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Monitoring urban heat island in the Eastern region of Thailand and its mitigating through greening city and urban agriculture

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Abstract Land Use/Land Cover change in the Eastern of Thailand was explored which related with the characteristic of urban heat island by analyzing and estimating the visible and near-infrared and thermal of Urban Heat Island (UHI) phenomenon that covered agricultural, industrial, and urban areas in the eastern region by using climate models in Geographic Information Systems (GIS) and RS (Remote Sensing) data. It integrated land surface temperature (LST) with estimated by single-channel algorithm for Landsat satellite data and ground-based weather stations in the years of 2006, 2011 and 2017. The eastern region of Thailand is the intensive industrial development region of the country, as a result, the region has developed and expanded into a city more than other regions. Land use is decreased in agriculture and forest and increasing of city/building all province in the region. Many of vacant land and agricultural land were replaced by roads, infrastructures, and buildings. There are many of urban communities and industries located spread throughout the region especially Chon Buri, Rayong, and Chachengsao provinces. Buildings and its surfaces and transport systems which constructed by brick, concrete and asphalt act as enormous heat storage. It accumulated the human and industrial activities of urban areas that had been caused urban zone to higher temperature than the surrounding countryside area. From the study, many cities in the region was significant increased in temperature.

The research found LST and UHI of Eastern Region including urban and industrial areas was higher temperature when compared to the surrounding agricultural areas. These different temperatures cause the formation of UHI. This study recognizes that the level of LST and UHI province increased to be the strongest in 5 provinces: Chon Buri, Prachin Buri, Sa Kaeo and Chachoengsao. UHI effect is a significant factor linking to anthropogenic sources, to protect the environment and to mitigate the UHI effect. There involved in different environmental strategies, one of the important strategy is a greening city with increasing green cover surface area in cities. The green infrastructure methods and techniques, urban agriculture is an alternative mitigation which currently being considered. Urban Agriculture is considered as an opportunity to mitigate the environmental impacts, because, urban agriculture can play a strong role in enhancing food security by providing agricultural products to the residents of the city, greening the city and improving the urban climate.

Keywords: Land surface temperature (LST), Urban Heat Island (UHI), Urban Agriculture, GIS, Environmental Mitigation, Greening City

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Introduction

Eastern region of Thailand is one of most extremely industrial development area. Industrialization and urbanization are increasingly and trending to be more than other region of country. Urbanization is modifying the climate of cities and surrounding area. The Urban Heat Island (UHI) effect is most indicator phenomenon for transforming urban climate. This phenomenon associated with socio-environmental impact: human health, livability and biodiversity. This paper was emphasized on how UHI situation in the eastern region of Thailand and how to mitigate its effects, though greening city and urban agriculture approach.

The general concepts about UHI is introduced, and a decade of changes in land use/land cover patterns in the eastern area of Thailand was reported mainly in 7 provinces (Chon Buri, Rayong, Chachengsao, Prachin Buri, Chantaburi, Trat and Sa Kaeo) by integrating with how land surface temperature (LST) distribution across the region is investigated. The past situation, current pace and trends of temperature and land use/land cover is given to draw current shift patterns of UHI in the region. The research presented a way to mitigate the effect of UHI, especially how to cool down the heat in the city, and introduced how the greening city and urban agriculture is practiced in the region.

Materials and methods

The research is based on the mixed methods which was multidisciplinary approach, in order to monitor the current and trend of the UHI in the eastern region of Thailand and how to mitigate its effects. It is based on qualitative studies, literature review and climate models in Geographic Information Systems (GIS) and RS (Remote Sensing) methods.

The empirical evidences and information is developed from primary data: measuring of surface temperature by surface temperature measurement tool (i.e. Infrared Thermometer) and the urban and industrial area survey: Global Positioning System (GPS) is used to position to collect the soil cover, materials used in construction, then analyzed the distances and shapes of cities and industrial areas for mapping, locating, measuring, and analyzing the relationships of factors affecting the island heat and climate phenomenon.

Secondary data: data from ground-based weather station of Meteorological Department and Landsat satellite data in year 2006, 2011 and 2017 were recorded. The relationship between temperature and land use were examined. Landsat satellite is used at a resolution height of 30 m in order to collect data and produced maps about temperature by Landsat 5 which used for

collecting data in the years 2006 and 2011. Landsat 8 is used for collecting data in the year 2017. Correspondingly, with map from Google Earth for data of urban and industrial areas was investigates where located the heat island phenomenon.

The data from both primary and secondary data is combined to monitor how UHI of the eastern region of Thailand. There were the steps for analyzing data as (1) data were prepared before processing image by composite band and mosaic image; (2) LST was estimated by single-channel algorithm which studied on a brightness temperature based on thermal infrared band 6 and studied on a land surface emissivity with NDVI Base and Fraction Vegetation Cover. Then, the map is generated. The map layers represented land use type, LST (℃) and UHI situation. All of output data is analyzed to monitor the intensity and patterns of heat in urban and industrial area in the eastern region.

Results

Urban Heat Island and General Concept

Heat Island phenomenon defines as the 'dome of heat' according to the nature of this phenomenon, as Thanakrit Tianmanee defines 'Heat island' is a phenomenon where the temperature of the atmosphere above the city is higher than the outside the city area. The temperature line looks like a large island or dome above the city (cited in Vishnu, 2013). The phenomenon of heat island or dome heat is a phenomenon that occurs in large urban areas. It is a phenomenon caused by the increase in temperature which caused by human activity, the air near the ground in urban areas with high buildings and dwellings located densely, with higher temperature than in rural areas, resulting to the area which surrounding with countryside or forest is cooler, the heat dome phenomenon as shown in Figure 1.

