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Examining NDVI Trends in Serang City to Assess Vegetation Changes between 2019 and 2023

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Abstract

This study examines changes in the Normalised Difference Vegetation Index (NDVI) for Serang City between 2019 and 2023 to quantify vegetation density and health in the face of urbanization. Using Sentinel-2 satellite data and GIS analysis, it investigates how urban development, climate change, and land use influence plant cover. The findings indicate a substantial decrease in high vegetation from 13,089.791 hectares in 2019 to 12,296.742 hectares in 2023, accompanied by increases in tiny vegetation and aquatic zones. Statistical experiments show that urban expansion is a significant cause of vegetation loss, with climate changes impacting sparsely vegetated areas. This study emphasizes the dynamic interplay between urban expansion and climate conditions in generating vegetation trends, providing essential information for urban planners and politicians. The results demonstrate the necessity for focused reforestation and sustainable urban development to save green places, enhance environmental quality, and alleviate the adverse effects of urbanization. Immediate urban planning initiatives are recommended to combat vegetation loss, promote sustainable development, and increase resistance to environmental change.

Keywords: GIS Analysis, Remote Sensing, Temporal Analysis, Environmental Change, Policy Intervention

INTRODUCTION

The Normalised Difference Vegetation Index (NDVI) is a well-known technique for assessing vegetation health and density, particularly useful in metropolitan environments where land use changes regularly alter the natural landscape. The NDVI is determined by comparing the reflection of near-infrared and red light by plants, providing a measure of vegetation vitality that is important in ecological and urban research. NDVI, which highlights plant cover density, enables researchers and planners to monitor vegetation patterns, estimate environmental impacts, and devise mitigation techniques. This measure has been used in research into urban heat islands, pollution control, and land use changes (Krupnova, 2022). Furthermore, NDVI is critical for understanding vegetation reactions to urban growth, frequently resulting in diminished green space and affecting ecological balance and urban sustainability (Yasin *et al*., 2022; Liu *et al*., 2015).

In recent years, rising urbanization in medium-sized cities, such as Serang City in Indonesia, has generated worries about vegetation loss, increased pollution, and increased urban heat. As Serang grows, balancing urban development and environmental preservation becomes increasingly essential. Reduced plant cover in cities undermines local biodiversity and worsens

heat, pollution, and overall quality of life. For example, reduced green space contributes to greater metropolitan Thermal measurements, which harms inhabitants' health and increases cooling energy demands. With Serang City's population expected to expand, maintaining and restoring vegetation becomes critical to the city's environmental health.

The significance of NDVI in urban monitoring has been proven in studies that use it with other indices to investigate urban growth, climate variables, and land cover shifts (Burkart *et al*., 2016). For example, Chen *et al*. (2022) used NDVI to track vegetation loss caused by urbanization in China's cities. Hashim *et al*. (2019) used high-resolution NDVI data to distinguish between vegetation types within urban zones. These studies demonstrate NDVI's capacity to detect immediate and long-term vegetation changes, giving critical insights for developing efficient urban planning strategies. However, research on mid-sized cities like Serang is rare, emphasizing the importance of localized studies that capture the specific ecological dynamics of such regions (Nguyen, 2023). Addressing these gaps is critical for improving urban environmental resilience and guiding policy changes in response to urban expansion constraints.

This study aims to fill a significant gap by analyzing NDVI data for Serang City over five years (2019-2023) and investigating changes in vegetation cover as the city develops. It specifically employs Sentinel-2 satellite data and Geographic Information Systems (GIS) to measure changes in vegetation density, categorizing land cover as dense or tiny vegetation and aquatic. The research also uses climate data to discern between the relative effects of urbanization and climate conditions on vegetation patterns. Statistical analyses determine these changes' significance, improving the findings' accuracy and policy implications.

The value of this work stems from its ability to provide data-driven insights into the complicated link between urban expansion and vegetation health in Serang City. The findings can help guide policies prioritizing sustainable urban expansion, such as targeted reforestation, afforestation, and green infrastructure development. By identifying areas of vegetation loss and their causes, this study hopes to aid in urban planning decision-making and offset the ecological implications of urbanization.

The goals of this research are to (1) assess the extent of vegetation change in Serang City from 2019 to 2023 using NDVI; (2) analyze the relative contributions of urban expansion and climate variability to these changes; and (3) provide practical recommendations for sustainable urban planning to preserve and improve green spaces in the city.

METHOD

Study Area

The research was carried out at Serang City, Banten Province, Indonesia. This area is characterized by fast urban growth, making it an ideal location for investigating vegetation changes caused by urbanization. The geographical coordinates and topographical information of Serang City were critical for accurate mapping, as seen in Figure 1, which depicts the research area.

