

2023

GLOBE LAC REGIONAL OFFICE – LAC ACADEMIC PEDAGOGICAL COMMITTEE

PEDOSPHERE

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LEARNING ACTIVITIES

THE GLOBE PROGRAM



The GLOBE program is an international hands-on science learning program that brings together students, educators and scientists from around the world in the study of Earth system science. The main goals of this program are to improve science education, raise environmental awareness, and create a greater understanding of the Earth as a system. For more information visit www.globe.gov

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Chlorides in soils

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	Soil pH	4 (Quality education)	Research
	Soil characterization: texture	12 (Responsible production and consumption)	

Overview:

Among the most abundant salts in saline soils appear halite or sodium chloride (NaCl) and magnesium chloride (MgCl₂), which can limit the growth of many crops. It is therefore of particular interest to determine their presence in soils, in the context of the chemical interaction of their components.

Time:

2 classes

Prerequisites

- Chemical reactions.
- Solubility

School Level

High School (K-10 to K-12).

Purpose

Establish the presence of chlorides (mainly sodium and magnesium) in the studied soil, their characteristics, and their effects on its functionality.

Student Outcomes:

- Understanding the influence of chloride presence on soil pH,
- Recognizing chemical precipitation and solubility reactions.
- Familiarizing with characteristics and effects of chloride application in soils.



Introduction

Chloride is an anion that carries a negative electrical charge, so it does not adsorb with soil particles and can move very easily with water in the soil. Because of this, irrigation water quality and irrigation management are the main factors affecting chloride concentration in the soil. However, chloride is necessary in small amounts because it contributes to plant metabolism, photosynthesis, osmosis (movement of water in and out of plant cells), and ionic balance inside plant cells.

Guiding Research Questions:

- What does soil salinity dynamics entail?
- What are the characteristics of chlorides in soil?

Materials and Tools:

- Test tubes
- Distilled or demineralized water.
- Funnel and filter paper.
- Silver sulfate solution, Ag_2SO_4 , 4 (grams per liter).

Scientific Concepts:

- Acid-base chemical reactions
- Concept of pH
- Chlorides
- Anionic and cationic exchanges
- Soluble chlorides
- NaCl
- Precipitates

What and how to do it:

– Beginning

When selecting sampling sites, it should be taken into account that the distribution of salts in a soil profile may not be very regular, both in land area and depth and in seasonal periods of the year. In rainy or low irrigation periods, it is possible that a superficial horizon may give a negative response to the presence of chlorides, but that these are easily detectable in deeper horizons.

Take at least three samples from different locations (or horizons from the same sample), proceed to take some soil from each one and place it in test tubes (one for each one); add distilled or demineralized water and shake. Once shaken conveniently, the content of the tube is filtered by means of a funnel and filter paper. The resulting filtrate is called "filtrate".



– **Development:**

To check whether the soils under consideration contain chlorides, a few drops of silver sulfate are added to the filtrate, and a white precipitate (silver chloride) will form, easily observed by the increase in turbidity. Care must be taken in the addition of the silver sulfate, as the precipitate that will form may dissolve and pass into the filtrate again if there is an excess of chloride.

– **Closing:**

Using the corresponding GLOBE protocols, establish the texture and pH of each sample and infer the relationships that exist between the deduced characteristics. Prepare a report of the experience and deduce the equations of the chemical processes that occurred in the tests.

Frequently Asked Questions

How to systematize the concepts and applications developed?

Conduct a literature search to deduce the eventual contribution of soluble chlorides in the soil, the potential benefits for its substrate function, the relationship of this function with pH and its texture. Arrange your above findings in a display format to communicate them in your immediate community.

Resources:

GLOBE program soil research and work materials (www.globe.gov).

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Determination of organic matter in soils

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	Soil Characterization	4 (Quality education)	Research
	Soil pH	12 (Responsible Consumption and Production)	

Overview

In the development of life cycles in ecosystems, a repetitive and vitally important process is oxidation, which is usually represented by a set of chemical reactions according to their specific occurrence. Additionally, an oxidative process can be an indicator of a certain condition-in this case, the presence of organic matter in soils treated with an oxidant (hydrogen peroxide), which will give us a qualitative indication of the presence of organic matter in that sample by means of an effervescence effect. Notwithstanding the above, it is interesting to know other daily applications of peroxide, such as the preservation against pathogens of rainwater used on crops, dental and wound sanitization, and fun science experiments.

Time

2 classes.

Prerequisites:

General knowledge of oxidative processes.

School level

Primary School.

Purpose

To acquire theoretical and practical knowledge of the application of hydrogen peroxide in the qualitative quantification of organic matter in soils, and their scope.

Student Outcomes

- To recognize the oxidation reaction of hydrogen peroxide and its visible effect.
- To optimize qualitative criteria to evaluate test results.
- To infer soil use possibilities from the measurements obtained.



Introduction

Soil organic matter consists of plant and animal residues in different states of decomposition, tissues and cells of soil-dwelling organisms, as well as substances produced by soil organisms. The most stable part of this organic matter is called humus, which is obtained from the decomposition of most of the plant or animal substances added to the soil. The soil organic fraction acts as a regulator of the chemical processes occurring there, influences the physical characteristics and is the center of almost all soil biological activities, including microflora and fauna (Shuyana, 2018).

The chemical processes in which organic matter is basically involved are:

- The supply of nutrients by mineralization, particularly the release of nitrogen, phosphorus, sulfur and micronutrients available to plants.
- The stabilization of soil acidity due to its buffering power.
- The contribution to the soil cation exchange capacity, important for clay-textured soils of such exchange capacity and high cation retention.
- The regularization of availability levels of major nutrients and minor elements through the formation of organic substances that constitute soluble compounds.
- The absorption phenomena.

Guiding Research Questions

- What is the chemical reaction between soil and peroxide?
- What are the important effects that can be deduced from the presence of organic matter in soils?
- What could be the alternative uses of peroxide?

Scientific Concepts

- Hydrogen Peroxide (H_2O_2)
- Oxidation (chemical process)
- Humus

Materials and Tools

- 20-volume hydrogen peroxide, 250 mls
- A wash bottle
- 500 g. of burned soil with presence of ashes
- 500 g. of eroded surface soil
- 500 g. of sand
- 500 g. of soil with animal feces (cow, horse, etc.)
- 500 g. of worm humus

What to Do and How to Do It



– **Beginning**

- We must initially consider that peroxide is an oxidant and provides OH groups and free radicals that can attack any oxidizable organic substance, in addition to a wide variety of organic compounds such as lipids and proteins... the bubbling is due to the release of oxygen (O₂). The test consists of placing quantities (200 g) of different soils in containers duly labeled with their characterization.

– **Development**

- Determine the pH of each sample, apply peroxide to each of the available samples and observe the appearance of effervescence, trying to establish an order from greater to lesser effect on the samples; take anecdotal and numerical records of your experiences.

– **Closing**

- Make a discussion of your results supported by the following table:

No	Soil	Reaction	Grade	Appreciation
1	burned	No reaction	0	Absence of organic matter
2	eroded	No reaction	0	Poor in organic matter
3	sand	Mild effervescence	1	Low in organic matter
4	with feces	Moderate effervescence	2	Regular in organic matter
5	humus	Abundant effervescence	3	High in organic matter

- Organize your data systematically using graphs and tables, record your inferences and conclusions, and set up an exhibition in your community.

Frequently Asked Questions

-Why is pH measurement recommended?

Because it is a measurement that provides a lot of information about the sample, and a correlation can be established with the amount of organic matter present.

-Are there special considerations to be taken into account when working on the experiences?

Not necessarily, but it is never a bad idea to wear goggles and safety gloves.

Suggested Resources

- GLOBE flooring materials (www.globe.gov)

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Earthworms, soil engineers

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	<ul style="list-style-type: none"> - Soil Characterization - Soil pH - Soil Moisture - Bulk Density 	4 (Quality education) 12 (Responsible Consumption and Production)	Research

Overview

There are several types of earthworms, the most important and well known being the Red Californian earthworm, belonging to the annelid family, with a cylindrical and segmented body; their color ranges from white to pink and dark red as an adult; when earthworms reach adulthood, they can measure from 6 to 8 cm. Their respiration is cutaneous, that is, they breathe through the skin, so their environment must be adequately humid. The activity of earthworms accelerates the decomposition of plant residues, increasing the rate of nutrient transformation, and promotes soil aggregation and porosity. In addition, earthworms also help in the straw decomposition, in the creation of nitrogen, which can be used in the soil, and in its ventilation, since they help with soil mobilization and surface air and water circulation through it, increasing water infiltration and solute transport.

By making their galleries, earthworms improve the water properties and soil structure. By feeding on organic matter, they degrade it and help its decomposition by microorganisms, which makes nutrients more assimilable by plants. The digestion of the organic matter they consume is known as "Humus". It has been determined that the distribution of earthworms globally is defined by climatic factors such as precipitation and temperature. This raises concerns about the effect that climate change could have on earthworm populations.

Back in those days, Darwin Ch., in 1881, gave an account of their relevance. He stated then that "it is doubtful whether there are any other animals that have played a more important part in the history of the world than these creatures of such simple organization".

Long before, the Egyptians already considered them "lesser gods" when they observed how, after the flooding of the Nile, they incorporated silt into the soil, which increased its fertility. The fact is that, without earthworms, there would be no soil as we know it, and without soil, agriculture would not have developed.

Time

12 hours. Over the course of a semester.

Prerequisites: (K-6 - K-8)

None.

School level

Primary.

Purpose

To learn about the living conditions of earthworms as an activating factor in the improvement of soil properties, their protein contributions and their importance in the associated processes.

Student Outcomes

- To identify the processes of humus production from earthworms.
- To relate the productive improvement of organic matter with optimal soil habitat conditions.
- To make inferences after comparing soils with and without earthworm participation.

Introduction

Determining the importance of earthworms in their interaction with the soil requires getting involved in their breeding and knowledge of their characteristics and life cycle, which is possible to do at different size and temporality scales. On this occasion we will consider the "Californian earthworm" in our research because it is the best option for an activity like ours.

In general, the Californian earthworm is a dark red or reddish purple worm species, with an antero-posterior and dorso-ventral gradient, whose body is divided into fragments or metamerisms, which are visible to the naked eye. They are about 8-10 cm long and 3-5 mm in diameter. They are photophobic. Each individual ingests an amount of organic material equivalent to its own weight daily (approximately 1 gram in adult individuals). Each worm is equipped with a male and a female genital apparatus (they are hermaphrodites). Copulation takes place every 7-10 days. After 14 to 21 days of incubation, the small worms emerge from the egg capsule, which has already acquired a darker color, producing between 2 and 21 white worms measuring approximately 1 mm in length.

Guiding Research Questions

- What earthworm entomological characteristics favor their virtuous interaction with soils?
- How does the earthworm community contribute to the soil ecosystem configuration?



Scientific Concepts

- Entomology, Insects, Annelids
- Humus
- Meteorological factors influencing soil
- Proteins and Nutrients

Materials and Tools

- A weighing scale
- Garden tools such as a small shovel and a rake
- Californian earthworms
- Materials to make worm castings according to the selected model
- Plastic pieces of 50x50 cms
- Measuring tape
- Log book and pencils

What to Do and How to Do It

– Beginning

- In a selected study site intended for your soil measurements, set up your earthworm castings, which you should first build according to the video in reference No.1, otherwise, select some other model that is more suitable for you. Additionally, build a 100 x 50 x 15 cm. box with a few holes in the bottom, like a flower pot, and fill the box first 10 cm. with soil.

– Development

- Research the ideal conditions for composting in the literature and begin the process with a given number of earthworms. Concurrently, start a similar process in the soil bin (also with a given number of earthworms), recording the amount of water you added, the temperature, the mass of organic matter for feeding, and any visible changes in the process.
- In the case of the box, apply the protocols for pH, humidity and bulk density at the beginning and then record all details every 15 to 20 days.
- Run a hydrogen peroxide test once a month.

– Closing

- After taking the measurements in all instances and recording the data, organize them systematically using tables and/or graphs. Make a discussion on the gathered facts you observed, the measurements you took and the inferences you made. As a complement, concurrently start a bibliographic research. Establish evidence of the contribution of the earthworm presence to the soil properties for their agricultural use and overall improvement.
- Finally, make a presentation about your work to your immediate community.

Frequently Asked Questions

-How do I get earthworms?

Earthworms can be purchased at different places that are advertised online.

Suggested Resources

- Soil investigation at (www.globe.gov)

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Manufacture of a bucket composter

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Manufacturing a tube for storing and transporting soil horizon samples

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	Soil Horizon Sampling protocol Learning activities: Auger method and pit method	3 (Good Health and well-Being) 12 (Responsible Consumption and Production)	Application

Overview

Students will learn how to make a tube to store and transport the soil horizon samples they obtain, using the auger or pit sampling method at the study site.

Prerequisites

None.

School Level

Secondary.

Purpose

To learn how to make a soil horizon sampling tube with a technique similar to the transparency tube, using homemade materials that are readily and inexpensively available.

Student outcomes

- To build their own instrument with guidance from the teacher.
- To understand the concept of scale and units of measurement.
- To apply manual skills in instrument making.
- To work collaboratively on a hands-on task.
- To understand the concepts of precision in scientific instruments.
- To represent situations on a different scale.



Introduction

In order to select a site for soil characterization and sampling, it is very important to find out beforehand what the history of soil use was, at least in recent years- whether it was a farm field, what crops were planted, fertilizer use, soil and water conservation practices, whether it was a forestry property or dedicated to livestock grazing, whether there were buildings on the site that were demolished, etc. To know if any watercourse passed through or near the site, if it was a flood zone, a wetland or a lagoon, if it was a quarry, etc. These terrain data provide valuable information when the decision to dig the site is to be made.

A retrospective search can be done by looking for aerial photos of the site, geographic charts, bibliography, or interviewing old neighbors in the area or experts who know the site. This study will help us to better understand the type of soil that we will be able to discover when we make the profile description, and also to identify possible materials, debris, etc. that may appear.

It is also advisable to prepare a map or sketch of the site using tools such as Google Maps, or other cartographic information, if available. This helps to determine the current use of the site, dominant topography, type of parent material or predominant rock and position in the soil profile, and to decide the sampling points. The selection of a sampling technique depends on the edaphic, meteorological, geological and hydrogeological conditions, depth and accessibility of the study site (Mendoza, 2017).

GLOBE proposes three different methods for exposing the soil characterization site. One is to dig a 1 meter deep by 1.5 m wide and 1.5 m long calicata that will expose an entire profile of soil horizons and can be observed in situ. The second is to use an auger to drill the soil and extract soil samples from each horizon and place them one after the other on the ground on plastic or nylon to expose the entire profile. What was extracted in the auger is measured and then when it is deposited on the ground, it is measured again so that the profile is of the same length. The third method is that of surface soil sampling, where samples are taken at a depth of 5 cm with a small garden spade previously marked so as not to exceed that measurement.

When the first two methods are used (sampling at depth), it requires several hours of preliminary work to have the complete soil profile and start the characterization analysis, especially the excavation of the calicata. In this case, it is advisable to have it ready the day before or even earlier. It also depends on the age of the students who will be doing the activity. It is a very heavy task for elementary school children, perhaps it could be suitable for advanced high school or technical agricultural and livestock education or university students.

