Suitability of Urban Green Belt and Green Wedges in Chittagong City, Bangladesh: An Investigation into the Sustainable Urban Environment

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Abstract

Green belts and green wedges promote ecological balancing and hazard reduction in urban areas. The study attempted to identify suitable locations for urban green belts and green wedges in Chittagong city (CC). The mechanisms of the study were reviewing CC Master Plan, Detailed Area Plan (DAP), field observation, key informant interviews, small group discussions, and SWOT analysis. Normalized Difference Vegetation Index was used for the vegetation classification from 1990 to 2021 at a 10-year interval and perception-based data were analyzed through the IDW technique. The urban built-up area of the Chittagong Development Authority (CDA) was 18.64 sq. km in 1990 while it became 139.74 sq. km. in 2021. In 1990, dense vegetation was 153.21 sq. km but it decreased to 19.39 sq. km in 2021, because of rapid population growth and unplanned urbanization. A highly suitable site for the green belt was found in CDA coastal area. Besides, Kalurghat industrial zone, Chittagong Export Processing Zone, Nasirabad, and Baijid area were found appropriate for urban green wedges. Most suitable (83.60 sq. km) and moderately suitable (232.60 sq. km) areas for the urban green belt were identified and in the coastal zone maximum suitable areas' length was 57.61 km. The study concluded by urging for land-use zoning and the implementation of the urban green belt and green wedges, and raising voices against hill cutting by urban neighborhood communities in CC.

Keywords: Urban green belt; green wedges; suitability analysis; CDA; sustainable urban environment

1. INTRODUCTION

Greening cities is important for the sustainable management of the urban environment (Haq 2011). Green spaces have had a significant impact on the economic development and the eco-functioning of cities, and have improved the use of environmental services (Horaginamani et al. 2012). The green belt is a policy and land use designation used in land use/land cover planning (Gant et al. 2011). The Garden City concept is a town planning initiative plan by Ebenezer Howard introduced to Britain in 1898 to ensure a sustainable urban environment (Richert & Lapping 1998). Historically, the Metropolitan Green Belt (MGB) has been proposed since the late nineteenth century but was first realized in the 1930s, and expanded under Abercrombie's 1944 Greater London Plan. An early reason for proposing an MGB was to give access to the countryside but later it was to physically constrain the growth of London (Mace et al. 2016).

The main purpose of the green belt is to protect the land from urban sprawl (Xie et al. 2020) and maintain the designated area for forestry, and agriculture as well as provide habitat to wildlife (Ramesh & Nijagunappa 2014; Li et al. 2005). The green revolution protects the city's heritage through functional planning that defines the rural-urban belt (Erickson 2004). The green belt creates ecological recreation and the aesthetic evaluation of its suburbs (Line 1996; Aguado et al. 2013).

Besides, green wedges are an urban containment mechanism intended to restrict the spread of built development beyond prescribed settlement boundaries and allocated sites (Dockerill and Sturzaker 2019). Green belts are non-statutory ones that add a layer of protection to those areas where it is considered that development pressure exists or will exist during the lifetime of a local development plan (Caerphilly County Borough 2015). On the contrary, greenways are corridors of land recognized for their ability to connect people and places (Tan 2006). Furthermore, green urban areas facilitate physical activity and relaxation and form a refuge from noise. Trees produce oxygen and help filter out harmful air pollution, including airborne particulate matter (Chakre 2006).

Since the last century, the utilization of green space or structure has been taken as a planning tool at both metropolitan and regional levels, in many different cities. The green belt is a classic and concrete pattern with a 'closed' spatial character. But the green belt is not the only constitution of this planning tool. Some other cities have turned away from this origin towards more fluid forms responsive to diverse environmental, social, and economic constraints and opportunities (Evans & Freestone 2010). On the other hand, urban green wedge, greenway, and green web are representatives of these alternatives to green belt for planners' options (Amati 2016). Some cities around the world accepted the concept of a green wedge; the multi-center city expansion is flexible with the existing transport network system on the periphery (De Oliveira 2017).

In Bangladesh, Dhaka Metropolitan Development Plan (DMDP) provides a long-term strategy for the 20 years for the development of the greater Dhaka sub-zone with a population target of 15 million. It identifies the order of magnitude and direction of anticipated urban growth and defines a broad set of policies considered necessary to achieve overall plan objectives. The plan recognizes the positive and sustainable role of green belts, preservation of high-quality wet and agricultural lands, and existing rivers in and around the city limits and their continuous upgrading and evaluation and thus recommends building a circular waterway around the city (RAJUK 2019).

Chittagong is the second-largest city in terms of population size and the financial capital of Bangladesh. About 90% of the national exports and imports take place in this port city went on and more than 11% of the national GDP also contributes to the city. In addition, it is one of the fastest-growing metropolitan cities in Bangladesh and currently has about 7 million people living in the city (Mia et al. 2015). Population and urban sprawling rate are highly increasing, as a result, it's the total environment with biodiversity are degrading at an alarming rate day by day. As a result, a better urban environment in Chittagong city would be regulated. Green belt and green wedges policies built up in Chittagong city were very much important to prevent urban pollution and improve biodiversity for a sustainable urban environment. This research tried to expose the current vegetation and build-up area in the Chittagong city Master Plan area with its green belt and green wedges site identification in the urban periphery and how to relate urban green belt in taking a good decision for a new Master Plan and Detailed Area Plan for the sustainable urban environment in Chittagong city.

2. METHODOLOGY

This research was a mixed-method that combines qualitative (qualitative data analysis) and quantitative (quantitative data analysis) studies. Primary data was collected from a questionnaire survey (KII and SGD) and field observation and secondary sources data were remote sensing especially NDVI. The suitability analysis of the urban green belt and wedges was identified through NDVI and validated by the questionnaire and field observation. Hence, some data from secondary sources were quantitative and it helped to make the research a mixed-method strategy.

2.1 Data Sources and Methods of Data Collection

All information and data were collected through primary and secondary sources. The primary data were collected through in-person key informant interviews (sample size 30), small group discussions (sample size 15), field observation studies, GPS, and Google Earth Pro software. A semi-structured questionnaire was constructed for collecting opinions from urban experts, Chittagong Development Authority, and the Chittagong City Corporation planning department. The four satellite imageries from 1990 to 2021 were acquired from the United States Geological Survey (USGS) to determine suitable locations for urban green belts and green wedges in Chittagong city areas. Besides, secondary data were also collected from the Chittagong Development Authority's (CDA) Master Plan from 1961 to 1981 and 1995-2015, Detailed Area Plan (DAP), and a significant number of various research organizations, journal articles, city corporations; Chittagong Development Authorities, etc. were also included from the secondary sources of data.

