UNDERSTANDING THE SPATIAL PATTERNS OF GREEN SPACES FOR 2000-2016 IN THE CITY OF AHMEDABAD

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Abstract: Urban Green Spaces (UGS) has numerous amenity values for recreation, socialization, environment, leisure, aesthetic, etc. well documented in many research studies to enhance and maintain the urban quality of life. Most studies focus on evaluating the functional benefits of green spaces or on other aspects of it like conservation and preservation. However, little is been known about the dynamics of spatial change of green spaces in terms of their geometry, landscape and arrangements. This paper studies the temporal as well as spatial change of green spaces in comparison to other classes like agriculture, vacant land, built up, water body and roads. Ahmedabad city has been chosen for this empirical study over the period of 2000 to 2016 due to high level of infiltration of people over the last decade along with maintaining its high urban green spaces compared to other growing cities of India. The study takes help of remote sensing Landsat USGS image data and GIS derived landscape metrics for its spatial analysis. Percentage changes in different classes of urban land cover especially vegetation were calculated for Ahmedabad city and each of the thirty seven common wards eliminating the six wards of old city for the year 2000 and 2016. The changes in landscape metrics, viz, class area, no. of patches, patch density, mean patch size, patch size standard deviation, edge density, mean shape index, area weighted mean shape index and largest patch index for Ahmedabad city as well common wards were calculated. These landscape metrics are only limited to shape and size measures of geometry for class of vegetation in this study. It revealed vegetation area is increased by 3% towards the periphery and decreased by 4% in the core of the city whereas total built up increased by 18.4%. Further, increase in vegetation shows increase in number of green patches, edge density, shape regularity, largest patch index and mean patch size except the few wards. It reveals contrasting pattern of sparse and conglomerated distribution of vegetation and its form of conversion. These patterns evolved over a period of 16 years helps to understand the spatial and physical behaviour of green spaces and other classes. Understanding such patterns deeply can assist for better urban planning monitoring, strategies and decisions. It should provide insights and aid in government policies for urban planning and conservation. The simulation of GIS applications in the study helps for analytical thinking and spatial tool-based planning.

Keywords: Green Spaces, Landscape Metrics, GIS, Ahmedabad, Spatial Pattern.

Introduction: Urban green spaces broadly classified as vegetation found in urban boundaries in the form of parks, open spaces, gardens, street landscaping, urban forests, cemeteries, city squares, etc. can help to improve the urban quality of life. In wake of climate change and rising urbanization green spaces provides relief measures like reduction in noise pollution by acting as a barrier, air pollution by providing fresh air and counteracting high surrounding temperature by their cooling mechanisms. In addition to that, green space have important social aspects attached to it acting as a common place for interaction among communities within a neighbourhood. It helps in increasing the native biodiversity of locality.

Human have innate desire to be close to nature however they modernize themselves and kindle earnestly in increasingly cramped and compact city. Often, habitation is preferred towards cities which have natural features such as open spaces, water bodies or forests, example; city of Patna, Vijayawada, Panaji, etc. This desire of humans in modern societies can be seen in their actions by taking leisure nature trips, weekend picnics to a park, going for a hike, buying houses near beaches or on a hill. These actions reflect the importance of green spaces and nature in the lives of human even in modern urban society. Urban green spaces play an important role in creating healthier societies by reduction in stress levels and psychological relaxation. Apart from positive influences of green spaces, negative implications have also been observed in some cases. For instance, surveys conducted by Bixler & Floyd in 1997 suggests residents staying near to unmanaged wild green spaces feel insecure and fearful of crime. Some may also face allergic reactions due to pollen of plants. But, positive benefits are far off than its negative effects.

All of these studies report on functions of green spaces in and around urban areas, little studies have shown its temporal and spatial change with the help of technological advancements in GIS and remote sensing data recently. The historical background and change over a period of 16 years from 2000 to 2016 can reveal a lot more findings than that of a study aimed at a particular snap shot in time. The changing dimensions and geometry of any class of an urban landscape will reveal some patterns or trends which can be further be investigated in detail at smaller scales. The revelation may help to solve the conflicting nature of influences by urban green spaces if we have more clarity and understanding on the form or physical aspects of it. It can act as a support study for other research studies based on functional parameters of urban classes. We aim to understand this different evolving spatial pattern of green spaces with respect to other urban classes especially built up. This is done with the help of three USGS Landsat maps of different timeline and corresponding landscape metrics extracted into two phase one at city scale and one at ward scale.

