Soil Management & Emissions

Experimental investigation

Canterbury Schools. Do not use if attending the Lincoln University Soils Revision Workshop

Developed and designed by Roger McLenaghen from the Lincoln University Soils Department.

This experiment can be integrated into soil, sustainability, or a livestock teaching unit. The focus is on soil microbes and their respiration of carbon dioxide into the atmosphere. The microbial population is an important indicator of soil health, but it also determines the amount of carbon dioxide release. The microbial population size and diversity is directly influenced by soil management practices that can be modelled in the classroom with this simple class experiment.

Set up

For this classroom experiment you will need to set up four airtight containers that each has a CO_2 meter inside it. Battery CO_2 meters can be brought from stores like Dick Smith for under $50. The class experiment needs to run for at least a week to see how the soil microbial populations change under the different conditions. The detector model used in the photos has a battery life of 10 hours. This is not long enough to run the experiment as it needs to last a week. A hole was made in the airtight container so the power cord could go through. Silicon was then used to fill the hole and Vaseline was used on the edges of the lid to ensure that it is airtight.

The same type of soil needs to be used in all the containers. Students can record the CO_2 over that week and create a graph if you are wanting them to practice graphing and interpretation.

Baseline

This sample provides the baseline to compare to the rest of the samples and should be consistent with the CO_2 background levels. In 2022 is a base line of 420 parts per million (ppm). It is good to point out that 420 ppm is the current background CO_2 levels.

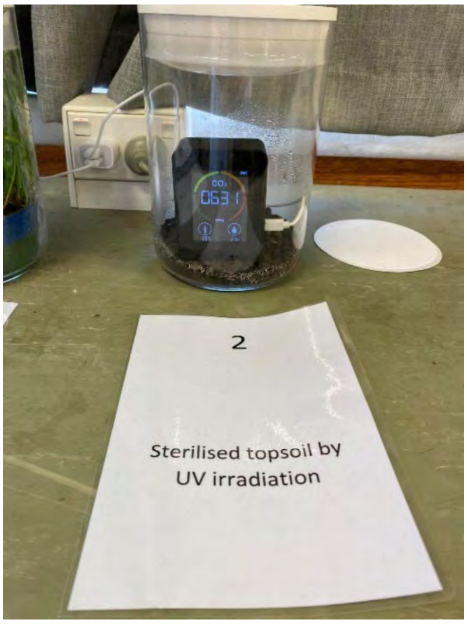
In the past they would have been significantly lower, and in the future, they are expected to rise. This provides the baseline for the other experiments.

The readings may vary over time depending on the number of students in the classroom and if the doors or windows are opened or closed.

Container 1: Soil with Pasture

This sample should have live grass with roots to simulate the environment of pasture. The soil microbes are breaking down organic matter and respiring which releases CO_2. Grass absorbs oxygen for respiration and carbon dioxide for photosynthesis. The amount of CO_2 being consumed by the pasture (ryegrass clover mix) is more than what is being emitted by the soil, but this can vary due to temperature, pasture type, soil type, soil moisture and other environmental factors. So, the results for this experiment can vary.

Research has just really begun in this area to determine if and how much pastures are a greenhouse sink. Often, nitrous oxide (N_2O) and methane (CH_4) is also measured as both potent greenhouse gases.



Container 2: Sterilised Soil

The second container will hold sterilised soil which means there will be no microbial activity and the meter should be the same as the background CO_2 levels (~420ppm).

To sterilise the soil a microwave or oven can be used, the most important part is for the soil to reach 93°C. To sterilise soil in the microwave, place soil in a microwave safe dish and mist lightly. Heat the soil on high in the microwave for 2 minutes. Use a thermometer to check the centre of the soil and if not up to 93°C continue heating in small increments.