2.2 Sample Size

Table 1 demonstrates the primary data collection sample size and types of respondents based on the detailed planning zones (DPZ). Key informant interviews (KII) and small group discussions (SGD) were conducted through in-person interviews and a semi-structured checklist was used in collecting the primary data.

2.3 Spatial Analysis

Normalized difference vegetation index (NDVI) and inverse distance weighting (IDW) methods were applied for the spatial data analysis. The four satellite imageries from 1990 to 2021 were acquired from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov/). The spatial resolution of all of these imageries was 30 meters and these imageries were kept closer in terms of acquisition date and months considering data availability to get a better result. All of the imageries have less than 2% cloud coverage. However, the study area has fallen in two scenes; rows/paths were 136/44 and 136/45. As all year images have two scenes of this study. Table 2 shows the specifications of Landsat 4-5 TM and Landsat 8 OLI datasets.

Table 1. Data collection based on the Detailed Planning Zones (DPZ)

Sample	DPZ1	DPZ2	DPZ3	DPZ4	DPZ5	DPZ6	DPZ7	DPZ8	DPZ9	DPZ10	DPZ 11	DPZ 12	Total
KII	3	2	3	2	4	2	2	2	2	3	2	3	30
SGD	2	1	1	1	1	1	1	2	1	1	1	2	15
Total	5	3	4	3	5	3	3	4	3	4	3	5	45

***Note:** DPZ1- Patenga-Halisahar, DPZ2- Agrabad-Kattoli, DPZ3- Sadarghat-Chawkbazar, DPZ4- Bakalia-Chandgaon, DPZ5- Lalkhanbazar-Pahartuli, DPZ6- Panchliash-Bayzid, DPZ7- Salimpur-Kumira, DPZ8- Hathazari-Raozan, DPZ9- Kulgaon-Halda, DPZ10- Madunaghat-CUET, DPZ11- Boalkhali-Patiya, DPZ12- Anwara-Karnaphuli.

Table 2. Specifications of Landsat 4-5 TM and Landsat 8 OLI datasets

Year	Date acquired (Y/M/D)	Path / Row	Scene ID	Sensor	Cloud cover	Projection	Resolution
1990	1990/03/05	136/44	LT51360441990064BKT02	Landsat 4-5 TM	< 2%	UTM 46 Zone	30 meter
		136/45	LT51360451990064BKT02				
2000	2000/01/28	136/44	LT51360442000028BKT00				
		136/45	LT51360452000028BKT00				
2010	2010/01/23	136/44	LT51360442010023KHC00				
		136/45	LT51360452010023BKT01				
2021	2021/02/06	136/44	LC81360442021037LGN00	Landsat 8 OLI			
		136/45	LC81360452021037LGN00				

*Source: USGS 2021 (https://earthexplorer.usgs.gov/)

Data processing and analysis:

Landsat TM imageries used for 1990, 2000, and 2010; and for year 2021 Landsat 8 OLI used. All image processing was carried out in Erdas Imagine 14 and Arc Map 10.8. The layer stack, correction, and mosaicking of all images were processed in Erdas Imagine. Layer stack processes had conducted with bands 1 to 7 except band 6 used for Landsat TM data and bands 1 to 7 for Landsat 8 OLI data. Atmospheric corrections like haze reduction, noise correction, and histogram equalization had been conducted for two scenes every year. After the image mosaicking, the subset process as study area extent had been carried out. The NDVI calculation was conducted in Arc Map using the image analysis toolbox.

Vegetation Index Calculation:

NDVI (Normalized Difference Vegetation Index) calculation formula was-

$$NDVI = \frac{NIR-Red}{NIR+Red} \qquad \text{(e.q.1)}$$

For Landsat 4-5 TM

$$NDVI= \frac{B_4-B_3}{B_4+B_3}$$

For Landsat 8 OLI

$$NDVI = \frac{B_5-B_4}{B_5+B_4}$$

Measuring the vegetation health of the CDA area in the Chittagong district, the NDVI index was followed. NDVI needs the red band and NIR (Near Infrared) band for the detection of the vegetation index from multispectral remote sensing which is present in the satellite image. Using Red and NIR bands, the NDVI was calculated. Various NDVI threshold values were used to extract the best result from the satellite images. Vegetation cover was classified as dense vegetation, moderate vegetation, and less vegetation from the NDVI threshold value. The threshold values of NDVI classes are 0.30 – 0.46, 0.47 – 0.59 and > 0.60 for light vegetation, moderate vegetation and dense vegetation respectively. Figure 1 shows the flow chart of the NDVI map procedure.

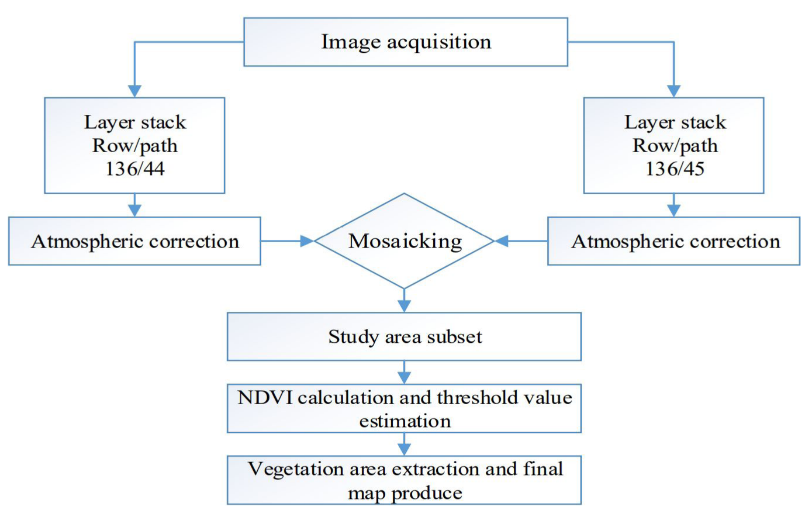


Figure 1. Flow chart of the NDVI maps procedure.

Inverse Distance Weighting (IDW) method

IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. The closer a point is to the center of the cell being estimated, the more influence, or weight; it has in the averaging process (Chen & Liu 2012; Bartier & Keller 1996). This study for the IDW method used weighted values. It was created as a CSV file with latitude, longitude, and weight value then added data even files where it displayed, X= Longitude, Y= Latitude, and Z= weight value and exported it as a shapefile. After being created as a shapefile and again adding the CDA shapefile where it was overlayed the export weighted value. Then it was used arc toolbox with spatial analysis tools by interpolation with masking CDA boundary area and prepared the map.

Urban green belt suitability analysis factors

A suitability analysis was performed using ArcGIS weighted overlay tool. The main objective of this analysis was to detect the suitable location for the green belt based on several factors such as land use and land cover (LULC) classes, elevation, distance to road, distance to shoreline, and distance to drainage pattern of CDA. LULC types, elevation, road, and shoreline were given more importance as CDA is located near the Bay as well as hill areas. The weight scale of suitability analysis was set from 1 to 5, where different weights were set for different variables. Each factor class was ranked based on its importance in the study area.

