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Analysis of biophysical interactions on Land Surface Temperature in Chon Buri Province

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Abstract The results showed that land surface temperature (LST) in Chon Buri Province increased an average of 1.36 ℃. Urban area increased to 4.95% at an average growth of 2.52% per year. It was related to LST over urban was at 23.19-33.19 ℃ in 2008 and increased to 29.87-34.35 ℃ in 2018. The agricultural area was reduced from 57.11% to 51.99% with a 0.9% reduction per year. In 2008, most of the area (52.73%) was found to be a medium land surface temperature of 26.01-29.86 ℃. In 2018, most of the area (81.21%) was recorded to be a high land surface temperature of 29.87-34.35 ℃. The biophysical interactions on land surface temperature was analysed and found that land surface temperature was a significant negative correlation with the vegetation index and water index. In addition, the land surface temperature, was shown to be a significant positive correlation with the built-up index, population density, and carbon dioxide. Finally, land use, LST, NDVI, NDWI, NDBI, CO_2, and population were identified with significant correlated interaction together which located in Mueang, Siracha, Bang Lamung, Phanat Nikhom, Bo Thong, Ban Bueng, Nong Yai District, Chon Buri Province.

Keywords: Land surface temperature, Land use, Biophysical interactions

Introduction

The climate change situation found that the global average temperature trend between 1850 – 2012 increased by 0.85 ℃. It causes to increase in heatwave phenomena in Europe, America, Australia and Asia. The numbers of rainy days and the frequency of heavy rainfall and sea level change are increased. Global ice mass change is declining. Snow melts due to rising temperatures and total global greenhouse gas emissions increased by 0.50% in 2014 if compared from 2013. Climate change and its impacts are wreaking havoc around the world. Thailand has ratified to join as a party to the Paris Agreement (National Reform Commission on Natural Resources and Environment, 2018). Thailand must cooperate in reducing the accumulation of greenhouse gases in the world's atmosphere and solving the problem of climate change impacts in Thailand. The main goals are to cover the implementation of

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energy industrial processes and product use, waste, and land use change from forestry and agriculture to urban and build-up areas (Office of the Council of State, 2020). Land use patterns changing with the expansion of urban communities have increased due to the growth of commerce, industry, expansion of transport networks, and household communities with increasing energy consumption, electrical appliances, amenities, and the lower volumes of agricultural and forest areas. It is causing urban temperatures to rise more than in other areas. This results in urban warming, where different land use characteristics are associated with different local surface temperatures. It can be used as an indicator of the trend of increasing surface temperature (Dontree and Choti Amornsak, 2009; Purkis and Klemas, 2011). This led to study of urban adaptation for climate change (Rhinane *et al.*, 2012). The city temperature tends to rise up in the development area in the Eastern Economic Corridor (EEC) of Thailand.

The development of Chachoengsao, Chon Buri, and Rayong provinces and other areas in the eastern region is systematic and consistent with the use of land appropriate to the conditions and potential of the areas. EEC has developed the infrastructure and utilities of the contiguous areas in the Eastern Special Development with Sustainable Development Principles (Government Gazette, 2018). Chon Buri Province is an important area to drive the economy and industrial sectors. Urban expansion, infrastructure, agricultural, tourism, and service sectors have restructured the economic growth that has been driven by technology and innovation (New Engine of Growth) as well as the large demands of labor (Office of the Eastern Economic Corridor Policy Committee, 2020). Land use/land cover, urbanization and industrialization, and non-agricultural activities are becoming more and more important explanations. Agriculture including green areas is reducing and affecting environmental quality. Therefore, the temperature changes are affected by land surface temperature in the end. Climate change factors have changed land use from forest and agricultural areas to developing urban communities, residences, factories, and industrial estates, commercial areas. Population and infrastructure have increased, especially in the Eastern Special Development Zone (Soytong *et al.,* 2018).

Many studies have presented the relationships between land use/land cover and LST (Garouani *et al.,* 2021). Remote sensing-derived land use/land cover indices to analyze the normalized difference vegetation index (NDVI), normalized difference built-up index (NDBI), and normalized difference water index (NDWI) (Patil *et al.,* 2018; Malik *et al.,* 2019). Population density and carbon dioxide (CO_2) have been used to examine the spatial variations of LST. (Apriana and Syahrani, 2022; Chejarla *et al.,* 2016). All of these used the multi-

wavelength LANDSAT satellite data and MODIS/Terra satellite data in the study.

For this reason, the objectives were to analyzed the biophysical interactions on land surface temperature in Chon Buri Province. The factors consisted of land use/land cover (LU/LC), land surface temperature (LST), vegetation index (NDVI), built-up index (NDBI) water index (NDWI) population density, and carbon dioxide (CO_2) were investigated. The various factors were analyzed for land use and temperature changing relation of biophysical interactions on land surface temperature in Chon Buri province.