Being able to transfer this representation of the soil to the classroom for further studies is very useful, especially for saving time when the classes are not long enough or when weather conditions prevent us from working in the field.

Guiding Research Questions

- What tool could you use to transport soil samples?
- Can you think of how to build it?
- What materials would you use and why?
- How would you represent each type of horizon and its extent?



Scientific Concepts

- Object representation models
- Scales / Units of measurement

Materials and Tools

- One acrylic, clear plastic, polycarbonate tube or similar
- A centimeter ruler
- Acetate sheets
- 2-inch (5 cm) wide adhesive tape
- A rubber plug, stopple or other object used to seal the bottom of the tube
- Scissors or a cutter
- A black or white fine-tipped permanent marker
- A styrofoam (foamplast, icopor or unicel depending on the country) or wooden board
- Glue suitable for the material to be used
- A small garden spade
- Optional: another stopple for the rubber lid



Fig. 1

What to Do and How to Do It

– Development

- Take an acrylic, clear plastic or PVC tube, depending on what you can get where you live. The diameter of the tube is suggested to be between 7 and 9 cm and the length at least 105 cm, because if you are going to extract samples from a one meter deep pit, you will need at least one meter. What is important is that it is a transparent material and that it is rigid enough to support the weight of the soil when filled with samples.
- Develop a ruler to place along the entire length of the soil tube. You can use one of the following methods:



A Method. Take an acetate sheet and using a millimeter ruler, mark the centimeters and millimeters on the sheet with a fine-tipped black permanent marker. Mark the centimeters first and then every five millimeters. It will not be necessary to mark millimeter by millimeter since with soil peds we will not have the possibility to discern in such detail. It is suggested to use a marker that does not rub off with water as the soil samples may have high moisture content (see figure 2). Place a white sheet of paper underneath the acetate sheets so that the numbering is visible on the tube, otherwise the black color of the marker may be lost against the brown background of the soil.

B Method. Photocopy a transparent ruler on an acetate sheet, then just cut the section and repeat it along the length of the tube. In the example in figure 3 you can see the actual photocopy of a numbered 30 cm ruler, and the other sections are photocopies covering the numbers so that they can be added after the first section to complete the total length of the tube. To show the numbering, glue a white sheet of paper underneath the rulers.

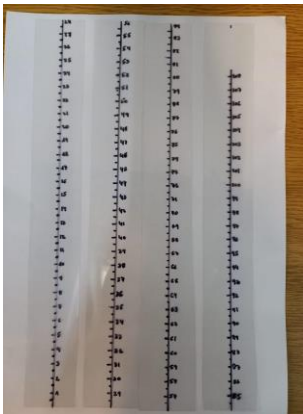


Fig. 2



Fig. 3

C Method. Draw the ruler directly on the transparency tube with the white permanent marker using a ruler as a guide.

Note: Be careful to keep the scale accurate when trying to print a ruler downloaded from the internet. Generally, when printed on paper or acetate sheets, the scale does not maintain the actual size, even though the file from which it was downloaded may make this clear. It is recommended in this case, once the sheet is printed, to check the centimeter measurement with a real ruler.

- When using either the method A or B, cut the rulers printed on the acetate into strips of 2.5 to 3 cm wide at the most.
- Take the stopple or rubber plug you have to seal the bottom of the soil pipe and test it. It should be of adequate diameter so that the diameter of the tube fits very well.
- When you put in the stopple, note that it is 3 or 4 centimeters high, which will cause a few centimeters of tube to be inside the stopple and the first soil sample will not be seen to its full dimension. A solution so that the zero centimeter of the ruler starts at the edge of the ruler is to mark the tube with a permanent marker at that height and then glue the ruler over the mark (see figures 4 to 6).



Fig. 4



Fig. 5



Fig. 6

- Fill in those centimeters that are left under the mark where the edge of the rim of the stopple is seen. One solution is to cut styrofoam disks of the inner diameter of the tube and glue them together as if they were a wafer until the height of the mark painted on the tube is reached (Figures 7 to 10). Once glued, they are tested on the stopple to see if they cover all the height needed. If more discs are needed, add more until that height is reached (Figures 11 and 12). Some other material, such as a plastic or acrylic plug, can also be used to fill in the rim.



Fig. 7



Fig. 8



Fig. 9



Fig. 10



Fig. 11



Fig. 12

- Place the insert into the stopple and then tighten the acrylic tube to the soil auger and insert. The soil auger must fit snugly to the tube so that it does not sag under the weight of the soil when filled.
- Align the acetate rulers on the tube, one next to the other from the edge of the ruler (zero centimeter) with special attention taken to respect the full centimeters at the joints of the rulers. Tape the rulers with a 5 cm wide adhesive tape to the transparency tube, forming a single straight line.



– **Closing**

How it works in practice

- Once in the field, and once the soil horizons have been sampled with a calicata or soil auger and spread out on the ground on a tarp or nylon, arrange all the horizons observed and sampled and measured with a ruler according to their depth in the ground (see figures 13 and 14).



Fig. 13. Soil Profile



Fig. 14. Characterized and measured horizons

- Proceed carefully to take a sample of the last extracted horizon with a garden spade (horizon A for the example of the photo). Place this sample inside the tube, making sure that if the extracted horizon was 25 cm, the tube should be filled up to the first 25 cm, measuring on the ruler of the tube to maintain the same proportion. Then continue with the B horizon (i.e, the second from bottom to top) and collect enough samples with the shovel to represent the height of that horizon (in this case 35 cm). Then complete in the order previously established until you reach the shallowest soil horizon (C in this example and measured 30 cm). (Figures 15 and 16).
- At the end of the procedure, you will have a tube filled with as many soil horizon samples as horizons you have extracted, and these occupy as many centimeters in the tube as total centimeters were measured in the total horizons extracted and corresponding to the depth you dug (see Figure 17). For this example, it represented a total of 90 cm.

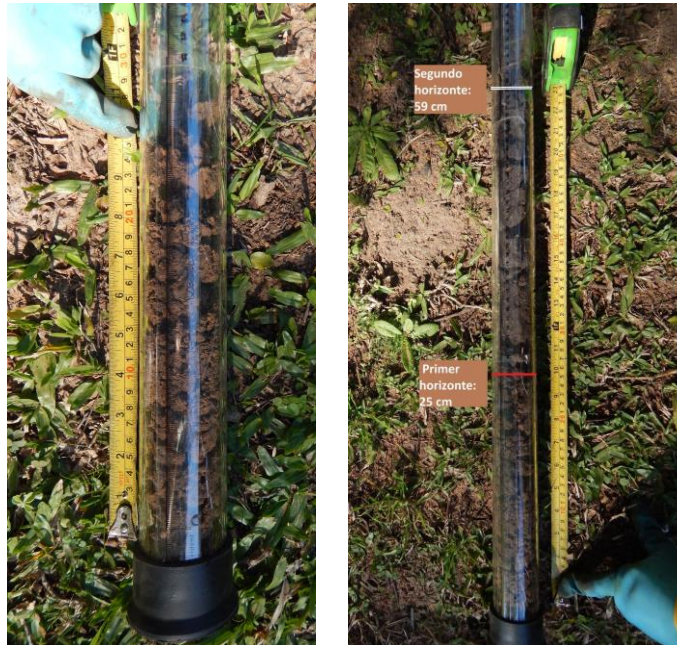


Fig. 15 and 16



Fig. 17

Note: it is recommended that when adding soil to the tube with the shovel, the tube should be tapped on the floor to settle the soil volume, and that when the next samples are placed, the samples below are not compacted by the weight, reducing the original size of the horizons.

Frequently Asked Questions

- What are the advantages of being able to store the samples in the tube?

- Transfer the samples to the classroom or laboratory and continue their analysis in the following classes, without losing the proportions and properties of the horizons, which allows you to perform the characterization and analysis in different stages.
- Keep as many soil horizons as sites you have sampled, if you have enough tubes to store them, and compare different study sites.
- Separate the different horizons with an acetate or nylon disc, or styrofoam inside the tube so that the samples do not mix.
- Observe and determine characteristics such as color, number of roots and rocks, and possibly also the structure without having to remove the samples from the tube.



- Extract a sample of each horizon from the tube when the soil characterization has been completed and study the pH, consistency, moisture, carbonates.
- Start the study in the field and continue it in the indoor classroom in case of inclement weather (rain, cold, etc.).
- Write down the characteristics of each soil horizon on the outside of the tube with a marker or stick a sticky note (note).
- Share the soil sample tube with other schools with which you are doing collaborative work. You only need to put a cap on the top of the tube and transport it vertically.

Glossary

Calicata: excavation of 1.50 m long, 1 m wide and 1 m deep, in which the soil, its layers or horizons are described, and various samples are taken for laboratory analysis, to know its characteristics and classify it under a taxonomic system.

Soil sampling: is the activity of collecting soil samples (representative), which allow characterizing the soil under study. The sample is defined as a representative part that presents the same characteristics or properties of the material under study; and, the samples sent to the laboratory constitute the samples chosen to be analyzed according to the established objectives.

Soil profile: is the vertical exposure of the horizons of an individual soil. An individual soil is a body that has been defined in terms of the characteristics of a profile whose arrangements and combinations over a geographic area are identical (Boul et al., 1997, cited by Mendoza, R., 2017).

Suggested Resources for Further Information

- <https://repositorio.una.edu.ni/3613/1/P33M539.pdf>
- <http://naturalis.fcnym.unlp.edu.ar/repositorio/documentos/sipcyt/bfa005974.pdf>

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Microbial activity in soils

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	Soil characterization Soil pH Soil texture	4 Quality Education 12 Responsible consumption and production	Research

Overview

Soil microorganisms interact with plant roots and other soil substances, promoting and benefiting plant nutrition and growth; they also facilitate the development of the cycle of matter in the biotopes, which can be classified into **viruses, bacteria, fungi, and parasites**. In principle, a criterion can be established by the approximate size of the organisms studied by microbiology. Viruses are the smallest known pathogenic microorganisms and do not constitute living things. Therefore, capturing its presence and possible quantity in each soil we interact with through global biological activity is essential, which can be established by measuring "soil respiration." Specifically, microorganisms consume the organic fraction and oxygen, releasing carbon dioxide (CO₂). The measurement of the latter gives us an indirect reference to the biological activity of the soil.

Time

Six classes.

Prerequisites

General knowledge of:

- Oxidative processes
- Precipitates
- Salt formation
- Acid-base titration indicator.

School level

K - 8 to k-12.



Purpose

Qualitatively identify soil microbial activity through observation of its CO_2 production.

Student outcomes

- Indirectly recognize the presence of microorganism activity in the soil.
- Infer possible qualities from the comparative analysis of the results obtained.
- Establish a quantification employing chemical assessment (optional).

Introduction

The microbial activity of the soil has to do with relevant processes such as nitrification, solubilization, mobility of microorganisms, growth of bacteria, fungi, and actinomycetes, among other specific functions that are dependent on the presence of water, pH, oxidation-reduction potentials, temperature, among others. The interactive relationship of the factors described above determines the degree of mobility of microorganisms in the soil and their potential interaction with the roots of plants to facilitate their nutrition and growth.

Guiding Research Questions

- What are the differences between the actions of microorganisms and insects in soils?
- What are the essential effects deduced from the presence of microorganisms in soils?
- What could be the effects of integrating a bacterial culture in a given soil?

Scientific concepts

- Carbon Dioxide (CO_2)
- Oxidation (chemical process)
- Chemical valuation or titration

Materials and tools

- Glass jars (used to store jams) of approximately 1 l. capacity, with hermetic closure
- Wet soil sample of two or three types
- Small bottle or beaker, 50 cc capacity.
- NaOH 2M



- BaCl_2 183 g/l
- Dropper
- HCl 1M (if you want to assess the dissolution of NaOH)
- Phenolphthalein (indicator if you want to assess the dissolution of NaOH)

What to do and how to do it

Beginning

- For each type of soil or horizon of each ground considered: at least 300 grams of fresh soil are taken and placed in a hermetically sealed canister (alternatively, consider reproducing directly in the flask the sequence of layers or horizons that form the soil or designing tests by specific horizon). In the small flask or beaker, arrange 20 ml of the 2M NaOH solution, insert it into the large flask to stand on the open soil sample in direct contact with the unoccupied space of the large container, close the canning jar, and allow two days to elapse, during which you should take note of the temperatures and incubation values (keeping the bottle tightly sealed).

Development

- After this time, the large bottle is opened, the glass of NaOH is collected, and a few drops of baric chloride (BaCl_2) are added. The solution acquires whitish turbidity (by precipitation of barium carbonate), proportional to the "respiration" of the soil. (When this method is used in specialized laboratories, it is normalized at a specific temperature and incubation time.)
- Proceed to the discussion of the results of the first stage, where each of the details of time and temperature is tabulated; determine with your working group the need to distribute some tests increasing or decreasing the amounts of sample to be used and the concentrations of the NaOH solution.
- On the fly, and according to your time and resources, define an experimental design with several samples or fractions of the same model under different temperature conditions and hermeticity times; also consider the possibility of testing with aggregation of leaves and organic matter to observe possible



variations. Optionally, you could use a chemical volumetric analysis technique (commonly referred to as valuation/titration) chemistry to have a qualitative background.

– **Closing**

- Proceed to the organization of the data in graphs, tables, and diagrams; make the final discussion of the results obtained, substantiate with theoretical data, and then make a presentation to the community or a publication in the medium available for the purpose.

Frequently asked questions

-Why is pH measurement recommended?

Because it is a measure that provides a lot of information about the sample, a correlation can be established with the amount of organic matter present.

-Should there be special considerations for working on experiences?

Not necessarily; however, it will never hurt to wear aprons, glasses, and gloves.

Suggested Resources

- GLOBE flooring materials (www.globe.gov)

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Nutrient retention in soils

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	Soil pH	4 (Quality of education)	Research
	Soil characterization: texture	12 (Responsible consumption and production)	

Overview

Soil pH is one of the most important chemical properties of soils. The availability of nutrients for plants, their solubility, and microbiota activity depend on it. In rainy climates, water washes cations and carries CO₂ that combines with soil cations. This leads to soil acidification and mineral impoverishment. On the other hand, we know that, in general, soils with high exchange capacity) have high contents of clay and/or organic matter. The high CEC gives them greater nutrient retention capacity, eventually making them more fertile. This is directly related to pH, which is also an indicator of multiple chemicals and physical and biological properties of soil that strongly influence the availability of essential plant nutrients. pH within a specific range allows most nutrients to maintain their maximum availability.

Time

Six classes.

Prerequisites

- Chemical reactions.
- soil pH.

School level

K-10 to K-12.

Purpose

Check the nutrient storage capacity of the soil associated with **GLOBE protocol procedures**.



Student outcomes

- Know instances that determine the pH of the soil.
- Identify the copper solution's characteristics and colorimetric effect to estimate soil nutrient retention.

Introduction

Cation exchange capacity refers to the total amount of negative charges on the surface of particles in the soil and their ability to retain cations. Organic matter and clay minerals in the soil possess several negative charges that can keep (absorb) nutrients such as potassium, calcium, magnesium, and other cations found in the liquid phase of the soil, known as cation exchange capacity (C.I.C.). The measurement of cation exchange capacity is a procedure that requires a specialized laboratory. However, it can be demonstrated using the following alternative method. When we add a solution of copper sulfate (CuSO_4 , blue in color, which is directly proportional to the concentration of copper in the solution) to a soil column, its discoloration occurs due to the retention of copper by the soil. This is verified by applying copper sulfate (e.g., 0.4 N approx.) to a column with relatively clay soil, so that the ground and dissolution remain in contact long enough. The percolating solution is discolored more or less depending on the type of soil (amount of organic matter and clays).

