JURNAL geografi

https://jurnal.unimed.ac.id/2012/index.php/geo/article/view/37183
https://doi.org/10.24114/jg.v15i1.37183 - (Vol 15, No 1 - 2023)
available at http://jurnal.unimed.ac.id/2012/index.php/geo
e-issn (2549-7057) & p-issn (2085-8167)

Spatiotemporal Analysis of Land Surface Temperature in Tainan City by using Landsat 5 & Landsat 8

Riki Rahmad*, Zhiyu Gong, Zhaohui Yang, Meijun Guo

Department of Civil Engineering, National Taipei University of Technology, Taipei City, Taiwan

ARTICLE INFO

Article History:
Received: July 25, 2022
Revision: September 07, 2022
Accepted: September 07, 2022

Keywords:
Land Surface Temperature (LST)
Landsat 5
Landsat 8
Tainan City
GIS

Corresponding Author
E-mail: t109429404@ntut.org.tw

ABSTRACT

Taiwan is a subtropic-tropic island with densely populated in the coastal plains surrounding its mountains. In recent years, due to global warming and the urban heat island effect, the surface temperature has continued to rise, and the seasonal temperature changes are also very different. Increased surface temperatures, particularly in cities, are a major environmental issue that intensifies urban heat islands (UHIs). Decadal time-series analysis has historically relied on meteorological data. Due to the limited availability of remote sensing technology, decadal analysis of land surface temperature has been a serious concern. However, according to advanced technologies in remote sensing methods and sophisticated GIS software, Land Surface Temperature (LST) now can be estimated using thermal bands. The objective of this study is to monitor the spatiotemporal changes of the land surface temperature using Landsat 5 and Landsat 8. Tainan city, which is a highly developed city in southern Taiwan, is selected as the research area. The changes in the land surface temperature are assessed between the years 2007 and 2021. It simply requires applying a set of equations through a raster image calculator using ArcGIS. The LST of any Landsat satellite image can be retrieved by following steps: 1) Top of Atmospheric Spectral Radiance; 2) Conversion of Radiance to At-Sensor Temperature; 3) Calculating NDVI; 4) Calculating the Proportion of Vegetation; 5) Determination of ground emissivity, and 6) Calculating Land Surface Temperature. Near Infra-red are used to obtain Normalized Different Vegetation Index (NDVI). The results show that the average surface temperature of Tainan City increased slightly by 1.1 0C. The most significant increase in temperature was in the northern region of Tainan City which was the agricultural area that was in the post-harvest period.

INTRODUCTION

Land surface temperature (LST) is described as the temperature felt while touching the land surface with one's hands or the ground's skin temperature (Avdan & Jovanovska, 2016). Land surface temperature (LST) is essential for all interactions and energy transfers between the atmosphere and the land surface (Cheng et al., 2021). On regional and global scales, it is a critical parameter in models of surface radiation budgets, energy balances, and water cycle. LST may currently be estimated by field measurements, remote sensing, and land surface modeling. Due to the scarce distribution of ground measurement sites and the inaccuracy of model simulations, it is practically difficult to monitor LST efficiently with spatiotemporal continuity; remote sensing is an indispensable method for obtaining LST at the global and regional scales. In comparison to traditional field research, remote sensing provides various advantages, including lower costs, greater size, and the ability to see remote areas (Lees et al., 2018; Esha & Rahman, 2021).

Thermal infrared data from satellites that look at the Earth is often used to look at how Land Surface Temperature (LST) changes over time and space. This data can be used to look at how LST changes globally, regionally, and locally. (Schuch et al., 2017) examined the relationship between air temperatures observed at ground weather stations and approximated land surface temperature using thermal infrared remote sensing data. They examined the relationship between air temperatures observed at ground weather stations and estimated ground surface temperatures from remotely sensed thermal infrared data. They discovered that the correlation was the most accurate, allowing future studies to get air temperature readings without the use of ground stations.

The Landsat series satellites have collected an extensive data collection covering more than four decades. The Landsat series' long-term high spatial resolution thermal infrared images are an excellent source of data for constructing long-term high spatial resolution LST records (Taripanah & Ranjbar, 2021; Abir et al., 2021). However, prior to the development of LST recovery techniques for Landsat Thematic Mapper (TM) data (Sobrino et al., 2004), Landsat TIR data were mostly ignored. Landsat 5 TM and Landsat 8 OLI thermal infrared data with spatial resolutions of 120 and 100 m, respectively, have been used to conduct investigations of Land Surface Temperature (LST) at the local and regional scale (Azmi et al., 2021; Al-Jbouri & Al-Timimi, 2021; Guha et al., 2018). Numerous techniques for retrieving LST from Landsat data have been developed, including the mono-window algorithm proposed by (Qin et al., 2001) and the single-channel algorithm proposed by (Sobrino et al., 2004).

