Title:

IDENDIFICATION OF URBAN GROWTH PATTERN BY USING REMOTE SENSING TECHNIQUES AND SPATIAL METRICS IN THE CASE OF URBAN DECLARED AREA OF VAVUNIYA

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Abstract: The core area of the research is focus to characterize the physical pattern of the build-up growth and its transition over the time, as it implies significant information about the changing nature of the city or urban area as a main transforming component of it. Regard to the purpose, this study is carried out based on the context of main parts of Vavuniya (including urban declared areas) having increasing tendency of physical development due to the location, connectivity and development programmes.

In order to achieve this task, remote sensing techniques, particularly image classification and change detection methods were used based on the four satellite images within the period of 1994-2014. Classification considers all the land cover features under build up and non-build classes, further to identify the trend in both composition and configuration, seven classes of most suited indices of spatial metrics were employed as they widely used to quantify the changing pattern of landscape. These were done on whole and relative scale, to get overall and comparative trend based on main four main divisions of the area, Results of these methods' are related with a real context and factors (development projects, demographic transition) of the area in a comparable way.

The results revealed that the expansion of built up area has increased from 12 % to 33% of the total land in compact manner in north western to south eastern direction, due to the concentration of development in road network and public services. Built cover in the town area is amalgamated as compact cover, due to the services of instant periphery residential expanded as homestead type of residencies. With the introduction of resettlement, considerable amount of built covers were newly emerged in the cluster form and division based comparable analysis shows that the central & southern part of the area under the compact development of each clusters, existing built covers were adjoining & increased in the extend, while in northern & eastern parts shows increasing trend in new built cover as low density residential development.

All the results and conclusions were derived with appropriate quantitative facts from the above methods then analysed with progress of the area to characterize it physical pattern over the time.

CHAPTER 01

INTRODUCTION

1.1 Background

Physical patterns & directions of expansion in the build-up environment become more concerning phenomenon of the urban planning in recent decade, which have huge influence in every aspect (social, economic, environmental, infrastructure) of sustainable development, Earlier in the subject of urban growth management most of the researches focused on investigating (both quantitative & qualitative) the urban growth in the perspective views of demographic transition, economic agglomeration, infrastructure (specially transportation) developments, since these are the main determinants of growth of the cities. (Besussi, Chin, Batty, & Longley) stated "*Traditional Urban theories investigate how cities develop and grow through systematic interactions of infrastructures, people and economic activities*", (2010, p. 14). However, later on, these static approaches have been changed, and then physical patterns & directions of built up growth & its management became as modern viewpoint of the urban planning, as it contains various information that used for decision making. Because of that different technical based aspects have been raised to configure it.

Based on that, this research is focused to study about the characterising of physical patterns of urban growth, mainly the expansion of built up area with respect to different time period at two different levels of scale to get overall tendency and regions wise comparable changes in the main part of Vavuniya district(urban declared area). As this area is a growing urban centre in Northern Province with strong regional linkage, while having environmentally sensitive areas such as forest, watersheds and vegetation lands, it is important to have an idea on patterns of the build-up growth to monitor the development in a sustainable way. Through the appropriate methods that used to characterize (quantifying & observing). Especially based on the various related literatures on this subject, remote sensing techniques such as image classification and change detection are used to extract the information about both land cover and uses as they represent the real context of the area. The availability of temporal satellite images provide a way to explore the transition on the changes. Further than this in order to get a deep understanding about tendency of physical patterns in a quantified way spatial metrics were suggested as an appropriate indicator, this contains set of metrics in three levels (patch, class& landscape). These explain about the land cover in different point of views (McGarigal & Marks, 1994). More than this to relate the outcomes of such methods with the study area, properly related information about the factors which affect the physical growth in this context such as political conditions, development plans and environment were reviewed in a comparable way.

1.2 Research question

This research focuses on two sets of questions. First what are the changes that have been taken place in the physical patterns of land cover (build up & non-build up cover) in the study area throughout the selected period, especially this focused to identify the directions and extend of built-up growth in different time period, Second is what are the major factors and their influence on urban growth pattern?.

1.3 Objective of the study

This research is focused

- To illustrate the tendency of the physical pattern of built up areas over the different time period.
- To analyse the major factors that affecting the physical growth pattern.

1.4 Scope and Limitation

Study is considered only the physical transition of built up areas, so it did not investigate other major aspects of the urban growth such as social and economic factors. Outcome of this research is mainly depending on the interpretation of the satellite images through the appropriate remote sensing techniques. Hence the quality, resolution, and other properties of the satellite images have a considerable influence in this analysis and also the selection of appropriate image classification methods and techniques were obtained through the literatures and selected through the comparison of the final result. The same procedure was followed in the selection of spatial metrics. By considering time and resources, widely used methods have been used for this research.

CHAPTER 02

LITERATURE REVIEW

2.1 Introduction

Growth of any city generally determine through the evolution in the physical elements of it. Batty & Longley (1994) stated that, like all natural growth, cities' basic units are evolve with time through accumulative process, in here basic units represent each component of built up elements such as residential, commercial, transport networks and etc. This growth can be identify in terms of various factors (I.e. economy, demography), however physical pattern of such built up elements is one of the most transparent factor which explicit the growth temporally.

2.2 The physical pattern of the urban (built up cover) growth & Significance

In the past recent decades, there is an increasing tendency towards monitoring and managing the physical growth of the urban areas in a more systematic way rather than depending on out-dated views & theories. This is an important consideration because almost all the form of the contemporary growth of any urban areas is considered as inappropriate for its sustainable development. Especially suburbanization & sprawl is the unique outcome of present urban growth (Besussi, Chin, Batty, & Longley, 2010). Further Razin & Rosentraub (2000) described that the growth could be defined through form, density and land use pattern, regard to that, the current urban forms such as strip commercial based linear development, leapfrog land use pattern and low density residential in scattered forms are mostly associated with it & all these urban forms can be identified based on two considerations such as physical configuration and density. Additionally, Gaslter, Hanson, Ratcliffe, Wolman & Coleman, (2010) described, this concern classifies the patterns of urban growth according to the eight unique components, they are: density, continuity, concentration, clustering, centrality, Nuclearity, land use mix and proximity. Following table 2-1 described this in detail.

Table 2-1: Components of urban growth

Components	Description
Density	The ratio of the total population or residential units of the developable area (sprawl area) to its total urban area.
Continuity	The amount of continuous built-up area of the developable area to the urban borders
Concentration	The degree to which development is located disproportionately in relatively few units of the total urban area rather than spread evenly.
Clustering	The degree to which development has been compactly crowd together to minimize the amount of land in each unit of developable land occupied by residential or non-residential uses.
Centrality	The degree to which development (both residential and non-residential) is located close to the central business district or the core of an urban area.
Nuclearity	Shows the degree to which developable land has been built in close proximity

	to the already existing urban fabric (which has one center)
Mixed uses	The degree to which two different land uses commonly exist within the same small area
Proximity	Degree of distance between different land use, which are close to each other across an urban area

(Source: Galster, et al., 2010, Wrestling Sprawl to the Ground: Defining and measuring an elusive concept)

These characteristics help to understand the aspects of physical growth pattern, mainly low level of tendency in these measures explicit the sprawl characteristics. (Galster, et al., 2010). However, all the growth patterns cannot be considered as sprawl or improper, for instance the infill & density growth toward core area considered as appropriate and alternative for city growth (Bhatta, 2012). Mainly the Built up area considered as vital part of the any urban system so the Increasing tendency (growth) in this element in uncoordinated pattern & direction identified as the main reason for various effects in both internal & external environments. Luck &Wu (2002) mentioned no matter about cities formation, their spatial pattern definitely affects physical, ecological and socioeconomic progressions within their boundaries and beyond. As described above, such improper pattern effect negatively and this effect almost depend on the nature of the area. Especially such scattered and low density build up developments lead to the fragmentation in agriculture & forest cover, cost to provide the infrastructure services and leads to inefficient use of the land etc. (Rui, 2013).

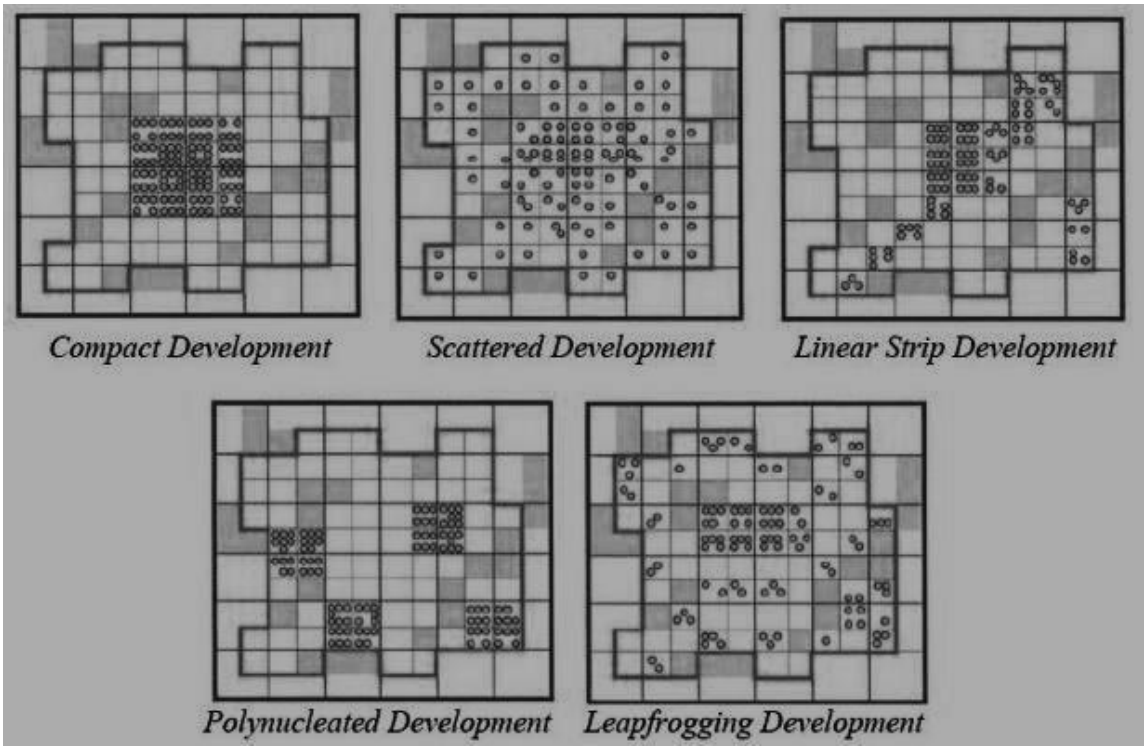


Figure 2-1: Physical pattern of contemporary growth
(Source: Besussi E. C 2010, the Structure and Form of Urban Settlements)

So investigations on the physical pattern & process of the growth (built up area) became more concerned point, as it has significant impact on urban system. Huang (2009) stated that *"The urban pattern growth analysis aids in understanding the underlying effects of urbanization such as sprawl, loss of rural land*" (p. 6). So having a deep understanding about such growth pattern, process and their interaction becoming main goal in the urban studies (Bhatta et al,2012,).

2.3 Methods used to characterize the physical pattern of the urban growth

In order to get a deep understanding about these physical patterns & form of urban growth, various contemporary approaches have been developed based on the improved technologies in the field of urban planning. Basically theories such as fractals, cellular automata, and dissipative structure theory and landscape metrics were broadly used to characterize the physical form of urban area (Suja, Letha, & Varghese, 2013). Based on these ideas, various methods have been used by different researchers to reach their objectives. However, all of these ideas are focusing on the quantification and characterization of the urban growth and its' expansion to have broad and accurate information to predict, visualize, calculate and characterize the growth which embeds on its physical pattern and structure. So the applications of quantitative indicators are one of the approach which presenting great prospective in characterizing the urban form (Costa, Rocha, & Rodrigues, 2009). Sudhira & Ramachandra (2004) stated that illustrating pattern involves detecting and quantifying it with proper scales and brief it statistically.

Especially numerical indices of proper quantitative measures give valuable Computational information of growth pattern which can be used as the main inputs for decision making. Among these methods spatial metrics, regression analysis, cellular automata based modelling techniques and gradient analysis (Sudhira & Ramachandra, 2004); (Suja, Letha, & Varghese, 2013) & combination of such these methods (Zhang, Wu, Zhen & Shu, 2003**)** are becoming widely using by the researches as per their case & purpose.

In order to employ the selected methods in a successful way almost all of the researches in this subject have used the remote sensing & GIS as their main platforms. Because,

Improvements in GIS techniques and remote sensing used to classify the spatial patterning of the size, shape and dimension of the land use. These indicators provide dynamic measures of physical form & morphology of the urban land cover that aid to manage the growth of the urban system, (Batty & Longley , 1994). Mainly these physical patterns are not a static phenomenon, but the process. They are evolving with the time, during the evolution period it takes different forms through driving factors. So this temporal change can mostly be able to observe by space borne satellites & asses through the remote sensing technology (Bhatta et al., 2012).

Accordingly, using the combination of RS & GIS basement with various methods those mentioned above are the current trend to study the physical pattern of the urban growth.

2.4 Remote sensing for understanding the physical pattern & tendency of urban growth

Built up Growth has been a significant element of land use and land cover change (Zhang, Wu, Zhen, & Shu, 2003), this phenomenon determines the tendency of patterns & physical structures of area as mentioned above. Thus having an up to date & detailed information about this changing process respect to the time is essential for monitoring the physical growth. For that various static methods have been used in the past years based on long gaped census & statistical information, which was highly based on bias samples and inaccuracy. Based on Bhatta et al. (2012) nevertheless with the development of remote sensing based on the satellite images becoming essential way to understand the spatial- temporal changes and transformation of any area which full fill the main purposes of current urban studies, as regard to that Besussi, Chin, Batty, and Longley (2010) explained Gathering and organizing practical information of physical growth of urban development through remote sensing are progressively growing procedure. Also Computerized Change identification in remote detecting considered as vital procedure which empower to recognize the evolution (transform) of any spatial components (urban, rural, vegetation cover, etc.) (Belal & Moghanm, 2011).

Particularly in this context availability and ease of access to different spatial & temporal data (satellite images) is significant to carry out the appropriate analysis (Herold, Goldstein, & Clarke, 2002). Bhatta (2012) explained Mostly Remote sensing data acquired through satellites with different sensors at high & medium temporal and spatial resolution available for past three decades that help to evaluating the spatial patterns of urbanisation. Currently with the development of the web based information storage systems, number of websites freely provides medium resolution multi temporal satellite images for research purposes. Specially web services like GLCF, USGS provides different types of satellite data e.g. such Landsat data set could be easy to access respect to the time. However there are various considerations should be take account before applying and selecting the data & techniques of remote sensing in this subject. Mainly factors such user's need, scale, characteristic of study

area and resolution of image have to be considered (Lu & Weng, 2006) further most of the researches indicate the following points,

- ★ The acquisition period (i. e., season, and month):-related to climatic conditions and solar angle may effect to the quality of the image. (Théau, 2011).
- ★ Time gap between multi date imagery:-to show the considerable differences in the land cover of the same area in same time period.
- ★ Sensor calibration or geometric distortions (Wang & Ellis, 2005).

Various researches that carried out to characterize and quantify the urban growth & landscape change used the Landsat satellite images (both medium resolution & multi temporal). Huang (2008) mentioned, medium resolution Landsat images play the key role in the investigation of urban change at different spatial scale. Development in the Landsat series such as thematic mapper(TM) & enhanced thematic mapper(ETM) satellite images have considerable spatial and temporal resolution, these are widely used data types for monitoring and mapping land cover which can be assist in this subject (Yesserie & Getnet, 2009).

Abebe (2013) used four medium resolution Landsat images of different years both (TM&ETM) to investigate how urban land pattern have changed over time in Kampala, Uganda. Mainly all the images were gathered from same season of different years in a way that cloud cover not exceeded 10%. In order to identify the transformation of physical pattern, all 4 images were in same resolution to make the comparison easy. Furthermore some very high resolution satellite images were obtained for clearly identify and assist the image classification & detection. Yesserie & Getnet (2009) have done the analysis used Landsat images (MSS, TM, ETM) to study the municipality level of spatial-temporal land cover change in Valencia, Spain for 23 year gap. Additionally used google maps & other high resolution satellite images (e.g.:- IKNOS, Quick bird) for the reference data to classify the land uses. Further various researches which focusing on land cover pattern change & transformation in a broad context mostly used these Land sat satellite data (TM, ETM) as their main input. Because these are flexible for different spatial scale, especially at local level (to make area wise comparisons with changes) & regional level (Haung et al., 2008; Deka 2012).

The next important consideration is how to approach the use of these satellite imagery through the remote sensing techniques in order to identify the change of physical pattern of area. There are a number of ways have been developed, among that Yuan (1998) mentioned image classification & change detection are widely used to produce proper classified spatial-temporal map of any area.

2.5 Image classification for produce classified land cover

Shau (2008) described that image classification characterized as a procedure of sorting all pixels in a satellite image data to get a define set of land cover or all the categories of land cover classes in that image. This process grouping comparatively small set of classes which pixels in the same classes are having comparable properties. There are number of methods have been developed to classify the images based on different aspect. So there is need to choose appropriate methods for regarded context (types of land cover, number of classes, and state of accuracy) of the research. Following figure 2.2 shows the main procedures that widely used in the subject of image classification.

