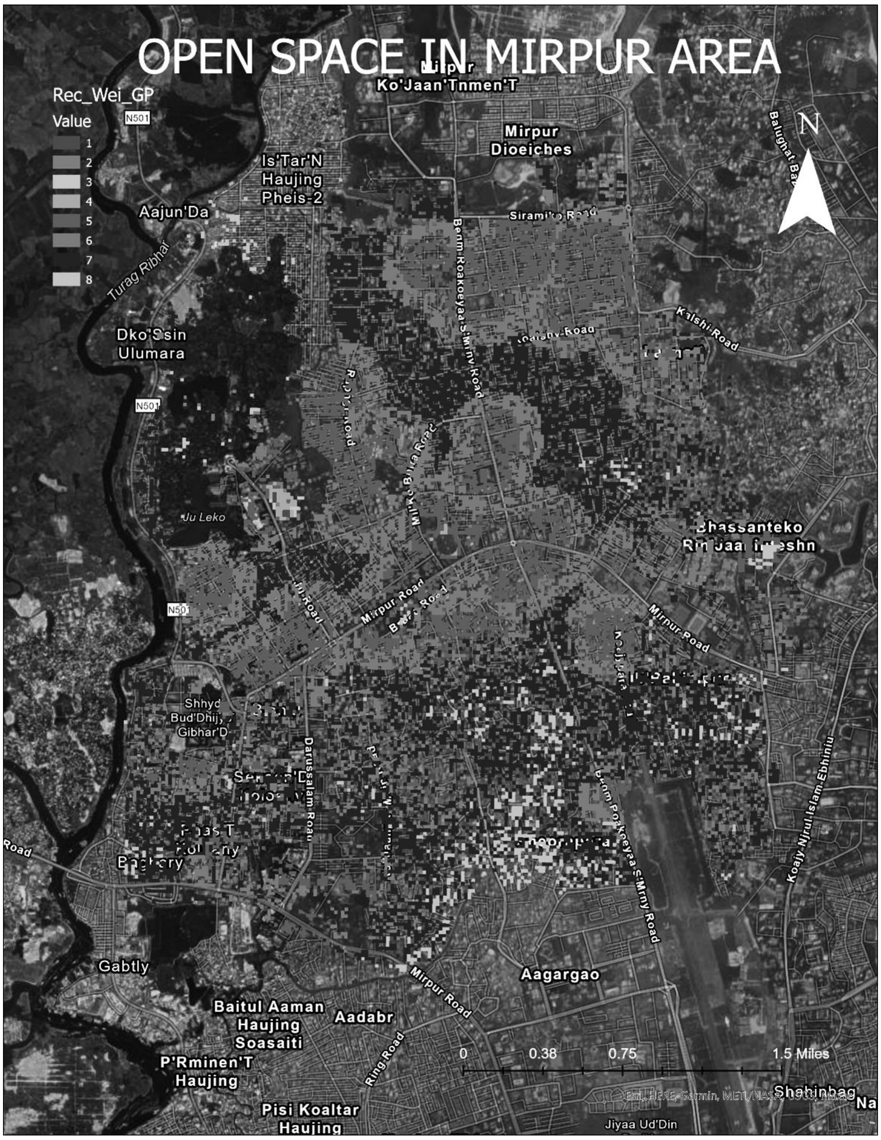

Figure 8: Map of potential park locations in Mirpur area from weighted overlay (weighted sum) analysis

5. CONCLUSIONS

This study identified the potential locations for establishing greenspaces in the form of parks or other social or recreational areas to promote both physical and mental well-being of people residing in urban settings (Mirpur area of Dhaka, Bangladesh). Five criteria were amalgamated and weighed according to their perceived importance when conducting suitability assessment. Finally, the combined areas of the highest two suitability values provided adequate spaces to satisfy the demand of the locals for open zones. Before assigning the suitability values, it was essential to take note of not only the magnitude of population but their frequency distribution beforehand. Suitability values could have been adjusted in such a fashion that mean population could readily access green spaces compared to a negligible clustered area, where very large number of people were present. By readjustment of suitability criteria for population, the final analysis could have been much more refined and accurate, having more weightage and in turn, resulted in further highly suitable free spaces. Besides, financially insolvent communities could reap the benefit for green zones more in addition to the richer counterparts. Finally, more spatial, and non-spatial criteria would make further improvements to the analysis. In addition, when weighing the all the criteria for the analysis, the inputs from all the stakeholders ranging from the urban planners, engineers, contractors, other professionals, politicians, and end-users are required to establish credibility in the work. Which means, the planning should not be restricted to field data collection and analysis only but focused group discussion and field survey to properly gather opinions of all involved.

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