Spatio-temporal Analysis of Urbanization, Urban Growth and Urban Sprawl Since 1976-2011 in Kandy City and Surrounding Area using GIS and Remote Sensing

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Abstract

Urbanization is the dynamic process and it is one of the more important indicators of development. Though it is happening rapidly, in developing countries like Sri Lanka, the process of urban expansion is underestimated, due to use of traditional administration boundaries to demarcate urban area. But in the developing countries the urban expansion is happening beyond the traditional boundaries and without proper planning. Therefore the identification of urban expansion and direction of urban expansion are important for urban planning and to measure the level of urbanization. Statistical information alone is difficult to measure urban expansion because, it is physically observable phenomena on the earth surface, both horizontally and vertically. Therefore spatial and temporal analysis is important to understand urban expansion, and for this both RS (Remote Sensing) and GIS techniques provide unrivalled opportunity to analyze urban expansion. Therefore main objective of this study is to analyze the urban expansion in the Kandy urban area both temporally and spatially since 1976, using RS and GIS. The findings of the study will be very useful to redefine the urban boundaries of the Kandy urban area and formulate policies and strategies for future urban development in Kandy urban area.

Introduction

Urbanization is a dynamic process and it is one of the most important indicators of development. In demographic point of view urbanization is defines as percent of urban population to the total population and the urban population is growing rapidly in Sri Lanka. Therefore the natural urban boundary is also expanding. But we still use the administrative boundary as the urban boundary which has created many problems in urban planning and service providing. Therefore identification of urban expansion and its direction is important for future planning and management of urban areas.

Urbanization is physically observable phenomena on the earth surface which happens both horizontally and vertically therefore spatial analysis is important to understand urban expansion and remote

sensing and GIS techniques provide unrivalled opportunity to analyse urbanization, urban growth and urban sprawl. The main objective of this study is to analysis the expansion of urban population in Kandy urban area since 1976 and identify new urban boundary for Kandy by using remote sensing and GIS.

Background

In broader sense urbanization is a vast process of development or increasing activities of people in an area known as “urban” reflecting the structural changes in physical, socio-economic, demographic and cultural aspects of human life. Normally, the level of development of a country has a direct relationship with the level of urbanization of the country since development of secondary and tertiary sectors of the economy influences the urban growth. This process is cumulative and increases general scale of settlements due

to progressive concentration of people and activities in urban areas. As results of these processes urbanism spreads beyond built-up areas of towns and makes economic, social and technological changes in surrounding rural areas.

When considering the process of urbanization in global context, level (rate) of urbanization in developed countries is much higher than the developing countries for instance average level of urbanization in South Asian region is around 30 percent compared to 75 percent in industrialized nations (United Nations, 2012). Sri Lanka is similar to most of the developing countries which has been experiencing a slow urbanization for a long time. The percentage of urbanization is 15.1 percent in 2012 suggesting that Sri Lanka has very low urbanization relative to its per capita income (World Bank, 2012).

Urban growth is the increase of population living in the urban areas of a country and it is measured as the percentage of average annual rate of change. Not like urbanization, urban growth is high in the developing countries than the developed countries. As an example the urban growth in the Asia is 1.5 and it is 1.1 in Africa (World urbanization prospect, 2014). The regions with relatively high level of urbanization have slow level of urban growth and it is less than 0.4 percent annually in developed countries. In general, urban growth slows down as population becomes more urbanized. In Sri Lanka, urban growth rate has stagnated at 1.1 per year for a long period. Official statistics shows that urban population growth averaged 0.3 percent a year over 2005-2010 (World Bank, 2010). The table 01 shows the trends of urbanization and urban growth in Sri Lanka since 1871 to 2011.