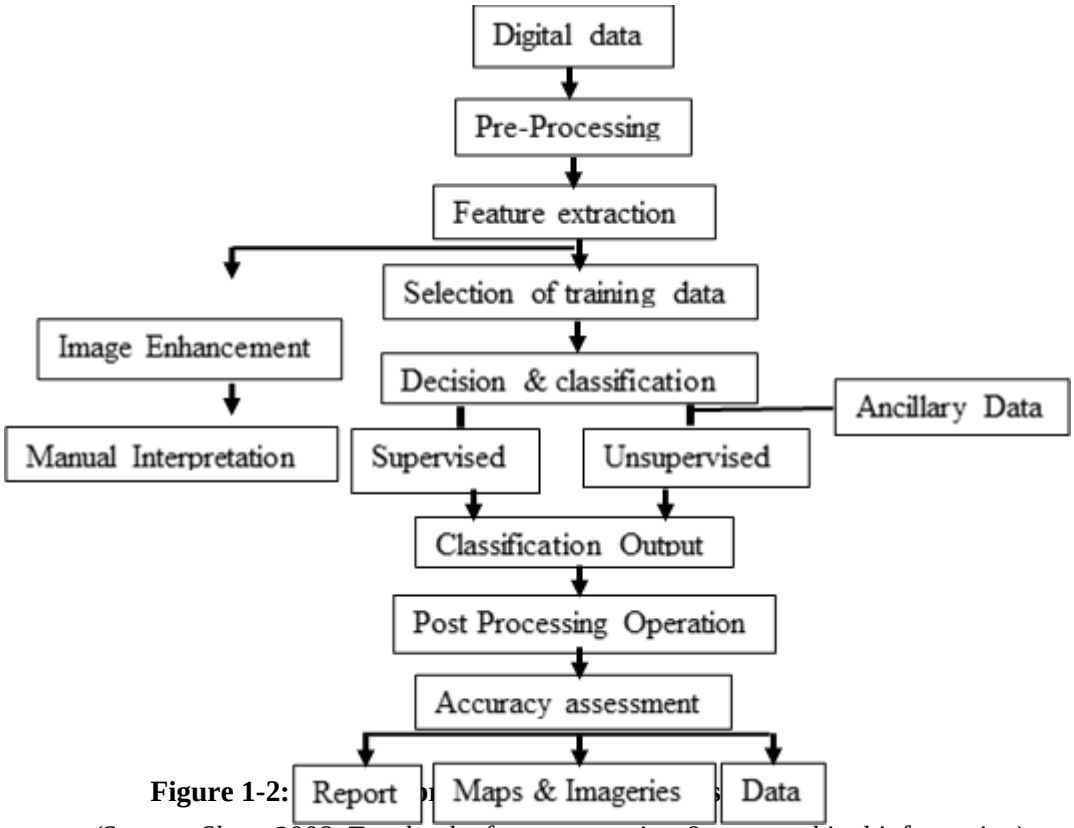


Figure 1-2: [illegible]

(Source: Shau, 2008, Text book of remote sensing & geographical information)

Initially it starts with categorizing the different theme classes, for example urban, agriculture, forest and etc. It could carry out through identifying the nature of a land cover pattern of the particular area. Then do all the correction as a pre - process & upgrade the satellite image (geometric, atmospheric, etc.). Once after choosing the sample area, generate the categorizing result through employing proper method, to do so appropriate decision rules have to be compared. As based on the decision rule pixels of the image will group, individual class, then it has to be classified (pixel by pixel) based on proper techniques, then the final categorized result has cross checked with the real ground situation (Al-doski, Mansor, & Shafri, 2013)

Jensen (2005) explained the majority of the studies which deal with this classification procedure to create the land cover maps to follow two main classification methods such supervised & unsupervised classification methods, because both of these methods are more flexible than other methods (eg. Parameter, Non-Parametric, pre pixel- object oriented & hybrid approaches) to this context.

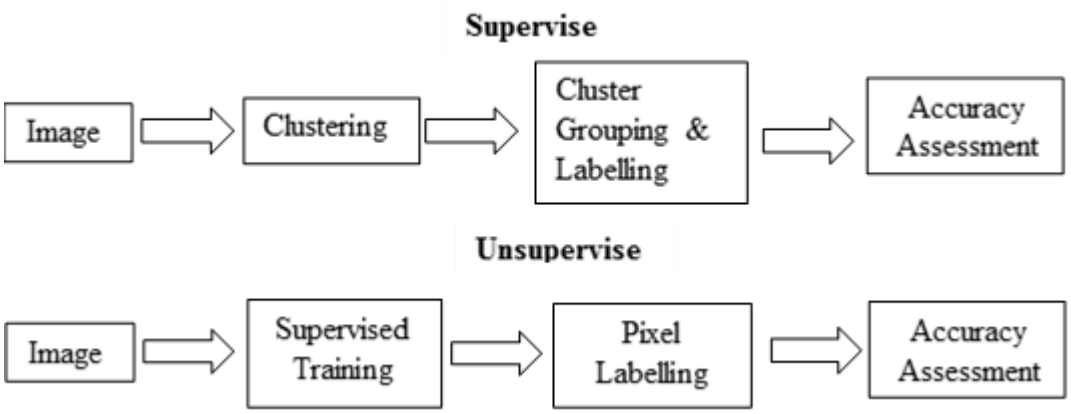


Figure 2-3 Common steps in Supervised & Unsupervised classification

(Source: Al-doski, Mansor, & Shafri, 2013 Image Classification in Remote Sensing. Journal of Environment and Earth Science.)

Supervised classification method delineates smaller patch of area as training data usually it called as spectral signatures (clearly identified) on the image, so this well identifiable sample data used to assign the doubtable (unknown) object to known element. Mainly it is important to have an idea of current land covers when define the training sample for indicted the unknown future (Xiaoling, 2013). In order to categorize the classes as heterogeneous group it need proper classifier, for most case maximum likelihood algorithm used as decision rule to evaluate each pixel in the supervised classification. Class mean & covariance matrix are the main inputs of this method, so it includes a variability of classes into consideration, this is a main advantage of this method. However its required considerable duration & manual attempt (ERDAS help).

Number of researches have employed the ML Classifier to categorize land cover classes, among that (Ahmad & Quegan, 2013) used ML to classify a varied tropical land covers in Selangor, Malaysia that gained from Landsat 5 TM satellite images. & they could able to identify 11 classes of land cover. (Yesserie et al, 2009) used combination of parallelepiped and maximum likelihood classification method to identify temporal changes of municipality land cover change in Spain.

2.6 Identify the changes through the techniques of remote sensing

In order to identify the spatial distribution & temporal changes in classified maps there is a need to employ the proper detection techniques. Singh (1989) revealed that change detection means the procedure of recognizing transformations in the state of an entity or phenomenon by noticing it at different time period. Mainly it gives both quantitative & qualitative details of target classes (Kandare,unkno) and currently change detection techniques classified under two categories such pre-classification and post- classification change detection (Yuan1,998).

Both of these categories contain variety of methods among that image differencing considering pixel value of the satellite images from different date & calculate ratio of corresponding pixels in each band of those images (Kandare, 2005). Within this method normalized difference vegetation index (NDVI) is commonly used indices which can be able to detect land use & land cover change (Sahebjalal & Dashtekian, 2013). Main purpose of this method is to calculate the vegetation cover through the multi- temporal images & outputs of this images show pattern of changes respect to time. It based on following equation, NDVI= (NIR -R) / (NIR+R), outputs range from -1 to +1; positive values represent the healthy vegetation while tendency towards negative values pointing lower level vegetation & non vegetation cover. Generally this used for monitoring the vegetation cover, however this could able to use for detect the built up environment where classes only limited to two or three categories & it does not reveal the main conditions & measure of change direction**.** Furthermore principle component analysis and change vector analysis also used by various researches. However most corporate method for detect the land use& land cover change is post classification comparison (Singh, 2010, p. 996). This method carry out based on separately classified temporal images, result is highly depend on the accuracy of the classified images (Rashed & Jurgens, 2010). This method indicate both spatial distribution & nature of the changes in each classes (Singh et al., 2010).

As based on the reviews, application of the remote sensing is act as basement for charactering and visualizing the physical pattern & structure of both land use & cover, as regard to that extract the information of built-up & none built up area is vital phenomenon in the urban planning as they are main visible component of the urban growth (Costa, rocha & Rodrigues, 2009). Mainly quantify the temporal changes of physical pattern is most concerning approach which can be produce valuable information to prepare inputs for the decision making, in this case particularly the contemporary techniques of remote sensing (as described above) play key role to achieve the task in this subject. Bhatta B. (2012) detail explained that understanding the urban growth through the RS revealed the following information (1) growth rate, (2) the spatial configuration of growth, (3) observed differences & estimated growth, (4) spatial & temporal disparity, and (5)whether the growth is sprawling or not.

Although outcome from these techniques not enough to detailed the comprehensive fact of the transformation of the physical pattern of built & non built environment. Therefore the usage of the spatial matrices implemented in various researches to full fill such information gap.

2.7 Quantify the physical pattern of built up cover by using spatial matrices

With the usage of properly classified spatial-temporal satellite images, the application of the spatial metrics become main tendency to characterize the process of physical pattern of urban area (built-up & non built-up characteristics) through the well-defined quantitative measurements (Mcgarigal & Marks, 1994)in further level. At beginning theses metrics were applied in landscape ecology in the name of landscape metrics to quantify the heterogeneity of land scape. It provides statistical understanding of spatial pattern (classified maps) at three levels such patch, class, & entire landscape level. (Herold et al., 2003; Bhatta, 2012)

As based on McGarigal et al., (2015), matrices in patch level compute for each patch in the landscape (in here it considers the combination of build-up & non build-up area). These matrices are used as indices of the spatial character & measures of the deviation from the

class and landscape. Class level matrices compute for every patch type or class in the landscape (homogenous land use classes) & these are the indices of the amount and spatial configuration of the each class. Landscape level metrics used for an entire patch mixture & it measure both composition and spatial configuration of the whole landscape.

Currently, spatial metrics contain numerous indices (type, level) for various purposes. Not all these are suite for this particular purpose, so selecting the proper matrices will determine the success of the result. Also McGarigal et al., (2015) strictly mention that "*user have to properly define the study area, including its thematic content and resolution, spatial grain, extent and boundary*" (FRAGSTATS help, p.26). Hence these have to be considered properly before employ such these matrices.

Researches which investigated around this subject have almost employed the same matrices among that**,** Weijers (2012) employed eight of widely used landscape metrics to analyse the urban sprawl through measure the physical pattern of it & (Cheng, 2003) employed these to quantitatively evaluating urban growth in Wuhan, china. The following table 2-1 indicate the most widely used spatial metrics in this context.

Table 1-2: Common Spatial metrics that used to characterize physical pattern of urban growth

Spatial metric	Level of heterogeneity	Description
Class area(CA)	Class level	Measures the area that covered by each identified land cover classes in hectares (built up, forest, etc)
Number of patches (NP)	class level	Measures the extent of fragmentation in each classes through calculate the individual patches on it.so it indicate the diversity of considered class, indicate as numbers
Edge density (ED)	Class level	Measures the configuration of each class through calculate the length of the edge (perimeter between two patches) of each patches, in different classes. Show as meter per hectares.
Patch density (PD)	Class level	Used to identify the spatial distribution of each patches in different classes respect to total area, show as numbers (NP) per 100 hectare
Largest patch index (LPI)	Class level	Measures the percentage of largest patch in each classes based on total landscape, so if the class contain higher amount of largest patches it represent more concentration of that class. Show as percentage
Shannon's diversity index (SHDI)	Landscape level	Measure the degree of dispersion & concentration of the patches in considered class, result range indicate the level of compact to fragmentation
Contagion (CONTAG)	Landscape level	It measure the overall extent of the diversity of the landscape, the result is depend on the characters (size, shape) of patches in the focused area.

Shannon's evenness index (SHEI)	Landscape level	Indicate the richness of the classes as based on the distribution of patches in each class, high value represent, highly fragmented nature of overall classes.

2.8 Researches related to this context

There are number of studies which relatively suite for this subject have employed this combination of techniques. Among that Abebe et al. (2013) have used Landsat TM & ETM images that derived from 4 different years (showing 10 year time gap), at same resolution and season. Then employed ERDAS imagine to implement the image classification and detection techniques to produce the classified images, basically those images were only contained three classes, which focus build-up area & non build up & water bodies. The main focus of the research was to quantify the urban growth pattern of Kampala, Uganda. This was done at two different scales, first scale focusing the entire study area as one region in order to have an idea about the overall process of the physical growth, secondly the area was divided as five numbers of region to have compared & relative tendency of the urban pattern, in the same way spatial metrics were employed (most of these metrics described above) at these different scales. Furthermore, research included the regression analysis to identify the factors of the physical growth. However the core subject of the research focused to quantify the physical pattern of the growth. The result of the metrics in each year was explicit the growing tendency of the built-up pattern based on the road direction & mainly the density & pattern of the

(Source: Weijers. D, 2012, the suitability of GIS methods for analysing urban sprawl, & the influence of scale & Mcgarigal. K, 2015, FRAGSTAT help manual)

CHAPTER 03

RESERCH DESIGN

3.1 The study area

In order full fill the objectives through the selected methods & techniques, case study area was selected in the main parts of Vavuniya district that including the UDA declared urban areas. It is located in the southern part of the Northern Province, including 2 DS divisions & 30 GN divisions, and it is one of the rapidly growing urban centre as it functioning as the gateway of the northern region by connecting the north with other parts of the country through major roads (A9, A14, and A29) & railway network.

Based on the census & housing preliminary report (2012), the highest annual population growth rate of 1.97% between 1981 and 2012 was reported in Vavuniya district & among the DS divisions in Northern Province the highest DS division population is reported (117,533) in Vavuniya (census & statistical department). Regard to the Disaster risk reduction & preparedness plan for vavuniya, this area can be urbanized and congested due to development of infrastructure facilities and increases of services will be come up with the North Development Programs (DRRP plan for vavuniya).

Particularly changes in the Physical development of this area has determined by the conflict situation of war & its consequences, mainly tendency of changes in physical growth of the built up pattern is highly related with this post & pre-war situations, such as displacements, resettlements, declared urban development plans and other implemented plans & proposals (i.e. DRR plans), with these external factors, the strategic location of this area have high influence on it physical development. Figure 3.1 shows the location of the study area.

Further in national physical plan 2030 this area has identified as first order city in terms of the urban hierarchy & especially major part of core area was declared as urban development Area in 2009 under the Urban Development Authority Law number 41 of 1978, (draft development plan for vavuniya UDA) & it covers vavuniya urban council area & other 13 surrounding GN divisions which include 169Km^2 of land.

As based on the DRRP plan major portion of the area has identified as environmentally sensitive & prone to disasters such as flood and drought, as the area contain numerous tanks & wet lands. Mainly considerable amount of vegetation (predominantly paddy) & forest cover (north-eastern part) located close next to the build-up features. So the transition in the physical patterns & directions of built-up growth has high possibility to have effect on such natural elements. Following figure 3.2 shows land use pattern of the declared urban development area.

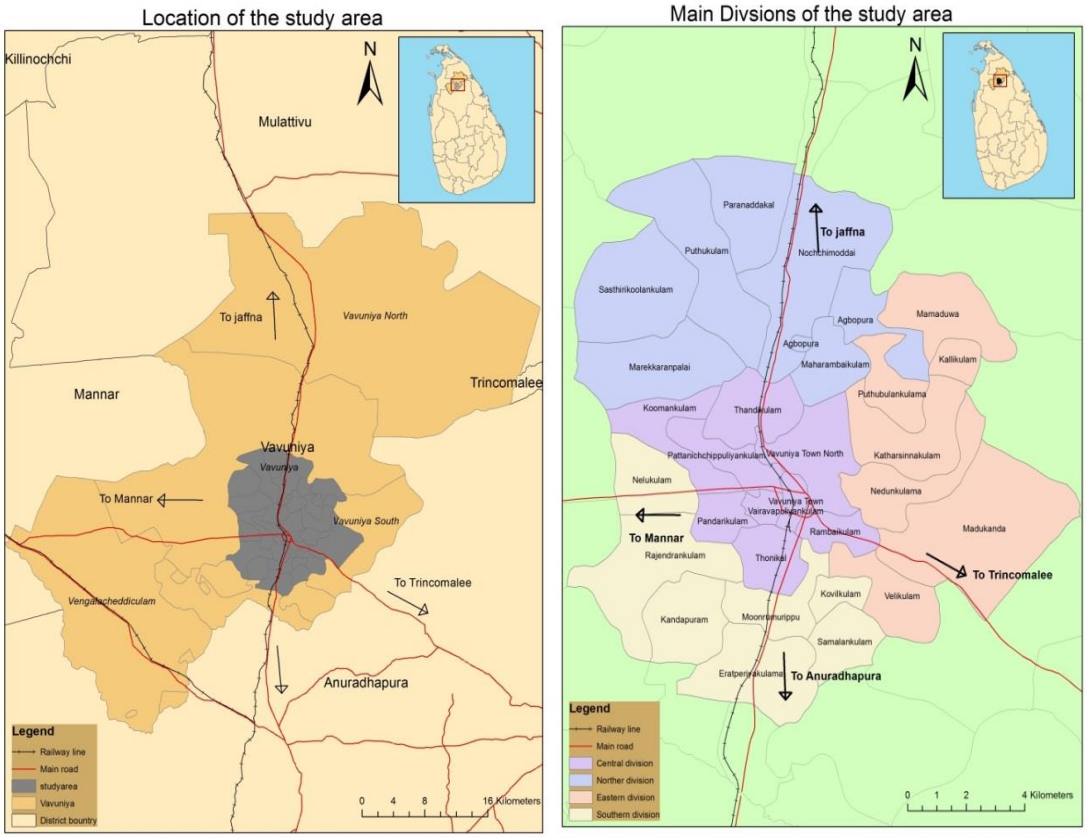


Figure 0-1: Location of the study area

(Source: Prepared by author, data from- GIS, TCP lab)

