

Review Article

Reviews on the Land Use and Land Cover Changes in Bangkok

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Abstract

Remote sensing has been a highly effective and efficient method for spatial and socio-political analyses for several decades. It utilizes satellite images to map land use and land cover (LULC) and detect changes in this regard. One of Southeast Asia's megacities, Bangkok has undergone significant land use dynamics and related socioeconomic activity changes. Recently, the new Land and Buildings Tax Act B.E. 2562 (A.D. 2019) has been implemented, which could impact land-use changes, particularly in vacant lands. This study aims to review the literature on LULC changes in Bangkok since the implementation of the land tax and to provide a summary of the main findings. The reviews indicate that previous literature on LULC in Bangkok has primarily focused on environmental or spatial factors, rather than socio-economic ones. This highlights a gap in our understanding of the socio-economic and LULC impacts of land taxation.

Keywords: land use and cover, Remote-sensing, Land and Buildings Tax Act, Bangkok

1. Introduction

Bangkok, the capital city of Thailand, is located in the southern portion of the Chao Phraya River delta. Its administrative boundaries are known as the Bangkok Metropolitan Administration (BMA), and it covers an area of 1570 sq. km. The city is highly urbanized and home to around nine million people, according to a 2016 government census. Being the political and economic center of the country, it houses the grand palace and the main offices of multiple government agencies and yielded approximately five million Thai Baht for its gross provincial product in 2016. Bangkok also boasts the highest concentration of land ownership in the entire kingdom, while experiencing high LULC dynamics throughout recent years (Kamchiangta & Dhakal, 2020). As the center of economy and government in its country, it has become a focal point in long-term government plans. Thus, understanding the patterns of land use and land cover in the area is crucial (Murayama et al., 2015). These characteristics illustrate the importance of Bangkok as a city, and for these reasons, it has been selected as the study area of this research.

Recently, a new property taxation policy, known as the Land and Buildings Tax Act, B.E. 2562 (A.D. 2019), was ratified by the government. This policy may have already affected or could be affecting the land use/land cover (LULC) in the city (Limteerakul, 2021; Sridith, 2022). Limteerakul (2021) argues that increasing the tax burden could lead to a reduction in land speculation and promote more efficient land use. The implementation of the land tax may also inadvertently reduce the biodiversity from the conversion of vacant lands to agricultural lands to lower the tax rate (Sridith, 2022). However, no study has yet assessed the relationship between this law and LULC in any city in the Thailand. Therefore, further research is needed to explore this topic.

Satellite imagery is commonly used for mapping land use and land cover changes in many places, including Bangkok. According to Murayama et al. (2015), this technique has proven to be efficient, as it allows researchers to cover large spatial scales across multiple timeframes, even in the past. Many studies have been conducted using remote sensing in the Southeast Asian region in the past two decades, focusing on environmental science. Specifically, these studies have examined the relationship between land use and land cover and the Urban Heat Island (UHI) phenomenon and other environmental applications, while others focus on the dynamic of land use changes (Du et al., 2017; Estoque et al., 2017). However, there has been no review of studies using these approaches in Bangkok.

This review article aims to evaluate the methodologies used in LULC mapping and change detection studies in Bangkok to determine a suitable approach for a socio-political study related to the new land and building taxation policy in Thailand. This article provides an overview of various studies that focus on remote sensing, LULC, and their applications in environmental analysis in Bangkok. This review pertains to the publications written in English and published in international journals, found through Google Scholar using the terms “land use and land cover” or “LULC” and “Bangkok.” It details the evolution of the methodology and also highlights the gaps in the existing literature. Additionally, the investigation suggests potential pathways for future research on this topic.

