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Spatial and Temporal Dynamics of Land Use/Land Cover in Kandy City, Sri Lanka: An Analytical Investigation with Geospatial Techniques

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Abstract

Land use/ land cover modifications in cities in developing countries in haphazard manner brings many detrimental effects to the both city dwellers and its environment and understanding the nature of this land modifications is vital for development planning of cities. The objective of this paper is to detect the land use/ land cover changes occurred during the period of 1994-2018 in Kandy city which is a world heritage site as well as the second largest city with a great national significance in Sri Lanka. This objective was achieved by using high and medium resolution satellite images and classifying them via supervised and unsupervised classification algorithms and finally applying post classification change detection techniques in GIS. Land use/land cover classification accuracy assessment also was performed to confirm the classification accuracy. Results revealed that the city has undergone a drastic conversion of lands up to 2003, has slowed down after 2003 and lowest conversion is after 2007. The foremost change within this twenty four year period is the substantial increase in built-up lands and substantial decrease in forested lands. Significant increase in built up lands within the period of 1994-2003 is evidently associated with the rapid increase in population in the city until 2001. Reserved forested areas in the city still remain unchanged and problem of forest loss is with the light forested areas spread throughout the city. Land use zoning regulations by Urban Development Authority to preserve world heritage and environmental status and the population shifting to the periphery after 2001 are the apparent reasons behind the slow growth of built-up areas after 2003. Facilitating new residential and commercial nodes emerging in outskirts areas of the city, continuing strict land use zoning regulations within the city, preserving and increasing existing urban vegetation cover, introducing green parking lots are some applicable strategies to minimize the land conversion further and to minimize the adverse impacts of the land use/land cover changes on the city.

Keywords: Land use/Land cover; Change; Kandy City; Remote Sensing; GIS.

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1. Introduction

As projected by the Department of Social and Economic Affairs, United Nation in 2018, all the expected world population growth during 2018-2050 will be in urban areas [1]. Population lived in urban areas in developing countries in 2018 was 50.6 percent and it will increase up to 65.6 percent in 2030. The growing population and increasing socio-economic necessities create an immense pressure on natural resources specially the land use/ land cover (LULC) and this pressure results in unplanned and uncontrolled changes in LULC. UN further cautions that in some cities, unplanned or inadequately managed urban expansion leads to rapid sprawl, pollution, and environmental degradation, together with unsustainable production and consumption patterns. As Angel and others noted today's cities are growing twice as fast in terms of land area as they are in terms of population [2]. Consequently, projections indicate that future trends in urbanization could produce a near tripling in the global urban land area between 2000 and 2030 as hundreds of thousands of additional square kilometers are developed to urban levels of density [3,4]. Such urban expansion threatens to destroy habitats in key biodiversity hotspots and contributes to carbon emissions associated with tropical deforestation and land use change [1]. In this context, mapping of spatial-temporal land use/land cover changes in cities is essential for planning of wide range of applications such as urban management analysis, environmental and land planning, mitigation of natural disaster such as floods, landslide and global warming in cities. Land use/land cover are two separate terminologies which are often used interchangeably [5]. Land cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities such as settlements. Land use refers to the way in which land has been used by humans and their habitats, usually with accent on the functional role of land for economic activities. The land use/land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Today, earth resource satellite data are very applicable and useful for land use/cover change detection studies [6,7]. With the invent of Remote Sensing (RS) and Geographical Information Systems (GIS) techniques, land use/cover mapping has given a useful and detailed way to improve the selection of areas designed to agricultural, urban and/or industrial areas of a region [8]. Application of remotely sensed data make possible to study the changes in land cover in less time, at low cost and with better accuracy in association with GIS that provides suitable platform for data analysis, update and retrieval [9,10]. The advent of high spatial resolution satellite imageries and more advanced image processing and GIS technologies, has resulted in a switch to more routine and consistent monitoring and modeling of land use/land cover patterns. Remote sensing has been widely used in updating land use/cover maps and land use/cover mapping has become one of the most important applications of remote sensing [11].

2. Study Area: Kandy City

Kandy city being a capital city in the central highland in Sri Lanka has a great national importance in terms of economic, culture, religious and administrative context. The city is situated in the valley bottom of Mahaweli river and surrounded by green hill slopes and bounded by the river Mahawali on the North East and West and South by the Hantane range. It has been the major urban center for the central hill country of Sri Lanka during the last 600 years history since its establishment as the capital of the Kandyan Kingdom in the 15^{th} Century. In 1986, it has been inscribed as a world heritage city by UNESCO owing to its religious, cultural and historic value. Kandy city is the location for the Sacred Tooth Relic Temple and was shaped by different ruling periods of local and colonial during the last 600 years of period. However, there was an economic boom in 1980s and 1990s in the country with the introduction of open economic policy in 1970s and this made unprecedented spatial growth of many secondary cities in Sri Lanka including Kandy city. This new economic surge created rapid constrictions in everywhere in the city without proper guidance and planning. Most of them were unauthorized constructions and have not been consistent with world heritage concept. Several research [12], [13,14] studies also have evidently shown that the Kandy city has undergone a significant physical expansion after 1971 and this physical expansion over the time may have definitely led to a huge transformation of its land use/land cover. Investigation of land use/Land cover changes occurred temporally as well as spatially in Kandy city will be uttermost important for its future development planning.

3. Methodology

3.1. Data and the Research Process

This study attempts to measure the land use/cover changes occurred in the Kandy city during the last twenty four year period of time. To achieve this objective, several high-resolution and medium resolution satellite images were used and details of the satellite images are given in the Table1 and status of original images are shown in Figure 1. Methodology employed to do the whole process of detection of land cover/land use change is demonstrated in Figure 2.

