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Effects of Agricultural Suburb on Urban Heat Island of Bangkok Metropolitan City, Thailand

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Abstract: *Bangkok metropolitan city is facing with urban heat island problem due to a huge of human activities and changes of urban composition and configuration occurred in the city. Preliminary observation of land surface temperature during past recent year found that land surface temperature trends to increase in suburban area in some seasonal, especially agriculture area. The purpose of this study is to explore the abnormal phenomena of land thermal pollution (LTP) on agricultural suburb with normalizes deferent vegetation index (NDVI) and LST methods. We analyzed seasonal variation in spatial patterns of LPT in the cold and dry season of Bangkok and vicinity. Temporal variation in distribution and magnitude of LST was also studied and analyzed with respect to paddy cover practices using Landsat 8 data in 2016. The 73.84% of NDVI values were more than 0.5, which lead to 100 % of vegetation in cold season and the highest NDVI value was recorded at 0.75 on paddy field. The LST interval was observed approximate 25-26 ℃ that was less than LST of urban zone (33-34℃). On the other hand, NDVI values of dry season were more than 0.5 founded only 26.26%. NDVI intervals were observed approximate 0.01 - 0.29 on bare soil cover. LST interval was observed approximate 40 -41 ℃ that was more than LST of urban zone (32-33℃).From field investigation, it founded the maximum LST was in the paddy fields (left fallow land). The land preparation of rice cultivation by burning straw and weed cover in dry season was able to emit heat and contribute to the accumulation of heat. The results of this study were the same trend to found in fallow land or bare soil of paddy field patch.*

Keywords: *Land surface temperature (LST), Land thermal pollution (LTP), NDVI, Paddy field, Left fallow land*

1. Introduction

An urban heat island (UHI) refers to the elevated temperatures in a developed area compared to more rural surroundings. Researchers has been interested in understanding the various aspects of this phenomenon including its causes (Huang et al., 2011), impacts (Imhoff et al., 2010) and complexity (Mirzaei and Haghighat, 2010). Additionally, UHI has the tendency to elevate heat wave intensities as observed in case of Chicago in 1995, Russia in 2003 (Sailor and Lu, 2004), Delhi, India in 2014 (Sharma et al., 2014), Shanghai, and Beijing, China (Chen et al., 2014) and recently in Bangkok, Thailand. From our preliminary observation of land surface temperature (LST), it is increasingly gaining interest as we found an abnormal phenomenon of land thermal pollution (LTP), especially suburban area of Bangkok metropolitan city. The observation of land surface temperature during past recent year showed that land surface temperature trends to increase on left fallow fields of paddy practices in agriculture area on dry season (April 2016). In constant, land surface temperature trends to decrease on built up area in cold season (February 2015). The objective of this study was to explore the abnormal phenomena of land thermal pollution (LTP) on agricultural suburb areas at the east side of Bangkok with normalizes deferent vegetation index (NDVI) and LST methods by analyzing Landsat 8 OLI satellite imagery during 2015-2016. This result of this study may be useful for managing urban composition and urban configuration planning in the future.

1.1. Study Area

Bangkok is the capital of Thailand~~,~~ with an estimated population in excess of 10 million people in its 1,576 sq.km area. Bangkok Metropolitan has divided into three zones, inner, middle, and outer zone, in accordance with the population density. In detail, Bangkok is subdivided into 50 districts (Department of Provincial Administration, Thailand, 2013). The study area was agricultural suburb areas in Nongchok, Latkrabang, Minburi and Khongsamwa District located in the eastern part of Bangkok as shown in Fig 1.