Table 01: Urbanization, urban growth in Sri Lanka during 1871-2011

Year	Urban population	Level of urbanization	Urban growth	No of towns
1871	260376	10.8		19
1881	281065	10.2	0.8	20
1891	321413	10.7	1.4	20
1901	414046	11.6	2.9	28
1911	537666	13.1	3.1	37
1921	631871	14.2	1.7	42

1931	737273	15.0	3.4	42
1946	1023044	15.4	1.9	42
1953	1239133	15.3	2.1	43
1963	2016285	19.1	6.2	99
1971	2848116	22.4	4.1	135
1981	3192489*	21.5	1.2	134
	2036237**		-1.1	
2001	2467171	14.6	1.0	45
2011	*****	15.1	1.36***	

*Including population in Municipal Councils, urban councils and Town Councils

**Excluding population in Town Council

*** Estimate

Source: Department of Census and Statistics, 2005, 2011

The above table clearly shows that the urbanization and urban growth has declined since 1980s. One reason for declining the percentage of urbanization and urban growth may be due to the change of the definition of urban area. Before 1987, areas which were classified as urban included municipal councils, urban councils and town councils. In 1987 under the 13th Amendment Pradeshiya sabhas (rural councils) were created. By this Amendment town councils which were classified under “urban” were amalgamated with rural councils (Pradeshiya sabhas), thus 87 town councils were reclassified as Pradeshiya Sabha. This situation lowered the percentage of country's urbanization and urban growth.

Definition of urban area of a country is very important in understanding the real picture of urbanization of a country. The literature shows that absence of an acceptable definition of urban areas as a major reason which is responsible for decreasing trend of level of urbanization in Sri Lanka (Uduporuwa, 2010). Unlike other countries an 'urban area' in Sri Lanka has not been defined based on the size of population, population density, proportion of the male population in non agricultural occupations or status of civil administration (Panditharathne, 1996). In Sri Lanka, “urban status” is conferred on an area by the Minister in charge of local government purely for local administrative purposes. However ministerial discretion seems to be based on the nature of the development of the locality or its amenities and urban characters (Mendis, 1982).

However, many areas that were not defined as 'urban' for the Census show in increasingly urban characteristics such as high population and building density and urban sprawl is happening beyond the urban boundaries. Urban sprawl is the expansion of human population away from central urban areas into previously remote and rural areas. Compared with the developing countries, urban sprawl is high in the developed countries, through the process of counter urbanization and suburbanization. In developed countries urban sprawl is happening concentric growth around the core, and this process counted as urbanization. But most of the developing countries the process of urban sprawl is happening along the main road. Being a developing country Sri Lanka is not an exception and urban sprawl is happening along the main road and suburbanization was underestimated. In addition, floating population may not be counted as urban in Sri Lanka. According to official statistics, approximately 400000-500000 and 150000 floating population attracts on any working day in the Colombo and Kandy city respectively (World Bank, 2012).

The above background clearly shows that urbanization and urban growth in Sri Lanka are much debated and there is consensus that the country is urbanizing faster than the statistical figures suggest and empirical evidences show that it is happening beyond the traditional urban boundaries. However, it is important to develop techniques to analyze urbanization, urban growth and urban sprawl in the country to get a real picture of urbanization in Sri Lanka.

Although, there are several writings which examined the trends of urbanization and urban growth in Sri Lanka (see Panditharatne, 1961, 1964, 1969, 1996, 2009 and 2011; Selvaratnam, 1970, Silva and Gunawardena, 1971) in the demographic and socio-economic perspective, there are hardly any studies which are based on spatio-temporal perspective. Spatial analysis was a popular approach in the positivist tradition in urban geography during 1950-1970 and it is still a popular approach in urban geography. This approach could redefine urban geography as a science of spatial relationship. However Sri Lankan

geographers have neglected this tradition because urban geography is considered as a branch of human geography rather than a science. Another reason is lack of technological and spatial analytical power among urban geographers. This study suggests 'spatio-temporal' approach to study urbanization, urban growth, and urban sprawl in Kandy city and surrounding area using GIS and Remote sensing techniques. RS is a helpful tool for better understanding of the spatio-temporal trends of urbanization and to monitor the spatial patterns of urban land use change compared to traditional socio-economic indicators such as population and employment. RS and GIS technology can play an important role in studying the pattern of urban growth. With multi-temporal analysis, these techniques give a unique perspective of how urban areas have grown and it is only a solution for continuous monitoring of urban areas.

