Evaluating the Limitations of the EPA's Landfill Gas Emissions Model

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Abstract

Our group, TigerGEM Consulting, has assessed the Landfill Gas Emissions Model (LandGEM) created by the Environmental Protection Agency (EPA) for potential biases, determined the sources of this bias, and has suggested edits to the model to mitigate these biases. It was determined that one source of bias lies in the default values for the methane generation capacity (k) and the potential methane generation capacity (L_0). This is because those values are dependent on the moisture content, average temperature, and cellulose content of the landfill, but these factors may be insufficiently accounted for in the current model. To investigate the impact of these factors on landfill gas estimations, the group recreated the model in Python and added a step which calculates values of k and L_0 based on user inputs. The new model found that in the current LandGEM model, the lack of options for L_0 ,leads to inaccuracies in estimating the total landfill gas emissions with a 70% disparity. Additionally, calculating a k value based on the typical precipitation in the area creates a k value that may be more precise than using the defaults, leading to emissions estimations that may be more accurate. This eliminates the limitation of only having two choices when selecting a value for k as it is in the current LandGEM model.

Introduction

When waste is deposited in landfills, anaerobic decomposition degrades organic material and creates methane in the process. Methane produced often escapes landfills and makes its way into Earth's atmosphere. Methane is categorized as a greenhouse gas because it traps heat within Earth's atmosphere and contributes to climate change by raising global temperatures. Landfills are the third largest contributors to greenhouse gas emissions, which has forced the solid waste industry to put a greater emphasis on mitigating these emissions in recent years. To combat climate change, The Environmental Protection Agency (EPA) has created regulations in order to limit the amount of landfill gas entering the atmosphere. These often include the requirement of a landfill gas collection system. Depending on the total amount of gas emitted, different gas collection technologies should be implemented. However, few methods currently exist for accurately estimating the amount of gas being emitted from a specific landfill. One of these existing methods is the Landfill Gas Estimation Model (LandGEM) which was created by the EPA. It has been noted by the Solid Waste Association of North America (SWANA) that the LandGEM model could be outdated and flawed. Thus, SWANA Young Professionals have been tasked with evaluating the limitations in LandGEM and developing an alternative method for estimating landfill gas emissions.

Approach to Assessing Biases

Studies have shown that two variables used in LandGEM, the methane generation rate (k) and the potential methane generation capacity (L_0), are based on multiple assumptions and are therefore not representative of actual site-specific methane emissions. Two factors that affect the k value are the moisture content and temperature of the waste mass. L_0 is a function of the cellulose content of the waste. Currently, LandGEM only provides default values based on whether a waste site receives more or less than 25 inches of rain per year, and there is no consideration for how temperature impacts the k or L_0 values. TigerGEM Consulting has investigated these assumptions and researched how a more accurate k value could be assigned to a landfill based on its climatological properties. The team recreated the original LandGEM in Python, then added a section which calculates k and L_0 rather than using the potentially biased default values. The new values of k and L_0 were used to run the code and output landfill gas emissions estimates. This was done for twelve landfills in the United States, each with varying amounts of rainfall and average temperatures. The group was then able to evaluate how differing k and L_0 impact the estimates for landfill gas emissions in assorted climates.

Results

Methane Emissions Over the Lifetime of a Landfill

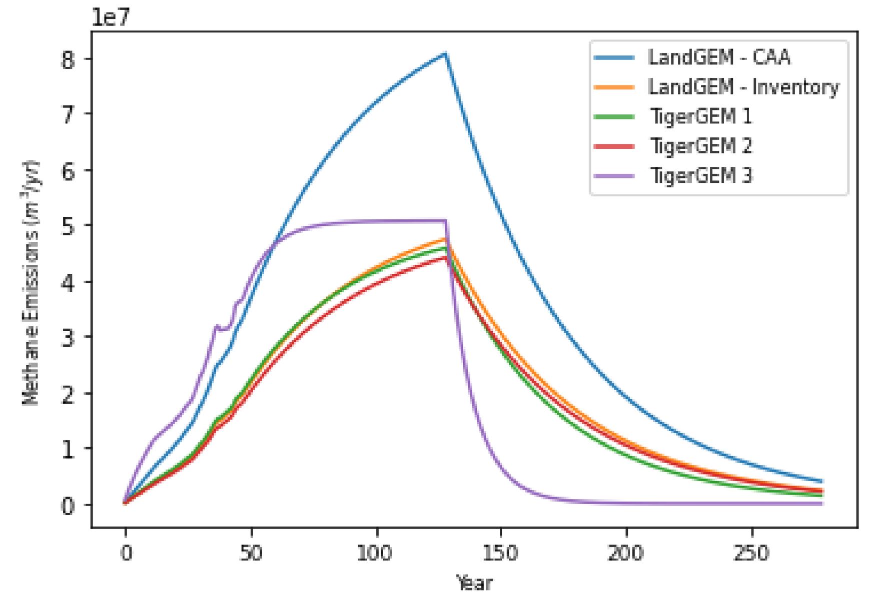

Figure 1. Boise, ID. Ada County Solid Waste Management.