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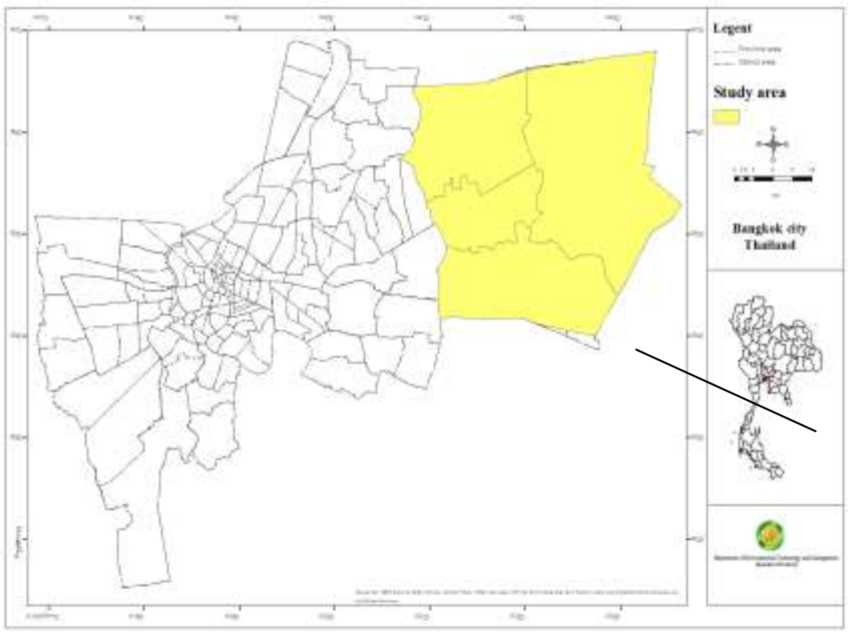

Fig. 1: Location of study area.

2. Methodology

2.1. Image and Image Pre-Processing for Land Cover and LST

In this study, we used the images taken by Landsat 8 OLI (Operational land imager), a medium resolution (30 m and 120 m). The data comprises of 12 bands, 2 – 5 bands of which are located in visible and near infrared regions (0.452–0.879 µm) and one band (Band 10) is thermal (10.60–11.19 µm). This band is widely used to measure seasonal land surface temperatures. Landsat 8 OLI images were downloaded from USGS website (http://glovis.usgs.gov/). The data was selected carefully to cover all the seasons and should preferably be cloud-free images. Land cover data was retrieved from visible band using supervises classification method (minimum-distance algorithm).

The LST was retrieved from the thermal Band (band 10). LST data were calculated by using USGS method obtained in three steps (USGS, 2016) At first, the image digital numbers were converted to radiance values as shown in Eq. (1)

$$L_{\lambda} = M_L \, Q_{Cal} + A_L \tag{1}$$

In our retrieval, $L\lambda$ is the wave- radiation value (Watts/ (m2 * srad * µm)) ; *ML is* radiance –multi-band 10 = 0.0003342; *QCal* is the Quantized and calibrated standard product pixel values (DN) and *AL* is radiance –add-band10 = 0.1. Secondly, the calculated radiance values were converted to effective satellite temperature in Kelvin (TB) by applying the inverse of the Planck function as shown in Eq. (2)

$$Tk = K_2 / (alog\,(K_1/Radiance\ (band\ 10)+1)) \tag{2}$$

Where K_1 and K_2 are pre-launch calibration constants (K_1 = 774.89, K_2 = 1321.08) and *Radiance (band 10)* is the spectral radiance of the sensor. Finally, the calculated temperature values in Kelvin were converted to Celsius degrees by using Eq. (3) for the clarity in data interpretation.

$$Tc= Tk-273 \tag{3}$$

The LSTs of Bangkok city computed using the Landsat 8 OLI were classified in to 2 seasons for identifying the LST distribution pattern in the agricultural suburb. The highest temperature values assigned with red colour indicates the regions where higher LST are accumulated. The lowest temperature assigned with blue colour indicates the sea and water bodies.

2.2. Image and Image Pre-Processing for NDVI

The vegetation cover of Bangkok city area was analyzed using 'Normalized Difference Vegetation Index' (NDVI) method. Visible light in the wavelength range of 400–700 nm. is strongly absorbed by chlorophyll in plant cells, in order to carryout photosynthetic reactions. Conversely, Near Infrared (NIR) light in the wavelength range 700–1100 nm. is strongly reflected by cell structures in green leaves, because absorption of NIR can damage the plant tissues by overheating. Due to this differential absorption and reflection of radiation, plants appear dark in visible range of the spectrum while they appear bright in the NIR wavelength range (Gates, 1980).