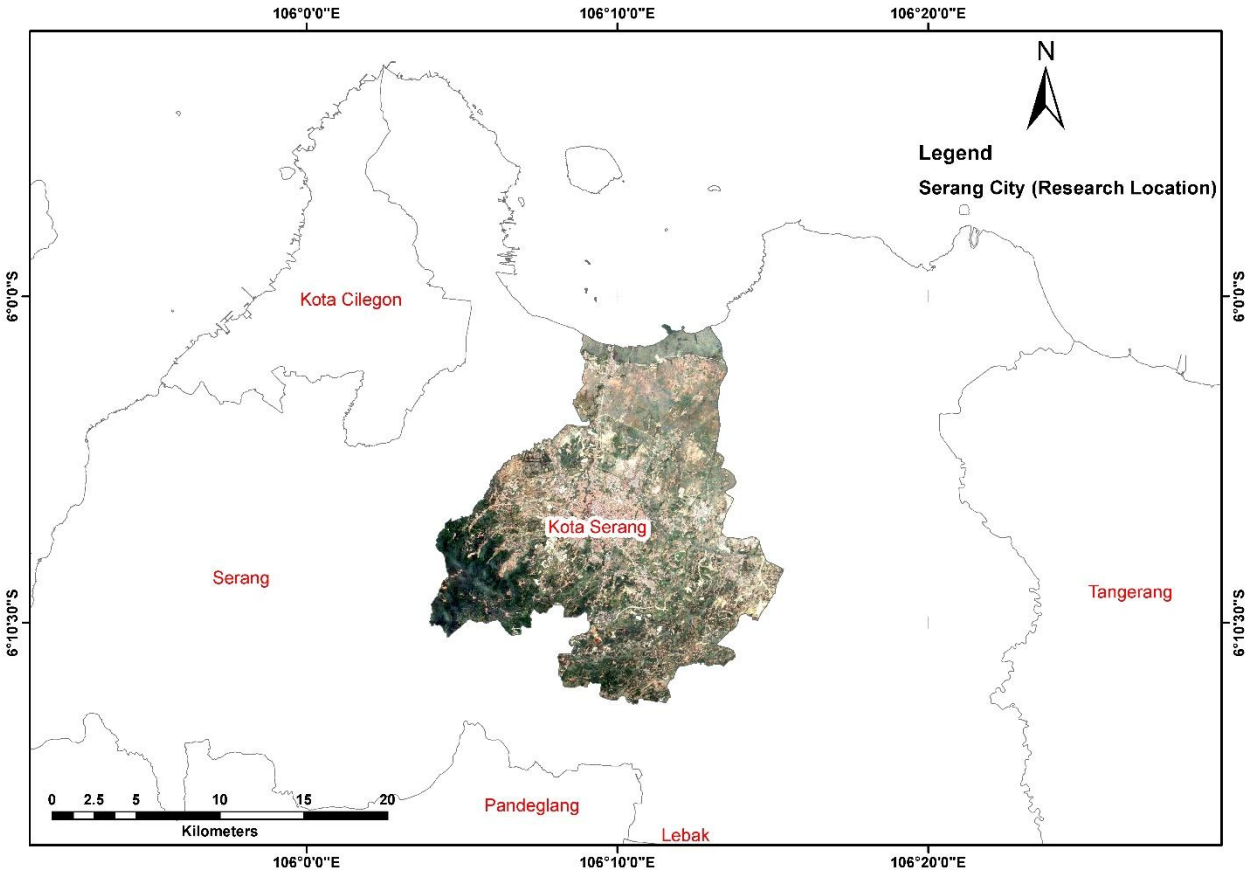

Figure 1. Study Area

Materials and Equipment

This research utilized Sentinel-2 satellite images supplied by the European Space Agency (ESA) to get multi-temporal data on vegetation in Serang City from 2019 to 2023. The Sentinel-2 satellite, launched in 2015, offers images of 13 spectral bands and a spatial resolution of 10 meters, making it appropriate for comprehensive urban vegetation monitoring (Clevers *et al*., 2017). Supplementary climatic data, encompassing Rainfall, Thermal measurement, and Moisture,

were acquired from the climatic CHIRPS dataset for Hazards Group InfraRed Rainfall with Station, enhanced with local meteorological data to ensure accuracy.

Image processing and analysis were conducted utilizing Geographic Information System (GIS) software, notably Google Earth Engine (GEE) and QGIS 3.16, facilitating NDVI calculations and categorizing land cover. Cloud-masking methods in GEE were used for data preprocessing to eliminate cloud covers and rectify atmospheric aberrations, improving data dependability.

Research Approach

The research utilized a quantitative methodology, employing remote sensing and GIS tools to examine NDVI trends and fluctuations in vegetation density. NDVI was selected for its consistent ability to indicate vegetative health by measuring the disparity between near-infrared (NIR) and redlight reflectance. NDVI values range from -1 to 1, with positive values signifying vegetation and higher values representing denser or superior plant cover.

Data Collection and Preprocessing

The principal data for the vegetation study consisted of NDVI values extracted from Sentinel-2 images acquired for the years 2019 and 2023. The photos underwent preprocessing in GEE, utilizing cloud-masking and smoothing methods to remove seasonal abnormalities and transitory environmental influences. Vegetation cover categorization was performed by establishing particular NDVI criteria for aquatic, tiny vegetation, moderate vegetation, and thick vegetation according to the pixel values in Table 1.

Data Analysis Methods

1. NDVI Calculation: NDVI was computed for each Sentinel-2 picture utilizing the usual formula:

$$NDVI = \frac{NIR + RED}{NIR - RED}$$

   The NIR and Red bands correspond to the Sentinel-2 sensor's spectral bands 8 and 4, respectively, as processed by QGIS 3.16. NDVI values for various vegetation types were assigned according to known ranges, with higher values indicating high vegetation.
2. Supervised classification was done using training data in QGIS to increase land cover classification accuracy. Field observations were utilized to test and enhance these classifications, accurately categorizing plant types within the urban, sparse, and aquatic categories. The NDVI values were separated into intervals to reflect aquatic, sparse, moderate, and high vegetation types.

3. These experiments assessed the statistical significance of the differences in thick and tiny vegetation regions and aquatic coverage between 2019 and 2023. Climate variables (Rainfall, Moisture, and Thermal measurement) were examined by correlation analysis to evaluate their association with NDVI variations, offering a detailed comprehension of the climate-urbanization interplay.
4. Trend Analysis: Temporal analysis focused on observed NDVI changes across the five-year research period, revealing patterns in vegetation loss, tiny vegetation expansion, and aquatic body growth. GIS mapping with a 10-meter spatial resolution enabled thorough visualization of land cover changes, providing insights into vegetation dynamics at the urban scale.

Limitations

This study is constrained by its dependence on satellite images, which may not accurately reflect all fine-scale vegetation changes. The five-year research period may be inadequate for comprehending long-term vegetation patterns. Notwithstanding these constraints, the selected methodology offers a dependable means for identifying and measuring NDVI variations in an urban setting.

Table 1. Pixel Range for Classification of NDVI

Class	Pixel Range
High Vegetation	0.5>
Medium Vegetation	0.3-0.5
Tiny Vegetation	0-0.3
Aquatic	<0

RESULTS AND DISCUSSION

The NDVI maps in Figure 2 are derived from Sentinel-2 satellite images supplied by the European Space Agency (ESA) for 2019 and 2023. Sentinel-2 provides high-quality multispectral imagery with a spatial resolution of 10 meters, rendering it appropriate for intricate vegetation studies in urban settings such as Serang City. NDVI values were derived by Sentinel-2 imaging, including near-infrared (NIR) and red bands. with Geographic Information System (GIS) tools. This facilitated categorizing vegetation cover into separate classifications: high, medium, tiny, and aquatic, according to NDVI criteria defined for this research. The NDVI maps illustrate alterations in vegetation density over five years, offering insights into the effects of urban development and climatic variability on the city's green spaces. The juxtaposition of the 2019 and

2023 NDVI maps elucidates geographical trends in vegetation loss or increase, with substantial consequences for urban planning and environmental protection.