Table 1: Information of data used for LULC change detection in Kandy city

Types of Data	Acquisition year/date	Sensor Name	Spatial Resolution/Scale	Source
Satellite images	1994	Landsat 5-TM LIT	30 meters	USGS
	2003	IKONOS-2	3 meters	Digital Globe, USA
	2007	IKONOS-2	3 meters	
	2018	GEO EYE-1	2 meters	

Figure 1: Original satellite images of Kandy city used for LULC change analysis

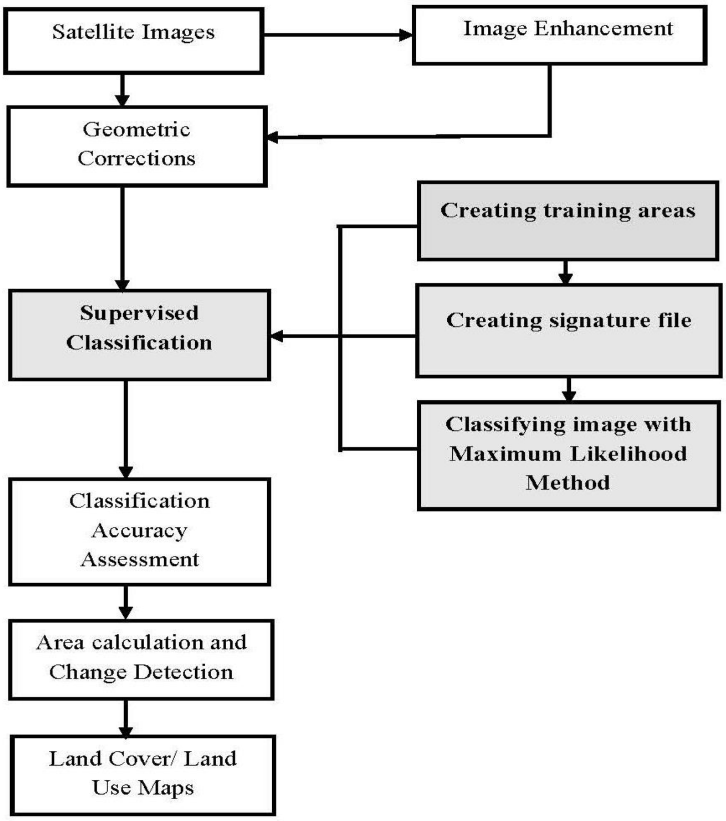

Figure 2: Methodology of LULC detection process

3.2. Image Classification

In this study mainly supervised classification which is a statistical method of classifying images according to the covariance and variance of the spectral response patterns of a pixel was conducted to classify the individual geo-referenced IKONOS and GEO-EYE images. Supervised classification is the process (Figure 2) of assigning objects of unknown identity to one or more known features using training data. In this context, user can select sample pixels in an image that are representative of specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image. Training sites (also known as testing sets or input classes) are selected based on the knowledge of the user. The user also sets the bounds for how similar other pixels must be to group them together. These bounds are often set based on the spectral characteristics of the training area (often based on "brightness" or strength of reflection in specific spectral bands). The user also designates the number of classes that the image is classified into. Based on the priori knowledge of the study area and having a reconnaissance survey in the study area a classification scheme was developed for the study area. The study area was classified into five LULC classes (Table 2). The classification scheme developed gives a rather broad classification where the land use/land cover was identified by a single digit. The accuracy of the classification was verified by doing accuracy assessment, field checking and comparing with existing land use and cover maps that have been field-checked.

Table 2: LULC calcification scheme

LULU Classes	Description
Water Bodies	Natural and artificial water areas (lakes, rivers, ponds)
Built-up Area	All the structures made by humans including residential, commercial, industrial areas, transportation and communication, public and semipublic areas, public utility and facility and plotted lands
Agriculture and Home Gardens	All crop lands and home gardens
Bare and Open Lands	Barren lands, play grounds, open spaces uncultivated agricultural lands
Forested Areas	Dense forest, light forest, scrub lands
Cloud Cover	Areas covered with clouds

In addition to the supervise classification, the study uses unsupervised classification also to classify LANDSAT 5 TM image in 1994. Since Landsat images are medium resolution images unsupervised classification is the best method of classification for the best results. Unsupervised classification is where the outcomes (groupings of pixels with common characteristics) are based on the software analysis of an image without the user providing sample classes. The computer uses techniques to determine which pixels are related and groups them into classes. The user can specify which algorism the software will use and the desired number of output classes but otherwise does not aid in the classification process. However, the user must have knowledge of the area being classified when the groupings of pixels with common characteristics produced by the computer have to be related to actual features on the ground.

3.3. Classification Accuracy Assessment Process

Accuracy assessment is the final step in the analysis of remote sensing data which help to verify how accurate the results are. In order to perform accuracy assessment correctly classified image derived from the remote sensing data and reference map (ground truth data) should be compared. In this regard, the error matrix and kappa coefficient which show the relationship between these two sets of information have become two standard forms of accuracy assessment of image classification. This study also uses these two forms of classification accuracy assessment. Error matrix, or often referred to as a confusion matrix, summarizes the relationship between the two sources of information is the probability (%) that the classifier has labeled an image pixel into the ground truth classes. It is the probability of a reference pixel being correctly classified. From an error matrix the, omission errors, commission errors, producer's accuracy, user's accuracy and images overall accuracy can be determined [15]. An omission error is an error where a sample (pixel) was omitted from the right class. Commission errors are made when samples are committed to the wrong class [15]. The producer's accuracy is a statistic that specifies the probability of a ground reference datum being correctly classified and it is a measure of the omission error. This statistic is calculated because the producer may want to know how well an area can be classified. The producer's accuracy is calculated by dividing the diagonal number from a class's column by the sum of the entire column including the number found within the diagonal [15]. The user's accuracy is a measure of the commission error. This statistic indicates the probability of how well the classified sample represents what is found on the ground. This measure is calculated by dividing the diagonal of a class by the sum of the numbers within the row of that class [15]. Overall accuracy is the probability (%) that the classifier has labeled an image pixel into the ground truth Class. It is the probability of a reference pixel being correctly classified. The overall accuracy is determined by summing all of the numbers within the matrix's diagonal (correctly identified samples) and dividing by the sum of all the errors (numbers found outside the diagonal) [15]. Another form of accuracy assessment is through Kappa analysis. This is a discrete multivariate technique that produces a K, which is an estimate of Kappa. This statistic is a measure of how well a classification map and the associated reference data agree with each other. This agreement is based on the major diagonal of the error matrix and a chance agreement (row and column values). Strong agreement occurs if the K is greater than 0.80. Moderate agreement occurs when K values fall between 0.40 and 0.80 and poor agreement occurs with K values less than 0.40[15].

