J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

GEOGRAPHIC ASSESSMENT ON SPATIAL VARIATION OF LAND SURFACE TEMPERATURES IN YANGON CITY

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Abstract

Biophysical attributes of earth surface in non-evaporating and impervious materials cause the solar energy to raise Land Surface Temperature (LST). At present, LST obtained by satellite technology can furnish effective assessment of surface temperatures variation than thermometer network based assessments. The main aim of this study is to evaluate the use of Thermal Infrared Remote Sensing for assessing temperature differences in Yangon City area. The estimation of surface temperature variation and areas of high temperature is the major objectives of this study. Local studies of LST need to use a sensor with high resolution, therefore, Thermal data of Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 with resolution of 30 meter for 1994, 2003, and 2014 are used respectively in this study. The output LSTs are classified into only two classes between low and high temperature areas according to the temperature ranges. Again the total area of Yangon City is divided into five categories from high temperature to low temperature for clear distinguishing. The obtained output images of LST are exported to present as layout maps for better understanding of the temperature variation in the area. It was observed that areas having built up surfaces contain high temperatures compared to the areas having vegetation cover. The thermal energy responses of different structures of the City indicate the variations in surface temperature. Ground-based observations reflect only thermal condition around the station. However, by using remote sensing thermal bands in this study enable to get the thermal condition for each pixel and assess the spatial variation of temperatures on the whole area of city.

Keywords: LST, thermal infrared remote sensing data (TIR), spatial variation

Introduction

The study of surface temperature, on local climate condition, has been important work in present days since global temperatures are increasing. The earth surface and all substances on it releases temperatures, but the urban centres are releasing much more heat than other places due to the large

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number of industries, the use of automobiles, dense settlement, uses of air conditioners and the lack of trees and other vegetation there. Urbanization refers to general increase in population and the amount of industrialization of a settlement (K. Sundara Kumar et al., 2015). The built-up area is generally considered as the parameter for quantifying urban sprawl (J. S.Yang et al., 2004). Urban sprawls have several environmental impacts and the extension of built up area that cause the increase in surface temperature and development of urban heat island is one of significant impact of climate on urban structure.

The climatic elements have been observed by climate stations and almost each city has at least one climatic station. In many cases, however, station based observations do not express actual climate variability and microclimate conditions. These observations reflect only thermal local condition around the station. At present, by using remote sensing thermal bands the researcher is enable to get the thermal condition for each pixel in the image. Remotely sensed thermal infrared (TIR) data have been widely used to retrieve land surface temperature (LST) since satellite sensor data provides a dense grid of almost instantaneous temperature measurements over a city by permitting spatial relationships between temperature patterns and land surface features. This study analyzes the surface temperature variation in terms of both temporal and spatial extent with the application of remote sensing data.

Study Area

Yangon City, a total area of 796.4 square kilometer, located between north latitudes 16° 30′ and 17° 11′ and 17° 31′, East longitudes between 92° 11′ and 92° 30′ is taken as study area (Figure 1). It is the most populated area in Myanmar.

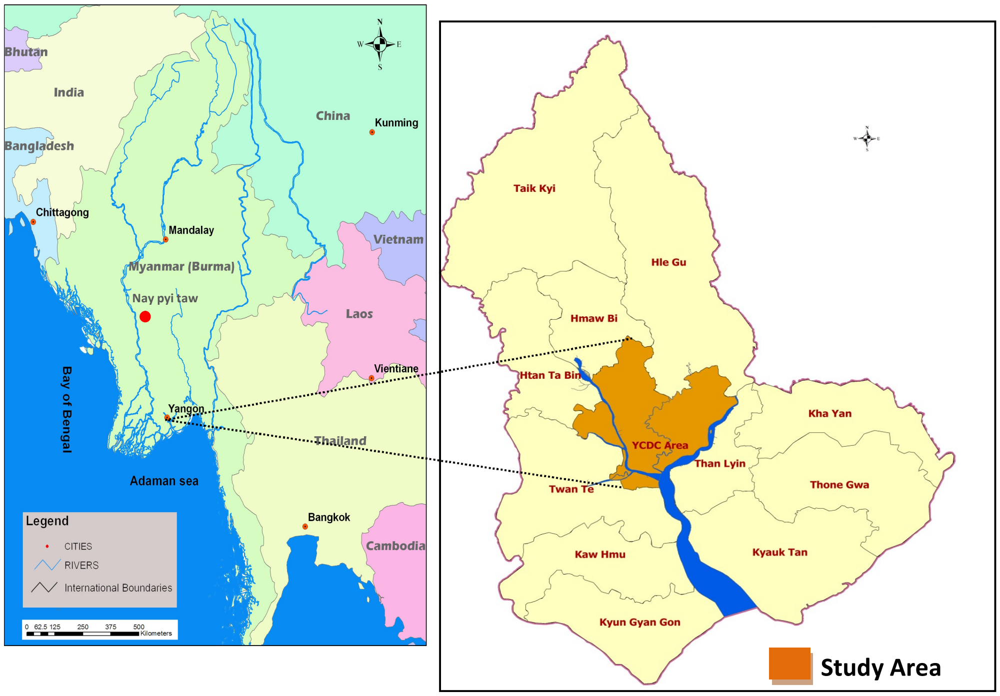


Figure 1. Location of Yangon City

Population of the study areas has increased rapidly within the past two decades mostly due to migration from the rural sites towards urban areas. In accordance with increasing population about, 2.99 million in 1994 to about 5 million in 2014, the surface structure of the city is changed significantly. Replacing natural land cover with pavements, buildings and other infrastructures takes away the natural cooling effect. According to YCDC, land use categories in Yangon City in 2013 are presented in figure 2.