There are a lot of studies use single channel algorithms to study Land Surface Temperature. To get LST from a single infrared channel, additional data such as the surface emissivity and temperature/water vapor profile are required (Giannini et al., 2015). The first can be produced from a classification image in which an emissivity value for each class is assumed, however this approach is restricted due to the requirement of a comprehensive understanding of the research area and emissivity. Other techniques, such as those based on the NDVI (Normalized Difference Vegetation Index), can be used to define surface emissivity (Nse et al., 2020; Richard & Abah, 2019; Kaviani et al., 2013). Land Surface Emissivity (LSE) is a key parameter for researching land surface processes and calculating the radiation budget. LSE is a material feature that can be used to determine the type of land cover and natural resource mapping, as well as a crucial variable in calculating LST from remote sensing data (Saradjian & Jouybari-Moghaddam, 2019).

Taiwan's main island, which is located in central East Asia off the coast of mainland China and has a total land area of 35,960 km^2, has shown a significant increase in air pollution emissions over the past few decades, despite the island's relatively small size. Taiwan has likewise had exceptional economic growth in the last four decades, comparable to that of the rest of the world. From 1910 to 2005, the warming at night in three major urban centers was high enough to have a considerable impact on Taiwan's average temperature trend (Shiu et al., 2009). (Chen et al., 2021) show in their research that extreme temperature occurrences have become more frequent and more intense in Taiwan in recent decades as a result of climate change, consistent with global patterns. (Hsu & Chen, 2002) hypothesized that the higher temperature increased over Taiwan than the global average could be caused by variations in the global large-scale circulation.

The objective of this study is to monitor the spatiotemporal changes of land surface temperature using Landsat 5 and Landsat 8. Tainan city, which is a highly developed city in southern Taiwan, is selected as the research area because based on the results of the research by (Tsai et al., 2016) shows a slight increasing tendency of NDVI in Tainan area and expresses increasing temperature trends over the period 1982–2012. The changes in the land surface temperature are assessed between the years 2007 and 2021. The land surface temperature in the study area is calculated by semi-empirical method where the surface emissivity is obtained based on the classification of the Normalized Difference Vegetation Index (NDVI) value.

RESEARCH METHODS

Study Area and Datasets

Tainan City is one of the 6 special municipalities in Taiwan. Tainan has an area of 2,191 km^2 with a population of 1.8 million, making it one of the most densely populated areas in southern Taiwan. The urban center area is in the southern region. Satellite towns spread across the region in a radial pattern from the city center. In the north, stretches the agricultural area which is one of the important agricultural centers in Taiwan. Tainan has a warm humid subtropical climate with mild, dry winters and hot, humid summers. The eastern part is a mountainous area and has colder temperatures compared to other areas. Beyond the south of the city, the climate transitions from subtropical to tropical.

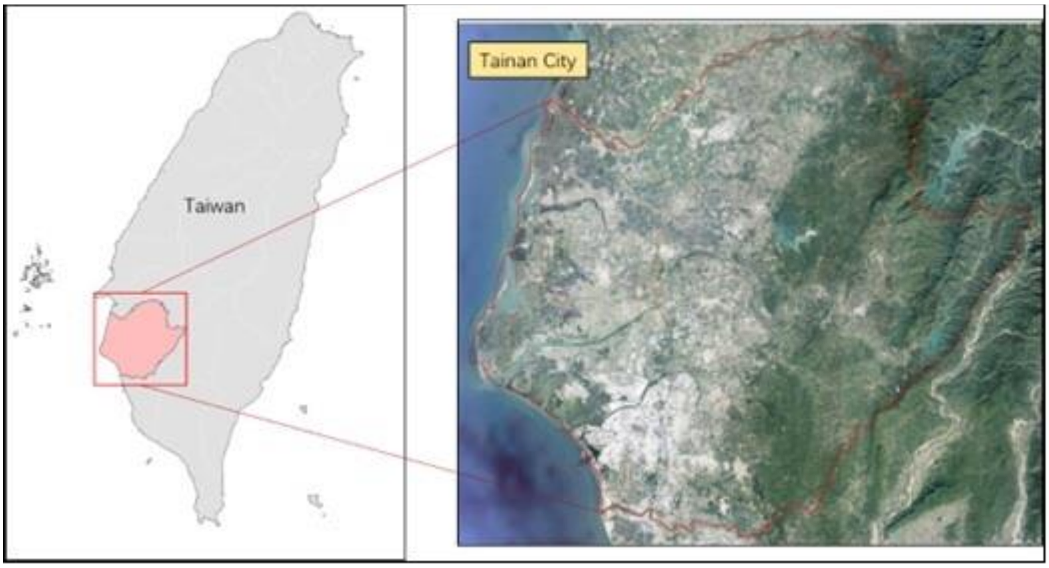


Figure 1. The Study Area

This study uses Landsat-5 TM and Landsat-8 OLI/TIRS data to monitor spatiotemporal changes in land surface temperature in Tainan City for 2007 and 2021. 2007 LST data obtained from Landsat-5 TM acquisition date March 9, 2007 (Path 118/ Row 044) with the criteria of cloud cover less than 1% above the land. LST data for 2021 is obtained from Landsat-8 OLI/TIRS acquisition date March 12, 2021, with the same path and row with cloud cover which is also less than 1%. These two level-1 Landsat images have been used as the representatives of same weather condition. The Landsat datasets have been freely downloaded from United States Geological Survey (http://earthexplorer.USGS.gov). Landsat-5 TM data has one band (Band 6) and Landsat 8 TIRS data has two bands (Band 10 and Band 11) having thermal characteristics. But only TIR Band 10 data has been used for the LST retrieval process because TIR band 11 data face some calibration uncertainty. Land surface temperature data processing in this study using Geographic Information System analysis. Some of the ArcGIS tools used include Raster Calculator, Get Raster Properties, Extract by Mask, Stack Profiles, and Reclassify.