$$\hat{K} = \frac{M\sum_{i=j=1}^{r} n_{ij} - \sum_{i=j=1}^{r} n_i n_j}{M^2 - \sum_{i=j=1}^{r} n_i n_j}$$

Where:

r = number of rows in error matrix

n_{ij} = number of observations in row i, column j

n_i = total number of observations in row i

n_j = total number of observations in column j

M = total number of observations in matrix

In the case of accuracy assessment, it is not practical to test every pixel in the classified image and a representative sample of reference points in the image with known class values should be taken. For this study 203 pixels were taken as reference points (ground truth) from each image (1994, 2003, 2007, 2015) according to the binomial probability theory assuming 85% at an allowable error of 5% (i.e., it is 95% accurate) as expected accuracy. Stratified random sampling method which is the mostly used sampling method in the accuracy assessment was used to locate the reference points in images since its advantage for represent the pixels in each land use category. In this sampling method points were generated proportionately to the distribution of classes in the image.

4. Results and Discussion

4.1. Land Use / Land Cover Change Detection

The purpose of this paper is to map, quantify and assess the spatio-temporal changes occurred in Kandy City in its evolutionary process. Results taken by following the step by step detection and quantification procedure are demonstrated in Figure 3 to Figure 10 and Table 3 and Table 4.

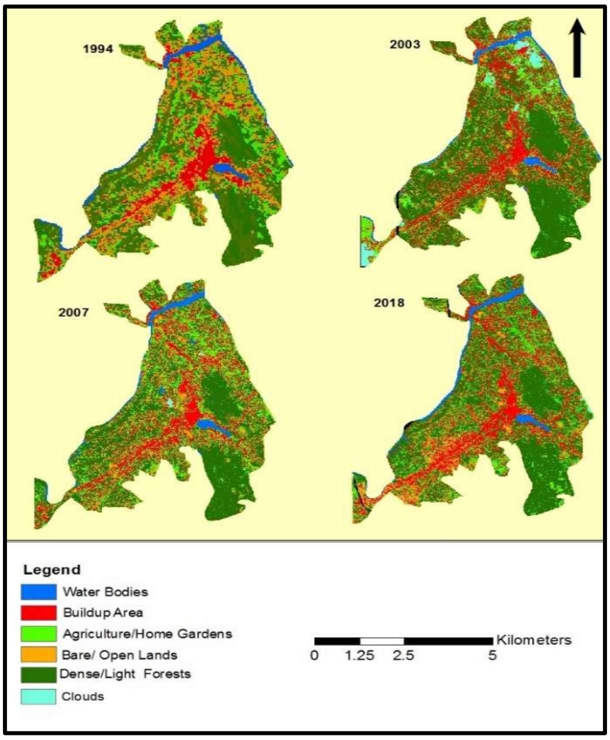

Figure 3: Classified images for LULC change detection in Kandy city, 1994-2018

All the figures and tables obviously demonstrate that land use/land cover in Kandy city has changed drastically during the last twenty four years. As indicated by the Figure 5, the highest land conversion in the city is in the period of 1994 to 2003 and after 2003 conversation of all land use/ land cover categories has slowed down except forest category. Twenty four year ago the city was dominated by more rural characteristics mainly the agriculture and home gardens which accounted for 23.8 percent, bare and open lands which accounted for 15.0 percent and forest which accounted for 49.3 percent. The major change which has undergone within these twenty four years is the substantial increase in built-up area and substantial decrease in forest lands. As Figure 6 visualizes all the land use categories in the city have decreased its land extent with the horizontal expansion of built-up area during last twenty four year period.

Table 3: Area statistics of LULC categories in Kandy city, 1994-2018

LULC classes	1994		2003		2007		2018	
	Area (sq.km)	Percentage	Area (sq.km)	Percentage	Area (sq.km)	Percentage	Area (sq.km)	Percentage
Water Bodies	1.08	4.2	0.89	3.49	1.09	4.3	0.91	3.64
Built-up area	2.09	8.1	5.68	22.35	5.91	23.36	6.43	24.99
Agriculture and Home Gardens	6.14	23.8	4.21	16.55	5.81	22.94	5/29	21.08
Bare and Open Land	3.8	15.00	1.58	6.23	1.95	7.71	3.31	13.2
Forest Area	12.73	49.3	12.33	48.52	10.28	40.61	8.90	35.50
Cloud Cover	-	-	0.72	2.85	-	1.08	0.24	0.95
Total	25.81	100	25.41	100	25.04	100	25.08	100

