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Dynamics of Urban Landscape Using Patch Parameters and Indices: An Analytical case Study of Salem city Tamil Nadu

[1]R. Vimala, [2]A. Marimuthu
[1] Assistant Professor, Department of Computer Science, Government Arts College for Women, Salem, Tamilnadu, India
[2] Associate Prof., Dept. of Computer Science, Government Arts College (Autonomous) Coimbatore, Tamilnadu, India

Abstract— Urbanization is serious challenges of growth in recent decades. The complications of urbanization are effected on the socioeconomic development of the Salem city. Salem is famous for mango and steel plant has been witnessing the same setup raising the question of its planning and management of growth to make it more efficient and sustainable. It raises the necessity to study the pattern of urbanization and its impact on other Land use and Land cover (LU/LC) categories in Salem City. In order to assess the urbanization dynamics in the study area, the changing landscape pattern of the three significant metrics such as patch parameters, patch frequency, largest patch size and average patch size of all affected LU/LC categories over a time gradient representing the formation phases of the Salem city have been analysed in Earth Resources Data Analysis System (ERDAS) and Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS) software's. The two conventional landscape indices such as Shannon's diversity index and Simpson's diversity index and a developed index Normalized Patch size Range Index' have been employed in the analyses which not only ascertained the finding derived but also provided meaningful insights pertaining to the temporal variation of urban landscape dynamics in the Salem city.

Keywords— Patch parameters, indices, Landscape Metrics, Landsat, and Diversity.

I. INTRODUCTION

The quantification of urban sprawl is a prerequisite to understanding sprawl dynamics. The Landscape is heterogeneous land area composed of the cluster of interacting systems which forms an interconnected system called an ecosystem. Landscape defined as a distinct, assessable unit defined by its spatially repetitive cluster of various interacting systems. Landscape influenced by humans may create a high contrast structures within large homogeneous patches (Forman and Gordon, [3]. As a result, micro-heterogeneity is induced in the original landscape having macro-heterogeneous patches and is extremely common in all parts of the earth. Thus, the reflectivity from the landforms decides the contrast which can be subdivided into low and high contrast. Urbanization incepts serious challenges of growth and its management. Across characteristics, the issues of urbanization perceptible are in the form of overcrowding, congestion, insufficient infrastructure, inadequate service provisioning, environmental degradation, and pollution etc. These, along with the poor management of hasty growth, affect the socioeconomic expansion of the city raising the question of its planning and management of growth to make it more efficient and sustainable. Salem city has been continually rampant urbanization with accelerated pace since its inception which has been observed other prominent Land use/Land cover. The indicators for achieving sustainable development have been evolved by Meadows [1]. However, there are in the recent past to characterize urban sprawl (Hurd et al; Barnes et al; Epstein et al.,; Sudhira et al.,[3] using spatial metrics using ArcGIS software. Essentially, the spatial metrics aids in quantifying the process, monitoring the extent of urban sprawl aid as useful indicators for measuring the implications of decisions. Gayda et al. [3] have evolved spatial metrics as indicators to achieve sustainable development.

II. DESCRIPTION OF STUDY AREA

The envisaged research has been undertaken in an urbanizing landscape covered by Salem city located in Tamil Nadu, India (Fig. 1). Although the process of urbanization is prevalent throughout the Salem city and within its surroundings, it is characterized by a large amount of diversity in terms of both pattern and magnitude within the boundary of Salem city.

