Appendix I:

Table 1: Landscape metrics with significance

SL NO	INDICATORS	FORMULA	RANGE	SIGNIFICANCE/ DESCRIPTION
Category : Patch area metrics				
1	**Built up (Total Land Area)**	------	>0	Total built-up land (in ha)
2	**Built up (Percentage of landscape)**	$BP = \frac{A_{builtup}}{A}(100)$ $A_{built\text{-}up}$ = total built-up area A= total landscape area	0<BP≤100	It represents the percentage of built-up in the total landscape area.
3	**Largest Patch Index (Percentage of built up)**	$LPI = \frac{\max_{i=1}^{n}(a_i)}{A}(100)$ a_i = area (m^2) of patch i A= total landscape area	0 ≤ LPI≤100	LPI = 0 when largest patch of the patch type becomes increasingly smaller. LPI = 100 when the entire landscape consists of a single patch of, when largest patch comprise 100% of the landscape.
4	**Mean patch size MPS**	$MPS = \frac{\sum_{i=1}^{n} a_i}{n_i}\left(\frac{1}{10,000}\right)$ i=i^{th} patch a=area of patch i n=total number of patches	MPS>0,without limit	MPS is widely used to describe landscape structure. Mean patch size index on a raster map calculated, using a 4 neighbouring algorithm.
5	**Number of Urban Patches**	$NPU = n$ NP equals the number of patches in the landscape.	NPU>0, without limit.	It is a fragmentation Index. Higher the value more the fragmentation
6	**Patch density**	f(sample area) = (Patch Number/Area) * 1000000	PD>0,without limit	Calculates patch density index on a raster map, using a 4 neighbor algorithm.

7	**Patch area distribution coefficient of variation (PADCV)**	$$PAD_{CV} = \frac{SD}{MPS}(100)$$ with:SD: standard deviation of patch area size $$SD = \sqrt{\frac{\sum_{i=1}^{Npatch}(a_i - MPS)^2}{Npatch}}$$ • MPS: mean patch area size • ai: area of patch i • N_{patch}: number of patch	PADCV≥0	PADCV is zero when all patches in the landscape are the same size or there is only one patch (no variability in patch size). .
8	**Perimeter-Area Fractal Dimension PAFRAC**	$$\frac{\left[N\sum_{i=1}^{m}\sum_{j=1}^{n}(\ln P_{ij}.\ln a_{ij})\right] - \left[\left(\sum_{i=1}^{m}\sum_{j=1}^{n}\ln p_{ij}\right)\left(\sum_{i=1}^{m}\sum_{j=1}^{n}\ln a_{ij}\right)\right]}{\left(N\sum_{i=1}^{m}\sum_{j=1}^{n}\ln p_{ij}^2\right) - \left(\sum_{i=1}^{m}\sum_{j=1}^{n}\ln p_{ij}\right)}$$ a_{ij} = area (m^2) of patch ij. p_{ij} = perimeter (m) of patch ij. N = total number of patches in the landscape	1≤PAFRAC≤2	It approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, perimeters. PAFRAC requires patches to vary in size.
		Category : Edge/border metrics		
9	**Edge density**	$$ED_K = \frac{\sum_{i=1}^{n} e_{ik}}{AREA}(10000)$$ **k**: patch type **m**: number of patch type **n**: number of edge segment of patch type k **eik** :total length of edge in landscape involving patch type k **Area**: total landscape area	ED ≥ 0, without limit. ED = 0 when there is no class edge.	ED measures total edge of urban boundary used to compare landscape of varying sizes.
10	**Area weighted mean patch fractal dimension (AWMPFD)**	$$AWMPFD = \frac{\sum_{i=1}^{i=N} 2\ln 0.25 p_i / \ln S_i}{N} \times \frac{S_i}{\sum_{i=1}^{i=N} S_i}$$ Where $s_i$and p_i are the area and perimeter of patch i, and N is the total number of patches	1≤AWMPFD≤ 2	AWMPFD approaches 1 for shapes with very simple perimeters, such as circles or squares, and approaches 2 for shapes with highly convoluted perimeter. AWMPFD describes the fragmentation of urban patches. If Sprawl is high then AWMPFD value is high.
11	**Perimeter Area Weighted Mean Ratio. PARA_AM**	PARA_AM= $\frac{Pij}{Aij}$ Pij = perimeter of patch ij Aij= area weighted mean of patch ij $$AM = \sum_{J=1}^{n}[Xij[\frac{aij}{\sum_{j=1}^{n} aij}]]$$	>0,without limit	PARA AM is a measure of fragmentation; it is a measure of the amount of 'edge' for a landscape or class. PARA AM value increased with increasing patch shape complexity.
12	*A. **Mean Patch Fractal Dimension (MPFD)***	*B.* $$MPFD = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\frac{2\ln(0.25 pij)}{\ln aij}\right)}{N}$$ *C. pij = perimeter of patch ij* *D. aij= area weighted mean of patch ij* *E. N = total number of patches in the landscape*	1<=MPFD<2	MPFD is another measure of shape complexity, approaches one for shapes with simple perimeters and approaches two when shapes are more complex.