Guiding research questions

- What is the phenomenon of cation exchange in soils?
- What cation exchange characteristics make the soil favorable for agricultural uses?
- What would be the advantages of using a copper solution to determine soil nutrient retention?

Materials and tools

- pH meter / pH bars or tape
- Two bottles of soda (disposable) of 1.5 or 2 l capacity
- Two soil samples contrasted in their nutrient retention capacity (for example, a sandy soil poor in organic matter and a clay soil rich in organic matter)
- Dissolution of $\text{CuSO}_{4,0.4N}$

Scientific concepts

- Concept of pH
- Anionic and cationic exchanges
- Copper solutions



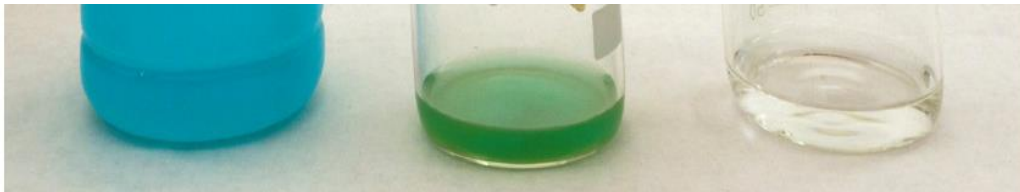
What to do and how to do it

– ***Beginning***

- Select the samples to occupy and determine their pH using the GLOBE protocol. Cut the two soda bottles (disposable) roughly in half. The top is turned upside down so that it operates like a funnel. You only have to make a few holes in the cap and fill this part of the bottle with the soil sample. The passage of the CuSO_4 solution can be improved by placing a tulle gauze between the bottle and the cap. The bottom of the bottle can be used as a support for collecting the solution that passes through the soil sample.

– ***Development***

- Once the filtration system has been mounted through the floor, pour the CuSO_4 solution and wait for the filtrate from the bottom. Once this operation has been performed for each sample, observe the colorations. In some cases, a transparent residue is obtained (almost total retention of copper) and a color change when combined with the yellowish tone of iron oxide.



The initial color of CuSO_4 solution

Greenish color (without RT h e)

Almost absorption complete

– ***Closing***

- Prepare a report of the experience with graphic details and photos before reviewing the information on the subject to develop a substantiated explanation of what was observed and present your experiences and findings in your social environment.

Frequently asked questions

-How to systematize the concepts and applications developed?



Perform a literature search and substantiate the cation exchange process in soils, its causes, potential benefits for the soil substrate function, and its components—priority of the role of pH in the general context. Arrange your previous findings in an exhibition format to communicate to your immediate community.

Resources

- GLOBE soil work and research materials (www.globe.gov)

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Passenger 26: iron in soils

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	Soil Characterization	4 (Quality education) 12 (Responsible Consumption and Production)	Research

Overview

Iron is the 26th element in the Periodic System of the elements, the fourth most abundant element in nature; it is said to be part of the Earth's core, to be found in mineral deposits and in our blood as part of the hemoglobin that carries oxygen in the blood, to be the metal used in the production of tools and structural equipment of domestic life, etc. This particular metal possesses magnetic properties (which are also attributable to nickel and cobalt to a lesser extent) and is present in some soil compounds in which it is involved.

In this activity we will determine the presence of the magnetic property of some iron compounds in the soil, infer some relationships among the soil composition properties, their agricultural use and the use possibilities as indicators in pedogenetic processes by which the soil is created, whose other aspects of study include the soil morphology, their soil classification (taxonomy), and their natural distribution, present and past (soil geography and paleopedology).

Time

6 hours.

Prerequisites: (K-6 - K-8)

None.

School level

Primary.

Purpose

To learn the association of the magnetic physical phenomenon with particles present in soils and its importance in the associated processes.

Student Outcomes

- To learn a way to measure magnetism qualitatively.



- To relate magnetism to other soil characteristics.
- To compare values associated with their measurement by making inferences.

Introduction

On the one hand, Iron oxides are found in all soils in varying amounts and are used as indicators of processes associated with soil origins, indicating soil formation environments. On the other hand, these components affect the soil properties and functions because they influence color, aggregation, cation exchange capacity and phosphorus retention in the soil. A characteristic of iron oxides is the formation of ferromagnetic minerals; due to this, and through the use of magnetic techniques, some pedogenetic processes can be identified. The objective of this activity is to give a first approach to the description of the soil magnetic properties and their potential applications in soil classification.

Guiding Research Questions

- Does the concept of soil magnetism pertain to all its components?
- How does magnetism contribute to soil characterization?

Scientific Concepts

- Concepts of magnetism, paramagnetism
- Magnet functioning
- Iron and its main soil compounds

Materials and Tools

- 4 to 5 magnets of the highest possible power
- A weight scale
- Tools such as a small shovel and a rake
- Sample bags
- Plastic pieces of 50x50 cms
- Tape measure
- A GPS

What to Do and How to Do It

– Beginning

- At a selected study site intended for your soil measurements, choose 10 sampling points, ideally with some kind of difference among them, and geosition them (record GPS coordinates). Provide a description and start an anecdotal record.

– Development



- At each selected point: collect soil samples with the shovel and place them on plastic, then remove stones and rocks, take a portion of about 500 g. and examine it with a magnet, collecting the particles that are attracted to it in a sample bag. Then, label and mash its contents.

– **Closing**

- After taking the measurements at all the selected points and recording the data, organize them systematically using tables and/or graphs. Make a discussion on the data you obtained and the inferences you made.
- As a complement, concurrently initiate a bibliographic research where you discover evidence that the soil magnetic properties allow identifying, quantifying magnetic minerals and relating them to pedogenetic processes, thus making possible the development of soil maps, the identification of pedogenetic processes and the improvement of soil classification.
- Finally, make a presentation for your immediate community.

Frequently Asked Questions

-Are there other ways to measure soil magnetism?

Yes, there are instruments of varied technologies that are not usually accessible to schools.

Suggested Resources

- Soil investigation at (www.globe.gov)

Bibliography

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Soil infiltration

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	<ul style="list-style-type: none"> - Gravimetric Soil Moisture - Absolute Bulk Density - Soil Particle Density 	4 (Quality education) 12 (Responsible Consumption and Production)	Research

Overview

Soils, in their function as biotope substrates, possess characteristics that will be of great importance for the successful occurrence of agricultural processes within them. The movement of water from the soil surface to the bottom and through the soil is called water uptake. It is the expression of several factors including infiltration, filtration (direct vertical passage of water to the water table) and percolation.

Infiltration is measured by the speed at which water enters from the surface into the soil (infiltration rate), the rates of which will be influenced by soil surface compaction, rainfall, soil cover, previous moisture, soil temperature and soil texture.

Time

6 hours.

Prerequisites

(k-6 -K-8) or The concept of density.

School level

Primary.

Purpose

To establish the relationship between water infiltration in soil and other characteristics of its composition in order to infer the best conditions for successful agricultural processes.

Student Outcomes

- To learn a way to measure infiltration.
- To relate infiltration to other soil characteristics.
- To compare rates associated with their measurement by making inferences.

Introduction



Measurements of water infiltration in soil allow us to determine the form and the flow of water that penetrates into the soil surface (runoff), at the same time the infiltration depends on the soil characteristics (mentioned above). On this occasion we will select measurement points on a study site, geoposition them, measure them with a handmade infiltration meter and infer the interrelations among other soil characteristics.

Guiding Research Questions

- Is the concept of soil permeability equivalent to infiltration?
- How do infiltration concepts relate to initial soil moisture?
- Is it possible to predict how runoff will occur in a rainy period?

Scientific Concepts

- Runoff
- Infiltration
- Percolation
- Filtration
- Density

Materials and Tools

- A metal cylinder (obtained from a gallon (4.5 L.) or larger paint can, with the bottom and handle removed). We will use it as an infiltrometer.
- A bucket with water
- A wash bottle
- A plastic bag
- Tools such as a small shovel and a rake
- A 250 ml test tube
- A stopwatch
- A GPS

What to Do and How to Do It

– Beginning

- At a selected study site (could be the same site for other soil measurements), choose 5 sampling points, ideally with some type of difference between them and geoposition them (record GPS coordinates). Prepare a description and start an anecdotal record.

– Development

- Then proceed with three rounds of measurements at each point, the second one an hour after the first one, and the third one, an hour after the second one. For each measurement, place the infiltrometer on a soil cleared of weeds and branches and insert it at a depth of one centimeter; then, place the plastic bag on top of the cylinder and pour 250 mL of water (measured by the test tube) over it while activating the stopwatch; carefully remove the bag so that the water enters



the soil without falling impact and record the time it takes for the water to soak into the soil.

– **Closing**

- After taking the measurements at all the selected points and recording the data, organize them systematically in tables and/or graphs. Choose the measurements of two points that seem most relevant, submit a couple of soil samples from each to the relative density protocol and make the appropriate comparisons. Discuss the data you obtained and the inferences you made and make a presentation for your immediate community.

Frequently Asked Questions

-Are there other ways to measure infiltration?

Yes, there are instruments of various technologies and one of them consists of two concentric metal rings, which requires a different application dynamic.

Suggested Resources

- Soil investigation at (www.globe.gov)

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Soil liming

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	Soil pH	4 (Quality education)	Research
	Soil Texture	12 (Responsible Consumption and Production)	
	Soil Fertility N-P-K		

Overview

Soil pH is one of the most important soil chemical properties. The availability of plant nutrients, their solubility and microbiota activity depend on it. In rainy climates, water washes away cations and carries CO₂ neutralizing itself with soil cations. This leads to soil acidification and mineral impoverishment.

Since ancient times in Tibet and China, calcium application has been a formula for improving pavements by liming (addition of lime), which is also a practice to reduce soil acidity through the contribution of calcium oxide (CaO), where calcium neutralizes the negative charges of clay, among other uses. Additionally, calcium application has to do with the soil improvement in agriculture uses, for the construction of building and road foundations in relation to drying, modification and stabilization, among others.

Time

4 classes.

Prerequisites

Knowledge prior to Upper Primary School, such as notions of chemical reactions.

School level

Middle School (K-10 to K-12).

Purpose

To apply methods to change soil pH and its characteristics, using calcium products and GLOBE protocol procedures.

Student Outcomes

- To know soil pH changing methods by recognizing acid-base neutralization chemical reactions.
- To know the characteristics and effect of applying calcium salts to soils.



Introduction

Cation exchange capacity refers to the total number of negative charges on the surface of soil particles and their capacity to retain cations such as: NH_4^+ , Ca^{2+} , K^+ and Mg^{2+} .

In general, it can be said that the greater the soil exchange capacity, the greater the fertility. There are also exchange anions absorbed by colloids where Al^{3+} and Ca^{2+} serve as a bridge to iron oxides and hydroxides, aluminum and manganese, the latter exchange cations are characteristic of acid soils. Because Cl^- and NO_3^- are poorly retained, they are easily washed out, hence most agricultural soils have a higher cation exchange capacity than anion exchange capacity (Salisbury, 1994).

Guiding Research Questions

- What is the soil cation exchange phenomenon?
- What are the cation exchange characteristics that make the soil favorable for agricultural uses?
- What are the lime properties that favor the soil establishment in the construction field?

Materials and Tools

- Lime
- Samples of different soils
- pH meter
- Various tools (shovel, brush, etc.)
- A gym weight

Scientific Concepts

- Neutralization chemical reactions
- pH Concept
- Soil Liming
- Anion and Cation Exchanges
- Calcium Salts

What to Do and How to Do It

Beginning

- Get a couple of kilos of acid soil (a clue is that it does not produce effervescence with vinegar) and check its pH using the corresponding GLOBE protocol, take three samples of 100 g. approx. and, by applying the GLOBE soil pH protocol, determine and record the initial values (they should be around 5). Apply an amount of 5g. of CaO , moisten the samples and let them sit for 24 hrs.



Development

- Mix the soil pieces to achieve homogeneity and measure again. Repeat this until the scope value reaches a value close to 8. Take the lime-treated soil, place one plant there (1 of 2) and put the other one in an original piece of soil. Monitor the plants, trying to maintain the same watering and access to sunlight in both.

Closing

- Prepare a report of your experience using graphic details and photos, prior to an information review on the subject to provide an explanation of what happened.

Frequently Asked Questions

-How can we systematize the concepts we developed and applied?

Conduct a bibliographic search and substantiate the soil cation exchange process, its causes, its potential benefits for soil substrate function and its components, highlighting the soil pH function in the overall context. Display your previous findings to share them with your immediate community.

Resources

- GLOBE program soil research and work materials (www.globe.gov)

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Soil moisture

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	Soil Moisture: Soil Water holding capacity	4 (Quality Education) 6 (Clean Water and Sanitation) 12 (Responsible Consumption and Production) 13 (Climate Action)	Research

Overview

Soil hydration is a very important phenomenon to consider because it influences the moistening of the atmosphere interface and its temperature and allows it to support the development of plants that are grown in them. The presence of water in soils is directly related to its apparent density, the existence of interstices in its body, where physical and chemical changes occur. In addition to the calculation of soil densities to estimate its capacity to retain water, in this activity we will see the possibility of considering the addition of a chemical product generically called Hydrogel, which is usually a hydrophilic polymeric compound, capable of retaining water in its structure and release it with some ease, reversibly modifying the condition of soil porosity.

Time

4 classes.

Prerequisites

Notions of GLOBE Soil protocols.

School level

Upper Middle School and Secondary Education.

Purpose

To know hydration management options in a given soil.

Student Outcomes

- To determine the indexes and modality of control of soil moisture factors, for agricultural use and entomological habitat purposes.
- To know the polymeric structures and their application and interaction characteristics of organic functional groups.
- To raise awareness of the importance and scarcity of water resources on the planet.



Introduction

The low availability of water due to global water scarcity and the high energy cost of accessing it in the depths of the groundwater table, as well as its growing demand for agriculture irrigable soils, make it necessary to implement a more efficient technological water use and management in order to reduce the volumes that must be applied to crop production to the minimum, without affecting their quality and yield.

In this context, the hydrogel is a polymer that has a high water-holding capacity. Hydrogels are made of soft and elastic materials that absorb aqueous solutions, depending on the nature of the polymer, and that are characterized by their hydrophilic and water insoluble capacity, which, according to their characteristics, can be classified as neutral or ionic and, according to the change of structures, as physical or chemical. These gels contain functional groups such as carboxylic acids or functional groups; they are usually cross-linked polymeric materials in the shape of a three-dimensional network that can be of animal or synthetic origin; They increase their ability to absorb the amounts of water available and their ability to be incorporated into the soil, forming soft and elastic materials which are harmless to crops, and improve the soil structure as a substrate and its eventual aeration; This way, hydrogels are a possible solution to maintain the moisture of these soils.

Scientific Concepts

- Hydration
- Water scarcity
- Structural polymers
- Organic functional groups

Guiding Research Questions

- How do hydrogels work to improve soil hydration?
- What are the advantages and disadvantages of using these types of products for soil biodiversity and agricultural uses?