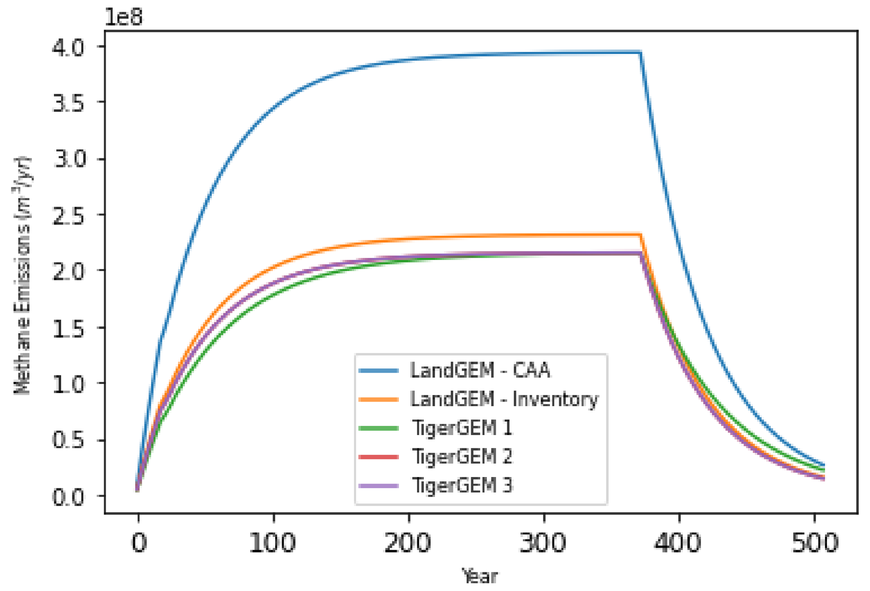

Figure 2. Las Vegas, NV. Apex Regional Landfill.

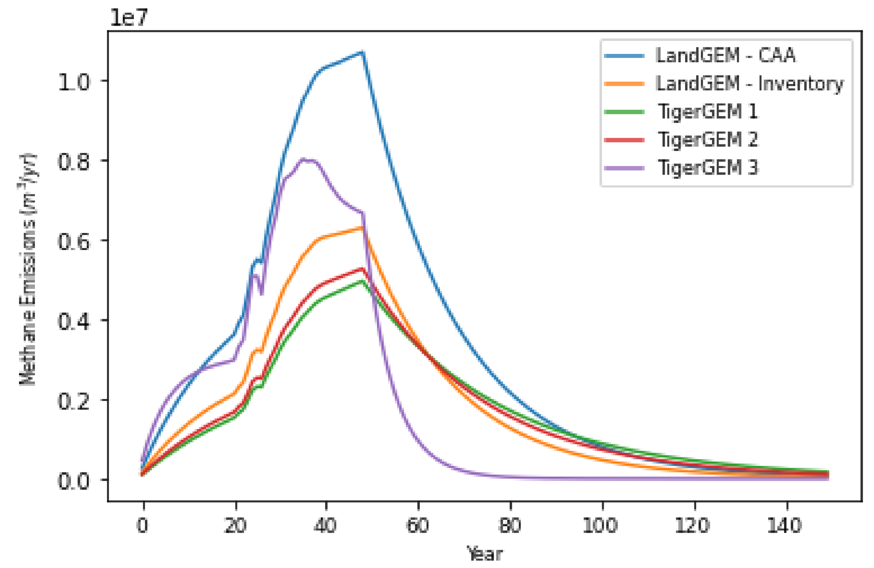

Figure 3. Bismarck, SD. Dakota MSW Landfill.

