CHAPTER: IV

URBAN LANDSCAPE ANALYSIS USING SPATIAL MATRICES

4.1 Introduction

Urban Sprawl is a pattern and rate of land use in which the pace of land consumed for urban purposes exceeds the rate of population growth, resulting in a disorganized and consumptive use of land and its allied resources. This trend is characterized by an unplanned and irregular pattern of growth, attributed to a host of processes apparent from lack of basic services. Urban sprawl is thus a term often used variously to mean the excessive use of land, uninterrupted monotonous development, leapfrog discontinuous development and inefficient use of land that are influenced by a many of factors, including land features, infrastructure, policies, and individual characteristics.

Urbanization has significantly changed natural landscapes everywhere. Urban growth and fragmentation caused by urban sprawl have been extensively studied (Herold et al., 2002; Ji et al., 2006; Tang et al., 2006; Gonzalez-Abraham et al., 2007).

It has been seen that landscape pattern is more fragmented around city centers and along coastlines, where urbanization and human economic activities are more concentrated (Yang and Liu, 2005). There are several possibilities as to how to use landscape metrics to detect spatial patterns caused by urbanization. For example, Seto and Fragkias (2005) calculated and analyzed landscape metrics spatiotemporally across three buffer zones, but another effective approach for analyzing systematically the effects of urbanization on ecosystems is to studying the changes in ecosystem patterns and processes along an urban-to-rural gradient (McDonnell et al., 1997). Studies of landscape pattern change along an urban-to-rural gradient focus on the identification of urban texture – whether urban landscapes have unique "spatial signatures" that are distinguishable from other types of landscapes (Weng, 2007). In many studies only land use changes in space are considered (Luck and Wu, 2002; Hahs and McDonnell, 2006; Conway and

Hackworth, 2007), but landscape pattern also changes over time. Spatiotemporal gradient analysis makes it possible to determine how the urban centre has shifted in space and time (Wu et al., 2006; Xie et al., 2006; Weng, 2007).

This is characterized by low levels of some combination of eight distinct dimensions such as density, continuity, concentration, clustering, centrality, nuclearity, mixed uses and proximity (Sudhira, et al., 2004; Ramachandra, et al., 2012a). Process of urbanization bring the development of a region (Verzosa and Gonzalez, 2010), which could be planned (in the form of townships) or unplanned (organic). Unplanned urbanization leads to the haphazard or irregular growth with the loss of green spaces and water bodies. Dispersed urban growth without proper infrastructure and basic amenities is often referred as sprawl (Yeh and Li, 2001; Sudhira et al., 2004; Verzosa and Gonzalez, 2010) and this phenomenon is widespread in developing countries (Bhatta et al., 2010).

The spatial patterns elucidate the heterogeneity and complexity of the urban patches in the landscape (Uuemaa et al., 2009)

Landscape structure is a prime factor in analysing the pattern and effects the various natural processes (Molles, 2006), which is determined by size, shape, composition of land use patches within the landscape. The analysis of structure of the landscape is essential to understand the implications of land use changes. In this regard, spatial metrics with a clear mathematical structure help to understand and measure the spatial patterns of urbanization

Evaluation of landscape dynamics qualitatively and quantitatively aids in understanding the changes and help to determine the effect of anthropogenic activities (Sudhira et.al. 2004, Ramachandra et al, 2012; Bharath et al, 2012; herold et al, 2005). The application of landscape metrics to Spatio-temporal data helps in analyzing the urban footprint. Landscape metrics aid in quantifying the spatial pattern of a particular landscape changes within the geographical area (Herold et al., 2005; Ji et al., 2004). These metrics enables to quantify the landscape with respect to spatial dimension, alignment, pattern at a specific scale and resolution

Spatial metrics can be computed using Fragstats and Patch Analyst. Fragstats is designed to compute a wide variety of spatial metrics to understand landscape dynamics (McGarigal and Marks, 1995).

The quantification of spatial heterogeneity is necessary to elucidate relationships between ecological processes and spatial patterns (Turner, 1990; Turner et al., 2003). Therefore, the measurement, analysis and interpretation of spatial patterns receive much attention in landscape ecology (Haines Young and Chopping, 1996). A great variety of metrics for landscape composition (e.g., the number and amount of different habitat types) and configuration (the spatial arrangement of those classes) was developed for categorical data. Software packages are widely used (e.g., FRAGSTATS, see McGarigal and Marks, 1995; McGarigal et al., 2002), and many metrics have been integrated into existing geographic information system (GIS) software (e.g., Patch Analyst in ArcView; and module Pattern in IDRISI).

On the one hand, this study determines the rapidly changing land cover and its effect on the landscape elements and on the other hand, it possibly will study the effect of landscape metrics on varied spatial extent i.e class, patch, and landscape. Thus, suggesting that these metrics can be applied at different extents while not affecting the overall inferences drastically. Finally, it concludes stressing the utility of landscape metrics as potential tools, which can be employed for formulation of land-use policies for future urban expansion. This application will enable the understanding of the nature and anthropogenic changes, allowing the corrective measures that can be taken, along with the new policy development.

The indices in different scale possess the challenge to the evaluator, as it is the nature of interaction that is to be considered for deriving the conclusion.

