Teachers manual

Teatime4GLOBE
Teatime4science

2017

Instructions & background material

Great that you and your class joined forces to study plant decay.

Enjoy your Teatime4science!

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This teacher's guide provides background information to the experiment, detailed instructions and suggestions on integration it with other subjects.

Thank you for helping me, Judith Sarneel, researcher at Umeå University and researchers from the Netherlands and Austria. Over the past two years, 350 Swedish, Dutch, Belgium and Scottish schools helped me. In 2017 we collaborate with the GLOBE program. This project is funded by The Swedish research council Vetenskapsådet.

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SUMMARY

Decomposition, that is the decay of plant parts (organic material), is a vital process for life on earth. Decomposition occurs when tiny soil organisms such as insects, fungi and bacteria eat the organic material and convert it into nutrients, soil and gas.

One of the gases that is generated is carbon dioxide. In the atmosphere, carbon dioxide contributes to warming our planet through the greenhouse effect. During the past century, human activities have increased levels of carbon dioxide in the atmosphere dramatically, with the ongoing global warming as a result. As the increased temperature in turn affects the decomposition, it is important to study this interaction in detail.

In the Tea bag experiment students will use a simple method to examine how much of the various types of plant parts are decomposed and thus converted into gas, nutrients and soil. The method is to bury tea bags and then dig them up again after about three months. By burying the tea at different locations one can compare the effect of the different environmental conditions in those locations on decomposition.

The difference in tea bag weight before and after it has been buried can be used to calculate how much was decomposed at your location. With the help of the weight losses, Judith Sarneel and her co-workers will calculate the so-called Tea Bag Index, which will be incorporated into the global soil map of decomposition. You will directly submit and see your data on this map. This map can be used as input to improve climate modeling. Thereby the students contribute to a real global research project.

The students will participate in real research and at the same time learn:

- That there is a biological activity in the soil which converts dead (plant) material into for example carbon dioxide, nutrients and soil.
- That decomposition depends on environmental factors such as moisture and temperature.
- That decomposition is an important process that has a direct impact on the global climate.
- That science can be fun.

Additional GLOBE protocols that relate to this subject and that contain useful information:
https://www.globe.gov/do-globe/globe-teachers-guide/soil-pedosphere
(soil filtration, bulk density, ‘why do we study soils’, ‘soil as sponges’, particle density)
https://www.globe.gov/do-globe/globe-teachers-guide/atmosphere
(especially temperature and precipitation)

IMPORTANT FACTS AND TIMELINE

Please join the Facebook group Teatime4science-schools international.
https://www.facebook.com/groups/teatime4science/?fref=ts

Here you can ask questions about the experiment and see questions and answers from the other participants.

Next to this instruction manual, there are instruction movies available on youtube, because of the timely sending of this instruction manual, please keep an eye on updates via the facebook pagina or the website.

Other important dates to remember

- Bury your tea before 16 June 2017.
- Retrieve your tea three months (10 to 14 weeks) after you buried them.
- Submit your data online before 16 September 2017

BACKGROUND

What is decomposition?

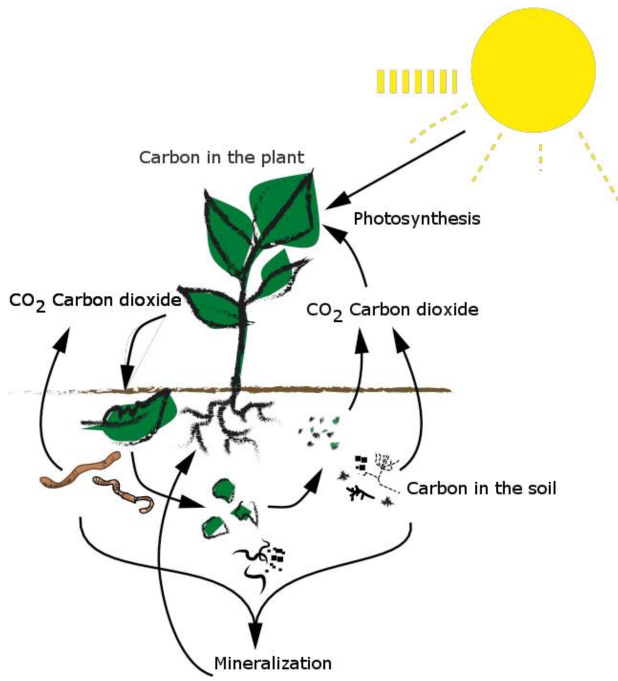


Figure 1: The carbon cycle. The arrows show the conversion of carbon. During photosynthesis, plants will take up carbon dioxide from the air and convert it into organic material (e.g. carbohydrates, wood or waxes). When plants and other organic materials decompose, carbon dioxide is released back into the atmosphere. Organic material that is not decomposed will be stored in the soil. Mineralization indicates that decomposition makes minerals and nutrients available for plants.