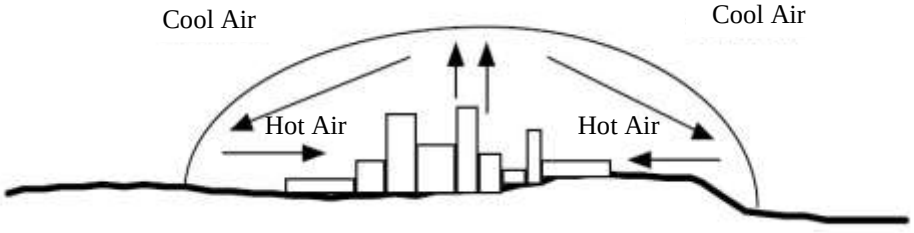


Figure 1. Heat Dome: Hot Air Circulation and Cold Air Pressure

The difference between urban and rural area, the range of thermal is difference, Urban Heat Island (UHI) is a phenomenon in an area where the temperature of the air layer near the ground in the community or in the metropolis is higher than the surrounding area, as U.S. Environmental Protection Agency (2012) defines UHI refer to the area where elevated temperatures in developed areas more than rural surroundings. Resulted of the urbanization, number of people who living in the cities is numerous increased. It estimated that until 2030 that urban will be home of at least 61 percent of the world's population (Taslim, Parapari and Shafaghat, 2015), with massive population, the heat is generated in the urban area more than the surrounding area. The change in the surface of the earth is increasing which is the reason from increasing the average temperature.

Causes of Urban Heat Island and Its Effects

There are the number of factors which contribute to significantly creation of UHI, e.g. using low albedo materials, increased the use of air conditioner, destruction of trees, urban canopy, wind blocking. U.S. Environmental Protection Agency (2012) defines that UHI is caused by development and the changes in radiative and thermal properties of urban infrastructure as well as the impacts buildings can face on the local micro-climate.

The causes of UHI are summarized n Figure 2, the main criteria that causes of UHI in urban area are as follows:-

(1) *Lack of plants:* In the city area is often lack of trees which help to absorb light energy and change into chemical energy in photosynthesis. It is affeted to evapotranspiration in the area, with replacing solar energy with heat due to lack of shade, resulting in sunlight hits the ground and buildings directly, then objects became heat and transfer to the surrounding air.

(2) *Land surface material*, especially absorption of solar radiation due to low albedo: thermal properties of the building material surface and lack of evaporation of dehydration. (evapotranspiration) in the city. In urban development, using materials that cause the accumulation of heat that cover over the surrounding city, along with the heat released by building energy. Typical materials in the city, such as concrete and asphalt, are big different in heating properties including properties of the heat capacity and heat transfer, the albedo and emissivity. These factors result in a change in the energy balance in urban areas, which causes higher urban temperatures. In general, the surface of building. The street is the main factor which effected to UHI. The urban surface materials have related to the capacity of heat storage. During the day, the materials absorb solar energy and release back during the night, there

are difference in the temperature of urban areas, rural area and surrounding area.

(3) *High buildings & urban structure*: 'Geometric effects': Many high-rise buildings in the downtown areas are multi-faceted, reflective and sun-absorbent. This makes the area to increase hot climate, which is called 'Canyon effect'. Moreover, heat during the night is caused by buildings, blocking the heat from the ground does not allow heat extending to the night sky. Significantly, the higher the temperature difference will be at night more than during the day, in winter rather than summer, and when there is no wind or mild winds.

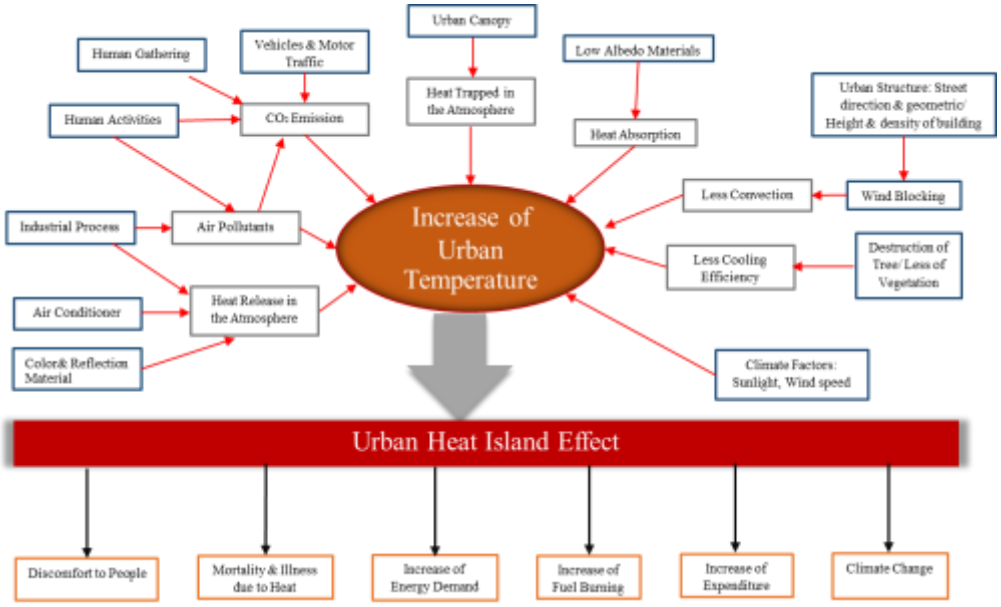


Figure 2. Process of Urban Heat Island Formation and its Effects
(Source: Adapted from Nuruzzaman (2015) and Taslim, Parapari, and Shafaghat (2015))

(4) *Human activities*, high amount of anthropogenic heat release: Densely populated areas discharge pollution in various forms. For example, air conditioner which eliminates cooling from convection, the heat released from the air conditioner of the building, industrial plants and other heat sources. Plus, abandoning human energy. All kinds of energy sources, when used often turned into heat, then left to the environment around including in cities with high air pollution. Associated with a local greenhouse effect, the smoke and dust that hangs in the air are absorped by heat radiation. Moreover, urban air often has a higher carbon dioxide (CO_2) content than surrounding area. The significant cause is air pollutants, which come from human and industrial activities, especially when human gathering in urban area, an emission of CO_2, this CO_2

stores heat which trapped from urban canopy at the atmospheric results to increase inn temperature. It assists in the formation of heat island.

The effects of UHI is shown in Figure 2. The effects of high temperature especially during summertime in the tropical region such as Thailand are devastating as it causes discomfort to people who living in the high rise and crowed building in the city, extreme heat and sunshine without shading able to cause heat stress and cause illness, death is possible. In the other hands, the higher temperature means people needs more operate air conditioners to cool down the building, the large amount of energy is required as well as the increasing of fuel burning. To manage and keep city cool down, there are required a lot of resource in addition to the increasing of the expenditure of the authority, involving agency and people.