Class indices represent the spatial distribution and pattern within a landscape of a single patch type; whereas, landscape indices represent the spatial pattern of the entire landscape mosaic, considering all patch types simultaneously.

Most of the class indices act as fragmentation indices because they measure the configuration of a particular patch type; whereas, most of the landscape indices can be interpreted more broadly as landscape heterogeneity indices because they measure the overall landscape pattern. Hence, it is important to interpret each index in a manner appropriate to its scale (patch, class, or landscape).

4.2 Materials

The temporal LULC maps were used with the 30 meters resample resolution. FRAGSTATS tool, LecoS tools are used on the open source GIS software, QGIS.

4.3 Methodology

Computation of spatial metrics: Spatial metrics are helpful to quantify spatial characteristics of the landscape. Select spatial metrics were computed to analyse and understand the urban dynamics through FRAGSTATS (McGarigal and Marks in 1995) at three levels: patch, class and landscape levels.

FRAGSTATS is a computer software program designed to compute a wide variety of landscape metrics for categorical map patterns. The original software (version 2) was released in the public domain during 1995 in association with the publication of a USDA Forest Service General Technical Report (McGarigal and Marks 1995). Since then, hundreds of professionals have enjoyed the use of FRAGSTATS. Due to its popularity, the program was completely revamped in 2002 (version 3). Recently, the program was upgraded to accommodate ArcGIS10 (version 3.4). The latest release (version 4) reflects a major revamping of the software, with a completely redesigned architecture intended to support the addition of cell-level metrics and surface pattern metrics, among other things. The current release of version 4 (v4.2) has essentially the same functionality as version 3, but with a new user interface that reflects the redesign of the model architecture, support for additional image formats, and a variety of sampling methods for analyzing sub-landscapes. McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4:

Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html.

FRAGSTATS computes several statistics for each patch and class (patch type) in the landscape and for the landscape as a whole. At the class and landscape level, some of the metrics quantify landscape composition, while others quantify landscape configuration.

Landscape composition and configuration can affect ecological processes independently and interactively (see FRAGSTATS Background document). Thus, it is especially important to understand for each metric what aspect of landscape pattern is being quantified. In addition, many of the metrics are partially or completely redundant; that is, they quantify a similar or identical aspect of landscape pattern. In most cases, redundant metrics can be very highly or even perfectly correlated. For example, at the landscape level, *patch density* (PD) and *mean patch size* (MPS) will be perfectly correlated because they represent the same information. These redundant metrics are alternative ways of representing the same information; they are included in FRAGSTATS because the preferred form of representing a particular aspect of landscape pattern will differ among applications and users. It is the user to understand these redundancies, because in most applications only 1 of each set of redundant metrics should be employed. It is important to note that in a particular application, some metrics may be empirically redundant as well; not because they measure the same aspect of landscape pattern, but because for the particular landscapes under investigation, different aspects of landscape pattern are statistically correlated. The distinction between this form of redundancy and the former is important, because little can be learned by interpreting metrics that are inherently redundant, but much can be learned about landscapes by interpreting metrics that are empirically redundant. Thus the final parameters are shown in this document are the one which hold some significance in the understanding of the landscape ecology study.

Total Class Area/Land cover (CA): Class area is a measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch type. In addition to its direct interpretive value, class area is used in the computations for many of the class and landscape metrics. 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); that is, total class area. CA > 0, without limit.

Percentage of Landscape / Landscape Proportion (PLAND) PLAND equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage). In other words, PLAND equals the percentage the landscape comprised of the corresponding patch type. Percentage of landscape quantifies the proportional abundance of each patch type in the landscape. Like total class area, it is a measure of landscape composition important in many ecological applications. However, because PLAND is a relative measure, it may be a more appropriate measure of landscape composition than class area for comparing among landscapes of varying sizes.

Mean shape Index (MSI): or Landscape shape index provides a standardized measure of total edge or edge density that adjusts for the size of the landscape. LSI = 1 when the landscape consists of a single square (or almost square) patch; LSI increases without limit as landscape shape becomes more irregular and/or as the length of edge within the landscape increases.

Largest Patch Index (LPI) Largest patch index at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance. LPI equals the area (m^2) of the largest patch of the corresponding patch type divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percentage of the landscape comprised by the largest patch.

Based on the land cover classification for VUDA area over the 3 time periods (1978-1990; 1990-2001; 2001-2011) land cover change were seen as in the previous chapter. Looking the changes the next question arises what has change and what is its relation with the environ.

Thus, the landscape ecological study has shown some of the remarkable understanding of the VUDA region characteristics.

The study can be looked at two levels that are

i. Landscape level

ii. Land cover class level

Landscape level analysis statistically quantifies the overall regional expansion characteristics amongst the land use classes.

The temporal study from 1978-2011 based on the detailed mapped LULC shows that the LULC patches have shown three different interactions in the region.

The Shannon diversity index shows a declining trend from 1.22 to 1.06 during the study period. This shows the process of compaction has evolved post 1978 and the formation of the city has come up due to post 1970's industrialization moment in and around the Vadodara city. In the duration of 1990-2001, again the areal extent has increased showing the growth of the outlier of the region. From the 2001-2011 the index suggests that the expansion more or less remains at the same intensity owing to the recent spurt in the infrastructure and reality sector development.