There are a number of research papers available; GIS and RS application on estimating urban population, monitoring urban land use changes and urban sprawl in other countries. Baudot (1993) has done a research on application of RS to urban population estimation in Marrakech, Morocco using SPOTS XS+P data. An estimation of the population was made by using a segmentation in areas of homogenous urban topology. The study done by Saravanan and Ilangoan (2010) demonstrated urban expansion of Madurai and identified the temporal and spatial development patterns by using multi-temporal RS images and GIS tool. Moeller (2005), Gupta (2013) analyzed urban sprawl using RS images and wind rose diagram in different directions and distances from growth centroid of an urban area. Moller carried his research on Phoenix, AZ metropolitan area. This study used satellite imagery from several sensor systems and an object oriented image analysis and classification approach. The change results of the six periods investigated have been analyzed in terms of growth direction and distance. Gupta has also done a very similar study for the Dehradun urban area in India. However these studies did not address under estimation of urbanization and just analyze urban growth, urban land use

changes and urban sprawl to show the strength analytical power of GIS and RS.

In Sri Lanka, there is hardly any study which is based on GIS and RS application on monitoring urbanization, urban growth and urban sprawl. According to the available literature in Sri Lanka, a few studies are available with GIS and RS applications which analyzed the vegetation changes and temperature in urban areas. Wijesekera and Manawadu (2009) analyzed the adverse impact of rapid urbanization on the vegetation cover in Colombo metropolitan region using remote sensing data. Meanwhile, Manawadu (2009) analyzed the changing patterns of surface temperature in Colombo city using remote sensing data. However these studies were not focused urbanization, urban growth and urban sprawl.

Aim and objectives

The overall aim of this study was analyze the urbanization, urban growth and urban sprawl in Kandy city and surrounding area using GIS and RS to find an answer for under estimation of urbanization.

The specific **objectives** of the study are;

1. Identify and analyze the urbanization and urban growth in Kandy city and surrounding area
2. Identify and analyze the land use changes in Kandy city and the surrounding area

3. Produce a land use/ land cover map of Kandy urban area in different time periods in order to detect changes that have taken place particularly in the built-up and homestead land

4. Analyze the urban sprawl of Kandy city.

These finding will help to predict urban growth and redefine urban area.

Five criteria have been developed to identify the urban growth and urban sprawl.

1. Population density should be increased spatially and temporally
2. Vegetation cover should be reduced spatially and temporally
3. Built up area and homestead area should be increased spatially and temporally

Land surface temperature should be increased spatially and temporally

Methodology

The methodology of the study is summarized in Figure 01 and all the steps and methods are described in detail below. As mention above, the information contained in this study is primarily generated by using population data and remote sensing data. The time series data of satellite images: 1976, 1992, 2001 and 2011 (See Table 02 and Fig 02) were used to generate land cover maps, to identify land cover changes and to extract built up and homestead area. Using population data population density maps were developed.

Figure 1: The Flow diagram of Methodology

Study Area

The study area of this research is the Kandy city and its surrounding. Kandy city is the second largest city in Sri Lanka and it is the urban center in central Sri Lanka. The shape of Kandy city is triangular and has about 5,900 acres in extent. The average elevation varies between 1500 feet in the flat surface of the core area and about 2600 feet in the hill tops. Kandy urban area is demarcated by natural boundaries. The south boundary falls along the limits of the hills representing approximately 30 percent of the perimeter. The West, North and East boundary is demarcated by Mahaweli river and it is nearly 55 percent of the total urban boundary. The other 15 percent falls along the natural streams or over hill tops. The expansion possibilities of the city are limited due to natural boundaries in all directions and the city is in a land locked location.