2. Studies Featuring the LULC of Bangkok

2.1 The Early Years: Pre-2016

The work of Madhavan et al. (2001) can be found in the early years. They conducted a satellite remote-sensing study on the land use and land cover (LULC) changes in

the city of Bangkok, Thailand. They aimed to track the LULC dynamics of Bangkok Metropolitan Area (BMA) from 1988 to 1994 using the vegetation-impervious-soil model. The study involved classifying different LULC types such as commercial, residential, vegetation, open land and water bodies. They used the Iterative Self-Organizing Data Analysis Technique (ISODATA) and maximum likelihood algorithm for classification and Earth Resources Data Analysis System (ERDAS) matrix multiplication model for detecting the changes in land features. The results showed a significant conversion of residential lands into commercial ones, amounting to 14% increase in commercial areas, and vegetated areas into residential land uses. Overall, there was an observed (approximately) 6% increase in urban or impervious land classes in the city throughout the study years. Though no formal accuracy assessment was done, the produced maps were said to be in general agreement with Japan International Cooperation Agency (JICA)-commissioned maps and ground data. At least for the articles found in this review, it is interesting to note that it took more than half a decade for satellite images to be used again for remote-sensing studies in Bangkok, with Shao’s study in 2007 and Chayapong in 2010 to be the next bodies of research that used the said method.

The studies that follow differ in their scope and methodology, but they all focus on discussing land use patterns in the city, without relying on satellite imagery. Murakami et al. (2005), for example, employed pre-fabricated land use maps provided by government agencies to identify urbanization trends in Southeast Asian megacities (namely Bangkok, Jakarta, and Manila) using the Clark and Newling models. Meanwhile, Hara et al. (2005) focused on a specific area on the southern outskirts of Bangkok. They used aerial photographs that were verified through field surveys to identify eleven land use classes based on man-made structures and functionalities. In contrast, Murakami et al. (2005) identified only three land use classes. Hara et al. (2005), in their focused and context-specific study, found that the elevation and agricultural history of Bangkok influenced the land use of the studied area at that time. On the other hand, Murakami et al. (2005) identified mixed land use “belts” or fully surrounding zones of mixed land use around the urban center in Jakarta and Manila, while Bangkok lacked a full mixed-use belt because of a protected green zone located only in the eastern side of the city. The researchers recommended controlling these unbalanced mixtures of land use as they cite Kelly (1998) and McGee (1991) who mention that such land use may be causing environmental and health problems. This, according to the

said authors, is due to the various commercial, industrial and residential activities that tend to concentrate in these areas. These activities produce effluents that are most likely deposited into the environment as a result of lacking environmental management interventions like proper sewage systems— thereby negatively affecting the environmental quality and quality of living in these same regions in cities.

2.2 The Environmental Application Period: Post-2016

Over the next decade, research on the LULC of Bangkok shifted its focus from urban form to applications in environmental science. Specifically, the academic scene was dominated by studies exploring the relationship between the UHI phenomenon and LULC. Out of the 25 papers reviewed in this study, fifteen focused on UHI-LULC relations. All of them used satellite images in their methodologies to extract LULC changes and surface temperatures in the area of interest. It is worth noting that these articles mainly covered the 90s and the early years of the 21st Century, with varying intervals between the years of interest. Additionally, the extent of study areas varied, with some considering only the administrative boundaries of Bangkok city (also referred to as Bangkok Metropolitan Administration or BMA), while others included the surrounding provinces of Bangkok, which are part of the Bangkok Metropolitan Region (BMR).

Chayapong (2010) conducted a study using satellite images from Landsat, which were obtained through the United States Geological Survey (USGS). The research team first applied unsupervised classification through ISODATA, similar to the method used by Madhavan et al. (2001), before performing supervised classification using the maximum likelihood algorithm. Unlike subsequent studies, Chayapong's research involved unsupervised classification to determine LULC classes. They classified the pixels into urban/built-up, vegetation, bare land, and water bodies, and compared the results with verified LULC maps. The study found a rapid increase of urban areas in the region, along with a continuous decline in vegetated land, which was correlated with the observed increase in surface temperatures in these same areas of LULC conversion. Additionally, the researcher assessed the impact of these phenomena on electric consumption, and found a strong positive linear correlation between the rising temperatures and urban expansion.

The majority of studies on Bangkok's urban areas show similar results. They reveal that while urban areas

are continuously increasing, vegetative areas are decreasing, and this is associated with the intensification of the UHI phenomenon. Various researchers have conducted these studies, including Adulkongkaew et al. (2020), Ali et al. (2018), Bonafoni and Keeratikasikorn (2018), Chayapong (2010), Chayapong and Dasananda (2013), Kamchiangta and Dhakal (2020), Kamchiangta and Dhakal (2021), Ongsomwang et al. (2018), and Srivanit et al. (2012).