Monitoring Urban Heat Island in the Eastern Region of Thailand

There are both direct and indirect methods to monitoring UHI: a direct methods technique is numerical modeling, and estimates based on empirical models; and an indirect measurement technique such as remote sensing to data collection to produce thermal images then estimate surface temperatures (U.S. Environmental Protection Agency, 2012). In this study of eastern region of Thailand, monitoring is based on remote sensing technique.

Urbanization and Industrialization Situation

The country's economic and industrial development has contributed to the development of the eastern region in various areas to support the expansion of Bangkok and its vicinities. Eastern area has become a new economic zone and the main industry, his resulted in the urbanization and industrial expansion in the eastern region. The result is a change in land use, infrastructure development and energy development for support this trend of development. As the result, not only industrial sector is developed and became a huge part contribute to economic of country, but urban also is developed and became more urbanization more than other region of country, the population in the eastern area is increasing during the industrialization, people came from around country for job opportunity as well as living.

In the east, urban expansion is often caused by immigration from people all over the country to the workplace, the business or industrial center. Resulted from the national development plan, the development of the eastern seaboard is started since 1981, industrialization and urbanization is developing in the eastern region since that time. Currently industrialization is located in 4 provinces, namely, Chachoengsao, Rayong, Chon Buri and Prachin Buri. In addition, urbanization is located over the region, there are 110 cities in the eastern, the provinces with the highest number of cities are Chon Buri, 27

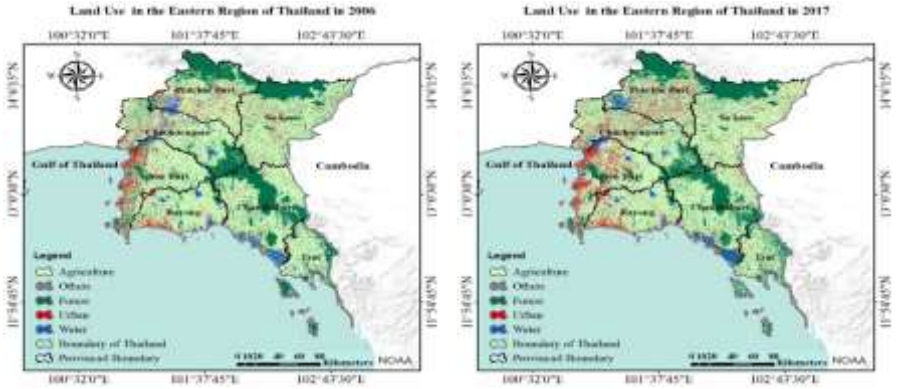
cities, followed by Chachoengsao, Rayong, Chantha Buri, Prachin Buri, Trat, and Sa Kaeo, respectively. The highest proportion of population who live in Chon Buri with 51.11 percent of the population, the classified population into 4 groups showed that the biggest city (1st city: national and regional center) is Pattaya city, 2nd city (center, region or province) are Muang Chon Buri, and Muang Rayong, 3rd city (provincial center or large district) spread in 14 different areas and 4th city which is a rural center is located spread in 93 cities around the region.

Land Use Situation in the Eastern Region

Urbanization and industrialization in the eastern region affected to land use in the area, as shown in Table 1, there were some change of land use/land cover in the area. It was evident that in 2017 there was an increase of building and city area, while land use in agriculture and forest decrease. When compared land use of all area in the eastern region in year 2006 and 2017, it found that in year 2006, agriculture is covered around 62.21 percent and the forest covered around 23.38 percent. Whereas, in year 2017, the agriculture area is decreased around 0.62 percent and forest area is decreased around 1.04 percent from year 2006, Figure 3 showed how land use changed in the eastern region between year 2006 and 2017.

Table 1. Land Use/Land Cover in the Eastern of Thailand in 2006 and 2017

Land Cover	2006		2017		Difference	
	Area (sq.km.)	%	Area (sq.m.)	%	Area (sq.m.)	%
Water source	1,203.89	3.50	1,203.56	3.50	-0.3312	0.00
City / Building	2,065.25	6.01	2,620.77	7.62	555.5232	1.62
Agriculture	21,387.79	62.21	21,175.07	61.59	-212.7168	-0.62
Empty land	1,685.08	4.90	1,698.69	4.94	13.6144	0.04
Forest	8,038.48	23.38	7,682.40	22.35	-356.0880	-1.04
TOTAL	34,380.00	100.00	34,380.00	100.00		



(a) year 2006 (b) year 2017

Figure 3. Land Use in the Eastern Region in 2006 and 2017

When considering the province, it found the increasing city/building areas in the year 2006, Chon Buri covered 569.69 sq.km., Prachin Buri covered 343.72 sq.km., Chachoengsao covered 337.12 sq.km., Rayong covered 286.01 sq.km., Sa Kaeo covered 278.05 sq.km., Chantaburi covered 178.38 sq.km., and Trat covered 72.27 sq.km. The year 2017, there were changed city/building area which Chon Buri covered 772.04 sq.km., Prachin Buri covered 425.72 sq.km., Chachoengsao covered 411.60 sq.km., Rayong covered 370.86 sq.km., Sa Kaeo covered 308.33 sq.km., Chantaburi covered 238.68 sq.km. and Trat covered 93.55 sq.km., all provinces in the eastern region were increased the city/building areas.