The Shannon diversity index (H) is an index widely used to characterize species diversity in a community. Like Simpson's index, Shannon's index explains for both abundance and evenness of the species present. The proportion of species *i* relative to the total number of species *(p_i)* is calculated, and then multiplied by the natural logarithm of this proportion *($\ln p_i$)*. The resulting product is summed across species, and multiplied by -1:

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

Shannon's equitability (E_H) can be calculated by dividing H by H_{max} (here $H_{max} = \ln S$). Equitability assumes a value between 0 and 1 with 1 being complete evenness.

$$E_H = H/H_{MAX} = H/\ln S$$

The Shannon equitability values in the present study shows that the region has vast heterogeneity in itself. The presence of the different patches scattered, uneven dispersal of various land use class makes this region as a challenge to understand its causal parameter. Thus, this region will result in the complexity situation while determining the varied influential parameter for understanding the future growth.

Simpson's diversity index (D) is a simple mathematical measure that characterizes species diversity in a community. The proportion of species *i* relative to the total number of species *(pi)* is calculated and squared. The squared proportions for all the species are summed, and the reciprocal is taken:

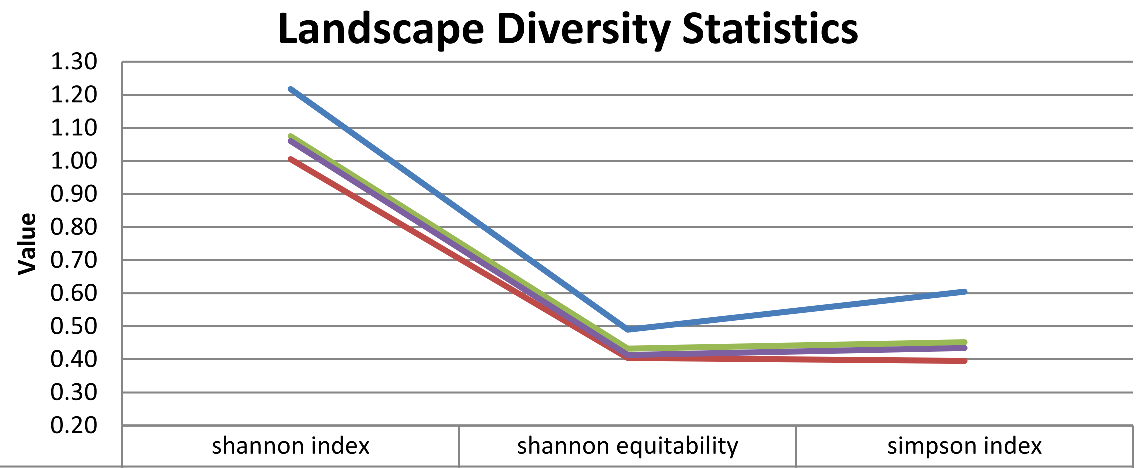
$$D = \frac{1}{\sum_{i=1}^{s} p_i^2}$$

For a given richness (S), D increases as equitability increases, and for a given equitability, D increases as richness increases. Equitability (ED) can be calculated by taking Simpson's index (D) and expressing it as a proportion of the maximum value D could assume if individuals in the community were completely evenly distributed (Dmax, which equals S-- as in a case where there was one individual per species). Equitability takes a value between 0 and 1, with 1 being complete evenness.

$$E_D = \frac{D}{D_{max}} = \frac{1}{\sum_{i=1}^{s} P_i^2} \times \frac{1}{S}$$

4.4 Analysis and Results

4.4.1 VUDA Landscape level analysis



	shannon index	shannon equitability	simpson index
1978	1.22	0.49	0.60
1990	1.01	0.40	0.40
2001	1.07	0.43	0.45
2011	1.06	0.41	0.43

Figure 4.1 Landscape Diversity of VUDA Area

The Simpson diversity index also shows the dispersed, scattered growth of the land use classes. Only in the 1978 the higher value suggests that the compactness. As the time advanced and provision of the transport networks, vehicle to and fro moment increased the probability for the expansion. The growth was in the direction to suitable and economically feasible land transformation by the individuals.

Thus the consistent lowering of the entropy suggests toward the central functionality of the Vadodara city and its cohesion with the new developments.

4.4.2 Class level analysis

The land-use class matrices present an ongoing scenario of transformation and the fragmentation that can be visualize by the quantity of the patch formation and decrease in the core area. Overall, the number of the patches have increased temporally which suggest that the transformation of the classes have not taken the continuous horizontal expansion. The expansions and shrinkage of the areas under different classes do account for the invasion of the different class seeding in the core areas of other classes. Further increasing patches also give the opportunity for the respective class to grow in the new region, depending upon the sustainability of the class and affinity towards the surrounding. In addition, that becomes threat to the existing land cover. In the study, fragmentation of the built-up is seen the most, especially post 1990 era. The open land patches have been the maximum in 2001, which may be because of the increased economy influx in the reality sector.