However, some unique observations and insights from respective studies include the following: the conversion of green areas to built-up cover is happening in the transport corridors of the city, amounting to around 42% growth in area from 1992 to 2009 (Srivanit et al., 2012); land surface temperature peaks have expanded from just the urban core into larger areas of central Bangkok (Chayapong & Dasananda, 2013); an S-curve can represent the urban density growth of the city; daytime UHI intensity is higher during the day than at night (Bonafoni & Keeratikasikorn, 2018); there is a need for the optimization of land developments to manage LST in cities (Adulkongkaew et al., 2020); and stronger green zone protection strategies are required to restrict urban expansion and the associated heating (Kamchiangta & Dhakal, 2021).

There are also differences in how researchers study the relationship between LULC and urban heat island (UHI) in Bangkok, despite the similarities in their methodologies. Adulkongkaew et al. (2020) differentiated between "above green" and "below green" vegetative covers to account for the differences between canopy and sub-canopy plants in relation to land surface temperature (LST). They also used the minimum distance algorithm for their supervised classification of LULC, instead of the commonly used maximum likelihood, which resulted in accuracy rates above 90% for their maps. In addition, they used a one-way ANOVA to infer associations between UHI and LULC, instead of the widely used correlation analysis. Another unique approach (at least for the case of Bangkok) was taken by Kamchiangta & Dhakal in their 2020 study. They analyzed hotspots and cool spots of LULC changes and LST signatures, and discovered that the western and eastern areas of Bangkok Metropolitan Administration (BMA) had lower LST signatures. These areas were found to be dominated by vegetation.

Some researchers have ventured into LULC modeling in order to predict future scenarios. In 2018, Ongsomwang et al. implemented the Single Channel Method to model UHI and urban expansion in Bangkok. Their study predicted that the years 2024 to 2026 would be particularly "severe" in terms of UHI intensity, citing Dan

et al. (2010)'s classification of Weighted Average Heat Island Intensity (WAI) levels, with 2-3°C of temperature anomalies between urban and non-urban areas. This is mostly due to the continued built up area growth, and the coinciding peak of the projected urban heat. Furthermore, they observed that the increasing trend of UHI intensity is happening more in urban expansion areas rather than in the city's core (Ongsomwang et al., 2018). Another modeling study was recently conducted by Kamchiangta & Dhakal in 2021. After performing LULC classification, they built the Spatial Logistic Regression (SLR) model, which integrates existing urban features into predictions for future urban expansion. They predict that the green areas in the western part of the city, which have been providing cooling benefits, would be affected by urban expansion and consequently experience warming (Kamchiangta & Dhakal, 2021).

There have been other studies in Bangkok that looked at land use and land cover with an environmental focus. These studies include evaluating the amount of carbon stored in the city's vegetation, as well as measuring daily levels of particulate matter (PM) in the expanded Bangkok Metropolitan Region (BMR). Ali et al. (2018) conducted research on carbon storage in the city, using LULC mapping and change detection to validate the existence of carbon sinks that were previously only reported in statistical data. While the focus of this study differs from that of previous research, Ali and other researchers noted that cities are losing vegetation as they are converted into urban areas. Meanwhile, Chalermpong et al. (2021) used land use maps created by Thailand's Land Development Department (LDD) to develop land use regression models that could reveal the daily concentration levels of PM 2.5 in Bangkok.

2.3 Continuous LULC Dynamics Research

Studies on urban form and LULC dynamics have been ongoing in Bangkok for many years. While most LULC research has focused on environmental applications, some studies have also continued to explore LULC dynamics in the context of urban form. For instance, Murayama et al. (2015) found that Bangkok has the highest built-up density among Southeast Asia's megacities and is simultaneously experiencing urban sprawl and infilling. Similarly, Thanapet and Kung (2015) used LULC maps from Thailand's Land Development Department (LDD) to model landscape diversity and found that Bangkok's landscape increased in complexity over time. However, they also observed that the city's landscapes are generally dissimilar and unpredictable due to improper zoning boundary defining, several adaptation patterns, and data

limitations. Finally, Losiri et al. (2016) utilized the Cellular Automata-Markov Chain and Multi-Layer Perceptron-Markov Chain methods to model urban expansions, and projected that the built-up class would dominate the Bangkok Metropolitan Administration (BMA) landscape by 2035. They also found that the main change in LULC in the city was from agriculture to urban classes.