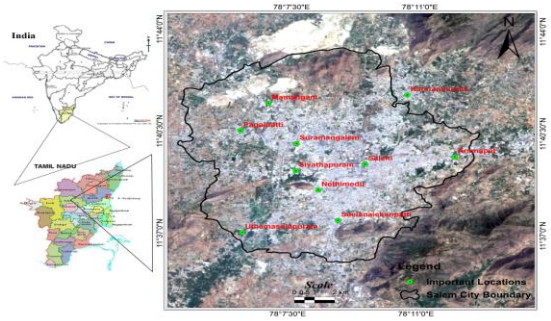

Fig.1.Location map of the study area

III. MATERIALS AND METHODS

The quantification of urban landscape metrics of the Salem has been carried out (Fig. 2) by a step by step methodological approach has been applied to dynamics of land changes for the Years of 1990 to 2015. Landsat satellite data of the same season from 1990 to 2015 in order to demarcate the eight LU/LC categories considered to investigate the nature of urbanization in Salem City. Using ERDAS Imagine 2015 has been performed the desired image processing and classification operations for patch parameters of the individual LU/LC such as Patch Frequency, Largest Patch Size (LPS) and Average Patch Size (APS) have been determined from the classified images of the respective years through ArcGIS version 9.3.1 software. There are three basic landscape metrics determined based on Patch Frequency, Largest Patch Size and Average Patch size have been analysed. The two widely used Landscape Indices such as Shannon's Diversity index (H) and Simpson's diversity index (1-D) have also been determined for in this selected case study area. Pammi Nitin Sinha et al [3] used new index Normalized Patch Size Range Index has been developed and used in the present case study.

A. Shannon's Diversity Index (H)

Shannon's diversity index (H) measure the diversity [3] is based on two components such as richness and plenty of species. In the present research, species are signified by LU/LC categories. Richness indicates the number of LC/LC categories and abundance represents the relative proportion of the different LU/LC categories. The index is computed using the following equation

$$H = -\sum (P_i * \log P_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where

H-Shannon index of diversity,

i-LU/LC category,

Pi- probability of the i = fi/n

Where

f_i-frequency of species, i.e. patch frequency of different LU/LC categories (i) and n = number of species (LU/LS categories) (equals 4 in the present study)Log p log of Pi.

The relative abundance of the individual LU/LC categories represents their respective patch frequency while the richness represents the number of LU/LC categories considered in the present study which is equal to eight [3]. The Shannon's index of diversity primarily determined by the comparative abundance of the eight LU/LC categories such as in 2015 (H) =1.72, evenness=0.83 and in 1990 (H) =1.7, evenness=0.82 present in the study area.

B. Simpson's Diversity Index (D)

The Simpson's diversity index (D) dealings the diversity between the species of their equitability of distribution within a landscape (Offwell Woodland and Wildlife Trust, 2005); and is expressed by equation

$$D = \sum (P_i)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where

D-Simpson's Diversity index,

p_i-probability of $_i^{th}$ LU/LC category = fi/n

Where

f_i-frequency of species, i.e. patch frequency of different LU/LC categories (i) and n =number of species (LU/LC categories) (equals 8).

The assessment of this index ranges between 0 and 1 the greater the value, the greater the sample diversity. Since it is neither spontaneous nor reasonable, so D is often subtracted from 1 , i.e. 1-D (Simpson's index of diversity) or its reciprocal, i.e. 1/D (Simpson's reciprocal index) is calculated for the diversity of landscape (Offwell Woodland and Wildlife Trust, 2005); in the present study, D=1.01, Simpson's index of diversity=0.01, Simpson's reciprocal index=0.99 [3].

C. Normalized Patch Size Range Index (NPSRI)

In the present study, Pammi Nitin Sinha et al [3] used a new index called 'Normalized Patch Size Range Index' has been formulated to assess the patch dynamics in a region between two time periods.

$$NPSI = \frac{\text{(Difference between largest and smallest patch in an LU/LC in time t2)}}{\text{(Difference between largest and smallest patch in the same LU/LC in time t1)}} \quad \ldots\ldots\ldots\ldots\ldots 3$$

Table 1 Normalized Patch Size Range Index (NPSRI) For LU/LC in SMC For 1990–2015

SI.NO	LU/LC	NPSRI
1	Water body	1.220238
2	Cropland	0.397687
3	Urban	0.957992
4	Barren Land	0.300204
5	Road Network	0.171518

6	Forest	0.125914
7	Fallow Land	0.351574
8	Mining activity	0.23326

The Normalized Patch Size Range Index (Table.1) signifies the ratio between the difference in the largest and least patch size of an individual category (i.e. Patch size range) in the later time period (t2) and the similar for that category in a prior time period (t1). In the present study, t2 and t1 represent from 2015 and 1990 respectively.