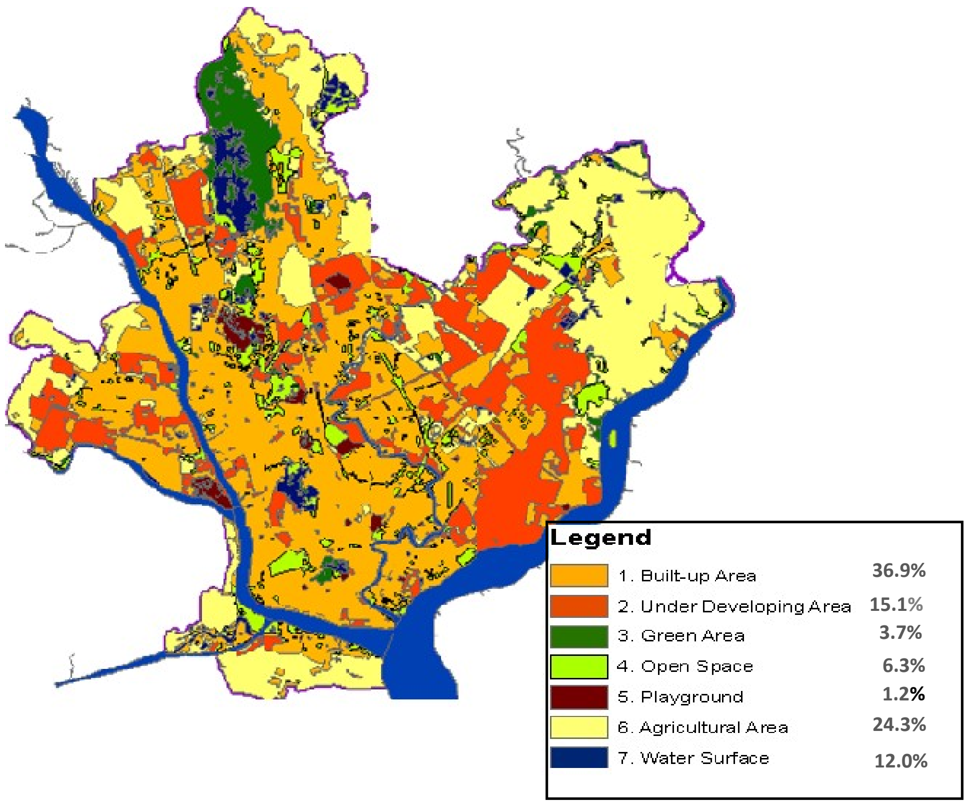


Figure 2. Land cover classification of Yangon City in 2013

Source: Khine Moe Nyunt and YCDC, 2013

Purpose

The main purpose is to evaluate the usefulness of remotely sensed thermal infrared (TIR) data in retrieving land surface temperature (LST). The major objectives are the estimation of land surface temperature variation during two decades and detection of area of high and low temperatures.

Materials

Satellite TIR sensors measure radiances at the top of the atmosphere (TOA), from which brightness temperatures (also known as blackbody temperatures) can be derived by using Plank's law (Dash et al., 2002). It is assumed that the water vapour content of the atmosphere is constant for a relatively small region, so that the atmospheric condition could be considered as uniform, and the influence of atmosphere on radiance temperature could be neglected (Xiao_ling Chen et al., 2006). To get pixel wise surface temperature in this study, satellite images are used as the main materials in this study. Landsat 5 (MSS TM) image, Landsat 7 (ETM+) image, and Landsat 8 (OLI-TIRS) image for Path 132 and Row 48 WGS 1984, Zone 47 used in the study are downloaded from USGS earth explorer website. The details of the Landsat satellite images selected for the present work are given in the table below.

Table 1. Details of satellite images downloaded from US Geological Survey

No	Types of Landsat sensor	Reference system, Path/Row	Bands used in this study	Date of Image acquisition	Spatial Resolution
1	Landsat 5	WRS-II/132/48	Band 6	4 March1994	30 m
2	Landsat 7(ETM+)	WRS-II/132/48	Band 6.1	5 March 2003	30 m
3	Landsat8(OLI-TIRS)	WRS-II/132/48	Band 10	11March 2014	30 m

Each satellite has several sensors and each sensor captures the data on the specific wavelength of the electromagnetic spectrum which is called the band. Among these several bands, some have been captured in the thermal spectrum, which can be used to find out the land surface temperature. For example, the bands 6 in TM sensor, 6.1 in ETM+, and, band 10 in LC 8 TIRS are thermal bands which were used for the present study.

Methodology

During this research work many research papers (K. Sundara Kumar et al, (2015), B mahalingam, (2013), J.S. Y and et al., (2004), P.V August et al. (2006) P. Dash, et al. (2002), Xiao_ling Chen, et al. (2006) etc.) concerning with the retrievals of surface temperature from satellite images and remote sensing data are studied in detail. By reviewing these papers, it is found that the formulas to convert digital number (DNs) to spectral radiance are slightly differing in some papers. This is may be due partly to the improvement of data processing technique and partly by periodically refreshing the global data achievement in landsat. After a comprehensive study of these papers, the input values in the computation are compiled. For the precision of formulas, calibration constants, and metadata of these images are checked with those of landsat 7 science data user handbook and landsat 8 data user guide book (Version 1.0, 2015). The following equations are used to convert DN's in a 1G product back to radiance Units and then to effective at-satellite temperature (Landsat 7 user handbook, 2010 and landsat 8 user guide book, 2013).

The equation 1 is used for landsat 5 TM and land 7 ETM+ and the equation 2 is used for landsat 8. The last equation, equation 3 is used to convert the radiance values to effective at-satellite temperature in Kelvin. And then the temperature in Kelvin is change to temperature in Celsius by subtracting 273.15°C. The calibration constants and scale factors needed are obtained from metadata files of respective images. The equations are given below and the methodological consideration as a flow chart is shown in figure 3.

