Engineering for One Planet Inclusion: Leveraging Emergent Technologies and Project-Based Learning

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Municipal Solid Waste Landfills:

Sustainability has become an increasingly urgent global priority. In the United States alone, each person generates between 4.5 and 5 pounds of trash daily, contributing to a staggering 300 million tons of waste annually. This waste management crisis directly impacts multiple United Nations Sustainable Development Goals.

Municipal Solid Waste (MSW) landfill operations face complex environmental challenges, including the management of dust emissions, waste containment, storm water runoff, cover material stability, leachate control, odor mitigation, and greenhouse gas emissions.

This ASEE project aims to leverage this context and a hands-on project to teach undergraduate civil engineering students and graduate students in travel technology programs in learning about key principles in the Engineering for One Planet Framework.
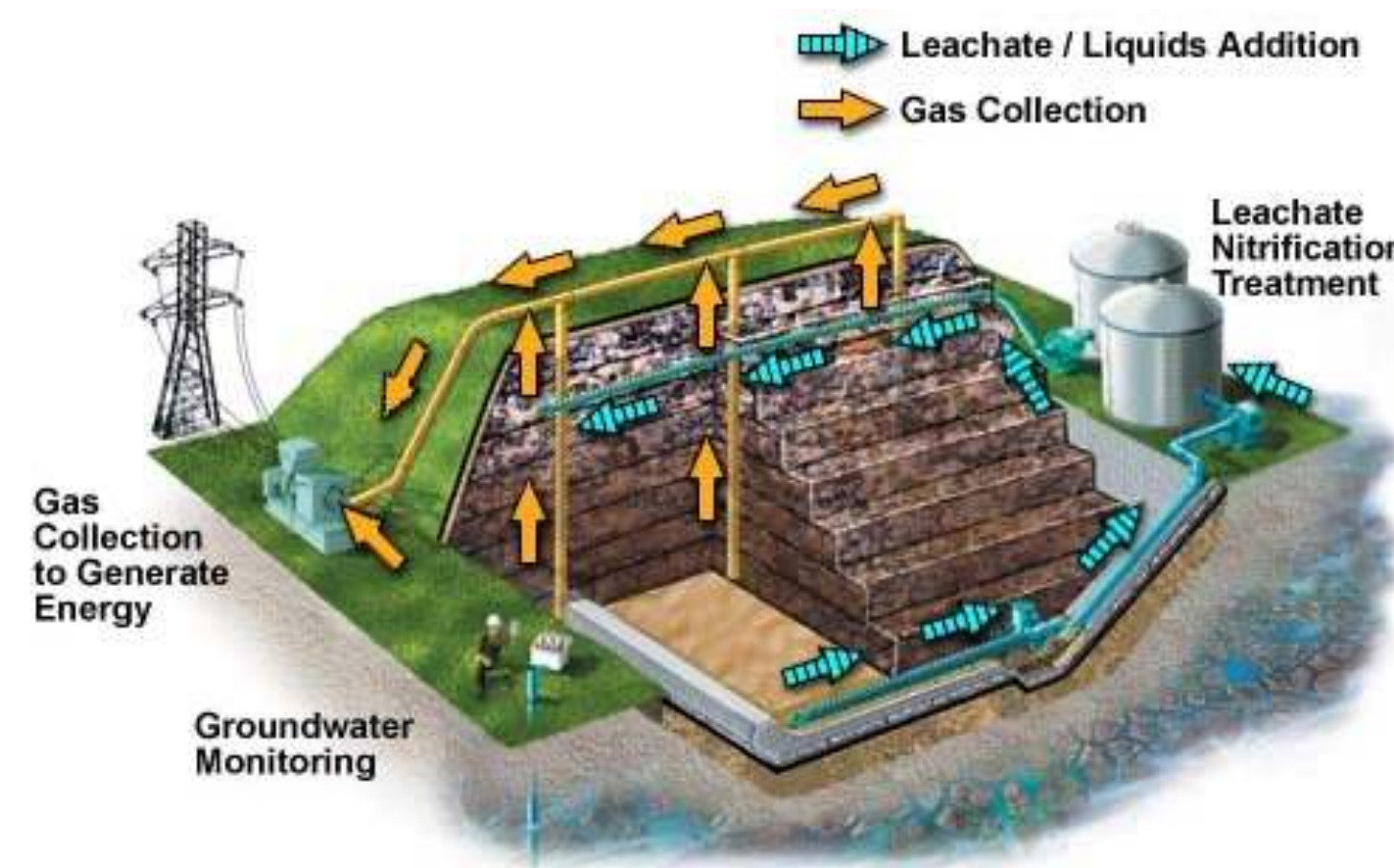
Nations Sustainable Development Goals