Land Surface Temperature retrieval

Conversion of Digital Number (DN) to TOA Spectral Radiance

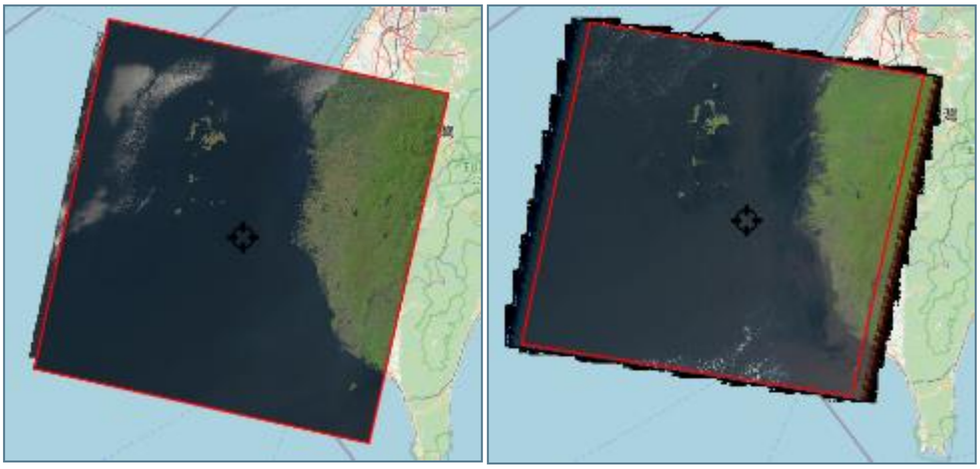
In the first step of Land Surface Temperature (LST), the digital number of Landsat-5 and Landsat-8 images are converted into spectral radiance by using Eq. 1 and Eq. 2, respectively.

$$L\lambda = \left(\frac{Lmax_\lambda - Lmin_\lambda}{Qcal_{max} - Qcal_{min}}\right) * (Qcal - Qcal_{min}) + Lmin_\lambda \quad (1)$$

Where:
$L\lambda$ = TOA spectral radiance (Watts/(m^2*sr*µm))
Qcal = Quantized calibrated pixel value in DN
$Lmax_\lambda$ = Spectral radiance scaled to $Qcal_{max}$
$Lmin_\lambda$ = Spectral radiance scaled to $Qcal_{min}$
$Qcal_{max}$ = Max quantized calibrated pixel value in DN
$Qcal_{min}$ = Min quantized calibrated pixel value in DN

$$L\lambda = ML * Qcal + AL \quad (2)$$

Where:
$L\lambda$ = TOA spectral radiance (Watts/(m^2*sr*µm))
ML = band-specific multiplicative rescaling factor
AL = band-specific additive rescaling factor
Qcal = Quantized and calibrated standard product pixel values (DN)



(a) **(b)**

Figure 2. (a) Landsat 5 scene acquisition date 9 March 2007; (b) Landsat 8 scene acquisition date 12 March 2021

Conversion of Radiance to TOA Brightness Temperature

Spectral radiance data can be converted to TOA brightness temperature using thermal constant values in metadata file.

$$BT = \frac{K2}{\ln\left(\frac{K1}{L\lambda}+1\right)} - 273.15 \quad (3)$$

Where:
BT = TOA Brightness Temperature (°C)
$L\lambda$ = TOA spectral radiance (Watts/(m^2*sr*µm))
K1 = Calibration constant 1
K2 = Calibration constant 2

Calculation of Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a standardized vegetation index which calculated using Near Infra-Red and Red bands.

$$NDVI = (NIR - RED)/(NIR + RED) \tag{4}$$

Where:
NIR = DN values from Near Infra-Red band
RED = DN values from the RED band

Bands 3 and 4 are the red and near-infrared band, respectively for Landsat-5 ETM+ imageries; and bands 4 and 5 for Landsat-8 OLI were utilized for NDVI calculation.