Materials and Tools

- Hydrogel (in a commercial variety available at an agriculture or farm shop)
- Soil samples of at least three varieties
- Water
- Drainage devices
- Volume-measuring instruments and record sheets
- Ad hoc tools (a small spade, a spatula, a paintbrush, etc.)
- A scale

What to Do and How to Do it

Beginning

- Have drainage devices available (they can be made from disposable beverage containers), and place equal portions of soil in each, identifying the type and origin of at least two of each type so as to place hydrogel in each of them in their conditions of origin.



Development

- Saturate them with an aqueous preparation, (hydrogel is used at a rate of 10 g. per liter), then place a collection container in each. Monitor the process by taking anecdotal records of the changes and the water release values. Using these data and samples taken from the GLOBE sample containers, run tests to calculate their moisture percentages, also considering the amount of water released from each portion of soil.

Closing

- Evaluate the holding capacity in the different samples, and try both to determine the temporality of this in some way and to model its behavior mathematically.

Frequently Asked Questions

-How could you contextualize this knowledge in an everyday reality?

It could be by performing an advanced activity like the following: In the same sampling conditions as above, take a crop of your choice and measure the quantities of water required for the vital process of the vegetables. In addition, investigate the hydrogel behavior in some macro crop, make comparisons and arrange an informed discussion of the topic, with audiovisual material that allows you to expose your research in your community, highlighting the use of these products in mitigating the effects of global water scarcity.

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Soluble sulfates in soils

GLOBE		<i>Related SDGs:</i>	<i>Type of activity</i>
Sphere	Protocols		
Pedosphere	pH soil texture	4 Quality Education 12 Responsible Consumption and Production	Research

Overview

The presence of sulfates produces different effects on soil properties and plant physiology. The main of these compounds is hydrated Calcium Sulfate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), known as gypsum, which in specific quantities is used as a natural fertilizer and as a soil amendment increasing its productive capacity.

In some soils, gypsum is very abundant (gypsum soils). Since their presence can have agronomic importance, it is essential to verify their presence.

Time

2 classes.

Prerequisites

Chemical reactions.

School level

High school (K-10 to K-12).

Purpose

Establish the presence of sulfates in the soil studied, their characteristics, and contributions to their functionality.

Student outcomes

- Know the influence of sulfates on soil pH.
- Recognize acid-base neutralization chemical reactions.
- Know the characteristics and effects of gypsum in its application in soils.

Introduction



When gypsum is applied with fine particle size, it allows a rapid availability of nutrients. It provides calcium to soils, maintaining cationic ratios at ideal levels. It contributes to increasing the availability of nutrients such as phosphorus, potassium, and calcium. It increases the cation exchange capacity and favors the supply of calcium (Ca) and sulfur (S) to plants.

In plants, nitrogen and sulfur are essential to achieve protein blockage. Sulfur deficiency will severely reduce nitrogen use efficiency and limit protein synthesis.

Guiding research questions

- What is the contribution of sulfates to the cation exchange in soils?
- What are the advantages and disadvantages of the presence of gypsum in the soil?

Materials and tools

- Test tubes
- Distilled or demineralized water
- Funnel and filter paper.
- Barium chloride solution, BaCl_2 , 15%

Scientific concepts

- Acid-base chemical reactions
- Concept of pH
- Plasters
- Anionic and cationic exchanges
- Soluble sulfates
- Precipitates

What to do and how to do it

Beginning

- Considering samples of at least three different types of soil, take some soil from each and place it in test tubes (one for each); Add distilled or demineralized water and shake. Once properly shaken, the tube contents are filtered by a funnel and filter paper. When the soil is of texture, it may be necessary to filter the extract several times so that it is transparent and the sediment can be seen if it appears in the next stage, or it can be filtered through two papers.

Development

- To check whether the soils in question contain gypsum or other sulfates, a few drops of the barium chloride solution are added to each of the filter liquids, where



the appearance of turbidity, attributable to the formation of a white precipitate of barium sulfate, will be easily observable,

Closing

- Using corresponding GLOBE protocols, establish the texture and pH of each sample and infer the relationships between the deduced characteristics. Prepare an experience report with details, deduction of the equations of the chemical processes that occurred in the tests.

Frequently asked questions

-How to systematize the concepts and applications developed?

Perform a literature search to deduce the importance of soluble sulfates in soils, their causes, and potential benefits for their function as substrate Priority of the function of pH and texture. Arrange your previous findings in an exhibition format to communicate to your immediate community.

Resources

- GLOBE soil work and research materials (www.globe.gov)

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Underground inhabitants (game with decomposers)

GLOBE		<i>Related SDGs:</i>	<i>Type of activity</i>
Sphere	Protocols		
Pedosphere	<ul style="list-style-type: none"> - Soil Characterization - Soil pH - Soil Moisture - Bulk Density 	4 (Quality education) 12 (Responsible Consumption and Production)	Research

Overview

The soil is perhaps an ecosystem in itself, it harbors a great biodiversity that can include organisms ranging from tiny microscopic bacteria and nematodes to springtails, mites, myriapods, earthworms, moles and worms. Each of these groups has a multitude of species. It is said that: "... in a spoonful of soil there could be more inhabitants than in the entire planet...". It is considered a complex and dynamic living organism that can be regarded as the living layer of the Earth, in a symbiotic condition with plants. This activity is proposed as a game through which we concretely get closer to the living things of the soil and sense those of microscopic condition, ideally establishing a connection that allows us to become aware that the soil is a non-renewable resource that must be treasured to give sustainability to the vital process of all living organisms.

Time

3 hours with a field trip.

Prerequisites: (K-3 - K-8)

None.

School level

Primary.

Purpose

To learn about some forms of soil life that participate in the underground community and their contribution to ecosystem development in an exploratory way.

Student Outcomes

- To identify specimens of living organisms, present in soil.
- To establish differences among specimens based on their physical constitution.
- To infer about their function and participation in the biotope context.



Introduction

Soil organisms act as primary agents for driving nutrient cycling, regulating the dynamics of soil organic matter, soil carbon sequestration and greenhouse gas emissions, modifying soil physical structure and water storage, increasing the amount and availability of nutrients for vegetation and increasing plant health. In addition, these organisms act as decomposers of living things residues for the continuity of the matter cycle in the ecosystem, returning the primary elements to the plants. These services are not only essential for the functioning of natural ecosystems, but also constitute an important resource for the sustainable management of agricultural systems.

Guiding Research Questions

- What physical characteristics do the soil visible inhabitants have?
- How does the earthworm community contribute to the soil ecosystem configuration?

Scientific Concepts

- Entomology, Insects, Microorganisms
- Biodiversity, Ecosystem
- Meteorological factors influencing soils
- Living things
- Symbiont community

Materials and Tools

- Garden tools such as a small shovel and a rake
- Plastic pieces of 50x50 cm
- Measuring tape
- A log book and pencils
- Simple magnifying glasses
- Magnifying glass adaptable to a cell phone for photos

What to Do and How to Do It

Beginning

- In a selected study site disperse your students and ask each one to start excavating to a depth of approximately 30 cm. The excavation material should be placed on plastic, where they should scatter the material and dig for identifiable living things. Anecdotal records of the activity should be kept at all times and the area should be geo-positioned.



Development

- Carefully, have your students capture the living things that they find, observe them with the help of a magnifying glass, ideally take photographs, and do a small sketch of their main characteristics (number of legs, shells, eyes, etc.). Have your students record the number of specimens they have seen and the land characteristics. Afterwards, they need to release the specimens back to the soil.

Closing

- After making the observations and taking the measurements, your students must organize their records and data systematically using tables and/or graphs. Have them make a discussion about the experience and record measurements and inferences.
- As a complement, concurrently make your students begin bibliographic research to find names of the specimens they found as well as any supplementary information. The students need to build a small collective atlas with the references of such specimens, make a presentation of their task for their immediate community and initiate a pluralistic debate on the following question: Is soil a living organism? Why?

Frequently Asked Questions

-Should special sanitary precautions be taken for this activity?

Only the common ones: hand washing, voluntary use of safety gloves, and application of hand sanitizer.

Suggested Resources

- Soil investigation at (www.globe.gov)
- Soil biodiversity textbooks

Bibliography

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Black Soils

GLOBE		<i>Related SDGs:</i>	<i>Type of activity</i>
Sphere	Protocols		
Pedosphere	pH Texture Composition	2 (Zero hunger) 3 (Good Health and well-Being) 6 (Clean Water and Sanitation) 13 (Climate Action) 15 (Life on land)	Research. Data management using descriptive statistics.

Overview:

Black soils are generally fertile and suitable for agriculture, making them an essential resource for food production in Latin America. Argentina, Brazil, Uruguay, Paraguay, and Mexico are some countries with considerable extensions of black soil, which are used to produce various crops such as soybeans, corn, wheat, rice, and other agricultural products. The productive capacity of these soils (like the different types) depends on multiple factors, such as climate, land use, and farming practices, among others, so agricultural production is not usually determined solely by the presence of black soils in a specific region; however, they are a significant contribution to agriculture.

In addition, it is essential to know about black soils, as they can significantly impact global climate change. They are rich in organic carbon, can help retain large amounts of carbon in the ground and reduce greenhouse gas emissions into the atmosphere.

Time:

Two classes

Prerequisites:

None

School Level:

High School (K-10 a K-12).

***Purpose:***

To understand the importance, constitution, and impact of black soils in the Latin American region.

Student Outcomes:

- Characterize black soils, their properties and connotations.
- Determine the land presence in Latin America.
- Estimate the incidence of black soils in the bio-geo-chemical cycle of carbon.

Introduction

Black soils refer to many different types of soils that share the characteristic of having a high percentage of base saturation. These soils are known to be very fertile and are suitable for agriculture. Examples of black soils include Mollisols, Vertisols, and Chernozems. Such soils are characterized by a high organic matter and nutrient content and a higher water-holding capacity. Volcanic ash soils can vary in composition and characteristics depending on the geological and climatic conditions of the region. Some volcanic ash soils can be considered a variety of black soil due to their high organic matter, nutrient content, and water-holding capacity. However, not all volcanic ash soils meet these characteristics, and their classification will depend on their composition and other relevant factors.

In general, black soils differ from other soils in their high organic carbon or humus content; they contain a large amount of organic matter, which gives them that dark color; their fertility is attributable to their high organic matter content, which makes them versatile for growing a wide variety of plants and crops. Moreover, black soils have a unique ability to retain moisture, which allows them to provide an optimal environment for plant growth and also has a characteristic texture that makes them very different from other types of soils; they are soft and easy to work, which makes them ideal for agriculture.

Black soils make an essential contribution to the biogeochemical carbon cycle by helping to store large amounts of carbon in the soil and maintaining a rich organic carbon content. The organic carbon in soils results from decomposition by plants and microorganisms over time. As organic carbon accumulates in black soil, it also increases water and nutrient retention, supporting plant growth and improving agricultural productivity.

The biogeochemical carbon cycle is a fundamental process in which organic and inorganic carbon is exchanged between the atmosphere, oceans, plants, animals, and soils. Once crops or other plants die, the organic carbon they contain is released back into the biogeochemical cycle through bacterial decomposition of plant material. Black soils can significantly impact global climate change, as their richness in organic carbon helps to sequester large amounts of carbon and decrease greenhouse gas emissions to the atmosphere. However, their degradation due to deforestation, intensive agriculture, and other land use changes can release large amounts of carbon into the atmosphere and impact climate change. When black soils degrade, organic carbon is released as carbon dioxide and other gases, contributing to global warming.



Guiding Research Questions

- How can we contribute to the conservation and proliferation of black soils?
- How do we mitigate the "carbon footprint" we produce daily?

Materials and Tools

- Excel-type software for data processing.
- Consumables for notes and final exposition.

Scientific Concepts

- Biogeochemical Carbon Cycle.
- Structure of CO₂ and its connotation as a greenhouse gas.
- "Black soil".
- Basic soil components.
- Decomposing microorganisms.
- Carbon footprint.

What to Do and How to Do It

- **Beginning:**

Organize inquiry groups using a flipped classroom dynamic to collect the necessary data for the activity and its corresponding initial reading. Specific information on black soils, their quantification in Latin American countries, the biogeochemical carbon cycle, and the concept of carbon footprint should be available.

- **Development:**

From the data input, elaborate a ranking of countries with black soils in Latin America, and arrange them in a table with each country's helpful soil data. Establish the percentages of black soils over the grounds and elaborate representative graphs. Determine central tendency statistics (range, average, median, etc.).

- **Closing:**

With the previous data processing results, establish a discussion on the circumstances and the reason for the percentage amounts of black soil, its maintenance, and eventual expansion. Propose improvement measures in a **GLOCAL** approach (local and global measures articulated in an objective). Additionally, establish the links of black soils with the biogeochemical carbon cycle and the production of CO₂ as a greenhouse gas. Determine the use and

calculation of the "Carbon Footprint" and organize a presentation for your immediate community.

Frequently Asked Questions:

- What is the usefulness of knowing and calculating the "Carbon Footprint" to raise awareness of the harmful effects of climate change?
- What could be the ecosystemic effects of an imbalance of the bio-geochemical carbon cycle in the biosphere?

Resources:

GLOBE program soil investigation and work materials (www.globe.gov).

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Burned soils

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	pH Texture Composition	3 (Good Health and well-Being) 4 (Quality education) 8 (Decent work and economic growth) 11 (Sustainable cities and communities) 13 (Climate Action) 15 (Life on land)	Research. Data management using descriptive statistics.

Overview

On several occasions, the soil is subjected to high temperatures, causing significant adverse changes, such as burning, whether for cleaning residues or other purposes, which is a common practice for agricultural soils. However, one of the phenomena with the most significant impact is forest fires, which tend to seriously affect the quality of soils and ecosystems in general, leading to the loss of soil nutrients, a decrease in biodiversity, and soil erosion, among other effects.

In the current planetary climate emergency, it is necessary to know these phenomena and raise awareness about their control and prevention, assuming this process from a "global" perspective (global and local at the same time). Ergo, knowing and analyzing data and reflecting on the scope of these phenomena will help to establish that the prevention and combat of forest fires are an essential part of the welfare and survival of the planet and can contribute to protecting it and contribute to a sustainable life for us and future generations.

Time:

Two classes

School Level:

High School (K-10 - K-12).

Purpose:

Reflect based on an analysis of data on burned soils in Latin American countries.



Student Outcomes

- Estimate the extent and impact of soil burning in the Latin American region.
- Infer the implications of soil burning on society and its basic structures, such as education and environmental preservation.
- Elaborate remedial and improvement proposals based on their analysis of the negative impact of soil burning on nature and society.

Introduction:

The consequences of burning and forest fires on the structure of forest soils can affect water retention, porosity, and soil permeability. Forest fires can also affect soil quality and chemical composition by altering key biogeochemical processes such as mineralization and nitrification. Additionally, edaphic biota are compromised, specifically organisms such as bacteria, fungi, and nematodes, which play an essential role in soil formation and nutrient availability. The study found that forest fires can alter the community of these organisms and suggest that the recovery of edaphic biota is fundamental in rehabilitating the ecosystem. Additionally, mycorrhizae (symbiosis between plant roots and certain fungi) can also be affected by forest fires, which decreases the ability of plants to take up nutrients and absorb water.