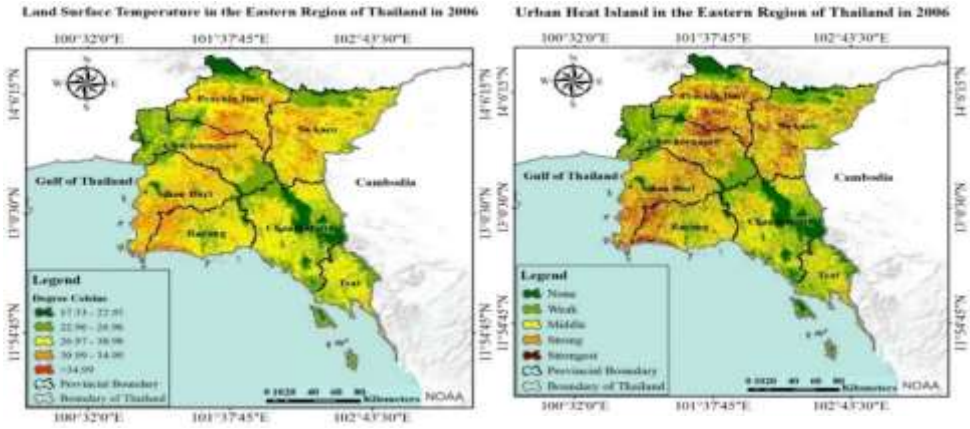
Monitoring Urban Heat Island in the Eastern Region

The eastern region of Thailand is both savanna climate (Aw) and tropical monsoon climate (Am), apart from the climate character of the region, the LST is also up to the other activities that generated heat and pollution in the area. The research on the LST and UHI of the eastern area found that LST of the region and UHI phenomenon of the region are related to the land use pattern of the region. The LST and UHI were changed according to the time period as shown in Figure 4, 5 and 6.

The results showed that the average temperature in the eastern region was 28.24 ℃ in 2006 and increased to 28.57 ℃ and 30.98 ℃ in 2011 and 2017, respectively.

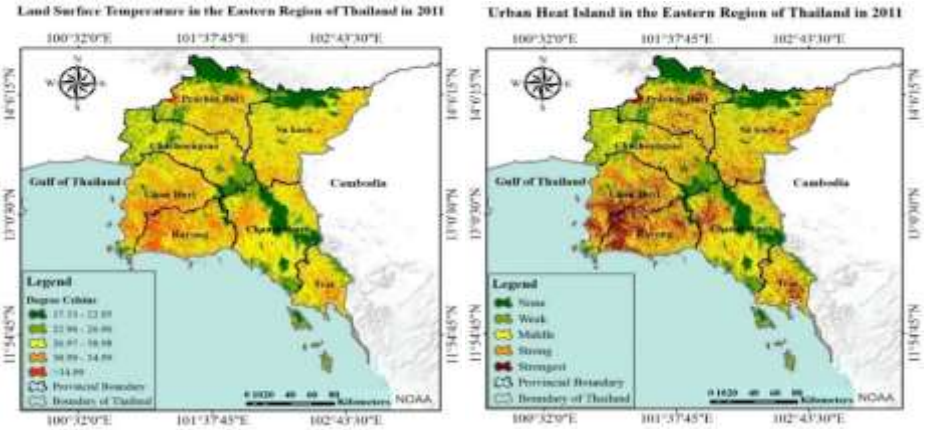
In 2006, Chon Buri Province was highest average temperature of 29.85 ℃, followed by Rayong, Sa Kaeo and Prachin Buri, with the average temperature was 29.36 ℃, 29.05 ℃ and 28.78 ℃ respectively. Chanthaburi and Trat averaged minimum temperature of 26.14 ℃ and 26.59 ℃, respectively. This illustrated in LST and UHI situation in 2006 of the eastern region as the LST shown in Figure 4 (a) which the most heat located on Chon Buri, Rayong, Sa Kaeo, Prachin Buri and Chachoengsao related to the UHI situation on Figure 4 (b) that only Chantaburi and Trat provinces did not have UHI.

In 2011, Rayong was the highest average temperature of 31.36 ℃, followed by Chon Buri, Trat and Sa Kaeo, with the average temperature was 30.48 ℃, 28.51 ℃ and 28.30 ℃, respectively. The average minimum temperature was 27.40 ℃, 27.56 ℃ and 27.81 ℃ in Chataburi, Prachin Buri, and Chachoengsao province, respectively as the LST shown in Figure 5 (a), that the most heat located in Rayong and Chonburi, followed by Trat, Sa Kaeo, Chachoengsao, Prachin Buri, Chantaburi, and related to the UHI situation as shown in Figure 5 (b), that all provinces of the eastern region had UHI which the strongest UHI in Chon Buri and Rayong province (the strongest UHI was the province had an average temperature over 30 ℃).



(a) LST (b) UHI

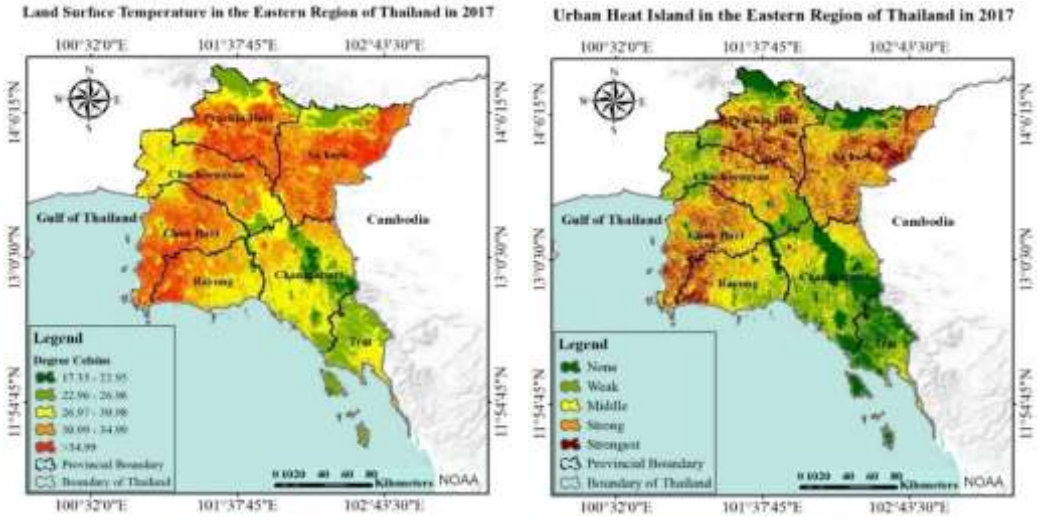
Figure 4. LST and UHI of Eastern Region in year 2006



(a) LST (b) UHI

Figure 5. LST and UHI of Eastern Region in year 2011

In 2017, Chon Buri was the highest average temperature province of 33.18 ℃. The second highest temperature was Sa Kaeo, Prachin Buri, and Rayong which were 32.82 ℃, 32.14 ℃ and 31.72 ℃, respectively. In the other hand, Trat, Chanthaburi and Chachoengsao had the lowest average temperature with 26.66 ℃, 27.98 ℃ and 31.13 ℃, respectively. The LST in Figure 6 (a) showed that the most heat located in Chon Buri, Rayong, Sa Kaeo, Chachoengsao and Prachin Buri, only some heat in Chantaburi, and none of heat in Trat. This related to the UHI situation on Figure 6 (b) that in Rayong, Chon Buri, Prachin Buri, Sa Kaeo and Chachoengsao had the strongest UHI situation, whereas had only few UHI in Chantaburi and none UHI in Trat.