This waste management challenge intersects with several United Nations Sustainable Development Goals (SDGs), particularly:
- SDG 11: Sustainable Cities and Communities
- SDG 12: Responsible Consumption and Production
- SDG 13: Climate Action
- SDG 10: Reduced Inequalities

Experimental Setup

M300 drone
The Matrice 300 is a 6 directional sensing and positioning drone that counts with a battery life of 55 minutes of flight time that is compatible with a vast number of payloads.
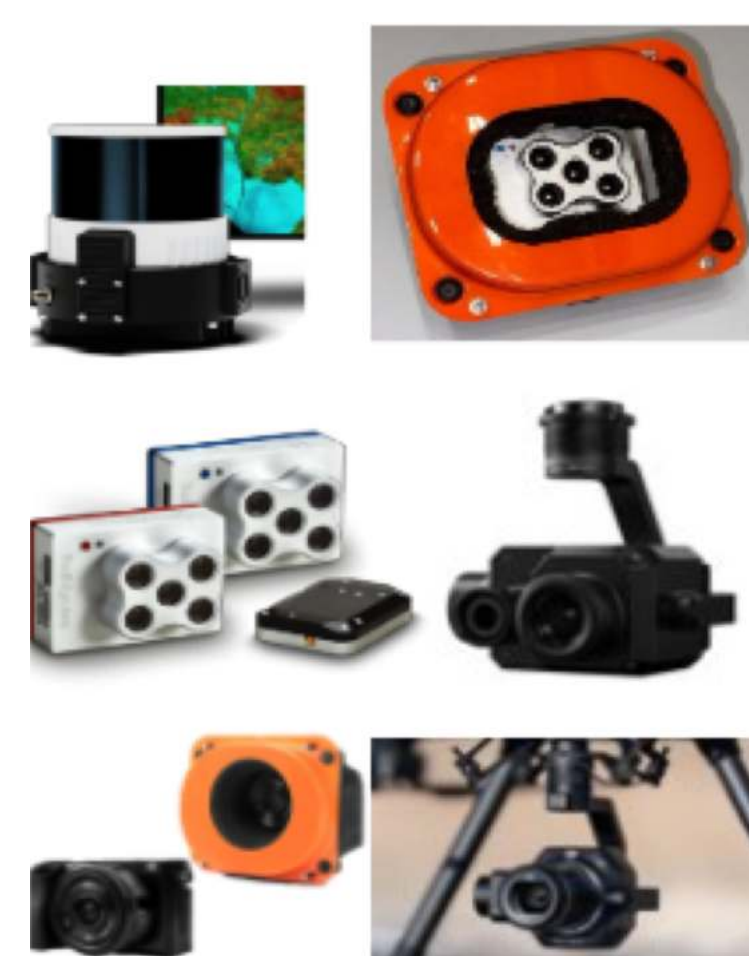
Matrice 300 Drone

Sensing Payloads
H20T, P1, L1
Micasense RedEdge Mx-Dual, Altum PT

RTK Units & Weather Station
DJI M300 RTK is a drone RTK base station that gives centimeter leve RTK.
Emlid Reach RS2+ is a GNSS base with centimeter-level RTK and PPK flexible to various platforms.

Sensing Payloads

Method and Materials

In order to get the 3D models that will serve us to calculate the volumes and settlement of Landfills there is multiple steps that are to be taken to followed. Setting up the drone based on the payload being used, planning the route, setting the RTK unit, flying the drone, retrieving the data, processing the data starting on DJI terra, LP360, and ending on ArcGIS Pro. The steps listed tend to vary depending on the payload used, and in this case is worth mentioning we are using the DJI Lidar(L1) as base. Extra peripherals may be implemented like could be methane detectors for air quality checks.