The GN division which is 2 km beyond urban boundary is selected as study area. Figure 02 present the study area.

Figure 2: The Study Area

Data Sources

Basically, this study is based on two types of data: satellite image data and population data. Details of the satellite data acquired for this study is given in Table 02 with the specifications of their spatial resolution, spectral resolution and date of data acquisition. These satellite images were downloaded from the United States Geological Survey (USGS). The downloaded temporal images of study area are shown in Figure 03.

Because the data availability is limited, data with varying resolution has been used and it will affect the area calculation and land use comparison in different time periods in the urban area. However, geometric correction and re sampling techniques were introduced to reduced some of these limitations. The other

type of data is population data which was collected from census reports in Sri Lanka. However the census years are not exactly compatible with the time of satellite image data therefore closest census years: 1971, 1981, 2001 and 2011 were considered.

	Landsat MSS (1976)	Landsat 5 TM (1992)	Landsat 7 (2001)	Landsat 7 (2011)
Spatial resolution	Ground sampling interval-57*32 Scene size-184*185.2 8 bit (256 level)	Band 1-5 and 7-30*30m Band 6-20*120 8 bit (256 level)	Bands 1-5 and 7-30*30 Band 6-60*60 Band 8-15*15	Bands 1-5 and 7-30*30 Band 6-60*60 Band 8-15*15
Spectral resolution	Band 1-0.5-0.6 Band 2-0.6-0.7 Band 3-0.7-0.8 Band 4-0.8-1.1	Bands 1-5 and 7	Bands 1-5 and 7 Band 6 Band 8	Bands 1-5 and 7 Band 6 Band 8
Date of acquisition		1992.02.10	2001.03.14	2011.03.16

Table 02: Specification of various sensors and image data used

Landsat MSS-1976

Landsat TM-1992

Landsat ETM+ 2001

Landsat ETM+ 2011

Pre Processing of Data

Population data of each GN division was collected and a spatial data base was developed to accommodate these population data. Before analysis started, satellite images were treated several times step by step. At the beginning the downloaded four satellite images were geo-referenced in UTM GS 84 projection system and they were then converted into the national coordinate system. Then the cloud-shadow masking was done to remove clouds which were present in some images. In the third step all the images were re-sampled by 30*30 spatial resolutions. Finally four subsets of study area were created by using study area shape file.

Data analysis: Identify urban growth, urban sprawl and derivation of urban growth

To identify urban growth and urban sprawl, population density maps, band math operations: NDVI (Normalized Difference Vegetation Index)¹, NDBI (Normalized Difference Built up Index)², surface temperature³ and land use/land cover maps were prepared.

The first criterion is to know whether the population and population density have increased with the time due to urbanization in the study area. For that purpose, population density maps were developed. The second criterion is to know whether NDVI decrease, NDBI and temperature increase with the time due to urbanization in the study area. For that purpose, NDVI, NDBI and surface temperature were calculated using ERDAS 15 software.

The third criterion is to know whether the land use changes have happened in the study area. The four sub set images of the study area were classified into five land use classes: built-up, homestead, paddy, forest and water by using the supervised classification method, by using parametric classification algorithm and Maximum Likelihood classifier. All the four data sets were classified with the help of identified training data sets in the defined five classes.

Built up and homestead areas were extracted by using classified land use maps and those areas were analyzed spatially and temporally by using 8 direction wind rose diagram. To develop the wind rose diagram⁴, Kandy clock tour was overlaid as a centroid and from that point 1 km incremental buffer was created by using GIS software. By overlaying 8 directions wind rose diagram, built up and homestead area were analyzed in different time periods.

Results

1. Identification of urbanization and urban growth in Kandy city

Urbanization and urban sprawl of the Kandy city were identified by doing demographic analysis, band math operation and creating land use maps, and it is the first objective of the study. According to statistic the Kandy city population was 98872 in 1981 and it has increased up to 125400 in 2011(see Figure 04).