Water bodies tend to absorb NIR radiation stronger than absorption of visible radiation and hence appear brighter in visible range than the NIR region. Bare soil and other features such as buildings absorb and reflect both visible and NIR radiation equally and hence appear similar in both visible range and NIR range. (Senanayake et al., 2013)

This discrepancy between the absorption and reflection characteristics of various features in visible and NIR radiation is used to distinguish between these features, namely vegetation cover, bare soil and water bodies (Gates, 1980 in Senanayake et al., 2013). NDVI values were calculated following the equation as shown in Eq. (4) (Goward et al., 1985)

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

Where ρNIR and ρRed are the radiance in reflectance units of NIR and RED bands respectively. NDVI values range from -1 to +1. Water bodies tend to have minus NDVI values. Bare ground usually exhibits NDVI values close to 0, whereas green vegetation exhibits NDVI values close to +1.

The NDVI layers of agricultural suburb area were generated from the data in 2016.~~,~~ Subsequently, the layers were classified to extract the vegetation cover of agricultural suburb using appropriate break values. The extracted vegetation cover layers were spatially verified by visual comparison with the natural colour composites of the relevant Landsat 8 OLI used in the study.

3. Results and discussions

3.1. Identifying the Abnormal Phenomena of LTP Patterns

Land cover data was retrieved from visible band using supervises classification method (minimum-distance algorithm). The results of land cover and the description are summarized in table I.

TABLE I: Summary of land cover category and details for identifying seasonal LST for year 2015 -2016.

Category	Area (%)	Description
Water body	10.5	An area of river ,canal ,pond, fish or shrimp farm
Crop	39.3	An area of agriculture such as rice paddy, floricultural and truck crop
Tree	5.9	An area of mangrove, chard and scrub
Bare soil	4.1	An area of abandoned paddy and area without any vegetation or scrub cover
Built-up	40.3	Urban area that has a cover of buildings or pavement and communication
Total	100	

Land surface temperature (LST) images were studied to analyze spatial patterns of LST through two seasons of Thailand; cold season (February 2015) and dry season (April 2016). The Fig 2 shows the LST distribution pattern for each season. Cold season showed the lowest LST values of crop (paddy fields), descriptive statistic of LST whereas the highest LST values were observed on built up area. All hot spots in cold season were located in built-up areas. In constant, a detailed analysis of dry season revealed that the high LSTs were in paddy field where left fallow. The highest LST (41.13 ℃) was recorded for dry season on paddy field where heat of left fallow land was very high and most of the agricultural fields in Nongchok district. On the other hand, Srivanit (2011) reported that the phenomenon of urban heat island in Bangkok was stronger in the city than in the rural areas and there was a relationship between urban composition and configuration. We extracted the hot spot of the land thermal pollution as shown in Fig. 2. The 62.5 % of the hot spot were located in paddy field area. Field investigations exhibited that these hot spots were not paddy cover practices but they were left fallow and bare soil. It was probably occurred from the direct releases of heat from soil. Related results were found by by Sharma and Joshi., 2014; Bunyantuyev and Wu., 2010 in built-up areas for Phoenix and Delhi city, where left fallow land appeared to be heat island while urban or built up and pavement area appeared to be cool island sites. In addition, the 37.5 % of the hot spot were located in built-up areas, which was less than some other large cities (e.g., Shanghai and Beijing) (Wu et al., 2014)