Introduction to Case Area – Ahmedabad: Ahmedabad city has been chosen for this empirical study due to high level of infiltration of people over the last decade maintaining its high urban green spaces than other cities. Ahmedabad is the 3rd fastest growing city in the world in 2010 as per Forbes magazine in the world in 2010. Ahmedabad has 202 public parks and gardens covering 1.92 sq.km area of land-use (other green spaces have not been accounted in this area). And as per Tree Census - 2012 Total no. of trees in the City - 6.18 lakhs. Thus, total area covered under green space = 4.66 %. The population of Ahmedabad has increased at the annual growth rate of 5.6% from 35.35 lakhs to 55.85 lakhs in the jurisdiction of Ahmedabad Municipal Corporation. Also, the no of wards and area has been increased to 57 from 43 and 449.9 sq.km from 302 sq.km between 2002 & 2008 respectively. The changes were made in the revised master plan of 2011 from the master plan of 2002 of Ahmedabad as shown in the landuse maps.

The Study done by Allen Bertaud and others on Ahmedabad in 2013 have developed the public land inventory including green spaces within the boundary of Ahmedabad Municipal Corporation (AMC). The study suggests that significance of public land on total availability of buildable land could add considerably to the usefulness of current records of land holdings. This helped to understand the existing scenario of land use in contrast to public lands and green spaces. Another Study by Soumya Desai in 2011 of CEPT University in Ahmedabad concluded that Ahmedabad has remained as a Compact City compared to other Metropolitan cities like Bengaluru and Hyderabad. Thus, Ahmedabad would make up for good case area having the combination of compactness as well as abundant green spaces within its municipal boundary. The old city wards are eliminated from the study because of its urban form and arrangement.

Data and Analytical Methods:

Land Use Land Cover -

For our study, USGS (United States Geological Survey) Landsat image data is the primary source of data regarding change in urban land cover of Ahmedabad. USGS is a scientific organization set up by Government of United States in 1879 to study landscape in its natural and geological form. It is a research organization with no regulatory obligations. Landsat Mission is a joint initiative between the USGS and NASA (The National Aeronautics and Space Administration) to collect moderate resolution remote sensing land data.

The Landsat 8, 7 & 5 image data were used for extraction of Land Use/Land Cover (LULC) Maps for the year 2016, 2008 and 2000 (resolution of 30m x 30m) with the help of supervise classification in ArcGIS. The year 2000 in the study was chosen because of the fact that census of India carries out its demographic census every 10 years at the start of the decadal year, i.e., in 2001, 2011 and so on. The study thus can further draw inferences from its comparable demographic data. Also, the year 2016 was chosen because that was the latest year for which the Landsat data was available. Further, the images selected are for the months of December, June and October for Landsat 8,7 & 5 which were freely available as well as had clear sky and weather conditions (cloudiness < 20%). The use of Landsat has clear advantages of free availability of data for three points in time (2000, 2008 and 2016) and even before, methodological consistency comparable to every other city of India or World, and finally the overall classification accuracy has been achieved near to 75% by Kappa Coefficient Method. Landsat also has disadvantages as that of moderately high resolution, given that mapping unit of green spaces or other urban classes less than $900m^2$ won't be captured and analysed. This makes it difficult to analyse the neighbourhood scale of 1 km^2 to 2 km^2 grid with the same resolution image data. Furthermore, it has discrepancy data with respect to the different seasons summer and winter prevailing in months of June and December in Ahmedabad which can affect the amount of vegetation on the total land cover. Despite these disadvantages we use Landsat as a data source due to its data quality and classification adopted in this paper gives reasonable results.

To delineate urban and ward boundaries of Ahmedabad, we used the land use shape files for clipping on Landsat image provided by AMC. The GIS boundary shape files of the year 2002 is used for the Landsat image of year 2000 and 2008 and shape file of the year 2011 is used for the Landsat image of year 2016 respectively.

To maintain the uniformity and consistency of data it was necessary to choose ward as a scale rather dividing the city into a certain grid fashion (1 km^2 or so) as the census and all other official government data are collected at ward scale.