1. The methane sensor is integrated into DJI M300 by connecting a Multi-Air Quality sensing module with a CH4 module into an air hose that connects to an air-pump with a funnel at the end. This is done with the help of a 3d printed support.
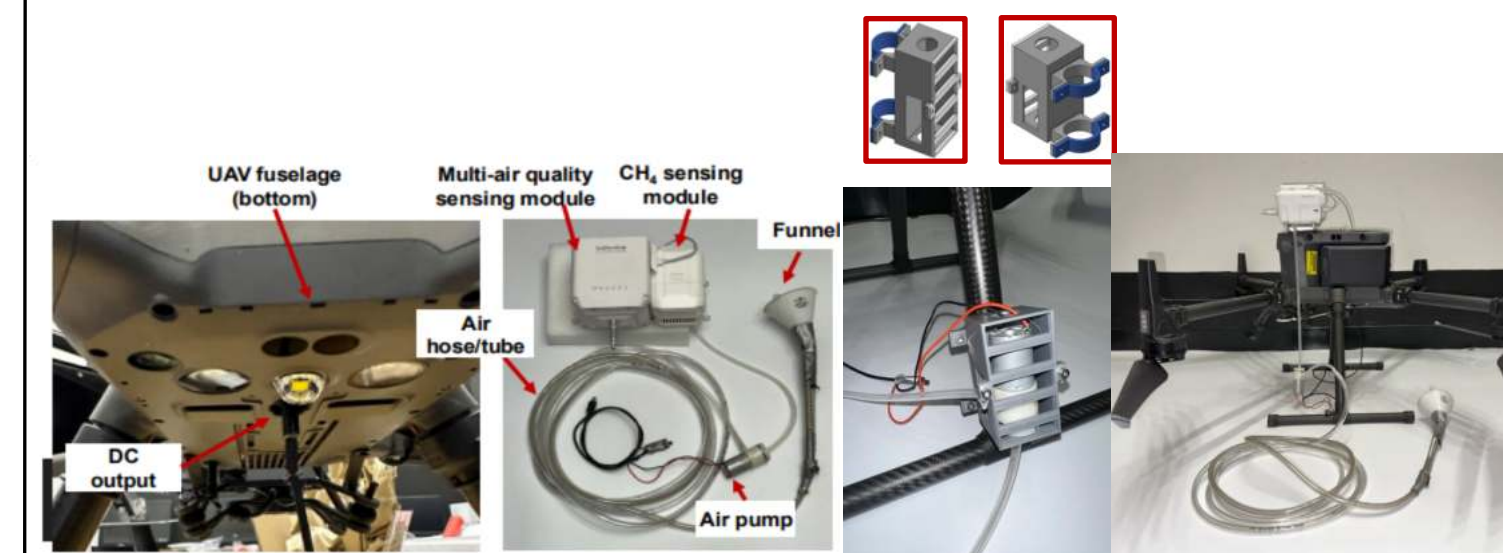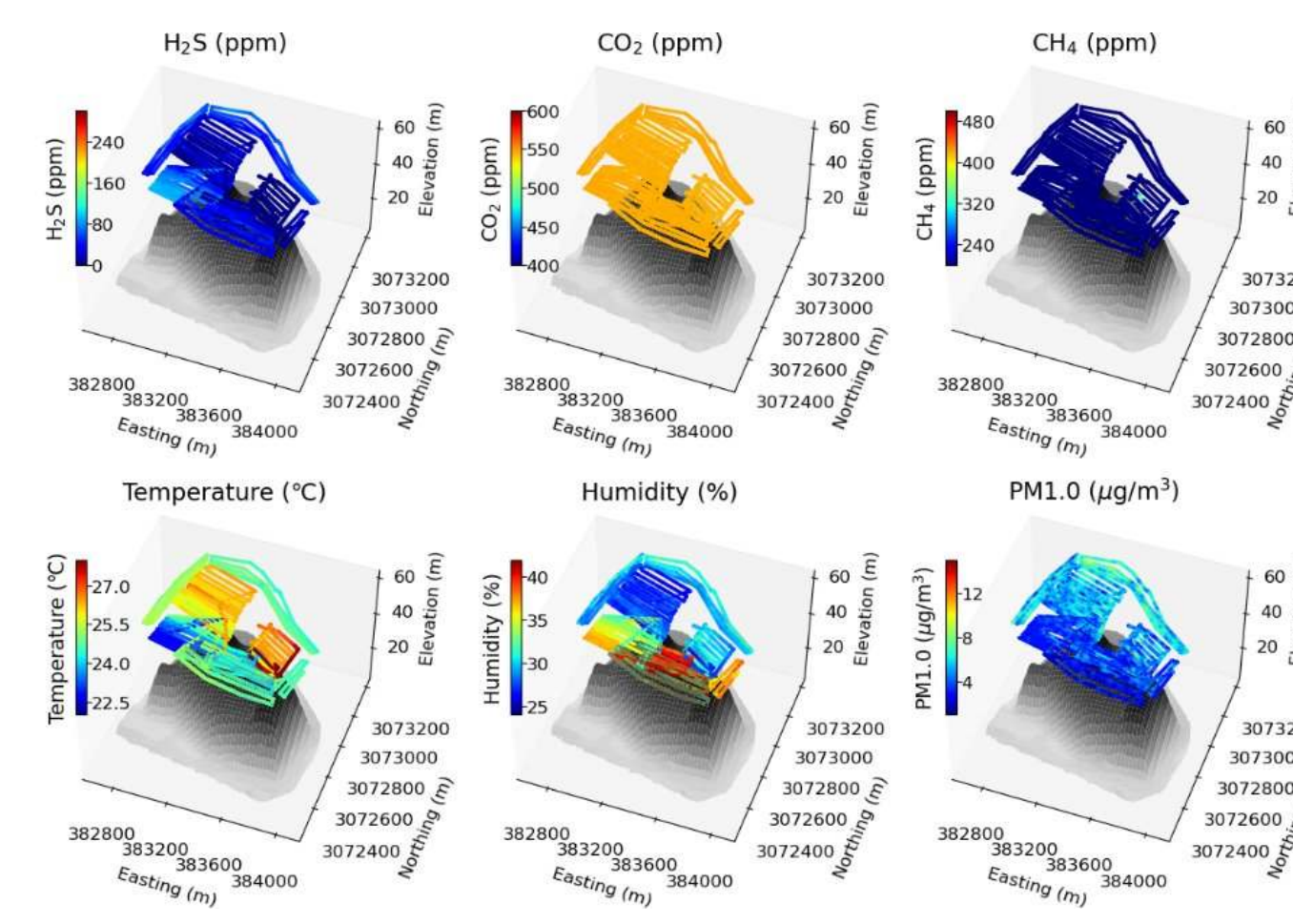
Air Quality Module Integration