A leaf falls from a tree, lands on the ground and turns into soil. The soil provides nutrients to the tree, which can thereby form new leaves. Decomposition occurs in between, when the "decomposers" - tiny organisms, fungi and bacteria in the soil - eat up the organic matter and turn it into nutrients (a process called mineralization) and soil. Soils are really crowded with such organisms. Under one foot print, ca 50 000 nematodes, 9500 mites and 750 springtails can be found (Ottosson and Widlund, 2004).

Through decomposition, plants and small soil organisms are provided with food to grow and thrive. Examples of decomposers are small animals such as beetles and earthworms, nematodes and unicellular animals and microorganisms such as bacteria's and fungi.

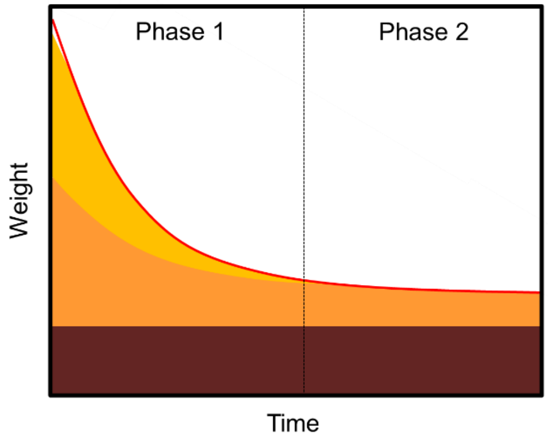
When plants remains decompose, the weight decreases, since the gas carbon dioxide (CO_2) is released into the atmosphere. Decomposition of plant remains, or "organic matter" is therefore a crucial process for life on our planet.

The tiny decomposers in the soil depend on different factors in their environment as they do not have a thick skin or cloths to help them to, for instance, have a constant body temperature. Therefore, decomposition is slower in cold climates and faster in warmer climates. This also means that in colder climates, less carbon dioxide will be released into the air and more is stored in the soil.

The decomposition rate depends on:

- Environmental conditions (humidity, acidity, the amount of nutrients in the soil, temperature). These factors affect the activity of the microorganisms; how fit they are and how much food they need.
- The chemical properties of the material that is going to be decomposed (e.g. a branch compared to a flower or plastic compared to paper). This is because microorganisms prefer some materials over other. Just like us, microorganisms love sugar, but are not so fond of harder materials like wood.
- Which decomposers are present: Mites, worms, fungi and bacteria all break down the different parts at different speeds.

All organic materials consist of a mixture of materials that are easy to decompose (for example sugars) and materials that are difficult to decompose (e.g. wood/waxes). As different materials will decay with different rates, the whole decomposition process can be separated into two phases (see figure 2).



• Red line shows the weight loss by decomposition.
• The colors below the line show what happens with different materials of the leaf. Yellow indicates easy decomposable materials, such as sugars.
• The orange area shows the material that is harder to decompose. And these substances are often only partly decomposed. The leftovers often very recalcitrant to further decomposition.
• The dark brown area shows leaf parts that are really hard to decompose, such as lignin.

Figure 2: Weight loss for organic material during the two phases of decomposition.

In the first phase all labile, easy to degrade material is decomposed, and the weight loss is fast. During the process a certain amount of the easy material is converted into material which is much harder to decompose. Those elements can be considered as left overs (for instance, when you chew on chewing gum, at one point it will taste different than first). We say that during decomposition, a part of the easy to decompose material gets stabilized.
In phase 2 only recalcitrant materials remain, and the further weight loss is minimal. This recalcitrant material will become part of the soil.