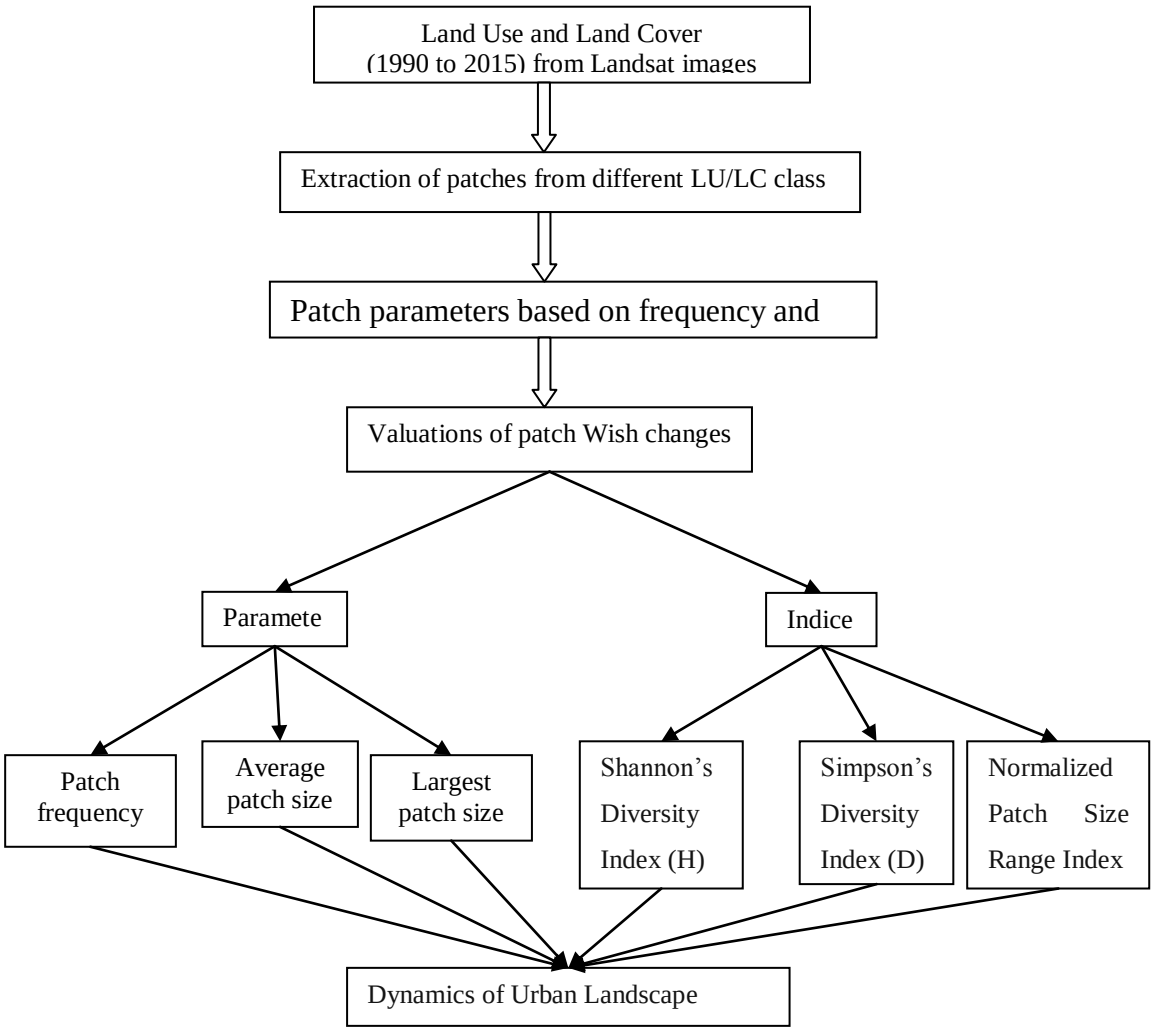

Fig.2. Flow Chart Showing detailed Methodology about Urban Landscape Dynamics

IV. RESULTS AND DISCUSSIONS

A. Assessment of the Patch Parameters:

The graphical plots represented the patch frequency ,largest and average patch size from the 1990 to 2015 together for the eight individual LU/LC categories such as Urban, Water bodies, Forest, Cropland, Fallow land and Mining activity are presented in Figs. 3, 4 and 5 for the Salem city. Patch frequency (Fig.4) showing it is clearly indicated that significant decrease of the three categories such as urban, water bodies Cropland and Fallow land to the extent of respectively from 1990 to 2015. On the other hand Cropland and Fallow land exhibit a remarkable increase in the patch frequency. The decrease in patch frequency for an urban area is the result of a coalescence of built up patches as a result of large-scale urbanization within Salem city area. The process has in turn resulted in the balanced decrease of the patch frequency of crop land and water bodies (Fig.4) and is also supported by the decrease in the area under different LU/LC (Table.2) other than urban.

The increase in the patch frequency of the agricultural land (Fig.4) attributed to its large-scale fragmentation as an outcome of the expansion of the remaining urban agglomerate and recent built-up activities on the agricultural land. On the further hand the considerable decrease in its largest patch size and a steep decline in its average patch size of the same indicates heavy encroachment of cultivated land by built-up areas as a result of extensive urbanization on the other hand from the Fig. 4, it is clear that there occurs the significant increase in the largest patch size of settlement from 1990 to 2015 that is supported by the corresponding increase in the average patch size of this category (Fig. 5).