Materials and methods

Chon Buri Province is located in the eastern part of Thailand. It is located between 12°30′–13°45′N latitudes and 100°45′–101°45′E longitudes. The province is an area of 4,363 square kilometers (Figure 1).

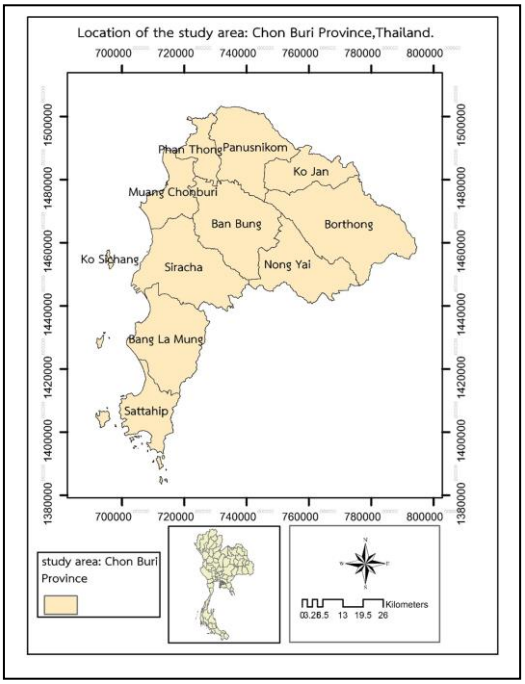

Figure 1. The study area of Chon Buri Province, Eastern Thailand

The research finding was used LANDSAT 5 TM satellite data in December 2008 and LANDSAT 8 OLI/TIRS in December 2018 at PATH/ROW 128/51 and 129/51. During the selection of satellite images to be

used, cloud-free images or images with minimal cloud cover (less than 10%) were considered. These were used to extract vegetation index, building index, and water index data. Monthly MODIS/Terra (MOD11B3 Version 6) satellite data in December 1, 2008 it was a period to analyze land surface temperature data and compared the temperature at different times with both satellite data that can be downloaded from http://earthexplorer.usgs.gov//.

Normalized Difference Vegetation Index (NDVI), Built-up Index (NDBI), Water Index (NDWI), and NDVI is negative values or close to zero associated with water body areas. The positive value is low which linked to the empty ground while more positive values indicate vegetation (NDVI) (Liu and Weng, 2012 and Zhang *et al.*, 2017). The NDVI is expressed as

(Eq.(1)) NDVI = (NIR - RED) / (NIR + RED) (1)

Where NIR = Band 4 (for Landsat TM) and Band 5 (for Landsat 8) and RED = Band 3 (for Landsat TM) and Band 4 (for Landsat 8)

The Built-up Index (NDBI) is an indicator of built-up or impervious surfaces. A negative built-up index usually indicates a water source while a built-up index close to Zero values indicates vegetation. A positive built-up index indicates a building (NDBI). (Liu and Weng, 2012 and Zhang *et al.*, 2017) The NDBI is expressed as

(Eq. (2)) : NDBI = (MIR - NIR) / (MIR + NIR) (2)

Where MIR = Band 5 (for Landsat TM) and Band 6 (for Landsat 8) and
NIR = Band 4 (for Landsat TM) and Band 5 (for Landsat 8)

The water Index (NDWI) is used to study the changes in vegetation water content. NDWI is used to identify water resources (Campos *et al.*, 2012 and Zhang *et al.*, 2017). The NDWI is expressed as

(Eq. (3)) : NDWI = (NIR - MIR) / (NIR + MIR) (3)

Where NIR = Band 4 (for Landsat TM) and Band 5 (for Landsat 8) and
MIR = Band 5 (for Landsat TM) and Band 6 (for Landsat 8)

These data were analyzed and used to study the relationship of LST with NDVI, NDBI, and NDWI in 2008 and 2018 in the forms of mapping, scatter plots, and linear regression.

Satellite data were used to analyze different effects on land surface temperature according to the condition and types of land use. In this study, land used data was taken from Land Development Department. This land use

is divided into 6 types. These were consisted of Urban and built-up land, agricultural, forest, water body areas, aquaculture areas, and miscellaneous areas. Land- use/cover maps were used to analyze the relationship between land surface temperature and each type of land use/land cover.

Population density is one of the key factors causing the city's temperature to rise. This study used data from http://web.ornl.gov/sci/landscan/ in 2008 and 2018 to study the relationship between mean LST and population density in Chon Buri Province in both time points was studied by means of scatter plots and linear regression. Chon Buri populations were 1,264,687 people in 2008 and 1,535,445 people in 2018.