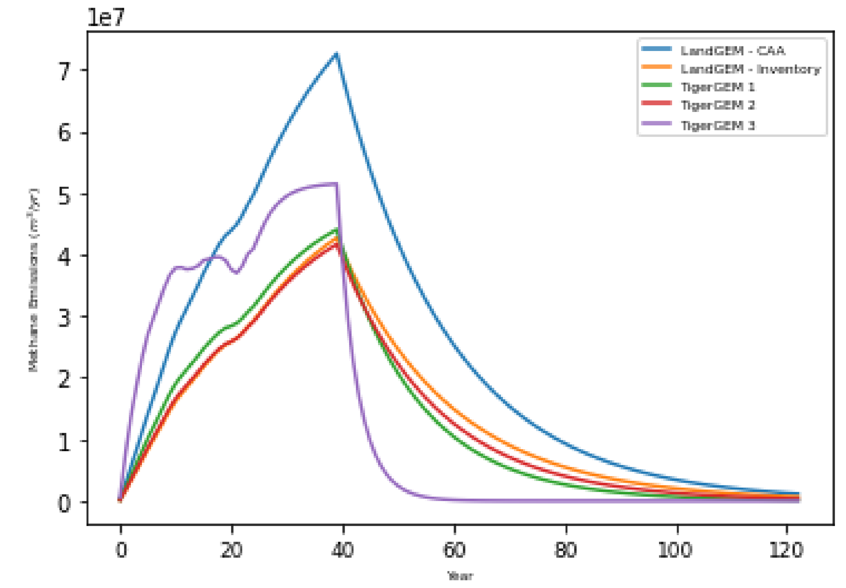

Figure 4. New Orleans, LA. EBR North Landfill.