Lλ = Grescale * QCAL + Brescale

which is also expressed as

Lλ = ((LMAXλ- LMINλ)/(QCALMAX-QCALMIN))*(QCAL-QCALMIN) + LMINλ ---------- 1

where: Lλ = Spectral Radiance at the sensor's aperture in watts/(meter squared * ster * μm)

Grescale = Rescaled gain in watts/(meter squared * ster * μm)/DN

Brescale = Rescaled bias in watts/(meter squared * ster * μm)

QCAL = the quantized calibrated pixel value in DN

LMINλ = the spectral radiance that is scaled to QCALMIN in watts/(meter squared * ster * μm)

LMAXλ = the spectral radiance that is scaled to QCALMAX in watts/(meter squared * ster * μm)

QCALMIN = the minimum quantized calibrated pixel value (corresponding to LMINλ) in DN

= 1 for LPGS products, 1 for NLAPS products processed after 4/4/2004

= 0 for NLAPS products processed before 4/5/2004

QCALMAX = the maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN= 255

Lλ = ML*Qcal + AL -------------------------2

where:

Lλ = Spectral radiance (W/(m2 * sr * μm))

ML = Radiance multiplicative scaling factor for the band from meta data

AL = Radiance additive scaling factor for the band from meta data

Qcal = Level 1 pixel value in DN

T = K2 / 1n ((K1 / Ll) + 1) ------------------ 3

T = Effective at-satellite temperature in Kelvin

K2 = Calibration constant 2 from meta data of respective image

K1 = Calibration constant 1 from respective image

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

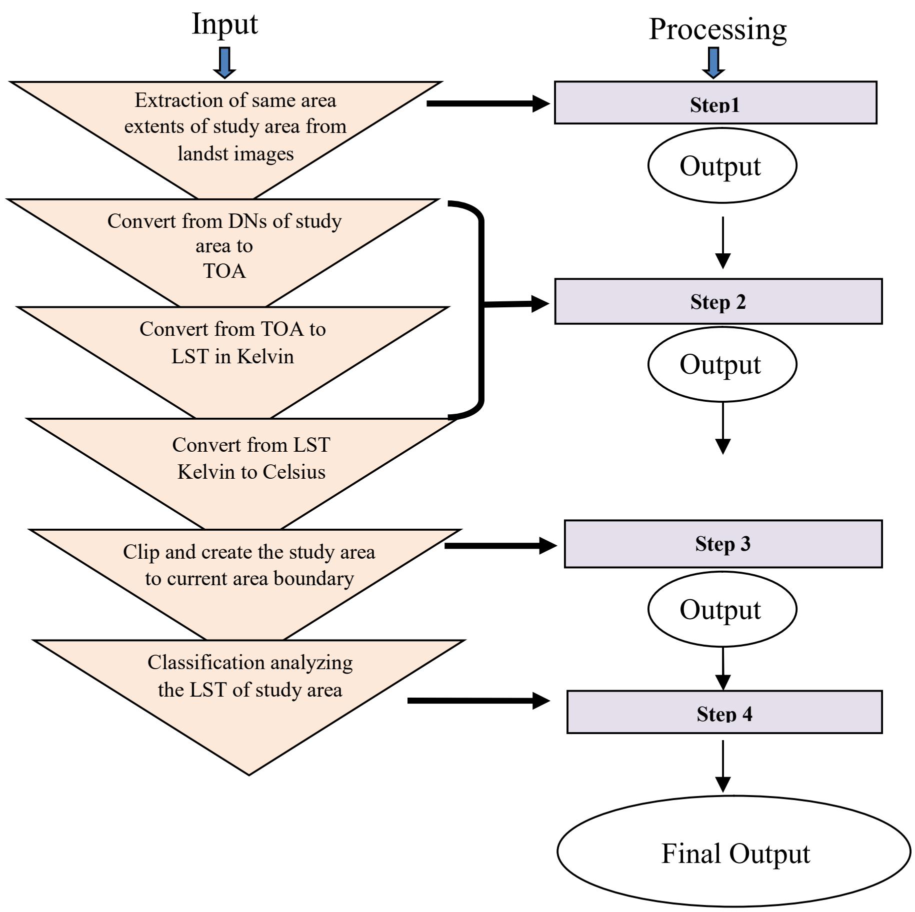


Figure 3. Flow chart of Land Surface Temperature (LST) estimation from landsat images

Step by step procedure for Estimation of LST

After the compilation of data needed, as the first step, the same area extent of images are extracted from thermal band images of landsat 5, 7 and 8 by using spatial analyst tools of ArcGIS.