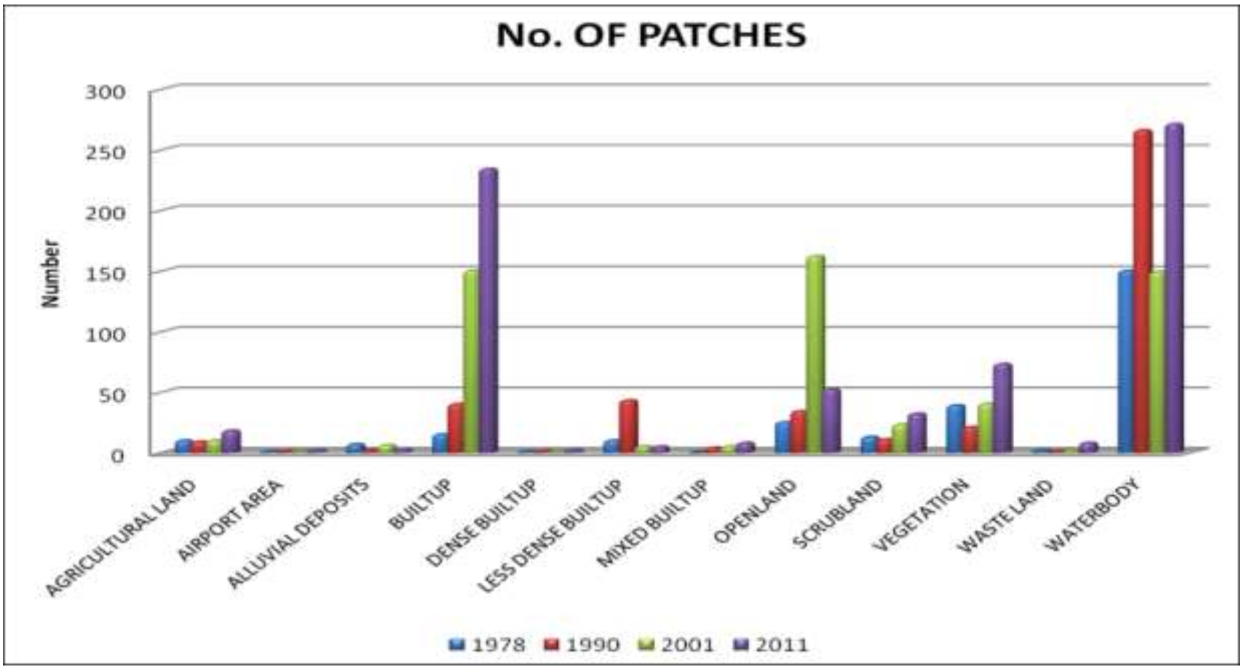


Figure 4.2 (a) LULC Classes and Number of Patches in year 1978, 1990, 2001 and 2011

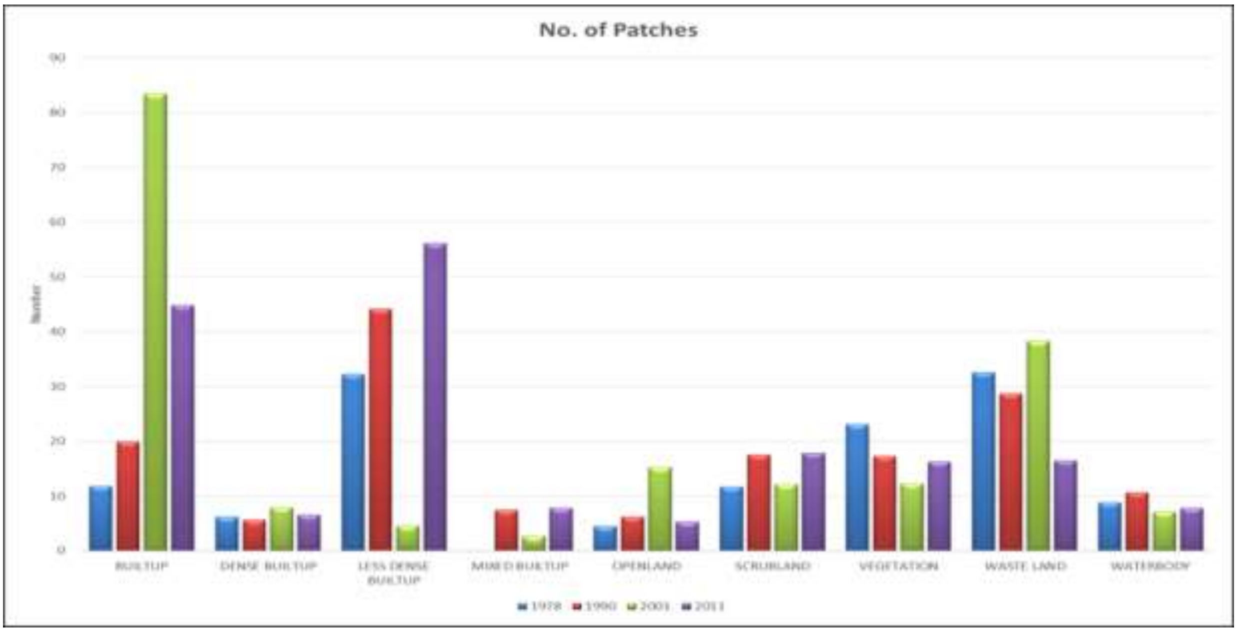


Figure 4.2(b) LULC Classes and Number of Patches in year 1978, 1990, 2001 and 2011

The open spaces are the one which has the propensity to be developed in the form of built-up structure due to the demand of city expansion area decline do direct us o the transformation taking due to city expansion demands.