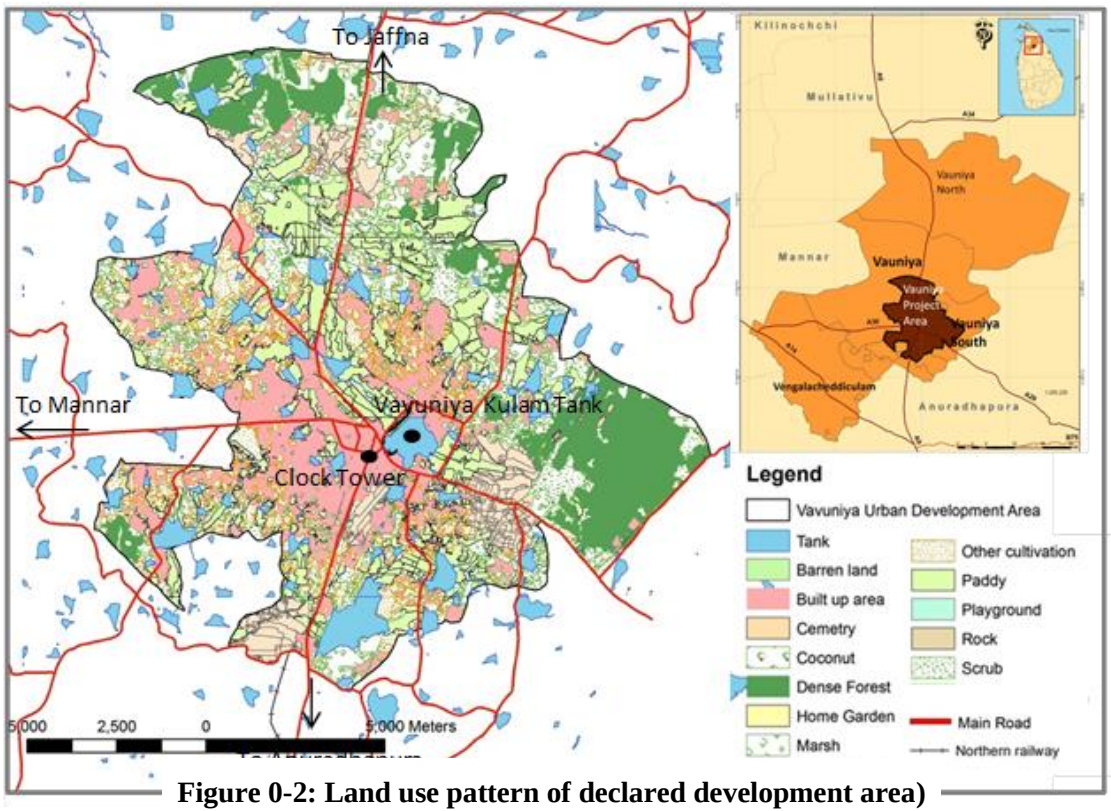


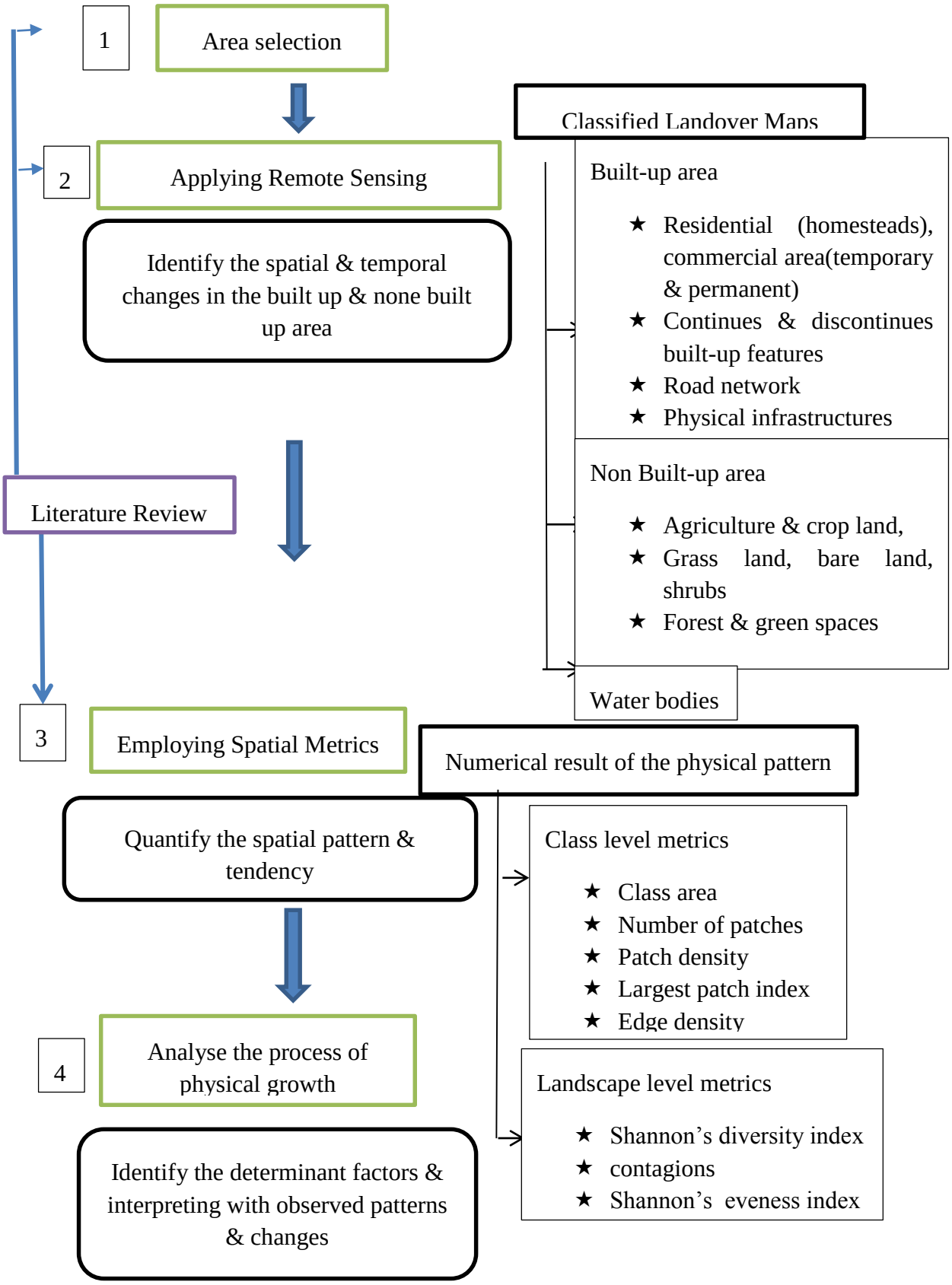
Figure 0-2: Land use pattern of declared development area)

As mentioned, due to the conflict situation most of the boarder part of this district were faced the problems in continuity of development, that create the fluctuation in the built up growth patterns in those area. Because of that situation rapid immigration & resettlement was taken place towards to this area (i.e. 2000 new housing units were constructed within the period of 1995-2001, (vavuniya divisional secretariat). Therefore this area has been through static growing tendency, particularly after the war various infrastructure development projects has been introduced & implemented, this has let considerable changes in the built-up environment. Following Figure 3-3 shows the visible transitions of the land use from non-build up to build up in the form of contiguous & newly emerged built up cover within the study area over the period of 2004-2014.

Figure 3-3: visible changes in the built cover

(Source: Google earth, historical imagery)

3.2 The process of the study



3.3 Techniques of remote sensing & spatial metrics

Regard to the methodology, once after selected the case study, satellite images of selected period (1994, 2001, 2009, & 2014) were obtained as main data for this analysis and those were processed through the following steps.

1. Image pre-processing
   This process contain layer staking & visual enhancement of the images, firstly four bands of each satellite images were staked additionally to merge the resolution as same for all the images, band 8 of the ETM, ETM+ images were merged through the pan sharping process.
2. Determine the land use categories that come under major classes

3. Selection of the classification method
   Supervised classification method was implemented to classify the selected images into mentioned categories, under this considered amount of signatures were collected based on the satellite images in each period, then maximum likelihood & minimum distance classifiers employed for trial process & proper method was selected based on the accuracy of the trial.

4. Assessing the accuracy
   The output classified images was checked through the accuracy assessment cell array calculations & results revealed by error matrix, percentage accuracy and kappa statistics reports.

For the second task these classified images were modified to use in spatial metrics calculation (as in the manual of input data), this task include following steps

1. Delineate the parameters
   - Background, boarder, no data values
   - Sampling system
2. Indicate the metrics
   - In class level (CA,NP,PD,LPI,ED)
   - In landscape level (SHDI,SHEI,CONTAG)
3. Run & analyse the quantified result

These Metrics were selected for study area at two levels, at first to identify the overall process of the physical transition & to get comparable progress among the four divisions, for the metrics calculation FRAGSTAT spatial statistical application was employed , Figure 3.4 explain briefly about these selected metrics. .

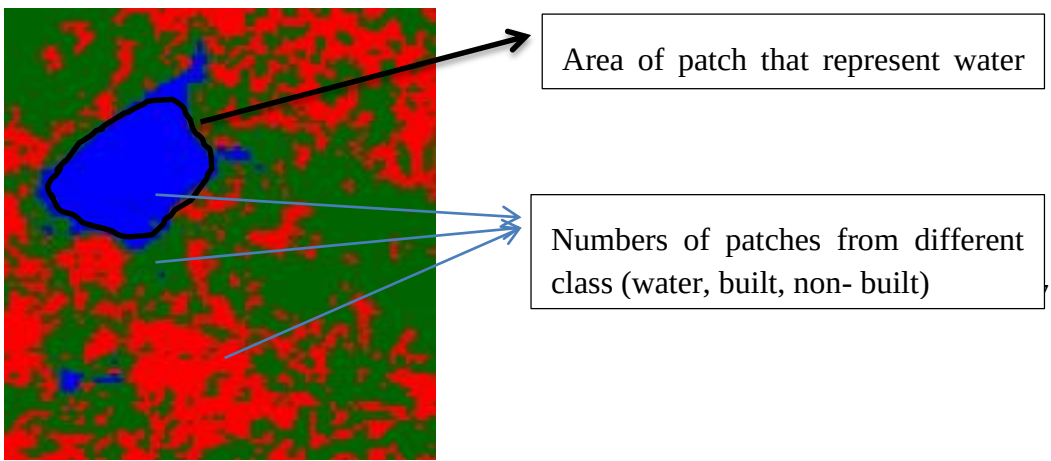


Figure 3-4: description of spatial metrics

(Source: compile by author, based on: FRAGSTAT help manual, 2015)

CA: Extend of each classes in hectares

NP: Number of patches in each class

PD: Density of each individual patches per 100 hectares

LPI: Occupation of the largest patch as a percentage of the total land

SHDI: level of diversity of all classes in the whole area

CONTAG: probability of being the homogenous class (based on vicinity pixels) in the percentage of total landscape.

Finally the results that derived from above two processes were analysed with the collected information on the tendency of the physical growth of the study area through the primary & secondary sources.

3.4 Collection of data

the selection of the proper satellite images of different period time was one of the main base step of this research, by considering the availability & purpose, "Landsat" type of satellite images were acquired from USGS website that freely accessible through web data base, by considering several criteria they were selected & pre-processed regard to the purpose of the work, further to assess the accuracy of the result & to compare with real situation Google earth images were used, however it limited with particular time period (2000-current period) therefore , the land use maps (1990) were gained from survey department. Following table 3-1 is showing the data that use for this process & figure 3.5 shows the satellite images.

Table 2-1: Description of the data

Time base of the data	Type of data	Spatial resolution	Data source
1994/9/3	Landsat 5 TM	30	USGS
2001/9/6	Landsat 7 ETM	30	USGS
2009/3/4	Landsat 7 ETM +	30	USGS

(Source: USGS website, Google earth, survey department)

2014/4/1	Landsat 8	30	USGS
1990	Land use vector data	1:10000	Survey department
2001/2014	Google satellite	Multi scale	Google earth

In order analyse these out comes with real context, especially information about the tendency in the physical development progress of this area were gathered through the regarded documents & statistic reports. Following data was collected for this task.

- Proposed & implemented Development plans
    - Draft development plan for vavuniya urban development area
- Population & housing census statistics
- Vavuniya District & DS divisional resource & statistic profiles

3.5 Satellite images for the selected period

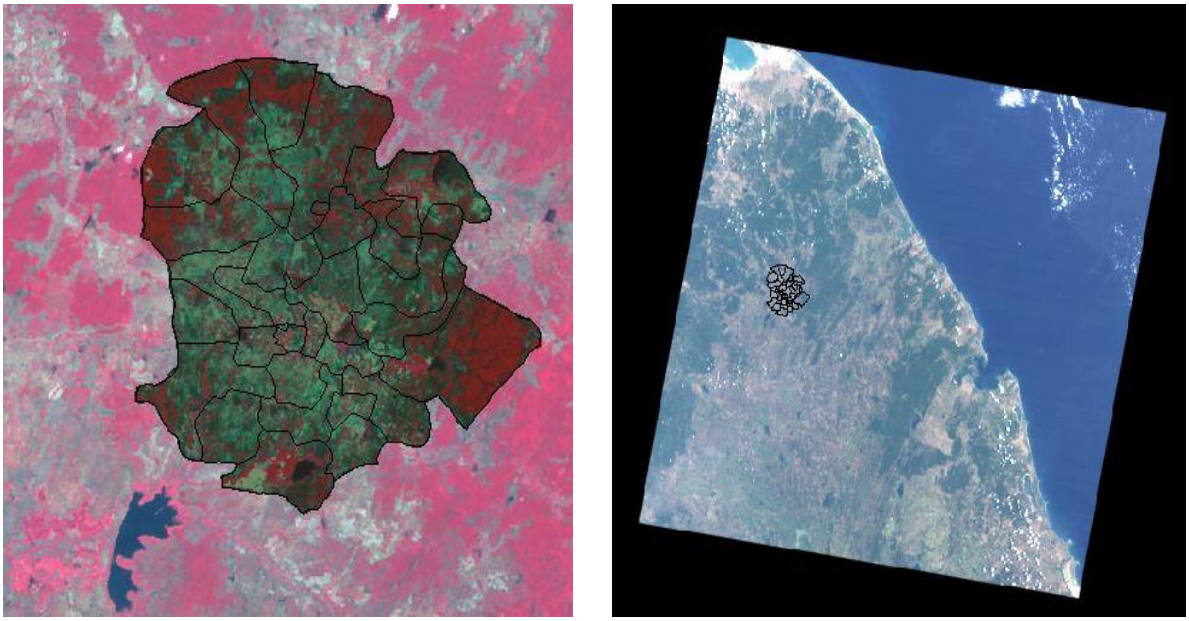


Figure 3-5: Satellite images that used for analysis of 1994

(Source: USGS official web site, https://ers.cr.usgs.gov)

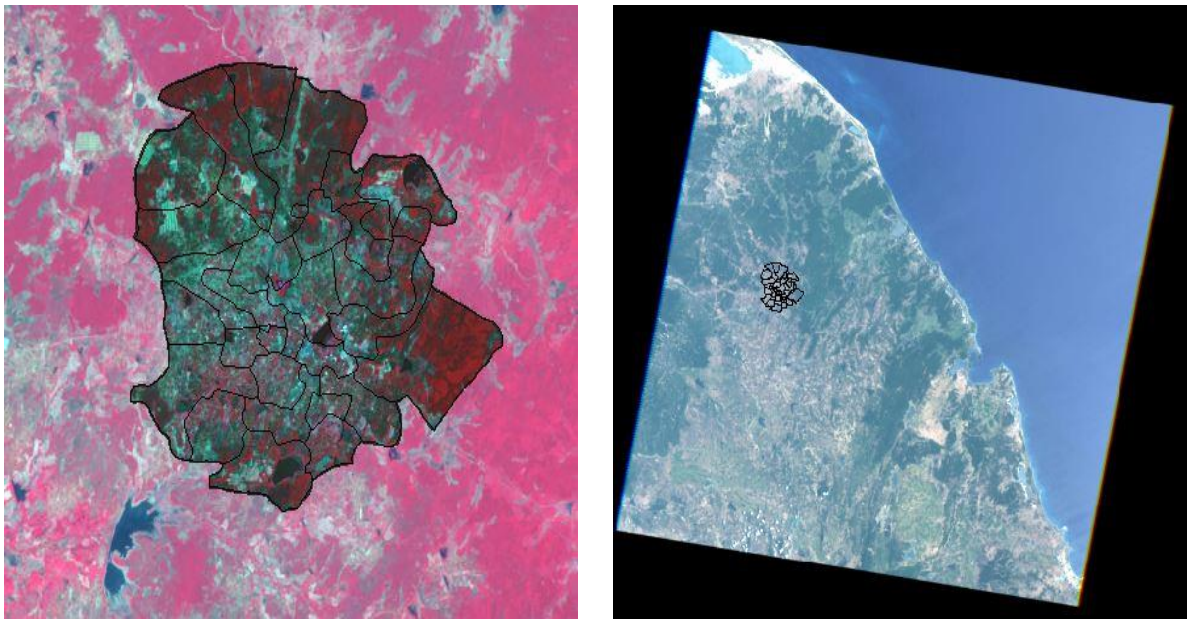


Figure 3-6: Satellite images that used for analysis of 2001

(Source: USGS official web site, https://ers.cr.usgs.gov)

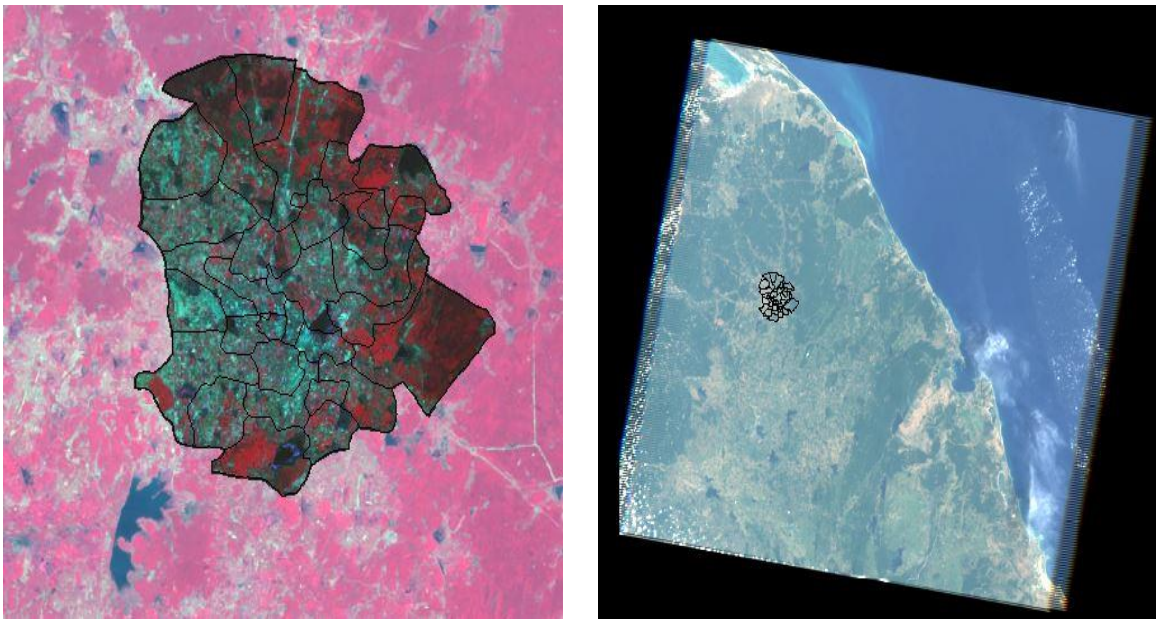


Figure 3-7: Satellite images that used for analysis of 2009

(Source: USGS official web site, https://ers.cr.usgs.gov)