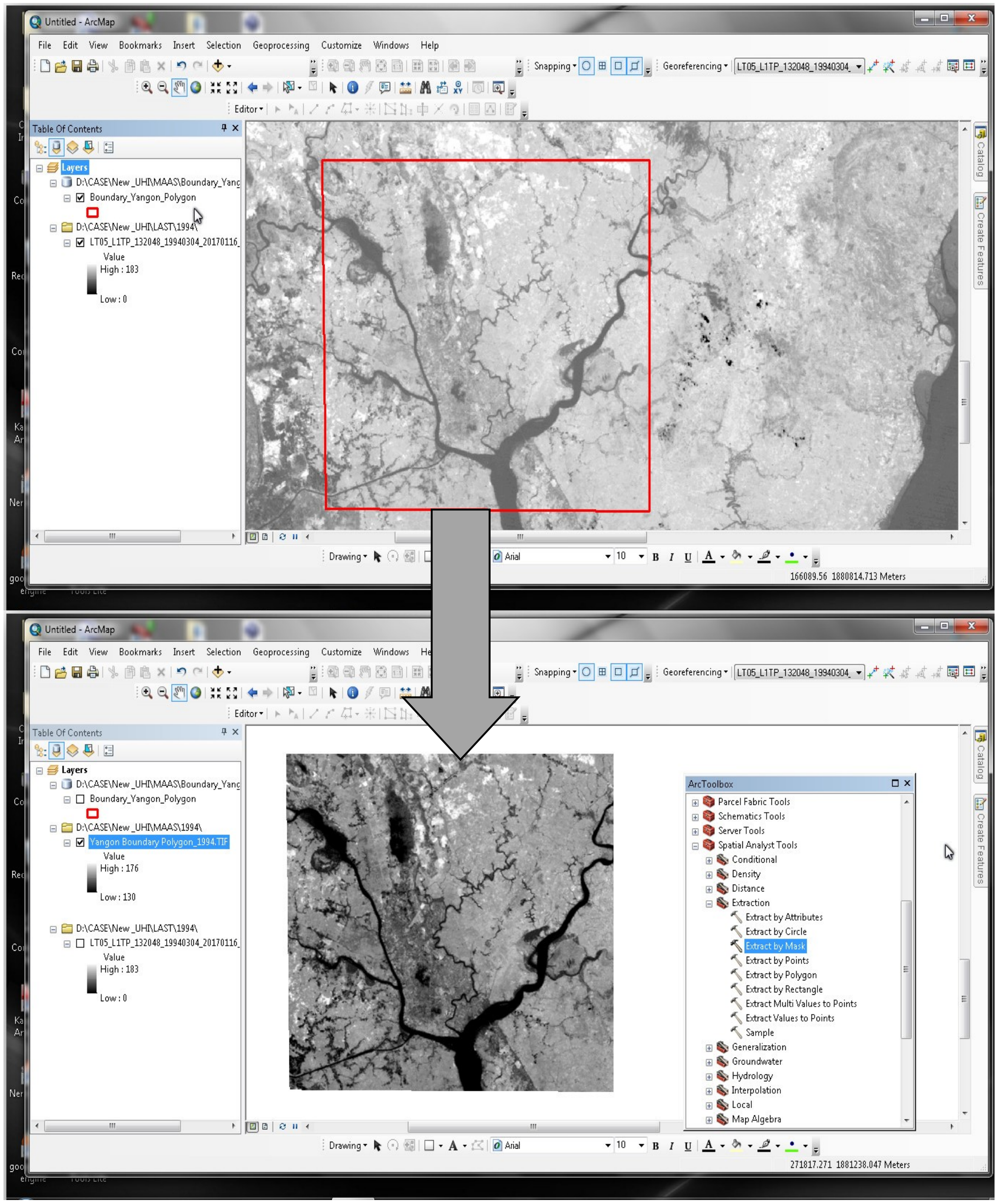


Figure 4. Window for Step 1, the extraction from raw image to study area.

After the first step, the extraction of same area extent from three satellite images under study, the different digital numbers of different images for study area are available. As a next step, the computation of TOA, at-satellite temperature in Kelvin, and changes to the temperature in Celsius is made by using Raster Calculator tool from the Map Algebra tool box of spatial analyst tool set (Step 2). It is shown by the following window of figure 5.

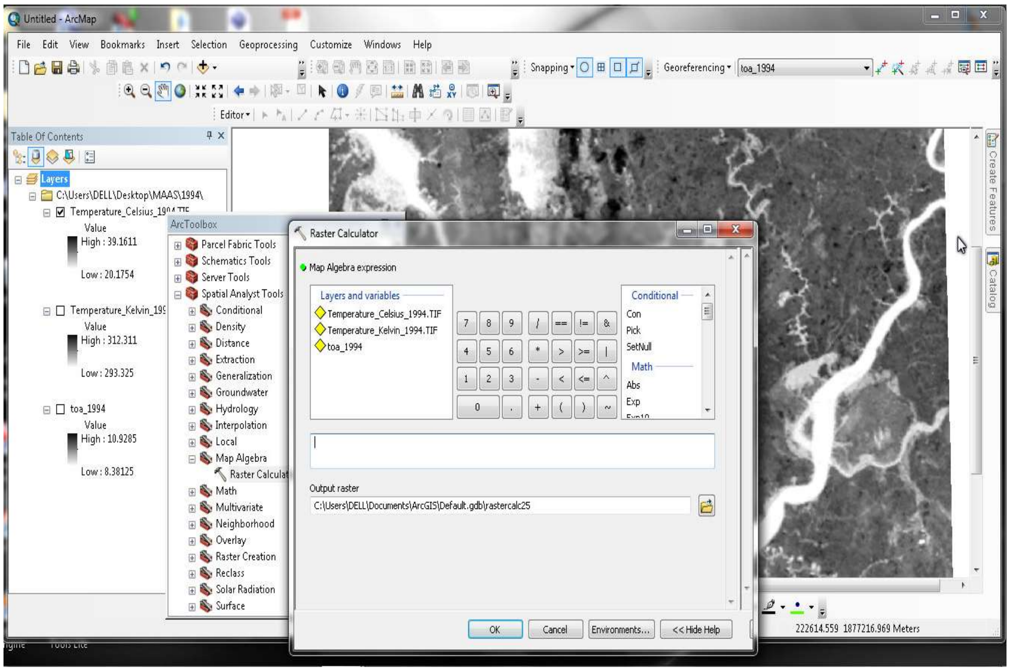


Figure 5. Window for Step 2, Raster calculator window and change from DNs to land surface temperatures

All of temperature values (LST) in Kelvin convert to LST in Celsius. After finishing the converting of DN values to land surface temperature LST) for 1994, 2003, and 2014 images, it is needed to specify the boundary of study area to get more precise data on temperature of study area. Therefore these images are clipped into boundary of YCDC area in Step 3. At the end of Step 3, processing the imagery, classifying, re classifying, analyzing, and evaluating the values of LST are conducted at Step 4 (Figure 6).