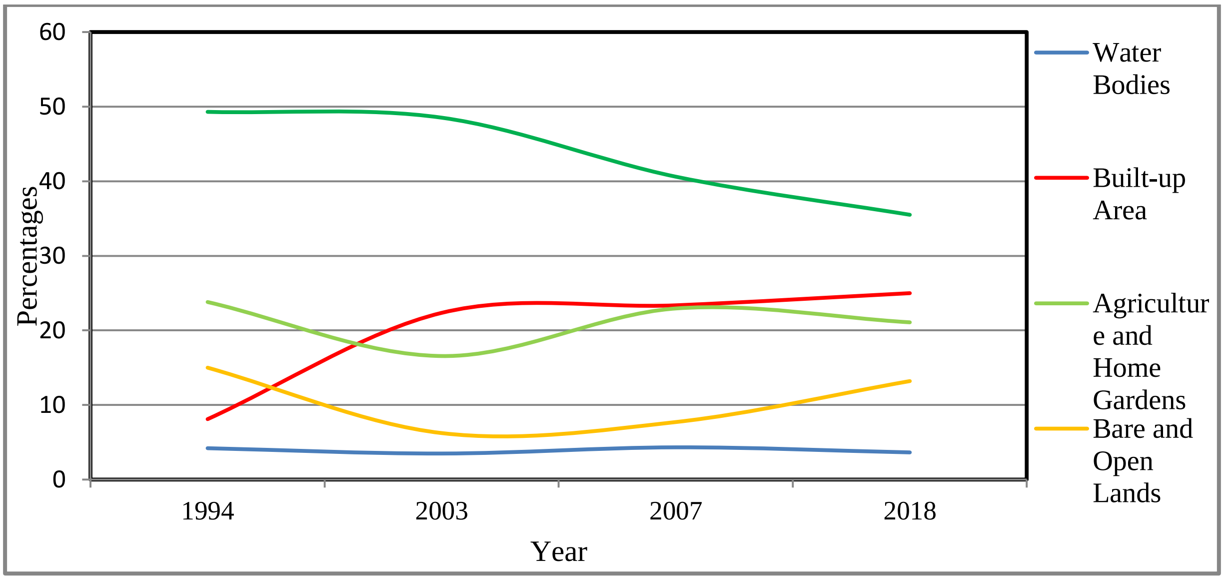

Figure 4: Temporal change in different LU/LC categories in Kandy city, 1994-2018

Table 4: Area statistics of change in LULC classes in different periods in Kandy city, 1994-2018

LULC classes	Percentage change in different periods			
	1994-2003	2003-2007	2007-2018	**1994-2018 (Total change)**
Water	-0.71	0.81	-0.66	**-0.56**
Built-up Area	14.25	1.01	1.63	**16.89**
Agriculture and Home Gardens	-7.24	6.38	-1.86	**-2.72**
Bare and Open Land	-8.77	1.48	5.49	**-1.8**
Forests	-0.78	-7.91	-5.11	**-13.8**

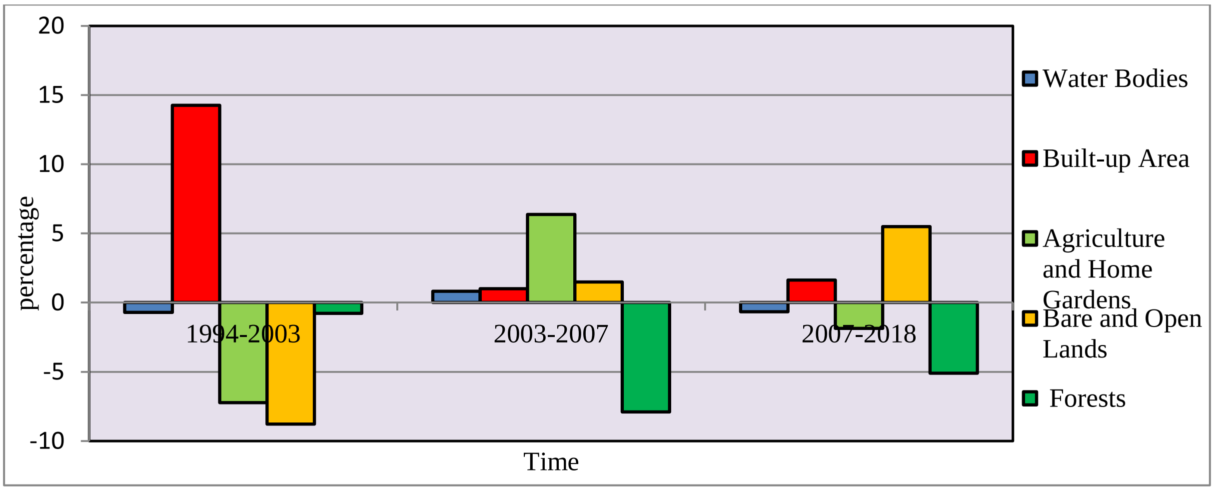

Figure 5: Change in LULC classes in different periods in Kandy city,1994-2018

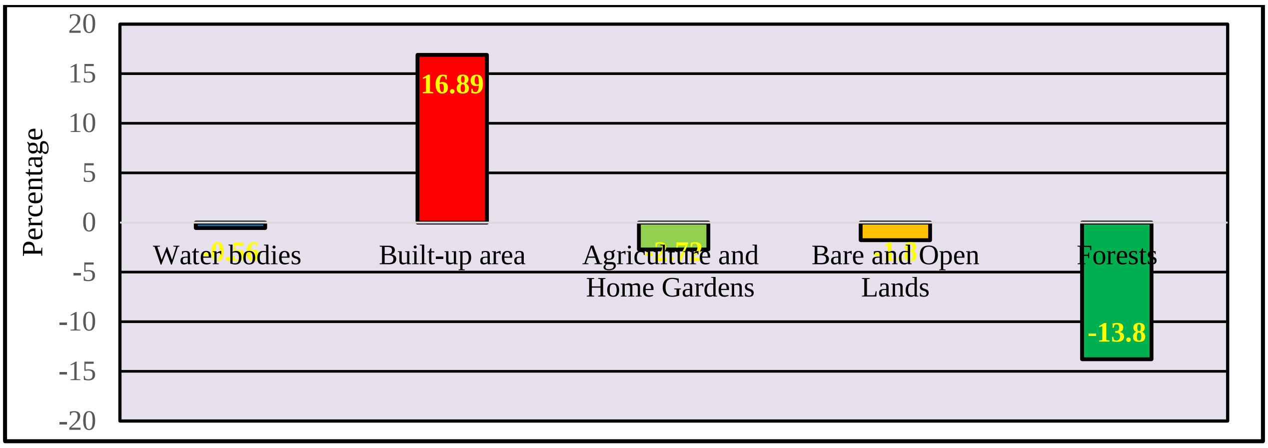

Figure 6: Total change in LULC categories in Kandy city during entire period of 1994-2018

According to Table 3 and Figure 7, city has noticeably expanded its built-up area within this time period. The highest percentage of built-up gain which is 14.25 percent out of the total built-up change of 16.89 percent is within the nine-year period from 1994-2003. Hereafter, the built-up area continuously increases but at a slow rate adding a small percentage which is 2.64 within rest of fifteen year period from 2003-2018 (Table 3 and Table 4). It indicates that the growth of built-up area has slowed down considerably after 2003. The fast growth of built up area before 2003 is a direct result of the rapid increase in population in the city until 2001. After the political independence of the country, decadal net addition of the population into the city has significantly increased (Table 5 and Figure 8). This trend extended up to 2001 (12.44 percent) and after that the net addition in next decade (-1.76 percent in 2001-2011) was negative with a negative population growth rate (-0.16 percent in 2011). This population gain has essentially inspired the various types of constructions within the city in chaotic manner.