Fossil Fuel Carbon Dioxide Emissions data were used in the study during December of both 2008 and 2018 from https://www.odiac.org to examine the relationship between mean LST with carbon dioxide emissions.

Interaction of biophysical characteristics is an analysis of the relationship of those factors related to human activities and landscapes that affect LST using the data from 2008 and 2018. In this study, the researcher used ArcGIS software in analysis. The results of the research have consisted of land use/land cover, NDVI, NDBI, NDWI, population density, CO_2, and LST overlay method scatter plots and linear regression and showed in mapping and bivariate maps, statistics, and description.

Results

Chon Buri Land use classification changed from an agricultural area of was averaged about 2,574.38 square kilometers (km^2) or 57.11% in 2008 and it reduced to 2,343.60 km^2 or 51.99% in 2018 or decreased 230.78 km^2 or 5.12%. It was decreased 0.90 percent per year. Aquaculture area and water resources were still remain 211.74 km^2 or 4.70% and increased to 265.97 km^2 or 5.90%. These were increased 54.23 km^2 or 1.20% or equivalent to 6.94 percent per year. Forest area was covered in 508.05 km^2 or 11.27% which increased only 509.84 km^2 or 11.31%, or increased 1.79 km^2 or 0.04% per year. Miscellaneous areas were covered in 327.38 km^2 or 7.26% and decreased to 278.97 km^2 or 6.19%. It was decreased by 48.41 km^2 or 1.07% or decreased 1.48 percent per year. Urban and build-up areas were covered in 886.26 km^2 or 19.66% and increased to 1,109.42 km^2 or 24.61%. These were explained by 223.16 km^2 or 4.95% or increased 2.52 percent per year. Land use/Land cover has changed from an agricultural area to urban and build-up areas which found mostly in the area of Siracha, Bang Lamung, and Phanat Nikhom District, Chon Buri Province as shown in Figure 2.

Land surface temperature and land use relatively found in Chon Buri province in 2008 and miscellaneous areas were shown to be the highest land surface temperature of 33.19 ℃. Forest areas have shown to be the lowest LST of 23.19 ℃. The average LST of all land use categories was 29.54 ℃. Forest areas averaged LST to 2-3 ℃ with lower than other types of land use.

In 2018, urban and built-up landwere shown to be the highest LST of 34.35 ℃. Forest areas were found to be the lowest LST of 25.97 ℃. The average LST of all land use categories was 30.90 ℃. Forest areas were averaged LST of 1-2 ℃ with lower than other types of land use.

The land surface temperature was found to be the highest about 33.19 ℃. located in Siracha District. The lowest LST was about 23.19 ℃ and is located in Bo Thong District. Siracha and Bang Lamung districts have the same average maximum LST of 30.75 ℃. Sattahip District was an average of the lowest LST of 28.12 ℃ in 2008. In 2018, the highest land surface temperature was found to be 34.35 ℃. in Muang district. Muang district has average a maximum LST of 31.74 ℃. The lowest LST was found at 25.97 ℃. in Bo Thong District. Sattahip District was an average LST of 29.61 ℃. Therefore, the highest LST areas are covered in urban and built-up land areas. Most areas of low LST are agricultural and forest land areas in Bo Thong and Nong Yai Districts (Figure 2).

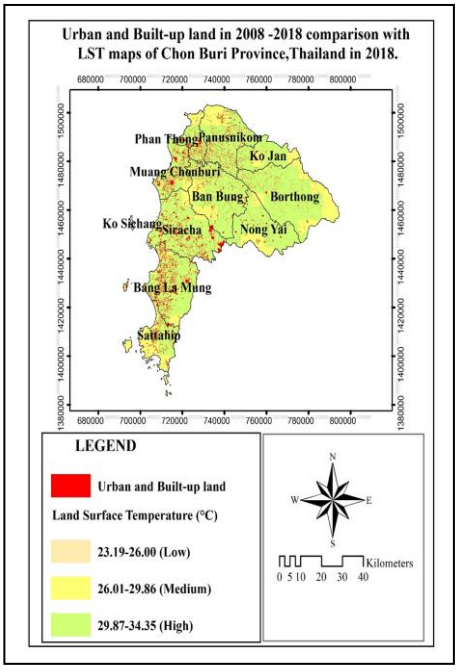

Figure 2. Urban and Built-up land in 2008 -2018 comparison with LST maps of Chon Buri Province, Thailand in 2018

In 2018, the Normalized Difference Vegetation Index (NDVI) was 81.21% of the area in the province with the correlation of LST in Chon Buri Province. NDVI was found at 52.73% with LST of 26.01-29.86 ℃ (medium level) in 2008. NDVI was found to be 39.70 percent at the high temperatures of 29.87-34.35 ℃. It found a high-level vegetation index of 0.30-0.75 and is located in Bo Thong District and Nong Yai District as shown in Figure 3.

