A001

Comparative Study on the changing Surface Energy Balance over Urban, Sub-urban and Natural Forest site in Tropical, Central Thailand

Parkin Maskulrath[a], Surat Bualert[b], Kasem Chunkao[a,b] and Thanit Pattamapitoon[a,b]

[a]*The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Chaipattana Foundation, Thailand*
[b]*Department of Environmental Science, Faculty of Environment, Kasetsart University, Bangkok, Thailand*
Correspondence to Mr. Parkin Maskulrath
The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Bangkok, 10900 Thailand Tel +6689-506-5608 E-mail: parkin.sea@gmail.com

Abstract

Increasing global in the temperature can be consider the reflection of the changes in the urban climate scheme, the background principles of these impacts are seen through the changes in land uses in which they occupy the changes in the overall energy balance of incoming and outgoing radiation, this can be refer to as the concept of Urban Heat Islands (UHI). From the systems concept, the UHI is controlled by the exchanges of energy between the surface and the atmosphere as surface structure, both nature and humans built are what controls these energy exchanges.

This study shows the comparison of the all the 3 sites that represented by the 1) Urban Forest (Bangkajao Urban Park), 2) Urban city (Kasetsart University) and 3) The Natural Mangrove Forest (LERD Project) that conveys on the differences in the changes of land-use towards the ratio of energy balance that are in division of the 3 major energy fluxes that is Latent, sensible and heat to ground. The measurement at all the sites were taken by the Campbell scientific IRGASON eddy covariance system that generated the Energy balance fluxes measurement.

The results depicted by the 3 locations with different land use and cover shows a different aspect in the ratio towards the consumptions of the energy balance equation. With the LERD project which is covered with the dense population of mangroves and water body being the gulf of Thailand is dominated by the amount of latent heat at 41% to 22 and 29% of the KU tower and the Bankajao Green Urban area. The KU tower on the other hand, is located in the denser urban areas of the city of Bangkok shows a domination of the sensible heat flux with 39% while the transfer for energy into (H) in the LERD project and Bangkajao was 17 and 26% respectively. With the Urban Forest of Bangkajao and the mangroves forest of the LERD project the (G) or the heat to ground within the two sites shows a similar comparison with 29 and 31% however, having the tick concrete and asphalt ground layers the storage of heat into the ground at the KU tower is lower with only 12%.

Keywords: Surface Energy Balance, Latent Heat, Sensible Heat, Urban Energy Balance.

1. Introduction

In short, in making cooler urban cities, understanding the science and nature of how the world works can be achieve through the understanding the surface energy balance and its processes. In first understanding, it is clear that the trends of urbanization have given the rise of the urban population and migration into cities. Through the fast and rapid development and commercialization (Driving forces), citizens of major cities around the world are able search for better livelihood and wellbeing in terms of providing them with the basic needs (health, warmth, resources, security) have become unmanageably and arguably large and expensive place to live, as many migrants from the rural areas are moving into the city in search for job due to its increasing economy and opportunities for a better livelihood. As for the definition of the developing country, their "driving forces" are often generated by having the ability to develop rural and urban economies, the development of the city also helps reduce congestion and improve quality of life and their primary goals of acerbating in both political and economy development. The key component of the strategies falls within the development of their capital with average 50% increase in their population in the past 50 years.

Extrapolating the major arising issue, the concept of urban heat island has come to the topic of environmental interest since the early 1970's, with urban climatologist trying to take grasp of the concept and the quantified, with scientific explanations on how why the urban cities are becoming more warmer than its rural despite its relative's geographical location. With explanation of different studies that includes the study of mean annual temperatures, power usage, land use mapping and urban fabrics (building, roads and green areas) that were being applied for quantifying the excess heat pollution, the best and most well-equipped methods can be consider as the energy balanced method or in this case the surface energy balanced equation. The surface energy balance (SEB) framework developed by Oke (1988) for urban areas applies to a control volume from the ground to the top of the urban canopy layer (UCL, Oke 1976)