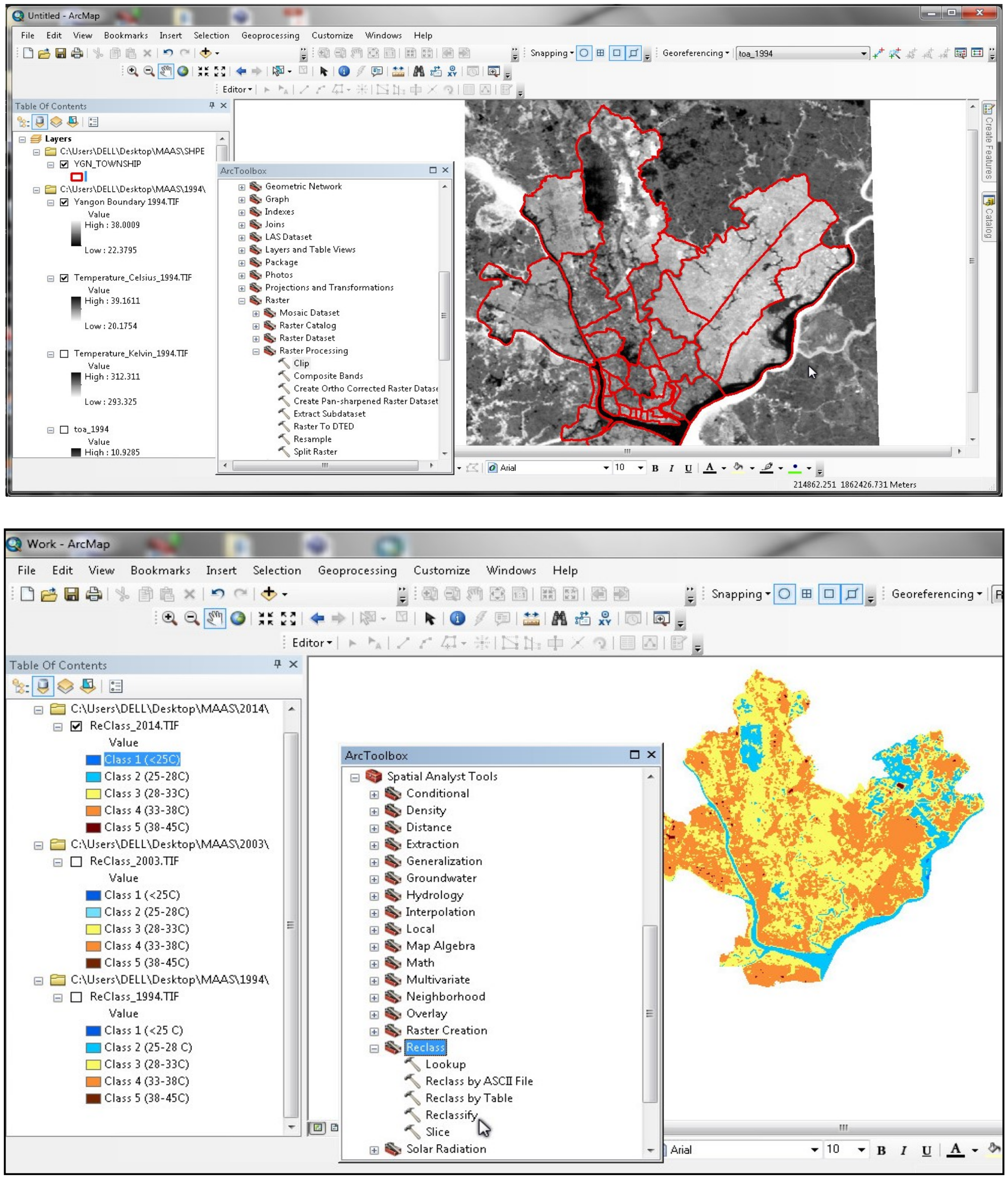


Figure 6. windows showing clip into YCDC boundary and Re-classifying and analyzing LST

Result and discussion

After completion of Step 3 and at the beginning of Step 4, LST surface form of study area can clearly be seen for 1994, 2003, and 2014. LST for these three periods are shown in table 2. In the whole study area, LST ranged from 22.4° C to 38.0° C in 1994, 22.3° C to 38.7° C in 2003, and 24.7° C to 44.1° C in 2014. Therefore LST variations in both form of spatial and temporal can clearly be examined.

Table 2. The LST results from selected landsat images of three periods

	1994 TM 5	**2003 ETM$^+$ 7**	**2014 LC 8**
Count	884893	884893	884893
Minimum	22.4° C	22.3° C	24.7° C
Maximum	38.0° C	38.7° C	44.1° C
Mean	29.6° C	30.4° C	32.1°C
SD	2.7° C	2.3° C	2.8° C

For the reliability of results, temperature data of the ground stations is used to compare these LST values. The following table 3 shows the LST of satellite data and station based observed data.