When researchers study the decomposition of plant material they usually calculate the decomposition rate called k. The decomposition rates in both phases depend on the three factors mentioned above (environmental conditions, chemical properties of the plant materials and the composition of the decomposer community).
The value of k usually varies between 0.01 and 0.4, with the lowest value in the cold climate and the highest in the warm (Zhang et al., 2008). Another constant is called S, which stands for stabilization factor. The stabilization factor indicates how much of the labile plant parts will stabilize. Stabilization usually ranges from 0.05 to 0.6 with lower values for warmer or moist locations (Keuskamp et al., 2013).

Decomposition and climate change

About a hundred years ago, the atmosphere contained ca. 0.03 per cent of carbon dioxide (CO_2). Today, the level of carbon dioxide has increased to approximately 0.04 percent, which is a very large increase (30%).

Carbon dioxide is a so-called greenhouse gas, which means that it contributes to warming of the earth. Solar radiation warms the earth. Part of the earth's thermal radiation bounces back into the atmosphere and returns to the earth's surface instead of radiating out into space (see Figure 3). The amount of greenhouse gas in the atmosphere determines how much of the earth's warmth is retained in the atmosphere. This warming effect is called the "greenhouse effect". In this way more energy remains in the atmosphere, allowing the temperature to increase. One could say that greenhouse gasses determine how dense, and thus warm, the blanket around the earth is. During the past century, human use of fossil fuels (such as oil and coal) have contributed considerably to increased carbon dioxide levels, and they are now

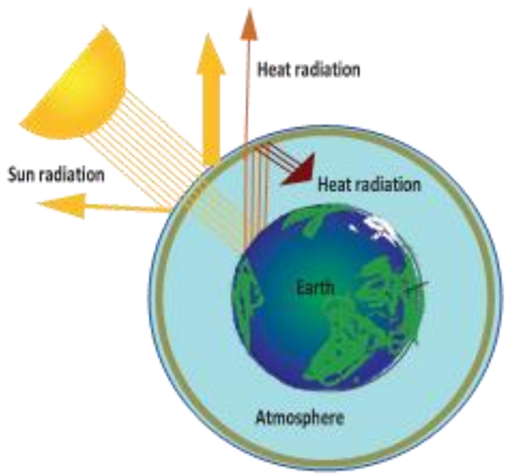


Figure 3: A schematic picture of the greenhouse effect.

far above normal levels. This results in further warming. Global warming is now one of the biggest challenges for humanity.

The amount of carbon dioxide in the air we breathe is a balance between how much carbon dioxide plants take up during photosynthesis and how much carbon dioxide is released – e.g. during decomposition. Changes in decomposition may therefore affect climate (i.e. faster decomposition leads to more carbon dioxide in the atmosphere and warmer climate, while slower decomposition results in less carbon dioxide and colder climate). However since we also saw that climate affects decomposition, knowledge on this feedback is very important. Given the large amount of carbon stored in the soil (2700 billion tons, gigatons, Gt) compared to in the living plants (575 Gt) and in the air (780 Gt), changes in decomposition can have very big effects (Crowther et al., 2016).

Decomposition research

In order to understand and predict the emissions of carbon dioxide from soils around the world, it is important to know decomposition rates in different types of soils. If you don't know what the starting values are, you cannot predict how it will change either.

What is for example the difference between a peatland in northern Scotland, a mixed forest in the Netherlands and arable field in Spain? The soils will likely vary in terms of temperature, moisture and fertilization. Measuring decomposition in many different kinds of soils will help the researchers of the Teatime4science project to understand the role of decomposition for global warming.

Many researchers on many different places on earth have tried to measure the decomposition. However they used many different methods and materials in their experiments, which makes it impossible to compare results between all those experiments. Another problem is that many methods for measuring decomposition rates require a lot of effort (Wieder and Lang, 1982).

Recently, a new method was developed to investigate the decomposition. The new method is called Tea Bag Index and uses tea bags with plastic mesh bags (Keuskamp et al., 2013). The tea inside the bags is plant material and decomposes just like all other plant material. By using tea bags, it becomes much easier to do experiments with exactly the same method. It will thereby become possible to compare the results. With use of the decomposition observed in the tea bags (i.e. the weight loss after 3 months) The Tea Bag index is calculated consisting of decomposition rate (k) and a stabilizing factor (S).

The Tea bag method

The tea bag experiment uses two types of tea: green tea and red tea (rooibos tea). Green tea is made from materials that are easily decomposed by microorganisms while red tea is more woody, and therefore more difficult to decompose. By comparing the decomposition of these two different kinds of tea, it becomes clear that decomposition of for instance a wooden branch and a leaf differ.

