Rationale:

Global climate change is a rapidly growing concern all over the world as the planet is at risk of more intense hurricanes and tropical storms as well as prolonged droughts and a growing number of wildfires [1]. The rising severity of natural disasters isn't the only concern as the warming climate is already causing problems for the environment and society. Research has shown that as more frequent and intense natural disasters emerge, the more expensive it becomes to repair and recover from the damages [2]. Global warming also affects agriculture, a necessity in maintaining a working society and human life as of current times. As temperature and CO_2 levels rise, crop yields are declining due to water precipitating faster and continuous flooding damaging the crops and farmland significantly [2,3]. The biggest contributing factors to climate change revolve around burning fossil fuels, farming, transportation, deforestation, drilling for oil and gas, and especially garbage and litter [4].

Litter is a common occurrence in cities and towns; however, this small action builds up and creates a major problem for the environment. Litter not only affects the appeal of cities and towns, but it can greatly affect wildlife and the environment, including plants. Litter creates toxins which can be absorbed by soil and can negatively affect the germination and growth of plants as well as killing vegetation surrounding littered areas [5, 6]. This results in the dead plants releasing CO_2, a greenhouse gas which is the biggest contributor to global climate change. Knowing several commonly littered items as well as runoff from vehicle and agricultural pollutants, the effects of litter and pollutants will be tested to determine which liquids contained or produced with/from litter develop the most negative effects against plants and

using the results of the testing to find out how the affected plants contribute to global warming.

Climate change is a shift in the Earth's climate, usually revolving around temperature, precipitation levels, and seasonal shifts. However, as pollution increases due to human activity, climate change has escalated to becoming a global issue leading to the destruction of cities and towns due to increasingly harsh natural disasters resulting from climate change. Dangers to wildlife due to littering and contamination of natural resources occur as well as the environment deteriorating as it many places now are growing unstable or are unable to survive worsening climate conditions like rising temperatures, flooding, and droughts [7]. Among the many contributors listed in the introduction, CO_2 emissions play the largest role in assisting climate change and global warming. CO_2 is produced from natural sources like including the breaking down and decomposition of dead organisms, volcanic eruptions, as well as oceanic respiration; however, human activity has exponentially increased the amount of CO_2 released in the past years from burning fossil fuels and oil, manufacturing processes, and deforestation [8, 9]. Although there are many large-scale factors contributing to climate change, there are smaller-scale factors as well.

Littering is a large source of CO_2 emissions and essentially resembles a landfill with time as litter often builds up. Not only does litter harm both land and marine wildlife, but the environment as well as inorganic waste which can be a serious hazard to wildlife like plastic and metal while organic waste can decompose, although it releases CO_2 and methane [10]. Different ways litter can impact the environment include runoff, human activity, and natural movement by wind or animals. Runoff is caused when land cannot absorb water and is

common in cities containing asphalt, pavement, and other impermeable surfaces. This results in water collecting things as it rolls off roads and sidewalks like litter, vehicle fluids, and toxic liquids, eventually reaching soil or other permeable surfaces [11]. Runoff, wind, animals, and human activity aid in the expansion of litter which leads to the contamination of soil that damages nearby vegetation.

Soil can be contaminated by runoff which mostly incudes gasoline and vehicle fluids as well as litter tossed out by humans. Vehicle fluids often contain heavy metals which are toxic in soil, decreasing diversity in soil and richness which are essential in healthy soil and aiding plant growth. They also produce toxic enzymes and harm soil microbial communities resulting in a decrease in activity necessary to maintain healthy soil [12]. Litter tossed out by humans including bottles, food and product wrappers, cigarette butts, and bags can also decrease diversity and population size of microbial communities in soil as litter covering up and decomposing/degrading in soil can alter soil conditions like humidity and temperature changes due to litter blocking light and harmful chemicals being released from decomposing litter. When toxic chemicals or large amounts of heavy metals like copper, lead, iron, nickel, and zinc are introduced to soil, it can harm surrounding vegetation as chemicals and high levels of heavy metals can lead to poisoning the plants as they are absorbed through the roots. For example, too high or too low amounts of lead in soil can lead to fluctuating productivity levels in plants, leading to difficulties performing photosynthesis and water absorption which results in the plants wilting or even dying. Fluctuating levels of heavy metals can also delay seed germination and plant growth [12].

