IDENTIFICATION OF WASTE DISPOSAL SITES USING THE GREENHOUSE GAS AND VEGETATION INDEX METHOD: A CASE STUDY OF JAKARTA PROVINCE

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Abstract: Waste dumps pose a significant environmental challenge in urban areas, such as Jakarta. Remote sensing provides an efficient and cost-effective approach for identifying waste accumulation sites. This study aimed to identify waste dump sites using open-source remote sensing data by integrating greenhouse gas indicators and vegetation indices. The Landsat 8, Sentinel-2, Sentinel-3, OCO-2 GEOS Level 3, and Sentinel-5P TROPOMI data were utilised to derive the Normalised Difference Vegetation Index (NDVI), Land Surface Temperature (LST), methane (CH_4), and carbon dioxide (CO_2). The Bantar Gebang Final Disposal Site was selected as the study area. The vegetation in this area was classified as class 5, indicating minimal vegetation presence. The deterioration in vegetation health is attributed to leachate infiltration into the soil and groundwater, subsequently absorbed by plants. Concurrently, the temperature ranges from a minimum of 43°C to a maximum of 63°C, exceeding that of the surrounding regions. The waste decomposition process is responsible for the elevated LST at the site. Methane (CH_4) and carbon dioxide (CO_2) concentration measurements revealed methane levels at 1,948 ppb and carbon dioxide levels between 413.617 ppm and 415.96 ppm. The rise in CO_2 levels is associated with a decline in vegetation index values, which impairs photosynthesis. These values are influenced by meteorological conditions. Verification was conducted using high-resolution aerial photographs to provide a real-color visualisation of field conditions. Further research is necessary to accurately identify waste accumulation points at various scales or sizes.

Keywords: Waste dump; identification; NDVI; LST; methane; carbon dioxide

Abstrak: Tumpukan sampah merupakan salah satu tantangan lingkungan yang dihadapi pada wilayah perkotaan seperti Jakarta. Identifikasi tumpukan sampah dapat dilakukan dengan menggunakan pendekatan penginderaan jauh. Hal ini dikarenakan pendekatan ini lebih efisien karena lebih murah. Penelitian ini bertujuan mengidentifikasi tumpukan sampah dengan mengintegrasikan indikator gas rumah kaca dan indeks vegetasi. Penelitian ini menggunakan data Landsat 8, Sentinel-2, Sentinel-3, OCO-2 GEOS Level 3, dan Sentinel-5P TROPOMI untuk menghasilkan *Normalized Difference Vegetation*

Index (NDVI), *Land Surface Temperature* (LST), metana (CH_4), dan karbon dioksida (CO_2). Fokus lokasi penelitian ini adalah tempat pembuangan sampah Bantar Gebang sebagai lokasi akumulasi sampah di Jakarta. Kondisi vegetasi pada area tersebut berada pada kelas 5 (lima) dengan kriteria very little vegetation. Penurunan kesehatan vegetasi dipicu oleh air lindih yang meresap ke dalam tanah dan air tanah yang kemudian diserap oleh tanaman. Sementara temperaturenya adalah minimal 43°C dan maksimal 63°C, lebih tinggi dibandingkan dengan area sekitarnya. Proses dekomposisi pada sampah menjadi penyebab peningkatan LST pada lokasi penelitian. Hasil pengukuran konsentrasi metana (CH_4) dan karbon dioksida (CO_2) diperoleh nilai konsentrasi metana sebesar 1.948 ppb dan karbon dioksida sebesar 413,617 ppm – 415,96 ppm. Peningkatan nilai CO_2 berkaitan dengan penurunan nilai indeks vegetasi yang menurunkan proses fotosintesis. Nilai-nilai tersebut dikontrol oleh kondisi meteorologi. Verifikasi dilakukan dengan menggunakan foto udara resolusi tinggi untuk menunjukkan visualisasi warna nyata kondisi lapangan. Penelitian ini masih perlu dikembangkan lebih lanjut untuk dapat menentukan titik-titik tumpukan sampah secara presisi pada berbagai skala atau luasan tumpukan sampah.

Kata kunci: Tumpukan sampah; identifikasi, NDVI; LST; metana; karbon dioksida

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Introduction

Jakarta, a bustling metropolis, had a population of 11,010,514 at the start of 2025 (Badan Pusat Statstik Indonesia, 2025). This large population contributes to the vast amount of waste produced in the city. As reported by (JaKita, 2024), Jakarta's residents generate 3.1 million tons of waste annually, which is distributed across various waste disposal sites throughout the city. The Jakarta Environmental Agency manages 1,077 officially registered waste disposal sites. spread across the region. However, this number only accounts for the registered and managed sites; numerous illegal and unmanaged waste piles still exist. These unauthorised waste sites can harm the environment, leading to air, water, and soil pollution.

Jabodetabek, encompassing Jakarta, Depok, Bogor, and Tangerang, is a metropolitan area in Indonesia comprising cities and regencies that are among the ten most populous regions. As reported by (Majid. A. A, 2025), the average daily waste produced per individual in Jakarta is approximately 0.65–0.7 kg. The study further indicates that a 1% increase in population correlates with a 0.432% increase in waste production. Additionally, (Diani. M. R, 2024)conducted an exponential analysis forecasting that Jakarta's population from 2020 to 2029 will reach 12,170,580, with waste generation amounting to 8,316.49 m^3/day. This suggests a continual rise in waste volume in Jabodetabek. Meanwhile, according to (JaKita, 2024) data, there are 1,077 trash bins distributed throughout Jakarta in 2024, as depicted in **Figure 1.** The Bantar Gebang Final Disposal Site, located in Bekasi City, West Java, was selected as the focal study area because it serves as a major

accumulation and disposal site for waste generated in Jakarta. The site is located in approximately 6°20′58″ S and 106°59′51″ E and covers an area of approximately 110.3 ha.