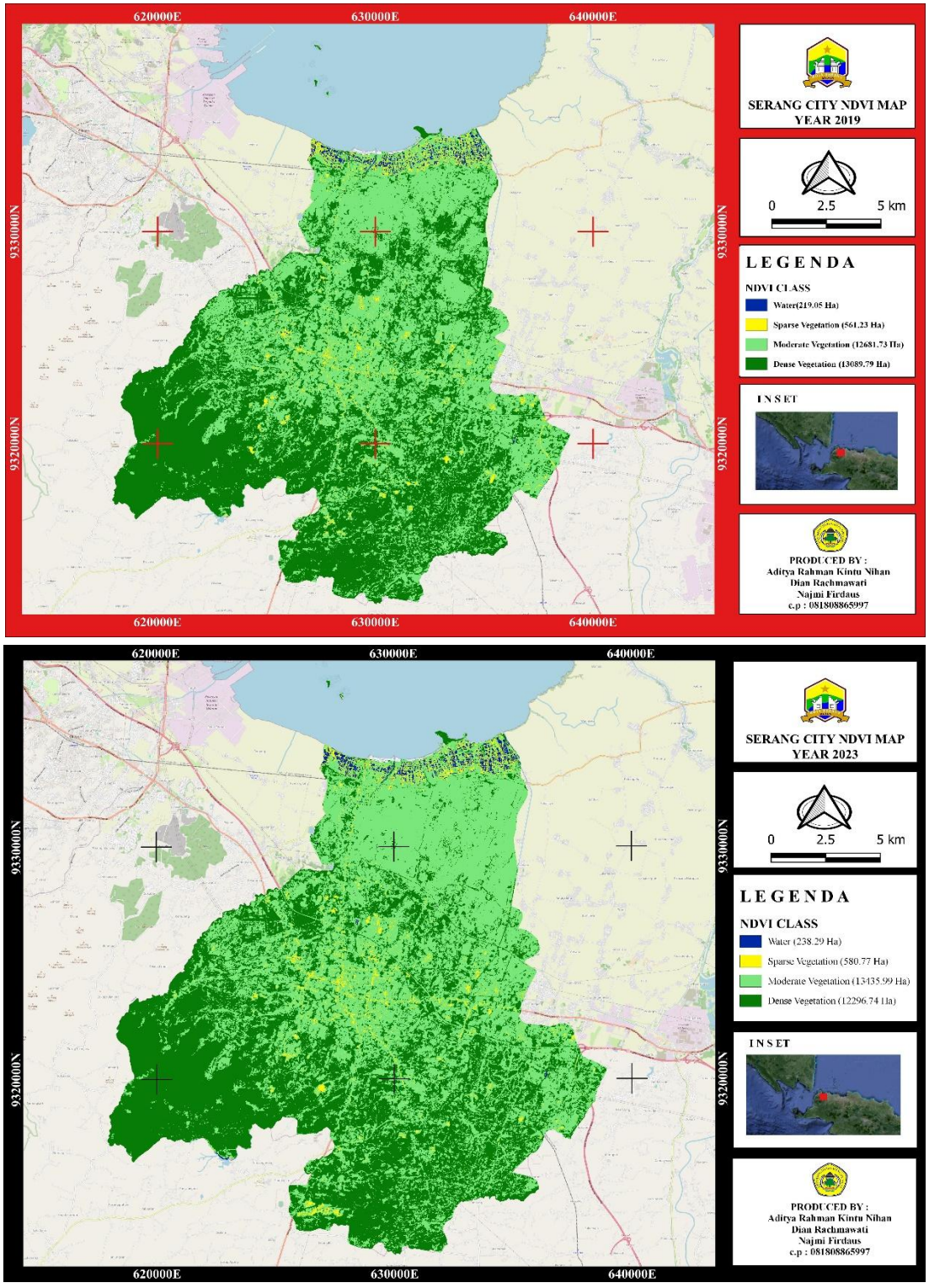

Figure 2. NDVI Maps of Serang City for the Years 2019 and 2023

The variations within land coverage categories in Serang City from 2019 and 2023 are illustrated in Table 2, utilizing data obtained from Sentinel-2 satellite images supplied by the European Space Agency (ESA). Employing Sentinel-2's 10-meter spatial resolution, NDVI values were computed for each pixel, facilitating the categorization of land cover into four classifications: high vegetation, moderate vegetation, tiny vegetation, and aquatic. The investigation utilized NDVI threshold values to differentiate distinct land cover categories, then quantifying them in hectares to discern trends during the study period.

These categories indicate changes in land cover, emphasizing a rise in tiny vegetation and aquatic bodies and a decline in high vegetation regions. Table 2 provides a quantitative evaluation of the urban and environmental effects on the green areas in Serang City, yielding essential insights into the role of urban expansion and climatic factors on plant distribution.

Table 2. Alterations in Land Cover Types (Hectares) in Serang City from 2019 to 2023

Land Use Types	Year 2023 (Ha)	Year 2019 (Ha)	Change (Ha)
High Vegetation	12296.742	13089.791	-793.049
Medium vegetation	13435.995	12681.731	754.264
Tiny vegetation	580.774	561.234	19.54
Aquatic	238.299	219.057	19.242

The examination of the NDVI for Serang City from 2019 and 2023 reveals notable changes in land cover classifications. The NDVI maps (Figure 2) illustrate significant variations, notably decreased high vegetation and increased alternative land cover types. Table 2 outlines the changes: The aquatic class grew by 19,242 hectares, increasing from 219,057 hectares in 2019 to 238,299 hectares in 2023. The area of small vegetation expanded by 19.54 hectares, going from 561,234 hectares to 580,774 hectares. The moderate vegetation area rose from 12,681.731 hectares to 13,435.995 hectares, reflecting an increase of 754.264 hectares. Conversely, the high vegetation area decreased from 13,089.791 hectares to 12,296.742 hectares, showing a reduction of 793.049 hectares. The results demonstrate that the decrease in high vegetation and the increase in tiny vegetation and aquatic areas is statistically significant, demonstrating the robustness of the observed trends across the research period.