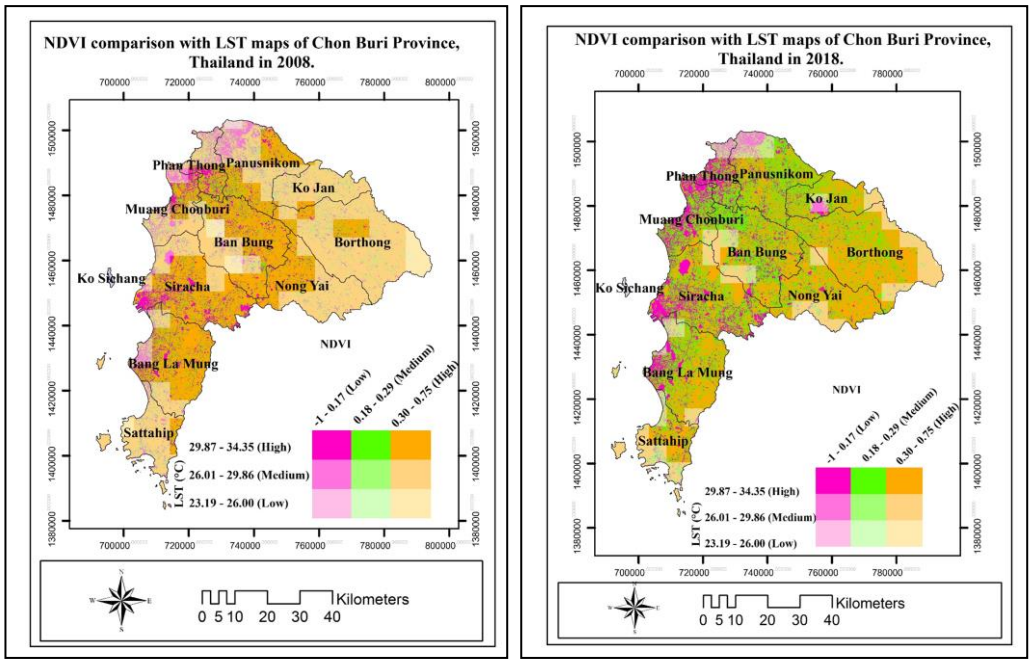

Figure 3. NDVI comparison with land surface temperature maps of Chon Buri Province, Thailand in 2008 and 2018

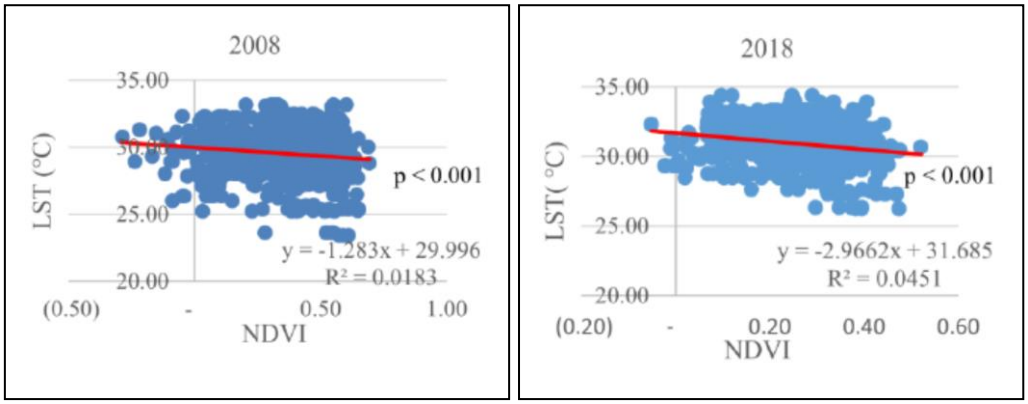

Figure 4. Scatter plots between NDVI and LST in 2008 and 2018

The correlations of LST with NDVI of Chon Buri Province in both periods were analyzed by linear regression. The land surface temperature was significant negatively correlated with the vegetation index at $p<0.001$ as shown in Figure 4.