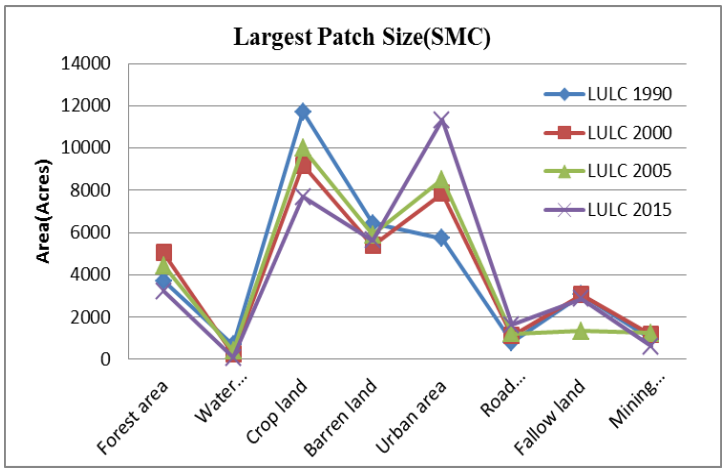

Fig.3. Variation of Largest patch size of different LU/LC from 1990 to 2015

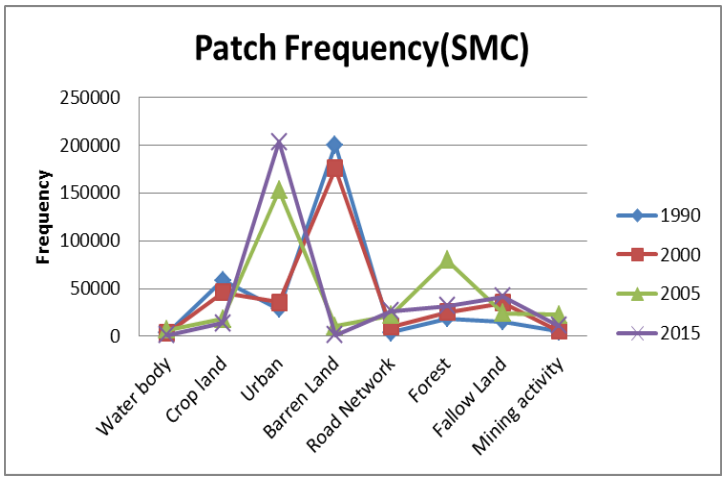

Fig.4. Patch frequency variation of different LU/LC from 1990 to 2015)

The increase in the Largest Patch Size (LPS) and Average Patch Size (APS) of the Urban or Built-up (Figs.3,5) can be attributed to its expansion by the process of urbanization leading to the decrease in its patch frequency resultant due to urban patches as observed [3] in Fig. 4. Analysis of the largest patch size (Fig.4) reveals the three categories such as water bodies, Crop land and Fallow land exhibit reasonable decrease in the largest patch size from 1990 to 2015 period contrary to the urban which is attributable to the fragmentation of these categories as a result of urbanization as substantiated by field observations.

A Significant increase in the patch frequency together with the decrease in the largest patch size and average patch size of crop land and fallow land are shown by its large-scale fragmentation successive to the creation of the wide urbanization (Figs. 3, 4 and 5). The water bodies are decreased in the patch frequency and Largest Patch Size (LPS) together with the increased in the average patch size could be attributed to both the shrinkage of the water bodies and decrease caused by its numbers due to urbanization. As showed in Fig. 6, the most significant change appears to be the spectacular expansion of built-up areas between 2000 and 2015, the growth of the human landscape and successive reduction of natural landscape, which clearly suggests the extent of anthropogenic activities.