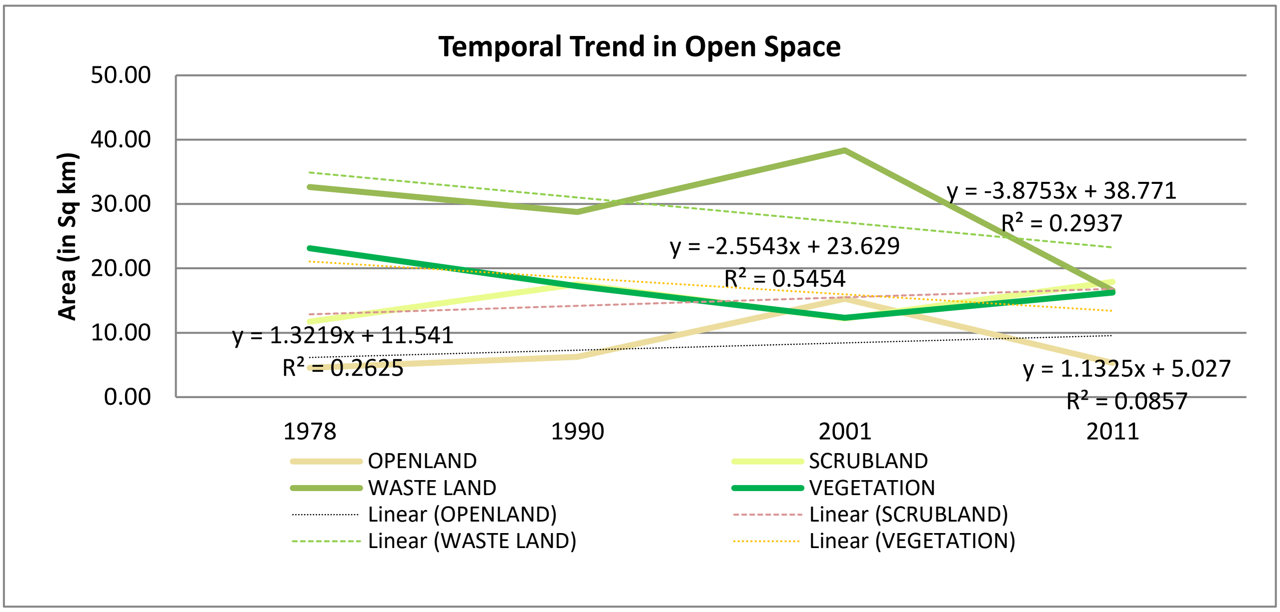


Figure 4.3 Temporal Trend in Open Space for VUDA region

4.4.3 Open space Analysis

Table 4.1 Open Space Indices and attributes in year 1978, 1990, 2001 and 2011 of VUDA.

Class	OPENLAND				WASTE LAND			
YEAR	2011	2001	1990	1978	2011	2001	1990	1978
Land cover	5.33	15.28	6.27	4.56	16.55	38.34	28.76	32.67
Landscape Proportion	0	0.01	0.01	0	0.01	0.03	0.03	0.03
Edge length	79020	232320	94200	65340	104940	156120	141480	139920
Number of Patches	52	162	34	25	8	2	1	2
Largest Patch Index	0.27	0.28	0.27	0.07	0.64	3.38	4.07	2.88
Fractal Dimension Index	1.06	1.06	1.08	1.07	1.11	1.13	1.22	1.1
Mean Shape Index	0.5	0.44	0.59	0.52	0.69	2.66	1.99	1.78
Overall Core area	3.24	9.2196	3.6468	2.736	13.470	33.68	24.50	28.484
Mean patch shape ratio	0.13	0.13	0.11	0.07	0.02	0.26	0.01	0.52
Splitting Index	113323.93	64214.17	92466.72	655671.54	10976.67	876.1	602.6	1205.52

4.4.4 Green space Analysis

Table 4.2 Green Space Indices and attributes in year 1978, 1990, 2001 and 2011 of VUDA.

Class	**SCRUBLAND**				**VEGETATION**			
YEAR	**2011**	**2001**	**1990**	**1978**	**2011**	**2001**	**1990**	**1978**
Land cover	17.91	12.21	17.53	11.73	16.26	12.33	17.25	23.13
Landscape Proportion	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.02
Edge length	161760	130020	125400	93600	210900	142500	152640	198600
Number of Patches	32	23	11	13	73	40	21	39
Largest Patch Index	0.55	0.28	1.2	0.28	0.76	0.25	0.44	0.37
Fractal Dimension Index	1.09	1.09	1.13	1.1	1.07	1.09	1.1	1.09
Mean Shape Index	0.61	0.63	0.82	0.66	0.51	0.73	0.64	0.73
Overall Core area Sq Km	13.22	8.4384	13.87	9.0162	10.468	8.3745	1.2847	17.398
Mean patch shape ratio	0.07	0.06	0.06	0.05	0.09	0.11	0.04	0.13
Splitting Index	17681.5	60739.92	5884.15	62546.43	11862.14	78277.11	16967.89	26762.26

4.4.5 Waterscapes Analysis

Table 4.3 Waterscapes Indices and attributes in year 1978, 1990, 2001 and 2011 of VUDA.