The comparative analysis of NDVI variations throughout the research period emphasizes the evolving state of vegetation cover in Serang City. The growth of small and medium-vegetated areas, alongside the decrease in densely vegetated zones, can be linked to multiple factors. A comparison analysis was carried out to isolate the effects of urbanization and climate conditions.

According to the findings, urban growth is the principal cause of the loss of high vegetation, particularly in rapidly developing areas. Still, Rainfall and Thermal measurement changes have a more significant impact on tiny vegetated zones. This distinction emphasizes the compounding impact of urbanization and climate conditions on vegetation dynamics, providing focused urban and environmental policy insights. Studies conducted by Jeong et al. (2009) and Park & Sohn (2010) Climatic factors like Thermal measurement and Rainfall greatly influence NDVI values. The growth of water bodies is driven by alterations in hydrological conditions or by human actions, such as building reservoirs, showcasing the area's dynamic land use and ecological state.

Du et al. (2016) and Wu et al. (2022) illustrate how climatic variables significantly affect NDVI fluctuations and vegetation responses. The transition from areas of high vegetation density to those with lower density might represent a natural ecological succession process, where initially lower vegetation gradually develops into denser forms over time. This supports the ecological succession hypothesis, which accounts for the evolution of plant communities toward increased complexity and density. According to Chen et al. (2022) and Li et al. (2023), recognizing the spatiotemporal changes in NDVI and their connection to environmental factors is crucial. These factors highlight the intricate interactions between climate, topography, and human activity. The consequences are essential for urban planning and environmental management in Serang City. The decline in high vegetation raises potential challenges for sustaining urban green spaces, which are vital for alleviating the negative impacts of urbanization. The rise in moderate and scarce vegetation signals the necessity for focused reforestation and afforestation initiatives, which have successfully improved vegetation coverage and fostered environmental stability (Rosleine & Irfan, 2021).

Reforestation efforts in the North Bandung Area and Southwest China have notably boosted vegetation coverage and played a vital role in environmental stabilization (Trac et al., 2007). Implementing effective environmental policies that encourage forest regeneration and ensure the sustainability of restored forests is essential for increasing vegetation cover density (Cunningham et al., 2015). The differences in vegetation density classifications stem from natural ecological succession processes, in which lower vegetation gradually develops into denser varieties over time. This highlights the significance of comprehending vegetation dynamics for successful ecosystem management and restoration (Chazdon, 2008).

The modest increase in aquatic class areas highlights the dynamic features of land use and ecological conditions in the region, influenced by climate factors and human activities. A

thorough examination of municipal policies and their impacts on land cover changes could provide a comprehensive understanding. It covers the specific factors that drive these changes. A broad approach is essential for developing effective land management and environmental protection initiatives.

The examination of NDVI (Normalized Difference Vegetation Index) data from 2019 to 2023 reveals significant changes in vegetation cover in Serang City. Figure 2 shows a decline in NDVI value from 0.485 in 2019 to 0.482 in 2023, indicating a drop in vegetation density. The data suggests a decrease in vegetation coverage over this period, likely due to both natural and human influences. Table 2 details the factors influencing fluctuations in NDVI, including Rainfall, Moisture, Thermal measurement, and population growth. Figure 3 highlights the population increase in Serang City, rising from 686,603 in 2019 to 723,794 in 2023. This increase may impact land use and plant cover. The slight rise in aquatic class areas emphasizes the changing nature of land use and ecological conditions in the region, influenced by climate factors and human activity. A thorough analysis of municipal policies and their impacts on land cover changes may provide a comprehensive understanding. It includes the specific variables driving these changes. An integrated plan is essential for developing effective land management and environmental protection strategies.

The analysis of NDVI (Normalised Difference Vegetation Index) data from 2019 to 2023 indicates significant changes in vegetation coverage within Serang City. Figure 2 indicates a decrease in NDVI value from 0.485 in 2019 to 0.482 in 2023, implying a reduction in vegetation density. The data shows a decrease in vegetation coverage during the study, probably attributable to environmental and anthropogenic factors. Table 2 delineates the parameters influencing variations in NDVI, including rainfall, Moisture, Thermal measurement, and population growth. Figure 3 depicts the population increase in Serang City, growing from 686,603 in 2019 to 723,794 in 2023. The increase may have implications for land use and vegetation cover.

Table 3 summarizes the essential environmental parameters influencing NDVI variations in Serang City from 2019 to 2023. The parameters, including Rainfall, Thermal measurement, and Moisture, were obtained from the Climate Hazards Group InfraRed Rainfall with Station (CHIRPS) dataset and supplemented with local meteorological data to understand vegetation impacts comprehensively. The selection of these parameters is based on their established impact on vegetation health and density, which influence NDVI values through modifications in moisture availability, Thermal measurement regulation, and general plant growth conditions.

Examining these environmental factors in conjunction with NDVI data facilitates a detailed comprehension of the impact of climatic variations on observed vegetation patterns. Table 3 presents a comprehensive overview of climate variables, aiding in interpreting their potential impacts on vegetation distribution and density. This research is crucial for evaluating the cumulative effects of urbanization and climate on the green spaces in Serang City.

Table 3. Factors Influencing NDVI

Specifications	Year 2023			Year 2019		
	Mean	Max	Min	Mean	Max	Min
Thermal measurement	32.943	37.430	28.590	32.786	37.450	29.025
Moisture	97.939	106.825	93.275	86.174	89.758	84.100
Rainfall	1632.428	2028.241	1448.556	1420.456	1730.688	1259.188
Normalized Difference Vegetation Index	0.482	0.8890	-0.4330	0.485	0.866	-0.300

Figure 3 depicts the population increase in Serang City from 2019 to 2023, derived from information obtained from municipal government documentation and data sets agencies. The population statistics are essential for comprehending the impacts of urban growth on the city's vegetation cover. Population expansion is a principal catalyst of urbanization, resulting in heightened land conversion for residential, infrastructural, and commercial purposes, which may diminish green areas and affect vegetation density, as shown by NDVI values. This study elucidates the correlation between human activities and environmental consequences in Serang City by analyzing population fluctuations in conjunction with NDVI trends. Figure 3 elucidates population dynamics as a contributing element to the vegetation changes seen over the research period, corroborating analyses that associate demographic expansion with urban land use pressures.