SWOT analysis

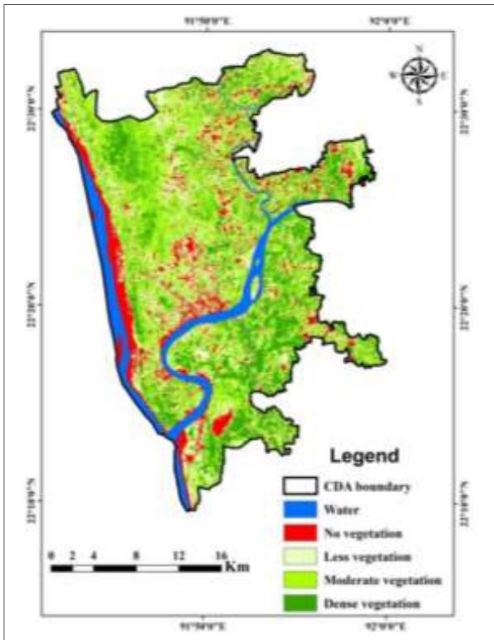
SWOT Analysis is a method used to evaluate the 'strengths', 'weaknesses', 'opportunities', and 'threats' involved in an organization, a plan, a project, a person, or a business activity (Teoli et al. 2019; GURL 2017; Leigh 2009). SWOT Analysis was conducted to determine the suitable locations of the urban green belt and the green wedges in Chittagong city for a sustainable urban environment.

3. RESULTS AND DISCUSSION

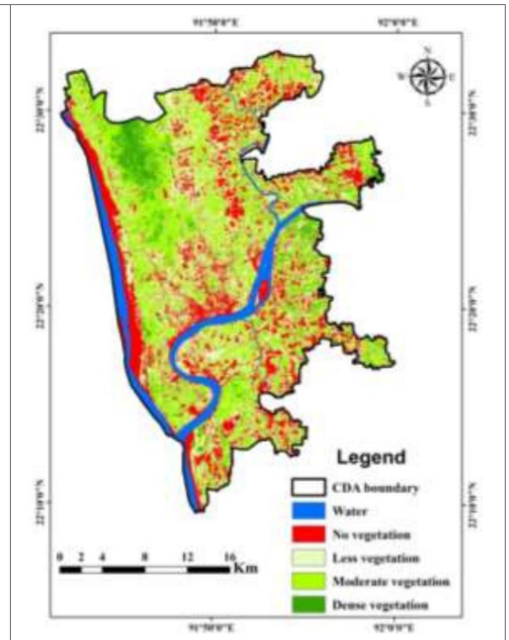
Urban green space is very significant for the sustainable urban environment because Chittagong city is facing tremendous environmental degradation. Unplanned urbanization was one of the major problems of the city. The city had a huge naturally grown urban green space that was used for various purposes. There have negative effects of urban green spaces depletion on the quality of the urban environment, although city development authorities were not enough committed to protecting the green spaces in the city. The study also identified various locations for the urban green belts and green wedges and their necessity. On the other hand, for its geographical location and expansion, all detailed planning zone (DPZ) boundaries were not suitable for the green belt, as a result of the various sites, that had needed urban green wedges mechanism. The implementation of green belts and wedges reduces environmental degradation and promotes the potential of improving biodiversity. Finally, the research assured some policy guidelines for a better urban environment in Chittagong city.

3.1 Normalized Difference Vegetation Index Classifications (NDVI) of CDA Area from 1990 to 2021

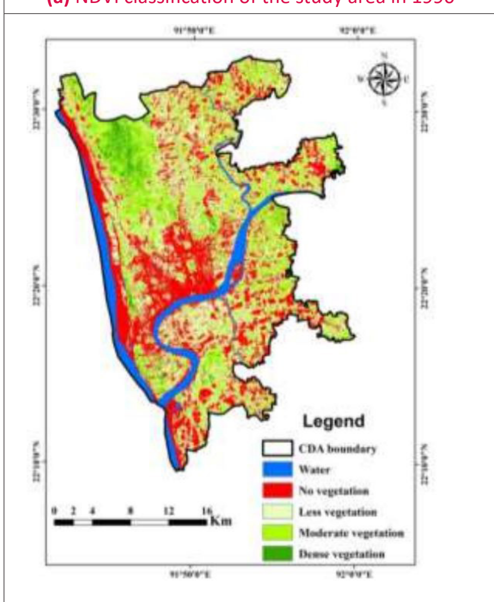
The study results found urbanization in Chittagong city played a vital role in changing the green infrastructure. The NDVI data showed that in the year 1990, the dense vegetation coverage was 22.62% but in the year 2000, it decreased to 7.02%. Sequentially, this trend continued to 2021 and it reduced to 2.86% in Chittagong Development Authority's (CDA) areas. Similarly, moderate vegetation coverage also reduced from 1990 to 2021 (32.09% to 19.45%). On the contrary, the light vegetation coverage increased from 1990 to 2021 (24.98% to 35.08%). Likewise, no vegetation coverage (11.80% to 33.00%) and water bodies (8.48% to 9.59%) increased from 1990 to 2021 in the CDA areas. Figure 2 and Table 3 demonstrate the NDVI results in CDA areas from 1990 to 2021.



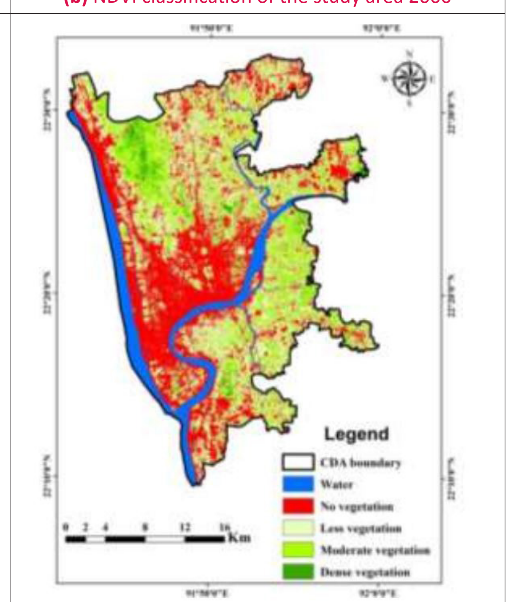
(a) NDVI classification of the study area in 1990