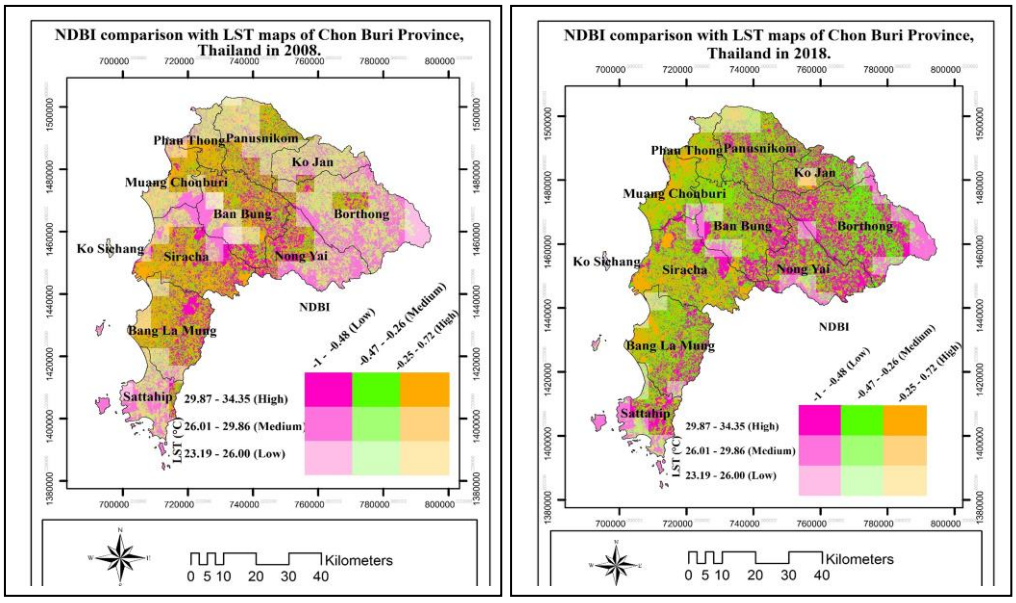

Figure 5. NDBI comparison with LST maps of Chon Buri Province, Thailand in 2008 and 2018

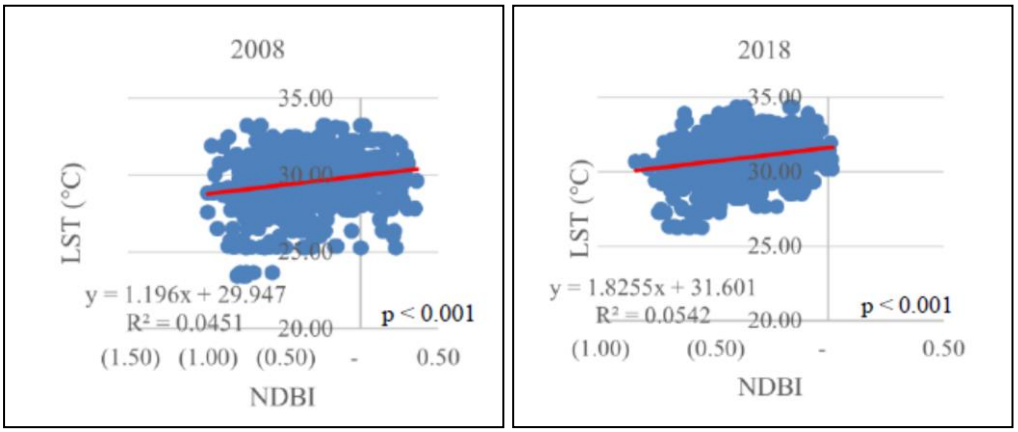

Figure 6. Scatter plots between NDBI and LST in 2008 and 2018

The correlation of LST with NDBI in Chon Buri province was found to be 52.73% in the area in the province in the medium LST of 26.01-29.86 ℃. NDBI was found to be 21.56% of low level from -1 to -0.48 in Bo Thong and Nong Yai Districts in 2008. NDBI was recorded to be 81.21% with a high LST of 29.87-34.35 ℃. NDBI was found to be 36.08 % in the medium level with -0.47 to -0.26 in Bo Thong and Siracha Districts in 2018 as shown in Figure 5.

The correlations of LST with NDBI in both time periods were analyzed by linear regression. LST was significant positively correlated with the built-up index at $p<0.001$ as shown in Figure 6.

The correlation of LST and water index (NDWI) of Chon Buri province in 2008 found that NDWI was 52.73% in the area in the province at the medium LST levels of 26.01-29.86 ℃. NDWI was found to be 22.61% at the medium level of 0-0.17 and is located in Bo Thong and Koh Chan Districts. NDWI was 81.21% at the high LST of 29.87-34.35 ℃. NDWI was found to be 34.54% for the medium level of 0-0.17 which located in Bo Thong and Ban Bueng Districts as shown in Figure 7.

The correlation of LST and NDWI in both time periods were analyzed by linear regression that LST was significant negatively correlated with the water index at $p<0.001$ in 2018 as shown in Figure 8.

The relationship between LST and population density in Chon Buri province in 2008 found to be 52.73% of the area in the province of population density with LST at the temperature of 26.01-29.86 ℃. The population was about 51.61% and found to be a low density of 0-1,812 people/sq.km. in Bo Thong and Nong Yai Districts. In 2018, the population density was 81.21% with a high LST of 29.87-34.35 ℃ in Mueng, Siracha, and Bang La Mung districts. The population was about 77.32% which found to be the low density 0-1,812 people/sq. km. in Bo Thong and Siracha Districts as shown in Figure 9.