Waste piles emit greenhouse gases like carbon dioxide (CO_2) and methane (CH_4), which contribute to air pollution (Zhou. Z, 2023). According to (Boongla. Y, 2025), waste disposal sites are significant sources of greenhouse gases in urban settings. Furthermore, leachate from these waste piles can infiltrate the ground, contaminating both soil and groundwater. Identifying the locations of landfills is crucial for pinpointing waste pile sites. This identification process involves two methods: direct field identification and remote sensing technology. Conducting surveys at each waste site is time-consuming and costly (Fraternali. P, 2024). Additionally, some waste sites are difficult to locate and frequently change positions.

Utilising satellite imagery simplifies the process of identification. Moreover, access to data over extended periods aids in tracking changes over time, such as pinpointing when waste piles first appeared. Time series data can also reveal the spread and extent of pollution resulting from waste (Acevedo. R. H. R, 2023) (Papale. L. G, 2023). The identification process involves examining remote sensing data (Landsat imagery) by assessing physical conditions, such as land surface temperature and methane levels (Song. Y, 2024) (Bozorgi. M, 2020) along with biological conditions (Normalised Difference Vegetation Index, Soil-adjusted Vegetation Index) (Acevedo. R. H. R, 2023); (Aquino. D. D. N, 2018) Waste piles lead to increased temperature and methane, causing spectral variations in the imagery compared to the surrounding areas (Papale. L. G, 2023); (Wang. Y, 2024). The identification system in this research integrates greenhouse gas variables (CO2, CH4, and temperature) with biological variables (Papale. L. G, 2023); (Fraternali. P, 2024). This study aims to identify waste piles/landfills based on these factors. The identification system in this research integrates greenhouse gas variables (CO_2, CH_4, and temperature) with biological variables (vegetation index). Previous remote sensing identification efforts have concentrated on a single variable. Meanwhile, the study's location, Jakarta, is a densely built urban area with high activity levels, making it challenging to conduct temperature- and vegetation-based identification. This study specifically focuses on the Bantar Gebang Landfill, a major waste accumulation and disposal site receiving waste generated from Jakarta.

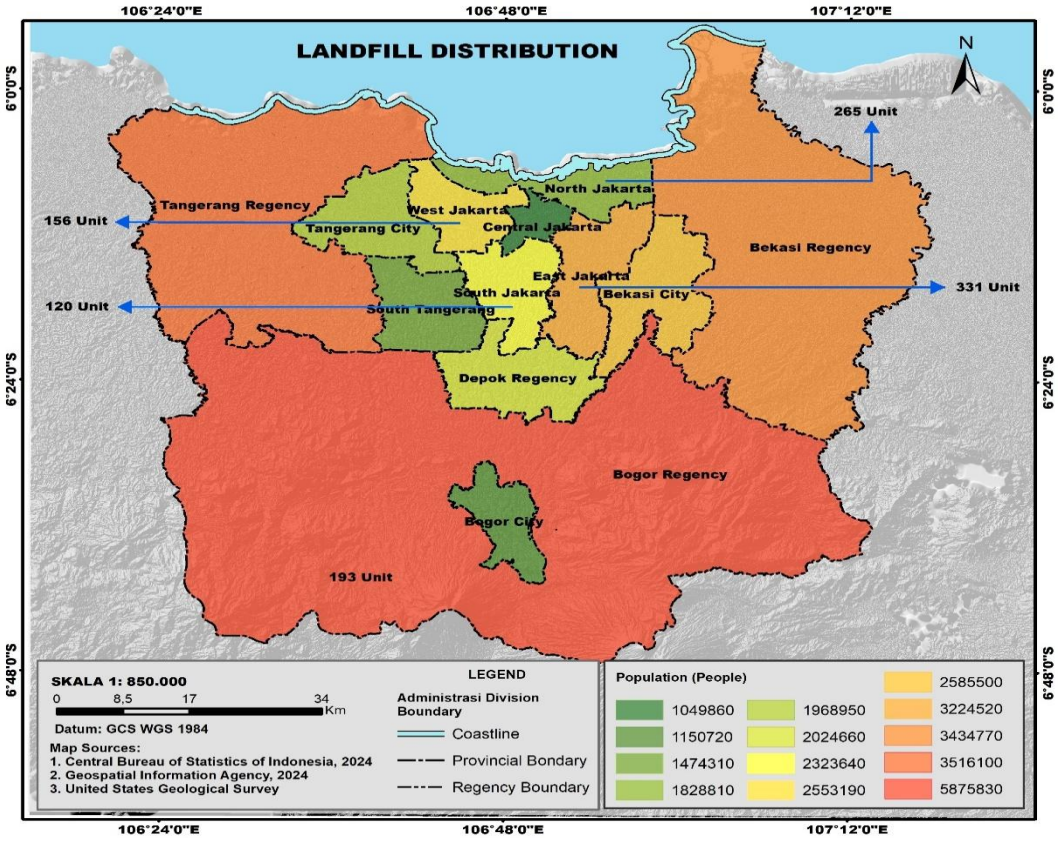


Figure 1. Landfill Distribution of Jabodetabek

Materials and methods

Data Acquisition

The application of remote sensing in identifying waste piles is carried out by measuring Land Surface Temperature (LST), Methane, Vegetation Index, and Carbon dioxide. These calculations used a combination of data, as shown in **Table 1**.