Calculation of Proportion of Vegetation (Pv)

The proportion of vegetation is defined as the ratio of the vertical projection area of vegetation (which includes leaves, stalks, and branches) on the ground to the total vegetation area (Neinavaz et al., 2020). With respect to Earth surface processes and biodiversity monitoring, climate model- ling and numerical weather prediction models all involving vegetation biophysics, PV is an essential quantity. Based on the NDVI value, the proportion of vegetation or fractional vegetation cover can be determined by Eq 5.

$$P_V = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2 \tag{5}$$

Where:
P_V = proportion of vegetation
NDVI = Normalized Difference Vegetation Index
$NDVI_{min}$ = minimum value of NDVI
$NDVI_{max}$ = maximum value of NDVI

Calculation of Land Surface Emissivity

Land surface emissivity is the average emissivity of an element of the surface of the earth calculated from NDVI value.

$$\varepsilon = 0.004 * P_V + 0.986 \tag{6}$$

Where:
ε = land surface emissivity
P_V = proportion of vegetation

Calculation of Land Surface Temperature (LST)

The Land Surface Temperature (LST) is the radiative temperature which is calculated using TOA brightness temperature, wavelength of emitted radiance, and land surface emissivity.

$$LST = \left(\frac{BT}{1}\right) + W * \left(\frac{BT}{14380}\right) * \ln(\varepsilon) \tag{7}$$

Where:
LST = Land surface temperature (°C)
BT = TOA brightness temperature (°C)
W = wavelength of emitted radiance
ε = land surface emissivity

RESULTS AND DISCUSSION

The transformation of Landsat images into Land Surface Temperature (LST) maps in this study uses Geographic Information System analysis. To implement the analysis of LST in a GIS environment, a new workflow has been developed with the ArcGIS Model Builder. ArcGIS ModelBuilder is an easy-to-use application for creating and running workflows containing a sequence of tools. ModelBuilder in ArcGIS allows us to build a model by adding and connecting data and tools, iteratively process every feature class, raster, file, or table in a workspace, visualize workflow sequence as an easy-to-understand diagram, run a model step by step, up to a selected step, or run the entire model, as well as make our model into a geoprocessing tool that can be shared or can be used in Python scripting and other models.

Image transformation in raster format is generally divided into two parts. First, thermal image processing of Band 6 on Landsat-5 and Band 10 on Landsat-8 for the transformation of Digital Number (DN) into spectral radiance, and spectral radiance into brightness temperature. Second, image processing of Near Infra-Red and Red channels (Band 4 & Band 3 on Landsat-5 and Band 5 & Band 4 on Landsat-8, respectively) for transformation of Digital Number (DN) values into Normalized Difference Vegetation Index (NDVI) values, conversion of the proportion of vegetation value based on the maximum and minimum NDVI values, to then be converted into land surface emissivity values. The Land Surface Temperature (LST) value is obtained from the calculation of the brightness temperature and emissivity values. LST ModelBuilder in this study can be seen in Figure 3.

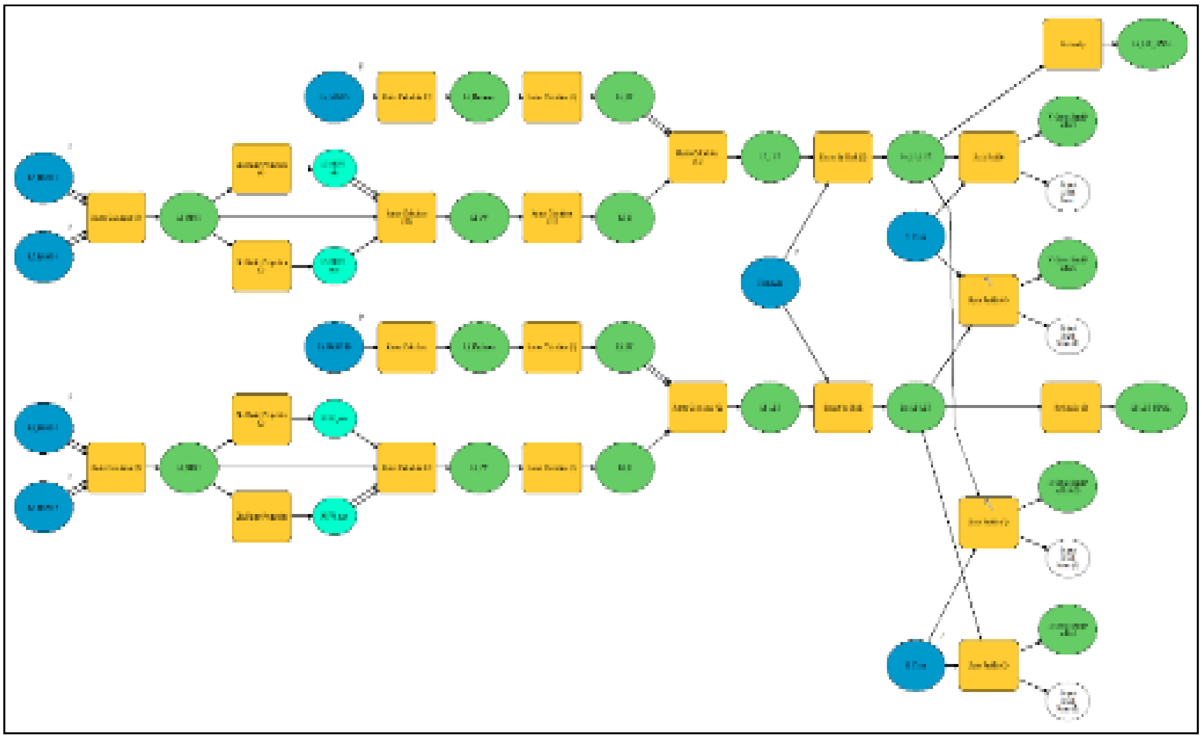
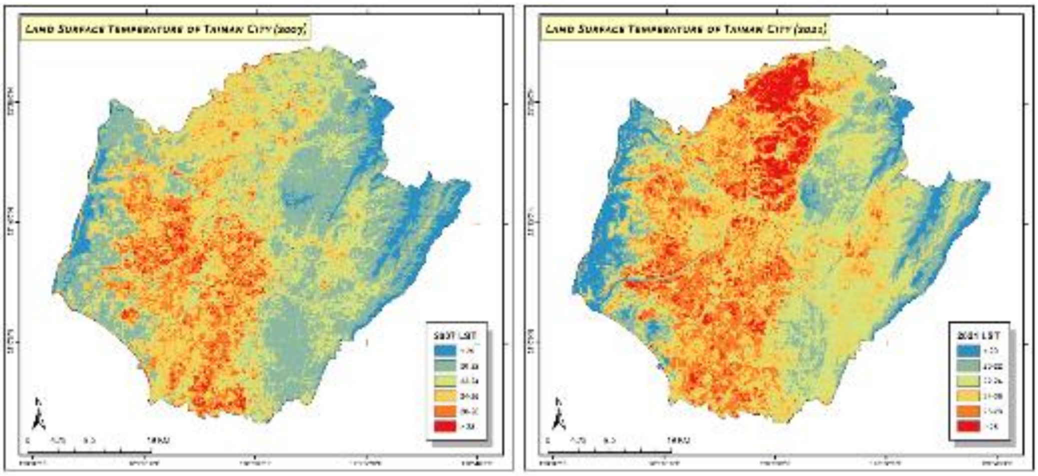