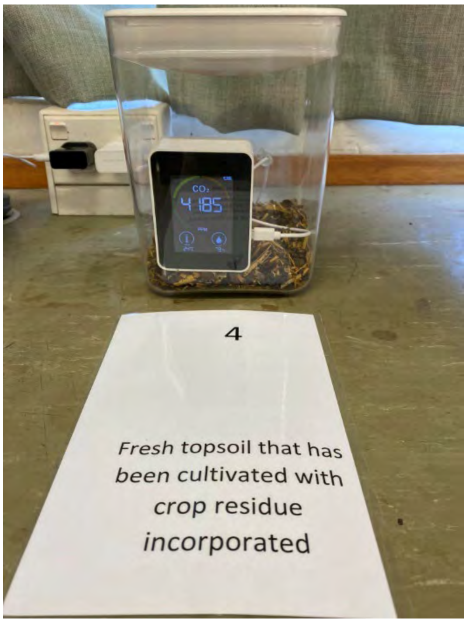
Note: in this case the readings in the picture are out due to leakage and the changes in student numbers respiring in Lincoln University labs.

Container 3: Cultivated Soil

This soil has not been treated and just left loose inside the container.

Cultivation/ ploughing is done before planting new crops or pasture. Its benefits include aerating the soil which leads to soil being warmer (due to the increase in air pockets) which leads to an increase in microbial action.

However, there is not a lot of food for the microbes to feed off, so the populations are small, and the rates of respiration are small. The population may peak early in the week and then drop.



Container 4: Cultivated Soil with Crop Residue

Lose soil represents cultivated soil, and mixing in some hay or pea straw represents the crop residue that is left over in the field.

Cultivation/ ploughing is done before planting new crops or pasture and often plant residue like crop stubble is ploughed in. This provides organic matter (food) to the microbes and leads to an increase in the microbial populations and there will be higher levels of respiration. But the organic matter is mostly carbohydrates, which provides energy, but it is of low nutrition. The microbial population is forced to get the nutrients they need from the soil which is a limiting factor. Over the week or weeks, they could see the respiration increase and then decrease.

Plants take carbon from the atmosphere to build their structure. When the plant material decomposes, the soil microbes break down the carbohydrate structure and through respiration releases CO_2 back into the atmosphere. This can make the whole process relatively carbon neutral and leads soil scientists to question carbon sequestration claims and what to know the finer details around them.

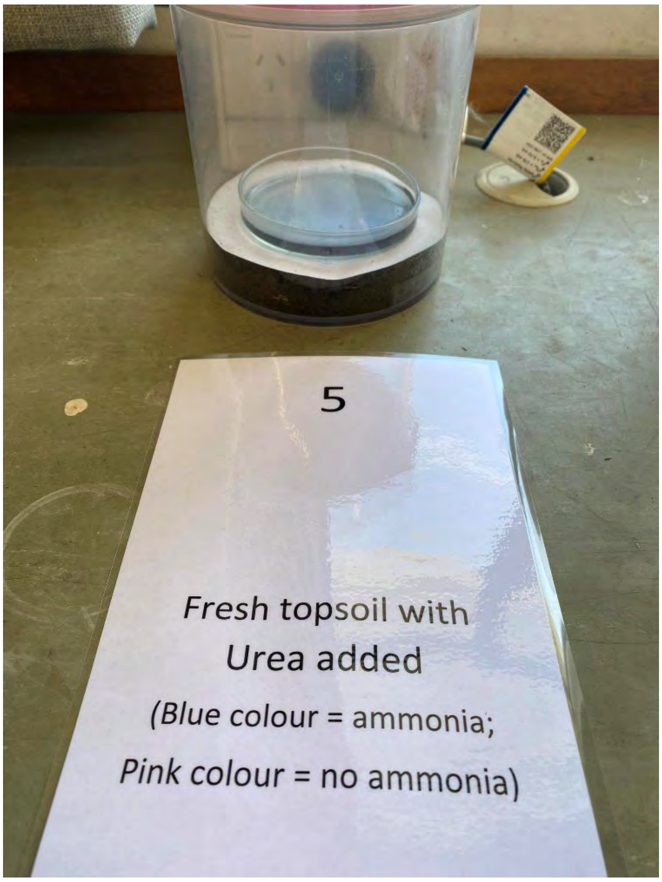
Container 5: Waterlogged Soil

This soil has been waterlogged and simulates excess rainfall/ flooding or ponding.