$$0 = (Rsu\text{-}Rsd) + (Rlu\text{-}Rld) + Ph + LE + H + M + G \qquad (1)$$

Where Q∗ (Rsu-Rsd) + (Rlu-Rld)), LE and H are respectively, the net all-wave radiation, the turbulent sensible heat and latent heat fluxes at the top of the control volume. G or the heat to ground, while M being the metabolism of living organism within the measurement boundary. However, further development of the energy balance equation has enabled scientist to understand the flow of energy in our environmental system (Oke 2019). with development of the equation in order achieve for the more realistic application to the heat circulating within our urban boundary layer often requires addition factors that are the involvement of the additional input of energy call "Anthropogenic heat" (Qf). Define as a heat sourcing from human's activities that contributes to the Urban metabolism which are the injections into the urban atmosphere through the release of waste by-products (heat, liquid water, water vapor, pollutants), through fuel combustion, manufacturing, irrigation, construction, etc. The magnitude of those injections varies according to human activity cycles (time, day of week, seasonal, cultural practice, technology) (Middel and Krayenhoff 2019). While it was also seen that the impacts from the heat generated have allow for the growing heat that are stored within the area to also increased. In order to fully understand the movement of energy movement in both a static and dynamics environment and to express of the energy balance in its different heat fluxes. It has been widely accepted that was the applications and used of an ultrasonic 3-dimensional anemometer is used. (Ichinose, Shimodozono et al. 1999)

$$(Rsu\text{-}Rsd) + (Rlu\text{-}Rld) \neq Ph + LE + H + M + G + Qf \qquad (2)$$

Altogether, the examination of this paper is to establish the in-depth knowledge on the problem which is, urban cities are becoming warming, as thus in defining such claims, the scientific

knowledge of the surface energy balance must be fully understand as thus in making management and mitigation measures will be more complete.

2. Method and Materials

2.1 Eddies Co-variance System:

The system of the open-path eddies covariance (EC) has been used to measure momentum, heat, water vapor, and water vapor and carbon dioxide exchanges fluxes between the biosphere and the atmosphere across a diverse range of climates and ecotypes, as this is done in the 3 dimensional format (T, Eugster, & Ojala, 2012). The uses of the Eddies co-variance are then able to extrapolate the heat/energy balance within an area as its unit for energy is outputted into a flux measure of space and time (Watts/meter^2). In this research the placement of the eddies co-variance system will be placed on the 15.0-meter height mangroves lookout tower located 450 meters into the mangroves forest walk way and the KU tower in Bangkok, Thailand at 15meters above ground level. The placement of the equipment following the methods as is presented by Campbell Scientific. Inc.

In the placement of each equipment, the EC system was then place within the height of 15 meters at the LERD Project Mangroves Forest, 30 meters at the KU tower and 2 meters at the Bangkajao site, respectively.

Lastly, the data analysis was then calculated in the normalization method in which the calculation of the flux contribution was made as thus the landcover within the range of the EC system were accounted for the require land use in each of the sites.

Figure 1 The Eddie co-variance

2.2 Site Study

In generating the different and in the comparison of the land use area, the site of study was selected base on the differences of the land cover where the 2 sites were that of

Urban Site: The KU tower located in the Bangkok at Kasetsart university
the Urban Green area (Bangkajao) located in the City of Bangkok
the Natural Forest Site (LERD) Project located in the Phetchaburi Province have mangroves being the dominate land cover

Figure 2 Sites of Study

2.3 Data Collection

The Process of the data collection are made with the monitoring was taken every 30minuites from 28th of August to the 11th of September, 2020 (14 days).

The Data set in the mangroves that was collected can be separated into 2 major parts where the energy (radiation), wind, gas and temperature are measured with the eddies-covariance system. While the ground surface temperature was measured by the temperature probe. Whilst comparing the LERD project data site representing the forested environment, the KU tower site location was the representative of the urban setting as in this urban site, only the eddies-covariance system was applied.

While in the two other site the Bangkok and the KU tower, the collection time as also place into two weeks with the data being located in January 14 till 28th 2021 (14 Days average).

3. Results and Discussion:

In defining the in-depth analysis of the philosophy of the how the heat waste emission is being generated, all in all the application with the different land use (structure) to provide with the different functions of the area can be explain with the 3 examples location that is depicted towards the ratio of the different division of heat being generated.

In comparison of the all the 3 sites, the measurement taken with the Campbell scientific IRGASON with the surface boundary layers is seen that in the usage of the main components of the heat being generated from the Energy balance closure of eddy-covariance measurements, as is suggested with the heat flux measurement that is define by, pie chart in figure 3

It is seen that the 3 locations with different land use and cover shows a different aspect in the ratio towards the consumptions of the energy balance equation. With the LERD project which is covered with the dense population of mangroves and water body being the gulf of Thailand is dominated by the amount of latent heat at 41% to 22 and 29% of the LU tower and the Bankajao Green Urban area. The KU tower on the other hand, is located in the denser urban areas of the city of Bangkok shows a domination of the sensible heat flux with 39% while the transfer for energy into (H) in the LERD project and Bangkajao was 17 and 26% respectively. With the Urban Forest of Bangkajao and the mangroves forest of the LERD project the (G) or the heat to ground within the two sites shows a similar comparison with 29 and 31% however, having the tick concrete and asphalt ground layers the storage of heat into the ground at the KU tower is lower with only 12%.