Figure 3. Land Surface Temperature (LST) ArcGIS Model Builder

The result shows that the range of land surface temperature varies from 10.8 °C to 31.7 °C in 2007 and 12.6 °C to 33.3 °C in 2021. The data is then reclassified into 6 classes of temperature ranges, including < 20, 20 °C to 22 °C, 22 °C to 24 °C, 24 °C to 26 °C, 26 °C to 28 °C, and > 28 °C. Land Surface Temperature (LST) map and table for 2007 and 2021 can be seen in Figure 4 and Table 1.



(a) (b)

Figure 4. (a) 2007 LST; (b) 2021 LST

The results of the analysis of the land surface temperature in Tainan City in 2007 showed that the average surface temperature was 23^{0}C, with a minimum temperature of 10.8^{0}C and a maximum temperature of 31.7^{0}C. Based on the temperature class categories that have been analyzed (see table 1), it is known that most of Tainan city area was within the 20-22^{0}C temperature class with an area of 716.92 km^2 or 31.67% of the total area. This can be seen in Figure 4a, the spatial distribution of this temperature class is spread in almost all regions, especially in the eastern part which is an agricultural and forest area and has a higher elevation than the western region.

Furthermore, the urban area was within the temperature class 26-28 ^{0}C and >28 ^{0}C with an area of almost 300 km^2 spread in the south and spreads to the north of Tainan City. The lowest temperature class within the temperature class less than 20 ^{0}C is spread in the easternmost part which is a high-elevation forest and the western part which is a water area along the coastline. This temperature class has an area of 145.97 km^2 or 6.49% of the total area.

The results of the Land Surface Temperature analysis in Tainan City in 2021 show that the average surface temperature was 24.1 ^{0}C, with minimum temperature of 12.6^{0}C and maximum temperature of 33.3 ^{0}C. Based on the temperature class category for 2021, it is known that most of Tainan city area was within the 22-24 ^{0}C temperature class, which covers 633.49 km^2 or 27.99% of the total area.

As seen in Figure 4b, the spatial distribution of this temperature class was dominantly distributed in the eastern part of Tainan City. After this class, the temperature class with the largest area was followed by the temperature class 22-24 ^{0}C with an area of 585.29 km^2 or 25.86% of the total area. The temperature class higher than 28 ^{0}C covers 6. 25% of the total area or 141.49 km^2. This class was the class with the smallest area in the northern part which is an agricultural area.

