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Quantifying meteorological impacts on local landfill methane emissions by using field measurements and machine learning

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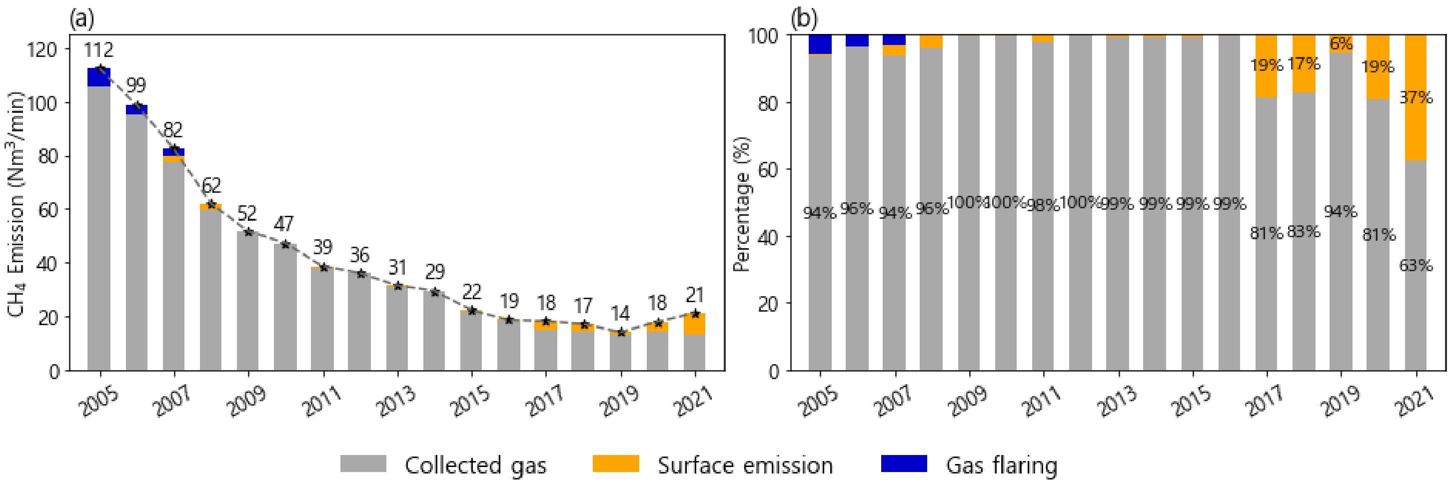

Fig. S1. (a) Annual CH_4 emission fluxes by pathway at SLS 1, and (b) the corresponding contribution of ratios of each pathway.

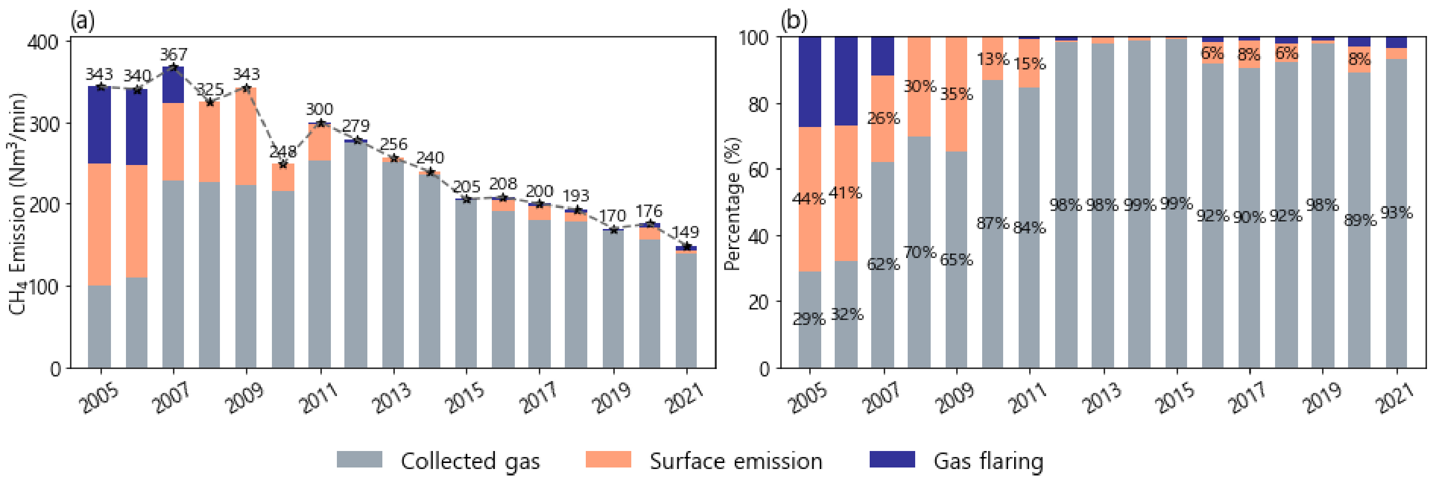

Fig. S2. (a) Annual CH_4 emission fluxes by pathway at SLS 2, and (b) the corresponding contribution of ratios of each pathway.