The relationship between LST and population density in Chon Buri province in 2008 was analyzed by linear regression that LST was significantly positively correlated with population density at $p<0.05$. In 2018, LST was significant positively correlated with population density at $p<0.001$ as shown in Figure 10.

The relationships between LST and Carbon Dioxide (CO_2) in Chon Buri province in 2008 found to be 52.73% of the area in the province which CO_2 was found at the medium LST of 26.01-29.86 ℃. CO_2 was recorded to be 48.89% within the low level of 0-96 Tonne Carbon/cell/per month in Bo Thong and Nong Yai Districts. In 2018, CO_2 was found to be 81.21% at the high LST of 29.87-34.35 ℃. CO_2 was found to be 68.77% at 0-96 Tonne Carbon/cell/month in Bo Thong and Ban Bueng Districts as shown in Figure 11.

The relationships of LST with CO_2 in 2008 were analyzed by linear regression that LST was significant positively correlated with CO_2 at $p<0.05$. In 2018, LST was significant positively correlated with CO_2 at $p<0.001$ as shown in Figure 12. Finally, the biophysical relationship with LST was negatively correlated with NDVI. LST was positively correlated with NDBI.

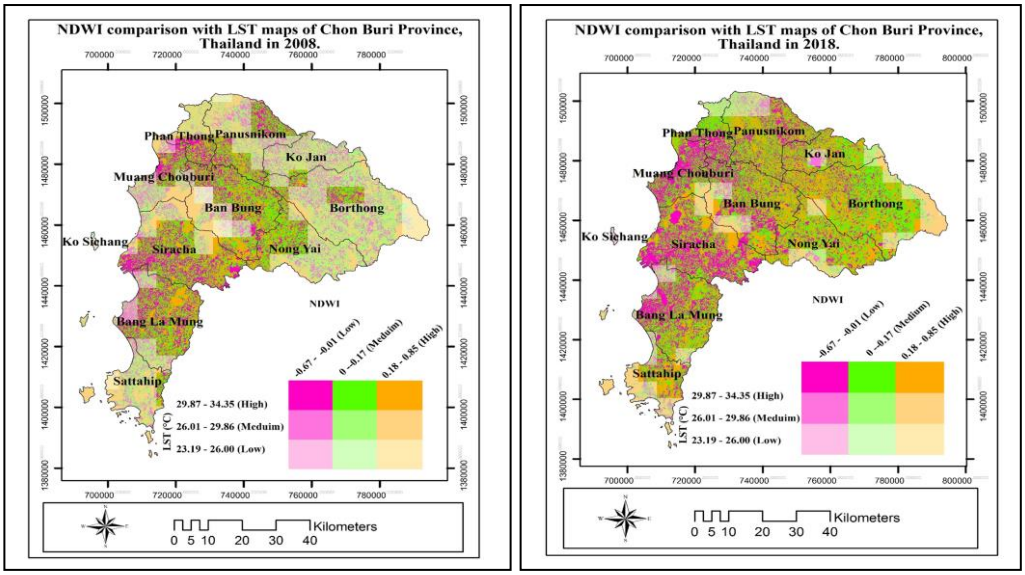

Figure 7. NDWI comparison with LST maps of Chon Buri Province, Thailand in 2008 and 2018