2. To plan the route for odor sensing it is required to subdivide the route into smaller sections for the drone safety.
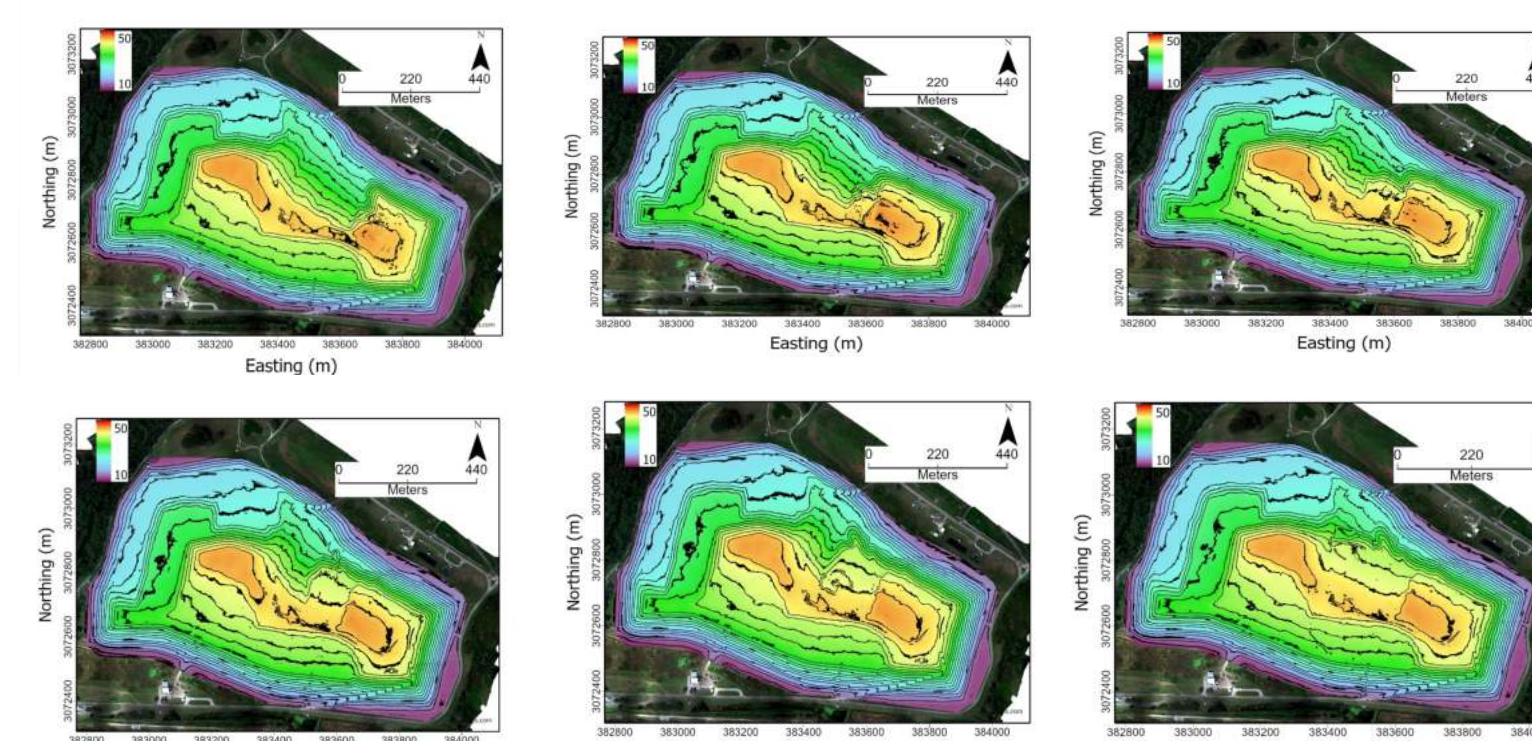
Mission Pictures