The data we get from USGS is raw, which needs to be processed in the software for atmospheric reflectance so that the image becomes clearer and then the stacking and mosaicking of different bands are done to get the desired output. The next step is followed by the process of creating LULC maps through supervise classification also known as maximum likelihood classification.

The supervise classification is more common and accurate because it considers human image interpretation and collects signatures files for making feature classes of water body, built up, roads, vegetation and agriculture. Besides, in unsupervised classification the software itself classifies the image into specified number of classes for making feature classes by grouping nearly matching pixel values which increases the chances of error accumulation. Training samples for supervise classification are mapped with the help of google earth and existing land use plans. The Maps generated in ArcGIS version 10.3 as shown below in fig 1.a, b & c.

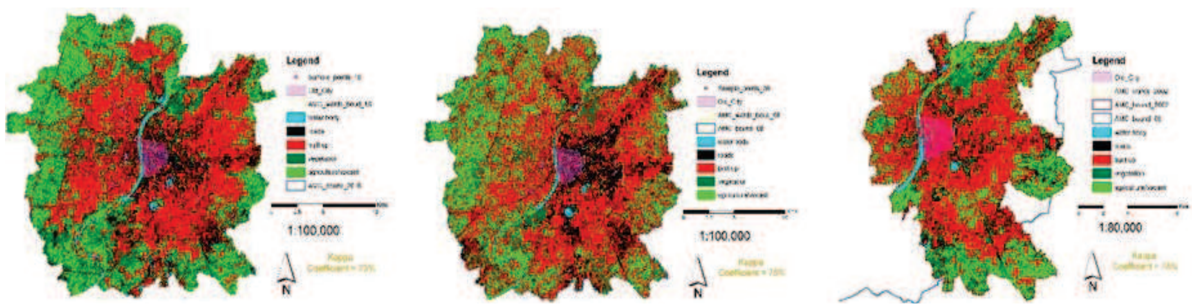

Fig. 1: A, B, C: Semi-Supervise Classification of Ahmedabad By Landsat 8, 7 & 5 For The Year 2016, 2008 & 2000 Respectively

Once, a map is generated geometric error clusters incorrectly labelled and undistinguishable classes. Thus, to identify source of error and minimize them, it is necessary to check for its accuracy before it can be used for analysis. This accuracy assessment is done by Kappa Coefficient (k) method which takes into account the possibility of the class occurring by chance. This accuracy rate represented by 0 to 100% in the range of 0 to 1. It derives an index for agreement between the already classified map and the reference data. This is done with the help of total 151 ground truth surveys and sites distributed randomly covering maximum area of Ahmedabad. These are unbiased reference points which are collected after classification and hence are not used to train the algorithm for classification. Below are the confusion matrix is generated as given by Cohen Kappa.

Count of Value	Column Labels	Classes_2016					
Row Labels	1	2	3	4	5	Grand Total	Individual Accuracy
water body	21	0	0	0	0	21	100.00
roads	13	37	1	0	0	51	72.55
built up	0	0	27	0	0	27	100.00
vegetation	0	6	0	17	3	26	65.38
agri/vacant	1	1	8	7	9	26	34.62
Grand Total	35	44	36	24	12	151	74.51 = OA

Count of Value	Column Labels	Classes_2008					
Row Labels	1	2	3	4	5	Grand Total	Individual Accuracy
water body	18	0	1	0	0	19	100.00
roads	12	32	3	0	0	47	68.09
built up	0	0	24	0	0	24	100.00
vegetation	1	6	1	19	3	30	63.33
agri/vacant	1	1	3	4	14	23	60.87
Grand Total	32	39	32	23	17	143	78.46 = OA

Count of Value	Column Labels	Classes_2000					
Row Labels	1	2	3	4	5	Grand Total	Individual Accuracy
water body	13	0	0	0	0	13	100.00
roads	11	28	1	0	0	40	70.00
built up	0	0	26	0	0	26	100.00
vegetation	0	4	2	18	3	27	66.67
agri/vacant	1	1	2	3	14	21	66.67
Grand Total	25	33	31	21	17	127	80.67 = OA

Tables 1: A, B, C: Accuracy Assessment of Generated Maps For The Year 2016, 2008 & 2000

Kappa coefficient and accuracies were improved in between 75% - 80% mark by redoing the exercise with a modified approach. The earlier generated unsupervised imagery with ten classes were reclassified into five classes along with training samples to give improved accuracy.