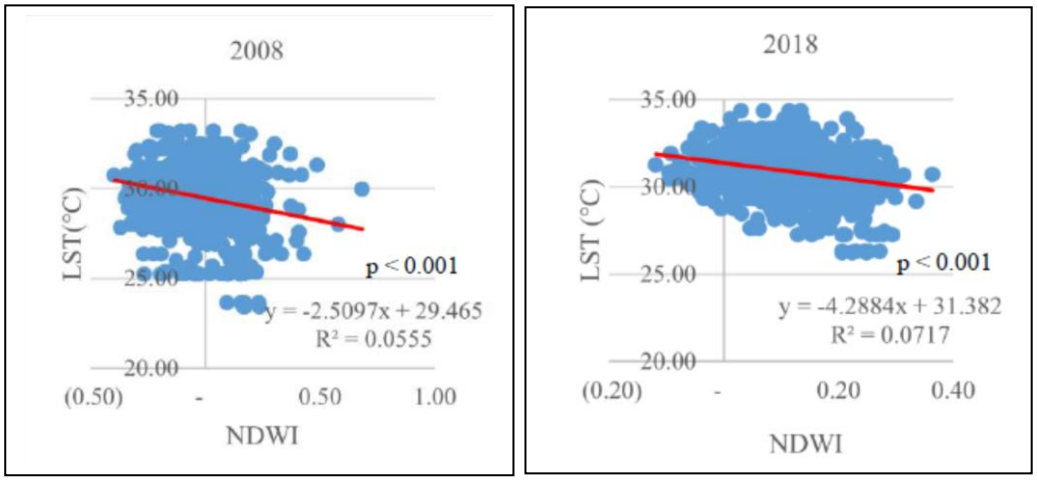

Figure 8. Scatter plots between NDWI and LST in 2008 and 2018

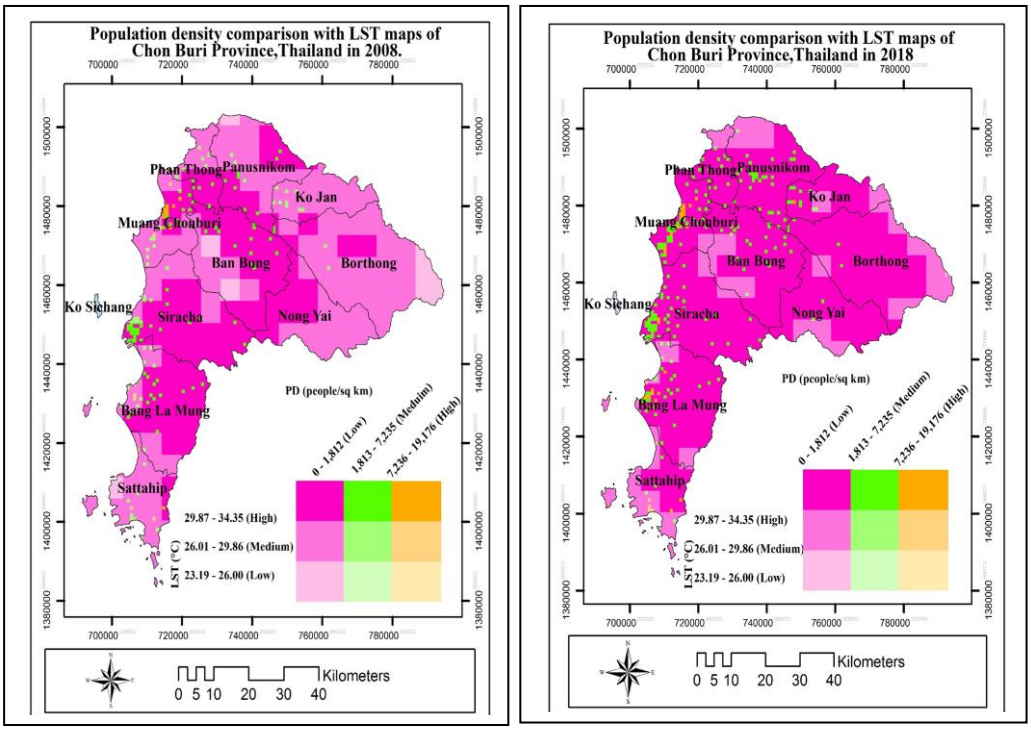

Figure 9. Population density comparison with LST maps of Chon Buri Province, Thailand in 2008 and 2018