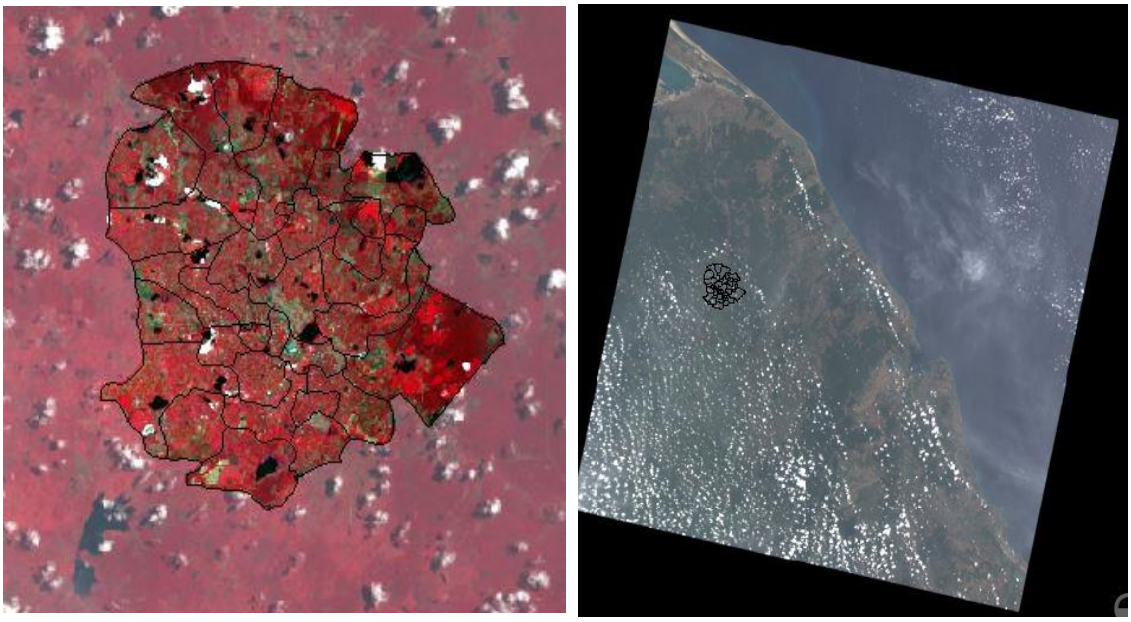


Figure 3-8: Satellite images that used for analysis of 2014
(Source: USGS official web site, https://ers.cr.usgs.gov)

CHAPTER 04

ANALYSIS

4.1 Introduction

This chapter focused to analyse the result of the tendency of the physical pattern of built up & non built up area in different period of time, that derived through the application of the remote sensing & spatial metrics then compared with the current situation of the area in two level of scale. The results are interpreted through the correlation of charts, tables & figures. spatial

metrics were used to identify the overall process in changes of the study area, for that 5 of metrics were employed such CA, NP, LPI, PD, ED. then to have division wise idea based on the nature in land cover pattern of each division further 3 of metrics (SHEI, SHDI, CONTAG) were employed at landscape level as they suit for quantifying the composition & configuration of both land cover.

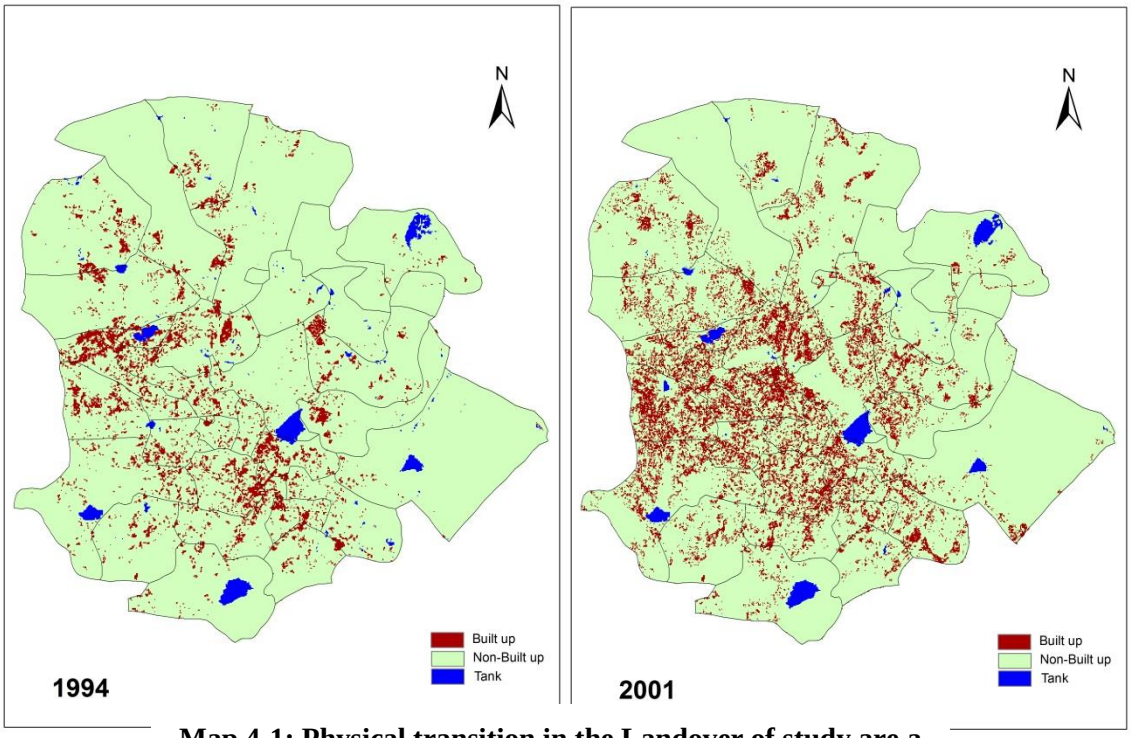
4.2 Accuracy assessment of the image classification & overall analysis

Following table 4-1 shows the accuracy results of the image classification that derived through accuracy assessment. Regard to this, higher accuracy value represented by water classes & build up class have lower accuracy in all classified images, due to the lack of correct representative data (land use, aerial photos, etc.) 1994's image classification shows lower value. Due to the occurrence of smaller patches of clouds resulted for the relatively lower rate of accuracy in 2014's classification.

Table 3-1: Result of the accuracy assessment

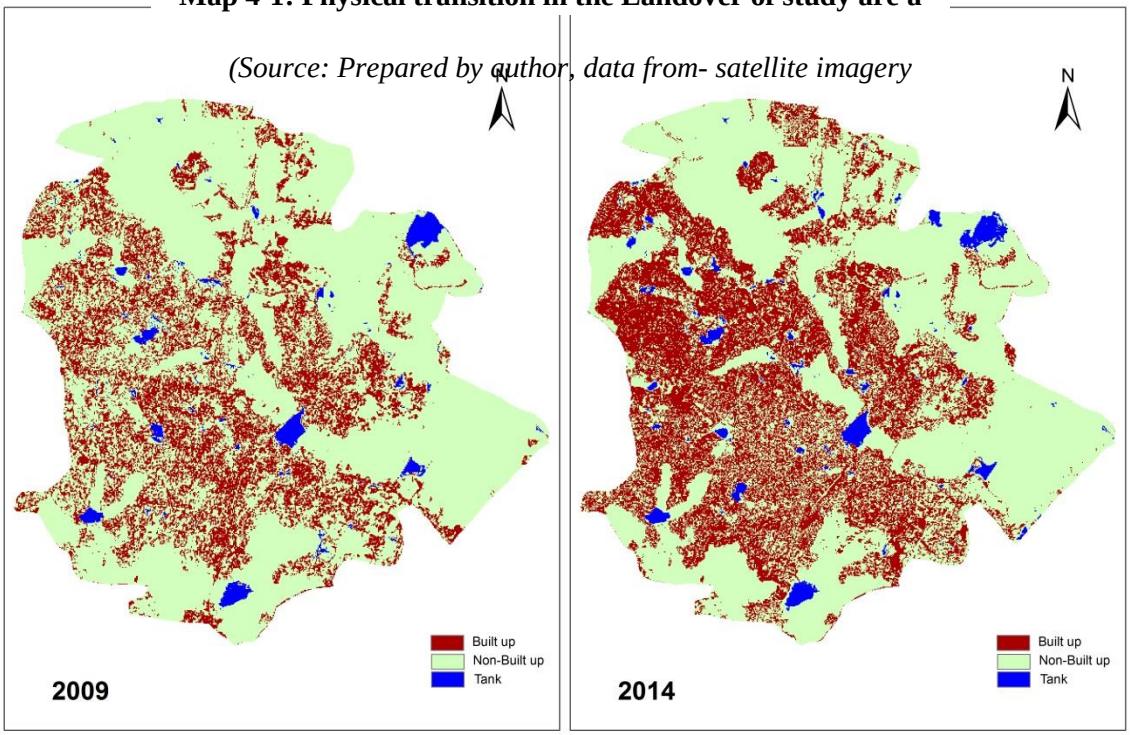
Time period of Satellite image	Type of data	Land cover class	Classification Accuracy		Kappa Statistics	
1994/9/3	Landsat 5 TM	Build- up	75%	79%	0.70	0.76
		Non build	78%		0.74	
		Water body	84%		0.79	
2001/9/6	Landsat 7 ETM	Build- up	78%	83%	0.74	0.80
		Non build	83%		0.80	
		Water body	87%		0.82	
2009/3/4	Landsat 7ETM +	Build- up	85%	88%	0.82	0.85
		Non build	87%		0.84	
		Water body	92%		0.88	
2014/4/1	Landsat 8	Build- up	80%	82%	0.75	0.79
		Non build	82%		0.78	
		Water body	93%		0.89	

Following maps 4-1 shows the spatial & temporal transition of the built & non- built cover of the study area.



Map 4-1: Physical transition in the Landover of study are a

(Source: Prepared by author, data from- satellite imagery



The table 4-2 shows the overall tendency of the changes in the built up & none built cover based on 4 metrics that derived from above maps.

Table 4-2: Result of spatial metrics for entire study area

	CA(hectare)		NP(number)		PD(number per 100 hectare)		LPI (%)	
year	**built**	**Non built**	**built**	**Non built**	**built**	**Non built**	**built**	**Non built**
1994	1874	18060	2093	135	6.60	0.43	0.38	69.21
2001	3599	16398	3933	419	12.41	1.32	0.62	61.34
2009	6290	13458	2321	1250	7.322	3.94	4.80	50.46
2014	6832	12881	1666	3380	3.51	7.24	16.92	21.31

Based on these results, class area measures the absolute size of the built up class, that indicates the increasing tendency of built up area in hectares, while non-built cover has decreasing tendency , considerable growth in build cover has been taken place at 8% of annual growth mainly in north western & south eastern based on horawapothane road direction. Especially from 1994 to 2001 built up cover has increased by 1725 ha at 13% of annual growth within 7 years, due to this period considerable amount of migration was taken place from the boarder districts of vavuniya to this study area (rajendrakulam & koomangulam). Lower level of annual growth rate 1.7 % has occurred 2009 to 2014. However absolute area of built up cover has continues growth. This revealed by figure 4-2.

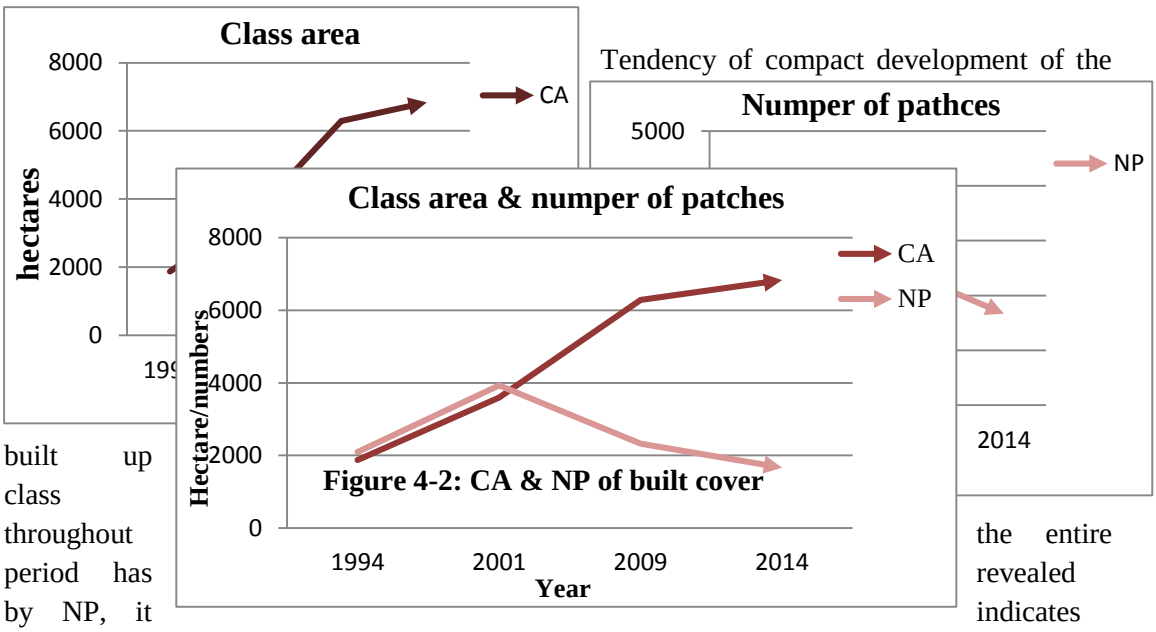


Figure 4-2: CA & NP of built cover

Tendency of compact development of the built up class throughout the entire period has revealed by NP, it indicates the number of individual patches in the built up & none built up class and especially it used to measure the level of fragmentation of each patch in the same class (McGarigal, 2015) In here decreasing tendency of the built up units showing the merging process of new built up units. However, it does not mean that low number of patches represent small area, because one of largest patch may equal for number of smaller patches in terms of size. As regards to this, the figure 4.3 shows the combination of NP & CA of the study area.

Figure 4-3: Negative relation between CA & NP of built cover

This revealed that built up cover has grown in the form of compact and dense pattern, same time this indicate the increasing levels of fragmentation of the non-built up area, mainly correlation between class area of built up cover & NP of non-built cover is (0.840905) indicating a high positive relation, so the increasing tendency in the built up area highly dispersed the non-built cover, especially the scrub land in the middle & southern portion, forest cover in northern & eastern boarder has slowly dispersed while reduced in the size. Mainly homestead type of built cover has emerged as contiguous of current residential area within the part of adjacent developable land close by it.

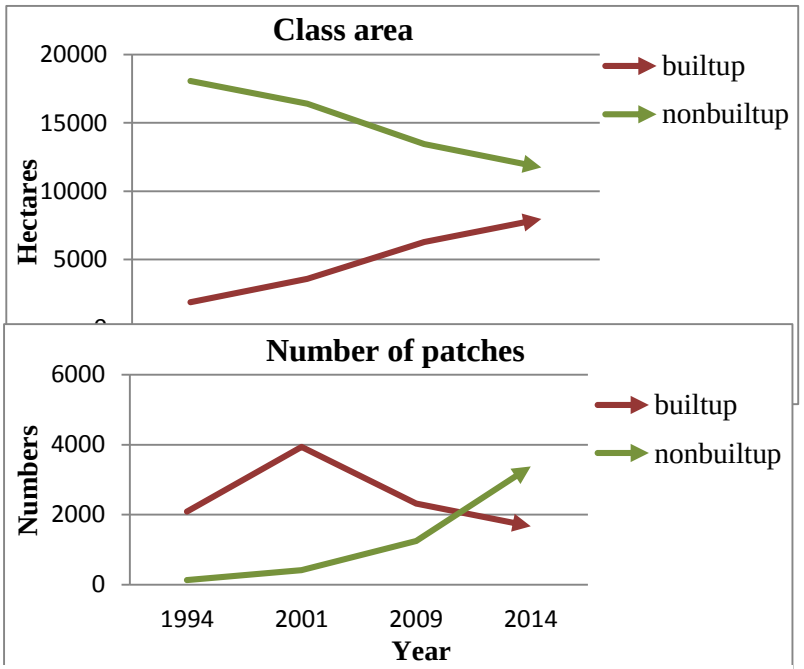


Figure 4-4: negative connection between both land cover

Density of disperse units (PD) of built cover shows the declining progress, in 2001 PD was 12.4 & reduce by 70 % as 3.3 units, due to the decline of NP, thus this also indicating the nature of continues development of the built up area through combining the adjacent built up units in the periphery area as a major unit, while non-built covers have high value of PD (o.4 in 1994 & 7.24 in 2014) this is because of the higher level of fragmentation compare to build up cover, mainly correlation between the extent of none built cover & PD of its shows (-0.97314)

high negative relation, while correlation between NP & PD of none built-up cover indicate as 0.9837 positive connection , thus declining tendency of area & increased amount of dispersed units were influence in this process.