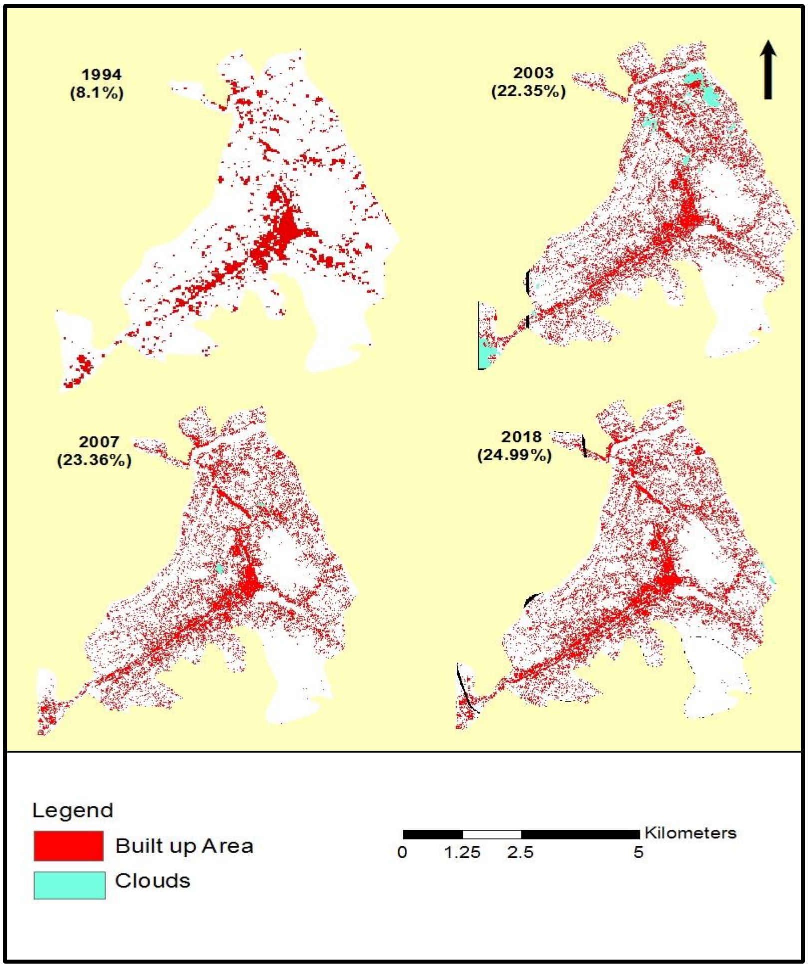

Figure 7: Spatio-temporal change in built-up Area in Kandy city, 1994-2018

Table 5: Population growth trend in Kandy city in Census years, 1871-2011

Year	Population size	Decadal growth		Change in decadal growth		Average annual growth rate (%)
		Absolute	Percentage	Absolute	Percentage	
1871	16881					
1881	22026	5145	30.48			3.04
1891	20375	-1651	-7.50	-6796	-37.97	-0.75
1901	26386	6011	29.50	7662	37.00	2.95
1911	29927	3541	13.42	-2470	-16.08	1.34
1921	32562	2635	8.80	-906	-4.62	0.88
1931	37147	4585	14.08	1950	5.28	1.41
1946	51266	14119	38.01	9534	23.93	2.53
1953	57200	5934	11.57	-8185	-26.43	1.65
1963	68202	11002	19.23	5068	7.66	1.92
1971	93303	25101	36.80	14099	17.57	4.6
1981	97872	4569	4.90	-20532	-31.91	0.49
2001	110,049	12177	12.44	7608	7.54	0.62
2011	108,113	-1936	-1.76	-14113	-14.20	-0.16

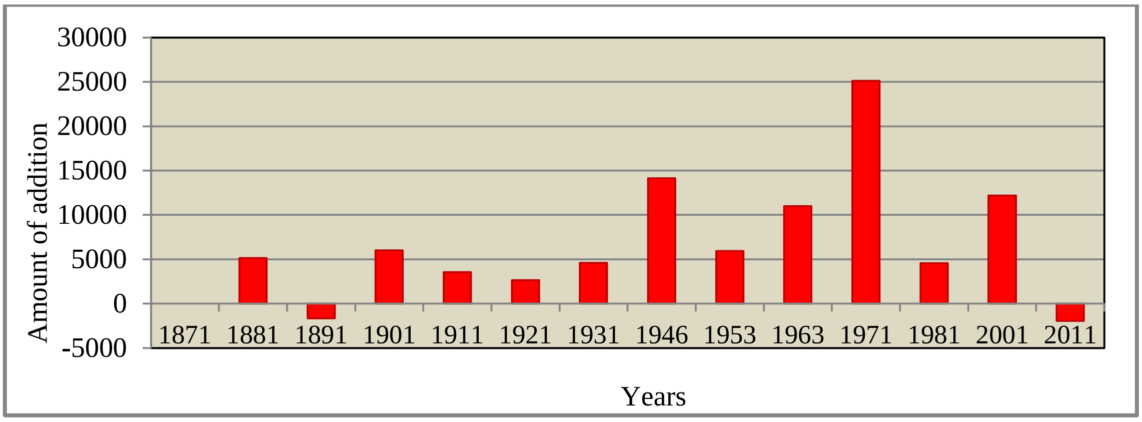

Figure 8: Decadal net addition to the population in Kandy city, 1871-2011

The two apparent reasons behind the slow growth of built-up area after 2003 are implementation of controlling measures of physical development of the city through land use zoning regulations by the Urban Development Authority (UDA), Sri Lanka and the suburbanization trend taking place around boundary areas in the city. UDA has enforced a set of zoning regulations to regulate the physical growth of the city through its "Development Plan for Urban Development Area of Kandy City" 2002-2016 which is the legal basis for the physical development of Kandy city area [16]. The main objective of the UDA is to develop the city preserving its world heritage status with its religious and cultural values and scenic beauty with its natural environment. In this context, UDA, with its city development plan strictly control the construction activities within the city center areas and environmentally sensitive areas and thoroughly monitor and supervise the construction activities which are carried out in other areas according to recommendations and approval of the planning committee. Suburban growth trend of the city is the other for the slow growth of the built-up lands after 2003. As illustrated by Figure 9 and Figure 10, population in the city is shifting into the peripheral areas from 2001 showing growth of the city boundary areas. This population shifting trend is associated with many inter-connected factors such as strong controlling regulations in the city center area, non-availability of suitable lands and high prices of the lands. Consequently, the slow growing trend of built-up of the city is a result of influence of urban development plan of UDA and the suburban growth trend of the city.