SEM Routes

3. The study gave the following results for the mission done on Nov. 2023

Air Quality Study(Nov. 2023)

4. From the Lidar camera the following results were given by surveying starting May 2023(Top Left), Sep. 2023, Oct. 2023, Nov. 2023, Dec. 2023, and Jan. 2024(bottom right)
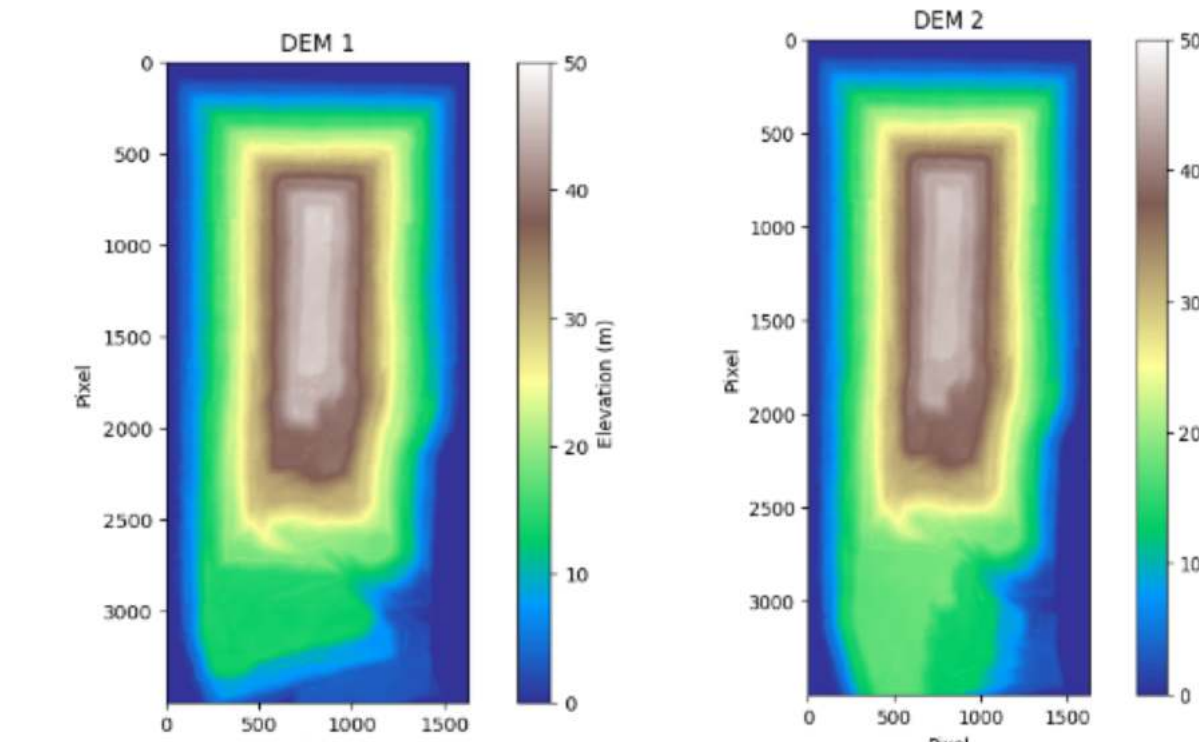
DSMs from Lidar(2023-2024)