Both tea types are buried for three months. Since the two tea types differ in material composition, the green tea with its easily degradable material will decompose faster than the red tea. Because of this, green tea will already be in the second phase of decomposition after three months. Remember, what is left of the green tea at this moment is the recalcitrant material plus the stabilized labile material.

The red tea decomposes slower and after three months, it will still be in the first phase of decomposition (see Figure 2). In this way, the different types of teas are indicative of the different phases of decomposition of organic material.

We will use this method and test which environmental conditions around us affect decomposition.

Did you know……

1. Each cubic meters (m^3) of wood stores over 200 kg carbon.

2. The Icelandic peatlands are important for sequestering carbon. Partly because there is a lot of peat, and partly because decomposition is very slow in peat, as the wet conditions do not provide decomposers with enough oxygen.

3. In the tropics, the degradation rate is very high and a fallen leaf is gone within a month. In a colder climate, as in northern Scotland, it takes more than ten years.

4. Degradation time for an orange peel is 2-5 weeks (www.ecowarriors.it).

5. It takes at least 10 years for an ice cream stick of wood to decompose, and under certain circumstances, it may take millions of years before the stick has been totally decomposed.

6. In the last 30 years, the global average temperature, both on land and in the oceans, has increased by about 0.85 degrees Celsius (IPCC, 2013).

7. The different scientific models to predict the temperature rise due to climate change says that the global temperature will increase by 1-4 degrees Celsius during this century. Differences between models are due to uncertainties of the estimates of how much human activity will increase (and how we think this affects, for example, the decomposition process) (IPCC, 2013).

TEA BAG EXPERIMENT – HOW IT WORKS!

Material

The following material are needed for the experiment.
You need mostly cheap and reusable materials. The only equipment you need is a scale (with at least 0.01 digits).

Research kit:
• 6 Lipton Rooibos tea bags
• 6 Lipton Green tea bags
• Form to fill in the data, so that you can take it to the field

Other material needed:
• Scale (0.01 digits). A scale can be bought online at amazon. Or local pharmacies and jewelers may have such scales.
• Waterproof marker pen, black.
• Spade or spoon.
• Sticks to mark where the tea bags are buried (such as barbecue sticks or straw).
• Ruler.
• A warm and preferably sunny spot indoors where the tea bags and soil samples can dry when you have dug them up (such as a window sill). Even better is an oven that can run for 48 h at 50°C, but absolutely not above 70°C!

On Youtube:
• Instruction film. The instruction video for 2017 will be available soon. Search for 'teatime4science' or keep an eye on announcements on the facebook page. Select the video for the correct year.

Practical instructions

You can divide the work between you and the students in the way that suits the students' age and educational purpose. We provided some suggestions for labor divisions between teachers (T) and students (S).

In the experiment, you will dig down a total of 6 tea bags - 3 red and 3 green – at two different locations. If you really want you can bury them at 3 locations, with two tea bags of each type. We bury three tea bags of each type on one location because of safety. You may not always be able to find back the tea bag, or animals may have made holes in the bags. Further, there may be small environmental differences that affect decomposition. By measuring three times at almost the same location, we will get an average, that will represent the main conditions and decomposition at this location.

The green and the rooibos tea bag should be 15 cm apart and the pairs of tea bags should be spaced about one meter from each other. Locations that you can choose should be preferably natural (a wet place along a river, the forest patch behind your school), but you can choose one location (not both) in a place strongly influenced by humans (e.g. your school garden).

NOTE! In case of mistakes, write down what happened and how you solved it.

Preparations

1. (T) Take 6 tea bags with green tea (Lipton Green Tea) and 6 tea bags with red tea (Lipton Rooibos tea) and the form to fill in the data for the experiment.

2. (T) On the white side of the label, number the red tea bags with R1-6 and green tea bags with G11-16 with a black, water-resistant marker. Use "R" for red and "G" for green tea. Since the white side of the label is made of plastic the label will remain. The green or red side is made of paper and will disappear.

3. (T/S) Using a scale, weigh all the teabags with an accuracy of at least 0.01 grams, and write it on the form in the column of "start weight". Make sure the scale is placed on a stable, horizontal underground.

Start: Planting tea

1. (T) Choose two locations. At least one should be a natural soil that is not too much influenced by human activities. Provide a description on the form, and make a map of each location so that you can find back your tea bags after three months.