(a) LST (b) UHI

Figure 6: LST and UHI of Eastern Region in year 2017

In 2006, there was no province with an average temperature of more than 30 ℃, only 5 years later there was two provinces, Chon Buri and Rayong had averaged temperatures over 30 ℃, and 5 years later, Sa Kaeo, Prachin Buri, and Chachoengsao provinces had an average temperature of more than 30 ℃ in the same direction with those two provinces. When analyzing the average temperature trend, it can estimate that Chon Buri, Rayong and Chantaburi are provinces where the average temperature rises continuously, the other provinces, the average temperature changes is not fixed, trend of average temperature as shown in Figure 7.

From the Figure 4, 5, and 6, there were some significant changed in 2006, only 4 provinces, Chon Buri, Rayong, Chachoengsao and Prachinburi had UHI that are home in the industrial estate of the eastern region, with 33 industrial estate located (IEAT, 2015). However, the biggest change of situation was in year 2011, when all eastern provinces faced UHI situation by the strongest significant UHI which located in Chon Buri and Rayong, where is biggest industrial estate of country. The changing of situation is trended to be stronger of UHI situation as the level of UHI province increased to be the strongest in 5 provinces: Rayong, Chon Buri, Prachin Buri, Sa Kaeo and Chachoengsao. It is considered with land use of the area, it is remarkable that not only 4 provinces, which are located with city and the industrial estate type of land use, but also UHI occurs in Sa Kaeo, where agriculture is most type of land use, the main areas of the province had high temperatures and the risk of heat island as same as the other provinces. This heat may not be the

phenomenon of UHI, but the temperature caused by agricultural activities. For minimum average temperature, Chantaburi had minimum average temperature in 2006, 2011, and Trat in 2017, however Chantaburi had trended for increasing temperature as shown in Figure 7.

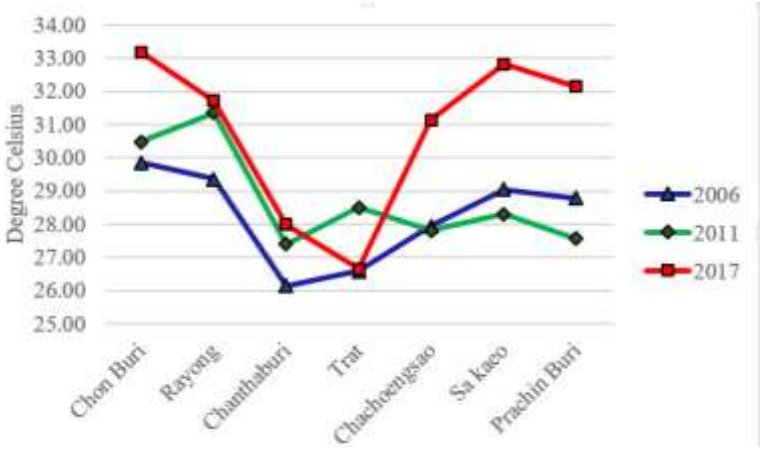


Figure 7. Trend of Eastern LST by province in year2006, 2011 and 2017

The land cover is one factor that affects the average temperature of the area. If the land cover is permanent, such as urban areas, industrial areas, and buildings, the average temperature of the area is significantly high. In the contrast, if most of the area is covered by forest or green space, the average temperature of the area is significantly lower. In the eastern region, comparing Chon Buri, Rayong, Chanthaburi and Trat, it was found that Chon Buri and Rayong provinces where located under the Eastern Seaboard Development Program, had higher temperature than Chanthaburi and Trat Provinces, even all of them has similar terrain and natural resources.

Reducing Urban Heat in a Growing City

Urban Heat Island Mitigation Option

To mitigate UHI effects, only one ways solution was not enough, there were many ways to reduce the effects from heat in the urban and industrial development, such as cool pavements, cool roof, green roof, green wall, and so on. The main idea of mitigating approach is reduced waste, heat or energy that released from industrial and human activities, vehicles and infrastructure (e.g. road or pathways).