Table 1. Research data

Citra Satellite	Sensor	Path/Row	Bands	Used For	Resolution	Time	Spectral Bands	Year
Landsat 8 Collection 2 Level-2 (L2)	OLI	122/65	Band 5 Band 4	NDVI	30 m	16 days	NIR: 0.85-0.88 µm Red: 0.64-0.67 µm	2013
	TIRS	122/65	Band 10	LST	100 m	16 days	Thermal Infrared 10.60 – 11.19 µm	2013
Sentinel-2 Level 2A (L2A)	MSI	MGRS Tile 48MVT	Band 4 Band 8	NDVI	10 m	5 days	Red: 0.665 µm NIR: 0.842 µm	2015

Citra Satellite	Sensor	Path/Row	Bands	Used For	Resolution	Time	Spectral Bands	Year
Sentinel-3 Level 2A (L2A)	SLSTR	-	S8 S9	LST	1 km	< 2 Global days	10.85 µm 12.00 µm	2016
Sentinel-5 Level 3 (L3)	TROPOMI	-	SWIR	Methane (CH_4)	7 km	daily	2.3 µm	2017
OCO-2 GEOS LEVEL 3	Three High-Resolution Grating Spectrometers	-		Atmospheric Carbon Dioxide (CO_2)	1,29 x 2,25 Km	Daily	Weak CO_2 Band 1.594 - 1.627 µm Strong CO_2 Band 2.043 – 2.087 µm	2014

Source: *USGS, 2026; ESA, 2026*

Analysis methods

This analysis applies the calculation formulas for land surface temperature (LST), NDVI, CH4, and CO2 using ArcGIS Pro, SNAP, and Google Earth Engine software, as follows:

Land Surface Temperature (LST)

The Land Surface Temperature was calculated by calculating the Brightness Temperature (Tb) using equation 1.

$$LST = \frac{T_b}{1+(\frac{\lambda T_b}{d})In\,(e)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where Tb is the Brightness Temperature (Kelvin), this value is obtained from equation 2, λ is the wavelength of radiance (µm) in Band 10, d is the ratio between the speed of light (3 x 10^8 m/s) and the Planck constant (6.626 x 10^-34 J·s), and In(e) is the emissivity. The emissivity was calculated using equation 2.

$$T_b = \frac{K_2}{In\,(\frac{K_1}{L\lambda}+1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where K1 and K2 are the thermal conversion constants used to convert spectral radiance to Tb. The values of K1 and K2 are the Top of Atmosphere (TOA) Spectral Radiance, using equation 3.

$$e = 0.004 + 0.986\,P_v \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where is the percentage of vegetation cover. Vegetation density was used to assess the level of vegetation health. The percentage of vegetation cover was calculated using Equation (4):

$$P_v = (\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}})^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

where the Normalised Difference Vegetation Index (NDVI) is obtained using equation 5, as follows:

$$NDVI = \left[\frac{NIR - RED}{NIR + RED}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where NIR is near infrared (Band 5) reflected by leaves, while RED is the light absorbed by vegetation for photosynthesis (chlorophyll). The maximum and minimum NDVI values were obtained using this calculation. The calculation of the normalised difference vegetation index (NDVI) was classified into six classes according to the classification by Aquino et al. (2018), as described in **Table 2.** The land surface temperature (LST) was classified into five classes based on the classification equationgi et al. (2020), as described in **Table 3**:

Table 2. Normalized Difference Vegetation Index Classification

NDVI Classification	NDVI Criteria
A complete lack vegetation	-1-0
Very little vegetation	0-0.1
Sparse vegetation	0.1-0.3
Moderate vegetation	0.3-0.6
Healthy thriving crops	0.6-0.9
Dense overgrown vegetation	0.9-1

Table 3. classification scheme based on mean standard deviation method

Temperature Classification	Category Interval
High temperature	Ts > μ + std
Secondary high temperature	μ + 0.5 std < TS≤ μ + std
Medium temperature	μ - 0.5 std≤ Ts≤ μ + 0.5 std
Secondary low temperature	μ - std ≤ Ts < μ-0.5 std
Low temperature	Ts< μ std

Methane (CH_4) and Carbon Dioxide (CO_2)

Tropospheric Monitoring Instrument (TROPOMI) satellite data are used to measure methane (CH_4). The working principle of TROPOMI is to measure the absorption of sunlight by methane in the shortwave infrared (SWIR) spectrum. Methane was measured using equation (6), as follows:

$$I(\lambda) = I_0(\lambda).\exp(-\sigma(\lambda).\mathrm{N}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where $I_0(\lambda)$ is initial light intensity, $\sigma(\lambda)$ adalah cross-section absorsi CH_4 pada and N are columns representing the number of CH_4 molecules in the atmosphere. The value of N is calculated using equation 7 as follows:

$$\mathrm{N} = \frac{In(I(\lambda)/I_0(\lambda))}{I_0(\lambda)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Carbon dioxide (CO_2) was calculated using OCO 2-GEOS-Level 3 satellite imagery data. This calculation utilised sunlight absorption.