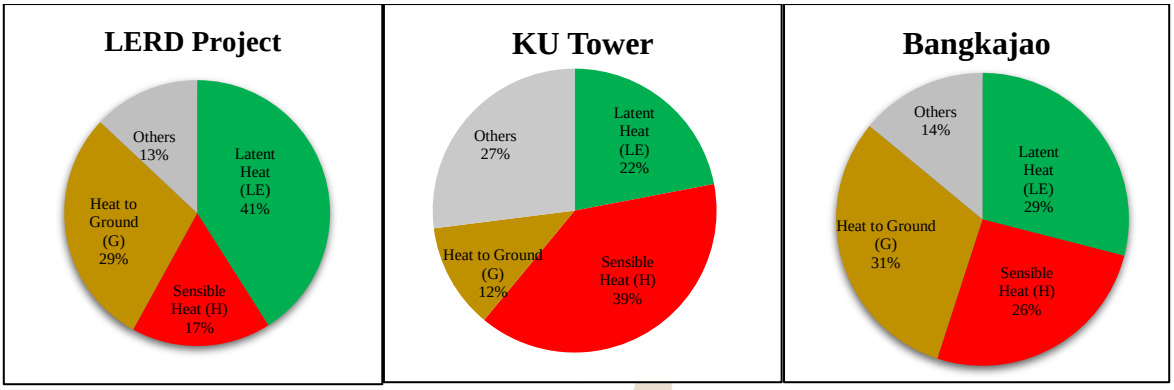

Figure 3 Energy Balance ratio

While to further putting the knowledge, the land used map with the energy balance was made to show the land use classification of the location. The comparison of the energy balance closure method was use in respect with the percentage of the area.

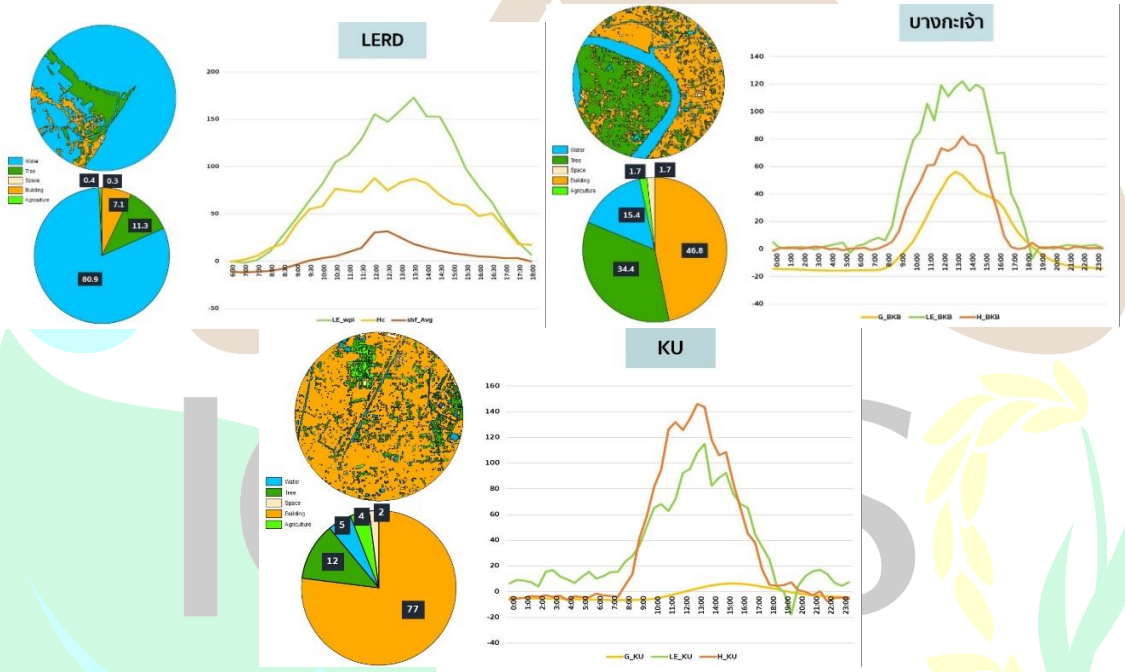

Figure 4 Land use and Energy Balance fluxes

Extrapolating the land use classification, the division of these maps to the ratio of the energy used is through the made into 5 different class with water, green areas, roads, buildings and open area (bare soils). Where from this the ratio can then be properly explained, whereas with the LERD Project, it was seen that over 70% of the land cover was made with variation in which the eddy co variance system was place. From this the measurement that has been taken place shows that the Latent heat used in the process of evaporation is the dominant energy within the area.