WATER LANDSCAPE	**2011**	**2001**	**1990**	**1978**
Land cover Area	7.83	7.151400	10.689300	8.814600
Landscape Proportion	0.006965267	0.006306	0.009425	0.007772
Edge length	185100.0	147300.00	244320.00	180660.00
Number of Patches	271	149	266	150
Largest Patch Index	0.265180332	0.134032	0.343732	0.150379
Fractal Dimension Index	1.04302913	1.048075	1.053856	1.047029
Mean Shape Index	0.362527344	0.657634	0.391595	0.953639
Mean patch shape ratio	0.149253135	0.344394	0.115415	0.559601
Landscape division	0.999989137	0.999997	0.999986	0.999997
Splitting Index	92053.5	368643.7	71758.1	323722.5
Overall Core area sq. km	3.681	3.581100	4.954500	4.196700

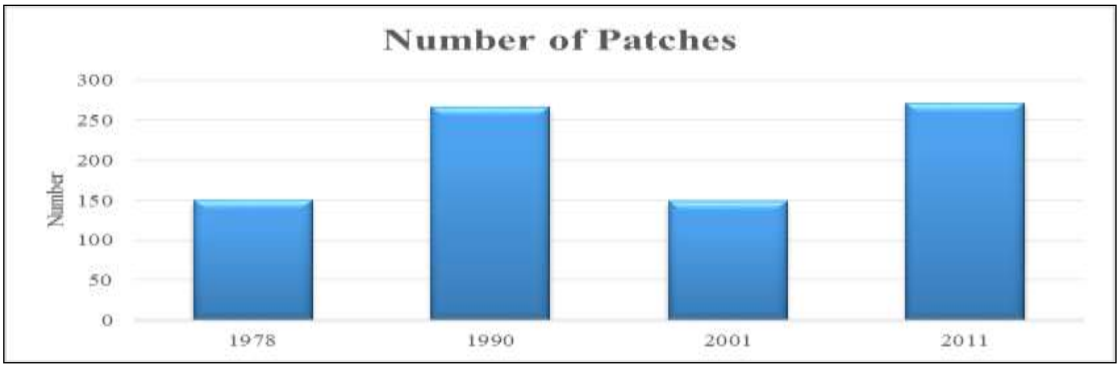


Figure 4.4 Waterscape Patches of VUDA region in years 1978,1990, 2001 and 2011.

The water body has shown an interesting relation which points towards the impact of urbanization in which the number of water body patches have increased in 1990 and 2011. The smaller number of patches in 1978 is due to coarser resolution of the images and in the year 2001, the scanty rainfall has resulted in the drying out of the numerous waterbody. Looking to the other parameter like edge length i.e. the interactive boundary between individual classes to other neighbor's classes. The length has shown that shrinkage of the boundaries is apparent. Thus, the higher number of recent patch shows the formation of the new waterlogged areas.