The production of this phenomenon of soil burning is primarily anthropogenic. It is, therefore, related to inappropriate practices for preserving soils in a fertile state for producing useful plants for living beings.

Guiding Research Questions

- What comparison(s) can be made between fires occurring in the Brazilian rainforest and the forested areas of Chile, Argentina, and Paraguay?
- How has the quantity of burned hectares varied over the last five years?
- How important is it to develop an international fire-fighting strategy?
- Is it relevant to develop a global attitude in people about caring for environmental assets?

Materials and Tools:

- General and statistical burned soil data in the Americas.
- Spreadsheet software (e.g., Excel, Google Sheets).

Scientific Concepts



- Edaphic biota
- Nematodes
- Bacteria and fungi
- Nitrification.

What and how to do it

- ***Beginning:***

Considering the application of a Flipped Learning class, collect data on soils burned by different forms and causes in South American countries. This can be obtained from scientific journals, government reports, or online databases.

Develop a spreadsheet layout in an orderly spreadsheet for the data collected. Be sure to consider relevant information such as location, extent of the burn, nature, remedial actions, and stated prevention strategies.

- ***Development:***

With the support of descriptive statistics resources, analyze the data to identify any significant findings or patterns in the development of these events, such as the existence of a seasonal seasonality in the occurrence of fire-type phenomena, the causes, and incident factors.

With the data collected, calculate statistics such as the mean, median, standard deviation, and range of the data to support the results and inferences you draw from your analysis. Use tables, bar charts, pie charts, and scatter plots to visually represent the data and identify trends or patterns of interest.

Ideally, articulate the present activity with soil analyses on related topics, using GLOBE protocols, performed in parallel or before the current action.

- ***Closing:***

Prepare a report of the results of your analysis highlighting the relevant points of the expressions reflected in the statisticians in a region that is particularly affected by soil burning. Background reports on the preferred location of burning phenomena state your inferences regarding their causes and contributing factors.

Based on the analysis, develop informed recommendations for preventing soil burning and mitigating its impacts.



Frequently Asked Questions:

- What is the most salient effect in a ground fire?
- What temperatures is the ground subjected to in a fire?
- How do wildfires influence global climate change?

Resources:

GLOBE program soil investigation and work materials (www.globe.gov).

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Qualitative variables to investigate soils

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Pedosphere	Soil characterization	2 (Zero hunger)	Cognitive
	Soil fertility	12 (Responsible production and consumption)	
		15 (Life on land)	

Overview

Research is a process that aims to generate knowledge. It begins with a research question that must be answered based on observations made of reality and becomes quantitative or qualitative data. Through this activity, students will integrate qualitative data to characterize soils.

Time

50 min.

Prerequisites

None.

School level

Primary.

Purpose

Students collect qualitative data to describe soils and infer from them their ability to produce food.

Student outcomes

- Define in your own words what qualitative data is.
- Collect qualitative data on soil.
- Assess the ability of soils to grow food based on qualitative data analysis.

Introduction

To answer a research question, it is essential to contrast the ideas or hypotheses of the researcher with reality, for which it is essential to take field information using a selection of variables (Manterola & Otzen, 2013). These variables are characteristics of the elements we are studying, which can be measured, and which change from one component to another or over time.

Variables can be quantitative or qualitative. This activity will focus on qualitative variables. These variables can express themselves with words. However, sometimes qualitative characteristics can be transformed into numerical variables.

Qualitative variables can be:

- Dichotomous or binary: When they admit two possibilities
- Polytomical: When more than two values can be attributed to a variable. This type of variable can be divided into:
 - Nominal: They do not support a hierarchy or order
 - Ordinals: When they can be sorted according to established rankings

On the other hand, soils can be defined as the natural environment composed of weathered minerals, organic matter, air, and water in which plants grow (FAO, 2022). Therefore, fertility is an essential characteristic of soils. To ensure fertility, soils must maintain an adequate structure that guarantees the amount of air and water for the roots and the necessary nutrient renewal (mediated by microorganisms) to sustain the plants.

Soil fertility can be determined based on three significant variables:

- Physical
- Chemical
- Biological

Among the physical characteristics of fertility can be considered the following:

- Soil texture: Proportion of sand, silt, and clay in the soil. The texture can be classified into three large groups (Figure 1)
- Sandy soils: It feels rough to the touch, characterized by large pores that easily let water pass and accumulate a good amount of air between their pores. The advantage that sandy soils have is a good ventilation capacity. The disadvantage is a poor ability to retain water.
- Loamy soils: The ideal soil for crops is an intermediate texture between sand and clay.
- Clay soils: They are excellent soils when they are slightly wet. Therefore, they can be molded with some ease. They have the disadvantage of retaining a lot of water, being able to drown the plants, and not having good ventilation.

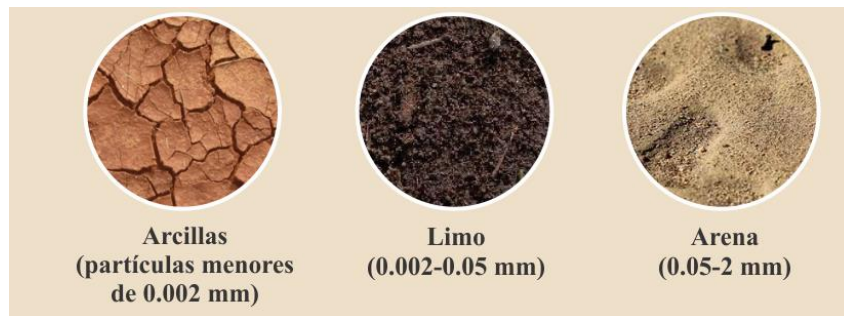


Figure 1: Soil texture
 Source: <https://gensoil.net/>

Among the chemical characteristics of the soil that can be considered:

- Soil pH: The pH results from the composition of the soil; this can be acidic, neutral, or basic. In this regard, some crops grow best in slightly acidic or basic soils.
- Minerals: The most critical minerals in the soil are Nitrogen, Phosphorus, and Potassium. These materials are also known as macronutrients for plants. Nitrogen offers vigor for the growth of plant leaves (its deficiency can be seen in the leaves when they appear yellowish or brown). Phosphorus benefits the root and the development of shoots and seeds (its lack can be noticed in the leaves when they turn a bluish-green color). For its part, potassium strengthens the metabolism of plants and helps generate resistance to pathogens (its deficiency is expressed in plants showing them withered).

Among the biological components of soils can be considered the following:

- Macroinvertebrate animals: Many insects and worms are crucial for fertility. Among these, for example, earthworms provide organic matter through humus and provide ventilation by creating channels in the soil through which air circulates.
- The presence of bacteria that facilitate the recycling of nutrients; many bacteria have an affinity for the roots of plants of the Fabaceae family with which they form a symbiotic relationship.
- The presence of leaves in the soil that is in the process of decomposition, produces.

Guiding Research Questions

- What is qualitative data?
- How is qualitative data taken?
- How can qualitative data help to make decisions?
- What observations can I make to describe soil fertility?

***Scientific concepts***

- Qualitative data
- Soil fertility

Materials and tools

- Writing paper
- Vinegar
- Water
- Stopwatch
- Pencil

What to do and how to do it***Beginning***

- Teachers take students to the field, or, if there are no gardens in the school, bring some pots with plants or ask students to bring some plants into the classroom.
- Once in the gardens or observing the pots, teachers ask students to write everything that catches their attention about the soil and plants in their own words on paper. Students are especially asked to observe the color of the plant's leaves and the color of the soil to see if there are animals in the soil or if there are little animals in the leaves of the plants. It will also be important to observe if the soil is cracked, wet, saturated, or garbage.
- Next, some students share what they have written.

Development

- It is time for more detailed observations. Teachers hand out Table 1, containing the data sheet, and ask students to do some simple experiments to record their observations, marking the correct answer.



Table 1
Soil characteristics

Texture	Water passage	Presence of animals on the ground	Soil color	Presence of leaves in the soil	Presence of carbonates, bubbles with vinegar	Leaf color	Other
Sand	Fast	Yes - Which	Black	Yes	Yes	Green	
Slime	Slow	No	Dark brown	No	No	Yellow	
Clay	Middle		Light brown			Bluish	
			Red			Brown	
			Orange				
			Green				

Closing

- Students analyze the information they have written and with it, they elaborate a news cable to describe the soils.
- The news cable consists of a short and clear paragraph in which students can share their main findings about the soil they analyzed and also be able to infer if they have good soil to cultivate or not based on the observed characteristics.

Frequently asked questions

-Can qualitative data be supplemented with quantitative data?

Of course, the idea is to have as much information as possible to describe soils better.

Suggested Resources

Elementary GLOBE Soils Description: [The Soils - Elementary GLOBE - GLOBE.gov](https://www.globe.gov/elementary-soils-description)

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Soils and climate change

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Atmosphere	Clouds	2 (Zero hunger)	Research
Pedosphere	pH Texture, Fertility	3 (Good Health and Well Being)	
Bundle	Earth as a System	4 (Quality Education) 7 (Affordable and Clean Energy) 9 (Industry, Innovation and Manufacture) 12 (Responsible Consumption and Production)	

Overview

Our planet's atmosphere has always functioned as a greenhouse that retains enough heat from the Sun to promote the biodiversity of the terrestrial ecosystem. This climate control system depends on the concentration of so-called greenhouse gases (GHG), among which stand out: carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). Without these gases, the average temperature on Earth would be about -18°C instead of the current 14.5°C.

Every 100,000 years, the Earth becomes more elliptical (warm or interglacial period) or more circular (cold or glacial period), causing the planet to move closer or farther away from the Sun. Likewise, every 41,000 years, the variation in the tilt of the Earth affects the intensity of the seasons: the steeper the summers, the warmer the summers, and the faster the glaciers melt. Precession – or Milankovitch cycles – are movements around the axis every 20,000 years, which will cause that within 10,000 years, winter in the northern hemisphere not begin in November but in July. Studies of Antarctic ice have shown that significant temperature increases occur in each interglacial era. The last interglacial era in which we live began 11,600 years ago, during the Holocene, and settled due to the instability of solar activity and changes in our planet's orbit, the axis of inclination, and precession movements. During an interglacial era, first of all, there is an increase in temperature, then the level of CO₂ increases, and finally, the sea level.

What varies from the current situation is that the CO₂ level is rising disproportionately concerning the temperature and sea level. Scientists attribute this disturbance to the



increase in greenhouse gas (GHG) emissions due (in part) to spectacular population growth, especially in the last 30 years, and to our increased energy consumption (industrial activities, domestic consumption, and transport). According to the Fourth Assessment Report of the IPCC (Intergovernmental Panel on Climate Change), the earth's average surface temperature has increased by 0.74°C in the last 140 years (1860-2000). A significant increase in CO₂ concentrations has accompanied this increase; about 99% of the Earth's atmosphere consists only of nitrogen and oxygen. Only a fraction of the remaining 1% is made up of gases capable of retaining heat, which is responsible for many consequences of global warming, the greatest historical thermal extremes, or the greater intensity of cyclones or frequency of hurricanes, all of which lead to agricultural damage, fires, migrations, changes in biodiversity and therefore significant imbalances in ecosystems.

According to the IPCC in its Fourth Climate Change Assessment Report (2007), Latin America emitted 2004 11% of all gases in the world considered in the Kyoto Protocol (approximately 5 Tg/year of GHG), including those emitted by land use change. The annual GHG emission per capita is close to 8 tons of CO₂, equivalent to approximately one-third of the average emission of the inhabitant in the United States; It is estimated that in 30 years, the energy consumption of Latin Americans will be similar to that of developed countries.

Time

3 classes.

Prerequisites

- Basic knowledge about climate change and global warming.
- Basic knowledge of Excel or other charting software.

School level

High school (K-10 to K-12).

Purpose

Establish the importance of raising mass awareness about the multicausal effects of climate change, its origins, and its impact on soils and their consequences.

Student outcomes

- Know the root causes of the effect of climate change on soils.
- Recognize global mitigation actions (global and local) on this effect.
- Propose corrective actions based on the knowledge and analysis of the actions already executed.



Introduction

Today, the effects of climate change install a planetary crisis; it is common to inform us in our daily lives to a greater or lesser extent of phenomena such as Cold and heat waves, extreme storms, droughts, floods, fires, pests, desertification, loss of forests, etc. The main risks that are visualized for Central and South America are lack of access to drinking water, serious health effects (due to increased epidemics), degradation of coral reef ecosystems (due to coral bleaching), frequent and extreme droughts that will jeopardize food security, floods, landslides, sea-level rise, storm surges, and coastal erosion that can cause severe damage to lives and livelihoods.

A maximum effect of climate change and global warming is the imbalance of the carbon cycle in ecosystems. This cycle consists of the circulation of carbon between the four natural reserves of this element: the atmosphere, the oceans, the fossil sediments, and the terrestrial biosphere, on which the regulation of the planet's climate depends. A stage of rapid exchange is present in all organic compounds, including soil, where when plants and animals die, they break down and integrate into clay, silt, or sand molecules through processes such as humification, translocation, or mineralization.

The main agents of disturbance of the natural carbon cycle are deforestation and changes in the land; use such as that forest use towards other uses produces 46% of the carbon emitted into the atmosphere in Latin America. These emissions originate from fire combustion, plant biomass, and mulch decomposition removed from forests and losses during carbon mineralization and erosion. Every year in Latin America, more than four million hectares of forests are transformed into new subsistence agricultural areas, pastures, or urban areas.

Climate change will directly affect the soil due to changes in rainfall patterns and increasing evapotranspiration that generates a more extreme climate and more favorable conditions to extend soil degradation, understood as the loss of biological and economic productivity of the land due to the effect of a combination of agents of change (deforestation, deforestation, etc.). agricultural practices, low efficiency in waste treatment) that dramatically affects the soil's physical or biochemical properties (depth, organic carbon, pH, salinity, and fertility). There are different ways in which climate change causes soil degradation: glacier reduction, erosion, soil compaction, landslides, flooding, and mineralization of organic matter, in addition to its eventual desertification.

Other effects to consider are erosion, landslides (soil loss due to water or wind) accentuated by human intervention through deforestation, poor agricultural practices, overgrazing, or direct soil removal by construction. Less topsoil translates into less food, greater poverty, and more stable atmospheric carbon emissions. The most active and severe erosion is generally found at the boundaries of the agricultural frontier, that is, those sites of great fragility where land use has recently been changed.



Guiding research questions

- What is the phenomenon of global warming?
- What are the stages of the carbon cycle and their relationship to soils?
- What are the effects of climate change on soils and its consequences in the future?
- What mitigation measures could be implemented?

Materials and tools

- Documents on the topic
- Calculator/ computer

Scientific concepts

- Climate change
- The greenhouse effect
- Carbon cycle

What to do and how to do it

Beginning

- For this activity, it is suggested to the teacher to occupy a learning strategy type like the flipped classroom (flipped class), where students previously perform a bibliographic search, review a note provided by the teacher or another assignment that constitutes a specific input for the realization of the activity, that they take it prepared to the class and work articulately in groups.
- In this initial stage, it is necessary to establish the stages of the carbon cycle in the biosphere and the greenhouse effect, identifying the major impacts, specifically on soils, and the stage of progress in which this phenomenon is currently located.