3. Discussion

As previously mentioned, and illustrated in [Figure 1](#), studies on LULC changes in Bangkok can be divided into two periods. The first group, marked with dark circles and lines, consists of studies that focused on the urban form or the spatial and physical configuration of the city and were conducted mostly in the first decade of the 21st Century up until 2016. The second group of studies, marked with lighter circles and lines, utilized LULC mapping and change detection techniques for environmental applications. All of these studies were conducted in the past decade, starting with Chayapong in 2010, with half of them investigating the Urban Heat Island (UHI) phenomenon (the authors of which are in bold text in [Figure 1](#)). The studies employed various methodologies, progressing from on-the-ground inspection and aerial photography to relying solely on satellite images due to their increased reliability, accuracy, and efficiency. The focus of the inquiries also evolved from merely detecting LULC changes in Bangkok to linking them to environmental phenomena in the city/region and eventually predicting future scenarios. This literature overview suggests that remote sensing could be utilized as a tool to examine land use and land cover changes in relation to socio-economic issues such as property taxation policies. [Table 1](#) summarizes the literature based on the key findings.

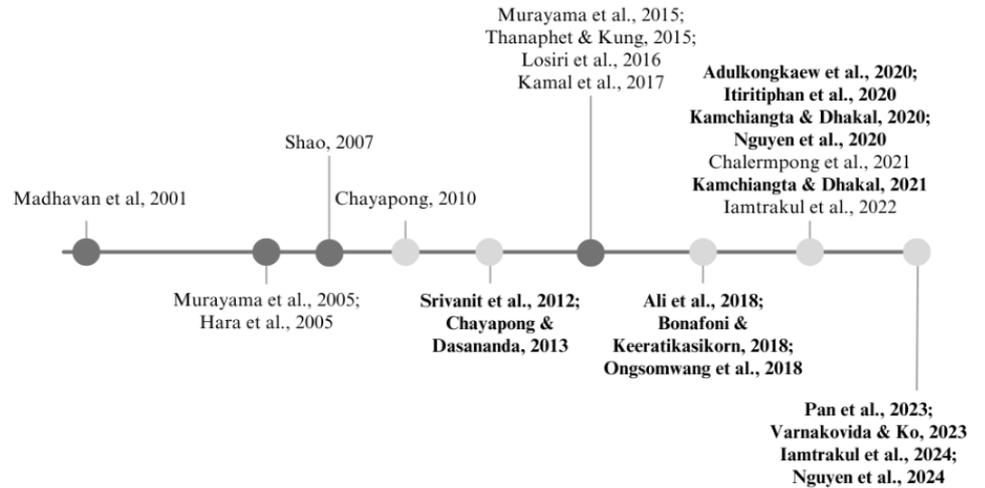


Figure 1. Timeline of Literature on LULC in Bangkok

Early Years

Environmental Application Period

Table 1 Key Findings from the Literature

Section	Key Findings	Citation	Variables
Early Years	Tracking LULC dynamics in Bangkok Metropolitan Area using satellite remote sensing, revealing significant changes in residential and commercial land uses.	Madhavan et al. (2001), Murakami et al. (2005), Hara et al. (2005)	Urban Zoning and Land Use Changes, and Spatial Efficiency and Environmental Health
Urban Heat Island Studies	Studies focusing on the relationship between LULC and UHI phenomenon, showing an increase in urban areas and decrease in vegetative areas.	Chayapong (2010), Adulkongkaew et al. (2020), Ali et al. (2018), Bonafoni and Keeratikasikorn (2018), Kamchiangta and Dhakal (2020, 2021), Ongsomwang et al. (2018), Srivanit et al. (2012), Iamtrakul et al. (2024), Varnakovida & Ko (2023), Nguyen et al. (2020), Itiritiphan et al. (2020), Nguyen et al. (2024), Pan et al. (2023)	Urban expansion and the accompanying rise in impervious land cover, and the increase in urban land surface temperatures
Environmental Studies	Research on carbon storage in Bangkok’s vegetation and daily levels of particulate matter in the expanded Bangkok Metropolitan Region.	Ali et al. (2018), Chalermpong et al. (2021)	Urban expansion and the accompanying rise in impervious land cover, and the decrease in carbon sinks and pollution assimilators
Continuous LULC Dynamics Research	Studies on urban form and LULC dynamics, revealing high built-up density, urban sprawl, and infilling in Bangkok.	Shao (2007), Murayama et al. (2015), Thanapet and Kung (2015), Losiri et al. (2016), Kamal et al. (2017), Iamtrakul et al. (2022)	LULC characteristics, and temporal change in urban landscape and form