Landscape Metrics -

The following are the landscape metrics which will be studied:

- Class Area (CA): CA equals the sum of the areas (m^2) of all patches of the corresponding patch type divided by 10,000 (to convert to hectares). Range - 0 to no limit
- Number of patches (NP): NP equals the number of UGS patch type. Range 1 to no limit
- Patch Density (PD): PD equals the percentage of patches in hectares per class to the landscape. Range - 0 to 100% constrained by ward area.
- Largest Patch Index (LPI): LPI equals the area (m^2) of the largest patch of the corresponding patch type divided by total landscape area (m^2). Range - 0 to 100%
- Mean Patch Size (MPS): MPS is the area occupied by a particular patch type divided by the number of patches of that type. Range - 0 to no limit.
- Patch Size Standard Deviation (PSSD): PSSD shows the standard deviation in the patch areas of a particular class in hectares.
- Edge Density (ED): ED is the amount of total edge per class relative to the landscape area in metres/hectare. Range - 0 to no limit constrained to ward area.
- Mean Shape Index (MSI): MSI is equal to 1 when all patches are circular (for polygons) or square (for raster grids) and it increases with increasing patch shape irregularity. It is a measure of shape complexity. Range - 1 to no limit
- Area Weighted Mean Shape Index (AWMSI): AWMSI differs from the MSI as its weighted by patch area so larger patches will weigh more than smaller ones.

These landscape metrics are only limited to shape and size measures of geometry for class of vegetation in this study.

Analysis: Percentage changes in different classes of urban land cover especially vegetation were calculated for referenced city and each of the 37 common wards for the year 2000 and 2016. We also calculated the percentage changes in landscape metrics for vegetation for Ahmedabad as well as common wards to explore the variations given an attribute of a physical form. The landscape metrics were extracted from the improved supervise classified raster maps with the help of Patch Analyst Tool of ArcGIS 10.3 and modified in Fragstat 4.2 software. Raster added maps for vegetation and builtup were generated divided into four major categories of stable class, increase in class, decrease in class, stable other classes. To assess the changing dynamics of urban form and green space, were associated spatially shown in the form of maps and pie charts below in fig 2 & 3. To draw comparison between the city as a whole and individual ward studying the form of green space, descriptive statistics of landscape metrics were introduced. To analyse it spatially, vectors maps for four parameters of size and three parameters of shape were then made as shown in Fig. 4.

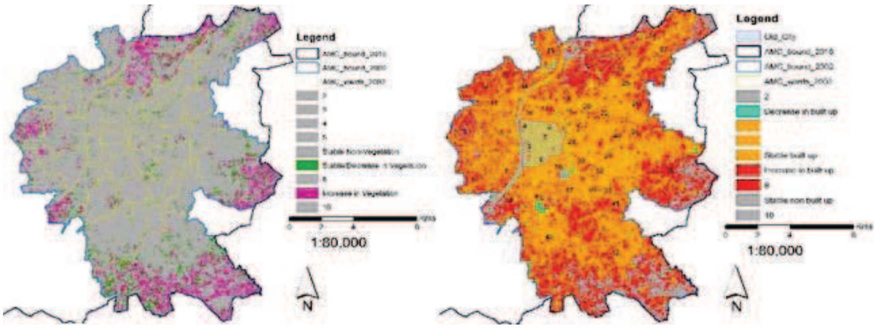

Fig. 2: Change Detection of Vegetation & Builtup from 2000-16

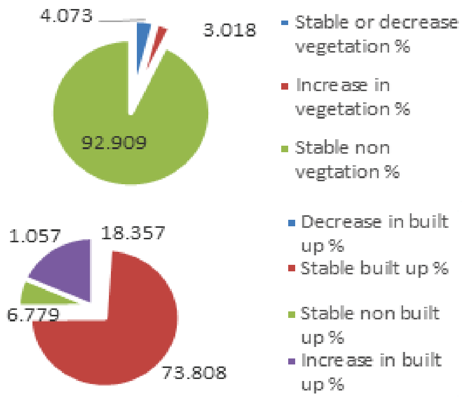

Fig. 3: City Distribution of Vegetation & Builtup Change From 2000-16

Results and Discussion: There is overall increase of 18.4% in builtup mostly outwards of the city. Also, the amount of vegetation is decreased in the core of the city to near about 4% converted to builtup area. The point of interest here is along with the increase in builtup there is also a considerable increase in vegetation of 3% towards the periphery. This shows that recent planned development has contributed in a way for environment. But, more robust mechanisms are indeed required in development to increase the percentage of vegetation as well as control market.