Development

- Using the inputs collected in the previous stage, collectively develop a presentation about this topic using mind maps, concept maps, and diagrams.
- Next, we leave the following table from the information recorded in Atlas prepared by international organizations. We invite you to process the information (with the support of available software) using central tendency statistics and graphing to generate inputs to build a presentation.



	COUNTRIES	Number of inhabitants	Surface (Km ²)	Main land uses (%)		
				Agricultural	Forest	Pastures
1	Argentina	40.764.561	2.780.400	12	11	40
2	Belize	317.928	22.965	10	62	2
3	Bolivia	10.088.108	1.098.581	4	53	30
4	Brazil	192.379.287	8.502.728	8	62	23
5	Chile	17.248.450	756.102	2	22	19
6	Colombia	46.581.823	1.141.748	5	53	30
7	Costa Rica	4.301.712	51.100	10	51	25
8	Cuba	11.247.925	109.884	38	28	25
9	Ecuador	14.666.055	256.370	10	41	20
10	El Salvador	6.216.143	21.041	44	14	31
11	Guatemala	15.073.375	108.900	23	35	18
12	Haiti	10.123.787	27.700	15	4	18
13	Honduras	8.215.300	112.492	13	47	16
14	Jamaica	2.709.291	10.991	41	37	12
15	Mexico	114.793.341	1.964.375	14	33	39
16	Nicaragua	6.071.045	130.373	40	38	22
17	Panama	3.571.185	74.177	9	44	21



18	Paraguay	6.568.290	406.752	10	45	43
19	Peru	29.797.694	1.285.216	4	53	13
20	Puerto Rico	3.706.690	9.104	12	61	10
21	Dominican Republic	10.056.181	48.671	26	41	25
22	Suriname	529.419	163.820	1	95	1
23	Uruguay	3.251.526	176.215	25	10	60
24	Venezuela	27.150.095	916.445	4	53	20

- From the data in the table above, determine and plot:
 - How many square meters of land are available per inhabitant in the respective LAC countries?
 - What is the preferred land use and least preferred in the countries?
 - How effective area (km²) does each country allocate to forest use?
- Develop a group analysis on the relationship between land use in Latin American countries and climate change.
- Develop proposals to mitigate this Global phenomenon (local and global).

Closing

- Gather your past findings in an exhibition format to communicate to your community.

Frequently Asked Questions

-What kind of software can be used to carry out the data management of this activity?

The most universal, adequate, and friendly to use is EXCEL; other statistical programs also serve, although they are designed for uses with greater quantity, magnitude, and complexity of data (SPSS, R, etc.).



Resources

- GLOBE soil work and research materials (www.globe.gov)
- Soil education resources are available in school libraries and online

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Agriculture

GLOBE		Related SDGs: (Related only to agricultural production)	Type of Activity
Sphere	Protocols		
Atmosphere	Air and Surface Temperature. Wind Direction and Speed. Precipitation. Relative Humidity.	6 (Clean Water and Sanitation) 7 (Affordable and Clean Energy) 12 (Responsible Consumption and Production) 13 (Climate Action) 14 (Life Below Water) 15 (Life on Land)	Exploratory
Biosphere	Land Cover. Biometry. Phenology		
Pedosphere	Soil Characterization. Fertility. Humidity. pH. Temperature		
Hydrosphere	Water Temperature. pH. Alkalinity. Electrical Conductivity. Transparency. Salinity. Nitrates.		
Bundle	Agriculture ENSO Rivers and Lakes Water Cycle. Water Quality Soils Meteorology		

Overview

Information derived from satellite images and maps is analyzed to determine the areas and status of the most productive crops, environmental conditions, disaster risks (droughts, fires, floods, etc.) and the impact of agriculture on land cover changes in recent decades. In addition, crops, harvests and the environmental conditions that allow the development of corn, rice, wheat, soybean and sunflower are analyzed.

Time

4 or 5 classes

Prerequisites

Basic knowledge of ecosystems, meteorology and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School level

Upper Elementary, High-School and University students



Purpose

To understand the interrelationship among the spheres of the Earth System in agricultural production, the impacts of the expansion of its borders and the challenge of feeding a growing world population.

Student Outcomes

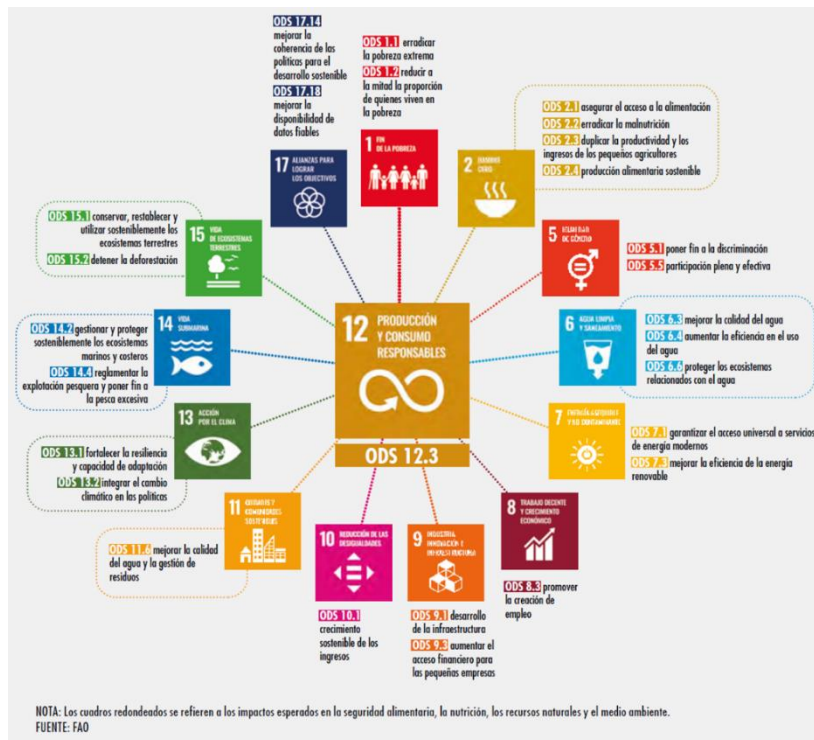
- To understand the impact of agricultural expansion on natural ecosystems and resource consumption.
- To analyze the production of some crops and the environmental conditions for their development.
- To know the distribution of crops according to temperature and precipitation patterns.
- To evaluate the information provided by satellites to know the environmental variables that influence crop growth and the information management systems available to producers.
- To assess the natural disasters that are affecting crops in different parts of Latin America and the Caribbean.
- To analyze the possibilities of sustainable agriculture for different types of crops and regions.

Introduction

FAO's report "*The Future of Food and Agriculture: Alternative Pathways to 2050*" points to the need to build more resilient agrifood systems to ensure food availability for all. Among the multiple variables that affect food production, FAO considers income growth and distribution, population growth, technological advances and climate change as key factors. Achieving environmental sustainability is a challenge that implies a global commitment from the governments of different countries, international organizations, civil society, the private sector, and academic and research institutions, among others.

Agriculture began in the Neolithic period, allowing the change from nomadism to sedentary life for long periods of time. Later it allowed the formation of cities. Before the industrial revolution, agriculture was the main source of income in most parts of the world. Today, agriculture continues to support much of the world's population. Agriculture is essential to human life because it provides us with the food we eat (cereals, fruits, vegetables, etc.) and also produces pastures that are feed for livestock. This food production takes place on both small and large scales. Agricultural production is part of SDG 12 and is closely related to the other 16 SDGs (Fig. 1).

Given the importance of agriculture in feeding people and the devastation caused by the World Wars, the need to establish agreements among countries became evident. For this reason, in 1945, the [FAO](#) (Food and Agriculture Organization of the United Nations) was founded, composed of 44 nations at that time that pledged to fight against hunger; currently, almost all of the countries in the world are part of the FAO.



Relationship between SDG 12 "Responsible Consumption and Production" and the other 16 SDGs.

Agriculture is very diverse [around the world](#). Climate conditions determine the type of agriculture that can be developed in a given place, the crops, the scale, the level of mechanization, or the cultivation of pastures to provide feed for the livestock we then consume, etc.

Table 1. Links to maps and crop data:

Grains	Oilseeds	Cotton
Barley https://bit.ly/3EVYDxi	Palm oil https://bit.ly/3VC6whD	Cotton https://bit.ly/3TkMTJo
Corn https://bit.ly/3N0hOZb	Peanuts https://bit.ly/3schJYs	
Millet https://bit.ly/3zihOOz	Rapeseed https://bit.ly/3VFSRpw	
Rice https://bit.ly/3TxzYDq	Soybeans https://bit.ly/3VFTnns	
Sorghum https://bit.ly/3EVodTa	Sunflower https://bit.ly/3MNtKgo	
Wheat https://bit.ly/3CL7sYo		



Fig. 2. Relevance of agriculture in food and main crops

The 1960s saw the beginning of the Green Revolution, which significantly increased production by increasing yields through the incorporation of new cultivation practices, irrigation, fertilizers, pesticides and mechanization. In order to continue responding to the growing demand for food, agriculture began to [expand its frontiers](#), generating a significant change in land cover, water consumption and other natural resources.



Fig. 3. Different agricultural cropping patterns. [Brazil](#), [Bolivia](#), [Argentina](#), [Uruguay](#).

Although agriculture has generated benefits for humanity, it has also had negative consequences such as soil degradation, salinization of irrigated areas, reduction of



aquifers due to excessive groundwater pumping, pest resistance, [forest loss](#) due to agriculture reconversion, biodiversity loss, etc. According to the IPCC and WWF, agriculture is one of the main human activities that release greenhouse gasses. Moreover, agriculture accounts for 40% of the land we occupy and uses most of the water we consume. [Water availability](#) is essential for agricultural production, it is also vital for natural ecosystems (forests, lakes, wetlands, etc.), but freshwater reserves are diminishing at an alarming rate. Some crops, such as legumes, for example, have a small water footprint (to produce 1 kg of lentils we only need 1,250 liters of water) while other foods require much more. To produce 1 kg of beef requires approximately 13,000 liters of water. The El Niño and La Niña phenomena impact water availability with different severity depending on the region; for example, in the [Central American Dry Corridor](#), the El Niño phenomenon causes severe droughts.

As a result of climate change, scientists predict water shortages due to rising temperatures worldwide. [Droughts](#) will become more frequent and severe, affecting [agricultural production](#), and rising temperatures will increase the demand for water. Agriculture today faces the challenges of feeding a growing population, providing income for farmers and protecting the environment. But at the same time, agriculture can contribute to sustainability. [Agriculture can be transformed](#) by incorporating good practices and appropriate technologies. [Risk management for crisis](#) such as droughts, floods and pests are essential contributions to help mitigate negative effects and adapt to change. For example, satellite images can detect water stress, provide information on [precipitation](#), temperatures, radiation, vegetation condition, soil moisture, etc., and help farmers make daily crop management decisions such as when and how much to irrigate or what soil treatments to use. FAO produces [Earth observation maps](#) using satellite data and makes them available to farmers. Field monitoring supplements satellite information and helps to understand interactions in agroecosystems to design mitigation measures to prevent negative impacts.

Guiding Research Questions

- What has been the impact of the expansion of the agricultural frontier on natural ecosystems in recent decades?
- How does the production of different crops vary according to temperature, precipitation and water availability patterns?
- How is climate change impacting agriculture?
- How can agricultural production be monitored?
- How does NDVI vary in crops throughout their development?
- How does water and soil quality influence crop development?
- Are there differences in the color of soil in agricultural fields compared to soil in nearby areas, e.g., cities, parks, etc.?
- How does soil moisture change in the different seasons of the year? Is irrigated farming done in your area?
- What crops are grown in your area (are they monocultures or polycultures)?

Scientific Concepts

- Crops
- Ecosystems
- Deforestation



- Land Cover
- Electromagnetic Spectrum
- Satellite Images - Spectral Bands - NDVI Index

Materials and Tools

1. ArcGIS StoryMaps <https://storymaps.arcgis.com>
2. Copernicus Global Land Cover (Land Cover - [2015 to 2019](#))
3. Map of [croplands](#)
4. Map of tree cover loss by dominant driver: [2001-2019](#)
5. Satellite information on crops:
 - a. Case 1. [Corn](#)
 - b. Case 2. [Rice](#)
 - c. Case 3. [Wheat](#)
 - d. Case 4. [Soybeans](#)
 - e. Case 5. [Sunflower](#)

Supplementary information to analyze each crop:

1. Summary map of [current crop conditions](#) in the world
2. FAO Earth Observation Map ([Global Seasonal Indicators](#): stress, drought, vegetation, precipitation)
3. Global Agricultural and Disaster Assessment System Map [GADAS](#)
4. Crop information [NASA Harvest](#)

What and how to do it

– Beginning

Show your students the [Land Cover](#), [Cropland](#) and [Tree Cover Loss](#) maps.

Note the types of land cover near croplands that could be replaced if the agricultural frontier is expanded. Make a list of the types of ecosystems that could be affected.

Watch the FAO videos ([institutional](#) and [sustainable agricultural video](#)) and analyze FAO's role in agriculture.

Ask your students to develop hypotheses about the challenge agriculture faces in feeding a growing world population in the coming decades.

– Development

1. Ask your students to read the introduction to this activity and make a concept map with the information.
2. Divide the class into groups and assign one type of crop to each group to analyze.
 - a. Look at the global crop map and locate the regions with the highest production in Latin America and the Caribbean.
 - b. Compare the areas of lower production with the map of [tree cover loss](#). Has this crop contributed to deforestation anywhere in Latin America and the Caribbean?
 - c. What are the [current conditions of this crop](#) in the region?



- d. Considering the major production areas and peripheral areas, analyze the following:
 - i. Consult the [seasonal indicators](#) and determine if there were negative impacts of drought, stress, etc. on the analyzed crop in the last year. (If you wish, you can compare this with previous years).
 - ii. Consult the [GADAS](#) Map to check if disasters affecting crops (hurricane, floods, fires, etc.) have occurred anywhere.
 - iii. Consult the [NASA HARVEST](#) crop map, search for the countries with the highest production and select a district. Check the evolution of the main variables affecting crops: NDVI (vegetation condition), precipitation, temperatures, evapotranspiration and soil moisture. Compare with other nearby and distant areas (only the countries and zones with the highest production are available). Are there any differences? What is the seasonal variation?
3. Ask your students to develop a presentation on the case study. They can make a story with maps (using ArcGIS StoryMaps), or a presentation with slides.
4. Bring all the groups together and ask them to explain the cases they analyzed and compare the similarities among such cases (e.g. overlapping crop areas).
5. Have your students complete the concept map with the examples of the crops they analyzed.
6. If there are nearby crops in your area, you can use the same tools to analyze their condition and production in recent years. You can also complement this with field measurements.

– **Closing**

Due to the relevance of this problem, it is important to develop outreach information materials. Students can create a story with maps ([Story Map](#)), a video, or flyers to post on social networks summarizing the analyzed cases.

Frequently Asked Questions

Where can I find crop information? - FAO -USDA/IPAD - NASA HARVEST - GADAS

Where can I find satellite images? - Worldview - EO Browser - Google Earth - Google Map

Where do I find information on forest cover loss? GFW has information on primary forest cover loss and gain.