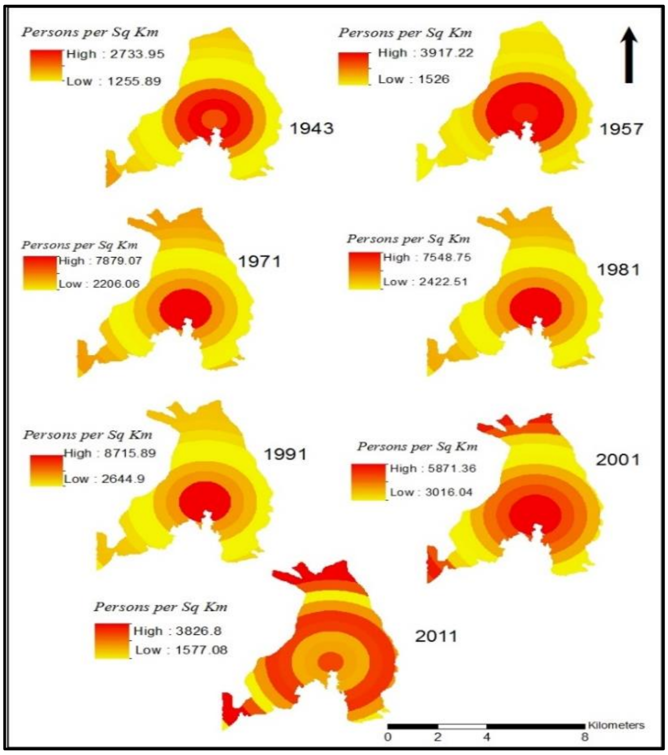

Figure 9: Generalized pattern of population density shifting by concentric circles in Kandy city,1943-2011

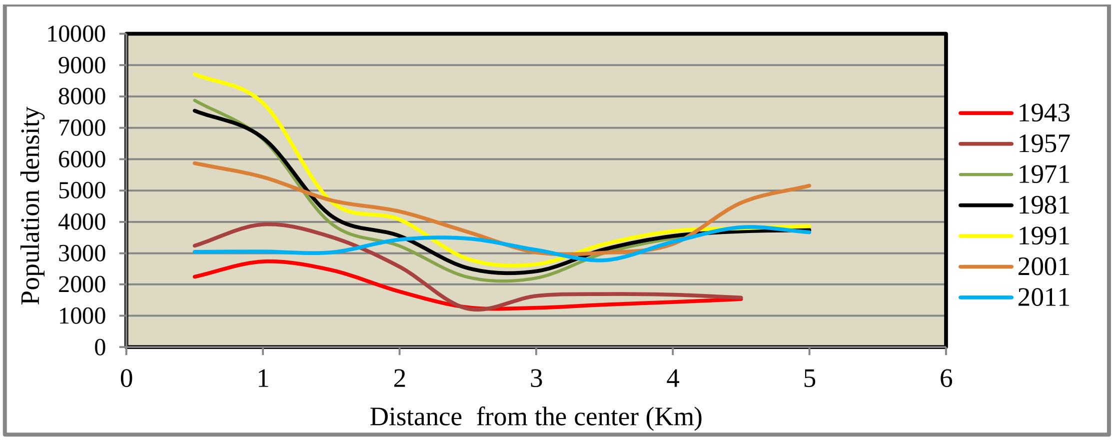

Figure 10: Population density curves from the city center to the periphery in Kandy city,1943-2011

In general context, built-up expansion of a city in horizontal manner is due to the transformation of other land covers such as agriculture, bare lands and forest lands in the city. Consequently, loss or reduction of these land cover types is a common incident in cities with their built-up expansion. However, Sri Lanka being an agricultural country always possesses a 75 percent of rural characteristics with agriculture and home gardens and this situation can be observed even in the towns and cities. Almost all the towns and cities in the country contain substantially a higher percentage of rural/ home gardens or agricultural lands.

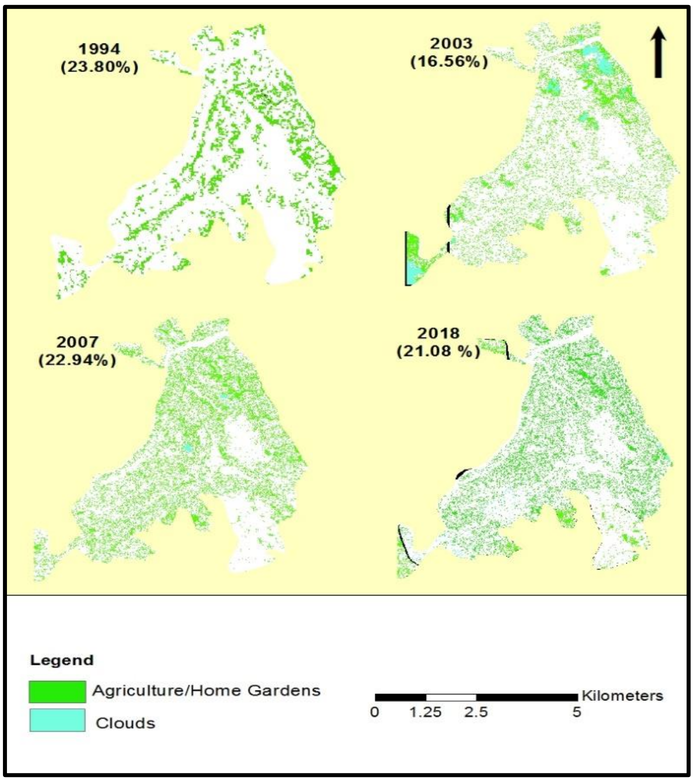

Figure 11: Spatio-temporal change in agriculture and home gardens in Kandy city, 1994-2015