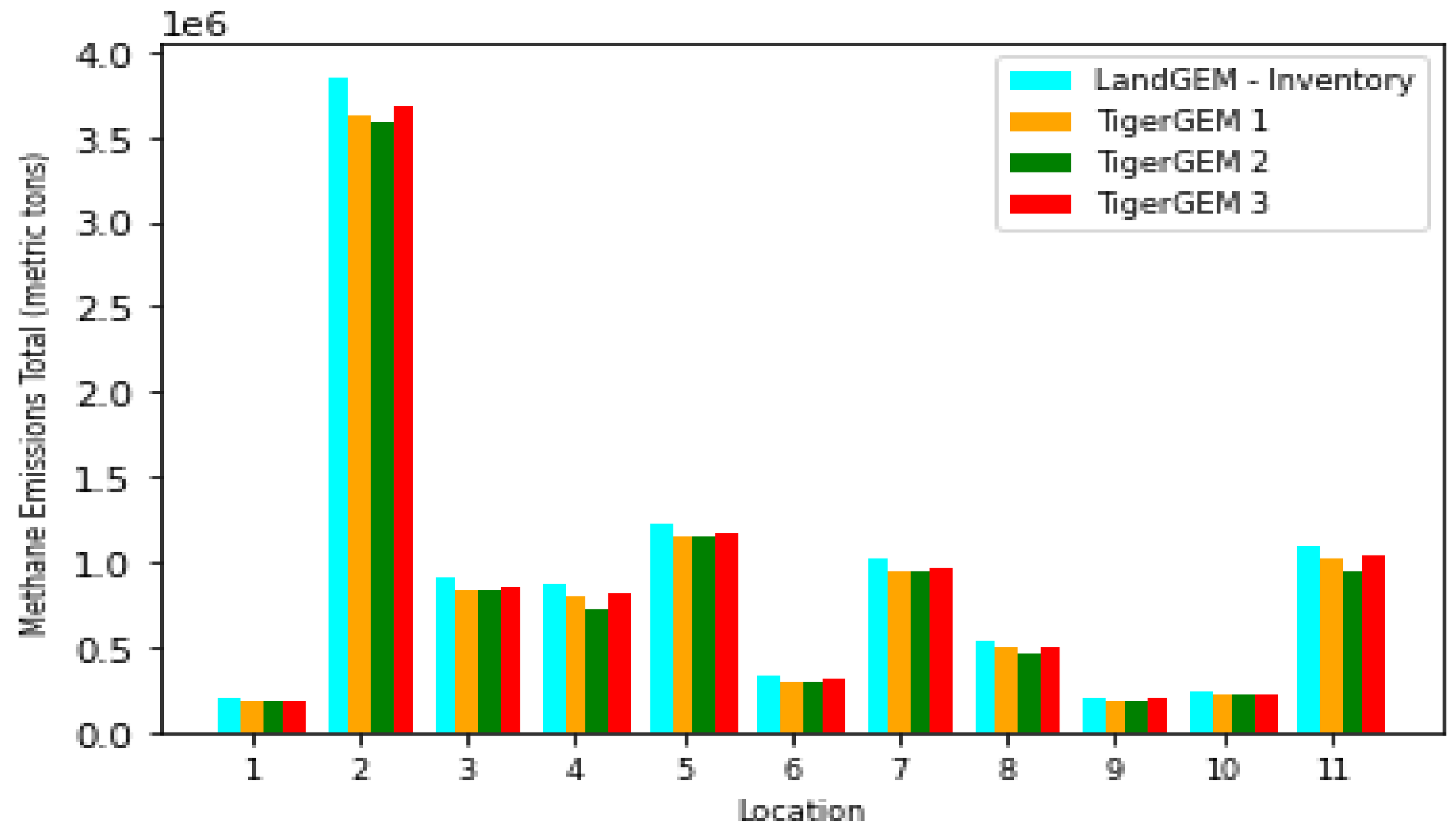

Figure 5: Total Methane Emissions: A summary of the total methane emissions for each landfill in units of metric tons. **(1)** Bismarck, ND **(2)** Boise, ID **(3)** Forks, WA **(4)** Laredo, TX **(5)** New Orleans, LA **(6)** Omaha, NE **(7)** Port Isabel, TX **(8)** San Angelo, TX **(9)** San Diego, CA **(10)** Seattle, WA **(11)** Wichita, KS. Las Vegas, NV was excluded due to the life of the landfill being greater than 300 years, resulting in unusually high emissions estimates.

Summary of Python

The team redeveloped the EPA's LandGEM in Python for further analysis. The model was run using varying methods that are referred to as: LandGEM-CAA, LandGEM-Inventory, TigerGEM 1, TigerGEM 2, and TigerGEM 3. Each method includes the average annual precipitation and average daily temperature for the last 10 years for an individual location from the National Oceanic and Atmospheric Administration (NOAA) Climate Database. LandGEM-CAA and LandGEM-Inventory use the default values suggested in the User's Manual for both k and L_0. All three of the TigerGEM runs use a calculated value for L_0 based on average waste composition in North America, a feature not available in the current LandGEM model. TigerGEM 1 calculates k using an extrapolated equation from LandGEM defaults and the climatological data of the landfill. TigerGEM 2 uses the default values from the Facility Level Information of Greenhouse Gasses Tool, the EPA's database for greenhouse gas emissions. TigerGEM 3 estimates k by proportionally scaling a suggested range from professionals based on the inputted climatological data. TigerGEM calculates a new value for L_0 using the fraction of degradable organic carbon (DOC) which can be found in the *GHG Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories*. These values are placed in the first-order equation for methane generation from waste, and the code outputs graphs showing methane emissions over the lifetime of a landfill and post-closure.

Discussion

TigerGEM displayed that there is some level of bias within the current LandGEM model, particularly with respect to the selection of k and L_0 values. An example of how the L_0 value contributes to bias is when comparing data for landfills in Boise **(Figure 1)** and Las Vegas **(Figure 2).** These two landfills use the same k values for the two LandGEM models because their precipitation is below the 25-inch threshold. However, there is a 170% difference in the estimated methane production which can be attributed to the change in L_0 since that is the only other parameter that changes in the current LandGEM model. Similarly, the default k values result in significant levels of bias for certain climates. The data suggests that k values should be calculated and be proportional to the annual rainfall in an area. This is inconsistent with the current model, as all landfills above or below the 25-inch threshold use the same value for k. The bias is exemplified by **Figures 3 and 4.** Landfills in Bismarck and New Orleans would use the same k value in the current model, though New Orleans often gets triple the amount of rainfall that Bismarck gets in a single year. This bias can be seen by the steepness of the methane generation rates on the plots. The landfill in New Orleans is much steeper because its calculated k value is greater than that of the landfill in Bismarck.

Proposed Solution

TigerGEM consulting suggests that more parameters be available for user input to mitigate the level of bias in the current LandGEM model. If one could upload rainfall data, a more accurate k value could be calculated and a greater variety of k values will be used, leading to more precise calculations of methane emissions. This would eliminate the discrepancies between landfills that get average and heavy annual rainfall. Similarly, a site-specific waste characterization feature would remediate issues with L_0 values. If proportions of biodegradable waste, such as food, wood, or textiles, could become a factor in LandGEM, then the model would be able to consider these factors and use an L_0 value other than the two defaults. This would aid in estimating the change in emissions if there is a change in the waste composition for a specific landfill. The SWEET model already does this; it uses a matrix to incorporate climatological data and waste characterization data to select the most appropriate value for L_0 and uses that for all further calculations. If this were to occur in LandGEM, it could result to more accurate estimations of emissions.

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References

1. Alexander, Amy, et al. "Landfill Gas Emissions Model (LandGEM) Version 3.02 User's Guide." *EPA.gov*, May 2005.
2. Stege, A. (2021). *Solid waste emissions estimation tool (sweet) version 4.0: Global methane initiative*. Retrieved February 20, 2022.
3. US Department of Commerce, NOAA, and National Weather Service. n.d. "AHPS Precipitation Analysis."
4. "Facility Level Information on Greenhouse Gas Tool (FLIGHT)." *GHG Data*, Environmental Protection Agency, 7 Aug. 2021.
5. "Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal Wastewater Treatment Ethanol Fermentation." *EPA*, Environmental Protection Agency, 14 Dec. 2010.

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