(b) NDVI classification of the study area 2000



(c) NDVI classification of the study area 2010



(d) NDVI classification of the study area 2021

Figure 2. NDVI classification of the study

Table 3. Normalized Difference Vegetation Index value of CDA area

Year	NDVI	Water	No Vegetation	Light Vegetation	Moderate Vegetation	Dense Vegetation	Total
1990	Area Sq.km.	57.44	79.92	169.21	217.34	153.21	677.13
	Percentage	8.48%	11.80%	24.98%	32.09%	22.62%	100.00
2000	Area Sq.km.	50.97	152.45	205.57	220.54	47.58	677.13
	Percentage	7.52%	22.51%	30.35%	32.56%	7.02%	100.00
2010	Area Sq.km.	55.81	197.00	247.92	154.26	22.13	677.13
	Percentage	8.24%	29.09%	36.61%	22.78%	3.26%	100.00
2021	Area Sq.km.	64.99	223.47	237.55	131.71	19.39	677.13
	Percentage	9.59%	33.00%	35.08%	19.45%	2.86%	100.00

3.2 Current Uses of the Green Space in Chittagong City

Modern urban planning recommends introducing more green space in the urban areas to improve environmental conditions, protect and improve biodiversity, and provide healthy urban conditions for good physical and mental well-being. The study results (KII, and SGD) showed that about 20% of existing green spaces were used for recreational and cultural purposes, and 20.56% were used for walking, playground, and physical exercise which were the highest use of green spaces in Chittagong city. Figure 3 shows the current uses of urban green spaces in Chittagong city.

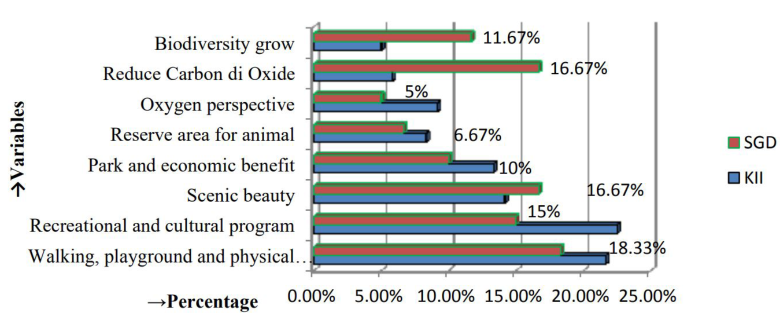


Figure 3. Current uses of the green space in Chittagong city, ***Note:** Open-ended multiple answers

Besides, the urban green spaces are also used for scenic beauty purposes (SGD, 15%, KII 13%). 9.44%, of respondents, mentioned urban green spaces contribute to carbon reduction, and 7.78% were used for the availability of oxygen. Most of the primary respondents opined that only 5% of urban green space was used for biodiversity conservation which indicates very alarming for a healthy urban environment.

3.3 Location of Urban Green Space in Chittagong City

The spatial distributions of current urban green spaces in Chittagong city were identified through IDW. The IDW results showed that the distinguished location of current urban green space in CDA areas was Fay's lake, Pahartali, War cemetery area, Chittagong Cantonment area, DC hill, North and South Khulshi area, Batali hill, CRB and Tiger pass area, and Jamal khan road. These locations are hilly and restricted. Therefore, urban administration, city planning authority as well civil societies keep their close observation due to severe environmental concerns of the city. Figure 4 displays the location of the urban green space using perception in Chittagong city.

3.4 Reasons for Decreasing Urban Green Spaces

The study indicates that urbanization was the prime reason for decreasing urban green spaces in Chittagong city (17.50%). The results of field investigation (KII and SGD) also showed that major causes of decreasing urban green spaces were increasing slum areas (9.44%), rising industry (13.33%), building settlements and construction of roads and streets (10%), lack of management (11.11%), unplanned urbanization (11.67%), lack of penalty (13.89%) and hill cutting and deforestation (8.89%) and lack of authority's awareness (5%), etc. Figure 5 demonstrates the causes of gradually decreasing urban green spaces in Chittagong city.

Figure 6(a) shows the urban green space coverage areas in 1990 and Figure 6(b) displays 2021 green spaces in Chittagong city.

Figure 6(c) shows the urban built-up areas in 1990 and 6(d) displays 2021 urban built-up areas in Chittagong city.

Besides, Table 4 demonstrates the urban built-up areas' threshold value and area of the Chittagong Development Authority from 1990 to 2021.

3.5 Suitable Areas of Urban Green Belt Suitability analysis of urban green belt and green wedges:

The study's main objective was to identify suitable locations to build urban green belts and green wedges for sustainable development. A suitability analysis maps were prepared considering six (6) indicators (distance to shoreline, elevation, road, drainage network, land use, and park) in building urban green space and green wedges. Later on, a combined map was prepared to show the magnitude of the suitability of building urban green space and green wedges in Chittagong city. Figure 7 shows the distance to shoreline, elevation, road and drainage network, land use, and parks in Chittagong city areas.

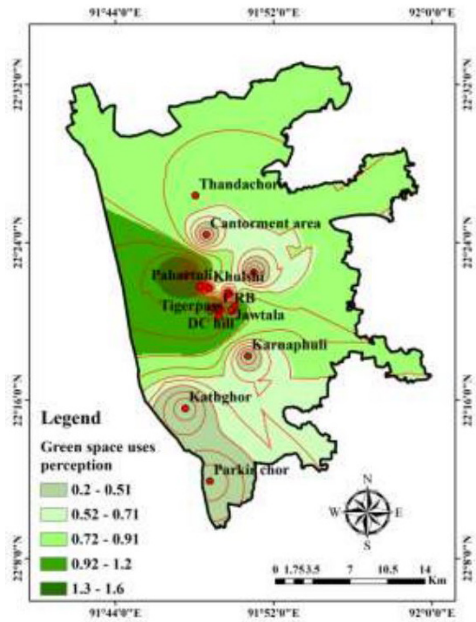


Figure 4. Location of the urban green space uses perception in Chittagong city

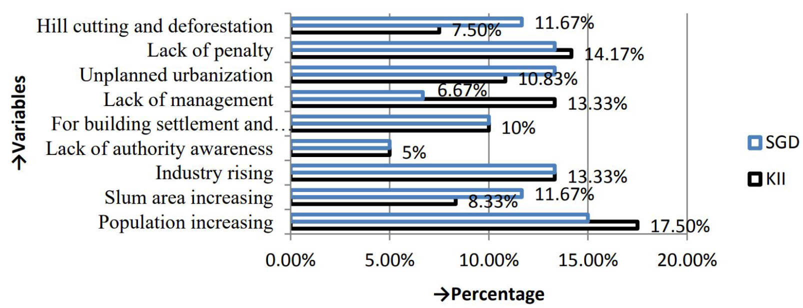
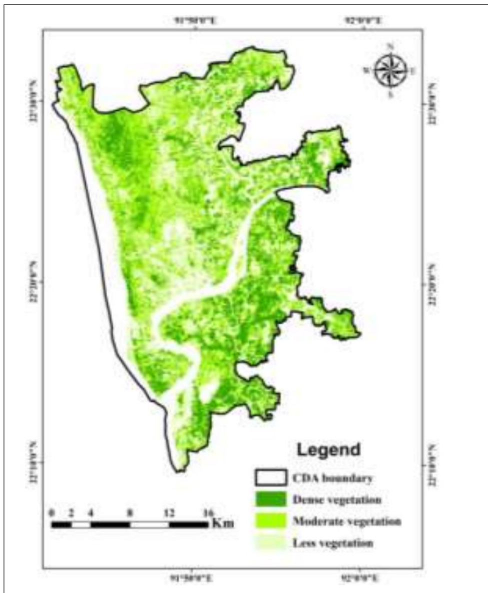