2. (S) Look at Figure 4 when you do the following steps. In each location, dig 6 holes, 8 cm deep, and place a tea bag in each hole, according to figure 4. The distance between the Rooibos and green tea bags should be 15 cm, and the distance between the pairs 75 to 100 cm.

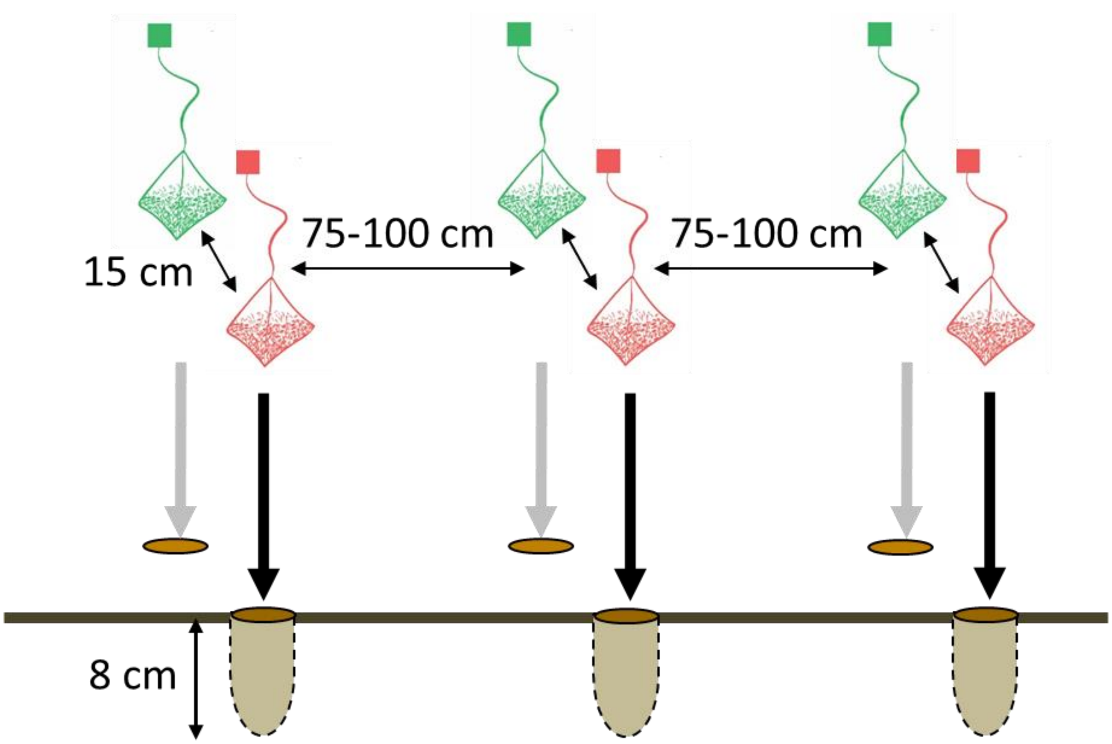


Figure 4: Experimental setup in one location.

4. (S) Keep the label above the ground. Put back the soil and press it firmly with your hands.

5. (S) Mark the place where you buried each tea bag with a stick and attach the label of the bag to this stick with tape. Draw a sketch to show how the tea bags are buried, and of other characteristics of the area (e.g. a tree or fence). This will make it much easier to find back the tea bags.

6. (T/S) Fill in the form: date of digging down, what kind of location did you use, etc.

7. (T/S) If you decided to do additional GLOBE protocols to characterize the soil, don't forget to do them. They are strongly advised, as they will help the students to explain differences in decomposition between the locations.

8. (T) Save the form in a safe place and remember to put a reminder in your calendar or your phone. You have to wait 2-3 months. In warm, moist environments (e.g. the tropics) the tea bags need to be in the soil for 2 months. In cold or dry locations (e.g. tundra's or deserts, respectively) the tea has to be in the soil for 3 months. It does not have to be exactly 3 months, it can be a week more or less, according to your own convenience. As long as you write down the exact dates.

End: retrieving the bags

Outdoor

1. (S) Find back the tea bags.
2. (S) Carefully dig up the tea bags. Do this CAREFULLY so that neither the labeling nor the tea bag is destroyed.
3. (S) Carefully remove soil and roots that are stuck to the tea bag. Put the tea bag in a (paper) bag or envelope. NOTE! Do not use water to clean the bag, and write down if something goes wrong or if you see anything strange on the tea bags (fungus, roots grown into the bag, holes in the bag etc.)