The results on the largest patch index (LPI) reveal the composition of the area, as percentage of the largest homogenous unit regard to entire study area (McGarigal, 2015) LPI for the built up cover indicates the rapid increase from 0.38 in 1994 to 16.92 in 2014 while none built covers shows negatively, in 1994 it had 70% of the total land as one homogeneous patch but currently decline as 1/5 of original extend, this also cooperate to indicates trend of compact & continues development of the built covers, & the continues fragmentation of non-built up cover, the figure 4-5 shows the trend of PD & LPI of both land covers.

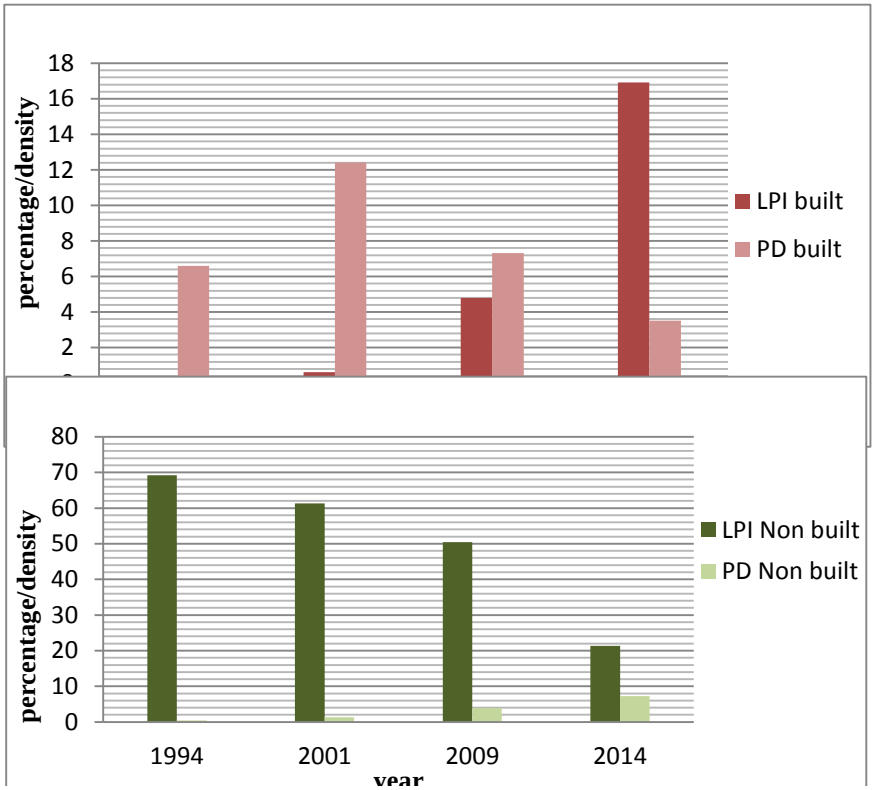


Figure 4-5: Negative trends of LPI & PD of both classes

Table 4-3: Overall tendency

class	CA	NP	PD	LPI	Trend of process	Level of impact
Built	+	-	-	+	Continuously integrate with the periphery units & agglomerate as compact cover	High

Non built	-	+	+	-	Increased in the Scattering form & fragmented within built cover as number of smaller units while declined in the extent	Moderate

4.3 Results based on the divisions based analysis

Study area was divided as four main divisions based on the heterogeneity in the land use & development process.

Table 4-4: Main divisions of the study area

Division	Area (hectares)	description	Population density Person per(hectare)
Vavuniya Town	3482	Functioning as main town centre, contain majority of Commercial & residential area of the study area while having paddy cultivation & homesteads	27
Northern	6828	Homestead type of built cover , mainly contain residential areas with larger portion of vegetation & forest cover	12
Eastern	5447	Major portion contain forest & barren lands, comparatively has low built up development.	8
Southern	4452	Growing as the continuity of the town centre, developing as residential area towards southern eastern direction	11
Total area	20209		

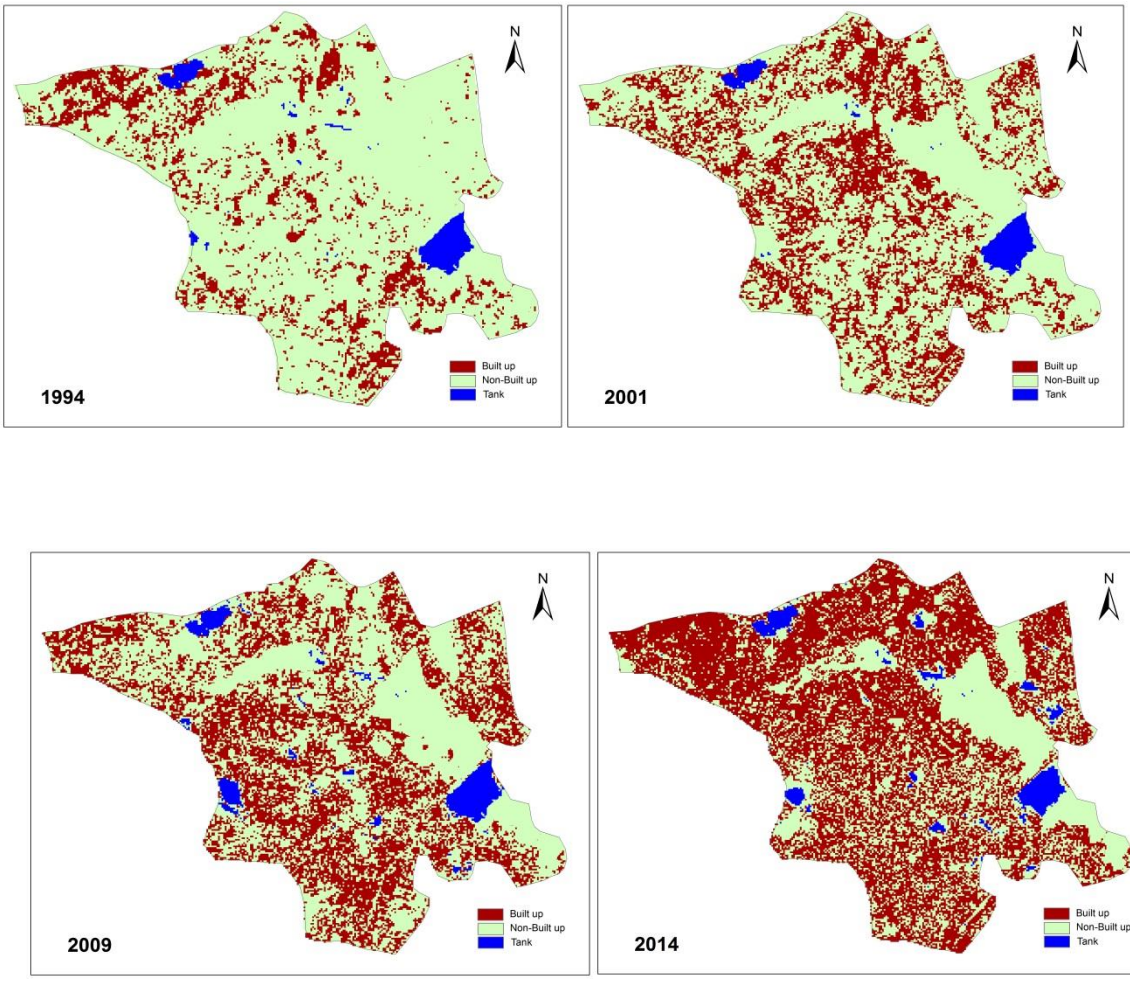
Main Divsions of the study area

Map 4-6: Divisions of the study area

(Source: Prepared by author, data from - GIS data of TCP lab)

4.4 Result for the town division

This division includes the main commercial & residential area of entire Vavuniya district. Vavniya town, town north, thonikal, pandarikulam, vairavapuliyankulam areas are functioning as main service centre for entire area, & total land is reserved for urban development, Map 4.7 shows the transition of physical pattern of built & non - built cover.



Map 4-7: Spatial & temporal transition of town division

(Source: prepared by author, data from: satellite imagery)

Based on the above transition, table 4-5 shows the result of class level metrics within study period.

Table 4-5: Result of the class level metrics (town division)

Study Year	CA (hectare)		NP (number)		PD (per ha)		LPI (%)		ED (M per hectare)	
	built	Non built	built	Non built	built	Non built	built	Non built	Built	Non built
1994	599	2791	696	61	10.18	0.89	1.37	40.37	51.03	55.74
2001	1232	2201	578	253	8.49	3.72	4.13	30.42	95.13	98.78
2009	1471	1916	473	392	6.95	5.76	13.17	22.33	105.42	108.37
2014	1797	1582	100	920	1.47	13.51	31.29	7.68	113.83	115.08

Within 20 years, built up area has been increased by 60 hectares per annually with the growth rate of 7.3 %, in 1994 built cover contain only 17% of total land, currently it increase up to 50% as main service provider of entire district, with cooperate this, declining tendency in NP shows the compact nature of built cover development, especially the built cover expand from the town centre to outer wards as residential & linear commercial development by taking the adjacent scrub cover in every direction, mean time the non-built cover continually decreased with the extend from 2791 to 1582 ha & increased with number of smaller units in fragmented form. Following figure 4-8 shows negative relation between CA & NP.

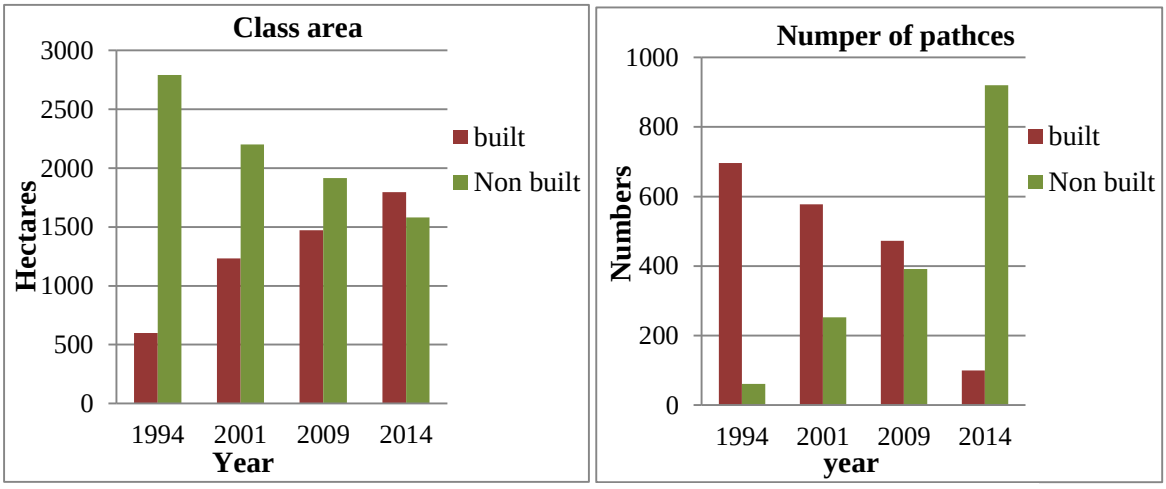


Figure 4-8: Negative trend in CA & NP of built & non built cover

Due to the trend of amalgamation of the smaller separated units as one adjoining patches, LPI for the built cover indicating the increasing trend, currently 31% of the land cover by one single continues built cover, correlation between LPI of built cover over the LPI of non- built shows (-0.97136) high negative relation, so increment of largest unit in built cover dispersed the extend of largest unit in non-built cover. In the same way the density of the fragmented units in the built cover have declined while the PD for non-built cover increased by 25% per year.

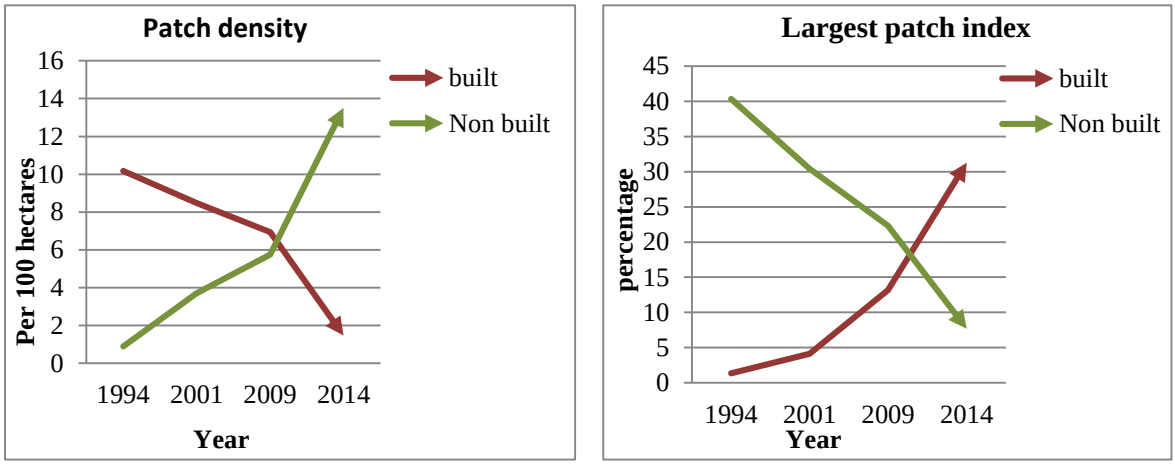


Figure 4-9: Opposite trend in LPI & PD

CONTAG indicating the accumulation or dispersion level of classes in particular landscape, contagion value for this division in 1994 is 56% that shows the homogeneous & contiguous level of non-built cover, but with the increment of built cover it has declined up to 43% then continuously increased, so it reveal that level of aggregation of built up area getting high through converting the non-built unit as built cover. SHEI representing the increasing tendency in the diversity (fragmentation) of patches, in 1994 value was law due to the largest patches in the non-built cover, then value increased by 11% in 2001 due dispersion of non-built cover by the contiguous increment in the extend of built cover, table 4.7 shows these tendency.

Table 4-6: Result of Landscape level metrics (town division)

year	SHEI	SHDI	CONTAG
1994	0.683	0.947	56.9606
2001	0.761	1.054	43.3498
2009	0.793	1.099	46.6554
2014	0.784	1.087	47.1341

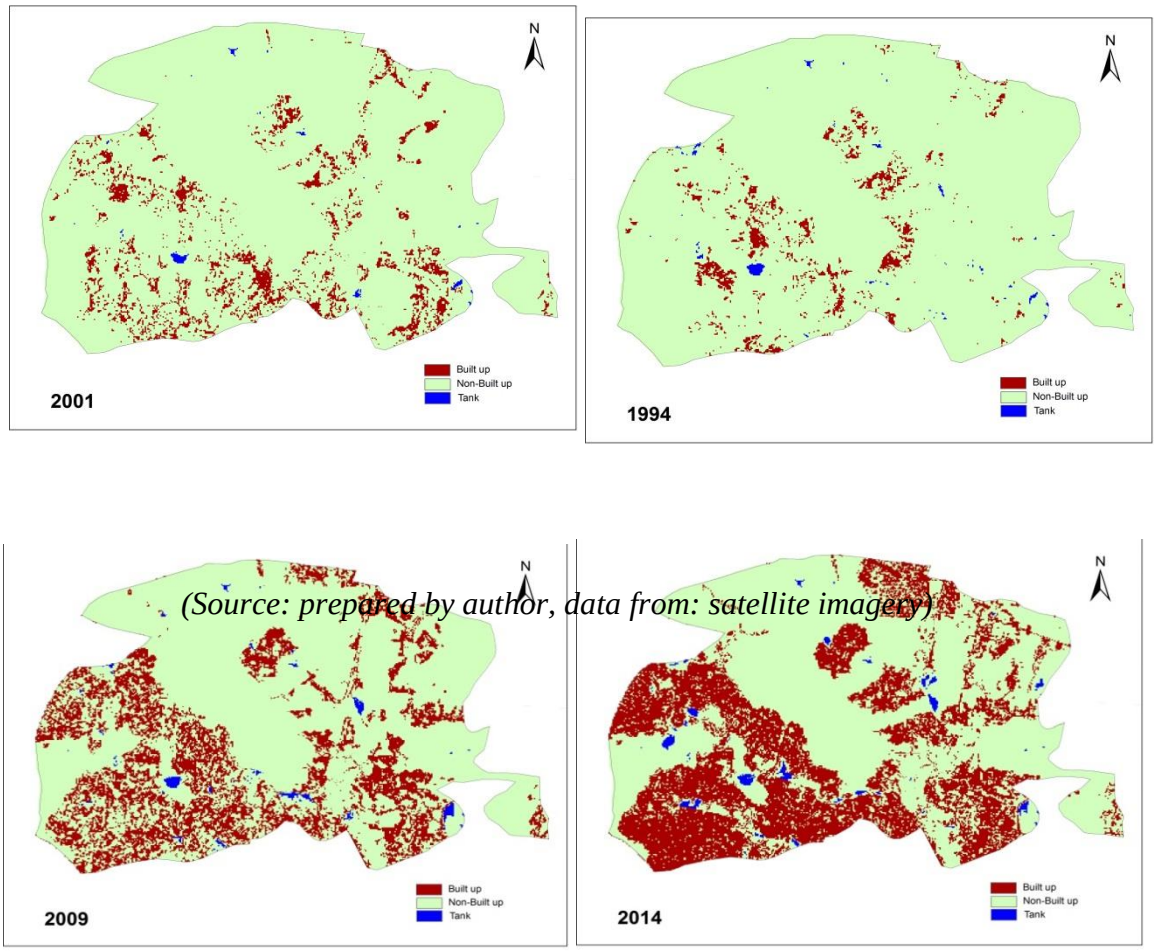
Table 4-7: Overall trend (Town division)

class	CA	NP	PD	LPI	Trend of process	rate

Built	+	-	-	+	Continuously integrate with the periphery units & agglomerate as compact cover	high
Non built	-	+	+	-	Increased in the Scattering form as number of smaller units while declined in the extent	moderate

4.5 Result for northern division

This division contain larger portion of land with homesteads type built cover, in western side contain paddy filed & forest cover in eastern & northern part (puthukulam & nochimodai) with new housing schemes in cluster form. Map 4-10 shows the trend in the built & non built cover transition.