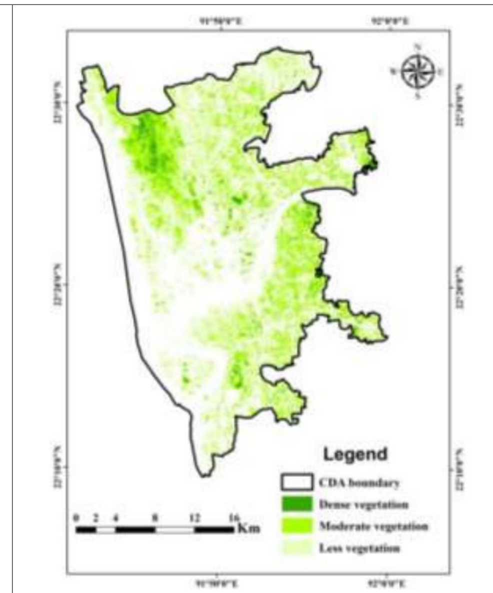
Figure 5. Reasons for decreasing urban green spaces in Chittagong city; Note: Open-ended multiple answers

Table 4. Urban built-up area threshold value and area (1990-2021)

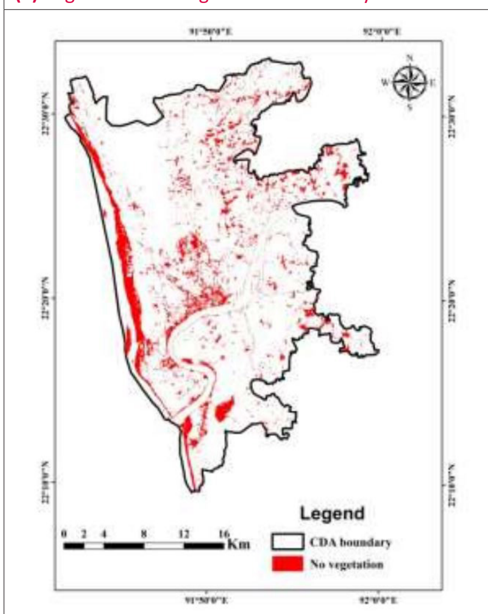
Urban and no built-up area	1990		2021	
	Threshold value	Area (sq.km)	Threshold value	Area (sq.km)
Urban area	0.08-0.347	18.64	0-0.4221	139.74
No built-up area	-0.778-0.08	658.39	-0.6708-0	537.36
Total		677.13		677.13



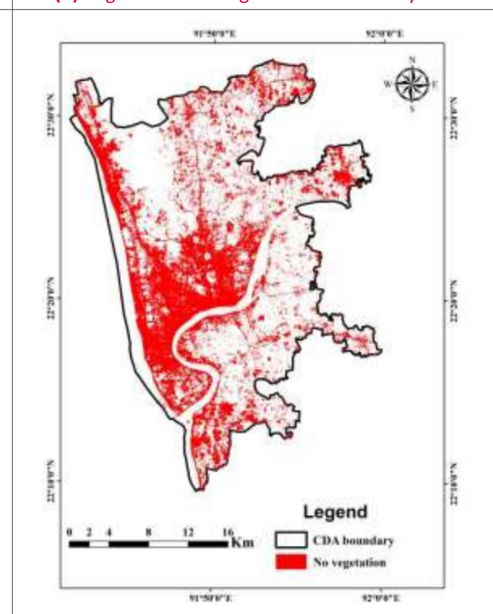
(a) Vegetation coverage of CDA boundary area 1990



(b) Vegetation coverage of CDA Boundary 2021



(c) No vegetation coverage map 1990



(d) No vegetation coverage map 2021

Figure 6. Change in urban green spaces and built-up areas from 1990 to 2021

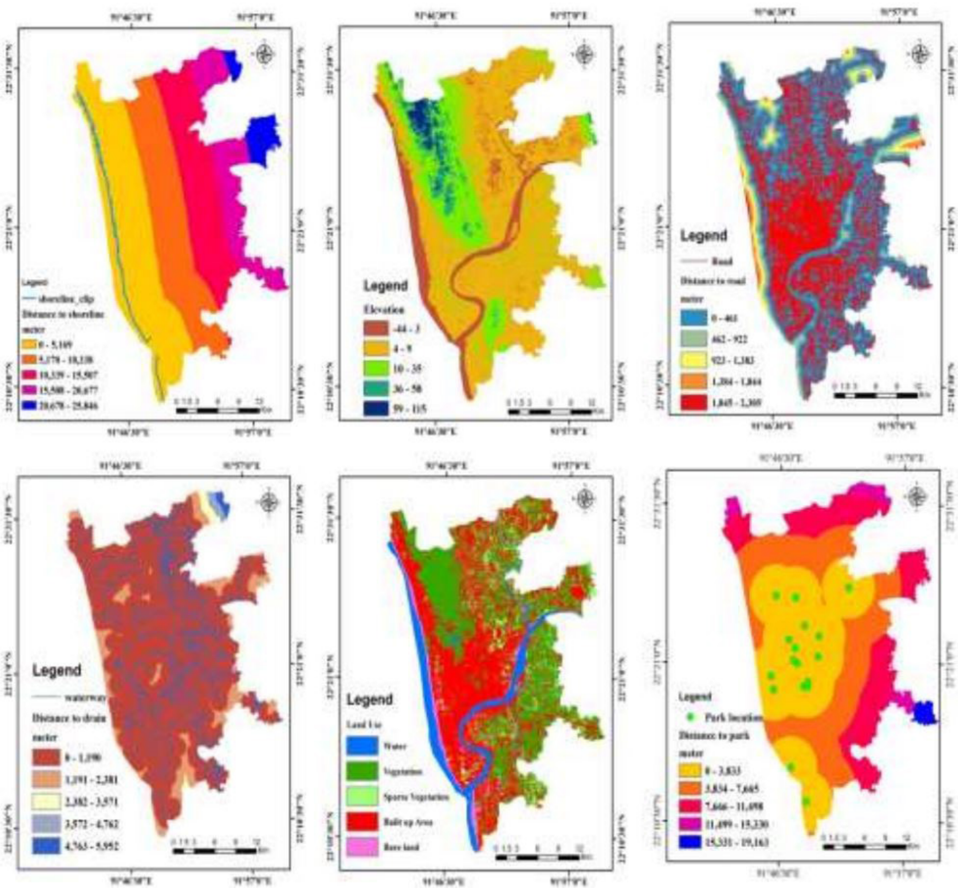


Figure 7 Distance to shoreline, elevation, road, drainage network, land use, and park-based map in the CDA area (left to right).