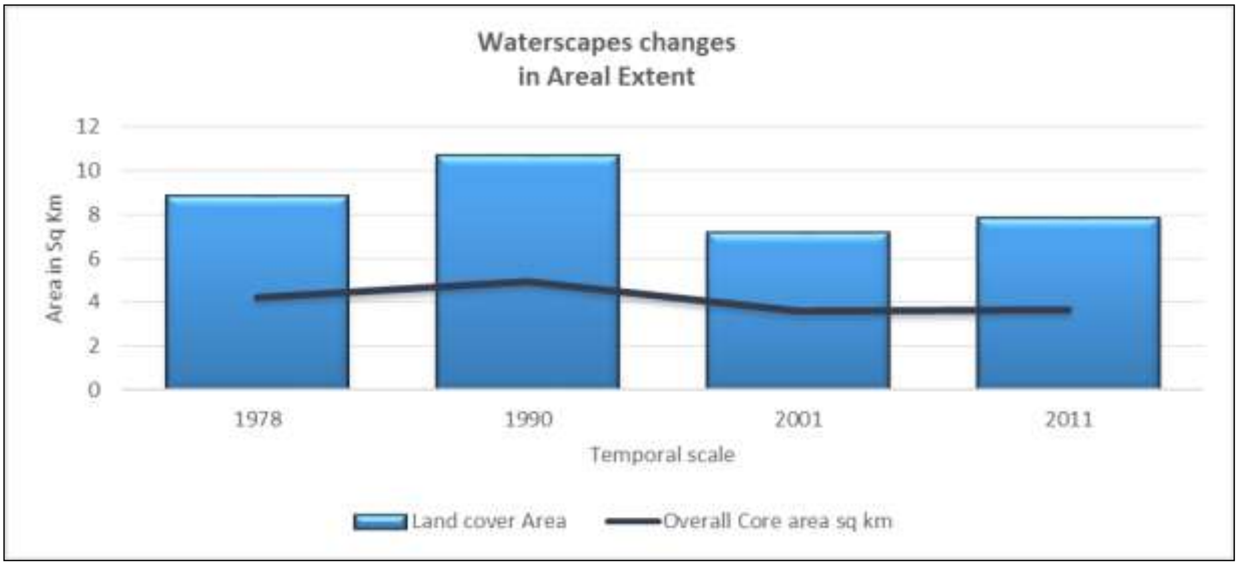


Figure 4.5 Waterscape Changes in areal extent of VUDA Region

Table 4.4 Landscape Matrices at class Level Year 1978

LULC Class_1978	Agricultural Land	Built-up	Dense Built-up	Less Dense Built-up	Open land	Scrubland	Vegetation	Waste Land	Waterbody
Land Cover	567.54	11.77	6.20	32.24	4.56	11.73	23.13	32.67	8.81
Landscape Proportion	0.50	0.01	0.01	0.03	0.00	0.01	0.02	0.03	0.01
Edge Length (In Km)	723.0	71.1	21.3	135.2	65.3	93.6	198.6	139.9	180.7
Number of Patches	10.00	15.00	1.00	10.00	25.00	13.00	39.00	2.00	150.00
Largest Patch Index	46.86	0.37	0.55	2.33	0.07	0.28	0.37	2.88	0.15
Fractal Dimension Index	1.10	1.07	1.10	1.09	1.07	1.10	1.09	1.10	1.05
Mean Shape Index	1.35	1.61	0.76	0.76	0.52	0.66	0.73	1.78	0.95
Overall Core Area (In Sq Km)	545.6	9.7	5.5	28.2	2.7	9.0	17.4	28.5	4.2
Mean Patch Shape Ratio	0.22	0.77	0.01	0.05	0.07	0.05	0.13	0.52	0.56
Landscape Division	0.78	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Splitting Index	4.54	33505.67	33479.86	1808.55	655671.54	62546.43	26762.26	1205.52	323722.52

Table 4.5 Landscape Matrices at class Level Year 1990

LULC Class_1990	Agricultural Land	Built-up	Dense Built-up	Less Dense Built-up	Mixed Built-up	Open land	Scrub land	Vegetation	Waste Land	Water body
Land cover	545.41	19.88	5.70	44.12	7.42	6.27	17.53	17.25	28.76	10.69
Landscape Proportion	0.48	0.02	0.01	0.04	0.01	0.01	0.02	0.02	0.03	0.01
Edge length (in km)	784.9	126.4	18.1	293.2	58.5	94.2	125.4	152.6	141.5	244.3
Number of Patches	9.00	40.00	1.00	43.00	4.00	34.00	11.00	21.00	1.00	266.00
Largest Patch Index	75.42	1.64	0.81	5.19	0.41	0.27	1.20	0.44	4.07	0.34
Fractal Dimension Index	1.09	1.05	1.08	1.08	1.12	1.08	1.13	1.10	1.22	1.05
Mean Shape Index	2.36	0.71	0.85	0.71	0.99	0.59	0.82	0.64	1.99	0.39
Overall Core area (In Sq Km)	521.4	16.3	5.1	35.6	5.7	3.6	13.9	12.8	24.5	5.0
Mean patch shape ratio	0.68	0.25	0.02	0.10	0.03	0.11	0.06	0.04	0.01	0.12
Landscape division	0.43	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Splitting Index	1.76	3239.9	15359.47	370.05	32564.7	92466.7	5884.1	16967.89	602.67	71758.0

Table 4.6 Landscape Matrices at class Level Year 2001

LULC Class_2001	Agricultural Land	Built-up	Dense Built-up	Less Dense Built-up	Mixed Built-up	Open land	Scrub land	Vegetation	Waste Land	Water body
Land cover	513.87	83.5	7.89	4.67	2.69	15.28	12.21	12.33	38.34	7.15
Landscape Proportion	0.45	0.07	0.01	0.00	0.00	0.01	0.01	0.01	0.03	0.01
Edge length (in km)	719.2	512.1	29.7	29.8	30.5	232.3	130.0	142.5	156.1	147.3
Number of Patches	10.00	150.00	1.00	5.00	5.00	162.00	23.00	40.00	2.00	149.00
Largest Patch Index	42.22	4.20	0.70	0.36	0.10	0.28	0.28	0.25	3.38	0.13
Fractal Dimension Index	1.08	1.05	1.12	1.09	1.10	1.06	1.09	1.09	1.13	1.05
Mean Shape Index	1.28	1.44	1.00	0.64	0.61	0.44	0.63	0.73	2.66	0.66
Overall Core area (In Sq Km)	491.9	68.8	7.0	3.8	1.8	9.2	8.4	8.4	33.7	3.6
Mean patch shape ratio	0.31	1.32	0.02	0.06	0.10	0.13	0.06	0.11	0.26	0.34
Landscape division	0.82	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Splitting Index	5.59	493.5	20637.00	76713.88	521161.35	64214.2	60739.92	78277.11	876.10	368643.70