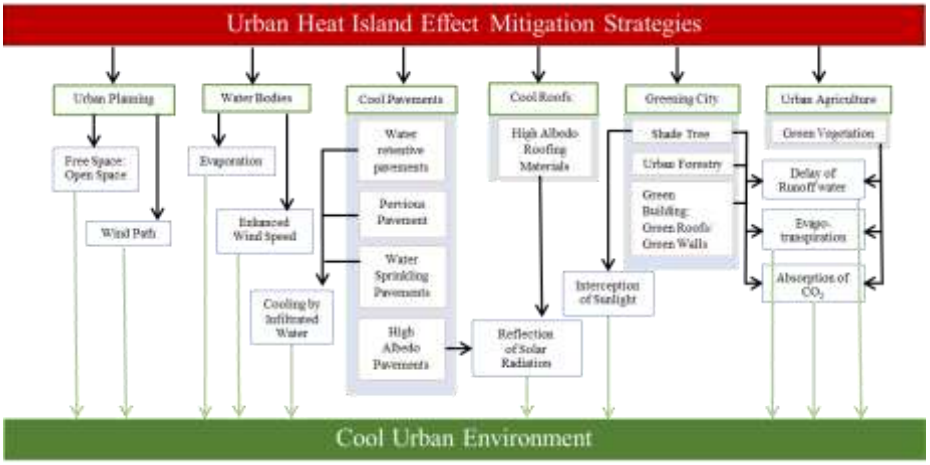


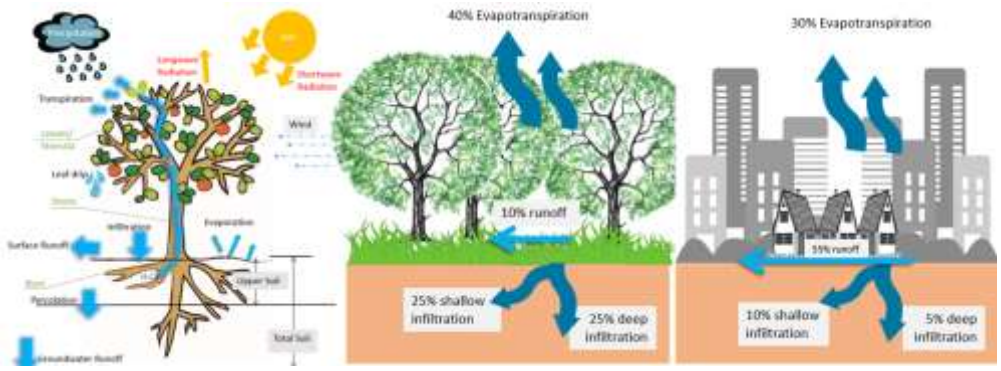
Figure 8. Urban Heat Island Effect Mitigation Strategies and Process (Source: Adapted from Nuruzzaman (2015))

LST and UHI mitigation: Greener city is need

There are many choices for mitigating UHI, however, the most effective approach that should to apply is greening city and urban agriculture by increase green and vegetation areas in urban and industrial spaces, because to cool down the city, greening city is best and easy ways to do, by only increase more plant on road and building e.g. shade tree, green roof, urban forestry and so on. The reducing of temperature is a process called evapotranspiration which is a process that help reduce air temperatures of surrounding area by plants release water to the surrounding air, dissolving ambient heat. The Figure 9 (a) illustrated some of the land surface processes which included the evapotranspiration process, the evapotranspiration was very important process which plants take water from the ground through their roots, move along the trunk then emit it through their leaves, water can also evaporate from tree surfaces, e.g. stalk or surrounding soil, this make the air to be more moisture and cool down the heat of surrounding area.

In rural areas, vegetation and open land typically dominate the landscape with many trees and vegetation helped to provide the shade and helped lower surface temperatures, as shown in Figure 9 (b), rural landscapes, the runoff was only 10 percent, infiltration was 25 percent on shallow infiltration same as deep infiltration, and evapotranspiration rates was 40 percent. Whereas, the urban landscapes, as seen in Figure 9 (c), was a totally difference, the runoff was 55 percent, infiltration was 10 percent on shallow infiltration and 5 percent for deep infiltration, and evapotranspiration rates was 30 percent, because urban area are characterized of dry and dense surface, urban land surface is covered by buildings, conventional roofs, sidewalks, roads, and parking lots, also when

city is developed the traditional plants/vegetation was lost. The pictures showede that highly developed urban areas (Figure 9 (c)) showed less surface moisture available for evapotranspiration than rural areas (Figure 9 (b)) which was a natural ground cover.



(a) evapotranspiration (b) rural landscape (c) urban landscape

Figure 9. Evapotranspiration and Differences between Rural and Urban Landscapes

(Source: Adapted from U.S. Environmental Protection Agency, 2012 and Goodchild, Parks, and Steyaert, 1993)

Following section is discussed the two mitigating strategies: greening city and urban agriculture. The greening city' is an approach including all components of a mitigation strategy that promote people to grow more plants in the city. Besides 'urban agriculture' is an approach that promote people to practice of cultivating, processing, and distributing food in or around a village, town, or city. As cited above, trees contribute to reducing the UHI effect by their evapotranspiration, also vegetations have a direct impact on absorbs CO_2, so many empirical evident show that temperature is reduced if the growing vegetation is applied, hence the one of the most effective strategies to mitigate the effects of the urban micro-climate is an increasing the amount of vegetation in the city, consequently the green is needed to cool down the city, not only environmental benefit, it bring economic benefits to cities, the associated with urban trees such as increased land, property, and rental value.

Greening City in the Eastern Region

'Greening city' consist of all components of a mitigation strategy that promote people to grow more plants in the city. The main three options: was explained as shade tree, urban forest, and green building (green roof/green wall), plus with open space.

Urban is the place that consists with many of building, as home or workplace, green building is main mitigation idea for reducing heat and gas. Green roof help to make roof cooler, the plants utilize heat energy to continue their evapotranspiration process, making the environment cool, so roof that plants tree on it is able to absorb heat and filter the air also able to keep the low temperature of area surrounding, as well as green walls as shown in Figure 9 (a). Moreover, green roof helped to delay the runoff duration which keep the cities cooler for a longer period.

(a) Green roof

(b) Green wall

Figure 10. Example Pictures of Green Building's Practicing in the Eastern Region

The practicing of green building is now widely applied to many places in Thailand especially in Bangkok, but it is still rarely found in the eastern region of Thailand. From the observation, green walls in the eastern region are either partially or completely walls that covered with vegetation, and they have enthusiastic green looks, but it has still less installation in the city or municipality area, also the practicing of green roof is very less and not full function as in theory. Figure 10 showed some practicing of green building in the eastern region.

Figure 11. Example Pictures of Shade Trees' Practicing in the Eastern Region

Figure 12. Example Pictures of Shade Tree planted in the Traffic Island

The principal role of shade tree is there shade provide protection to houses and pedestrians from direct sunlight by shade and keeping them comparatively cool, also shade trees help to lower the temperature by evapotranspiration. It effects to cool down surrounding, shade tree also helps to reduce using of air conditioning in the building. For Thailand, shade trees were planted year by year since there are more a strategy to mitigate environmental problem and to improve air quality in urban areas. In eastern region, there are many of trees which planted in a front yard to shade the walkway and frame the residence, and many province or areas have a good practice of reserved a big tree in the city in the east, such as in Chantha Buri province, some example of a good practices planting shade tree as shown in the Figure 11 However, planting shade tree need some issues to be concerned, the big tree need space for rooting, most places that shade tree able to root is the traffic island, however the what kind of plant or tree that plant it up to the authorities, the Figure 12 show some example of difference kind of plants that planted in the traffic island in the eastern region of Thailand.