Result and discussion

Normalized Difference Vegetation Index (NDVI)

The Normalised Difference Vegetation Index (NDVI) was evaluated using a scale ranging from -1 to 1. A score of -1 indicates the absence of vegetation, whereas a score of 1 indicates dense vegetation. The concept of NDVI lies in the role of vegetation in controlling soil moisture and biodegradation processes that affect greenhouse gas emissions. By incorporating NDVI analysis, it becomes possible to analyse the landscape characteristics within landfill areas that have better potential to reduce emissions through healthy vegetation cover. In short, the underlying conceptual process of NDVI is as follows: Measurement of reflectance influenced by the health and abundance of vegetation. This reflectance indicates certain ecological conditions that affect biogeochemical processes, including their impact on surface temperature and soil moisture. Good vegetation conditions (high NDVI) are usually associated with a stable environment, vigilance towards temperature and moisture, and influence gas emissions from the area as presented in the equation approach (5) (Ali et al., 2025).

This evaluation is based on the absorption of red-light during photosynthesis (due to chlorophyll in leaves) and the reflection of near-infrared (NIR) light, which is higher in healthy vegetation. Consequently, the NDVI value reflects the chlorophyll content in leaves, suggesting that vegetation in poor health will have a low index value (Papale. L. G, 2023). In Jabodetabek, NDVI calculations reveal that most areas exhibit low values, as depicted in **Figure 2**. This is expected given the region's land cover, which is predominantly urbanised. Therefore, NDVI alone is insufficient for identifying waste disposal sites or garbage piles in urban settings, although it can be combined with other variables. In this study, the Bantar Gebang Final Disposal Site was analysed as a known waste site. The analysis, using NDVI and high-resolution aerial photos, shows vegetation presence in the area according to the photos. However, the NDVI classifies the area as having very little vegetation, with values between 0 and 0.1, indicating deteriorating vegetation health, possibly due to soil contamination (Acevedo. R. H. R, 2023); (Vanguri. R, 2024). The study by (Papale. L. G, 2023) indicates that the removal of waste piles results in an increase in NDVI values as determined through image processing.

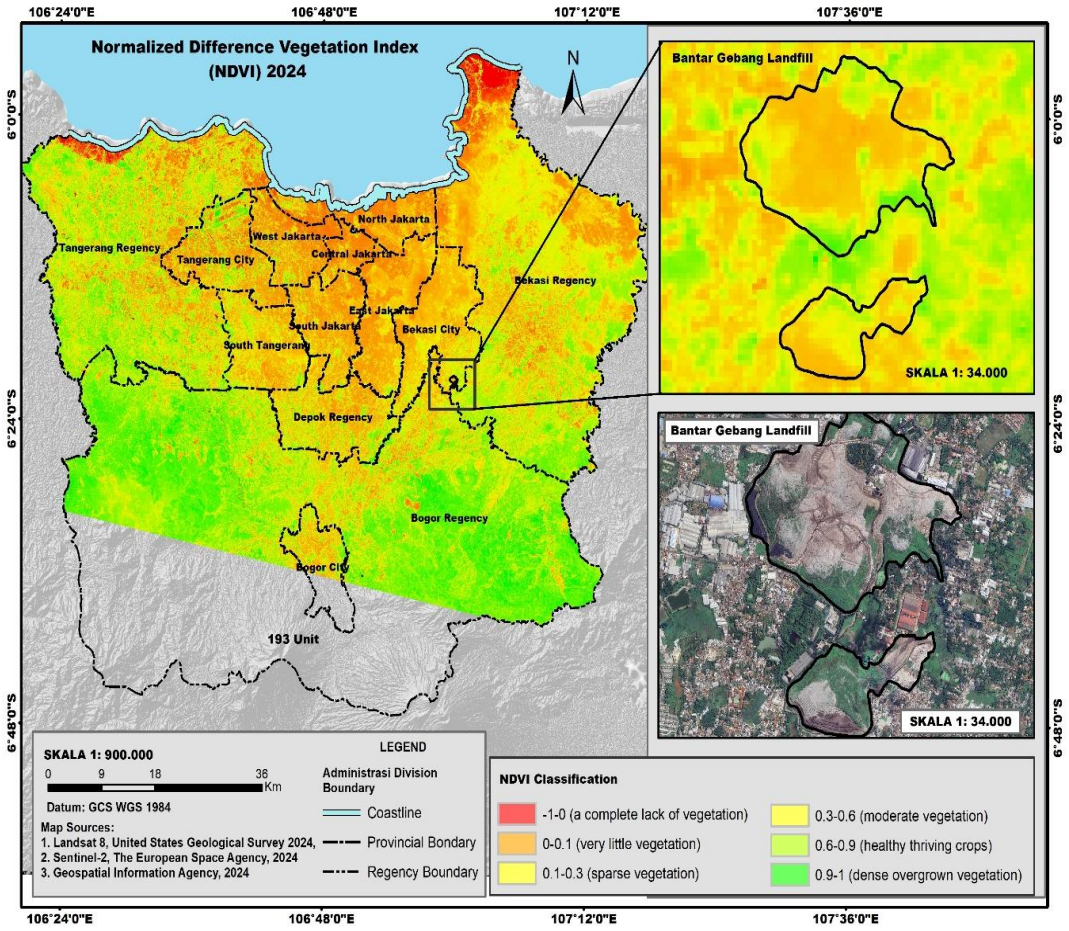


Figure 2. Normalized Difference Vegetation Index (NDVI)

Land Surface Temperature

The determination of land surface temperature (LST) is influenced by the land cover within the study area, which is primarily an urban zone characterised by extensive built-up land. Urban regions typically exhibit higher temperatures than their non-urban counterparts. In urban settings, LST is often represented by a central area with elevated temperatures, encircled by zones where LST values gradually diminish, known as sub-urban areas (Aslam. B, 2021). (This pattern is akin to NDVI analysis, where identifying waste sites or piles cannot rely solely on the LST variable, as depicted in **Figure 3**. The LST calculation outcomes for the study area are shown in the Figure. The LST at the study site predominantly falls into class 5, labeled as Very High LST. The temperature at the waste pile site exceeds 40°C, significantly surpassing the temperatures of the surrounding areas, with differences reaching up to 20°C (Trinh. L. H, 2022). The analysis indicates that temperatures at Bantar Gebang range from a minimum of 43°C to a maximum of 63°C, contrasting with the surrounding areas, which are classified as Medium with temperatures below 40°C. The elevated Land Surface Temperature (LST) values observed in this region are attributed to the process of waste decomposition.