Table 1. Land Surface Temperature (LST) classes of Tainan City

Temperature (°C)	2007			2021			Difference	
	Grids	Areas (km²)	Areas (%)	Grids	Areas (km²)	Areas (%)	Areas (km²)	Areas (%)
< 20	163297	147.0	6.5%	169874	152.9	6.8%	5.9	0.3%
20-22	796582	716.9	31.7%	369432	332.5	14.7%	-384.4	-17.0%
22-24	717817	646.0	28.5%	703878	633.5	28.0%	-12.5	-0.6%
24-26	512565	461.3	20.4%	650318	585.3	25.9%	124.0	5.5%
26-28	281144	253.0	11.2%	464450	418.0	18.5%	165.0	7.3%
>28	43758	39.4	1.7%	157211	141.5	6.3%	102.1	4.5%

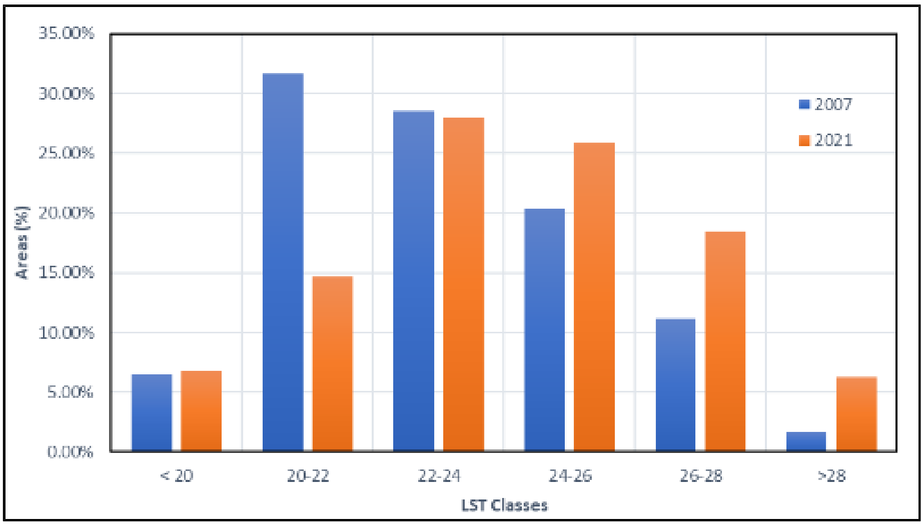


Figure 5. Land Surface Temperature (LST) classes of Tainan City

Based on Land Surface Temperature (LST) data for 2007 and 2021, in general, the average surface temperature of Tainan City increased slightly by 1.1 ^{0}C from 23.0 ^{0}C to 24.1 ^{0}C. Furthermore, over a period of 14 years, the minimum and maximum land surface temperatures have also increased by 1.8 ^{0}C and 1.6 ^{0}C, respectively. Judging from Table 1 and Figure 5, there was a change in the area of the temperature class 20-22 ^{0}C by 16.98% of the total area or 384.44 km^2, from originally covered 31.67% changed to only 14.69%. This makes this class no longer a temperature class with the most dominant area.

In 2021, the temperature class with the most dominant area has increased to a temperature class of 22-24 ^{0}C. As seen from Figure 4b, the most significant increase in temperature is in the northern region of Tainan City which is the agricultural area. This increase exceeds the average temperature in urban areas. To see further the causes of this change, we compared the 2021 Land Surface Temperature (LST) with composite true color image and NDVI (vegetation density class) to see the actual land use in 2021. From Figure 6, it can be concluded that the northern area that experienced a significant increase was an agricultural area that was in the period of post-harvest. This vacant land absorbs and reflects heat at a higher rate than during other cultivation times. This can be seen in the NDVI class, where the northern region has less vegetation density than the eastern region which is also an agricultural area.

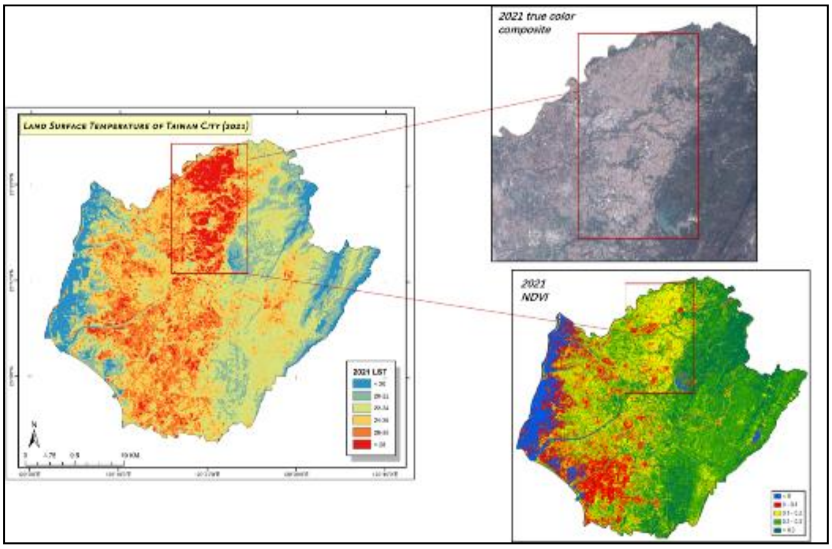
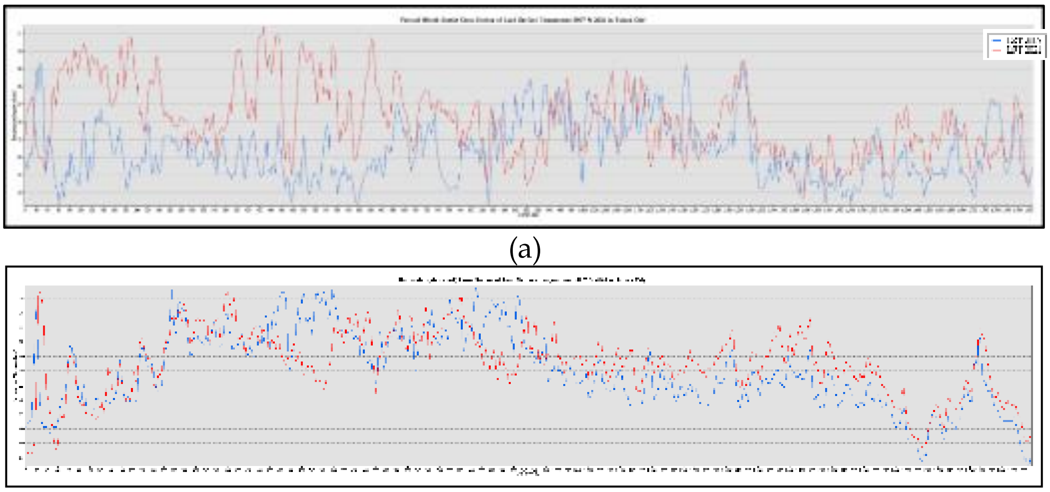