4. Conclusion

This article provides an overview of the literature on LULC in Bangkok. Academic research on this topic mostly involves remote-sensing techniques using satellite images and digital software for LULC mapping through supervised classification using the maximum likelihood algorithm. So far, the studies on the LULC of Bangkok have focused mainly on urban and environmental studies applications. However, there is a need to explore the politico-economic aspects of the topic, especially in relation to the new property taxation policies of Thailand on the capital city's LULC using the same methodologies. This is because remote-sensing techniques have proven to be cost-efficient, given how researchers may not have to allocate resources for extensive site inspections, and are comprehensive, as they cover relatively large spatial and temporal scales. Such aspects make them effective methods for monitoring relatively minute and fast LULC changes, which may be caused by the new land taxation policy. As mentioned earlier, the high taxation of "vacant" or "idle" land may incentivise LULC conversion into other land typologies in Bangkok, particularly into agricultural lands that have the lowest tax rates and high tax exemption thresholds. Additionally, not much research has been conducted on the newly ratified law, except for one conducted by Limteerakul in 2021 to assess its impacts on income inequality for the entire country. Therefore, it is essential to investigate more of the possible changes instigated by the said legislation, particularly in one of the most economically and politically significant cities in Thailand.

As a final note, we would like to point out two important limitations of this review. First, it only covers articles written in English and published in international journals, which means that any articles in Thai are not included. Second, the review focuses mainly on articles published after 2000, as remote sensing technology has become more widely available and applicable during this time. Consequently, it is important to note that there may be valuable insights in older articles and in Thai language publications that have not been considered in this review. Hence, future research could include these sources to further improve the breadth and depth of the analyses.

CRedit Authorship Contribution Statement

James Anthony Orina: Methodology, Software, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization

Nij Tontisirin: Conceptualization, Writing - Original Draft, Writing - Review & Editing

Sutee Anantsuksomsri: Conceptualization, Methodology, Validation, Investigation, Resources, Supervision, Project administration, Funding acquisition



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References

- Adulkongkaew, T., Satapanajaru, T., Charoenhirunyingyos, S., & Singhirunnusorn, W. (2020). Effect of land cover composition and building configuration on land surface temperature in an urban-sprawl city, a case study in Bangkok metropolitan area, Thailand. *Heliyon*, 6(8). <https://doi.org/10.1016/j.heliyon.2020.e04485>
- Ali, G., Pumijumnong, N., & Cui, S. (2018). Valuation and validation of carbon sources and sinks through land cover/use change analysis: The case of Bangkok metropolitan area. *Land Use Policy*, 70, 471–478. <https://doi.org/10.1016/j.landusepol.2017.11.003>
- Bonafoni, S., & Keeratikasikorn, C. (2018). Land surface temperature and urban density: Multiyear modeling and relationship analysis using Modis and Landsat Data. *Remote Sensing*, 10(9), 1471. <https://doi.org/10.3390/rs10091471>
- Chalermpong, S., Thaithatkul, P., Anuchitchanchai, O., & Sanghatawatana, P. (2021). Land use regression modeling for fine particulate matters in Bangkok, Thailand, using time-variant predictors: Effects of seasonal factors, open biomass burning, and traffic-related factors. *Atmospheric Environment*, 246, 118128. <https://doi.org/10.1016/j.atmosenv.2020.118128>