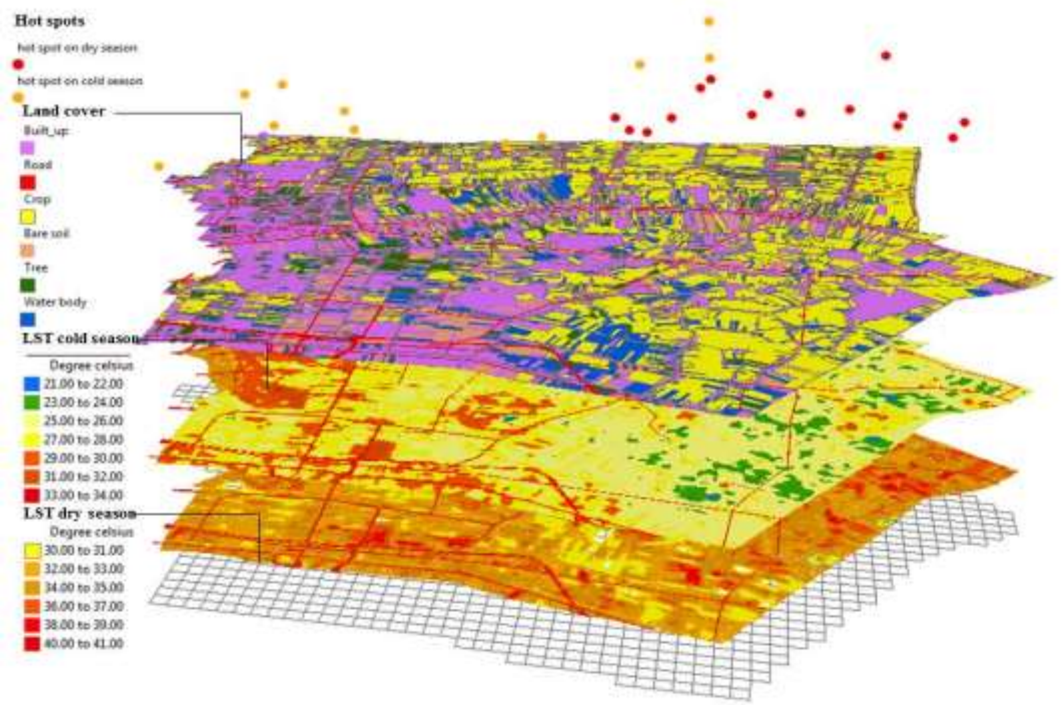

Fig. 2: Abnormal phenomena of land thermal pollution on cold and dry season.

NDVI values indicating vegetation cover on land thermal pollution at the class are show in the Fig 3. NDVI ranges of agriculture suburb area were -0.19 to 0.75 for cold season and -0.12 to 0.71 for dry season. The 73.84 % of NDVI values were more than 0.5 which lead to 100 % of vegetation (Chen et al., 2006; Liet al., 2011) in cold season and the highest NDVI value was recorded at 0.75 on paddy field. The LST interval was observed approximate 25-26 ℃ that was less than LST of built up zone (33-34℃). On the other hand, NDVI values of dry season were more than 0.5 founded only 26.26%. NDVI intervals were observed approximate 0.01 - 0.29 on bare soil cover. LST interval was observed approximate 40 - 41 ℃ that was more than LST of built up zone (32-33℃). From field investigation, it founded the maximum LST was in the paddy fields (left fallow land). The land preparation of rice cultivation by burning straw and weed cover in dry season was able to emit heat and contribute to the accumulation of heat. The results of this study were the same trend to found in fallow land or bare soil of paddy field patch.