Figure 8 shows the suitability analysis procedure.

Figure 9 (a) shows the suitability analysis results and Figure 9 (b) proposed suitable locations for the green belt in Chittagong city.

The study results reveal that some suitable places for the urban green belt were Patenga-Halisahar coastal area (DPZ-1), Anwara-Karnaphuli coastal area (DPZ-12), Agrabad-Kattoli beach area (DPZ-2), and Salimpur- Kumira (DPZ-7) coastal and north-eastern side. Besides, some portions are in the Hathazari-Raozan area (DPZ-8). The total area of the proposed green belt was 83.6028 Sq.km which was highly suitable and 232.6032 Sq.km for moderately suitable. The widths of the green belt vary from site to site and in the coastal area, it was 220 meters to 330 meters near the DPZ-7 and DPZ-8 areas, it was 100 meters to 120 meters.

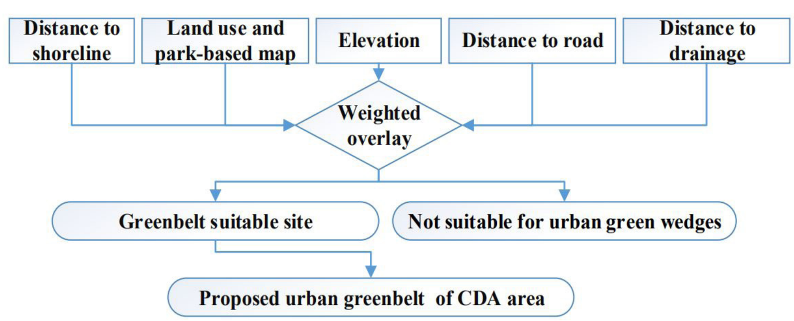


Figure 8. Suitability analysis process of urban green belt and green wedges

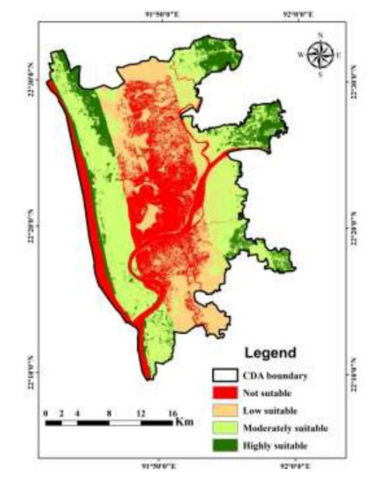


Figure 9(a) Suitability analysis for proposed green belt

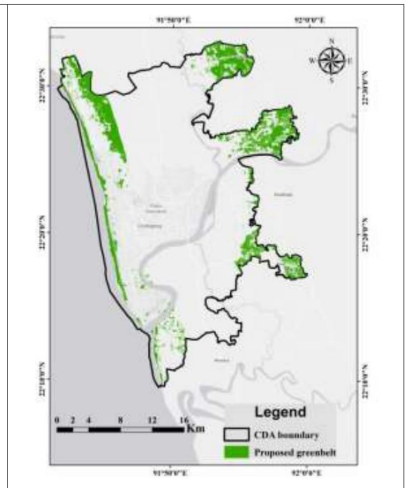


Figure 9(b) Proposed urban greenbelt in the CDA boundary area

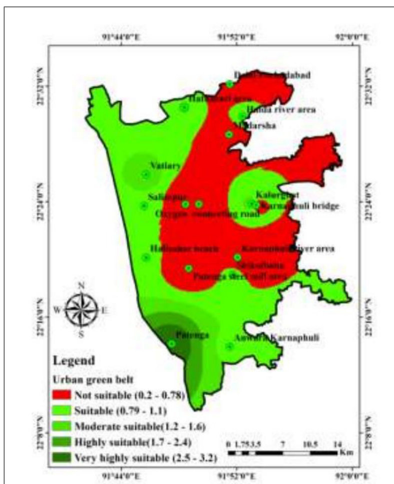


Figure 10 (a) Suitable areas of urban green belt in the CDA boundary area

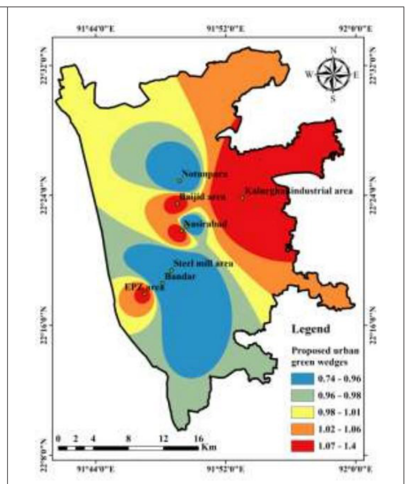


Figure 10(b) Proposed urban green wedges in the CDA boundary area

Primary field survey results also supported the remotely sensed data analysis results but in some cases showed a little variation. Primary data (KII and SGD) analysis results also identified some similar places for the urban green belt in Chittagong cities such as Shitakunda, Vatiary, Kumira, and Halisahar areas of the coastal area belt. Besides, both banks of the river Karnaphuli and Halda are also suitable for the urban green belts, especially Madarsha, Shikolbaha, and Hathazari areas. Along with these, outer road areas of Chittagong Cantonment were significantly suitable for urban green belt design. According to the primary field investigation (KII and SGD), the most suitable place for the urban green belt was Patenga and Halisahar, and the Vatiary area. Figure 10 (a) demonstrates the suitable areas of the urban green belt in the Chittagong Development Authority's boundary area.

Besides, suitable locations for urban green wedges were identified as the alternative to the urban green belt through IDW methods. Urban green wedges also promote urban environmental sustainability through plantation in the road islands and road dividers and parks system, etc. The IDW method helped to identify some suitable locations for urban green wedges in CDA areas such as Bandar, Notunpara, Kalurghat industrial area, Steel mill area (Patenga), Sholosahar (Nasirabad) area, etc. Figure 10 (b) shows suitable locations for urban green wedges in the CDA areas.