- Chayapong, P. (2010). Spatial analysis of urban heat island phenomenon and its relationship with land use and land cover and electrical energy consumption: A case study in Bangkok metropolitan area [Doctoral dissertation, School of Remote sensing Institute of Science]. Suranaree University of Technology Intellectual Repository.
- Chayapong, P., & Dasananda, S. (2013). Urban heat island phenomenon in relation to land use/land cover in Bangkok metropolitan administration area. *Applied Environmental Research*, 35(1), 27–41. <https://ph01.tci-thaijo.org/index.php/aer/article/view/9751>
- Du, H., Cai, W., Xu, Y., Wang, Z., Wang, Y., & Cai, Y. (2017). Quantifying the cool island effects of urban green spaces using remote sensing data. *Urban Forestry & Urban Greening*, 27, 24–31. <https://doi.org/10.1016/j.ufug.2017.06.008>
- Estoque, R. C., Murayama, Y., & Myint, S. W. (2017). Effects of landscape composition and pattern on land surface temperature: An urban heat island study in the megacities of Southeast Asia. *Science of Total Environment*, 577, 349–359. <https://doi.org/10.1016/j.scitotenv.2016.10.195>
- Hara, Y., Takeuchi, K., & Okubo, S. (2005). Urbanization linked with Past Agricultural Landuse patterns in the urban fringe of a deltaic Asian mega-city: A case study in Bangkok. *Landscape and Urban Planning*, 73(1), 16–28. <https://doi.org/10.1016/j.landurbplan.2004.07.002>
- Iamtrakul, P., Padon, A., & Chayphong, S. (2024). Quantifying the impact of urban growth on Urban Surface Heat Islands in the Bangkok Metropolitan Region, Thailand. *Atmosphere*, 15(1), 100. <https://doi.org/10.3390/atmos15010100>
- Iamtrakul, P., Padon, A., & Klaylee, J. (2022). Analysis of urban sprawl and growth pattern using geospatial technologies in megacity, Bangkok, Thailand. *Geoinformatics and Data Analysis*, 109–123. https://doi.org/10.1007/978-3-031-08017-3_10
- Itiritiphan, F., Wu, F., Gantumur, B., & Lkhagva, O. (2020). Analysis of urban green spaces and surface temperature using quantitative remote sensing technology in Bangkok. *Remote Sensing Technologies and Applications in Urban Environments V*. <https://doi.org/10.1117/12.2573921>
- Kamal, N., Imran, M., & Tripathi, N. K. (2017). Greening the urban environment using geospatial techniques, a case study of Bangkok, Thailand. *Procedia Environmental Sciences*, 37, 141–152. <https://doi.org/10.1016/j.proenv.2017.03.030>
- Khamchiangta, D., & Dhakal, S. (2020). Time series analysis of land use and land cover changes related to urban heat island intensity: Case of Bangkok metropolitan area in Thailand. *Journal of Urban Management*, 9(4), 383–395. <https://doi.org/10.1016/j.jum.2020.09.001>
- Khamchiangta, D., & Dhakal, S. (2021). Future urban expansion and local climate zone changes in relation to land surface temperature: Case of Bangkok metropolitan administration, Thailand. *Urban Climate*, 37, 100835. <https://doi.org/10.1016/j.uclim.2021.100835>
- Limteerakul, V. (2021). Inequality in household real estate ownership and the effect of property taxes on income inequality in Thailand. *Economics and Public Policy Journal*, 12(23), 55–77. Retrieved March 23, 2022, from <https://so01.tci-thaijo.org/index.php/econswu/article/view/254916/169964>
- Losiri, C., Nagai, M., Ninsawat, S., & Shrestha, R. (2016). Modeling urban expansion in Bangkok metropolitan region using demographic–economic data through cellular automata-markov chain and Multi-Layer Perceptron-Markov chain models. *Sustainability*, 8(7), 686. <https://doi.org/10.3390/su8070686>
- Madhavan, B. B., Kubo, S., Kurisaki, N., & Sivakumar, T. V. (2001). Appraising the anatomy and spatial growth of the Bangkok metropolitan area using a vegetation-impervious-soil model through remote sensing. *International Journal of Remote Sensing*, 22(5), 789–806. <https://doi.org/10.1080/01431160051060200>
- Murakami, A., Medrial Zain, A., Takeuchi, K., Tsunekawa, A., & Yokota, S. (2005). Trends in urbanization and patterns of land use in the Asian Mega Cities Jakarta, Bangkok, and Metro Manila. *Landscape and Urban Planning*, 70(3-4), 251–259. <https://doi.org/10.1016/j.landurbplan.2003.10.021>
- Murayama, Y., Estoque, R. C., Subasinghe, S., Hou, H., & Gong, H. (2015). Land-Use/Land-Cover changes in major Asian and African cities. *Annual report on the multi use social and economic and data bank*, 92, 1–42. Retrieved April 19, 2022, from https://www.researchgate.net/profile/Yuji-Murayama/publication/274712830_Land-useland-cover_changes_in_major_Asi_and_African_cities/links/55c93e4008aea2d9bdc927fc/Land-use-land-cover-changes-in-major-Asian-and-African-cities.pdf