As a result of the increase in contaminated soil and vegetation, there is a loss of plant population and diversity. The organisms that eat and live in the contaminated soil and plants due to litter and runoff are at risk of illness or death, leading to more carbon emissions from failing crops, vegetation, and lower population of organisms. A way to combat these risks, governments can reinforce laws and fines against littering as well as installing more trash and recycling bins to discourage littering [12]. Civilians can also keep bags and bins in their vehicles to encourage proper waste disposal as well as spreading awareness about littering, its effects, and recycling [15]. Litter can greatly affect the environment in many ways and is harmful to the planet. Keeping litter off the streets and into trash bins not only makes urban areas more beautiful but helps maintain a healthy ecosystem allowing both animals and humans to thrive.

Research Question:

The purpose of this project was to determine if pollutants commonly found in stormwater runoff has an effect on the germination and growth of Cress seeds.

Independent variable: Type of liquid pollutant added to the soil the seeds will grow in.

Dependent Variable: The seeds' ability to germinate and their efficiency in growth.

Hypothesis:

If Coca Cola is added regularly to the soil a Cress seed lays in, then the seed will not germinate because of the soda's lack of any nutrients that may aid in plant germination. Additionally, Coca Cola is very acidic with a pH level of 2.3 compared to the 6-7 pH level that most plants can thrive in. The high pH level can cause the enzymes in the seed to break down or stop functioning entirely which are necessary for the development of an embryo and the start of seed germination.

Procedure:

1. The 12-cell plastic seed tray was placed on a clean, solid surface cleared of any items.
2. The 12-cell plastic seed tray was cut along the tray's edges with scissors, divided into 6, 2-cell groups with 2 cells connected to each other in each group.
3. 13 cups of dry soil were sifted through a kitchen sieve with a wide container below the sieve to catch the sifted soil.
4. The sifted soil was collected for the cells.

5. The 12 cells were filled with about 1 cup of dry sifted soil each, leaving a small amount of room at the top of the cell for more soil later.
6. The soil in each cell was lightly pressed down about ½ cm with a finger across the entire surface of soil in each cell.
7. The soil was watered with a water hose (on light pressure), or watering can (both with a small sprinkler head) with about 1½ cups of water total for all cells.
8. 1 small hole about ¼ cm was made in the soil in the center of each cell with a finger.
9. 1 Cress seed was placed in the hole in the soil in each cell which used 12 Cress seeds in total.
10. The remaining cup of dry soil was sprinkled over the seeds across all 12 cells and covered the seeds with about ¼ inch of soil. The new layer of soil was not pressed or watered.
11. All 6 4x2x4 inch containers were lined at the bottom with 1 strip of paper towel folded to size per container. 6 pieces of paper towel were used in total.
12. The cell pairs were placed upright into each 4x2x4 inch container.
13. 1 piece of 5x3 inch Saran wrap was placed over each container.
14. The Saran wrap was secured with 1 rubber band per container. The rubber bands were placed over the excess Saran wrap on the sides of each container.
15. 1 toothpick was used to gently poke 2 small holes in the Saran wrap above the soil in each container. 1 small hole per cell.
16. The containers were labeled with a marker on the side of the containers with one of the following labels per container: water, canola oil, coca cola, vegetable oil, pesticide alternative, and fertilizer alternative with an A and B for each pair. On the side of the containers, 1 cell was labeled “A” and the other cell was labeled “B” and was repeated for each container.
17. The containers were placed by a window with sunlight available often on a table in the same area 2 inches apart from each other under a shaded area with access to sunlight throughout the day based on the sun’s position.
18. The Saran wrap and rubber bands were removed from the containers and set aside the morning after the Cress seeds were planted.
19. 1 teaspoon of water was gently poured over the surface of the soil with a teaspoon measuring spoon in each cell. 12 teaspoons of water were used in total with 1 teaspoon of water per cell.
20. 1 teaspoon of Crisco vegetable oil was gently poured over the surface of the soil with a new, clean teaspoon measuring spoon in the 2 cells labeled “vegetable oil”. The vegetable oil was only applied to the 2 cells labeled “vegetable oil”.
21. Step 20 was repeated 4 more times with 1 teaspoon per cell. 1 teaspoon of the fertilizer alternative mix, Crisco Canola oil, pesticide alternative mix, and Coca cola added to the cells with their corresponding labels.
22. The Saran wrap and rubber bands set aside earlier were placed back on their corresponding containers.
23. Steps 18-22 were repeated for 9 days in the morning and afternoon at around the same times.
24. All visible data was recorded throughout the 10-day germination period. The containers were not moved during this period.
25. The Saran wrap and rubber bands were removed after 10 days of planting the Cress seeds and were not put back on for the rest of this experiment.
26. Steps 18-22 were repeated for 18 days.
27. All visible data was recorded throughout the 18-day period.