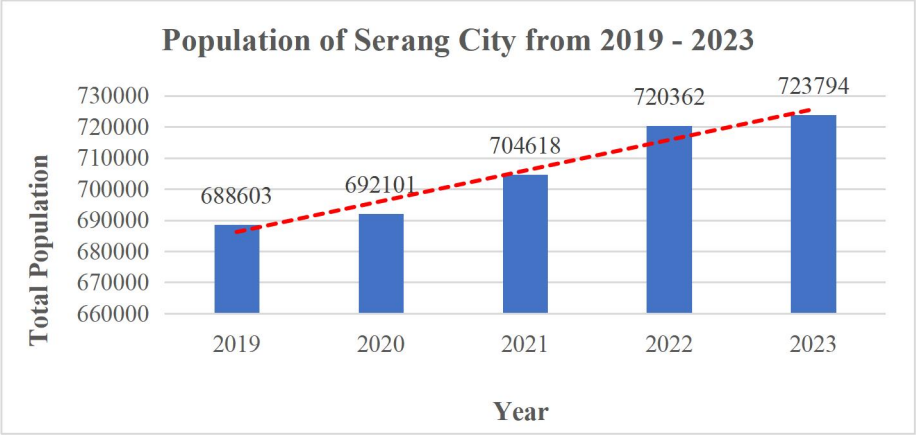

Figure 3. Population Growth in Serang City from 2019 and 2023

Figure 4 illustrates the Rainfall patterns in Serang City for 2019 and 2023, utilizing data from the Climate Hazards Group InfraRed Rainfall with Station (CHIRPS) dataset. This dataset integrates satellite observations with ground-based rainfall measurements to provide accurate Rainfall data, essential for analyzing environmental conditions affecting vegetation. Rainfall significantly influences vegetation health by impacting soil moisture, plant growth, and NDVI values.

The Rainfall maps in Figure 4 allow for a comparative view of rainfall distribution across Serang City during the study years. This helps to understand how annual rainfall variability may influence vegetation density. Examining these Rainfall trends with NDVI data offers valuable insights into how climate factors contribute to vegetation changes, supporting data-driven planning for urban and environmental resilience.

Figure 5 illustrates the Moisture distribution in Serang City for 2019 and 2023, utilizing data from local meteorological records and the Climate Hazards Group InfraRed Rainfall with Station (CHIRPS) dataset. Moisture levels significantly impact vegetation health by affecting evapotranspiration rates, influencing soil moisture and overall plant vitality. Comprehending Moisture swings can yield insights into NDVI variations since vegetative vitality is responsive to alterations in atmospheric moisture.

Figure 5's Moisture maps compare moisture levels across Serang City, emphasizing any changes between 2019 and 2023 that may have affected plant cover. Examining Moisture trends in conjunction with NDVI data facilitates the understanding of climatic influences on plant dynamics, providing essential insights for urban planning and environmental conservation initiatives.

The examination of NDVI values in Serang City from 2019 to 2023 shows a slight decrease of 0.003, indicating a minor decline in vegetation health (Table 3). This change points to the potential effects of urban expansion on nearby plant life. Figure 2 illustrates the population growth in Serang.

The population is projected to rise from 686,603 in 2019 to 723,794 by 2023. Figure 4 presents a comparison of key climatic factors, showing an increase in rainfall of 211.972 mm, moisture by 11.765, and a temperature increase of 0.157°C within the same timeframe. Figures 5 and 6 depict changes in rainfall and moisture distribution, emphasizing the environmental shifts.

The findings in Serang City align with broader trends observed in urban environments. Liao and Du (2022) and Sumarmi et al. (2022) emphasize the importance of green spaces in

enhancing individual health and well-being. It is argued that even minor reductions in NDVI can adversely affect air quality and social cohesion. Barboza et al. (2021) and Grover & Singh (2015) demonstrate a correlation between higher NDVI values, reduced land surface Thermal measurements, and mortality rates. Decreasing NDVI may exacerbate the risks linked to heat-related health issues and negatively impact overall environmental quality.