This decomposition results in a substantial increase in air temperatures, reaching between 90°C and 140°C, in contrast to the surrounding areas. Furthermore, LST values are also affected by meteorological conditions. During the dry season, heightened thermal activity at waste sites induces an increase in LST values (Papale. L. G, 2023) (Yalçınkaya. s, 2023).

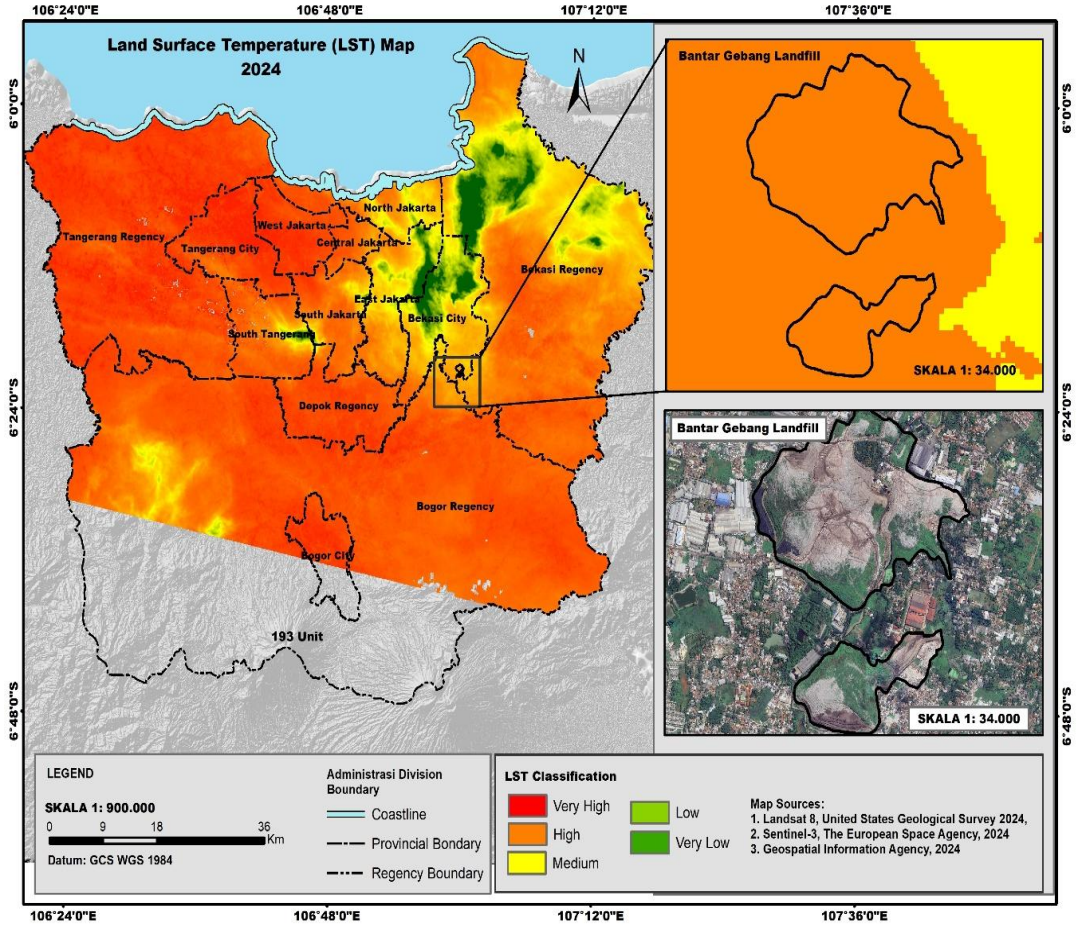


Figure 3. Land surface temperature (LST)

Methane (CH_4) and Carbon Dioxide (CO_2)

According to research conducted by (Gavrila. G. O, 2025), the concentration of CH_4 in landfill sites was 137,300 ppb, while the level of carbon dioxide (CO_2) is 249 mg/m3. The study identified two primary locations with the highest Methane concentrations, one of which was the Bantar Gebang Final Disposal Site. This site is classified as Class 5, with Methane levels exceeding 1,948 ppb, as depicted in **Figure 4**. This demonstrates that waste pile identification can be achieved by measuring Methane and Carbon Dioxide concentrations. Analysing Methane (CH_4) levels over a time series from 2019 to 2024 reveals that the peak concentration occurred in 2021. Factors contributing to this include weather conditions, the increase in waste volume, and the types of waste present.