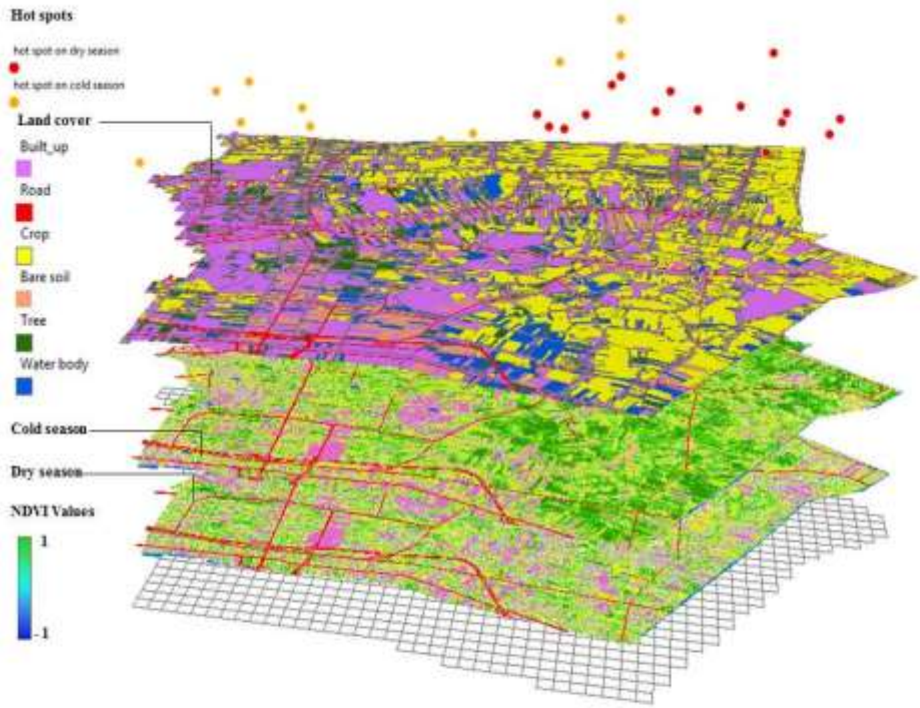

Fig. 3: NDVI distribution in land thermal pollution on cold and dry season

For each image, thermal infrared mean was computed, which was used as an indicator of LST distribution. (Sharma et al., 2014) The higher LST value (hot spot) was the abnormal of land thermal pollution (LPT). The spatial shifts in LPT were observed over dry seasons which are attributed to different agricultural area, changes in removal vegetation of paddy. In addition, we focused on composition of LPT on dry season for random grid scale sampling.

3.2. Identifying Land Cover Composition for The Abnormal Phenomena Of LTP

The locations of the measuring stations were selected on the hot spots follows as Fig. 4. The hot spots of appropriate location in agricultural areas were randomly chosen. With respecting to the LTP, eight stations were calculated land cover compositions, LST and NDVI percentage. The analysis was taken for only dry season. The land cover composition used for the calculation is: built up ,crop ,bare soil, tree and water body. The summary of land cover composition in each hotspot is shown in table II.

Almost hotspot centers were located on agricultural practices (crop or paddy field). The highest LST mean was recorded approximate 37.02 ℃ and the NDVI mean was recorded approximate 0.31 at station 3 which was highest percentage of bare soil composition. At station 2 was recorded approximate 37.00 ℃ and the lowest NDVI mean was recorded approximate 0.25 which was the highest percentage of crop composition (paddy). From field investigation, it founded that the lowest NDVI mean was in the paddy fields (left fallow land). In constant, the lowest LST mean was recorded approximate 35.86 ℃ at station 6 which was highest percentage of built up composition. Related results were found by by Sharma and Joshi., 2014; Bunyantuyev and Wu., 2010 in built-up areas of Phoenix and Delhi city, where appeared to be cool surface in building area. The urban morphology, especially medium and high building can create shade, and reduce solar radiation and LST on dry season (EPA. 2009).

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TABLE II: SUMMARY OF land covers composition for the abnormal phenomena of LTP

Station 1	**Composition%**	**LST**	**NDVI mean**	**Station 5**	**Composition%**	**LST mean**	**NDVI mean**
Water body	5.05	Mean 36.56	Mean 0.33	Water body	4.25	Mean 36.76	Mean 0.36
Crop	14.69	SD 1.40	SD 0.12	Crop	33.48	SD 1.30	SD 0.10
Tree	0.00			Tree	10.27		
Bare soil	31.87			Bare soil	0.00		
Built-up	48.38			Built-up	52.00		
Total	100			Total	100		
Station 2	**Composition%**	**LST mean**	**NDVI mean**	**Station 6**	**Composition%**	**LST mean**	**NDVI mean**
Water body	4.63	Mean 37.00	Mean 0.25	Water body	4.42	Mean 35.86	Mean 0.33
Crop	92.06	SD 1.49	SD 0.09	Crop	18.86	SD 2.25	SD 0.13
Tree	0.00			Tree	12.42		
Bare soil	0.00			Bare soil	0.00		
Built-up	3.31			Built-up	64.31		
Total	100			Total	100		
Station 3	**Composition%**	**LST mean**	**NDVI mean**	**Station 7**	**Composition%**	**LST mean**	**NDVI mean**
Water body	1.77	Mean 37.02	Mean 0.31	Water body	0.00	Mean 36.35	Mean 0.32
Crop	16.35	SD 1.73	SD 0.10	Crop	58.81	SD 1.50	SD 0.10
Tree	1.01			Tree	0.00		
Bare soil	57.11			Bare soil	0.00		
Built-up	23.76			Built-up	41.19		
Total	100			Total	100		
Station 4	**Composition%**	**LST mean**	**NDVI mean**	**Station 8**	**Composition%**	**LST mean**	**NDVI mean**
Water body	0.6	Mean 36.75	Mean 0.25	Water body	2.95	Mean 36.56	Mean 0.34
Crop	99.1	SD 1.59	SD 0.11	Crop	67.39	SD 2.24	SD 0.08
Tree	0.0			Tree	21.87		
Bare soil	0.0			Bare soil	0.00		
Built-up	0.3			Built-up	7.79		
Total	100			Total	100		