28. 1 cell tray pair was removed from its container and slowly turned upside down with a hand below the surface soil to keep the soil and plant from falling out. The hand was spread out to support both cells and fingers held gently around the soil surrounding the plant shoots as to not damage the plant with the soil surrounding the plant shoot held between 2 fingers.
29. The bottom of the cells was shaken gently with caution as to not let the plants fall out completely.
30. The cells were slowly shaken until the plants and soil were released from their cells and gently set down on a table or floor.
31. 1 small, tall container is filled with 2 cups of cool, clean water.
32. 1 plant with soil residue from the cell tray pair was placed in the water soil first with the plant shoot above water. The soil was gently shaken and rubbed until all the soil was washed away from the plant roots.
33. The clean plant was placed on a dry piece of paper towel on a clean surface and covered with a separate piece of dry paper towel.
34. The paper towel on top of the plant was pressed down lightly on the plant to dry the exterior of the plant of any leftover water after it was cleaned The paper towel was set aside.
35. The paper towel the plant was laid down on was labeled with a marker under the plant with its corresponding label. (Ex: water A, water B, Canola Oil A...)
36. Step 32-35 was repeated with the other plant in the cell tray pair and labeled. The plants were placed next to each other on the same paper towel.
37. Steps 28-36 were repeated for all cells.
38. Results were observed, measured, and recorded. Curled roots and shoots were uncurled and measured at full length.

Risk and Safety:

Potential hazards include getting cut by scissors while handling them, eye exposure to Coca Cola may cause eye irritation, eye exposure to canola oil or vegetable oil may cause eye irritation, eye exposure to Castile soap may cause eye irritation or eye damage, eye exposure to bone meal may cause eye irritation, inhalation of bone meal may cause respiratory irritation, excessive inhalation of ground coffee may cause respiratory irritation, eye exposure to ground coffee may cause eye irritation.

Scissors will be used with caution and held by the blades closed together when not in use rather than held by the handles with blades out. 1 pair of safety goggles will be worn while handling all liquids. Medical care will be easily available in case of any accidents as well as eye and hand wash stations available nearby. If Coca Cola, canola oil, or vegetable oil get into contact with the eyes, eyes will be rinsed with water immediately. Cell tray pairs will be checked daily for leaks to ensure so harm is done to the nearby environment.

For safety, all cell tray pairs with contaminated soil were kept upright in a sturdy container away from outside interferences like pets.

After the experiment is concluded, the remaining contaminated soil pairs (5 total contaminated soil pairs as the soil pair with only water does not need to be flushed) will be set into separate containers with 1 cup of water in each container. The soil will sit in their containers for 4 days outside in the shade then be removed from their containers and set aside on a clean surface temporarily. The 5 containers

would be dumped of their contents in an area where runoff won't occur (dirt/soil with no plants or open areas nearby), cleaned, and refilled with 5 more cups of clean water with 1 cup per container. The soil would be placed back into their containers and left to sit for another 4 days. After the soil is removed from their containers, the water will be dumped. The same area as before and soil stored for future uses. A pair of Nitrile gloves will be worn for the duration of transferring soil. After all soil is set in their containers, gloves will be removed, and hands washed with clean water and soap, scrubbed together between each finger, under nails, and backs of hands for 30 seconds minimum.