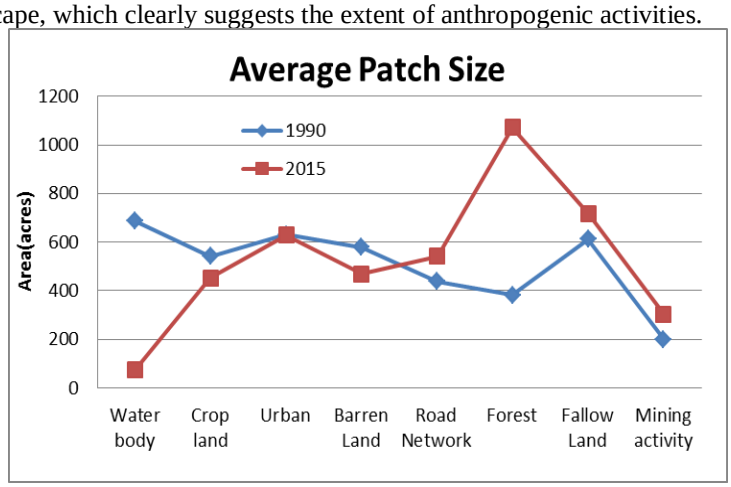

Fig.5. Variation of average patch size of different LU/LC from 1990 to 2015

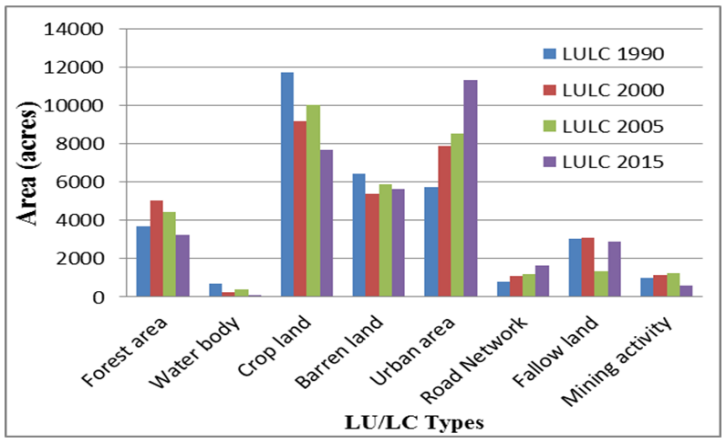

Fig.6. Area statistics (acres) of LU/LC of Salem city

TABLE 2 AREA (ACRES) UNDER DIFFERENT LU/LC IN 1990 AND 2015

Category	**LULC 1990**	**LULC 2000**	**LULC 2005**	**LULC 2015**
Class names	Area(acres)	Area (acres)	Area (acres)	Area (acres)
Forest area	3707.73	5057.11	4437.44	1302.08
Water body	681.012	243.663	384.187	30.33
Crop land	11708.1	9195.37	9999.04	3112.51
Barren land	6430.98	5196.41	5895.52	2275.81
Urban area	5736.92	7164.58	8508.27	4577.83
Road Network	797.023	2016.14	1210.22	656.685
Fallow land	3060.84	3068.67	1340.37	1163.12
Mining activity	986.093	1166.73	1246.91	245.97

B. Assessment of Landscape Indices:

The landscape indices are two conventional by Shannon's diversity index (H), Simpson's diversity index (1-D) and a newly developed Pammi Nitin Sinha et al [3] Normalized Patch Size Range Index have been analyzed with assessing the process of urbanization in the Salem city area. Analyses of the H values yielded that there occurs the significant increase in the value of H from the 1990 to 2015) within the Salem municipal corporation (SMC) area from 1.72 to 1.7 indicating relative abundance of the eight LU/LC categories. Means the urban landscape has become more diversified in the study area as a result of intensive urbanization during 1990 to 2015. The Simpson's index of diversity (D) are 1.01 computed in the area for the 1990 and 2015 and index diversity is 0.01,reciprocal index is 0.99 which also corroborated the results form Shannon's index of diversity (H) for the study area thereby proving the prevalence of significant increase in the equitability among the various LU/LC categories[3].