Our focus was to see the emerging trends in shape and size of conglomerated and distributed green patches that has increased over the decade. Increase in vegetation ward wise was associated with increase in number of green patches except for ward Odhav and Naroda-Muthiya where it shows vice-versa. In Odhav, it was found that all the three PSSD, LPI and MPS has increased which states that patches have merged or gaps in between them have filled to make more no of larger patches having edge to edge connectivity. In fact, in Odhav agriculture/vacant lands have converted to vegetation patches more towards the outskirts than 55% total builtup towards the inside. This can be more certain as there is less chance of climatic seasons affecting the vegetation growth on both the Landsat images. Since, autumn is prevalent in the month of October and fall in the month of December for India. The decrease in Narod-Muthiya number of green patches can be related to decrease in overall vegetation and LPI.
Further investigation in these wards on ground may substantiate the results

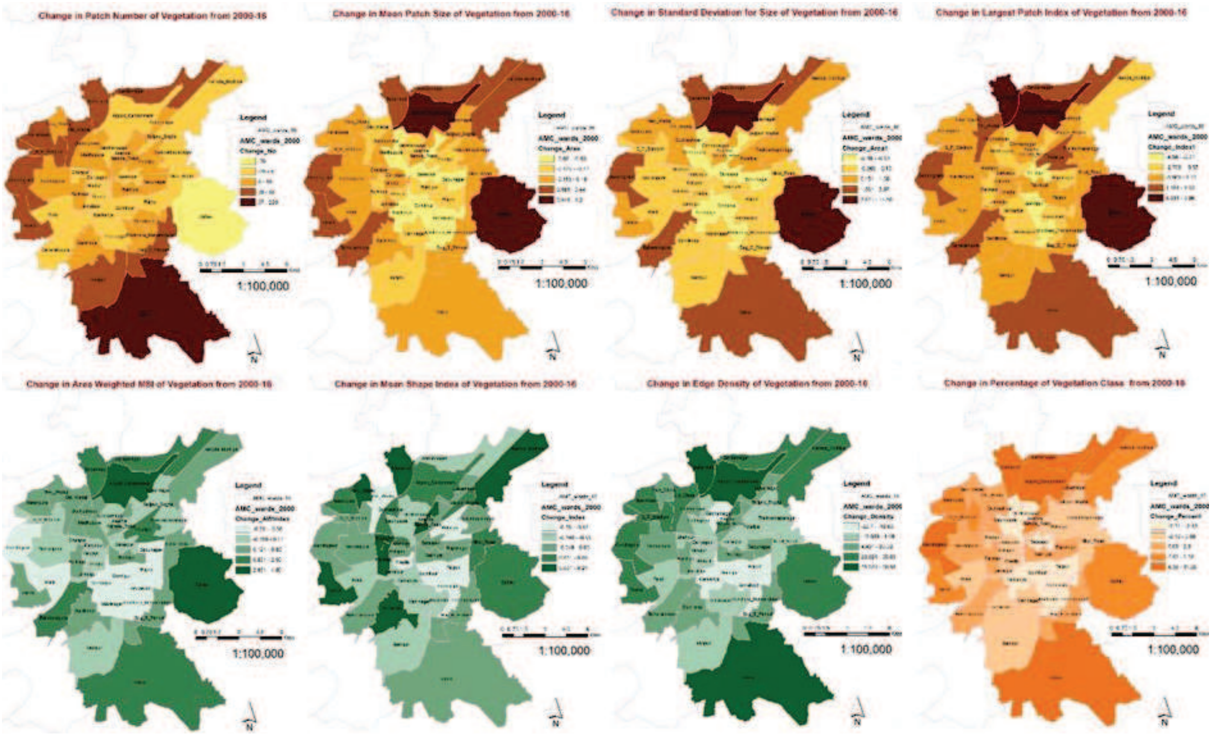

Fig. 4: Thematic Maps Showing Change of Landscape Metrics

Also, other peripheral wards like Vatva, Airport-Cantonment, S.P. Stadium, Sardarnagar and Sabarmati are major gainers upto 8% increase in vegetation from 2000. They all show increase in NP, MPS, LPI and PSSD except Vatva which shows decrease in MPS meaning sparse distributed patches and random vegetation unlike in ward of Odhav.