Although, a slight drop is noticeable in agriculture and home gardens in Kandy city during the entire period from 1994-2018, it always possesses considerably a higher percentage of agricultural lands and home gardens (Figure 11) especially with its *Kandyan Home Garden concept.* Agriculture including paddy, tea cultivation, home gardens which is termed as "*Kandyan home gardens*" with mixed crops are the main economic activity according to the climatic and terrain configurations in Kandy city and they were mainly scattered in the peripheral areas. *Kandyan home gardens* in hill country areas are considered as integral part of the landscape and culture for centuries and maintained as a family property. However, in 1994 city has accounted for 23.8 percent of agricultural and home gardens and has reduced up to 16.56 percent in 2003 which is the period where the highest percentage of built-up area changed was recorded. Afterward, there is a slight increase in agricultural and home lands in the period of 2003-2007 while a slight decrease in the period of 2007-2018. Considerable percentage of large paddy lands are located in North-eastern part of the city and other lands are small scale-agricultural and home gardens. However, *Kandyan home garden concept* extremely influences to have a higher percentage of agricultural and home gardens in the city. Bare lands in a city are empty lands not covered by vegetation, water, buildings, or roads. It is one of the most important and typical land covers all over the world. In cities under rapid development, the spatial-temporal changes of the bare lands are commonly recognized along with urbanization processes. As statistics indicate there had been a considerably higher percentage of bare lands (15 percent) in Kandy city in 1994 but only a small reduction (-1.8 percentage) has occurred in last twenty four year period similar to the change in agricultural and home garden category. According to the statistics, a significant reduction in bare and open lands has occurred within 1994-2003 due to the rapid conversion of these lands into built-up lands within 1994-2003. After 2003, bare and open lands show a rather increasing trend which is associated with the conversion of many forest lands (Figure 12 and Figure 13) located along the Kandy-Colombo road in South-Western part of the city. Most of the bare lands in Kandy city are environmentally sensitive areas owing to its topographical nature.

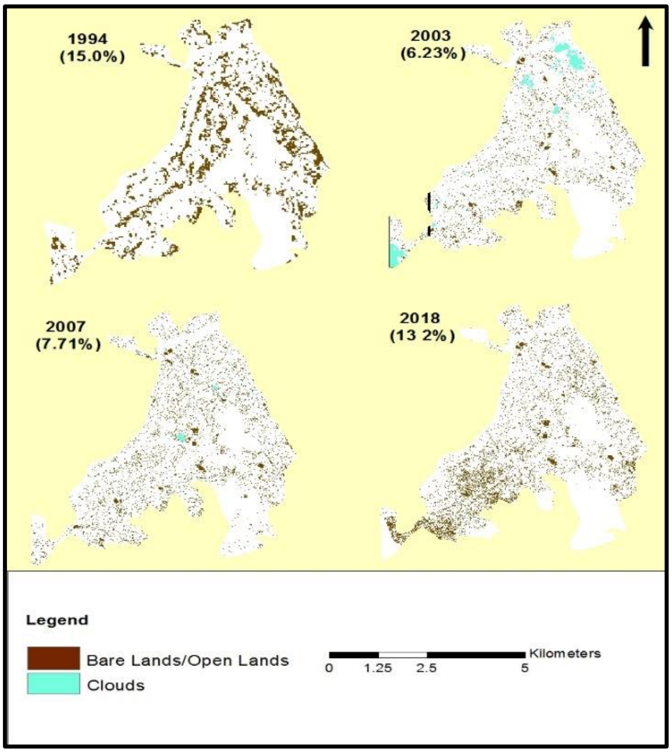

Figure 12: Spatio-temporal change in bare/open lands in Kandy city, 1994-2018

Forest cover is the most vulnerable land use category in any city. Forest is the strongly affected land use category in Kandy city also compared with the other land use categories during the entire period of time from 1994-2018. From ancient time Kandy city is covered with dense and light forests and even today dense forest patches are still protected because of declaration of them as reserved forested areas. There are two reserved forest patches in Eastern and South-Eastern part of the city which are important in the environmental point of view. Forest cover has a continuous decline from 1994 to 2018 but percentage of forest conversion within 1994-2003 is minimal compared with the percentage of conversion agricultural lands and bare lands. It is only a 0.78 percent and has not been affected by the rapid built-up expansion in 1994-2003. A large amount of forest loss has started after 2003. The city lost its forest cover by 8 percent during 2003-2007 and by 5 percent during 2007-2018 out of its total change of 13.8 percent in 1994-2018. This loss is not associated with the reserved forested areas but with the light forested areas spread out through the city. All the imageries show (Figure 13) the two reserved forested areas remain unchanged from 1994-2018.