The percentage of urbanization (urban population to total population) was 9.1 in 2011 but it was 12.0 in 1964. The urbanization has declined from 1964 to 2011. However the urbanization value in 2011 should be high compared to 1964 value because in-migration from other areas to the urban areas is usually high. There may be possible reasons for this unusual drop in urbanization such as increase of rural population compared to urban population, increasing out migration and declining in-migration to urban areas. However demographic analysis shows that the urban growth rate has increased by 26.83 percent and population density in urban areas has increased from 3606 to 5260 per square kilometer within the urban boundary and surrounding area between 1981 to 2011 period.

Population density maps clearly show that population is congested along the low land areas within the urban boundary and high density can be observed beyond the city boundaries; North- West towards Katugastota, South-East towards Ampitiya and South West towards Peradeniya (see Figure 05).

Figure 04: Population growth in Kandy urban area since 1881-2011

Population density map of Kandy city and surrounding area

Figure 05: Population density in 2001 and 2011 in the study area.

The results of the three band math operation; NDVI index, NDBI index and surface temperature clearly show that the urbanization had happened beyond the administrative boundary of Kandy city. NDVI index has declined through space and time (See Figure 6) and we can conclude that urban growth and sprawl has happened beyond city limits.

Theoretically, NDVI value over 0.4 represents green vegetation. Figure 06 clearly shows that highest NDVI value of the value range has reduced with the time. This can further be confirmed by the reduction of white area of the map and the increase of dark area.

Figure 06: NDVI index in study area

The NDBI index has increased through space and time and this is an indication to conform that the urban growth and urban sprawl has happened beyond city limits. Produced NDBI images are shown in the Figure 07. Theoretically, NDBI value over 0.4 represents built up area and the color of that area is white. If the NDBI value of 1992 is compared with NDBI value of 2001 there is an increase. However that value is slightly reduced when it comes to 2011. The reason for this reduction

may be the spectral confusion of the images. But when the images are visually observed, the gradual spatial increase of white color area can be seen from 1992 to 2011. This reflects the gradual increase of built up areas from 1992 to 2011.

Like other two indices, land surface temperature has also increased in the time and space and this indicates that the urbanization, urban growth and urban sprawl have happened beyond city limits. The surface temperature ranges of 1992, 2001 and 2011 image are 286.62 K to 306.88K, 294.79K to 316.92K and 297.36K to 315.4K respectively. The

gradual increase of both upper and lower limits of the range can be observed from 1992 to 2011 through 2001. However the upper limit of 2011 image is slightly lower than the upper limit of 2001 and this may be due to spectral confusion of the image (see Figure 08).

Figure 08: Surface temperature in the study area

Further analysis of land use changes were done to confirm the urbanization beyond city limits.

2. Land use/ land cover changes

The population increase and urbanization in an area put great pressure on the land and as a consequence the land cover will change dramatically. Therefore the analysis of land use changes was other way of identifying the urban growth and urban sprawl. Four land cover maps were developed for the year of 1976, 1992, 2001 and 2011 according to five major land use types. These maps clearly show that the extents of forest cover and paddy lands have gradually decreased from 1976 to 2011. (See Figure 09). The lost extent of the vegetation has replaced by built-up areas and homestead (see Figure 10). The forest cover has reduced by 41% and the paddy land has decreased by 35% during the

period of 1992 to 2011. However the extent of water bodies has increased from 1992 to 2011 but it has to be decreased. This calculated increase may be due to seasonal changes of the water bodies in the area at the time of image taking. These maps show that the homestead area has expanded into three directions from the city center. At present the homestead is fully congested within the urban boundary and has gone beyond the urban boundary.