- Nguyen, C. T., Nguyen, D. T., & 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*, 28(10), 12056–12066. <https://doi.org/10.1007/s11356-020-09157-6>
- Nguyen, C. T., Nguyen, H., & Sakti, A. D. (2024). Seasonal characteristics of outdoor thermal comfort and residential electricity consumption: A Snapshot in Bangkok metropolitan area. *Remote Sensing Applications: Society and Environment*, 33, 101106. <https://doi.org/10.1016/j.rsase.2023.101106>
- Ongsomwang, S., Dasananda, S., & Prasomsup, W. (2018). Spatio-Temporal urban heat island phenomena assessment using Landsat imagery: A case study of Bangkok metropolitan and its vicinity. Thailand. *Environment and Natural Resources Journal*, 16(2), 29–44. <https://ph02.tci-thaijo.org/index.php/ennrj/article/view/117655>
- Pan, L., Lu, L., Fu, P., Nitivattananon, V., Guo, H., & Li, Q. (2023). Understanding spatiotemporal evolution of the surface urban heat island in the Bangkok metropolitan region from 2000 to 2020 using enhanced land surface temperature *Geomatics, Natural Hazards and Risk*, 14(1). <https://doi.org/10.1080/19475705.2023.2174904>
- Shao, Y. (2007). *Mapping and modeling the urban landscape in Bangkok, Thailand: Physical-spectral-spatial relations of population-environmental interactions* [Doctoral dissertation, University of North Carolina at Chapel Hill]. ProQuest Dissertations and Theses. Retrieved July 20, 2024, from <https://www.proquest.com/openview/531d1311404e20fa21f49b6c8fc68259/1?cbl=18750&pq-origsite=gscholar>
- Sridith, K. (2023, March 15). Land tax loophole endangers our environment. *Bangkok Post*. <https://www.bangkokpost.com/opinion/2471122/land-tax-loophole-endangers-our-environment>
- Srivanit, M., Hokao, K., & Phonekeo, V. (2012). Assessing the impact of urbanization on urban thermal environment: A case study of Bangkok metropolitan. *International Journal of Applied Science and Technology*, 2(7), 243–255. Retrieved Apr 19, 2022, from https://www.researchgate.net/profile/Manat-Srivanit/publication/286451131_Assessing_the_Impact_of_Urbanization_on_Urban_Thermal_Environment_A_Case_Study_of_Bangkok_Metropolitan/links/566a337c08aea0892c49ec14/Assessing-the-Impact-of-Urbanization-on-Urban-Thermal-Environment-A-Case-Study-of-Bangkok-Metropolitan.pdf
- Thanapet, K., & Kung, S.-F. (2015). Spatial composition and configuration changes in the Bangkok metropolitan region landscape. *Nakhara : Journal of Environmental Design and Planning*, 11, 9–28. <https://ph01.tci-thaijo.org/index.php/nakhara/article/view/104848>
- Varnakovida, P., & Ko, H. Y. (2023). Urban expansion and urban heat island effects on Bangkok metropolitan area in the context of Eastern Economic Corridor. *Urban Climate*, 52, 101712. <https://doi.org/10.1016/j.uclim.2023.101712>