(Source: prepared by author, data from: satellite imagery)

Map 4-10: Spatial & temporal transition of northern division

Based on above maps, the table 4-8 shows the result of the class level metrics for this division,

Table 4-8: Result of class level metrics (Northern division)

Study year	CA (hectare)		NP (number)		PD (per ha)		LPI (%)		ED (M per ha)	
	built	Non built	built	Non built	built	Non built	built	Non built	Built	Non built
1994	477	6322	492	31	5.02	0.32	0.61	64.61	24.44	31.03
2001	760	6040	894	76	9.16	0.78	0.45	60.20	45.31	50.59
2009	2236	4499	523	521	5.36	5.34	5.26	42.323	93.82	99.01
2014	2599	4146	515	1191	5.28	12.21	29.33	23.84	98.46	102.02

Due to the 20 years of gap, built cover increased from 2.3 % of total land to 12.5 %, mainly 2001 to 2009 it increase by 1476 hectares at 24% of annual growth rate. Correlation between CA of built & non built cover indicates (-0.99996) high negative connection, increasing process in the NP of non-built cover is higher than decline of its area (-0. -0.91905), so it leads to the increases in density of smaller patches therefore PD & ED represents high values, while percentage of largest patch declined rapidly. So it revealed the level of fragmentation of the non- built cover continuously increasing than the rate of agglomeration of the built cover, (figure 4-11).

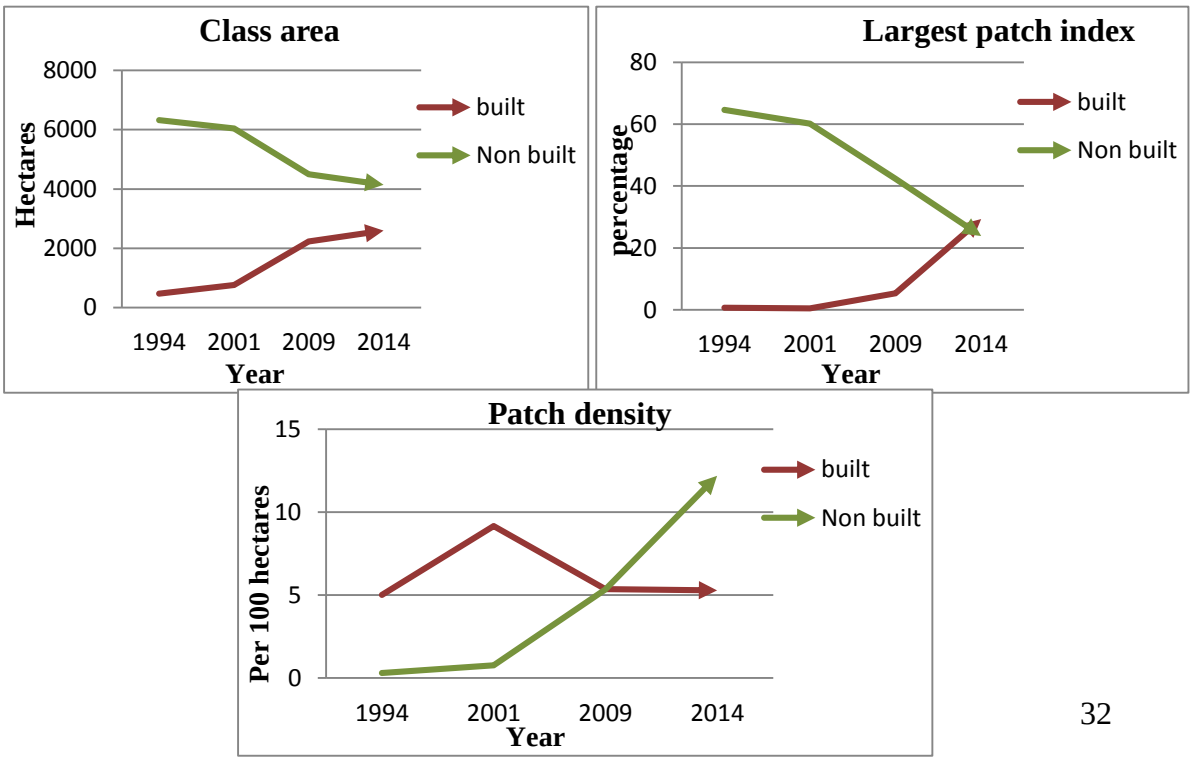


Figure 4-11: trends of the class metrics in both classes

Higher rate of decreasing trend in the contagion show higher level of dispersion have taken place in the overall land cover, higher homogeneity value of 64.5% of northern forest cover reduced up to 43%, further increasing tendency in SHDI & SHEI shows diversity of both classes are increased, it indicate the new emerging number of patches of the built cover is lower than the non-built cover but bigger in the extend & penetrated through non built cover as contiguous unit so it dispersed the land cover particularly in western direction (Marekkaranpalai, sasthirikulam) of the division (Table 4.8).

Table 4-9: Result of the landscape metrics (Northern division)

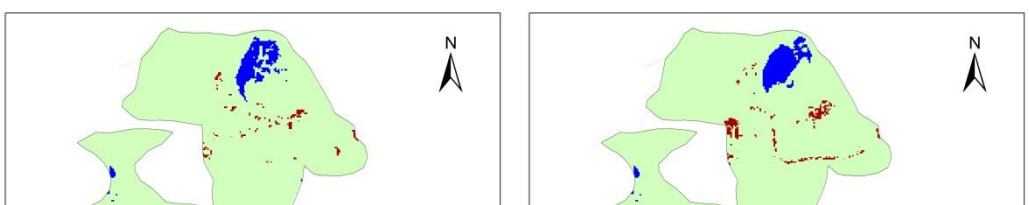
Year	CONTAG	SHDI	SHEI
1994	64.5602	0.8083	0.5831
2001	59.8459	0.8734	0.6301
2009	45.6022	0.9453	0.7123
2014	43.7137	1.1045	0.7514

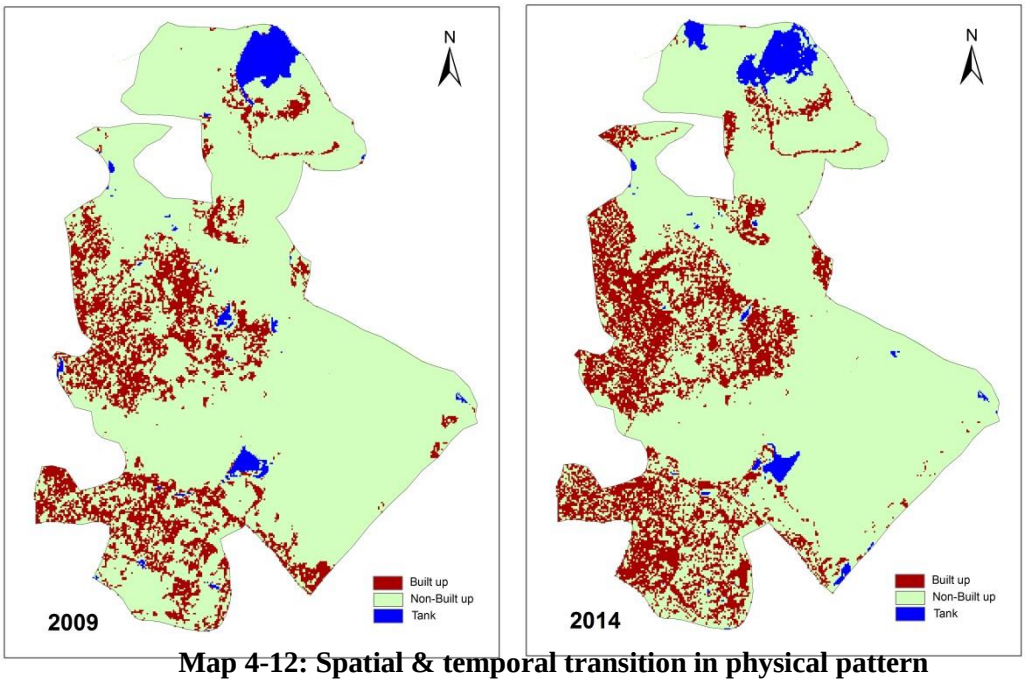
Table 4-10: Overall trend (Northern division)

class	**CA**	**NP**	**PD**	**LPI**	**Trend of process**	**rate**
Built	+	-,+	-,+	+	integrate with the periphery units & agglomerate as contiguous cover	high
Non built	-	+	+	-	Increased in the Scattering form as number of smaller units while declined in the extent	high

4.6 Result for the eastern region

This division contain the largest contiguous forest & scrub cover (madukanda & kallikulam forest). Emerging trend of built up units in the eastern part close to main town centre has led the smaller scale of built development into this division, map 4-12 shows the changes in the physical pattern.





Map 4-12: Spatial & temporal transition in physical pattern

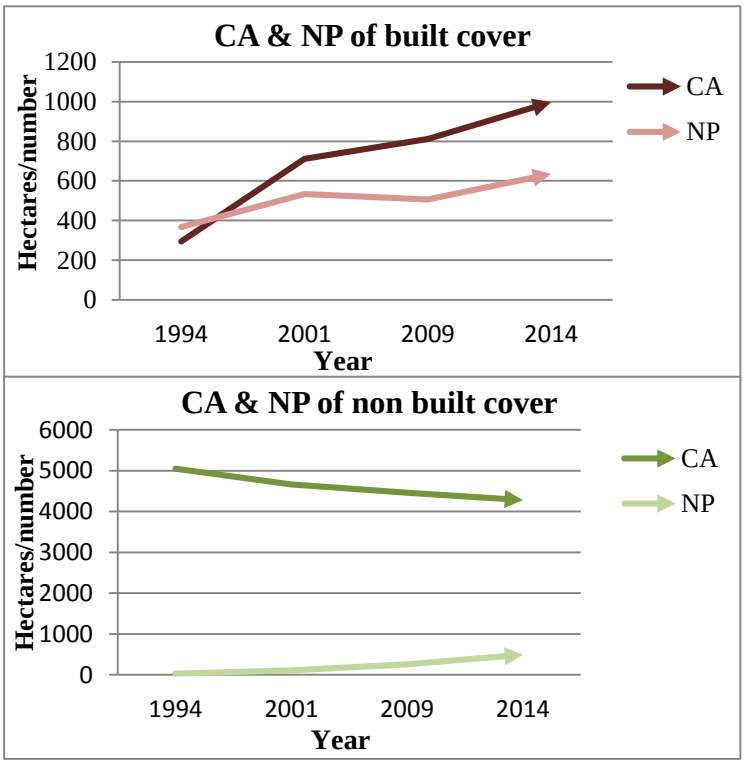
(Source: prepared by author, data from satellite imagery)

Regard to the transition map the following table 4-11 shows trend of class level metrics,

Table 4-11: Results of the class level metrics (Eastern division)

year	CA(hectare)		NP(number)		PD(per 100 ha)		LPI (%)		ED(M per ha)	
	built	Non built	built	Non built	built	Non built	built	Non built	built	Non built
1994	294	5052	367	31	3.63	0.31	0.30	50.26	15.88	25.00
2001	711	4666	534	106	5.28	1.05	0.99	45.90	33.09	38.42
2009	811	4459	506	256	5.01	2.53	3.50	38.75	56.13	61.63
2014	997	4282	636	494	6.29	4.89	9.45	28.99	77.22	81.99

Expansion of the residential development in the boarders of Vavuniya town division has influenced the growth of built cover in eastern side of this area, built up area has increased by 703 hectares at the 8.8% annual growth rate & new built patches also emerged at the 3% annual growth, so this trend cause fragmentation in the non-built cover that declined by 15% from earlier extent & fragmented as 463 new patches. So this fragmented situation of both classes indicated through the increment in both PD & ED; however rate of dispersion of non-built units are 50% higher than built cover. Due to increases in class area of each unit, extend of largest patch of built cover increased by 32% of annual growth, & it cause the decline in compactness of the non-built cover. Following figure 4-13 shows the trend in comparable manner



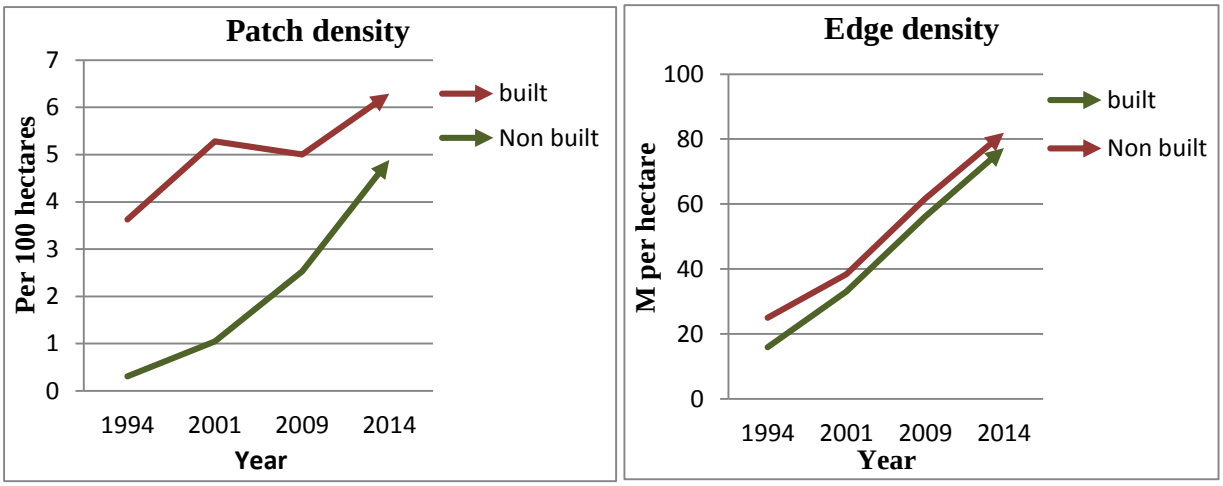


Figure 4-13: trends of class metrics in both land cover

Tendency of the entire division is characterized through the lower level scattered development of built units & mainly it concentrated on the western & southern part of the division which close to northern part of the town division.

The occurrence of adjoining & largest units (forest cover) in 1994 indicated by the high value of contagion, with the increases in size & units of the built cover, value is continually declining, it reveal the loss of homogeneity of the forest cover. Formation of new patches in built cover slowly separates the non -built units. That revealed by lower rate of increases in both diversity indexes (table 4-12).

Table 4-12: Result of the landscape metrics (Eastern division)

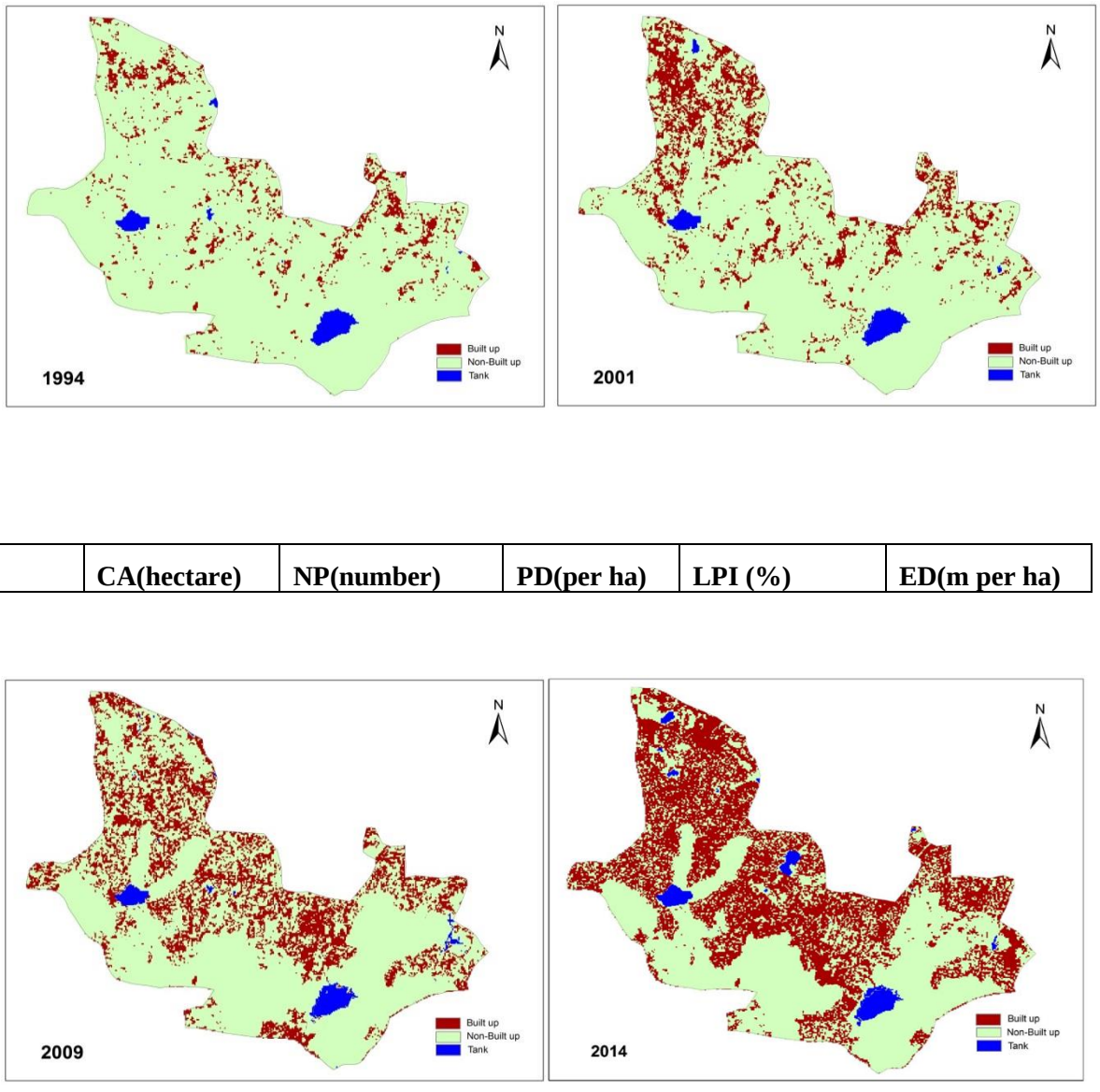
year	CONTAG	SHDI	SHEI
1994	69.7654	0.8529	0.5452
2001	58.9028	0.9365	0.6256
2009	51.6833	0.9521	0.6589
2014	47.5467	0.9992	0.7001

Table 4-13: Overall trends (Eastern division)

class	**CA**	**NP**	**PD**	**LPI**	**Trend of process**	**rate**
Built	+	+	+	+	Lower rate of Continuous increasing in extend & newly emerged as separated units	moderate
Non built	-	+	+	-	Increased in the Scattering form as number of smaller units while declined in the extent	Moderate

4.7 Result for the southern region

Increasing tendency of residential expansion in the border of town division has been continued through the development of the road & other infrastructure facilities into this division, following map 4-14 reveal the changes of the land cover over the time.