Where can I look up fires? - NASA Firms - GFW Fires - Worldview

Suggested Resources for Further Information

As an extension of this activity, students can analyze other crops and different regions, etc. Considering climate change, they can analyze [precipitation](#) patterns to detect changes, the same with forecasts on the [impact on crops](#) and the [incidence of the ENSO](#)



[phenomenon](#) (El Niño and Southern Oscillation) on agricultural production in different regions.

Videos:

FAO. FAO Corporate Video <https://youtu.be/Ub6N8aWThw4?si=mqh9Sh-ZNUarMBGM>

FAO. Sustainable and resilient agriculture to climate change. https://youtu.be/sPpwu6a_qdl

NASA Goddard: Climate Change Could Affect Global Agriculture Within 10 Years <https://youtu.be/-NZlvvhGIR0>

NASA Goddard: NASA Remasters Nearly 20 Years of Global Rain <https://youtu.be/qNIRQgACTFg>

NASA Goddard: NASA Satellites Help Farmers in Central America's Dry Corridor. <https://youtu.be/WH-tzUVk9eE>

Other Resources:

Crop Explorer - Crop Explorer <https://ipad.fas.usda.gov/cropexplorer/>

Data and maps of environmental and crop conditions by country and agricultural production districts - NASA HARVEST - Earth data for informed agricultural decisions. <https://cropmonitor.org/tools/agmet/>

FAO Land Observation Map (Environmental Conditions and Crops: Global and by country) - <https://www.fao.org/giews/earthobservation/index.jsp?lang=es>

Map Global Agricultural & Disaster Assessment System - Global Agricultural & Disaster Assessment System (GADAS) <https://geo.fas.usda.gov/GADAS/>

Cropland Map - Global Cropland Extent 2015 <https://on.doi.gov/3Sc5KF7>

Global expansion of cropland in the 21st century - Global Land Analysis & Discovery (GLAD) (2000 to 2019) <https://bit.ly/3eKcooe>

Map of tree cover loss by dominant driver: 2001-2019 (Commodities: beef, soybeans, palm oil, corn and cotton, shifting agriculture, afforestation, fire, urbanization) <https://bit.ly/3Mlfxl7>

Tutorials of: [Worldview](#), [EO Browser](#), [Story Map](#)

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NASA Earth Observatory (2009) *Drought in Southern South America*. <https://go.nasa.gov/3TwH6k5>

NASA Earth Observatory (2009) *Flooding in Brazil, Argentina, and Uruguay*. <https://go.nasa.gov/3CQB3PZ>

NASA Earth Observatory (2016) *Argentina's Changing Chaco Forest*. <https://go.nasa.gov/3MK6sIB>

NASA Earth Observatory (2019) *Human Activities Are Drying Out the Amazon*. <https://go.nasa.gov/3EUmZrr>

NASA Earth Observatory (2019) *Lake Aculeo Dries Up*. <https://go.nasa.gov/3DcMgfa>

NASA Earth Observatory (2019) *Long-Term Drought Patches Chile*. <https://go.nasa.gov/3CQxliM>

NASA Earth Observatory (2020) *A Strained Water System in Chile*. <https://go.nasa.gov/3eMZKVA> In Spanish: [Un sistema de aguas sobrecargado en Chile](https://ciencia.nasa.gov/un-sistema-de-aguas-sobrecargado-en-chile)

NASA Earth Observatory (2020) *Measuring Drought in South America*. <https://go.nasa.gov/3VGywAB> In Spanish: [Mediando la sequía en Sudamérica](https://go.nasa.gov/3yXnkpm)

NASA Earth Observatory (2020) *The Parched Paraná River*. <https://go.nasa.gov/3MVPS8z>

NASA Earth Observatory (2020) *The Spread of Soy in South America*. <https://go.nasa.gov/3Sbgwv3> In Spanish: [La expansión de la soja en América del Sur](https://ciencia.nasa.gov/expansion-de-soja-en-america-del-sur)



NASA Earth Observatory (2021) *Brazil Battered by Drought.*
<https://go.nasa.gov/3VFPuim>

NASA Earth Observatory (2021) *Sizing Up How Agriculture Connects to Deforestation.*
<https://go.nasa.gov/3EX3Chw> - In English: *Evaluating the Relationship Between Agriculture and Deforestation* <https://ciencia.nasa.gov/relacion-agricultura-deforestacion>

NASA Earth Observatory (2021) *Widespread Drought in Mexico.*
<https://go.nasa.gov/3eJdKQ3>

NASA Earth Observatory (2022) *A Reservoir Runs Dry.* <https://go.nasa.gov/3F3Zn3P> In English: *A reservoir in Mexico runs dry.* <https://go.nasa.gov/3CNZoGk>

NASA Earth Observatory (2022) *Global Croplands Expand.*
<https://go.nasa.gov/3EW0MJB>

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<https://www.globe.gov/es/web/earth-systems/>

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<https://labs.waterdata.usgs.gov/visualizations/water-cycle/index.html#/>



Cities in Latin America and The Caribbean

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Atmosphere	Air and Surface Temperature. Wind Direction and Speed. Precipitation. Relative Humidity	6 (Clean Water and Sanitation) 11 (Sustainable Cities and Communities) 12 (Responsible Consumption and Production) 13 (Climate Action) 14 (Life Below Water) 15 (Life on Land)	Exploratory
Biosphere	Land Cover. Biometry. Phenology		
Pedosphere	Soil Characterization. Fertility. Humidity. pH. Temperature		
Hydrosphere (if there are bodies of water in the city)	Water Temperature. pH. Alkalinity. Electrical Conductivity. Transparency. Salinity. Nitrates.		
Bundle	Urban. Mosquito. Air quality. Meteorology Water Cycle. Water Quality		

Overview

Urban growth is analyzed through Landsat and Sentinel 2 satellite images of large and small cities. Image series are compared to detect changes in the last decades. Natural color and false color images of green areas at night are used to learn about different aspects of each city. Satellite images of the Earth at night are used to know the distribution of cities, detect changes in brightness due to events, and analyze human activities that generate nighttime light, such as fishing or fossil fuel extraction.

Time

4 or 5 classes

Prerequisites

Basic knowledge of ecosystems, meteorology and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School level

Upper Elementary, High School and University students



Purpose

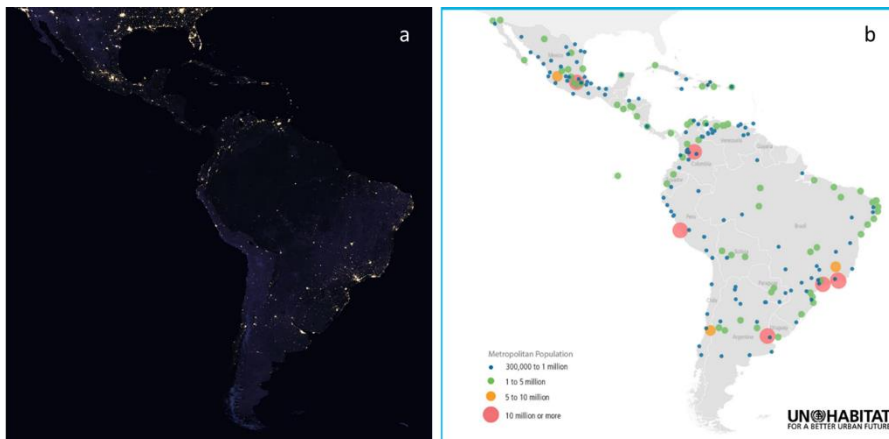
To understand the impact of cities on the interrelationships of the Earth’s system spheres.

Student Outcomes

- To identify the main types of land cover in satellite images of cities
- To analyze changes in urban cover in recent decades through satellite images
- To analyze the environmental impact of cities, urban growth and human activities through satellite images
- To recognize the importance of nighttime satellite images to study phenomena that affect cities (hurricanes, volcanic eruptions, forest fires) and human activities (fishing, fossil fuel extraction, etc.)

Introduction

According to UN-Habitat, in 2020 there were 1934 cities with more than 300,000 inhabitants, representing 60% of the world's urban population. In Latin America and the Caribbean there are 215 metropolises, 6 of which have more than 10 million inhabitants (Fig. 1). On a global scale there is a trend towards urbanization; therefore, most cities will continue to expand in their periphery or will become denser with a greater number of taller and taller buildings, and new cities will also emerge. This is why the UN points out that sustainable development increasingly depends on the successful management of urban growth. The Sustainable Development Goals (SDGs) have considered cities in [SDG 11 "Sustainable Cities and Communities"](#). This goal seeks to make cities and human settlements inclusive, safe, resilient and sustainable. The importance of sustainable development in urban areas can be seen in the relationship between SDG 11 and the other 16 SDGs.



Fuente: Worldview. Black Marble (Annual, 2012 & 2016)
<https://go.nasa.gov/3MCKHKs>

Source: UN-Habitat. <https://bit.ly/3Ht19MD>

Fig. 1. Cities of Latin America and the Caribbean. a) Cities at night. b) Metropolis in 2020.

Greater job opportunities and prosperity, education and other factors attract people to cities. Urban growth puts pressure on surrounding natural ecosystems. In many cases, areas rich in biodiversity are lost, deforestation has accelerated, negative impacts are produced in watersheds by channeling rivers or altering their course, by changes in water flow, pollutants, erosion, etc. Cities also make impacts at great distances, for example, when dams are built to supply drinking water or hydroelectric power. Cities are heat islands, they are always a few degrees warmer than the periphery, they have few trees



and less vegetation, their soil is generally impermeable and prevents rainwater infiltration, causing an increase in runoff (and in some cases causing floods).

Cities are also sources of [air pollution](#), mainly carbon dioxide, nitrogen oxides, tropospheric ozone, among others. Cities produce a large amount of waste of various origins: domestic, industrial, sanitary, commercial and urban (produced in public spaces). The health of residents is often affected by these impacts.



Fuente: NASA Earth Observatory <https://go.nasa.gov/3CKOQiw>

Fig. 2. Growth of the city of Cancun from 1985 to 2019.

Urban growth can be due to many factors. Some cities have been large for a long time, such as [Sao Paulo](#), Mexico, Buenos Aires, Rio de Janeiro, Bogota, Lima, Santiago de Chile and have continued to grow, while other relatively small cities have grown rapidly in recent decades, such as [Cancun](#) due to the boom in tourism, [Santa Cruz de la Sierra](#) due to agriculture (especially soy, sugar cane and rice), oil and natural gas extraction, as well as industries (oil, dairy and meat products and oil refineries). In other cases, the relief has limited growth, as in the case of [Quito](#), which extends along a valley. However, not all cities grow, some have remained small or have grown little, like [Mal Abrigo](#) in Uruguay or [Miramar de Ansenuza](#) in Argentina, other cities have disappeared, as in the case of [Villa Alicura](#), which was intended only for the construction of a reservoir.

As night falls, cities are illuminated with artificial lights, and as NOAA scientist Chris Elvidge says, "Nothing tells us more about the spread of humans across the Earth than city lights" [Satellite-detected nighttime lights](#) provide a new source of data that helps us better understand the interactions between human systems and the environment. For example, [large cities](#) glow, and illuminated coastlines allow us to map them. Sometimes city lights form strange patterns like the [cities that were created along the railroad tracks](#) every 30 or 40 km in central Argentina. The lines of lights correspond to [illuminated roads](#). Sometimes [cities intensify their illumination](#) for festivities such as New Year or others. Some sites remain [dark](#) to avoid light pollution in order to prioritize the observation of the sky, e.g. in the Atacama region of Chile, where large telescopes are located.

Images of the Earth at night help to better understand some events that impact cities such as the path of [Hurricane Grace](#) approaching Mexico, or the impact on the [power grid](#) of Hurricane Maria in Puerto Rico. [Forest fires](#) and [volcanic eruptions](#) also light up the sky and are possible to detect at night. Some human activities related to consumption in cities are visible at night, such as [oil extraction](#), or [squid fishing boats](#) that look like cities in the ocean.

To better understand the urban environment, in addition to satellite monitoring, field measurements of existing vegetation, tree height and their impact on air and surface temperature help to understand interactions and prevent impacts.

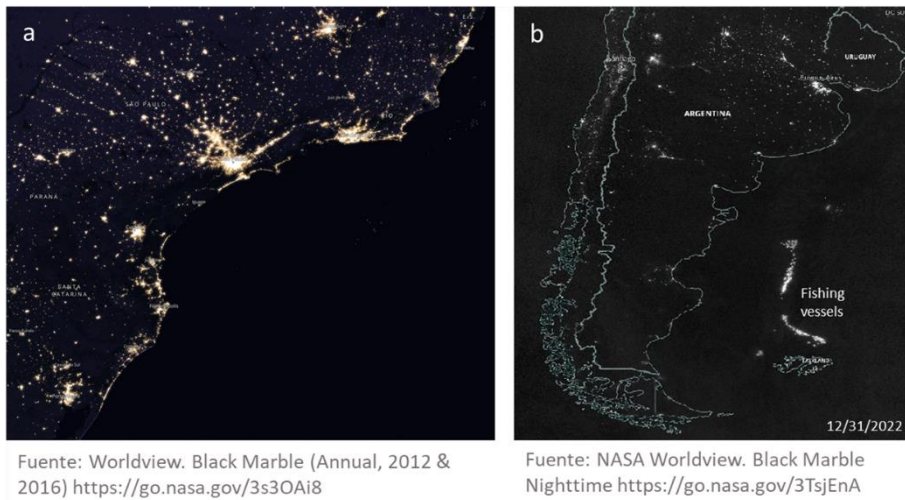


Fig. 3. Lights during the night. a) Illuminated cities and coasts in Brazil. b) Squid fishing in the Atlantic Ocean.

Guiding Research Questions

- How do seasonal changes occur in your city?
- What percentage of green areas does your city have?
- Where does the water you use every day in your city come from? Is there more than one water source?
- Where and how is the electricity, you consume every day in your city generated?
- How has the land cover in your city changed in the short and long term? Has your city remained stable, grown or decreased in population? - Compare your city's growth with other cities in Latin America and the Caribbean.
- Is your city a heat island? Are there differences in surface and air temperature? Are there differences in the surface temperature of different materials? What differences do you observe between the center and the periphery of the city?
- What is the air quality like in your city? Have pollutants ever come in from other places, e.g. smoke from forest fires, gasses from industrial areas in nearby cities?
- How does your city look at night? Do the lights extend beyond the city, e.g. on roads, parks, etc.?
- How is the intensity of noise and lighting in different places in your city?