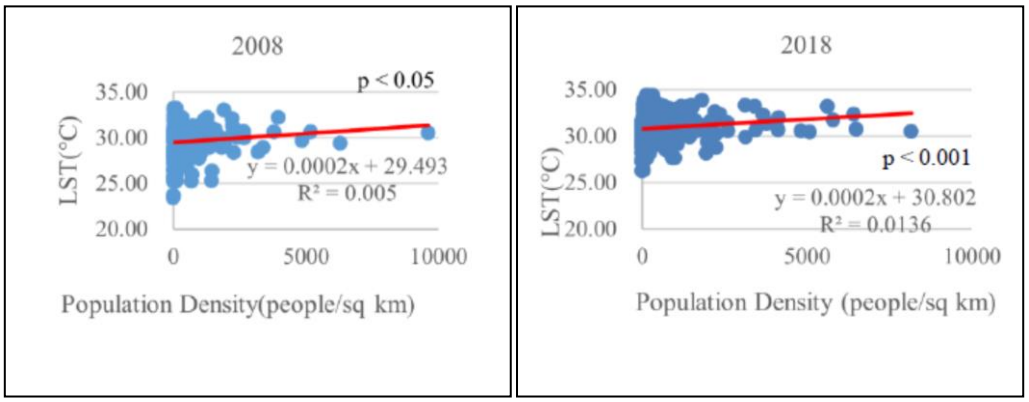

Figure 10. Scatter plots between population density and LST in 2008 and 2018

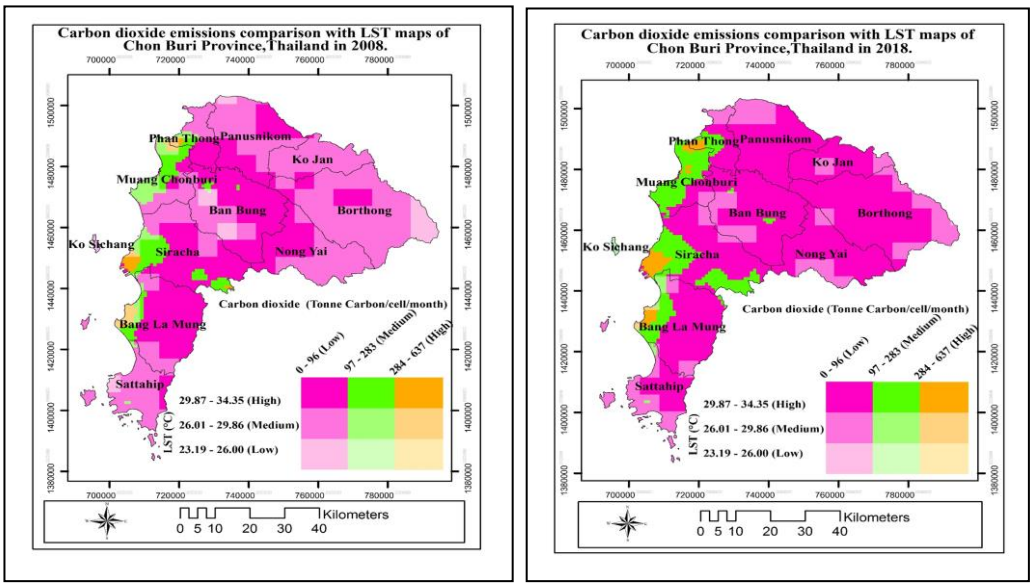

Figure 11. CO_2 emissions comparison with LST maps of Chon Buri Province, Thailand in 2008 and 2018

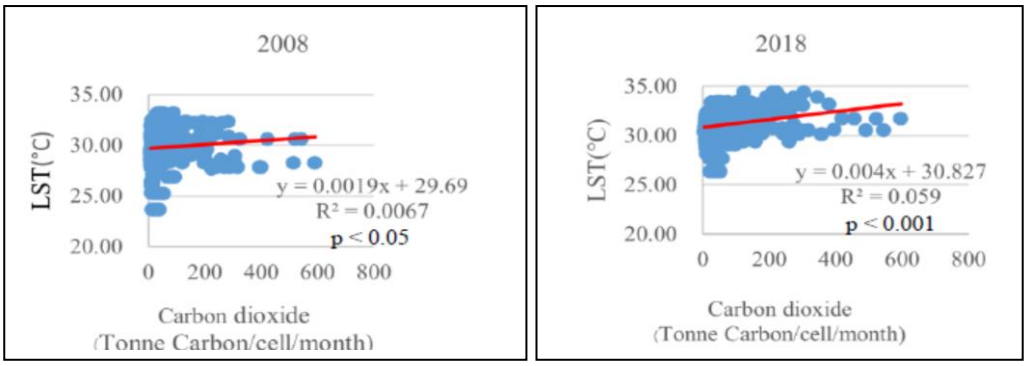

Figure 12. Scatter plots between fossil-fuel CO_2 emissions and LST in 2008 and 2018

Discussion

The study of land surface temperature related to the types of land use in Chon Buri province. Urban and built-up land and miscellaneous areas are shown to be high LST levels which located in Siracha and Muang districts. Both of these districts are economic development areas. It is the consistion of Urban and built-up land and the main industrial area of the province as same as the European reported to be different in LST between urban and rural areas.

(Heinl *et al.*, 2015). LST was negatively correlated with the difference in NDWI. (Charoentrakulpiti, 2012; Dontree and Choti Amornsak, 2009; Guo *et al.*, 2015; Zhang *et al*., 2017). This is similar to the work of Zhang *et al.* (2017) with statistical significance at $p<0.001$ for NDVI, NDBI, and NDWI. Land Surface Temperature is positively correlated with higher population density and high-rise residential buildings and industrial areas. The population related to the economy and society activities e.g., residential, industrial, commercial areas, parking lots are supposed to be one of the key factors contributing to the formation of higher urban heat levels (Zhang *et al.*, 2017; Chakraborty *et al.*, 2015; Apriana and Syahrani, 2022). The urban and industrial areas have shown to be a higher energy consumption and human heat per unit which led to higher temperatures in those areas. Deilami and Kamruzzaman (2017) found that two factors were significantly influenced on urban heat island concentrations including population density and sparseness. There was a correlated between the LST positive with carbon dioxide (Chejarla *et al.*, 2016). Fossil fuel is used rapidly due to urbanization and industrialization and it directly contributed for air pollution and global warming (Zhang *et al*., 2017).

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