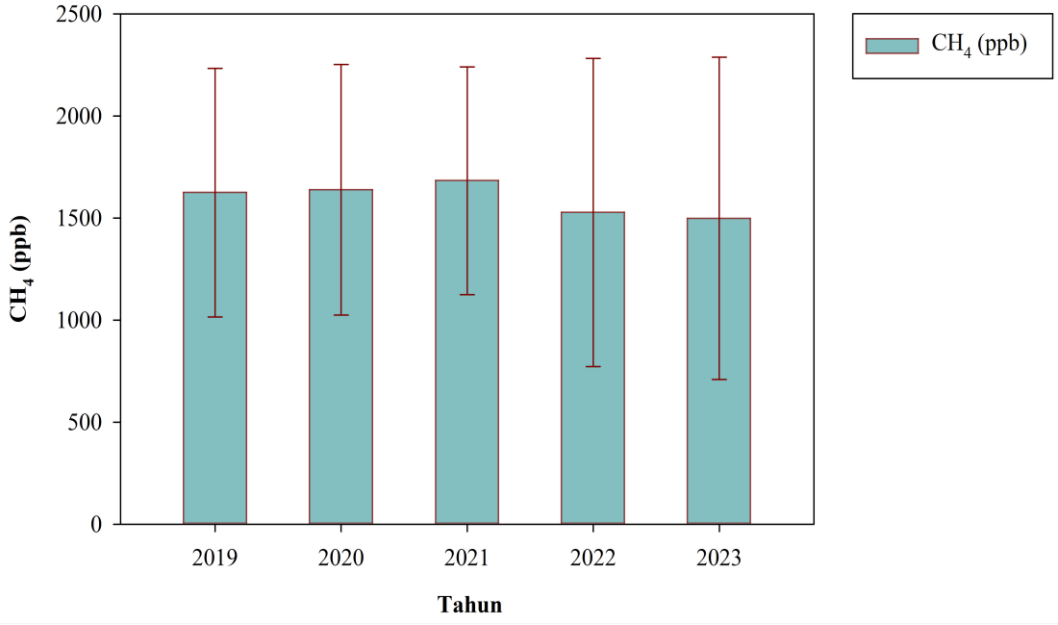


Figure 4. Time series methane (CH_4)

The geospatial analysis results (**Figure 5**) for methane (CH_4) levels in 2024 across the Greater Jakarta area (Jabodetabek) revealed notable spatial differences, with concentrations ranging from 1,803 to over 1,948 ppb. The highest levels were detected near the Bantar Gebang landfill in Bekasi City, marked by the red zone (>1,948 ppb). This pattern indicates that the Bantar Gebang landfill serves as a significant source of methane emissions in the Jabodetabek metropolitan area. The peak concentrations were highly concentrated in the active landfill zone, as shown in the detailed scale enlargement, which illustrates a direct spatial link between the waste disposal site and elevated CH_4 levels. Beyond the landfill's core area, methane concentrations gradually decreased (spatial gradient) towards the surrounding regions. Western Bekasi, East Jakarta, and parts of Depok exhibited medium to high concentrations (1,889–1,948 ppb), reflecting the impact of gas dispersion from the primary source and contributions from urban human activities such as domestic waste management, industrial operations, and transportation. Conversely, areas with more vegetation and lower urban density, such as southern Bogor and parts of Tangerang, displayed lower concentrations (1,803–1,858 ppb). Overall, this spatial distribution highlights the link between the intensity of waste management activities at the Bantar Gebang landfill and the rise in regional methane levels. These findings emphasise the urgent need to enhance landfill gas collection and utilisation systems as a strategy to mitigate greenhouse gas emissions in densely populated urban areas. In addition to aiding in climate change mitigation, optimising methane gas management also has the potential to improve environmental quality and support the sustainable use of waste-based energy.