5. At a different location at Orange County Utilites Class 1 Landfill a mission was conducted back on 04/09/2024 and other on 10/08/2024
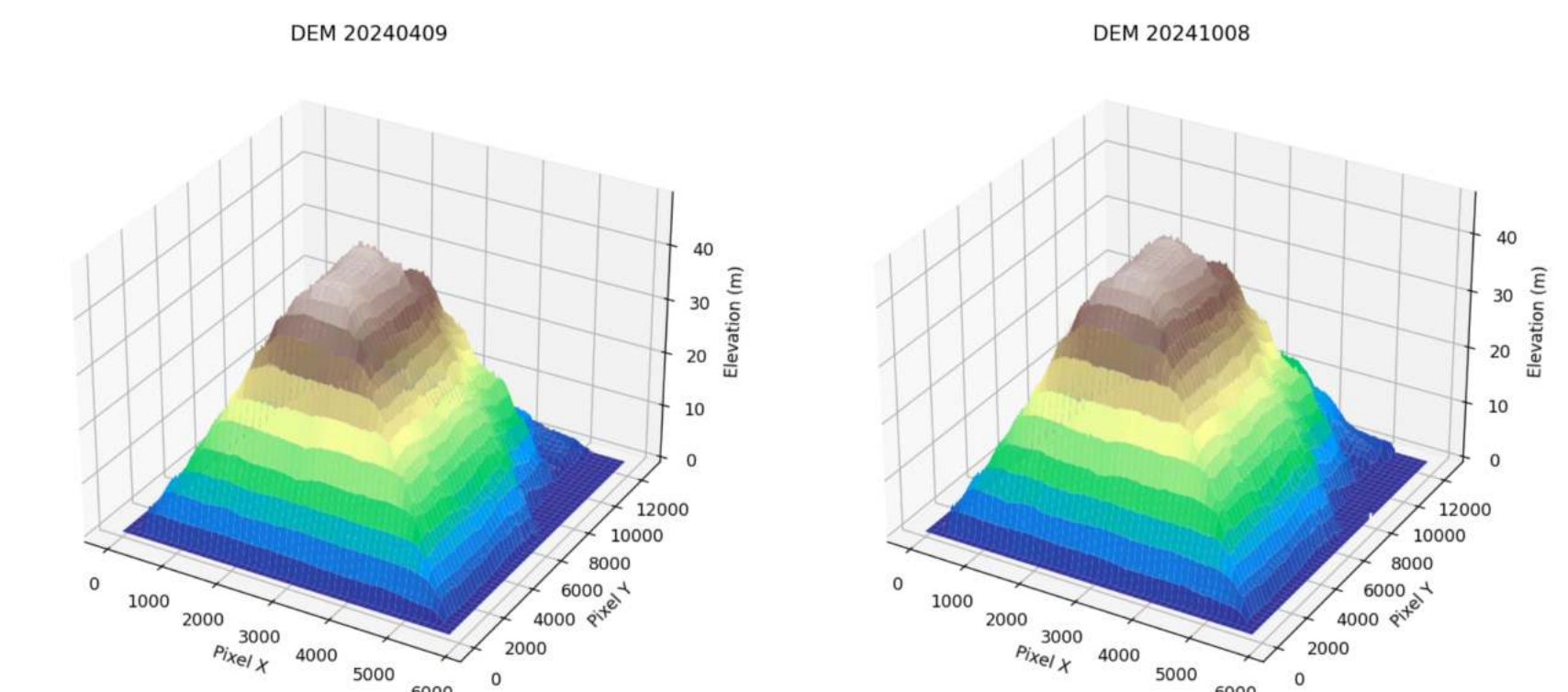
Orthomap(10/08/2024)