The edge density of green patches of all wards have increased with increase in vegetation. The area weighted mean shape index provide efficient insights as compared to mean shape index observed in case of wards of Vatva, Odhav, Naroda-Muthiya and Sardarnagar. The association of these results is linked to their large patch index clearly visible in the maps of Fig 4.

Landscape metrics are widely used for the study of habitat in various ecosystems at larger scales to study the climate change and species behaviour with changing ecosystems. But, rarely used in the context of an urban canvas. The introduction of landscape metrics in to studying of urban green spaces or urban form as a whole reveals some unusual findings which can be utilized for policy level as well as grass root design level interventions. In fact, the possibilities of analyzing it is endless clubbed with numerous other parameters.

As previous studies done on ecosystems of grassland, forest, etc. suggests size, area or core area of the patch especially green patch will have greater impacts on its design, accessibility, vulnerability and functions than shape or fractal dimensions. But, it will much depend on existing planning norms, DCRs and tools for implementation if it's an urban context.

Conclusion: Digital analyses of Landsat images during the past 16 years along with the introduction of landscape metrics for vegetation was carried out. It revealed vegetation area is increased by 3% towards the periphery and decreased by 4% in the core of the city whereas 18.4% total built up increase. The variations of landscape metrics ward wise reveal the patterns of change in dimensions of green patches which can be further analysed with ground truth. The results represent the foundation regarding the new challenges and possibilities for urban planning improving quality of life for its residents. This remote sensing generated resulted can act as a primary source of data for further investigation at neighbourhood levels with the add on of social, demographic and climate change data. Furthermore, it can be expanded by detailing out the types of green spaces like parks, gardens, cemeteries, forests, street landscape, waste lands, etc. with finer resolution imagery data. Also, weightage can be given to landscape metrics to eliminate the chances of influence prominent for change in smaller size wards than bigger size wards. It shows meaningful impact of GIS based tools in urban planning.

References:

1. Nadja Kabisch and Dagmar Haase. "Green spaces of European cities revisited for 1990–2006". Landscape and Urban Planning 110. Elsevier. (2013): 113– 122.
2. Zongming Wanga, *et al.* "Shrinkage and fragmentation of marshes in the West Songnen Plain, China from 1954-2008 and its possible causes". International Journal of Applied Earth Observation and Geoinformation 13. Elsevier. (2011): 477–486.
3. "The Death and Life of Great American Cities". New York: Random House. (1961): ISBN 0-679-60047-7.
4. Dempsey, Nicola. "Revisiting the Compact City?" Built Environment 36(1). (2010).
5. G. B. Dantzig and T.L. Saaty, "Compact City: Plan for a Liveable Urban Environment". W. H. Freeman, San Francisco. (1973).
6. Kaid Benfield. "The Country's Most Ambitious Smart Growth Project". The Atlantic. (July, 2011).
7. B. Goodall "Dictionary of Human Geography". London: Penguin. 1987
8. Helen Webberley. "Town-planning in a Brand-New City." Brisbane: AAANZ Conference. (2008).
9. Peter Hall and Colin Ward. "Sociable Cities: The Legacy of Ebenezer Howard". John Wiley and Sons. (1998): p. 41.
10. Resolution adopted by the General Assembly - UN. "Transforming our world: the 2030 Agenda for Sustainable Development". (September 2015): 70/1.
11. Alfirevic Djordje, *et al*. "Interpretations of Space Within Space Concept". Contemporary Open-Plan Architecture No.42. (2016): pp. 24–40.
12. Paul James, Meg Holden *et al.* "Managing Metropolises by Negotiating Mega-Urban Growth". Harald Mieg and Klaus Topfer. Institutional and Social Innovation for Sustainable Urban Development. Routledge (2013).
13. Smith Morris, et al. "British Town Planning and Urban Design". Longman, Singapore. (1997): ISBN 0-582-23496-4.
14. M. Jansson. "Green space in compact cities: the benefits & values of urban ecosystem services in planning". Nordic Journal of Architectural Research 2. (2014): 139-160.
15. C. Y. Jim. "Green-space preservation and allocation for sustainable greening of compact cities". Elsevier: 2004.04.004.

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