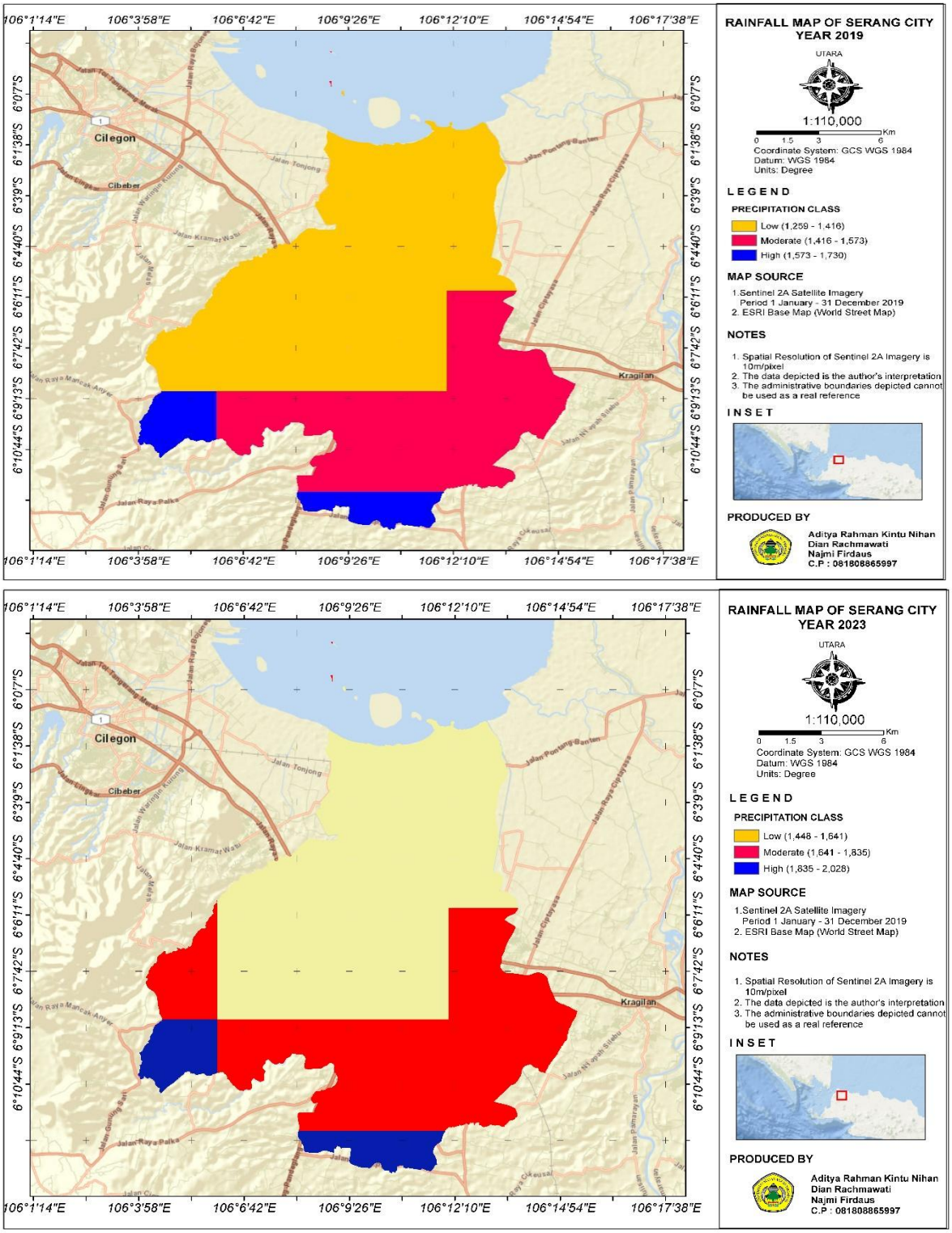

Figure 4. Rainfall Maps for Serang City: 2019 and 2023

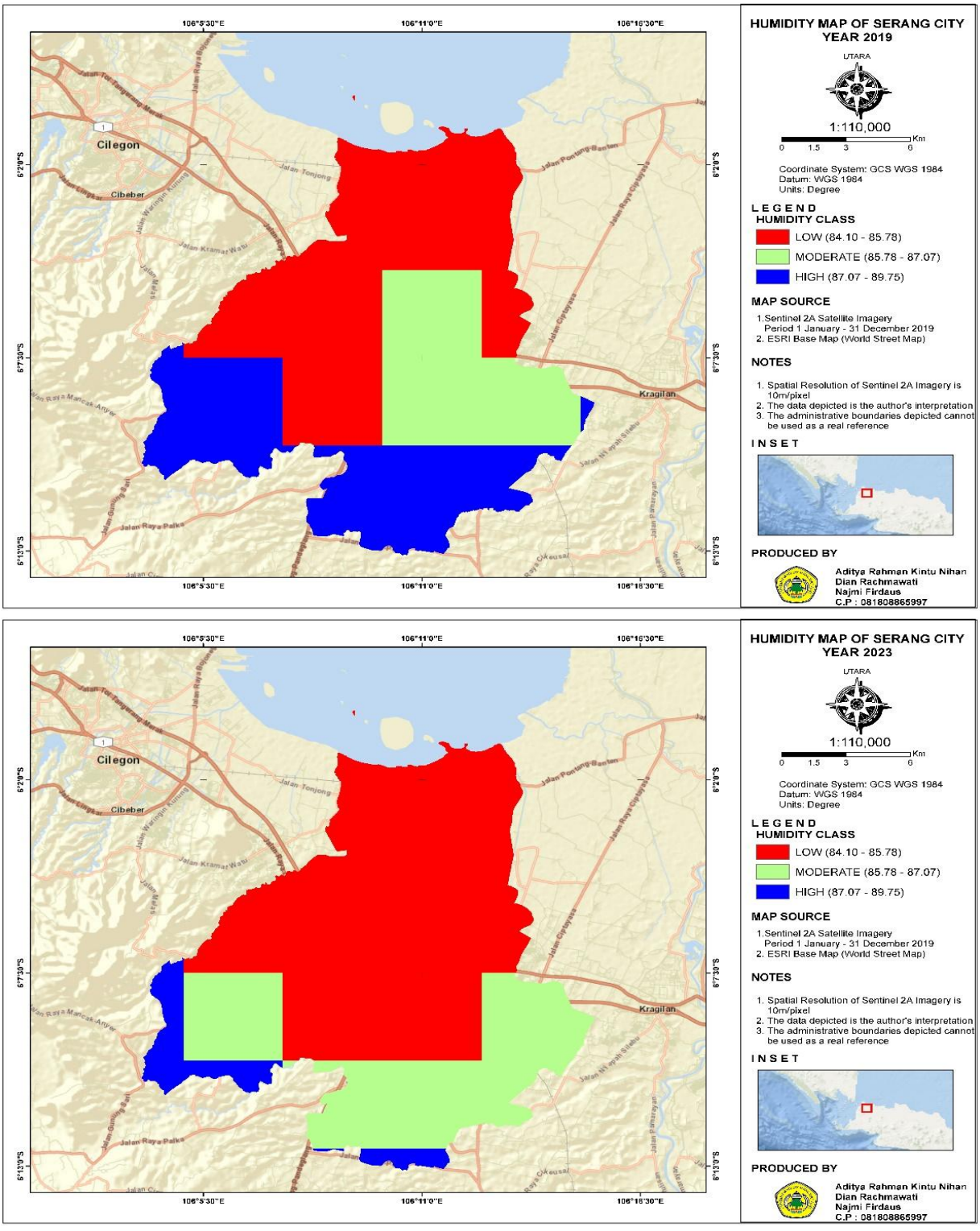

Figure 5. Moisture Map of Serang City for the years 2019 and 2023

Research by Çolakkadioğlu (2023) and Wikantiyoso et al. (2021) adds further evidence regarding these matters. Their findings indicate that areas with lower NDVI values are more susceptible to intensified urban heat island (UHI) effects, which can, in turn, cause heightened

heat stress for residents in those locations. Furthermore, Rahman et al. (2022) and Dagnachew et al. (2020) pointed out that increased rainfall and moisture in Serang City might mitigate these adverse effects, as more rainfall fosters healthier vegetation