6. Processing the images in DJI Terra, Lp360, and ArcGIS Pro the DEMs were built.

**DEMs (04/09/2024 vs. 10/08/2024)**

Assignment Example

After the construction of the DEMs Python was used to build 3D models of the Landfills based on the elevations recorded.

3D Models based on DEMs

To compare the 2 DEMs another Python Script was developed to overlay one of the models over the other with transparency to show the elevation difference at the different dates.
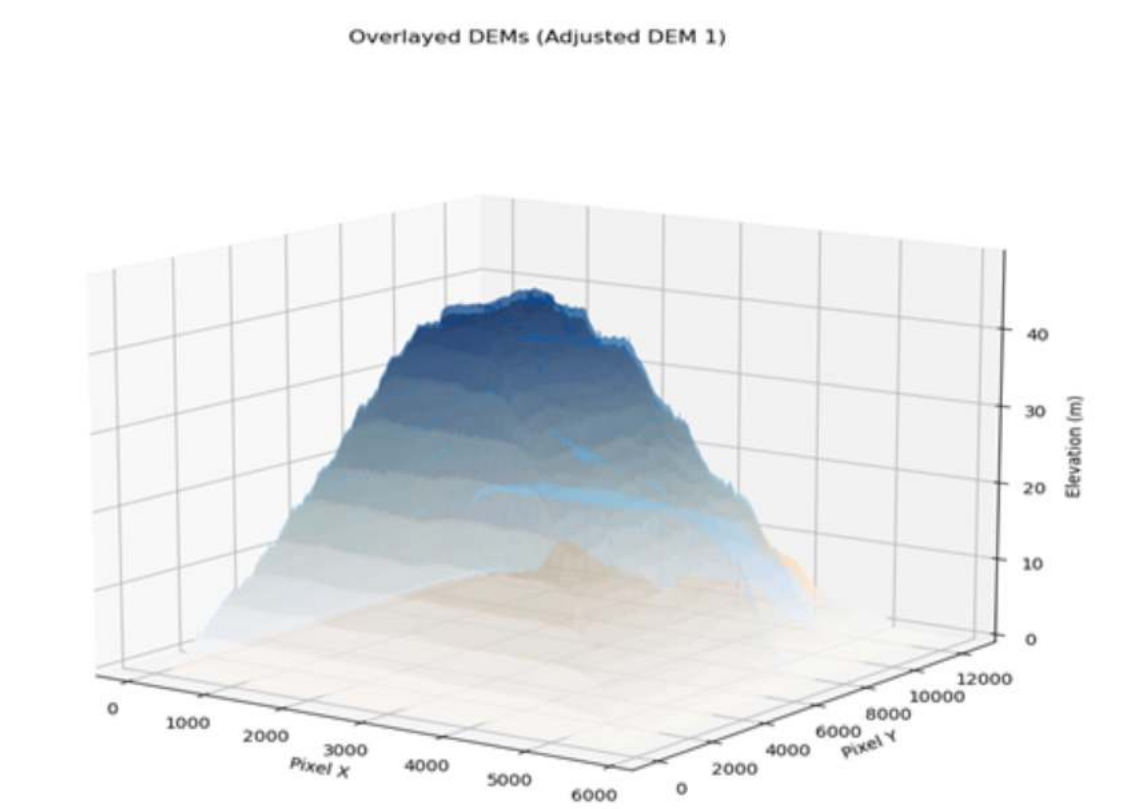
DEMs Overlayed