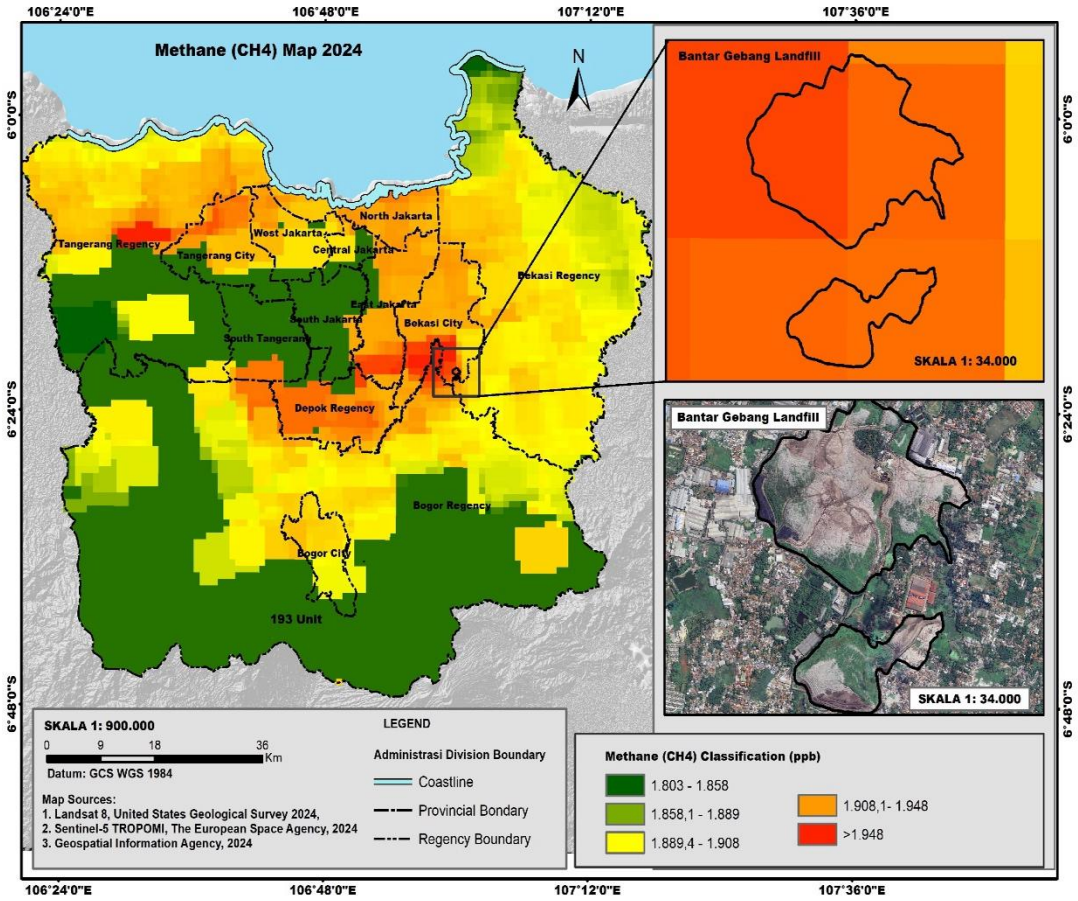


Figure 5. Dispersion of methane (CH_4) 2024

The calculation of carbon dioxide (CO_2) concentration adheres to the same principles as those used for determining methane and land surface temperature (LST) concentrations, with meteorological conditions significantly influencing the fluctuations in CO_2 levels. The distribution of CO_2 values, as depicted in Fig 6, indicates that the Bantar Gebang Landfill exhibits concentrations ranging from 413.617 to 415.96 ppm, which is classified as a moderate level. This concentration is notably higher than that of the surrounding areas. Elevated CO_2 concentrations are observed in August, coinciding with the dry season. The CO_2 concentration at the research site is associated with the calculation of the vegetation index, where unhealthy vegetation results in suboptimal photosynthesis, thereby increasing CO_2 levels (Gavrila. G. O, 2025). The dispersion of CO_2 in the air at the site can extend up to 5 km from the landfill. The distribution of CO_2 is predominantly governed by wind movement at the location.

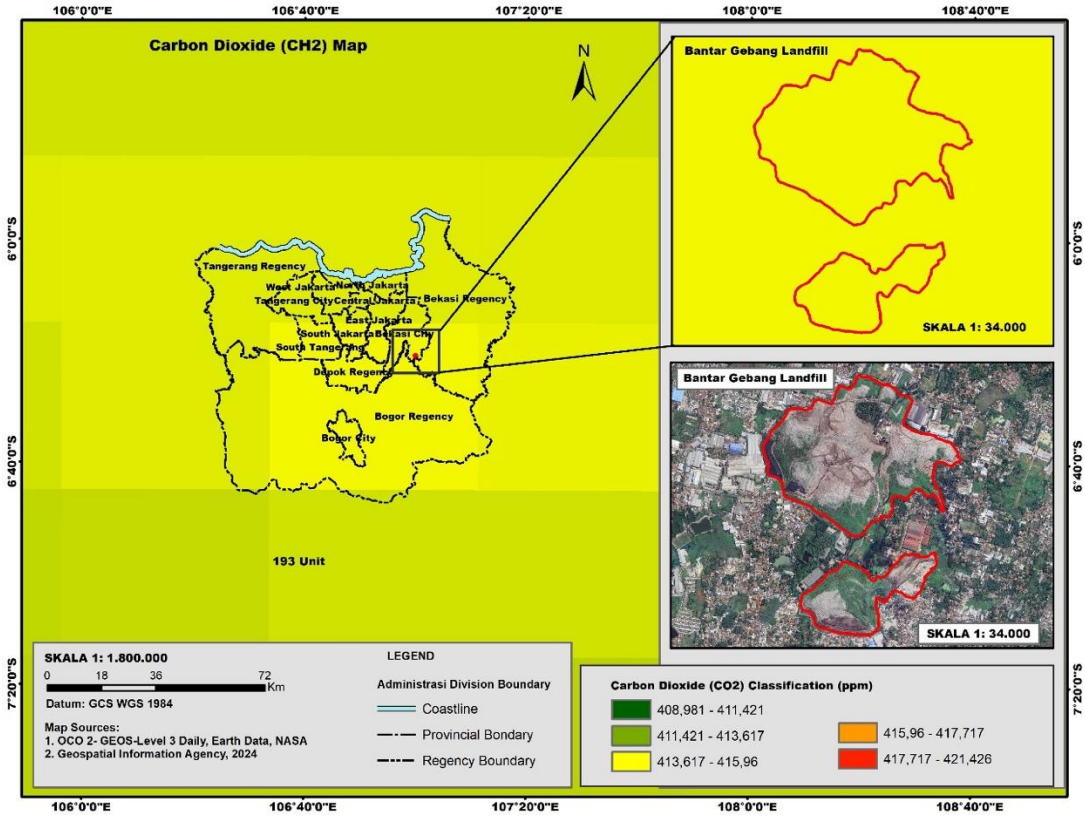


Figure 6. Carbon dioxide (CO_2)