The Normalized Patch Size Range index values for the different LU/LC [3] in Table.1 are given and showed in Fig.7. Comparative analyses of the index values of the eight Land use/Land cover categories in the study area reveal the following observations. A Number of Urban patches show clearly indicates increased from 1990 to 2015 from the analyses made above in the section of patch parameters, it is clear that the increase in the magnitude of the Normalized Patch size Index for urban Land use/ Land cover category in the study area. The Urban largest patch size increased during the time period 1990 to 2015 as evidenced in Fig.3 showed the intense urbanization. On the other hand, an index value of 0.95, which is close to 1 associated with the water bodies occurring within the area, might have resulted due to the shrinkage of the largest patch size. The cropland exhibits acres of 12000 to 6900 acres which are decreasing in its largest patch size during 1990 to 2015.

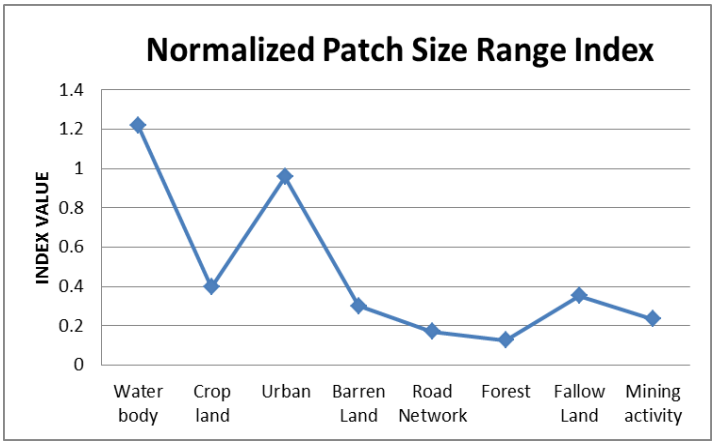

Fig.7. Variation of Normalized Patch Size Range Index of LU/LC

The large scale fragmentation is due to the intensive urbanization subsequent to the formation of the capital in the year 2015. Three categories of LU/LC that have been significantly influenced by built-up activities are crop land, water body, and barren land. The urbanization in patches that have led to the increase in the patch size of the urban clusters and shrinkage of the patch size (Fig.8). Table.3 provides a brief description about metric adopted to examine the structure of landscape in Salem City.