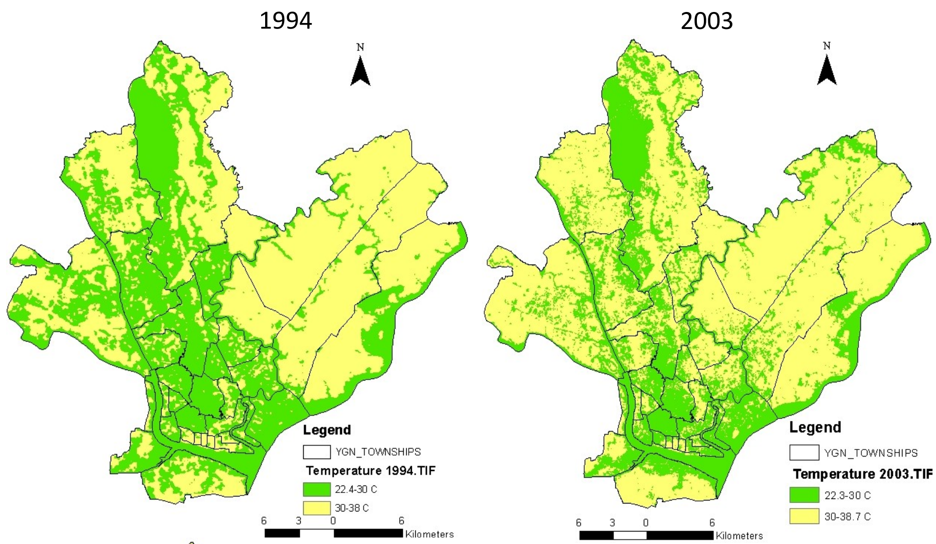
Table 3. LST from satellite data and recorded observed air temperature from Mingaladon

Mingaladon (North Latitude 16.9036°, East Longitude 96.1349°)			
Date	Station based Observed Data*		Satellite Data**
	Mini (06:30 a.m.)	Maxi (06:30 p.m.)	11:00 a.m.
4 March 1994	19.3° C	35.5° C	31.23° C
March 2003	20.9° C	36.5° C	33.12° C
March 2014	21.4° C	36.8° C	34.68° C

Data source: * are from DMH, Myanmar, ** is from calculated LST

06:30 a.m. and 06:30 p.m. are recorded time for observed data and 11:00 a.m. is saltllite passing time over study area. According to diurnal temperature cycle, the calculated LST are consistent with station based observed data.

According to the results in table 2, the mean values of LST become higher from 29.6° C in 1994 to 30.4° C in 2003 and 32.1° C in 2014. The standard deviation value between highest LST value and lowest LST value for the whole city is highest in 2014. It can be stated that LST of the area significantly increase throughout the study area over time. This is due to the increase in population, building density, concrete area and decrease of vegetation cover. In order to clear the spatial and temporal change of LST, the output LST images are classified into only two classes by using a threshold value of 30°C. The corresponding areas are also calculated. Hence below 30° C areas are classified as low temperature areas and above 30°C are classified as high temperature area. The area of low temperature in 1994 was 55.3% of total study area and it decreased to 34.4% in 2003 and to 20.5% in 2014. Therefore the area of high temperature was increased from 44.7% in 1994 to 79.5% in 2014. The area changes from low to high temperature can clearly be seen in figure 7.



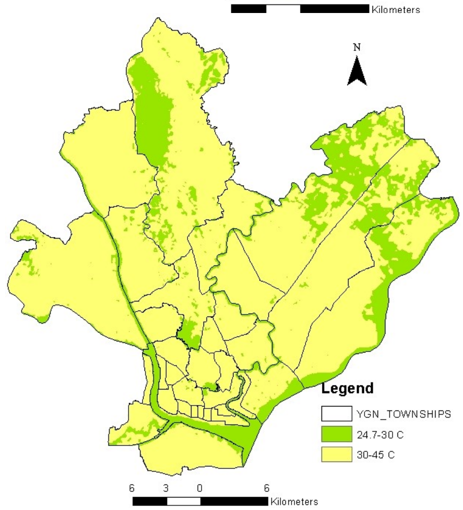


Table 4. percentage of total area under low LST value and high LST values in different time

	1994	2003	2014
Low area of LST	55.3%	34.4%	20.5%
High area of LST	44.7%	65.7%	79.5%

Figure 7. The low and high surface temperature area of Yangon City

This process coincides with settlement area expansion and landuse change of YCDC. The Yangon City area was faced with the remarkable development under the rule of State Law and Order Restoration Council (SLORC) during the two decades of study period. Most land area under cultivation also changes to residential plots and more roads are converted to concrete which are non-absorbing materials of sunlight and emit heat to the atmosphere. The increase number of vehicles and large trees removal of

Nagis, devastated storm of 2008, is also the contributors of the increase of LST in study area.

The output results of the LST are classified into 5 groups again from lowest to highest value of during study period, such as, Class 1- very low (< 25°C), Class 2- low (25°C - 28°C), Class3- moderate (28°C - 33°C), Class 4- high (33°C - 38°C), Class 5- very high (38C° - 45°C). ArcGIS was used to classify the raster layer into these classes and each class of spatial extent is also calculated and these are presented in figure 8.