13	**Mean Patch Fractal Dimension (MPFD) coefficient of variation (COV)**	$$MPFD = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\frac{2\ln(0.25pij)}{\ln aij}\right)}{N}$$ $$CV = \frac{SD}{MN}(100)$$ CV (coefficient of variation) equals the standard deviation divided by the mean, multiplied by 100 to convert to a percentage, for the corresponding patch metrics.	It is represented in percentage.	It gives coefficient of variation of patches.
Category : Shape metrics				
14	**NLSI (Normalized Landscape Shape Index)**	$$NLSI = \frac{\sum_{i=1}^{i=N}\frac{p_i}{s_i}}{N}$$ Where s_i and p_i are the area and perimeter of patch i, and N is the total number of patches.	0≤NLSI<1	NLSI = 0 when the landscape consists of single square or maximally compact almost square, it increases when the patch types becomes increasingly disaggregated
15	**Mean Shape index MSI**	$$MSI = \frac{\sum_{j=i}^{n}\left(\frac{0.25p_{ij}}{\sqrt{a_{ij}}}\right)}{n_i}$$ p_{ij} is the perimeter of patch i of type j. a_{ij} is the area of patch i of type j. n_i is the total number of patches.	MSI ≥ 1, without limit	Explains Shape Complexity.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
16	**Area Weighted Mean Shape Index (AWMSI)**	$$AWMSI = \frac{\sum_{i=1}^{i=N} p_i / 4\sqrt{s_i}}{N} \times \frac{s_i}{\sum_{i=1}^{i=N} s_i}$$ Where s_i and p_i are the area and perimeter of patch i, and N is the total number of patches	AWMSI ≥ 1, without limit	AWMSI = 0 when all patches in the landscape are circular or square. AWMSI increases without limit as the patch shape becomes irregular.
Category: Compactness/ contagion / dispersion metrics				
17	**Clumpiness**	$$CLUMPY = \begin{bmatrix} \frac{G_i - P_i}{P_i} \; for G_i < P_i \; \& \; P_i < 5, else \\ \frac{G_i - P_i}{1 - P_i} \end{bmatrix}$$ $$G_{i=}\left(\frac{g_{ii}}{\left(\sum_{k=1}^{m} g_{ik}\right) - \min e_i}\right)$$ g_{ii} =number of like adjacencies (joins) between pixels of patch type (class) I based on the *double-count* method. g_{ik} =number of adjacencies (joins) between pixels of patch types (classes) i and k based on the *double-count* method. min-e_i =minimum perimeter (in number of cell surfaces) of patch type (class)i for a maximally clumped class. P_i =proportion of the landscape occupied by patch type (class) i.	-1≤ CLUMPY ≤1 .	It equals 0 when the patches are distributed randomly, and approaches 1 when the patch type is maximally aggregated.

18	**Area weighted Euclidean mean nearest neighbor distance AW_MNND**	$ENN = h_{ij}$ h_{ij}isdistance(m) from patch ij to nearest neighboring patch of the same type(class) based on shortest edge to edge distance.	ENN>0, without limit	ENN approaches zero as the distance to the nearest neighbor decreases.
19	**ENND coefficient of variation**	$ENN = h_{ij}$ $CV = \frac{SD}{MN}(100)$ CV (coefficient of variation) equals the standard deviation divided by the mean, multiplied by 100 to convert to a percentage, for the corresponding patch metrics.	It is represented in percentage.	In the analysis of urban processes, greater isolation indicates greater dispersion.
20	**Aggregation index**	$AI = \left[\sum_{i=1}^{m}\left(\frac{g_{ii}}{\max \to g_{ii}}\right)P_i\right](100)$ gii=number of like adjacencies (joins) between pixels of patch type (class) i based on thesingle count method.	1≤AI≤100	AI equals 1 when the patches are maximally disaggregated and equals 100 when the patches are maximally aggregated
21	**Interspersion and Juxtaposition**	$IJI = \frac{-\sum_{i=1}^{m}\sum_{k=i+1}^{m}\left[\left(\frac{e_{ik}}{E}\right).\ln\left(\frac{e_{ik}}{E}\right)\right]}{\ln\left(0.5\left[m(m-1)\right]\right)}(100)$ e_{ik} = total length (m) of edge in landscape between patch types (classes) i and k. E = total length (m) of edge in landscape, excluding background m = number of patch types (classes) present in the landscape, including the landscape border, if present.	0≤ IJI ≤100	IJI is used to measure patch adjacency. IJI approach 0 when distribution of adjacencies among unique patch types becomes increasingly uneven; is equal to 100 when all patch types are equally adjacent to all other patch types.
Category : Open Space metrics				
22	**Ratio of open space (ROS)**	$ROS = \frac{s'}{s} \times 100\%$ Where s is the summarization area of all "holes" inside the extracted urban area, s is summarization area of all patches	It is represented as percentage.	The ratio, in a development, of open space to developed land.
23	**Patch dominance**	$Dominance = ln(m) + \sum_{i=1}^{m} pi\ ln(pi)$ **m**: number of different patch type **i**: patch type; **pi**: proportion of the landscape occupied by patch type i	----------	Computes dominance's diversity index on a raster map.