Urban forestry is the care and management tree populations in urban settings for the purpose of improving the urban environment. Urban forestry advocates the role of trees as a critical part of the urban infrastructure, e.g. public park. Figure 13 showed some public parks in the eastern region, in the east, mostly in the large cities have a public park, but not all of them have a well management and good practices. However, Phanat Nikhom municipality, Chon Buri province have a good practice in urban forestry, they got many of award on the green and sustainability for their practices.

(a) Public park in Muang Chantaburi

(b) Public park in Muang Rayong

(c) Public park in Phanat Nikhom municipality,

Figure 13. Example Pictures of Urban Forest's Practicing in the Eastern Region

To meet the need and serve the people in their area about reducing CO_2 emission, Phanat Nikhom municipality, run a program call 'Tree Registration and Preservation Program', the program mainly aims to study and explore a big tree in the municipality, so they collected the statistical data of trees in the city area, include all area of the park in the city, in the community area and the middle of the street. With public participation, people able to tell the information about big tree in their community area, then the authorities surveyed the tree in the municipality area.

The survey steps consisted of measuring tree circumference (Figure 14 (a)) and tree heights (Figure 14 (b)), also pointing a geographic coordinate and taking a photo of each tree, then making a tree map with giving the tree code and registration it. The resulted of the survey found that there are 13 places in Phanat Nikhom municipality that located of 969 trees with a height more than 1.3 m. and a circumference size more than 14 cm. which classified as 66 species of plants. The municipality also asked the people in the community both public and private sectors to find the solution for preserving those trees together, then make Memorandum of Understanding (MOU) with all sectors for preserving and maintaining the registered trees. Based on the survey in 2012, the calculation of carbon captured by the trees of the Phanat Nikhom municipality, the tree biomass assessment for total 969 trees have a biomass of 170,985.06 kg., calculated as 85,492.53 kg. of carbon captured in the plant's biomass or 85.49 tonnes of carbon. Pictures of program's practicing in Phanat Nikhom municipality as shown in Figure 14.

(a) Measuring tree circumference (b) Measuring tree heights

(c) Tree registration label with its details and signboard about the project

Figure 14. Tree Registration and Preservation Program's Practicing in Phanat Nikhom Municipality (Source: Municipality League of Thailand, 2014)

Figure 15. Example Pictures of Open Space's Practicing in the Eastern Region

Open space is a useful space that brings natural environment into downtown for pleasure and relaxation, for this kind of land is unprofitable, nevertheless it can provide social benefits, the open space will be most advantage if it is turn to public parks and vertical gardens. The open space in the eastern region is plenty as there are many vacant lands in the city as well as the rural area, some open space is only be vacant lands, which does not do anything. In other hands, some city manages to keep open space to be a green space and water space (e.g. canal or pond), for example, in Phanat Nikhom municipality there are existing open space that are a linear chain of water channel as open space which provide the way for wind blow through from the water sources to building, then it bring cool from water to the city. As seen in Figure 15 showed that the kind of open space reserves in the city help urban has a recreation corridor. All the greening city, green building - shade tree - urban forest, well-maintained of those trees help to make good looking the business districts landscape which associate to encourage consumer purchases and attract increased residential, commercial, tourist and public investments. Moreover, trees located in urban which is business areas may also increase worker productivity, recruitment, retention and satisfaction for who living and working in the areas.

Urban Agriculture in the Eastern Region

The Urban Agriculture Network defines as an industry that produces, processes, and markets food, fuel, and other outputs, largely in response to the daily demand of consumers within a town, city, or metropolis, on many types of privately and publicly held land and water bodies found throughout intra-urban and peri-urban areas. The urban agriculture makes people in city more direct access to fresh fruits, vegetables and meat products, which guarantee for food safety and food security to the costumer, so the agricultural plots within the city and suburbs, is approached how to reduce the distance of food to delivery from field to city, and it can be done by both private/small scale farming sites and larger scale agriculture.

Figure 16. Example Pictures of Urban Agriculture in the Eastern Region

The impacts of urban agriculture are affected to the energy-efficient, as it can reduce carbon footprint of the city by reducing the amount of transport that occurs to deliver goods to the consumer, as well it helps to environment in overview, the reduction in ozone and particulate matter, also the reduction of soil decontamination and noise pollution, in the contrast, it provides a nutrition and quality of food, which lead to health equality, food justice and environmental justice. The agricultural sectors in the eastern region of Thailand is located all around the region, mostly in the rural area, so for eastern people the accessing to agriculture product is easy than who live in Bangkok. From the survey, urban agriculture in the sense as the definition does not yet exist in the eastern region, however, urban agriculture in the eastern region is called as urban garden which a tidy front yard flower and vegetable garden, as shown in Figure 16.

Discussion

The cool pavement refers to a range of established and emerging materials, these pavement technologies tend to store less heat and may have lower surface temperatures compared with conventional products, also water retentive pavements and water sprinkling is used by installed underground water piping to ensure the pavement stays moist which keep pavement temperatures low (U.S. Environmental Protection Agency, 2012). Taslim,

Parapari, and Shafaghat (2015) reviewed literature on UHI strategies and found that there are three main mitigation strategies, (1) planting tree in open spaces or along the streets, (2) cover rooftops with vegetation (green roof/living roof) and (3) increasing the reflectivity of built surfaces. The UHI mitigation strategies and process shown as in Figure 8, the important strategies are layout on ideas that the building and streets should to allow wind flows and cool the air through evapotranspiration, such as green walls can cool the surface of walls'building through evapotranspiration process: evaporation from the soil media and transpiration from plants, result to reduce air temperature around the walls which then effect to air surrounding area. For more details of mitigation option, this paper will present two choices of mitigation strategies, greening city and urban agriculture with some example of Thailand case, especially the eastern region of Thailand.