Conclusion

In urban centres, such as Jakarta, persistent waste accumulation results in contamination of air, water, and soil. To efficiently identify these waste accumulations, an economical and time-efficient remote sensing technique can be employed. This method utilises data from Landsat 8, Sentinel-2, Sentinel-3, and Sentinel-5P TROPOMI. The detection process involves evaluating vegetation health through the normalised difference vegetation index (NDVI), assessing land surface temperature (LST), and analysing greenhouse gases, including methane and carbon dioxide. The Bantar Gebang Final Waste Disposal Site served as the primary focus of these measurements. Vegetation in this area was classified as class 5, indicating sparse vegetation cover. The temperature ranged from 43°C to 63°C, significantly higher than that of the surrounding regions. Methane (CH_4) and carbon dioxide (CO_2) levels were measured, with methane concentrations recorded at 1,948 ppb. High-resolution aerial images were employed for validation, providing true-color visuals of the site conditions. Further research is required to accurately locate waste piles at varying scales or extents. This study illustrates that the integration of multi-source remote sensing data effectively identifies landfill areas within densely populated urban environments. By spatially overlaying land surface temperature (LST), normalised difference vegetation index (NDVI), methane (CH_4), and carbon dioxide (CO_2), the Bantar Gebang landfill was accurately identified as the primary

waste disposal site in the Jabodetabek region. This landfill is characterised by high LST (43–63°C), elevated CH_4 levels (1,948 ppb), and CO_2 concentrations (413.617–415.96 ppm), along with poor vegetation health, as indicated by lower NDVI values. These environmental conditions are linked to the decomposition of organic waste and leachate pollution, which increase greenhouse gas emissions and hinder vegetation growth. The findings suggest that integrating physical, biological, and atmospheric indicators enhances landfill detection and offers an effective approach for environmental monitoring and sustainable waste management in urban areas.

Conflict of Interest

The authors declare no competing financial interests or personal relationships that could influence the work reported in this study.

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References

Acevedo. R. H. R, R. B. (2023). Analysing solid waste landfills using satellite imagery and designing new landfill reception areas. *Journal of Applied and Natural Science*, 732-740. https://doi.org/10.31018/jans.v15i2.4456

Ali, Md T., Bari, Q. H., & Rafizul, I. M. (2025a). Field validation of predictive model for greenhouse gas emissions from unsanitary landfill. Cleaner Engineering and Technology, 29, 101086. https://doi.org/10.1016/j.clet.2025.101086

Aquino. D. D. N, N. O. (2018). Use of remote sensing to identify areas at risk of degradation in the semi-arid region. *Revista Ciencia Agronomica*, 420-429. https://doi.org/10.5935/1806-6690.20180047

Aslam. B, M. A. (2021). Urban overheating assessment through prediction of surface temperatures: a case study of Karachi, Pakistan. *ISPRS int. J. Geo-Inf*, 539. https://doi.org/10.5935/1806-6690.20180047

Badan Pusat Statstik Indonesia. (2025). *Statistik Indonesia Tahun 2025*. Jakarta: Badan Pusat Statistik.

Boongla. Y, C. S. (2025). Estimating of characteristics, Methane generate and sustainability of Municipal landfill waste in urban city, Thailand. *Recycling*, 15. https://doi.org/10.3390/recycling10010015

Bozorgi. M, F. N. (2020). Trend analysis development of urban heat island using thermal remote sensing. *Earth Observation and Geomatics Engineering*, 1086. https://doi.org/10.22059/eoge.2021.309046.1086

Diani. M. R, H. D. (2024). Analisis proyeksi pertumbuhan penduduk dan volume sampah DKI Jakarta terhadap dampak yang ditimbulkan . *Journal of Waste*

and Sustainable Consumption, 27-41. https://doi.org/10.61511/jwsc.v1i1.2024.691

Fraternali. P, M. L. (2024). Solid waste detection, monitoring and mapping in remote sensing images: a survey. *Waste Management*, 88-102. https://doi.org/10.1016/j.wasman.2024.08.003

Gavrila. G. O, V. G. (2025). Assessment of CH4 and CO2 Emissions from a Municipal Waste Landfill: Trends, Dispersion, and Environmental Implications. *Atmosphere*, 752. https://doi.org/10.3390/atmos16070752

JaKita. (2024). *Laporan Utama: Edisi 2 TPS3R Solusi Jitu Atasi Sampah Jakarta.* Jakarta: Jakita Sarana Informasi Pemerintah Provinsi DKI Jakarta.

Majid. A. A, W. A. (2025). Dampak sampah terhadap perekonomian Kota Jakarta sebagai visi kota global. *Kajian Akademik BPPk*, 710-744.

Papale. L. G, G. G. (2023). Satellite data potentialities in solid waste landfill monitoring review and case studies. *Sensors*, 3917. https://doi.org/10.3390/s23083917

Song. Y, S. C. (2024). Estimating methane emissions in rice paddies at the parcel level using Drone-Based time series vegetation indeces. *Drones*, 459. https://doi.org/10.3390/drones8090459

Torres. R. N, F. P. (2021). Learning to identify illegal landfills through scane classification in aerial images. *Remote Sens*, 4520. https://doi.org/10.3390/rs13224520

Trinh. L. H, Z. V. (2022). Mapping assessing landfills temperature using Landsat 8 Satellite Data. A case study in Vietnam. *Izvestiya, Atmospheric and Oceanic Physics*, 1098-1107. https://doi.org/10.1134/S0001433821090632

Vanguri. R, L. G. (2024). Assessing the impact of landfill on surrounding vegetation: a remote sensing analysis with Sentinel-2 and Landsat 8. *Environ. Sci. Proc*, 21. https://doi.org/10.3390/ECRS2023-15865

Wang. Y, F. M. (2024). Methane emissions from landfills differentially underestimated worldwide. *Nature sustainability*, 496-507.

Yalçınkaya. s, D. F. (2023). Investigation of land surface temperature heterogeneity in municipal landfills by satellite images. *Environmental Research and Technology*, 359-370. https://doi.org/10.35208/ert.1353244

Zhou. Z, S. M. (2023). An easy and fast method for landfill identification by image-based deep learning. *Resources, Conservation and Recycling*, 219. https://doi.org/10.1016/j.resconrec.2025.108322