Map 4-14: Spatial & temporal transition of southern division

(Source: prepared by author, data from satellite imagery)

Based on this classified land cover maps, the table 4-14 shows the result of the class level metrics

Table 4-14: Result of the class level metrics (Southern division)

	CA(hectare)	NP(number)	PD(per ha)	LPI (%)	ED(m per ha)

year										
	built	Non built	built	Non built	built	Non built	built	Non built	built	Non built
1994	452	3940	612	32	5.99	0.31	0.59	38.55	25.91	30.47
2001	971	3406	660	125	6.50	1.23	1.85	33.21	48.58	51.91
2009	1520	2833	612	297	6.03	2.93	4.36	19.77	73.78	76.35
2014	1998	2354	159	1268	1.57	12.49	26.48	2.86	82.75	82.70

As a contiguous expansion of central town, extend of built cover has rapidly increased with the 9% of annual growth & currently occupied the 44% of total land of the division. Chain type of development of residential cover dispersed the vacant vegetation land as small clusters, this phenomenon indicated by 97 % increases in the NP of non-built covers, high rate of contiguous development of built cover revealed by LPI, that increased by 96% & currently occupying 26% of the area as single patch.

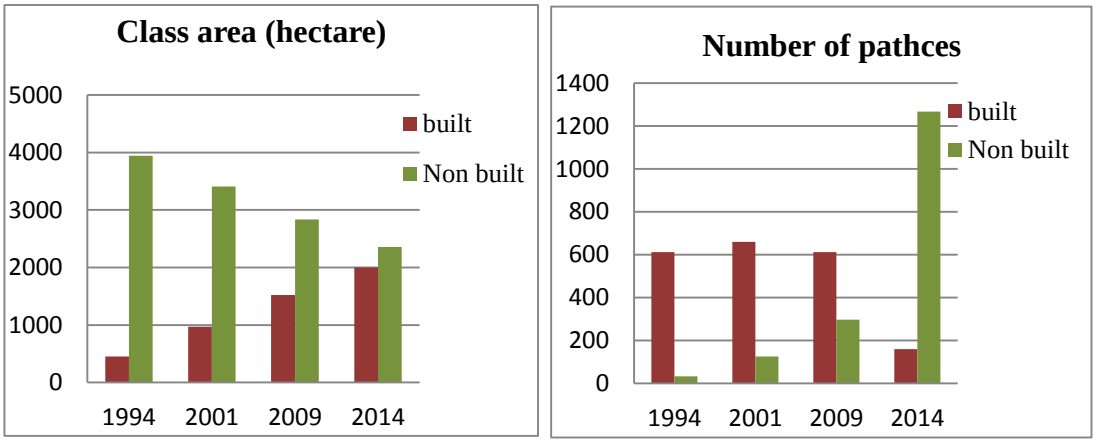


Figure 4-15: Inverse relations between CA & NP

Due to the inverse connection of CA & NP (figure 4-15), correlation in the patch density between built & non-built indicates through (-0.97832) high negative value. Increasing tendency of edge density in both classes indicating that already existing separate units are combine through the integration especially in built cover & emergence of new smaller units as fragmented patches of non-built cover (figure 4-16). Due to the concentration of commercial activies in horowapathana side, residential developments are newly forming & adjoining with existing residents based on trinco-vavuniya road in south western direction.

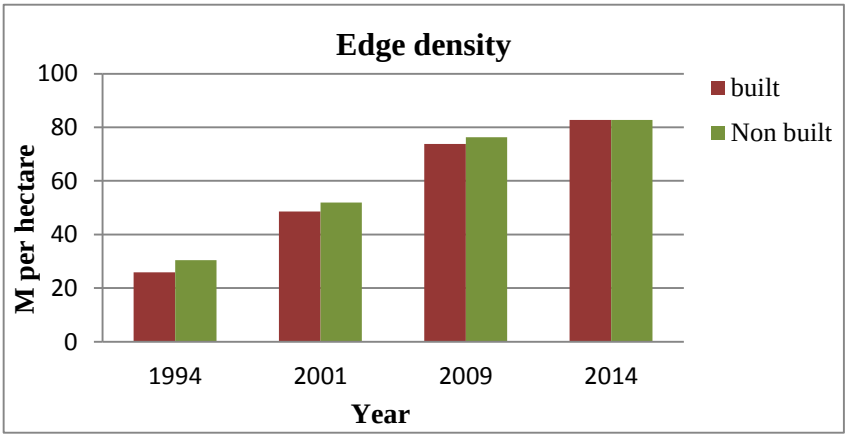


Figure 4-16: Increasing trend in Edge density

Lower rate of decreasing trend in the contagion value indicating the continues minor level of dispersion of non-built cover due to the new emerging residential units, value getting stabilize in the period of 2009 – 2014, that shows the moderate level of amalgamation of the residential units have taken place through adjoining as one unit, in the same way diversity indexes represent higher level of changes at the beginning as study area contain dispersed individual units, later on increasing trend is getting lower up to 0.7% annual growth, it reveal the rate of dispersion of both classes are at declining stage, (table 4-15).

Table 4-15: Result of landscape metrics (Southern division)

year	CONTAG	SHDI	SHEI
1994	63.2764	0.8616	0.6215
2001	57.4503	0.9543	0.6877
2009	52.854	1.0117	0.7298
2014	52.6152	1.013	0.7308

Table 4-16: Overall trends (Southern division)

class	CA	NP	PD	LPI	ED	Trend of process	rate
Built	+	-	-	+	+	Continuously increasing in extend & in the chain form	high
Non built	-	+	+	-	+	Moderate increasing rate of fragmentation within residential units while declined in the extent	moderate

Furthermore the complexity level of patch shapes of each classes explained through the fractal dimension of area weighted mean patch (refer appendix 3)

4.8 Tendency in the result of the analysis based on current context of the area

To identify the level of changes in the physical pattern, results of the metrics for all four divisions were compared. Figure 4-17 indicate Trend in the class area of both built &non build cover.

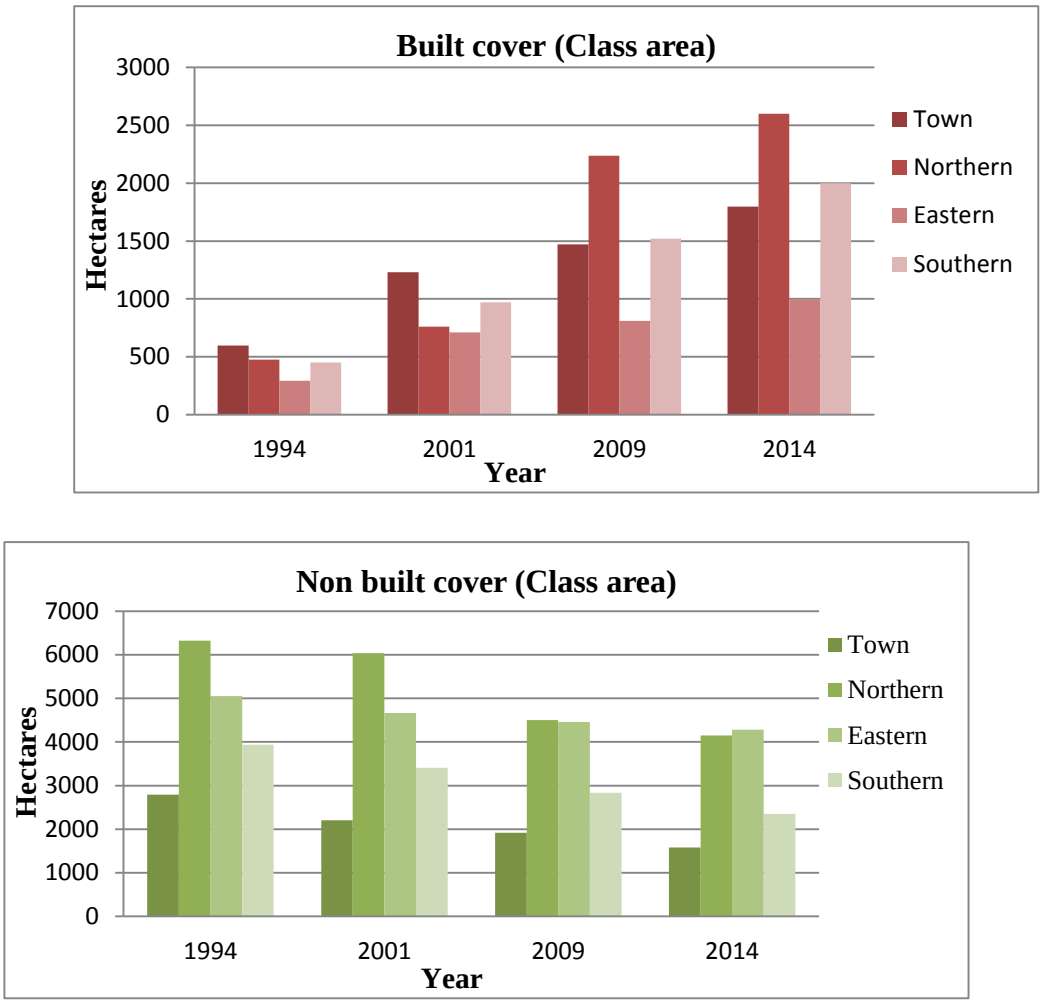
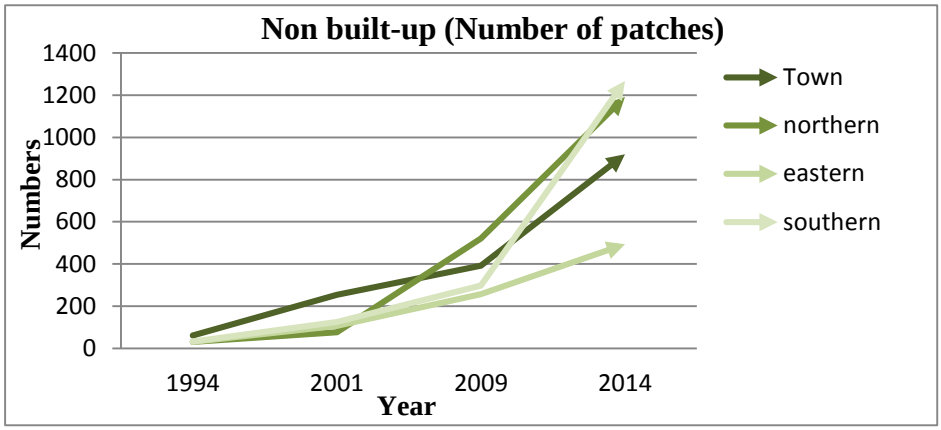


Figure 4-17: Overall trends in built & non - built cover

Among all division, Northern division has highest growth of 11% of annual growth rate due to reasons of the rapid resettlement progress while eastern division has been through lower growth rate of 7.5% of annual growth. Both town divisions & southern periphery have moderate level of built cover growth. Regard to the number of patches in the built cover, town & southern division showing the continues declining tendency, in town NP has declined by 85% & southern division declined by 75 %, this shows both of the division has been through amalgamation process as a one contiguous residential cover with moderate growth, while northern region have slight increasing trend in the built up patches with higher rate of CA because of the construction of new housing schemes (Paranaddakal in omanthai root, Marekkaranpalai in mannar root) (figure 4-18) & contiguous low density residential development as continuing part of central division, so this region has been through compact development in the existing area & newly dispersed into non –built areas. While built up growth in eastern division forms as continuity of residential in central area. Figure 4-18 show trend of NP in both built & none built cover.



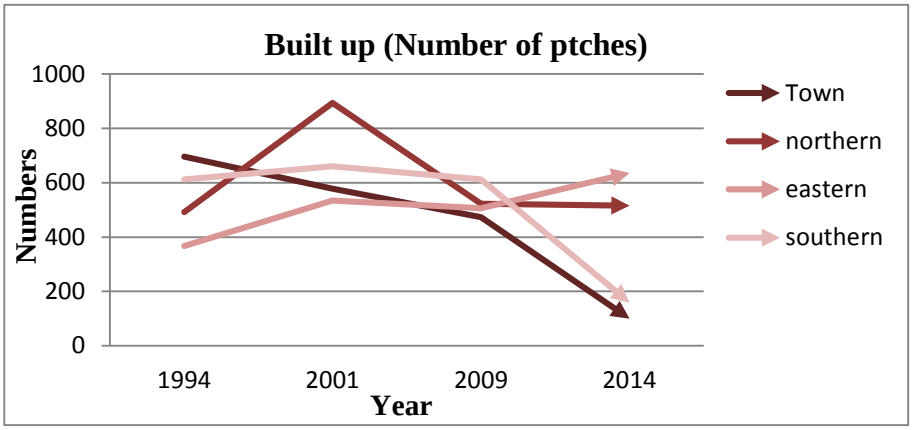
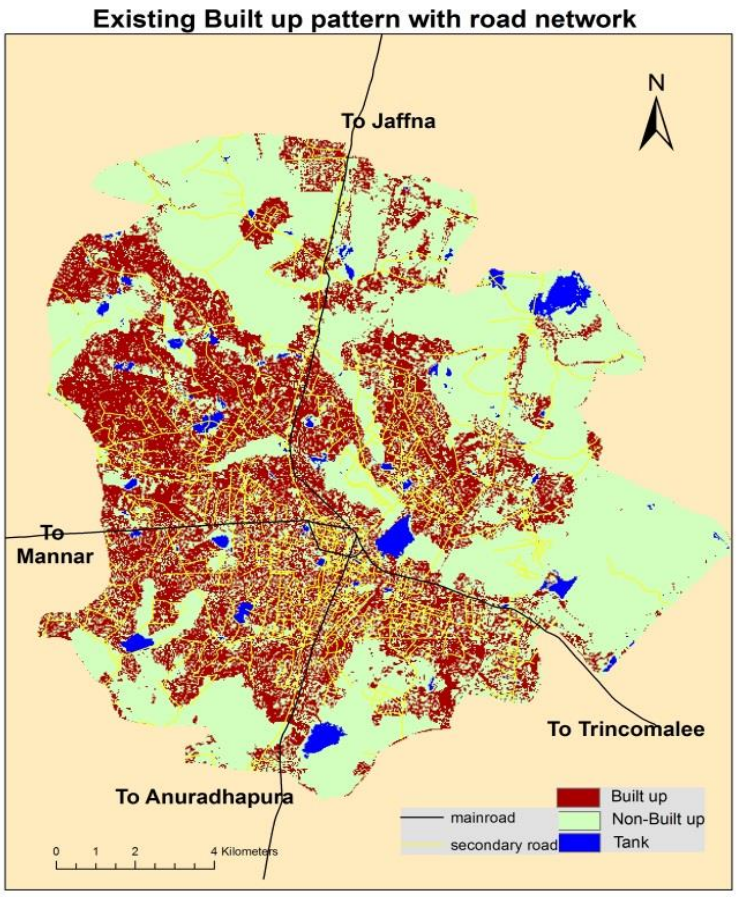


Figure 4-18: Overall trend in number of patches

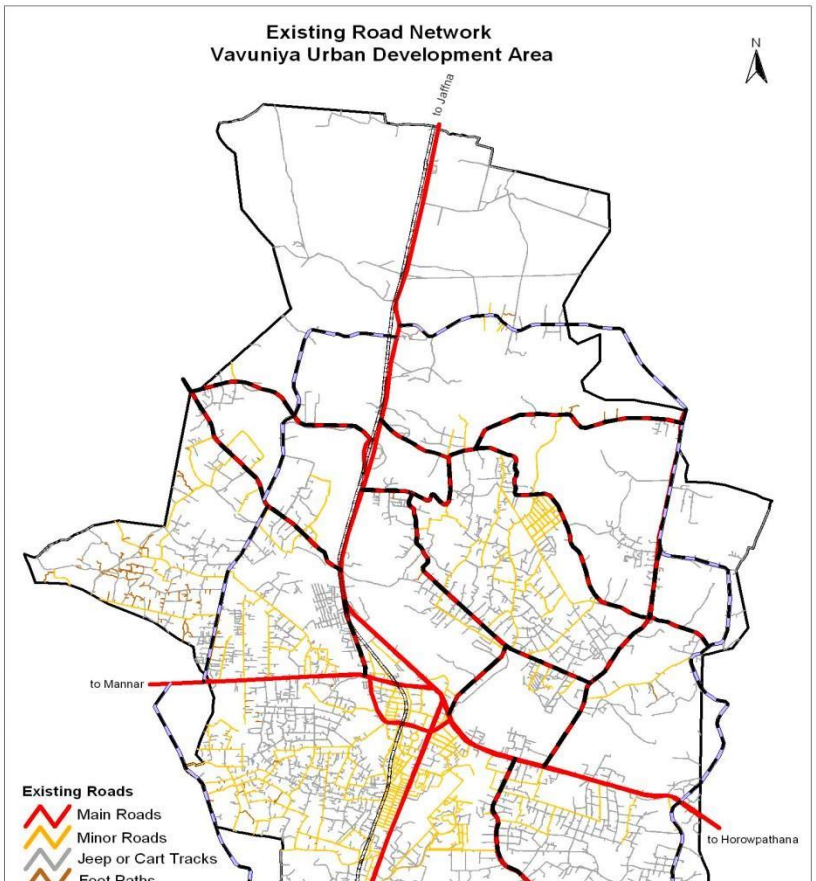
The major trend in the physical pattern of built & non built cover observed through the overlay of present road networks & land use map of the area with classified map of the current situation, it shows that the built pattern highly correlated with the development of transport root mainly in the centre & western direction have higher level of road network than other parts, especially the development of new roads(secondary, pave roads) in southeast (trinco – vavuniya) towards



horowapothane is led the medium density residential development into that area, maps 4.19 & 4.20 show the developed road linkages of both study & urban declared area.