Figure 6. 2021 Land Surface Temperature (LST)



(a)

(b)

Figure 7. (a) Vertical (North-South) Cross-section of 2007 & 2021 LST; (b) Horizontal (West-East) Cross-section of 2007 & 2021 LST

We have also displayed a vertical cross-section profile (north to south) and horizontal cross-section (east to north) which can be seen in Figure 7. Based on figure 7a, a significant increase in land surface temperature occurred in the northern region, while in figure 7b slightly increased in the eastern region. This result in line with (Abdulmana et al., 2021) research finding that a significant increasing in surface temperature and tremendous vegetation loss were observed at high elevations in the southern regions of the Central Mountain Range in Taiwan. Overall, it can be concluded that the increase in land surface temperature (LST) in Tainan City occurred in the northern and eastern regions.

CONCLUSION

By applying a set of equations through a raster image calculator using ArcGIS, The LST of any Landsat satellite images can be retrieved by following steps: 1) TOA Spectral Radiance; 2) Conversion of Radiance to At-Sensor Temperature; 3) Calculating NDVI; 4) Calculating the proportion of Vegetation; 5) Determination of ground emissivity; and 6) Calculating Land Surface Temperature. The range of land surface temperature varies from 10.8 °C to 31.7 °C in 2007 and 12.6 °C to 33.3 °C in 2021. The mean LST has been increased from 23 °C to 24.1 °C during 2007 to 2021. The LST maps clearly show that the warmest regions lie in and near the urban areas in the southern part (2007) and have expanded in spatial extent to northern part in 2021. ArcGIS ModelBuilder can be easily built up to run complex processing. Ground check of temperature will be needed to assess the accuracy of LST estimation.

REFERENCE LIST

Abdulmana, S., Lim, A., Wongsai, S., & Wongsai, N. (2021). Land surface temperature and vegetation cover changes and their relationships in Taiwan from 2000 to 2020. *Remote Sensing Applications: Society and Environment, 24*, 100636. https://doi.org/10.1016/j.rsase.2021.100636

Abir, F. A., Ahmmed, S., Sarker, S. H., & Fahim, A. U. (2021). Thermal and ecological assessment based on land surface temperature and quantifying multivariate controlling factors in Bogura, Bangladesh. *Heliyon, 7*(9), e08012. https://doi.org/10.1016/j.heliyon.2021.e08012

Al-Jbouri, S. Q., & Al-Timimi, Y. K. (2021). Assessment of Relationship Between Land Surface Temperature and Normalized Different Vegetation Index Using Landsat Images in Some Regions of Diyala Governorate. *The Iraqi Journal of*

Agricultural Science, 52(4), 793-801.

Avdan, U., & Jovanovska, G. (2016). Algorithm for automated mapping of land surface temperature using LANDSAT 8 satellite data. *Journal of Sensors,* 2016. https://doi.org/10.1155/2016/1480307

Azmi, R., Koumetio, C. S. T., Diop, E. B., & Chenal, J. (2021). Exploring the relationship between urban form and land surface temperature (LST) in a semi-arid region case study of Ben Guerir city - Morocco. *Environmental Challenges*, *5*, 100229. https://doi.org/10.1016/j.envc.2021.100229

Chen, C. C., Wang, Y. R., Wang, Y. C., Lin, S. L., Chen, C. T., Lu, M. M., & Guo, Y. L. L. (2021). Projection of future temperature extremes, related mortality, and adaptation due to climate and population changes in Taiwan. *Science of the Total Environment*, *760*, 143373. https://doi.org/10.1016/j.scitotenv.2020.143373