Figure 09: Land use/ land cover maps of study area

Figure 10: Land use changes since 1992-2011 in acres

Further by using derived NDVI, NDBI and surface temperature images of 2011, land use were reclassified as built-up, homestead and vegetation using natural breaks. The results are shown in Figure 11. The results of these three methods are

almost similar and those results are compatible with the land use classification map of 2011. The results of all methods clearly show that the urbanization, urban growth and urban sprawl has happened beyond city limits (see Figure 11)

Figure 11: Comparisons of the land cover classification with NDVI, NDBI and surface temperature in 2011

However within the urban boundary, there is huge vegetation land (Udawatha Kele and Hantana) which does not show urban characteristics. However those natural forest areas should be preserved to achieve sustainable urban development in Kandy city. Although the urban expansion possibilities are limited it is hard to expect that urban expansion will be limited, because urban expansion is happening three direction along the main road and beyond the boundary.

3. Urban sprawl in Kandy city

In previous studies, the urban sprawl was analyzed by considering only built up area, but this study considered both built up and surrounding homestead areas as 'urban'. Kandy city is surrounded by hills and the homestead is mixed with forest lands which are known as Kandyan home garden. Therefore both built up and homestead area was analyzed separately.

The built up and homestead areas were extracted from land use/ land cover maps and

those areas were overlaid on wind rose for spatio-temporal analysis of urban sprawl. Figure 12 illustrates the urban sprawl (for built up area only) in different directions from 1976 to 2011. Kandy built-up area had been limited to Kotugodella which was the core city area then it had expanded into two directions namely South-West and North- East along the Peradeniya-Kandy road and Kandy Katugastota road respectively. First urban expansion has happened towards South-West direction and has continued to the North-East direction. The growth radius has increased up to 8km from the city core along the Kandy-Peradeniya road towards Peradeniya and 4 km towards north and north-west directions. Four urban centers; Peradeniya, Katugastota, Ampitiya and Kundasale can be observed now at the edge of the present urban boundaries in the South-West, North-West, South-East and Eastern directions respectively. The analysis shows that the extent of the built-up area is 2191 acres in 2011. Built up area has grown by 14% between 1976 and 1992 and during 1992 to 2011 it has grown up to 54% and that is a huge increase.

Figure 12: Spatio-temporal dynamic of urban sprawl, 1976-2011 (based on 8-direction wind rose diagram)

Further the directions and magnitudes of the urban sprawl were analyzed spatially and temporally by using 8-direction wind rose analysis. After overlaying the wind rose diagram, the built up and homestead area were

calculated for each sector by using zonal statistics in GIS. The tabulated data has converted to several graphs (Figure 13 and 14)

Figure 13: Spatio-temporal analysis of built up area in acres

Figure 14: Spatio-temporal analysis of homestead area in acres

Findings

The morphology of the urban sprawl of Kandy city can be observed in three directions along the three main roads which can be represented by the letter 'Y'. The node of 'Y' is the center of the city and the three lines represent the three main roads. The south west limb represents the Peradeniya road. The north-west limb represents the Katugastota road. The south eastern limb represents the Hewaheta road. All these three limbs run beyond the city boundary and terminate in an area where there are urban morphological characters. This analysis clearly shows that the urbanization is happening beyond the administrative boundaries and three towns are emerging with urban characters at the vertex of the triangular area.

Recommendations

Based on these findings, we propose the urban area should be expanded beyond the present urban boundary and new boundary should be introduced taking the emerging cities at the vertex of the triangular area into consideration. However this study along does not provide the necessary information to reintroduce new urban boundary. Therefore a detail ground survey and social survey should be done to gather other important information. This type of situation can be observed all over the country therefore these types of studies have to be done to identify urbanization, urban growth and urban sprawl in other areas of the country and such findings will give the real picture of urbanization in Sri Lanka.

Conclusion

New criteria is needed to demarcate urban area rather than using administration boundary, because this analysis shows that urban growth is happening beyond the administrative boundaries and sometime the true boundary of urbanization is smaller than the administrative boundary. RS and GIS analysis can be used to analyze urban growth, urban sprawl and urbanization because RS and GIS provide effective, logical and visual (geographic) solutions.