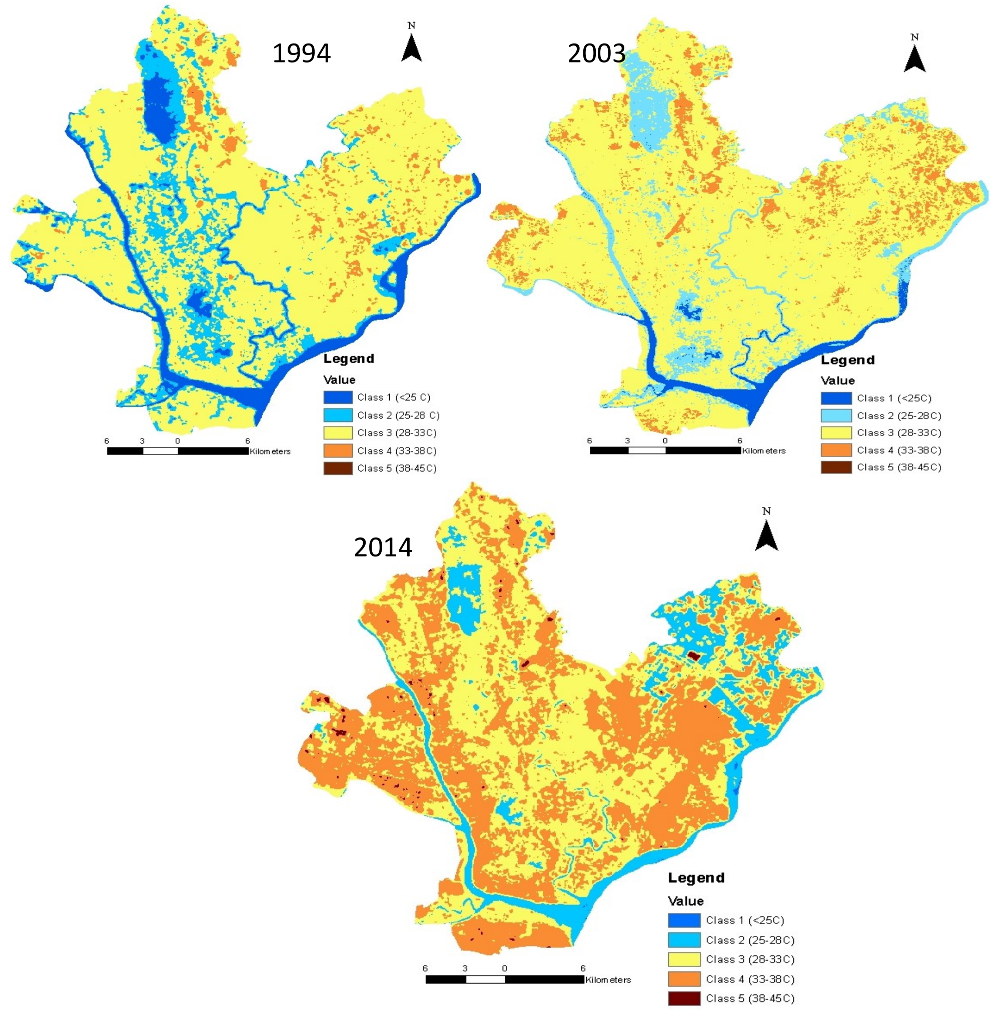


Figure 8. Spatial variations in land surface temperature of Yangon City

In 1994, the area under Class 1 was 8.7% of total area but it was nearly absent in 2014. The area under Class 2 was also decreasing from 16.2% in 1994 to 11.5 % of total area in 2014. Although the area under Class 3 was increased from 1994 to 2003, from 70.7% to 76.3% of total area, it decreased to 45.4% in 2014. This is due to significant increase in Class 4. Therefore, the relatively moderate to high surface temperature area of Yangon City is increasing during the last two decades (Figure 9 and Table 5).

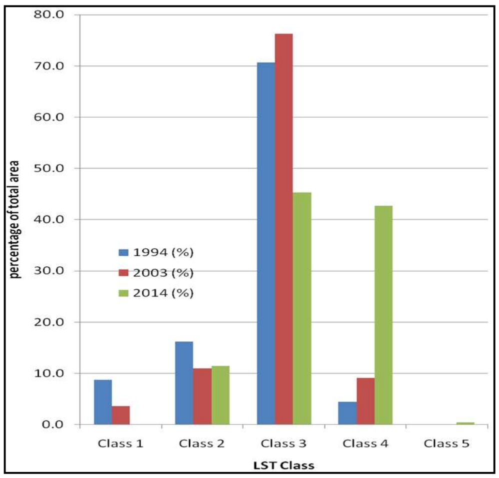
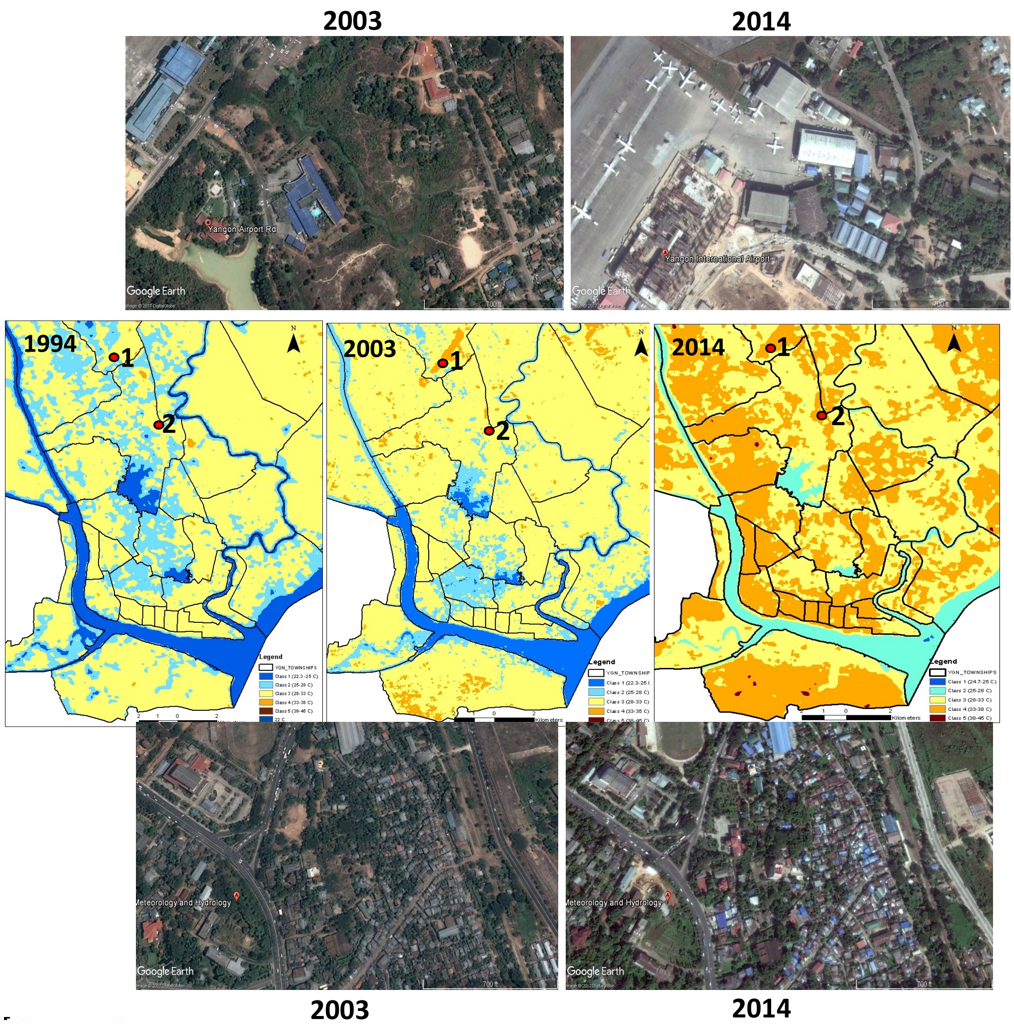