Data Analysis:

During the span and end of 4 weeks, the growth of the seeds would be observed and recorded in a journal based on length and height of the roots and shoots from the soil over time, how long each seed takes to germinate, the color and width of the shoots and roots, the form/shape of the roots and shoots after 4 weeks. The length of the roots and shoots will be unraveled if curled and measured with a ruler in centimeters. The time it takes for the samples to germinate will be based on observations made twice a day, in the morning and afternoon. After 4 weeks, all plants will be gently removed, cleaned of dirt, and data recorded.

Samples	Shoot Color	Stem Width (mm)	Root Color	Primary Root Width (mm)	Root Length (cm)	Shoot Height (cm)	Time until germination (days)	Root Cap Width (mm)
Water A								
Water B								
Canola Oil A								
Canola Oil B								
Coca Cola A								
Coca Cola B								
Fertilizer alternative A								
Fertilizer alternative B								

Pesticide alternative A
Pesticide alternative B
Vegetable Oil A
Vegetable Oil B

Graphs:

Double bar graphs with both samples in each category comparing the final root length, shoot height, stem width, and primary and root cap width. Graph 1 x-axis will have all 12 samples and the y axis labeled with their final root length in cm. Graph 2 x-axis will have all 12 samples and the y axis labeled with their final shoot height in cm. Graph 3 x-axis will have all 12 samples and the y axis labeled with their final stem, primary root, and root cap width in mm.

Line graphs will be used for measuring the height of the shoots over time each day from the start to end of 4 weeks (labeled day 1, day 2, day 3...). There will also be a line graph for each category going by weeks and the plant's growth. Graph 1 x-axis will have 28 days (4 weeks) and the y axis labeled with their final shoot height from the soil in cm with 12 lines (1 for each sample). Graph 2 x-axis will be labeled by weeks with 4 weeks total (4 points) and the y axis labeled with their final shoot height in cm at the end of week with 6 lines (1 for samples labeled A). Graph 3 x-axis will be labeled by weeks with 4 weeks total (4 points) and the y axis labeled with their final shoot height in cm at the end of week with 6 lines (1 for samples labeled B).

Materials:

- **1 packet of Cress seeds** for testing how plants are affected by liquid pollutants in storm water runoff.
- **21.8 cups of clean water (hose or sink water)** for watering soil and plants and to balance the other liquid pollutants with a 1:1 ratio of water and liquid pollutant. 10 cups of water will be reserved for flushing the soil. 1.2 cups will be reserved for the pesticide alternative mix.
- **2.4 cups of Crisco Canola oil** to be used for the plant samples.
- **2.4 cups of Coca Cola** to be used for the plant samples.
- **2.4 cups of Crisco Vegetable Oil** to be used for the plant samples.
- **1.2 cups of Coffee grounds** to be used for the plant samples and fertilizer alternative.

- **1.2 cups of Bone meal** to be used for the plant samples and fertilizer alternative.
- **1.2 cups of Castile soap** used for the plant samples and pesticide alternative.
- **13 cups of dry soil** for planting the Cress seeds in.
- **1 2x2x4 inch plastic cell seed tray (12 cells total with hole(s) at the bottom of each cell)** for holding the Cress seeds and soil.
- **2 teaspoons measuring spoons** for measuring the amounts of water to pollutant ration used for the plants.
- **1 wooden ruler (in/cm)** for measuring the length and width of the plants' roots and shoots.
- **1 pair of scissors** for cutting the plastic cell seed tray into cell trays with 2 connected cells.
- **1 garden or kitchen sieve** for separating and filtering large clumps of soil or unwanted materials such as rocks from the soil.
- **1 wide container** for collecting the soil as it is sifted.
- **1 small, tall container f**or washing soil off the plant roots after the experiment is concluded.
- **6 4x2x4 inch containers** for supporting the cell tray pairs and keeping them upright.
- **1 water hose with a small sprinkler head or 1 watering can with a small sprinkler head** for watering the soil in the cells before planting the Cress seeds.
- **6 pieces of 5x3 inch Saran wrap** for covering up the cell tray pairs for germination as to prevent the escape of moisture and heat.
- **8 strips of paper towel, small and thin cloths, or pages of newspaper** for absorbing excess moisture at the bottom of the cell and keeping the soil moist throughout the day.
- **1 black Sharpie or marker** for labeling each container.
- **6 rubber bands** for securing the Saran wrap around the containers holding the cell trays pairs.
- **1 toothpick** for poking small holes in the Saran wrap to allow excess moisture out and increase air flow to prevent the growth of fungus.
- **5 small containers** for flushing the soil after experiment.
- **1 pair of safety goggles** for protecting eyes while working.
- **1 dust mask** to protect from inhalation of bone meal and coffee grounds while working.