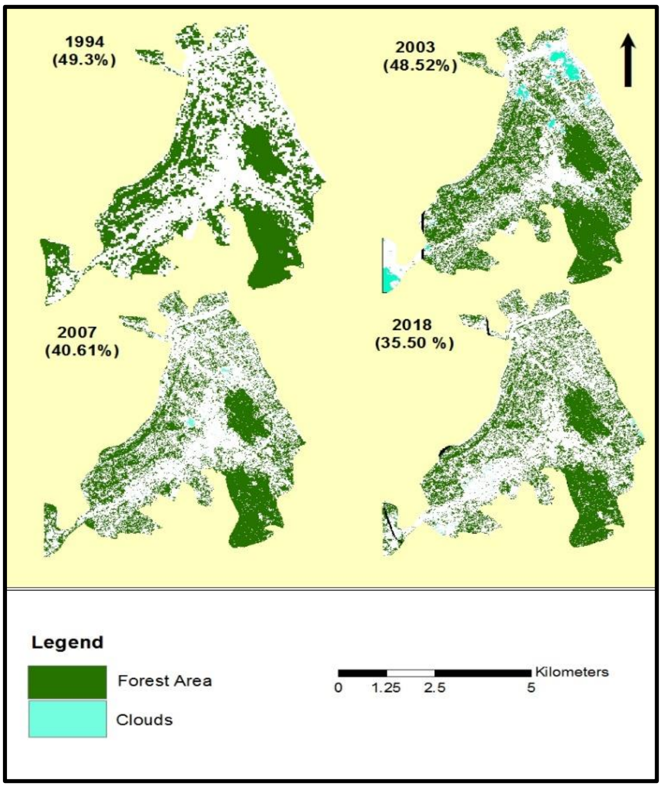

Figure 13: Spatio-temporal change in forest areas in Kandy city, 1994-2018

As shown by statistics (Table 4), higher percentage of forest conversion from 2003 is not due to the increase in the built-up area but due to the increase in the agricultural and home gardens and bare and open lands. After 2003 growth of built-up area is not significant but there is an increasing trend in agricultural and home gardens and bare and open lands which is a result of forest conversion. Considering the temporal change in land use/land cover in the city in the overall context, the city was very dynamic in terms of its population growth and land use/land cover transformation during the period of 1994-2003, but now it is not experiencing an extensive transformation. As shown by Figure 5 lowest land user/land cover modification is observable in 2007-2018. UDA intervention toward controlling of physical growth through strict land use zoning regulations and suburban growth trend taking place around the city after 2001 are the major factors behind this situation.

4.2. Classification Accuracy Assessment

Results of the classification accuracy assessment carried out for the study are shown in Table 6 and Table 7. Table 6 shows the overall accuracy derived from the stratified random sampling method for the 1994 is 92 percent, 2003 is 95 percent, 2007 is 94 percent and 2018 is 96 percent. Considering the land use categories' accuracy (Table 7), the stratified random sampling method provided a very high accuracy assessment in water with an accuracy of 100 percent. Almost all the other categories have a high accuracy level above 83 percent. Only built-up area in user's accuracy in the year 1994, and both agriculture and bare lands in both producer's and user's accuracy in the year 2003 show a considerably low accuracy (User's accuracy is 77 percent for built-up in 1994, producer's accuracy is 72 for agriculture in 2003 and user's accuracy is 72 for bare lands in 2003). This is due to incorrect identification of pixels. However, Kappa coefficient for each classification is above 90 percent and it indicates a good classification performance.

Table 6: Overall accuracy and K_{hat} coefficient of agreement for satellite images in Kandy city, 1994-2018

Year	Image	Overall accuracy	K_{hat} coefficient
1994	Landsat 5 TM L1T	92 %	78 %
2003	IKONOS-2	95 %	93 %
2007	IKONOS-2	94 %	91 %
2018	GEO EYE-1	96 %	94 %

Table 7: LULC categories' accuracy in Kandy city, 1994-2018

LULC Class	1994		2003		2007		2018	
	Producer's accuracy (%)	User's accuracy (%)	Produces accuracy (%)	User's accuracy (%)	Produces accuracy (%)	User's accuracy (%)	Produces accuracy (%)	User's accuracy (%)
Water	100	100	100	100	100	100	100	100
Built-up	94	77	100	93	96	90	94	97
Agriculture	91	88	72	96	94	86	96	95
Bare lands	83	96	100	72	89	94	97	100
Forest	94	96	98	100	92	100	97	92

5. Conclusion

The quantification of land use/land cover changes in a city space over the time is very significant for policy makers, urban planners, environmentalists, administrators and politicians in relevant local government for better understanding of changes happening in city space with time with different human activities. This study attempted to evaluate spatial-temporal changes occurred in land use/land cover in Kandy city which was vastly impacted by the rapid growth during the last twenty four years. Results display that the conversion of lands in the city in to different uses was faster within the period of 1994 to 2003 and afterward conversation of all land categories has slowed down. The lowest land use/ land cover change can be observed in 2007-2018. Substantial increase in built up area and substantial decrease in forest lands are the major changes undergone in the city within this twenty four year period. Significant increase in built up area is the direct result of rapid increase in population in the city until the year 2001. As illustrated by the land use/land cover maps after 2007 most of the urbanized areas are concentrated in the central part of the city. Recently, built-up area has been expanding towards the hilly areas surrounding the center with the construction of buildings such as houses and hotels on the hilly areas of the city. A large amount of forest loss in the city started after 2003 is not associated with its reserved forested areas, but with the light forested areas spread out throughout the city. Implementation of strong controlling measures of physical development of the city through land use zoning regulations by UDA to preserve world heritage status and the natural environmental condition of the city and the population shift from city core to the periphery indicating the suburbanization trend after 2001 are the major reasons behind the slow growth of built-up lands in the city after 2003. With these trends significant land use/ land cover changes in the Kandy city would not be expected in future.

6. Recommendations

Suburbanization occurring beyond the city limits is a good trend to preserve the historic and environmental values of the city. Outskirts towns such as Peradeniya, Katugastota, Ampitiya, Kundasale, Digana should be facilitated to develop as new nodes of growth which accommodate the migrants to the Kandy city. The city, being a world heritage city should be developed mainly as a main cultural and tourist center enhancing and protecting its historic, cultural, artistic and religious value as well as its scenic beauty rather than residential and commercial activities. Residential activities within the city should be discharged so far to minimize the land subdivisions further, and growth of new residential nodes mentioned above should be encouraged by providing amenities and utilities. Strict land use zoning regulations are compulsory so far, to discourage the constructions on the slope areas and conversion of agricultural lands to preserve the natural setting and the existing wooded hills. Conservation of agricultural lands specially Kandyan home gardens as environmental resources of the city because they are vital to keep the city climate better. Protecting existing urban vegetation cover and increasing vegetation cover in the city by planting trees where necessary, introducing green parking lots in environmentally more sustainable manner also are applicable strategies to minimize the land conversion further and to minimize the adverse impacts of the land use/land cover changes in the city.

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