The literature reviews found that each 10 percent vegetation able to reduce 0.6K of temperature (Theeuwes, 2012 cited in Nuruzzaman, 2015). The reducing of temperature is a process called evapotranspiration which is a process that help reduce air temperatures of surrounding area by plants release water to the surrounding air, dissolving ambient heat. Nuruzzaman, Md. (2015) mentioned that roof in the cities represent about 21% to 26% of the city area, so if the roof is made green by vegetating, it will act a major role in mitigating the UHI effect. Besides that, green walls can absorb heat and gas in the air which make temperature cool down both indoor and outdoor temperature, also providing a more beautiful looking space, helping to refreshing the environment and a healthier air quality, there are two primary types of green wall: the green façade, walls that are covered with climbing plants or cascading vegetation; and the living wall, bio-walls or vertical garden (Yeh, n.d.).

Urban forest function as the dynamic function includes, biochemical cycles, gas exchange, primary productivity and regeneration, as McPherson (2006) cited that urban forests improve air quality, absorb rainwater, improve biodiversity and potentially allow recycling to 20% of waste which is wood-based. The survey of Puntipha and Kritaporn (2009) on open space in Silom Road, Bangkok, confirms that the characteristics of the open space can reduce heat in downtown. The open space in the eastern region is plenty as there are many vacant lands in the city as well as the rural area.

Typically, urban agriculture applies intensive production methods, frequently using and reusing natural resources and urban wastes, to yield a diverse array of land-, water-, and air-based fauna and flora, contributing to the food security, health, livelihood, and environment of the individual, household, and community (Ratta and Nasr, 2001). In short, urban agriculture, urban farming, or urban gardening is the practice of cultivating, processing, and

distributing food in or around a village, town, or city (Bailkey and Nasr, 2000), which make people in city more direct access to fresh fruits, vegetables and meat products, which guarantee for food safety and food security to the costumer, so the agricultural plots within the city and suburbs, is approach for how to reduce the distance of food to delivery from field to city, and it can be done by both private/small scale farming sites and larger scale agriculture.
There are many social benefits from urban agricultural practices, such as improved overall social and emotional well-being, improved health and nutrition, increased income, employment, food security within the household, and community social life. Also, urban gardens are thought to be relaxing and calming, and offer a space of retreat in densely populated urban areas. (Wakefield *et al.*, 2007). Creating a community-based infrastructure for urban agriculture means establishing local systems to grow and process food and transfer it from farmer (producer) to consumer (Boeing, 2016). Bangkok is located of many urban agriculture, there are many projects was initiated to serve the environmental needs of the city, and it quickly illustrated the positive side effects of urban agriculture (Fraser, 2002).

People move to urban areas for working, living and settlement, results in a growing of buildings and activities, these situations can lead to phenomenon call 'Heat island' or 'Urban Heat Island'. Population in the eastern region is increasing during the industrialization, people come from around country for job opportunity, urban also is expanded. People also come to city for finding more advance technology, modernize and convenience ways of life. Buildings and activities in the eastern region is more increasing, temperature of these area is higher than surrounding area, consistent with the reduction of tree, water source and green area, heat absorption of building (tall building and concrete building), consuming and burning of energy from car and industrial process, increasing of suspended in the air which it absorbs heat. The heat also released from the air conditioner of building. Industrial plants, infrastructure (e.g. roads) and other heat sources in the cities and industrial estate/plant also contribute heat to possible the heat island phenomenon.

The UHI in the region related to the climate trends, urban form and the large amount of industrial land use of the region. The effected of UHI with extreme heat during the day is considered that effected to health risk of people in the area. Currently, the eastern region of Thailand is facing with UHI phenomenon which affected from heat that generated from urban and industrial area. To mitigate its effect, there are many strategy choices, the small-scale mitigation can be a greening city: green roof, green wall, shade tree, urban forest, however each option have its limitation, such as shade trees can be used where there is enough space in house yard or public space, so there may not be

enough space in a land property to plant a shade tree, also planting shade trees comprise some sort of maintenances cost, moreover sometime big trees with less of maintenances can cause some threat to human life, so before operate this option, carefully considering all possible situation. So, the city or municipality should develop their own key performance indicators for developing their own a management tool and guidance for operate mitigation strategy.

In the other hands, greening city option is not enough for solving the problem there are another concept which cited as sustainable approach, namely 'Greening of City'. The greening of city does not mean only plants a tree in the city but also associate with concepts that focused on sustainability, so greening of city associate with 'sustainable city' or 'eco-city' approaches, so there are many activities practiced around the world to reduce the impact of environmental problem, for example, there are many cities that promote on reduce the heat with concepts that reduce the need for air conditioners which have a massive energy demand, such increasing of water features and green spaces (e.g. green roof, green wall) on urban landscape lightening of surface colors, using high albedo roof.

The greening of cities will require some, or preferably all, of the following: (i) reduction of chemical and physical hazards, (ii) control over environmental impacts on health, (iii) creation of quality environments for all, (iv) minimized ecological footprints outside the urban area, (v) ensured sustainable consumption, and (vi) adaptation to climate change impacts (Satterthwaite, 1997 cited in Lindfield, Michael and Florian Steinberg, 2012). Consequently, there are many means practicing for greening of city, for instance, to avoid the creation of UHI, changing mode of transportation is need, as well as improving public transportation and increasing sustainable mode of transportation to reduce car emissions e.g. bike or walk by increasing bike lane and pedestrianized. In addition, an encouraging sustainable local businesses development by re-planning city for integrated business and residential zones to minimize cost of transportation is another choice, this include optimal building density while expanding open space and make affordable public transportation. Furthermore, there are options such as zero-energy building, energy conservation systems/devices, renewable energy sources (e.g. wind turbines, solar panels, or bio-gas created from sewage), sustainable urban drainage systems, garden and landscape design for water conservation, expanding recycling, reducing waste and so on. Moreover, urban planning can play an important role in the mitigation of the UHI effect. Planning build the buildings in such a way that wind path which allow airflow, as well as planning for preparing a sufficient amount of free space and channel to circulate the wind, this will help to minimize the effect of the heat of urban.

Management challenges for implementation of mitigation strategy is how to maintaining a tree and planting site inventory, quantifying and maximizing the benefits of trees, minimizing costs, obtaining and maintaining public supports, participation and funding, also enforce in laws and policies that related to trees on public and on private land. To achieve this, it is needed to get participatory and supportive from both private and public sectors.

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