In the same script a cut was made at the middle of the landfill(at row 6264) which showed an elevation profile of both DEMs. This way a difference can be observed between the two models.
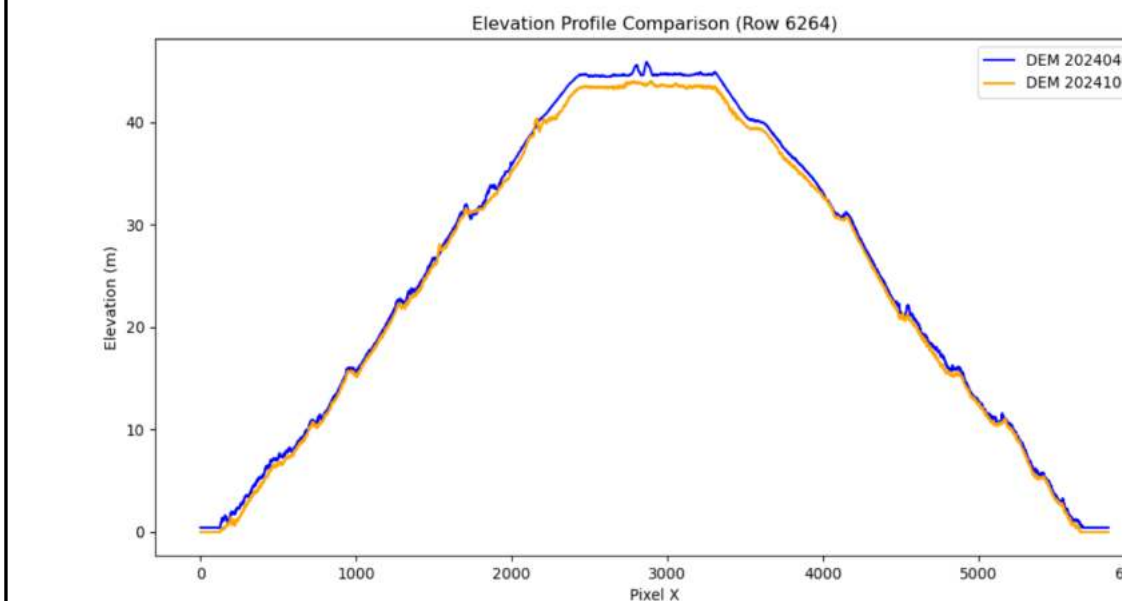
Elevation Profile Comparison

Sample questions:

Based in the information given an assignment was developed for the students. Where the following questions were asked:

A) If the landfill is a Class-III landfill, which only stores concrete debris (doesn't degrade). In addition, there is no additional waste has been dumped on top of the landfill between the first survey and second survey. What is the average strain in z direction, at the location (x=2861 px and y=6264 px) due to self-weight? Please list formula and computation process.

B) If the landfill is a Class-I (municipal solid waste) landfill instead, with a lot of food waste and household waste, which can cause biodegradation during time. The bio-degradation will cause the green-house gases, such as methane (CH_4) and carbon dioxide (CO_2). Another reason for the decrease in elevation (or settlement) during the 4 months for a Class-I landfill is biodegradation of the municipal solid waste. Landfill operation will collect and treat the landfill gases, such as methane (CH_4) and carbon dioxide (CO_2). Do you know what is negative effect if excessive methane (CH_4) and carbon dioxide (CO_2) are emitted to our environment?

Key takeaway Lessons

- Student feedback demonstrated that undergraduate engineering students found significant value in real-world project assignments, which provided opportunities to develop systems thinking and complex problem-solving skills.
- Project-based learning proved to be an effective method for incorporating the Engineering Opportunities Program (EOP) framework into existing STEM curricula without requiring additional courses.
- Complementary activities such as mentorships and internships would further enhance students' practical skill development and professional readiness.