3.7 SWOT Analysis for Suitability of Urban Green Belt and Green Wedges in CDA Areas

The SWOT analysis was performed to triangulate people's (KII and SGD) perception, CDA Master Plan, Detailed Area Plan, and parameters (LULC types, elevation, distance to road, distance to drainage, distance to shoreline, and existing parks and gardens) of suitability analysis. A SWOT analysis was conducted to identify the suitable locations for urban green belts and green wedges in CDA areas. The mechanism of SWOT analysis was based on primary and secondary sources of data. Table 5 shows the SWOT analysis results on the suitability of urban green belts and green wedges in CDA areas.

3.8 Necessity of Urban Green Belt and Green Wedges in CDA Areas

Urban green belts and green wedges (UGBGW) are basic components in modern urban planning and development. Primary field survey results also exposed the necessity of urban green belts and green wedges in CDA areas. UGBGW helps to prevent cyclone and tidal surges (10.98%) and reduce the damage to lives and properties, increasing the scenic beauty (10.57%) and creating a healthy environment (10.16%). Along with these, UGBGW contributes to improving air quality (9.35%), decreasing air temperature (8.94%) and increasing physical exercise ground (8.13%), etc. Table 6 shows the necessity of urban green belts and green wedges in CDA areas.

The purpose of the urban green belt is to manage urban growth and control urban boundaries. The study results indicate that in the Chittagong city managing urban growth (7.72%) and creating networks of public transportation (1.22%) by the urban green belt was less significant. On the contrary, creating land-use zoning was very much important for the planned urban growth (KII 11.67% and SGD 26.67%). Figure 11 exhibits the importance of planned urban growth in Chittagong city.

The study also found urban green belts support controlling the chaotic urbanization (17.78%), keeping static city boundaries (16.67%), regulator unplanned urbanization (13.33%), and protecting open space (8.89%) which will help to manage planned urban growth and enhancing the quality of urban life. Specifically, UGBGW contributes to improving environmental quality such as increasing relative humidity, thermal balance, and controlling bacteria (14.44%,), lower air temperatures (13.33%), and reducing air pollution (12.22%). Table 7 shows the types of environmental quality improvement by green belt and wedges in Chittagong city.

Besides, UGBGW helps in enhancing natural landscape beauty (15%) and attracting biodiversity (23.33%) in Chittagong city. Figure 12 demonstrates the major benefits of UGBGW in attracting biodiversity in Chittagong city.

UGBGW also assists in the protection of the natural ecosystem (16.67%) and diversification of plant and animal species which are the key factors for attracting biodiversity. It creates a sanctuary for animals and birds' nests (4.44%) and contributes to balancing the food chain (11.11%) which promotes a sustainable city environment. UGBGW promotes conserving and increasing diversity in Chittagong city which delineate by various processes. Figure 13 shows the ways of conserving or increasing biodiversity in Chittagong city.

The study results indicate stopping felling trees (18.89%), strict application of the law on environmental issues (16.67%), protecting natural trees (13.33%), community awareness (13.33%), more plantations (10%), ensuring the security of animals (13.33%), and maintaining policy (14.44%) were urgently needed to conserve biodiversity which prescribed the mechanized green belt and wedges policy.

4. CONCLUSION AND RECOMMENDATIONS

Unplanned and rapid urbanization is one of the major challenges for city dwellers because of its negative impact on the lives and livelihoods of the urban neighborhood. Once WHO declared Chittagong city is healthy for its hilly area, vegetation coverage, landscape beauty, and a long sea beach to the western belt in the coastal area. Day by day the decreasing trend of the urban green spaces in the coastal area, hill cutting, and unplanned settlement and infrastructure are the reasons for the depletion of the urban green spaces and green belt near the Patenga, Halisahar, and Kattoli beach area. Chittagong Development Authority was not concerned enough to control and well-organized the naturally grown green belt although they mentioned its necessity in the Master plan and Detailed Area Plan for the urban environment. It was also found the important of implementing the urban green belt near the coastal area, on the bank of the Halda and Karnaphuli rivers for a sustainable urban environment. Besides, the alternative mechanism for the barrier of the green belt that to reduce the specific environmental degradation and delineate the improvement of the biodiversity by building urban green wedges in the Chittagong city, especially in the Patenga steel mill area, Kalurghat industrial area, Notunpara, Bandar, and Sholosahar (Nasirabad) area. Finally, the study exposed the policy guidelines for a sustainable urban environment through the implementation of urban green belt and green wedges in Chittagong city.

Table 5. SWOT analysis for suitability of urban green belt and green wedges in CDA areas

	Planning zone	Internal		External		Suitable/not suitable for urban green belt and wedges
		Strength	Weakness	Opportunities	Threats	
SWOT analysis for suitability of urban green belt and wedges in CDA areas	DPZ-1	Coastal area	Disaster-prone area	Recreational purpose	Green spaces depletion day by day	Green belt
	DPZ-2	Coastal area	Disaster-prone and heavy metal industrial pollution	Reduce disaster and pollution by coastal belt	Green spaces depletion	Green belt
	DPZ-3	Karnaphuli river and natural green spaces	Huge population density	Physical exercise Protection of the natural green space	Unplanned urbanization	Not suitable
	DPZ-4	Open spaces in the Bakalia and planned settlement (Chandgaon)	Lack of sustainable management (Bakalia) and not open spaces (Chandgaon)	Planned urbanization and sustainable land management.	Unplanned and illegal settlement (Bakalia)	Not suitable
	DPZ-5	Naturally grown green spaces	Unplanned and illegal settlement	Recreational purpose and urban ecological balance	Hill cutting	Not suitable
	DPZ-6	Hill and vegetation (Naturally grown) coverage area	Huge population density, industry	By thermal balance, reduce particle matter reduction	Hill cutting, unplanned and illegal settlement	Green wedges (Baijid area)
	DPZ-7	Coastal area	Shipbreaking industry and disasters	Animal sanctuary, Reduce flood protection and create a healthy environment	Industrial pollution	Green belt
	DPZ-8	Low population density and more greening	Agricultural field and lack of proper land-use zoning implementation	Attracting biodiversity and environmental balance by the sanctuary	Growth urban expansion	Green wedges
	DPZ-9	Halda river	Agricultural field and lack of proper land-use zoning implementation	Sustainable land management,	Unplanned urbanization	Green wedges
	DPZ-10	Halda river and natural drainage	Unplanned settlement	Sustainable land management and planned urban growth	Unplanned urbanization	Green belt (CUET area) and Green wedges (Madunaghat)
	DPZ-11	Naturally grown green spaces	Agricultural field and lack of proper land-use zoning implementation	Sustainable land-use zoning planned urban growth	Rising industry and unplanned satellite town growth	Green wedges
	DPZ-12	Karnaphuli and coastal area	Disaster-prone (Cyclone) and industrial pollution	Planned urbanization, Reducing industrial pollution	Industry and unplanned urbanization	Green wedges (Anwara industrial area) and green belt (Coastal area)

Source: Based on the questionnaire survey (2022), CDA Master Plan (1995-2015), Detailed Area Plan (1995-2015), Map analysis (GIS and remote sensing), and field Observation.