The slight decline in the Normalized Difference Vegetation Index (NDVI) in Serang City emphasizes the importance of strategic urban planning to preserve and improve green spaces. These results deepen our comprehension of the intricate relationship between urban growth and ecological well-being. Factors such as population increase, thermal measurements, and heightened moisture levels intensify pressures on urban ecosystems, underscoring the need for sustainable development strategies. Research by Coffel et al. (2018) highlights that maintaining and enhancing NDVI quality is critical for alleviating Urban Heat Island (UHI) effects and supporting public health. Effective management of increased rainfall and moisture can positively influence vegetation health. It is essential for policymakers and urban planners to prioritize green space development, utilizing natural climatic benefits to strengthen urban vegetation. This approach is consistent with insights from Azizah et al. (2022) and Xu et al. (2021), which advocate for the integration of green infrastructure into urban planning. The trends observed in Serang City stress the urgent requirement for sustainable urban design that prioritizes environmental health. Continuous monitoring of NDVI and other vital environmental metrics allows policymakers to make informed choices that enhance urban vegetation, mitigate UHI impacts, and cultivate a healthier urban environment. This research enhances our understanding of urban ecological dynamics while offering guidance for creating sustainable and resilient cities.

CONCLUSION

This research utilizes the Normalized Difference Plant Index (NDVI) to examine changes in plant cover in Serang City from 2019 to 2023. The results reveal a substantial decline in NDVI, suggesting a decrease in vegetation cover primarily due to rapid urban development and shifts in land use practices. The rise in aquatic areas, along with the decrease in plant life and loss of high vegetation, underscores the evolving landscape of land cover changes.

Monitoring levels of carbon monoxide (CO) and carbon dioxide (CO2) is crucial for understanding the link between rising thermal measurements and shifts in vegetation in Serang City. Increased concentrations of these gases point to worsening air quality and intensify the urban heat island effect, which negatively impacts plant health.

The study highlights the importance of NDVI in evaluating the urban environment, showcasing its role in analyzing the effects of urbanization on vegetation health. By combining

advanced remote sensing techniques with NDVI analysis, this research provides accurate data and valuable insights into the vegetation dynamics of Serang City. Assessing changes in land cover and land use is vital for understanding the connections between variations in thermal measurements and vegetation dynamics. These insights are essential for urban planners and policymakers as they devise strategies to enhance green spaces, counteract the negative effects of urbanization, and encourage sustainable urban growth.

This study reveals gaps in current literature by offering specific data and analyses focused on mid-sized urban areas like Serang City. The results emphasize the urgent need for targeted reforestation and afforestation efforts to combat vegetation loss. The research advocates for the inclusion of green infrastructure, such as urban green belts, rooftop gardens, and vertical green spaces, alongside reforestation initiatives within sustainable urban development plans. Policies that limit urban sprawl through zoning regulations and incentives for high-density development can help alleviate the detrimental impacts of urban expansion on green spaces. These methods will not only enhance vegetation cover but also bolster climate resilience and improve the overall environmental quality in Serang City. Future research should persist in monitoring NDVI trends and investigating the long-term consequences of urbanization on vegetation abundance. This study plays a significant role in fostering a balance between urban development and environmental sustainability, providing actionable strategies to enhance urban ecosystems and improve residents' quality of life.

Policymakers should integrate green infrastructure into urban planning frameworks and prioritize the preservation of existing green spaces through enforceable zoning restrictions. Incentives for sustainable construction designs, such as green rooftops and vertical gardens, can further mitigate the impacts of urbanization on vegetation density. The combination of these initiatives and ongoing NDVI monitoring will constitute a comprehensive approach to support sustainable urban growth and enhance environmental quality for the people of Serang City.

REFERENCES

Azizah, S. N. N., June, T., Salmayenti, R., Ma'rufah, U., & Koesmaryono, Y. (2022). Land use change impact on normalized difference vegetation index, surface albedo, and heat fluxes in Jambi province: Implications to rainfall. *Agromet*, *36*(1), 51-59.

Barboza E. P., Cirach, M., Khomenko, S., Iungman, T., Mueller, N., Barrera-Gómez, J., Rojas-Rueda, D., Kondo, M., & Nieuwenhuijsen, M. (2021). Green space and mortality in European cities: a health impact assessment study. *The Lancet Planetary Health*. 5(10):e718–e730. doi:10.1016/S2542-5196(21)00229-1.

Burkart, K., Meier, F., Schneider, A., Breitner, S., Canário, P., Alcoforado, M. J., ... & Endlicher, W. (2016). Modification of heat-related mortality in an elderly urban population by vegetation (urban green) and proximity to aquatic (urban blue): evidence from Lisbon, Portugal. *Environmental health perspectives*, *124*(7), 927-934. doi:10.1289/ehp.1409529.

Chazdon, R. L. (2008). Beyond deforestation: restoring forests and ecosystem services on degraded lands. *Science*, *320*(5882), 1458–1460. doi:10.1126/science.1155365.

Chen, S., Zhu, Z., Liu, X., & Yang, L. (2022). Variation in vegetation and its driving force in the Pearl river delta region of China. *International Journal of Environmental Research and Public Health*, *19*(16), 10343. doi:10.3390/ijerph191610343.

Chen, X., Liu, C., & Yu, X. (2022). Urbanization, economic development, and ecological environment: evidence from provincial panel data in China. *Sustainability*, *14*(3), 1124. doi:10.3390/su14031124.

Clevers, J. G., Kooistra, L., & Van den Brande, M. M. (2017). Using Sentinel-2 data for retrieving LAI and leaf and canopy chlorophyll content of a potato crop. *Remote Sensing*, *9*(5), 405. doi:10.3390/rs9050405.

Coffel, E. D., Horton, R. M., & De Sherbinin, A. (2017). Thermal measurement and Moisture based projections of a rapid rise in global heat stress exposure during the 21st century. *Environmental Research Letters*, *13*(1), 014001. doi:10.1088/1748-9326/aaa00e.