There is decreased CO_2 production due to decreased microbial activity. The soil pores that had air have filled up with water so the microbes can't respire, and the environment becomes anaerobic. The soil microbial biomass decreases as a result.

This is why anaerobic conditions (found in environments like swamps) are being explored as a carbon sink option. The microbes' populations are not present, so carbon accumulates. When wetlands are drained the microbial populations increase and the there is a lot of carbon material for them to eat, making drained swampland very productive areas for growing. The production of rice tends to have a low carbon footprint, but waterlogged soils often emit nitrous oxide (N_2O), and methane (CH_4) which are both potent greenhouse gases.

For teacher interest…



Topsoil with Urea

On-farm nitrogen sources include fertiliser (urea), clover and urine patches.

Cow urine patch = 700 kg N/Ha = due to consuming clover.

Urea fertiliser = 30 kg N/Ha

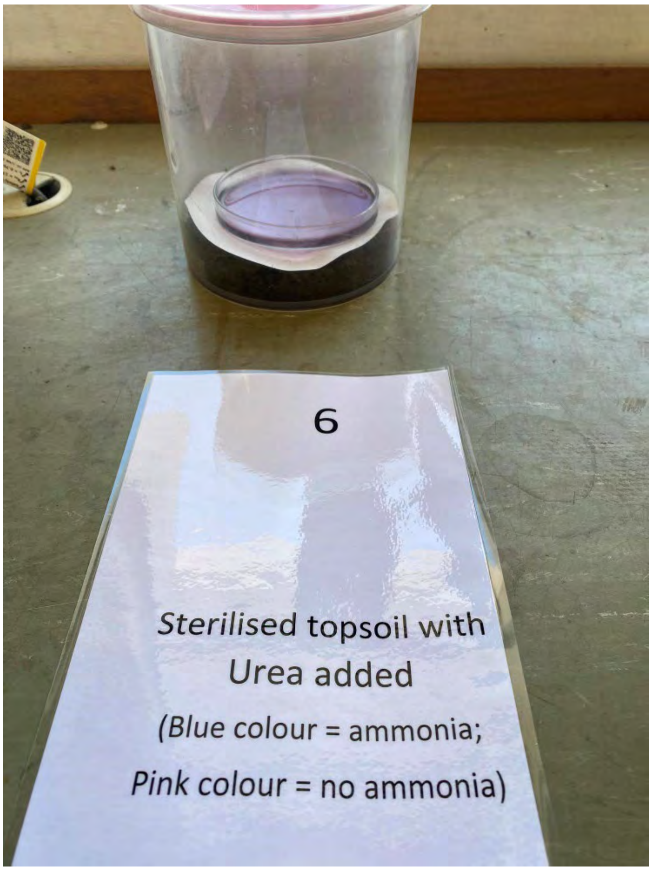
Urea is a source of nitrogen fertiliser that is used on farm. For plants to absorb the nitrogen from Urea it must first be broken down by soil microbes.

Urea is not an oxidizer at standard temperature and pressure, so it is safer to handle than other fertilisers. Soil microbes break down the urea into the soil but during the process they release the gas ammonia. Because the solution turned blue it is indicating that soil microbes are present and active.

If it rains or there is irrigation the ammonia gas will react with water to form ammonium which is held in the soil rather than air. Up to 30% of available nitrogen will be lost to the atmosphere within seventy-two hours if the soil doesn't have enough moisture.

The amount of ammonia volatilization depends on several environmental factors. Warmer temperatures increase volatilization due to increased microbial activity and decreased soil moisture.

Ideally the urea is applied before a moderate rain event that has around 2.5ml of rainfall so it is washed into the soil. Plant cover also helps as it helps retain soil moisture.



Container 6: Sterilised topsoil with Urea

There are no microbial populations, so the urea is not being broken down and is being stored. It also means no ammonia gas is being produced.

Some urea products have started to include formaldehyde, so the soil microbes are directly around the pallet are killed giving more time for the urea granules to break down due to exposer rather than microbial activity. This allows more of the Nitrogen to enter the soil before being broken down further by soil microbes which can then be taken up by plants.