Table 4.7 Landscape Matrices at class Level Year 2011

LULC Class_2011	Agricultural Land	Built-up	Dense Built-up	Less Dense Built-up	Mixed Built-up	Open land	Scrubland	Vegetation	Waste Land	Water body
Land cover	525.50	44.80	6.61	56.19	7.78	5.33	17.91	16.26	16.55	7.83
Landscape Proportion	0.47	0.04	0.01	0.05	0.01	0.00	0.02	0.01	0.01	0.01
Edge length (in km)	1044.12	534.12	39.48	287.64	69.66	79.02	161.76	210.90	104.94	185.10
Number of Patches	18.00	234.00	2.00	5.00	8.00	52.00	32.00	73.00	8.00	271.00
Largest Patch Index	74.28	0.91	0.84	3.57	0.32	0.27	0.55	0.76	0.64	0.27
Fractal Dimension Index	1.06	1.06	1.13	1.16	1.11	1.06	1.09	1.07	1.11	1.04
Mean Shape Index	1.87	0.76	1.23	1.65	0.86	0.50	0.61	0.51	0.69	0.36
Overall Core area (In Sq. Km)	493.64	30.11	5.43	47.50	5.77	3.24	13.22	10.47	13.47	3.68
Mean patch shape ratio	2.19	0.24	0.05	0.05	0.05	0.13	0.07	0.09	0.02	0.15
Landscape division	0.45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Splitting Index	1.81	4457.5	14062.4	508.3	43994.5	113323.9	17681.47	11862.1	10976.7	92053.5

4.5 Landscape Metrics in Land-Use Policy and Planning

An important aspect that is revealed in the land cover maps for the three extents was rapid increase of built-up areas, with increased dominance of built-up patch type and aggregation. Land-use policy is governed by the preparation of development plans / master plans through zoning of land-use; the respective Development Authority is mandated to prepare land-use plans indicating the zoning for permissible land-uses once in every ten years. This is prepared based on projected future population and with allocations of land-use based on certain assumptions. This does not assign to the landscape level characterization including some of the sprawl and landscape specific spatial metrics. Additionally, it is alarming that in the absence of approval to landscape ecology isolation and fragmentation of habitats and dispersed growth in the periphery of the city will be inevitable. Heterogeneous configuration and complex interaction of urban fabrics makes modelling of urban process a difficult task. Now to decide what is required in what pattern? i.e ….settlement dispersed or compact? Green space dispersed or compact? Waterscapes are essential or problematic. So many function and ecological services are required to have sustainability addressed.

Thus, a quantification of pattern measure will give insight tool to planners to have segregation of ecological services of landscapes and its judicious allocation to balance the growth and development

The future household level development also depends on the public demand how he wants its surrounding to be, for example everybody wants to have nature visible form the house i.e riverfront building attract more, walk ability to green space, etc. Thus, the ecological plan can include the development of the plans with respect to the edge length and its core area proportionality such that the interaction can be sustained.

Thus, it is suggested that when landscape metrics are considered as potential instruments in the preparation of future land-use zoning plans, they can aid in guiding the land-use policy to avoid isolation and fragmentation of such habitats. The landscape metrics when used in conjunction with existing norms can facilitate land-use planning to acknowledge the landscape dynamics and avoid fragmentation of habitats.

It is imperative that future studies can attempt to address the growth pattern and landscape fragmentation at varied spatial scales. Furthermore, it would also be sensible to analyses the metrics in light of the wide-ranging development plan – revised master plan prepared by Vadodara Development Authority and evaluate the inference.

The sustainability of cities has become a central theme in applied landscape and urban ecology. This challenge is well suited to landscape ecology because of its commitment to interdisciplinary, understanding of spatial heterogeneity, attention to stochastic processes, and intentional linkage of research with application.

The ecosystem services concept provides useful benchmarks and performance indicators to link science with planning

4.5.2 Limitations:

Area metrics have limitations imposed by the scale of investigation. Minimum patch size and landscape extent set the lower and upper limits of these area metrics, respectively. These are critical limits to recognize because they establish the lower and upper limits of resolution for the analysis of landscape composition and configuration. Otherwise, area metrics have few limitations. All edge indices are affected by the resolution of the image. Generally, the finer the resolution (i.e., the greater the detail with which edges are delineated), the greater the edge length. At coarse resolutions, edges may appear as relatively straight lines; whereas, at finer resolutions, edges may appear as highly convoluted lines. Thus, values calculated for edge metrics should not be compared among images with different resolutions. In addition, patch perimeter and the length of edges will be biased upward in raster images because of the stair-step patch outline, and this will affect all edge indices. The magnitude of this bias will vary in relation to the grain or resolution of the image, and the consequences of this bias with regards to the use and interpretation of these indices must be weighed relative to the phenomenon under investigation

Despite best efforts, there are limitations to the present study. The analysis was confined to spatial resolution of satellite remote sensing data with 30 m and temporal resolution of about 10years. It would be a worthwhile exploration to evaluate the effect of scale (say less 30 m) in the estimation of these metrics and their effectiveness in capturing the patterns.

Conclusion

This study quantified the land cover change for Vadodara Urban Area during 1978 to2011 and studied the effect of varied spatial extents on the estimation of landscape metrics. Some of the landscape metrics were estimated to demonstrate their utility, combined with the spatial analysis to drive the point of considering landscape metrics as potential instruments in the preparation of land-use policy for future urban growth. This approach will help to plan for the ecological interaction for the climate resilient region.