Çolakkadioğlu D. (2023). The effects of urbanization and vegetation cover on urban heat island: a case study in osmaniye province. *International Journal of Environment and Geoinformatics*, *10*(1):120–131. doi:10.30897/ijegeo.1144167.

Cunningham, S. C., Mac Nally, R., Baker, P. J., Cavagnaro, T. R., Beringer, J., Thomson, J. R., & Thompson, R. M. (2015). Balancing the environmental benefits of reforestation in agricultural regions. *Perspectives in Plant Ecology, Evolution and Systematics*, *17*(4), 301-317. doi:10.1016/j.ppees.2015.06.001.

Dagnachew, M., Kebede, A., Moges, A., & Abebe, A. (2020). Effects of Climate Variability on Normalized Difference Vegetation Index (NDVI) in the Gojeb River Catchment, Omo-Gibe Basin, Ethiopia. *Advances in Meteorology*, *2020*(1), 8263246. doi:10.1155/2020/8263246.

Du, J., Zhao, C., Shu, J., Jiaerheng, A., Yuan, X., Yin, J., ... & He, P. (2016). Spatiotemporal changes of vegetation on the Tibetan Plateau and relationship to climatic variables during multiyear periods from 1982–2012. *Environmental Earth Sciences*, *75*, 1-18. doi:10.1007/s12665-015-4818-4.

Grover, A, & Singh R. (2015). Analysis of Urban Heat Island (UHI) about Normalized Difference Vegetation Index (NDVI): A Comparative Study of Delhi and Mumbai. *Environments*. *2*(4):125–138.doi:10.3390/environments2020125.

Hashim, H., Abd Latif, Z., & Adnan, N. A. (2019). Urban vegetation classification with NDVI threshold value method with very high resolution (VHR) Pleiades imagery. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*, 237-240. doi:10.5194/isprs-archives-XLII-4-W16-237-2019.

Jeong, S. J., Ho, C. H., & Jeong, J. H. (2009). Increase in vegetation greenness and decrease in springtime warming over east Asia. *Geophysical Research Letters*, *36*(2), 2008GL036583. doi:10.1029/2008GL036583.

Krupnova, T. (2022). Urban greening for lead soils pollution control in a russian industrial city: the use isotope signatures analysis and remote sensing. *GEOMATE*, *23*(100). doi:10.21660/2022.100.3659.

Li, G., Yu, L., Liu, T., Bao, Y., Yu, J., Xin, B., ... & Zhang, S. (2023). Spatial and temporal variations of grassland vegetation on the Mongolian Plateau and its response to climate change. *Frontiers in Ecology & Evolution*, *11*, 1067209. doi:10.3389/fevo.2023.1067209.

Liao, L., & Du, M. (2022). Associations between Greenspaces and Individual Health: A Longitudinal Study in China. *International Journal of Environmental Research and Public Health*, *19*(20), 13353. doi:10.3390/ijerph192013353.

Liu, Y., Wang, Y., Peng, J., Du, Y., Liu, X., Li, S., & Zhang, D. (2015). Correlations between urbanization and vegetation degradation across the world's metropolises using DMSP/OLS nighttime light data. *Remote Sensing*, *7*(2), 2067-2088. doi:10.3390/rs70202067.

Nguyen, T. P. C. (2023). Analyzing the urban heat island in ho chi minh city in relation to urban planning processes from 2010 to 2020. *IOP Conf. Ser.: Earth Environ. Sci.* 1170(1), 012016. doi:10.1088/1755-1315/1170/1/012016.

Park, H. & Sohn, B. J. (2010). Recent trends in changes of vegetation over East Asia coupled with Thermal measurement and rainfall variations. *J. Geophys. Res.* 115(D14), 2009JD012752. doi:10.1029/2009JD012752.

Rahman, M., Hossain, K., Islam, M., & Zahid, D. (2022). Land use / land cover changes monitored by NDVI index in Rangamati, Bangladesh for the last four decades. *Bangladesh J. Agri.*:127–140. doi:10.3329/bjagri.v46i1-6.59980.

Rosleine, D., & Irfan, M. Land Cover Change and Land Surface Thermal measurement (LST) in North Bandung Area (NBA) from 2010-2018. *J. Biol. Sci. Technol. Man, 3*(2):51–59. doi:10.5614/3bio.2021.3.2.6.

Rouse, J. W., Haas, R. H., Schell, J. A., & Deering, D. W. (1974). Monitoring vegetation systems in the Great Plains with ERTS. *NASA Spec. Publ*, *351*(1), 309.

Sumarmi, S., Mariza, S. S. R., Sari, R. R. A., Pratama, M. R., & Tanjung, A. (2022). The effect of vegetation density on land surface Thermal measurement in Klojen District. *KnE Social Sciences*, 426-437.

Trac, C. J., Harrell, S., Hinckley, T. M., & Henck, A. C. (2007). Reforestation programs in Southwest China: reported success, observed failure, and the reasons why. *Journal of Mountain Science*, *4*, 275-292. doi:10.1007/s11629-007-0275-1.

Wikantiyoso, R., Sulaksono, A. G., & Suhartono, T. (2021). Detection of potential green open space area using landsat 8 satellite imagery. *ARTEKS: Jurnal Teknik Arsitektur*, *6*(1), 149-154. doi:10.30822/arteks.v6i1.730.

Wu, H., Zhang, J., Bao, Z., Wang, G., Wang, W., Yang, Y., ... & Kan, G. (2022). The impacts of natural and anthropogenic factors on vegetation change in the Yellow-Huai-Hai River Basin. *Frontiers in Earth Science*, *10*, 959403. doi:10.3389/feart.2022.959403.

Xu, B., Qi, B., Ji, K., Liu, Z., Deng, L., & Jiang, L. (2022). Emerging hot spot analysis and the spatial–temporal trends of NDVI in the Jing River Basin of China. *Environmental Earth Sciences*, *81*(2), 55.

Yasin, M. Y., Abdullah, J., Noor, N. M., Yusoff, M. M., & Noor, N. M. (2022, October). Landsat observation of urban growth and land use change using NDVI and NDBI analysis. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1067, No. 1, p. 012037). IOP Publishing.