Notes

1. The NDVI is an index of plant 'greenness' or photosynthetic activity, and it is one of the most commonly used vegetation index. The NDVI land images were produced by using NDVI index with the following equation.

$$NDVI = (NIR - RED) / (NIR + RED)$$

2. The NDBI is widely used index to strengthen building information and extract built-up land from urban areas. The NDBI land images were produced by using NDBI index with the following equation.

$$NDBI = (MIR - NIR) / (MIR + NIR)$$

3. The following formula and steps are used to calculate at sensor spectral radiance for Land Sat TM and ETM+

- **Step 01-** Calculation of at-sensor spectral radiance for Landsat TM and ETM+

$$L_{\lambda} = ((LMAX_{\lambda} - LMIN_{\lambda}) / (QCALMAX - QCALMIN)) * (QCAL - QCALMIN) + LMIN_{\lambda}$$

L_{λ} = at-sensor spectral radiance

$LMAX_{\lambda}$ = the spectral radiance that is scaled to QCALMAX in watts/(meter squared * ster * μm)

$LMIN_{\lambda}$ = the spectral radiance that is scaled to QCALMIN in watts/(meter squared * ster * μm)

QCALMAX = the maximum quantized calibrated pixel value (corresponding to $LMAX_{\lambda}$) in DN = 255

QCALMIN = the minimum quantized calibrated pixel value (corresponding to $LMIN_{\lambda}$) in DN (equals to 1)

QCAL = DN value

The table shows, each values for $LMAX_{\lambda}$, $LMIN_{\lambda}$, QCALMAX and QCALMIN Landsat 4, 5 and 7.

	Landsat 4, 5	Landsat 7
$LMAX_{\lambda}$	15.303	17.04
$LMIN_{\lambda}$	1.234	0.00
QCALMAX	255	255
QCALMIN	1	1

- **Step 02** – Conversion to at – satellite temperature

$$T = \frac{K2}{\ln\left(\frac{K1}{L_{\lambda}} + 1\right)}$$

T = Effective at-satellite temperature in Kelvin

K2 = Calibration constant 2 from Table 1

K1 = Calibration constant 1 from Table 1

L = Spectral radiance in watts/(meter squared * ster * μm)

The parameters of calibration constant 1 and 2 provide the following table.

ETM+ and TM Thermal Band Calibration Constants		
	Constant 1- K1 watts/(meter squared * ster * μm)	Constant 2 - K2 Kelvin
Landsat 7	666.09	1282.71
Landsat 5	607.76	1260.56
Landsat 8 band 10	774.89	1321.08
Landsat 8 band 11	480.89	1201.14

- **Step 03** - Calculation of Emissivity

NDVI	Land surface emissivity
NDVI < - 0.185	0.995
-0.185 < NDVI < 0.157	0.970
0.157 < NDVI , 0.727	$1.0094 + 0.047\ln(\text{NDVI})$
NDVI > 0.727	0.990

• **Step 04** - Calculation of Emissivity Corrected Land Surface Temperature

$$St = T / (1 + (\lambda * T / \rho) \ln \varepsilon)$$

$$\rho = h * c / \sigma = 1.438 * 10^{-2} \text{ mK}$$

$$-\sigma = \text{Boltzmann Constant } (1.38 * 10^{-23} \text{ J/K})$$

$$-c = \text{Velocity of light } (2.998 * 10^8 \text{ m/s})$$

$$h = \text{Plank's Constant } (6.626 * 10^{-24} \text{ Js})$$

Wave Length (λ)

Satellite	Thermal band(m)	Wavelength(m)
Landsat 4 -5	6	10.4 - 12.5
Landsat 7	6	10.4 -12.5
Landsat 8	10	11.6 -11.9
Landsat 8	11	11.5 -12.51

4. The 8-direction wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. Presented in a circular format, the wind rose shows the frequency of winds blowing from particular directions over a period of time. In this diagram north direction corresponds to 0/360, east to 90, south to 180 and west to 270. In the same way, the directions of the wind rose diagram showing frequency of wind can be the frequency of urban growth in particular direction (Sudhira etl, 2003)

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