Bibliographies:

Pusz, A., Wiśniewska, M., Rogalski, D., & Grzyb, G. (2018). Identification of Threats to the Soil and Water Environment on the Example of an Inactive Landfill Site. Journal of Ecological Engineering, 19, 181-190.

The authors, students from Warsaw University of Technology, collected samples of soil from varying depths at a closed landfill on Głębocka Street in Warsaw to test their hypothesis that soil and ground water can be negatively affected and contaminated by potential hazards in landfills. After conducting a few tests, they find that their hypothesis is heavily supported as the results show that the lower areas in the landfill have high amounts of leachate, risking the contamination of groundwater and causing the soil around it to be incredibly acidic.

Kim, M., Min, H., Lee, S., Kim, J. (2016). The Effects of Various Amendments on Trace Element Stabilization in Acidic, Neutral, and Alkali Soil with Similar Pollution Index. Public Library of Science (PLoS ONE), 11, e0166335.
The authors, students from O-Jeong Eco-Resilience Institute in Korea, collected contaminated soil samples from 3 parts of Korea, all having an abandoned mine nearby to test their hypothesis that they will be able to determine the best amendments for phytotoxicity and trace element stability. After germinating 12 Buk choy seeds in each of the soil samples with amendments and seeing their results, the authors were able to determine that using acid mine drainage sludge, and amendments containing iron and calcium helped significantly in stabilizing soils.

Eghdami, H., Azhdari, G., Lebailly, P., Azadi, H. (2019). Impact of Land Use Changes on Soil and Vegetation Characteristics in Fereydan, Iran. MDPI AG, 9, 58.
The authors, students at the Universities of Trier, Tehran, Liege, and Ghent, collected soil samples in different areas regarding distance from human activity and infrastructure to test their hypothesis that the more varying chemical and physical characteristics, the more plant diversity there will be. This hypothesis was rejected after a series of multiple tests consisting of rangeland quality, soil characteristics and quality, amendments in the soil, and vegetation diversity. The result was that organic matter played the biggest role in plant diversity.

Bona, C., Rezende, I., Santos, G., Souza, L. (2011). Effect of Soil Contaminated by Diesel Oil on the Germination of Seeds and the Growth of Schinus terebinthifolius Raddi (Anacardiaceae) Seedlings. Instituto de Tecnologia do Paraná (Tecpar), 54, 1379-1387.

The authors, students at the Universities of Parana and Maringa, collected 250 seeds and planted them into 4 soil treatments, each containing the same amount of diesel oil (except for the control group with no diesel) but waiting 180, 90, and 30 days after soil contamination to plant the seeds. This was to test their hypothesis that if diesel oil is added to soil, then the seeds' germination and growth would be altered. This hypothesis was supported by the results showing that all contaminated soils had adverse effects on the plants' growth, the 30-day treatment leaving the largest effect. However, it was also shown that with time, the toxic effects of diesel oil in the soil grew less.

Yu, H., Qi, W., Cao, X., Hu, J. Li, Y., Peng, J., Hu, C., Qu, J. (2021) Microplastic residues in wetland ecosystems: Do they truly threaten the plant-microbe-soil system? Elsevier, 156, 106708.

The authors, students at the Chinese Academy of Sciences, Wuhan University, and Tsinghua University, collect soil samples and observe the effects of microplastics, polystyrene, polyvinyl chloride, polypropylene, and polyethylene on the germination of seeds to prove their hypothesis that if microplastics are added to soil, it will directly affect the ecosystem functions of above/belowground ecosystems. Their hypothesis was proved somewhat correct as the addition of microplastics affected the wetland simulation both directly and indirectly. They find that the addition of microplastics affects the diversity and function of plants and organisms as well as altering physical and chemical properties resulting in limited growth and population development.