Figure 9. Graph showing the LST in different period

Table 5. Percentage of total area of land under different class of LST

Year	1994(%)	2003(%)	2014 (%)
Class 1	8.7	3.6	0.1
Class 2	16.2	11.0	11.5
Class 3	70.7	76.3	45.3
Class 4	4.4	9.1	42.7
Class 5	0.0	0.0	0.4

Where are these changes and why do they change? It is the most important question need to be answered. The LST changes can be seen especially on water surface area, downtown area, the areas of Dagon Myothit area, Thanlyin, Seikkyi Khanaungto. The example of significant change in part of the area under study is shown in figure 10. The figure clearly shows the increasing changes of LST of from one class to another during the period from 1994 to 2014. These changes are mainly due to the landuse changes especially to dense, tall, and concrete buildings. The changing landuse and the processes under these changes are interesting to do further study.



Note: 1- Mingaladon Weather Station on map
2- DMH, Kaba-Aye Weather Station

The upper images are the surrounding area view of Mingaladon weather station from 2003 and 2014 Google earth images and the lower images are the surrounding area view of Kaba-Aye weather station from 2003 and 2014 Google earth images

Figure 10. The LST changes in part of Yangon City from 1994 to 2014

Conclusion

Temperatures are retrieved from landsat images to analyze the changes of temperature distributions for the past 20 years. The results in the study suggest that the spatial temperatures are High buildings densities result large LST effect and uneven distribution of surface materials create the variation in LST. The temperature variations may be attributable to greater absorbency of man-made materials. Landsat satellite is one of the longest running programs for global change research and has been applied for agriculture, geology, regional planning and urban environment.

It has been observed that the surface temperature is higher in urban areas than vegetation and water body areas, because of lower contributions of evaporation and transpiration in non-vegetation areas. It is noted that occasionally vegetation areas might show higher temperature when the area is covered with relatively shorter plants such as shrubs or dried paddy fields. This increase of high temperature area is posing a serious threat to the urban thermal environment. Because of this heating with high temperature may cause discomfort to the city dwellers. Consumption of energy for artificial cooling of buildings and other work places will increase enormously. These high temperature urban heat islands may cause increase in death rate of old age people due to heat waves. Towards a solution the city planners must take into account the loss of green cover and propose social forestry and other community greenery development to mitigate the development of high temperatures. This study can clearly show the usefulness of remotely sensed thermal infrared (TIR) data in retrieving land surface temperature (LST) that can make the estimation of land surface temperature variation for both temporal and spatial, and the detection of area of high and low temperatures over a given area.

Acknowledgement

I would like to acknowledge my gratitude to express my special thanks to Dr. Kay thwe Hlaing, Professor, Department of Geography, YU, for her guideline to download the satellite images from USGS website for this paper. I would like to thank my Professor Dr. May Myat Thu, Head of Department of Geography, Pathein University, for his kind permission to carry out this study. Last but not least, I am greatly indebted to U Zaw Win, MIMU, for his solutions of my difficulties.

References

Dash, P., Gottsche, F. -M., Olesen, F. -S., & Fischer, H. (2002). Land surface temperature and emissivity estimation from passive sensor data: Theory and practice—current trends. International Journal of Remote Sensing, 23(13), 2563–2594.

Issue 3, Volume 2, ISSN: 2349-2163.

J. S.Yang, Y. Q.Wang and P. V. August (2004), Estimation of Land Surface Temperature Using Spatial Interpolation and Satellite-Derived Surface Emissivity, Journal of Environmental Informatics 4 (1) 37-44

K. Sundara Kumar1, Bontha. Amar Deepak, Arneepalli. Chaitanya Kumar ,Chandrala. Mounik Tekumudi. Venkata Prasad (2015)Study on Urban Surface Temperature Changes of Vijayawada City Using Remote Sensing and GIS International Journal of Innovative Research in Advanced Engineering (IJIRAE)

Khine Moe Nyunt (2013). Interaction of Land and man in Yangon City, Unpublished research paper, Zoning & Land use Sector, Urban Planning Division, City Planning & Land Administration Department, YCDC.

Qihao Weng, Dengsheng Lu, Jacquelyn Schubring (2004), Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies, Remote Sensing of Environment 89 (2004) 467–483.

Xiao_ling Chen, Hong-Mei Zhao, Ping-Xiang Li, Zhi-Yong Yin (2006) Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes Remote Sensing of Environment 104 (2006) 133–146, Elsevier.