To quantify the uncertainty in landfill CH4 generation estimates, a Monte Carlo simulation was conducted. For each simulation run, uncertain inputs were randomly sampled from pre-defined probability distributions (Herrador & González, 2004; Kalos & Whitlock, 2009; Papadopoulos & Yeung, 2001). The methane generation potential (L_0) was assumed to be uniformly distributed within the range derived from the BMP test. For the first sudokwon landfill site (SLS 1), the waste composition of food, textile and yard waste (*F, TX, Y*) were sampled from uniform distribution with a ±10% uncertainty range, following the IPCC guidelines (Eggleston et al., 2006), due to the lack of period-specific composition data. In contrast, the second sudokwon landfill site (SLS 2) had annual waste composition data, a normal distribution was used to reflect the observed inter-annual variability. For seasonal variables, the values followed a normal distribution with the seasonal mean (μ) set to the observed seasonal value and the standard deviation set (σ) to measurement error. The mass of waste (M) was varied only during the actual landfilling duration. Temperature (T) and precipitation (P) data were sampled within each season to reflect seasonal characteristics. A total of 1,000 iterations were performed to ensure a stable and statistically significant sampling distribution. The model uncertainty was summarized using the empirical distribution of simulated CH4 generation values, and the reported uncertainty bounds corresponds to the 2.5th-97.5th percentiles (95% interval).

Table S1. Probabilistic characteristics of the random variables

Input (x_i)	SLS 1					SLS 2				
	Mean	Standard deviation	Min	Max	Distribution	Mean	Standard deviation	Min	Max	Distribution
L_0 (m^3/Mg)	40.2		33.7	46.7	Uniform	47.5		37	58	Uniform
F (%)	34.1		30.7	37.5		13.7	8.3	6.8	38.7	Normal
TX (%)	4.7		5.1	4.2		5	0.8	3.1	6.9	
Y (%)	1.35		1.2	1.5		1.2	0.6	0.5	2.9	
M (Gg/season)	1,827	711	136.08	3454.3	Normal	1,155.2	342.9	311.1	3454.3	
T_{spring} (℃)	11.7	0.85	9.7	12.9		11.6	0.8	9.67	12.9	
T_{summer} (℃)	23.8	0.88	21.8	25.3		23.9	0.8	22.3	25.3	
T_{fall} (℃)	15.0	0.74	13.6	16.1		15.2	0.7	13.6	16.1	
T_{winter} (℃)	-0.05	1.16	-2.7	2.4		-0.03	1.3	-2.7	2.43	
P_{spring} (mm/d)	2.2	0.92	0.4	4.4		2.2	1.0	0.4	4.4	
P_{summer} (mm/d)	7.7	2.81	3.1	15.0		7.6	3.0	3.1	15.0	
T_{fall} (mm/d)	2.6	1.20	0.7	5.5		2.5	1.3	0.7	5.5	
T_{winter} (mm/d)	0.7	0.39	0.2	1.6		0.7	0.4	0.1	1.6	

$$y = f(x_i) \qquad \text{(Eq. S1)}$$

$$Y = (y_1, y_2, \ldots, y_M) = (f(x_1), f(x_2), \ldots, f(x_M)) \qquad \text{(Eq. S2)}$$

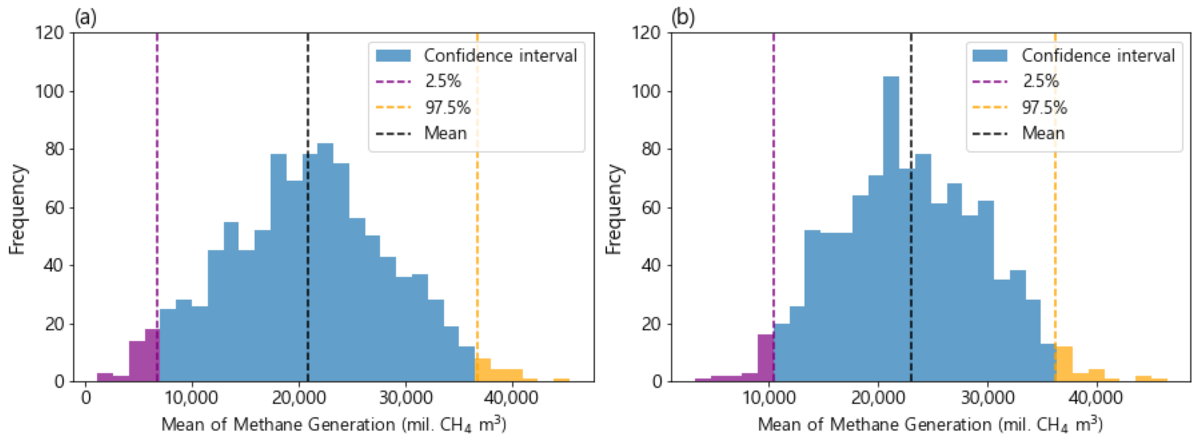

Fig. S3. Histogram representing the result for the error of measurement estimated by Monte Carlo simulation. The confidence interval (Blue bar), under 2.5% range (purple line), upper 97.5% range (orange line) for (a) SLS 1 and (b) SLS 2.

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