Map 4-19: Built up pattern with road network

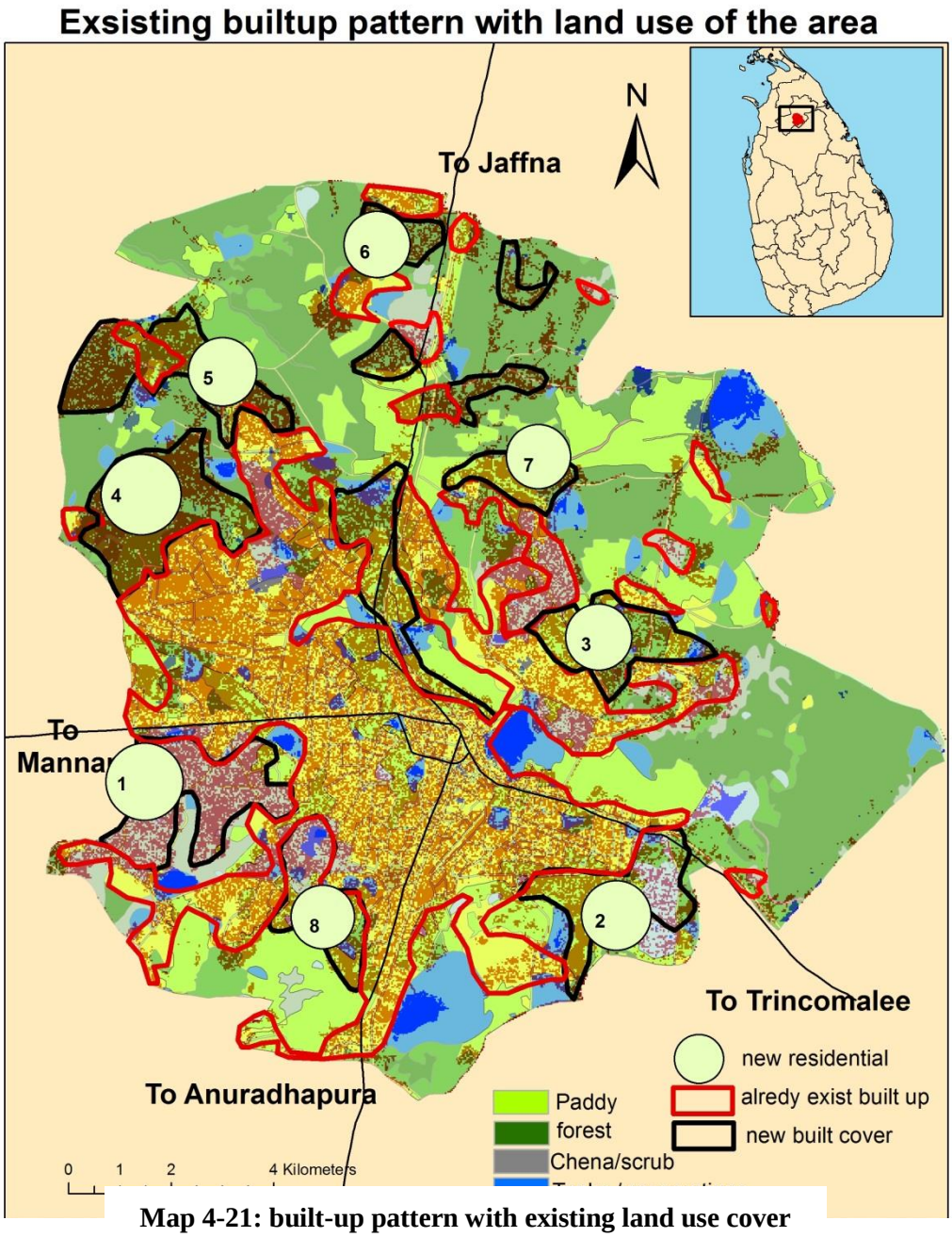
(Source: prepared by author, data from, satellite imagery & UDA-vavuniya)



Map 4-20: present road network of vauniya urban development area

(Source: draft urban development plan of vavuniya, UDA-vavuniya)

Major portion of the newly emerged built cover identify as low residential settlements, especially the homestead type of development & new housing units are still in the process of construction for displaced people, which taken place in the periphery of already existing residential area. Most of the newly formed areas are located on vacant & scrub land particularly in zone 1, 2,8 within central & southern division(figure 4.20) so this do not have much impact on the environment as they not suit for any agriculture purpose, however due to the compact trend in development within town centre considerable portion of the paddy lands have dispersed, also within the northern part considerable portion of low & density forest covers (paranadakal forest) were occupied by this residential development, zone 4, 5, & 6 . Map 4-21 shows these trends.



Map 4-21: built-up pattern with existing land use cover

(Source: prepared by author, data from satellite imagery & GIS data-UDA, Vavuniya)

Further the level of indication of the main components of urban growth such centrality, clustering, density, concentration, proximity, mixed uses, has relatively high within the 8 km radius of the area, it contain major part of central division & small portion of adjoining part in the southern & northern division, after this ring dispersion of the built pattern getting high. (Map 4.22).

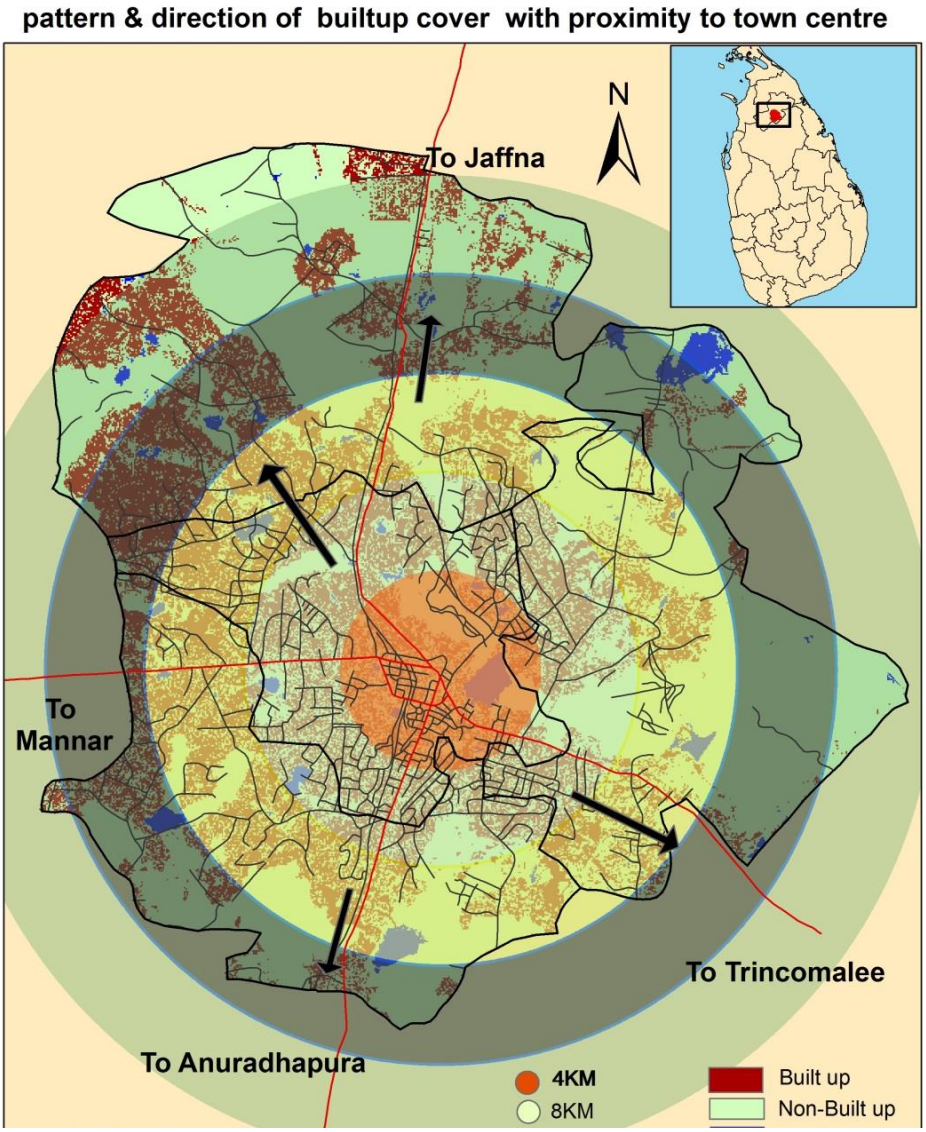


Figure 2-22 Pattern & direction of built cover with proximity to town

(Source: prepared by author, data from satellite imagery & GIS data-UDA, Vavuniya)

CHAPTER 05

CONCLUSION & RECOMMENDATIONS

This research is focus to characterize the physical pattern of built up growth in the main parts of Vavuninya district that based on the urban declared area, the analysis was done through remote sensing techniques (image classification) & application of the spatial metrics such as class level (CA,NP,PD,ED,LPI) & landscape (CONAG,SHEI),at two level of scale. Analysis was considered that build up & non build classes as main land cover. According to that the results & findings of overall scale analysis revealed that the built up cover has been increased from 12% to 33% of the total land extend within the 20 years gap at 8% annual growth. Overall growth direction is oriented towards north western in the form of residential areas

(due to the implementation of number of housing schemes) to south eastern direction (horowapothane & Anuradhapura) as commercial development based on A30 road. Furthermore in northern part separate clusters of residential areas were recently (2001-2014) emerged (due to resettlement programme) based on A9 road towards Mankulam area (proposed regional urban centre). Continues increase in class area & largest patch index with the declining process of number of patches & patch density of built cover indicating the amalgamation process of built-up area through the development of connectivity through the improved road network.

Based on the comparable scale the main centre (town division) & its periphery such lower part of northern division & upper part of southern divisions have been through the contiguous & relatively high compact pattern in build growth, particularly town division contain major portion of commercial & service centre, next close to that residential areas were taken place. It spread outer wards as low density homesteads type of residential because of continues increases in both population (mainly because of the immigration & resettlement) & physical infrastructure (road network, public services) towards to the core area. Increasing tendency of NP, PD, ED & diversity indexes with the correlation of increasing trend of class area in border divisions (northern, eastern) revealed the new emergence of built up units as a continues development of town divisions & individual clusters of residential (resettled areas). Due to this trend the non – build cover has (scrub, forest, abandon paddy) and considerable portion of the paddy (in town division) have fragmented over the time.

This particular tendency in physical pattern has been determined by factors such as locational context (main gateway & transits to Northern Province with good regional linkages), political phenomenon (displacement in northern part, immigration, resettlement, housing schemes, and urban development plans, disaster risk reduction plans ,etc.) and suitable geography (flat terrain, availability of the land for development).

Furthermore the application of these techniques were generated useful quantitative information about physical pattern & direction of built cover, which can be use as input data for decision making where census & other data cannot be accessible.

The results of this study is derived based on the quantitative measures which represent the abstract information of the physical pattern of the build & non build up growth. so as the main element of the urban area, the transformation of the pattern of built growth have high influence on the cities sustainable development, so identifying the exact information (in a quantifies way) & visualization of such extend, direction, pattern & interconnection between determinant factors gives broad idea on the tendency of development (is it sustainable or not), & these data can be used for both management & monitoring of infrastructure provision in effective way.

As based on the future interest, research context will be focused about the investigation on correlation between the tendencies of main determinants of urban growth (distance, population growth, economic structure, etc.) & components (as mentioned) of urban growth to characterize the physical development in an effective way.

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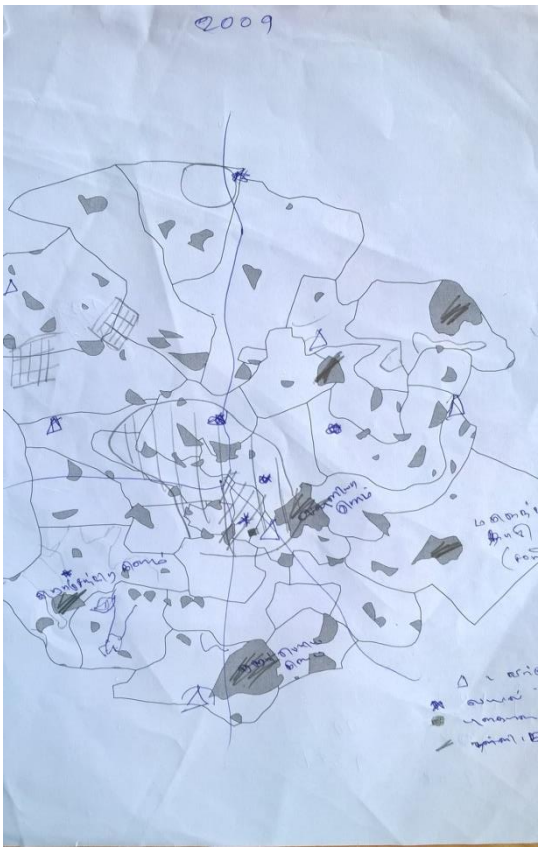
APPENDIX 1

Maps of changing physical elements derived through the discussion



(Source: Drawn by interviewees, derived through the discussions

Completed Housing schemes

Year	**Completed Housing units**	**division**
1995	100	Northern
1996	350	Northern/eastern
1997	162	Northern
1998	305	Northern
1999	214	Northern
2000	100	Northern
2009	450	Northern

(Source: Compile by Arthur, derived from: District Statistical Hand Book-2009, Vavuniya

APPENDIX 2

Result of the accuracy assessment for 1994 classified image

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.7652

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	1.0000
non-buildup	0.7462
water	0.7925
buildup	0.7024

----- End of Kappa Statistics -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	10	10	10	---	---
non-buildup	95	90	70	100.00%	77.77%
water	15	25	21	30.00%	84.00%
buildup	80	75	56	100.00%	74.67%
Totals	200	200	92		

Overall Classification Accuracy = 79.00%

----- End of Accuracy Totals -----

Result of the accuracy assessment for 2001 classified image

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.8016

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	1.0000
non-buildup	0.8034
water	0.8257
buildup	0.7421

----- End of Kappa Statistics -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	12	12	12	---	---
non-buildup	112	108	90	95.00%	83.33%
water	10	16	14	40.00%	87.50%
buildup	66	64	50	80.00%	78.13%
Totals	200	200	166		

Overall Classification Accuracy = 83.00%

----- End of Accuracy Totals -----

Result of the accuracy assessment for 2009 classified image

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.8529

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	1.0000
non-buildup	0.8461
water	0.8857
buildup	0.8271

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	9	9	12	---	---
non-buildup	86	95	83	95.00%	87.36%
water	17	12	11	40.00%	91.66%
buildup	88	84	71	80.00%	84.52%
Totals	200	200	177		

Overall Classification Accuracy = 88.50%

----- End of Accuracy Totals -----

Result of the accuracy assessment for 2014 classified image

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.7921

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	1.0000
non-buildup	0.7854
water	0.8974
buildup	0.7514

----- End of Kappa Statistics -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	7	7	7	--- ---	
non-buildup	73	78	64	90.00%	82.05%
water	15	16	15	50.00%	93.75%
buildup	105	99	79	75.00%	79.79%
Totals	200	200	165		

Overall Classification Accuracy = 82.50%

----- End of Accuracy Totals -----

(Source: prepared by author, generated through ERDAS imagine)

APPENDIX 3

Fractal dimension of area weighted mean patch

Town division

Year	built	Non built
1994	1.1798	1.3232
2001	1.2908	1.3979
2009	1.3661	1.3833
2014	1.4348	1.2997

Northern division

year	built	Non built
1994	1.1555	1.2488
2001	1.1672	1.2996
2009	1.3239	1.3669
2014	1.3669	1.3261

Eastern division

year	built	Non built
1994	1.143	1.2434
2001	1.2061	1.2931
2009	1.2838	1.3445
2014	1.3341	1.3563

Southern division

year	built	Non built
1994	1.1468	1.2828
2001	1.2316	1.3511
2009	1.299	1.3714
2014	1.4136	1.2314

This index measures the complexity of the patch shape of each classes , output values are greater than 1 & less than 2, value 1 representing the simple perimeter of patches also show compactness & less fragmentation level of patches, while value near to 2 represent complex patch shape & higher level of fragmentation.

APPENDIX 4

Temporal changes of the built up area based on the class area

Town division

Time period	change	Change rate%	Time (years)	year rate	Average%
1994-2001	633	105.6761	7	15.09659	7.31
2001-2009	239	19.39935	8	2.424919	
2009-2014	326	22.16179	5	4.432359	

Northern division

Time period	change	Change rate%	Time (years)	year rate	Average%
1994-2001	283	59.32914	7	8.475591	11.99
2001-2009	1476	194.2105	8	24.27632	
2009-2014	363	16.23435	5	3.246869	

Easter division

Time period	change	Change rate%	Time (years)	year rate	Average%
1994-2001	417	141.8367	7	20.26239	8.8
2001-2009	100	14.0647	8	1.758087	
2009-2014	186	22.93465	5	4.58693	

Sothern division

Time period	change	Change rate%	Time (years)	year rate	Average%
1994-2001	519	114.823	7	16.40329	9.9
2001-2009	549	56.53965	8	7.067456	
2009-2014	478	31.44737	5	6.289474	

(source: prepared by author, based on the results of spatial metrics calculation)