At Bangkajao on the other hand, the site was established with the high levels of green area as this consuming about 35% of all the land use while as this it's urban environment these green areas are also surrounded by the urban core located to the north and east of the location. Thus, that with this green area, the emphasis here is then taken into consideration that in order to have a proper function and structural green space, the needs for vegetation, soils and water are what

is required. As so, again like Bangkajao as a case example the green space allows for such arising portion of the energy balance equation to be occupied within the measurement site.
Lastly, the KU tower, in which the land use around the measurement was taken is surround by all anthropogenic sources, whereas from the classification over 90% of the surrounding areas are roads and buildings. Thus, mentioned with the properties of concrete and man-made materials, the thermal conductivity is very high while as well as through the process of energy consumptions that would generate the positive feedback that would allow for more energy to be used with the cooling system as this would provide the output of energy into making coolers indoor temperatures.
The "other" in the pie change can also be a representation of the addition of heat under the Energy Balance Closure (EBC), as studies have shown that these emissions are the sources of the anthropogenic heat source emission, beside the sun solar and longwave reradiation from the earth.
While in placing this into the simpler explanation with the high sensible heat fraction in the urban areas, it was seen with the average temperatures during the day (*Shortwave down >30W/m2), where at the KU tower the average temperature was 34.23 °C while at the LERD Project and the Bangkajao Urban green area was at 33.84 °C 32.03 °C respectively.
While in connecting with the 25 years average data, the changes that was made with the city of Bangkok is through the changes in the structure of the city as the increase in the urban population has been at 2% per year, the urban structure would then have to be increase as the expansion would then result in higher sensible heat flux.

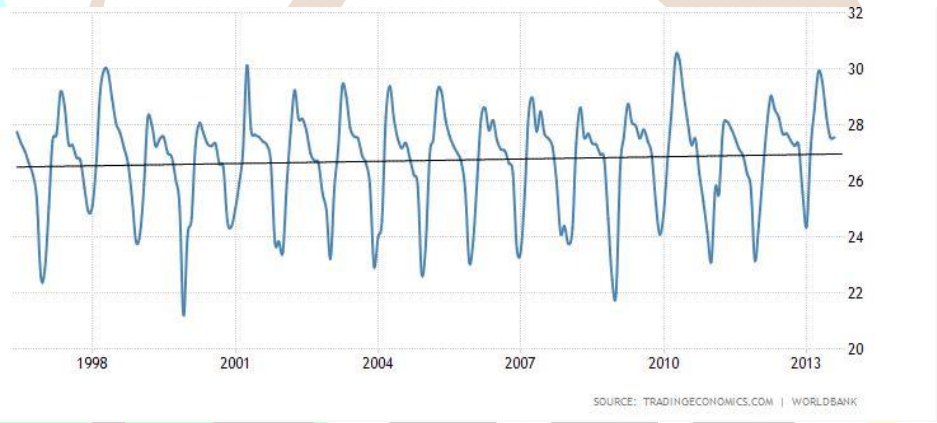

Figure 5 Bangkok average temperature (25 years)

Furthering the connections with the philosophy, the study from Alonkorn, 2014 has shown this difference in the land use classification towards the Bowen ratio. Having seen that the increase in green area is related to the increasing percentage of latent heat flux within the energy balance, the conclusion of the study suggested at least 20% of the green area within the urban city site would allow for the compensation of the appropriate Bowen ratio to counter for the changes in the sensible and latent heat flux within the Bangkok urban area.
Again, this was seen with the sensible heat flux that was taken with the KU tower results in the past 4 years, where the seasonal variation is in effect with the humidity and vapor air pressure within the ambient air. Suggested that during the rainy seasons the levels of vapor air pressure and humidity rises, the increase in latent heat flux also rises, while the opposite is shown during the summer months.