4. (S) If you decided on any additional soil characterization, don't forget to do them again, see if it has changed under the duration of the experiment.

In the classroom:

5. (S) Dry the tea bags indoors in a warm (and preferably sunny) place for at least three days, or longer, until they are completely dry.

5. (S) Carefully remove the remaining soil from the tea bags with your hands.

6. (T/S) open the tea bag, and take out the tea. You can put the tea in a cupcake holder. Take great care that you do not loose any material. Take also great care that there are no soil particles from outside the bag falling into your tea material.

7. Weigh the tea. Make sure that you weigh only the tea, not the weight of the tea and the container that is holding the tea. Use the TARE function of your scale, or weigh the container with and without the tea, and calculate the tea weight afterwards.

8. The tea bags (with string and label) should be sorted as other waste and not with the green waste because the tea bag is made of plastic.

9. (T/S) Fill in the rest of the form.

10. Go to www.teatime4science.org, select 'data' and 'submit a single data point'. You have to fill in the form 6 different times, for each pair of tea bags. Do not submit data from bags that were broken. If you at one location, only found the rooibos of one pair and the green of another pair, you can combine those two. Under 'remarks' provide a short description of your location and write down any abnormalities

11. Done! If you do not see your data point appearing two hours after submission, please contact Judith@decolab.org.

Additional exercises

Calculate weight loss of tea and soil samples as a percentage of the starting weight. Calculate the mean values per tea type for each location.

Discuss: What location characteristics may have affected the weight loss of the tea?
How will the soil moisture of both locations affect decay?
What has caused the differences in weight loss between green and red tea?

TIPS AND TRICKS

- For quality control, it may be recommended that the teacher weights all the tea bags him- or herself and then let the students weigh them again. It is also helpful if the teacher checks the weight of the tea bags recorded on the forms.

- The tea bags must be completely dry before they are weighed.

- Remember to have the scale stable, horizontal surface.

- Broken tea bags cannot be used because weight loss are than not solely due to decomposition. Be careful during retrieving the bags!

- Remember to mark the tea bags labels on the white side with a waterproof pen. Otherwise, the marking will be gone by the time the tea bags should be dug up! Therefore make also a good map of the area.

- Aim to have the tea bags buried for three months. This can vary between 65 and 100 days for the Tea Bag index to be calculated.

RELEVANCE FOR DIFFERENT SUBJECTS

Mathematics – Calculation of the results and statistical comparisons.

Sports – The practical outdoor part of the experiment can be upgraded to an orienteering or geocaching activity.

Biology – The area around the digging site can be used for teaching for example plant species, soil organisms or ecology.

Chemistry – It is possible to expand chemically on how the decomposition and/or the carbon cycle works to a molecular level (how does photosynthesis and burning work chemically, and how can energy be stored in organisms). It also links to enzyme activity, and hypothesis building on why or how different environmental factors influence the decomposition.

General – The Tea bag experiment invites to discussions about how climate change affects our daily lives. Or on waste management. What will, for example, happen with all our waste? How long is the decomposition time for a plastic bag? Is it sustainable that we use materials that do not decompose naturally? Why do we have a plastic soup and not a paper soup?

FURTHER READING

Tea Bag Index Projects homepage: http://www.teatime4science.org

Facebook: https://www.facebook.com/groups/teatime4science/?fref=ts

Soil GLOBE protocols: https://www.globe.gov/do-globe/globe-teachers-guide/soil-pedosphere

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Additional information on decomposition: https://en.wikipedia.org/wiki/Decomposition

Movie on yearly global fluctuations of carbon dioxide:
http://www.vox.com/2014/11/19/7246067/nasa-animation-carbon-dioxide

How to measure climate: http://www.windows2universe.org/earth/climate/direct_measures.html

Information about soiltypes: http://www.soils4teachers.org

Soil fractions: http://eisforexplore.blogspot.nl/2013/03/soil-density-column.html

Soil categories: http://cmase.pbworks.com/f/ Soil+Texture+By+Feel.pdf

Carboncycle:http://epa.gov/climatestudents/basics/today/carbon-dioxide.html

Plant identification: http://kukkakasvit.luontoportti.fi/index.phtml?lang=en

A big thank you for your participation to you and your students!

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