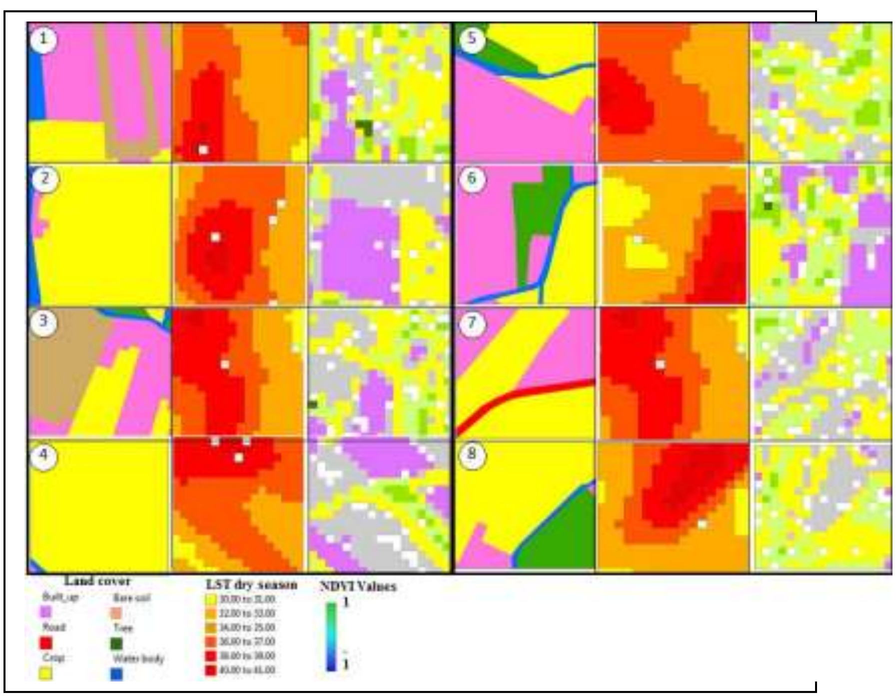

Fig. 4: Stations for measure land cover composition on land thermal pollution and NDVI values

4. Conclusion

This study was to explore the abnormal phenomena of land thermal pollution (LTP) on agricultural suburb with normalizes deferent vegetation index (NDVI) and LST methods. We found seasonal variation in spatial patterns of LPT in the cold and dry season of Bangkok and vicinity. Temporal variation in distribution and magnitude of LST was also studied and analyzed with respect to paddy cover practices where left fallow land or bare soil. The result of LTP on dry season showed that the agricultural area (paddy field) exhibited higher LST than built up area as compared to same period of time. In some instances, LTP on cold season showed LST on the built up area were higher than on paddy cover practices or bare soil as compared to same time. The LST of cold season appeared to be cool surface in building area, where urban morphology, especially medium and high building can create shade, reducing solar radiation and LST on dry season. In addition, NDVI of agricultural suburb showed 73.84% of NDVI values were more than 0.5, which lead to 100 % of vegetation in cold season and the highest NDVI value was recorded at 0.75 on paddy field. On the other hand, NDVI values of dry season were more than 0.5 founded only 26.26%. NDVI interval was observed approximate 0.01 - 0.29 on bare soil cover or felt fallow.

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