4. Conclusion

The understanding in the roles and the science of the energy balance equation would help explain on the division of energy into H LE and G. while further studies have shown that the

impacts on the anthropogenic heat fluxes, in broad perspective there are two sets of urban features that modify the urban atmosphere: 1) Those related to changes in surface properties and 2) those due to anthropogenic emissions in altering of the positive feedback to generated more heat. Where from the calculated energy flux differences between the KU tower (urban) and LERD Project (Forested) and Bangkajao it was seen that in generating the green areas to compensate and designing with the urban can help the production of sensible heat as thus would allow for the inputted energy into the system dominate itself with the latent heat instead.
Thus, as the suggested mitigating the forces of these fluxes. The application of the aspect ratio of buildings, green area patches place and building materials can be the suggested urban movement that help tropical mega cities like Bangkok to mitigate their local short- and long-term climate impacts and to sustain the well-being of the population.

5. Acknowledgements

This study was funded by the King's Royally Initiated Laem Pak Bia Environmental Research and Development Project (LERD) together with the support of the "Monitoring of Microclimate and Air Pollution in Thailand" project of the Hydro and Agro Information Institute (HAII), Thailand and the Faculty of Environment, Kasetsart University, Bangkok, Thailand.

6. Reference

Ashrafuzzaman, M., & Furini, G. L. (2019). Climate change and human health linkages in the context of globalization: An overview from global to southwestern coastal region of Bangladesh. *Environment International, 127,* 402-411. doi:https://doi.org/10.1016/j.envint.2019.03.020

Christen, A., Coops, N., Crawford, B., Kellett, R., Liss, K., Oke, T., & Olchovski, I. (2010). *Comparing an urban metabolism model to long-term CO2 eddy-covariance measurements*.

Giambellucaa, T. W., Foxb, J., Yarnasarnc, S., Onibutrc, P., & Nulleta, M. A. (1999). *Dry-season radiation balance of land covers replacing forest in northern Thailand*.

Heusinkveld, B., Jacobs, A., Holtslag, B., & Berkowicz, S. (2004). Surface energy balance closure in an arid region: Role of soil heat flux. *Agricultural and Forest Meteorology, 122,* 21-37. doi:10.1016/j.agrformet.2003.09.005

Ichinose, T., Shimodozono, K., & Hanaki, K. (1999). Impact of anthropogenic heat on urban climate in Tokyo. *Atmospheric Environment, 33*(24), 3897-3909. doi:https://doi.org/10.1016/S1352-2310(99)00132-6

Intaraksa, A., Chunkao, K., & Bualert, S. (2014). Bowen Ratio Method for Measuring Heat Transfer on Land Cover Change in Establishing Green Patch in Urban Heat Island of Bangkok. *Modern Applied Science, 8*. doi:10.5539/mas.v8n4p158

Jitthaisong, O., Dhanmanonda, P., Chunkao, K., & Teejuntuk, S. (2012). Water Quality from Mangrove Forest: The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Phetchaburi Province, Thailand. *Modern Applied Science, 6*. doi:10.5539/mas.v6n8p1

Middel, A., & Krayenhoff, E. S. (2019). Micrometeorological determinants of pedestrian thermal exposure during record-breaking heat in Tempe, Arizona: Introducing the MaRTy observational platform. *Science of The Total Environment, 687,* 137-151. doi:https://doi.org/10.1016/j.scitotenv.2019.06.085

Nguyen, C. T., Nguyen, D. T. H., & Phan, D. K. (2020). Factors affecting urban electricity consumption: a case study in the Bangkok Metropolitan Area using an integrated approach of earth observation data and data analysis. *Environmental Science and Pollution Research*. doi:10.1007/s11356-020-09157-6

Oke, T. (2019). *Boundary layer climates / T. R. Oke*.

Oke, T., Mills, G., Christen, A., & Voogt, J. (2017). *Urban Climates*.
T, V., Eugster, W., & Ojala, A. (2012). Eddy Covariance: A Practical Guide to Measurement and Data Analysis. In (Vol. 12, pp. 365-376).
Peter John Robinson, A. H.-S. (1999). *Contemporary Climatology*.
T.W.Giambelluca, J. F., S.Yarnasarn, P.Onibutr, M.A.Nullet. (1999). Dry-season radiation balance of land covers replacing forest in northern Thailand. *Agricultural and Forest Meteorology*.
Velraj, R., Seeniraj, R. V., Hafner, B., Faber, C., & Schwarzer, K. (1999). HEAT TRANSFER ENHANCEMENT IN A LATENT HEAT STORAGE SYSTEM1Paper presented at the ISES Solar World Congress, Taejon, South Korea, 24–29 August 1997.1. *Solar Energy*, *65*(3), 171-180. doi:https://doi.org/10.1016/S0038-092X(98)00128-5