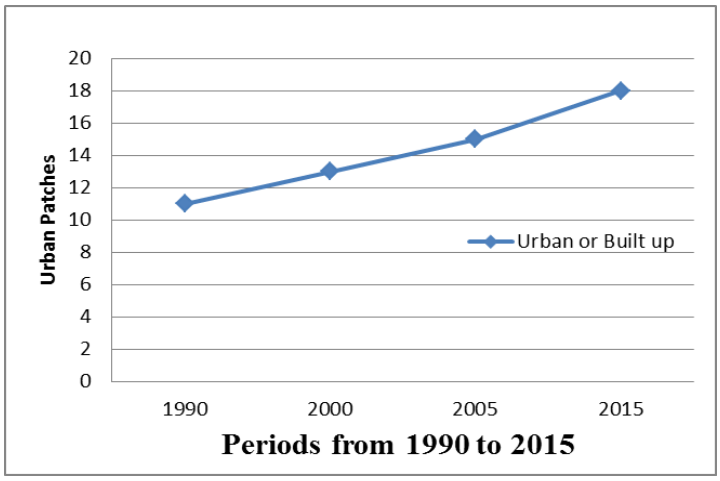

Fig.8. Variation of number of urban Patch of LU/LC

Table 3 Landscape Metrics Selected In This Study Area

Name of the units	**Explanation**	**Justification**
Average patch size (APS)	Average patch size of each class, expressed in acres	Fragmentation
Patch frequency(PF)	Result of the expansion of the existing urban agglomerate	Fragmentation
Largest patch size (LPS)	When the entire landscape consists of a single patch of, when the largest patch comprises 100% of the landscape.	Dominance
Shannon's Diversity Index (H) (SDI)	Equals minus the sum, a measure of diversity. Approaches 0 when there is no diversity, increases with a number of patch types.	Diversity
Simpson's Diversity Index (D)(SDI)	The Value of D ranges from 0 to 1 with D=0 representing the infinite diversity while D=1 representing no diversity.	Diversity
Normalized Patch Size Range Index (NPSRI)	Urban exhibits a value of greater than 1 which clearly indicates towards the first situation (1) of the Normalized Patch Size Index.	Index
Number of Urban Patches(NPU)	*N P U=n* NP equals the number of patches In the landscape. NPU>0, without limit.	Fragmentation

Source from McGarigal et al. (2002)

V. CONCLUSIONS

In recent, decades over the population, it is necessary to quantify the pattern of urban landscape dynamics for good planning and management of Salem city. Urbanization occurred through the consumption of crop land, fallow land and water body have suffered intensive fragmentation of built-up activities as evidenced by the significant decrease in the number of crop land, fallow land and water body. Decrease in the patch size of 2015 is indicating massive cropland and fallow land patches within the area for urbanization activities. A Significant decrease in the patch frequency of settlement within the area is attributed to the expansion. The Shannon's diversity index and Simpson's index of diversity determined parallel trends in the respective study areas signifying the existence of a strong correlation between them. Shannon's diversity index and Simpson's index of diversity are capable of the period's dynamics of the diversity and equitability among the different land use and land cover. The Normalized Patch Size Range Index enabled significantly understanding of the patch dynamics, especially the expansion of patches a particularly growth urban or built of patches observed that the urban patches have expanded within boundary of city while another patch of six classes have reduced.

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