***Note:** DPZ1- Patenga-Halisahar, DPZ2- Agrabad-Kattoli, DPZ3- Sadarghat-Chawkbazar, DPZ4- Bakalia-Chandgaon, DPZ5- Lalkhanbazar-Pahartuli, DPZ6- Panchliash-Bayzid, DPZ7- Salimpur-Kumira, DPZ8- Hathazari-Raozan, DPZ9- Kulgaon-Halda, DPZ10- Madunaghat-CUET, DPZ11- Boalkhali-Patiya, DPZ12- Anwara-Karnaphuli.

Table 6. Types of the necessity of green belt and green wedges

Types of the necessity of green belt and green wedges	KII (n_1=30)		SGD (n_2=15)		Total (N=45)	%
	∑ f	%	∑ f	%		
Managing urban growth	10	6.25	9	10.47	19	7.72
Flood protection	9	5.63	9	10.47	18	7.32
Preventing cyclone tidal surges	19	11.88	8	9.30	27	10.98
Reducing riverbank erosion	10	6.25	7	8.14	17	6.91
Preventing salinity intrusion	7	4.38	7	8.14	14	5.69
Improving air quality	19	11.88	4	4.65	23	9.35
Reducing air temperature	17	10.63	5	5.81	22	8.94
Improving healthy environment	15	9.38	10	11.63	25	10.16
Increasing scenic beauty	17	10.63	9	10.47	26	10.57
Creating leisure places	12	7.50	6	6.98	18	7.32
Increasing physical exercise ground	15	9.38	5	5.81	20	8.13
Attracting biodiversity	9	5.63	5	5.81	14	5.69
Networks of public transportation	1	0.63	2	2.33	3	1.22

***Note:** Open-ended multiple answers

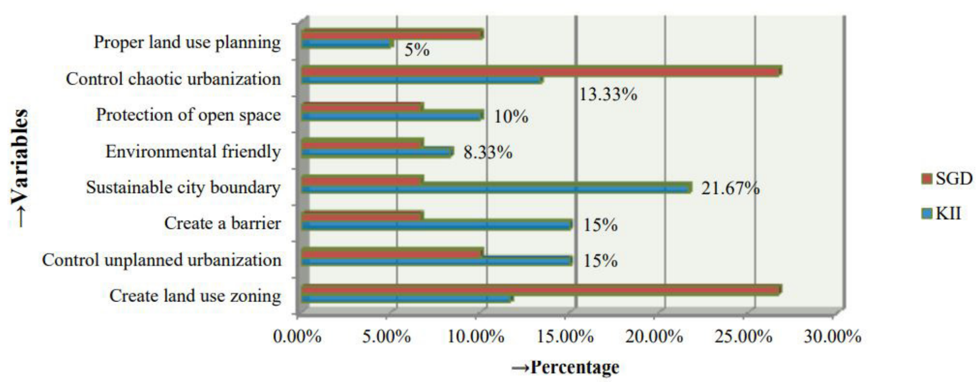


Figure 11. The green belt for sustainable and manageable urban growth
***Note:** Open-ended multiple answers;

Table 7. Types of environmental quality improvement by green belt and wedges

Improve environmental quality	KII (n_1=30)		SGD (n_2=15)		Total (N=45)	%
	∑ f	%	∑ f	%		
Lower air temperature	9	15.00	3	10.00	12	13.33
Improve air quality	4	6.67	2	6.67	6	6.67
Reduce air pollution	9	15.00	2	6.67	11	12.22
By thermal balance	6	10.00	7	23.33	13	14.44
Increase relative humidity	8	13.33	5	16.67	13	14.44
Control bacteria rate	11	18.33	2	6.67	13	14.44
Decreasing Carbon di Oxide rate	5	8.33	5	16.67	10	11.11
Particle matter reduction	4	6.67	3	10.00	7	7.78
Medicine purpose	4	6.67	1	3.33	5	5.56
					90	100.00

***Note:** Open-ended multiple answers;

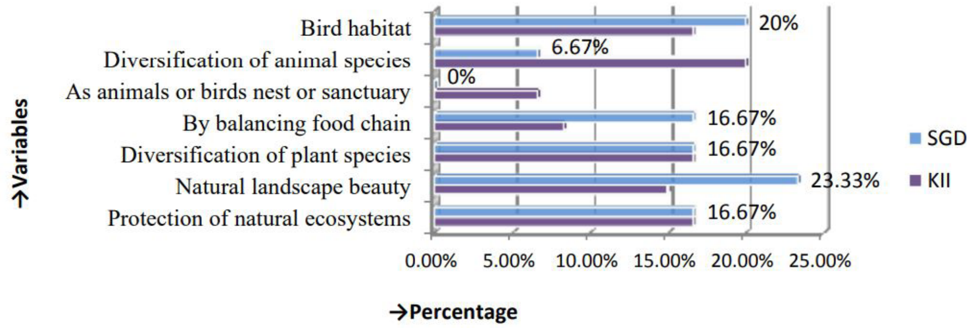


Figure 12. Attracting biodiversity by green belt and green wedges
***Note:** Open-ended multiple answers;

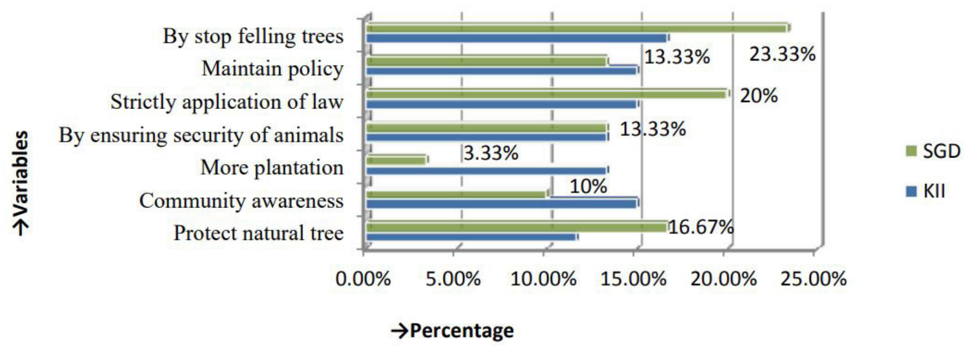


Figure 13. Conserve or increase biodiversity by green belt and wedges
***Note:** Open-ended multiple answers;

Hence further research on the necessity of urban green belts and green wedges was urged as well as national policy-level, institutional level, community-based and individual initiatives were advised to protect urban green spaces especially naturally grown belts in the coastal and river belt area.

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