Cheng, J., Meng, X., Dong, S., & Liang, S. (2021). Generating the 30-m land surface temperature product over continental China and USA from landsat 5/7/8 data. *Science of Remote Sensing*, *4*, 100032. https://doi.org/10.1016/j.srs.2021.100032

Esha, E. J., & Rahman, M. T. U. (2021). Simulation of future land surface temperature under the scenario of climate change using remote sensing & GIS techniques of northwestern Rajshahi district, Bangladesh. *Environmental Challenges*, *5*, 100365. https://doi.org/10.1016/j.envc.2021.100365

Giannini, M. B., Belfiore, O. R., Parente, C., & Santamaria, R. (2015). Land Surface Temperature from Landsat 5 TM images: Comparison of different methods using airborne thermal data. *Journal of Engineering Science and Technology Review*, *8*(3), 83–90. https://doi.org/10.25103/jestr.083.12

Guha, S., Govil, H., Dey, A., & Gill, N. (2018). Analytical study of land surface temperature with NDVI and NDBI using Landsat 8 OLI and TIRS data in Florence and Naples city, Italy. *European Journal of Remote Sensing*, *51*(1), 667-678. https://doi.org/10.1080/22797254.2018.1474494

Hsu, H. H., & Chen, C. T. (2002). Observed and projected climate change in Taiwan. *Meteorology and Atmospheric Physics*, *79*(1–2), 87–104. https://doi.org/10.1007/s703-002-8230-x

Kaviani, A., Sohrabi, T., & Araste, P. D. (2013). Estimation of land surface temperature using NDVI in MODIS and Landsat ETM+ imageries. *Journal of Agricultural Meteorology, 1*(1), 14-25.

Lees, K. J., Quaife, T., Artz, R. R. E., Khomik, M., & Clark, J. M. (2018). Potential for using remote sensing to estimate carbon fluxes across northern peatlands – A review. *Science of the Total Environment*, *615*, 857–874. https://doi.org/10.1016/j.scitotenv.2017.09.103

Neinavaz, E., Skidmore, A. K., & Darvishzadeh, R. (2020). Effects of prediction accuracy of the proportion of vegetation cover on land surface emissivity and temperature using the NDVI threshold method. *International Journal of Applied Earth Observation and Geoinformation*, *85*(October 2019), 101984. https://doi.org/10.1016/j.jag.2019.101984

Nse, O. U., Okolie, C. J., & Nse, V. O. (2020). Dynamics of land cover, land surface temperature and NDVI in Uyo City, Nigeria. *Scientific African*, *10*, e00599. https://doi.org/10.1016/j.sciaf.2020.e00599

Qin, Z., Karnieli, A., & Berliner, P. (2001). A mono-window algorithm for retrieving land surface temperature from Landsat TM data and its application to the Israel-Egypt border region. *International Journal of Remote Sensing*, *22*(18), 3719–3746. https://doi.org/10.1080/01431160010006971

Richard, J. U., & Abah, I. A. (2019). Derivation of Land Surface Temperature

(LST) From Landsat 7 \& 8 Imageries and Its Relationship With Two Vegetation Indices (NDVI and GNDVI). *International Journal of Research-Granthaalayah, 7*(2), 108-120. https://doi.org/10.29121/granthaalayah.v7.i2.2019.1013

Saradjian, M. R., &Jouybari-Moghaddam, Y. (2019). Land Surface Emissivity and temperature retrieval from Landsat-8 satellite data using Support Vector Regression and weighted least squares approach. *Remote Sensing Letters, 10*(5), 439-448. https://doi.org/10.1080/2150704X.2019.1569273

Schuch, F., Marpu, P., Masri, D., & Afshari, A. (2017). Estimation of Urban Air Temperature from a Rural Station Using Remotely Sensed Thermal Infrared Data. *Energy Procedia*, *143*, 519–525. https://doi.org/10.1016/j.egypro.2017.12.720

Shiu, C. J., Liu, S. C., & Chen, J. P. (2009). Diurnally asymmetric trends of temperature, humidity, and precipitation in Taiwan. *Journal of Climate*, *22*(21), 5635–5649. https://doi.org/10.1175/2009JCLI2514.1

Sobrino, J. A., Jiménez-Muñoz, J. C., & Paolini, L. (2004). Land surface temperature retrieval from LANDSAT TM 5. *Remote Sensing of Environment*, *90*(4), 434–440. https://doi.org/10.1016/j.rse.2004.02.003

Taripanah, F., & Ranjbar, A. (2021). Quantitative analysis of spatial distribution of land surface temperature (LST) in relation Ecohydrological, terrain and socio-economic factors based on Landsat data in mountainous area. *Advances in Space Research, 68*(9), 3622-3640. https://doi.org/10.1016/j.asr.2021.07.008

Tsai, H. P., Lin, Y. H., & Yang, M. D. (2016). Exploring long term spatial vegetation trends in Taiwan from AVHRR NDVI3g dataset using RDA and HCA analyses. *Remote Sensing*, *8*(4). https://doi.org/10.3390/rs8040290