Scientific Concepts

- Cities
- Land Cover
- Ecosystems
- Deforestation
- Crops
- Hydrology
- Fishing
- Hydrocarbon Extraction
- Electromagnetic Spectrum
- Satellite Images - Spectral Bands



Materials and Tools

1. ArcGIS StoryMaps <https://storymaps.arcgis.com>
2. Satellite images of:

Growth of cities:

Case 1: São Paulo, Brazil

- Google Map - [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- Wordview ([comparison](#) 1985 and 2022)
- Wordview night lights [07/16/2022](#)
- EO Browser - [Natural Color](#) - [False Color](#) - [Green Areas in the City](#)

Case 2: Quito, Ecuador

- Google Map - [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- Wordview ([comparison](#) 1985 and 2022)
- Wordview night lights [10/10/22](#)
- EO Browser - [Natural Color](#) - [False Color](#) - [Green Areas in the City](#)

Case 3: Santa Cruz de la Sierra, Bolivia

- Google Map - [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- Wordview ([comparison](#) 1985 and 2022)
- Wordview night lights [06/20/22](#)
- EO Browser - [Natural Color](#) - [False Color](#) - [Green areas in the city](#)

Case 4: Cancun, Mexico:

- Google Map - [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- Wordview ([comparison](#) 1985 and 2022)
- Wordview night lights [01/14/22](#)
- EO Browser - [Natural Color](#) - [False Color](#) - [Green areas in the city](#)



Case 5: Mal Abrigo, San José, Uruguay:

- Google Map - [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- Wordview ([comparison](#) 1985 and 2022)
- Wordview night lights [06/18/22](#)
- EO Browser - [Natural Color](#) – [False Color](#) - [Green areas in the city](#)

Case 6: Miramar de Ansenuza, Argentina:

- Google Map - [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- Wordview (1991 and 2022 [comparison](#))
- Wordview night lights [05/19/22](#)
- EO Browser - [Natural Color](#) – [False Color](#) - [Green areas in the city](#)

Case 7: Villa Alicura, Argentina (town with no inhabitants):

- Google Map - [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- Wordview ([comparison](#) 1985 and 2022)
- Wordview night lights [10/10/22](#)
- EO Browser - [Natural Color](#) – [False Color](#) - [Green areas in the city](#)

Earth at night:

Case 1: Human footprint in night lights - cities:

- Patterns of roads and cities. [Cities that were created from the installation of railroad tracks.](#)
- [Illuminated roads.](#) A section of National Route 7 in Argentina. [Location](#) (use Street View to see the illumination).
- Increased light intensity in cities for New Year's festivities. [Santiago de Chile and Mendoza](#), [Montevideo](#), [Asunción](#), [San Juan](#).
- [Dark areas.](#) Telescopes in the Atacama Desert, Chile.

Case 2: Human footprint in nighttime lights - human events and activities:

- [City lights and hurricane trajectory.](#) Trajectory of [Hurricane Grace](#).
- [Damage to power service](#) caused by [Hurricane Maria](#) in Puerto Rico.
- [Forest fire lights.](#) Comparison with heat and smoke sources.
- Eruption of [Wolf volcano](#) in Ecuador, at night.
- [Fishing area](#) lights. Compare the period of [fishing vessel activity](#) in Global Fishing Watch. Check Marine Traffic for [current marine](#) traffic in this region (not all vessels are fishing vessels).



- Lights of [oil extraction activity](#). On full moon nights the images are [clearer](#).
Google Map - [Location](#)

What and how to do it

Beginning

Show your students the map of the [Earth at night](#) and compare the impact of the light of different sites in Latin America and the Caribbean.

Activate the [Place Labels](#) layer and ask your students to write down the cities that have the highest illumination (zooming in you will find the city names).

Compare the list of very brightly lit cities with the most populated cities in 2020. [UN-Habitat brochure p. 15 and 16.](#)

Ask students to develop hypotheses about the environmental impacts of large cities.

Development

1. Ask students to read the introduction to this activity and make a concept map with the information.
2. Divide the class into groups and assign one case to each group to analyze.
 - a. Look at the current satellite image on Google Map. What do you see in that image (cities, forest, plantations, roads, rivers, lakes, etc.)? What type of land cover do they correspond to (Urban, Suburban, Roads, Forest, Grassland, Crops, Bare Soil, Water, etc)?
 - b. Open the Google Earth sequence and observe the changes in each year. Record the main changes.
 - c. Compare satellite images (old and current). Record the observed changes.
 - d. View current Sentinel images in natural color, false color and green areas.
 - i. Observe water sources (rivers, lakes, reservoirs, etc.) in or near the city. Do these water sources have their banks protected with vegetation along their entire course or only in some places?
 - ii. Use the ruler (from the menu on the right) and draw the approximate city outline to know the area it covers.
 - iii. Repeat the same procedure with the green areas (squares, parks, etc.) and calculate the percentage with respect to the city area.
 - iv. Note the color changes in the urban cover (best visualized in the false color image) Which city areas do you estimate to have the highest density of buildings?
3. Ask your students to develop a presentation on the case study. They can make a story with maps (using ArcGIS StoryMaps), or a presentation with slides.
4. Bring all the groups together and ask them to explain the cases they analyzed and compare the similarities and differences among such cases.
5. Complete the concept map with the examples they analyzed in each case.
6. With the whole group carry out a quick analysis of the night lights:
 - . Case 1 - Cities
 - a. Case 2 - Human events and activities.



7. Ask your students to return to their groups to analyze the night lights of the city they studied earlier in each case:
 - . Compare the lights in the city you analyzed with the surrounding cities. Do you observe any differences in light size and intensity?
 - a. Do you observe other lights that do not correspond to cities, e.g. fishing vessels, oil extraction, fires, etc.?
 - b. Change the date in the lower menu to observe changes in illumination intensity, cloud cover or other events.
8. Bring your students back together and ask them to explain the cases they analyzed. Then compare with each other to analyze similarities and differences.

Closing

Due to the relevance of this problem, it is important to develop outreach information materials. Students can make a story with maps ([Story Map](#)), a video, or flyers to post on social networks summarizing the cases they analyzed and highlighting the impact of cities on the environment.

Frequently Asked Questions

Where can I find satellite images? - Worldview - EO Browser - Google Earth - Google Map

Where can I find information on city growth? UN-Habitat

Suggested Resources for Further Information

As an extension of this activity, students can consult satellite images from different dates and locations, or explore the same in their own city or other sites of interest to them. Worldview and Google Earth store imagery from the 1980s. They can supplement this by taking measurements on the ground with GLOBE Program protocols and use apps such as [Physics Toolbox Suite](#), [Phyphox](#) or similar to measure noise in cities (decibels), and if the phones have a light sensor, they can measure the intensity of light, especially at night.

Other Resources:

ArcGIS StoryMaps <https://storymaps.arcgis.com/>

WorldView - Earth at Night <https://go.nasa.gov/3gf90SM>

Global Fishing Watch <https://bit.ly/3S9sq1k>

Marine Traffic <https://bit.ly/3MAc6wN>

Tutorials of: [Worldview](#), [EO Browser](#), [Story Map](#)

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Remote sensing – Cities and agriculture

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Atmosphere	Air temperature. Surface temperature. Wind direction and speed. Rainfall. Relative humidity	11 (Sustainable cities and communities) 13 (Climate action) 15 (Life on land)	Exploratory
Biosphere	Land cover. Biometrics. Phenology		
Pedosphere	Soil characterization. Fertility. Humidity. pH. Temperature		
Package	Agriculture ENSO Soils Towns Meteorology		

Overview

The basic concepts of remote sensing are explained to analyze cities and crops with satellite images. Satellite images processed with a combination of bands and indices are used. In addition, students can try different combinations of bands and apply other specific indices to highlight some features.

Time

4 or 5 lessons

Prerequisites

Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School level

High school and college students



Purpose

Understand the application of wave properties, use satellite sensors and satellite images to obtain information from the Earth and process it to observe changes, trends, and interrelationships between the biosphere, atmosphere, hydrosphere, and pedosphere.

Student outcomes

- Know the types of electromagnetic waves satellite sensors use to obtain information from the Earth system.
- Identify changes and trends in satellite imagery.
- Apply combinations of the bands assigning the colors Red (R), Green (G), and Blue (B) to identify specific features in the field.
- Apply specific indexes to analyze information from satellite images.
- Analyze changes in land cover due to the growth of cities and crops.
- Analyze seasonal changes in cities and crops.

Introduction

Remote Sensing

Remote sensing is acquiring information from a distance using remote sensors. For example, a camera is a sensor that allows us to obtain information about an object from space (when we take a photograph), and our eyes are sensors that enable us to get information about our surroundings when we look at something. To study the Earth, sensors placed on [satellites](#), the international space station, airplanes, drones, balloons, and others are used to detect and record reflected or emitted energy—fig. 1.



Fig. 1. Different types of remote sensors that obtain information from the Earth. Source: <https://svs.gsfc.nasa.gov/30892>

Remote sensors provide a global perspective and a large amount of atmospheric, hydrosphere, pedosphere, and biosphere data that allow us to know the current state, study trends with historical information (e.g., [20-year record of rain and snow](#)), and use them for data-driven decision making. NASA has its [fleet of satellites orbiting the Earth](#), and some satellites operate in consortium with other countries (several of them belong to the [Latin American and Caribbean](#) region). An example of this is the [International](#)



Afternoon Constellation, formed by a coordinated group of satellites from different countries that travel in a synchronized orbit with the sun, passing at approximately 13:30 local solar time, with a difference of seconds to minutes between them (for this reason it is called the Afternoon Constellation). This constellation of satellites performs near-simultaneous observations with a wide variety of sensors that are of great utility for conducting research, issuing warnings, making decisions, etc. Fig. 2.

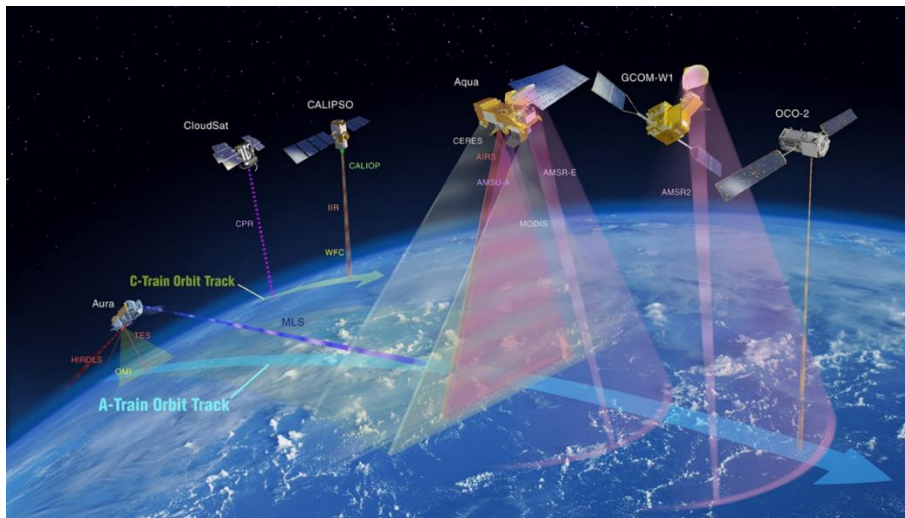


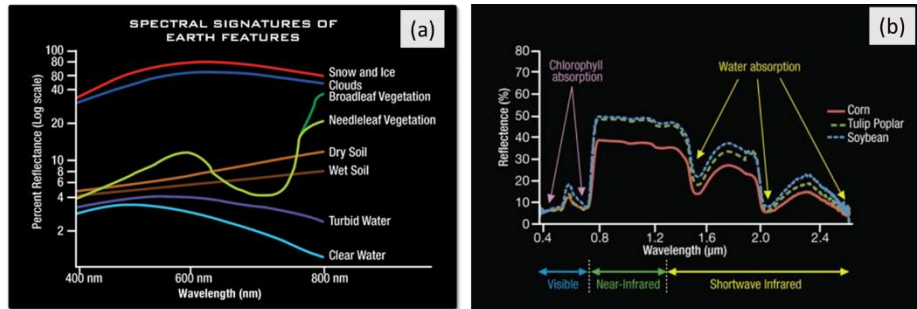
Fig. 2. International Afternoon Constellation. Source: <https://atrain.nasa.gov/>

Some sensors are passive, i.e., they detect electromagnetic waves reflected from the earth's surface when illuminated by the sun or when it emits light (e.g., city lights at night). Most passive sensors operate in the electromagnetic spectrum's visible, infrared, and microwave portions. Passive sensors measure land and sea surface temperature, vegetation properties, cloud properties, aerosols, and soil moisture. However, they have limitations because they cannot penetrate the dense cloud cover that regularly covers the tropics. Active sensors emit waves that bounce off the Earth's surface and return. Most operate in the microwave band of the electromagnetic spectrum, allowing them to penetrate the atmosphere (e.g., radar). These sensors measure aerosol vertical profiles, forest structure, precipitation and winds, sea surface topography, and ice.

The Sun is the primary source of energy observed by satellites. Different types of surfaces reflect different amounts of solar energy. The albedo is the property of anybody to reflect incident radiation. For example, snow is a light surface and has a high albedo (it reflects up to 90% of incoming solar radiation). The ocean is dark, with low albedo (it reflects only about 6% of incoming solar radiation and absorbs the rest). When energy is absorbed, it is re-emitted, usually at longer wavelengths. In the case of the ocean, the absorbed energy is re-emitted as infrared radiation. The amount of energy surfaces reflects, sponge, or transmit varies with wavelength.

Spectral bands and signatures

As the reflected energy goes according to the surface type, it can be used to identify different characteristics of the Earth; it works just like our fingerprints and is called a spectral signature. Thanks to the spectral signature, it is possible to identify different types of rocks and minerals, clear and turbid water, soil moisture, different types of vegetation, vegetation conditions, etc.). Fig. 3.



Fuente: NASA - Jeannie Allen <https://go.nasa.gov/3DnmbK2>

Fuente: NASA - Eric Brown de Colstoun <https://go.nasa.gov/2Pk20k8>



Spectral signatures obtained with the MultiSpect Software <https://bit.ly/3HinHtz>

Fig. 3. Spectral signatures: (a) of different Earth features. (b) of vegetation. (c) Examples of spectral signatures in different pixels of the satellite image of Rondônia, taken by the Landsat 8 satellite on 27/07/17.

A digital image comprises pixels (or squares) whose color represents a number each. Thus, a picture is a matrix of grayscale numbers ranging from 0 (white) to 255 (black). Any other value within that range is a variation of gray (Fig. 4).

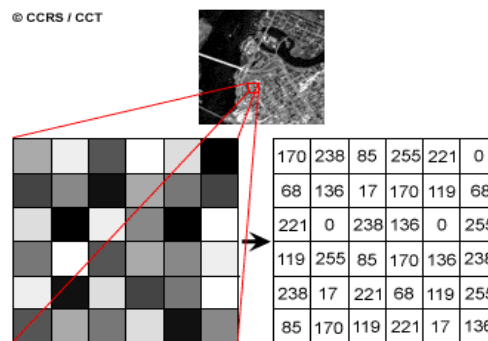


Fig. 4. Satellite image and numerical matrix of a Landsat 7 satellite image band. Each pixel (or square) represents a land area of 30m x 30m and a specific brightness color. Source: <https://www.nrcan.gc.ca/>

Each satellite image has multiple bands representing different [electromagnetic spectrum wavelengths](#) [Fig. 5 (a)]. Sensors on most satellites use [infrared](#) to [ultraviolet](#), including [visible light](#). The bands represent data from the visible and infrared (shortwave infrared, near-infrared, and mid-infrared) regions. [Fig. 5 (b)] When we [combine the bands](#) in an RGB image to obtain a color similar to natural color, we work with three matrices, one per color channel: Red, Green, and Blue. [Fig. 5 (d)] As in the grayscale images, 0 represents the absolute absence of color, and 255 is the total presence of the hue corresponding to a particular channel. One of the RGB colors is assigned, and the false



color is obtained to observe other aspects reflected in infrared bands or different wavelengths that are not perceived by our eyes. [Fig. 5 (c)]

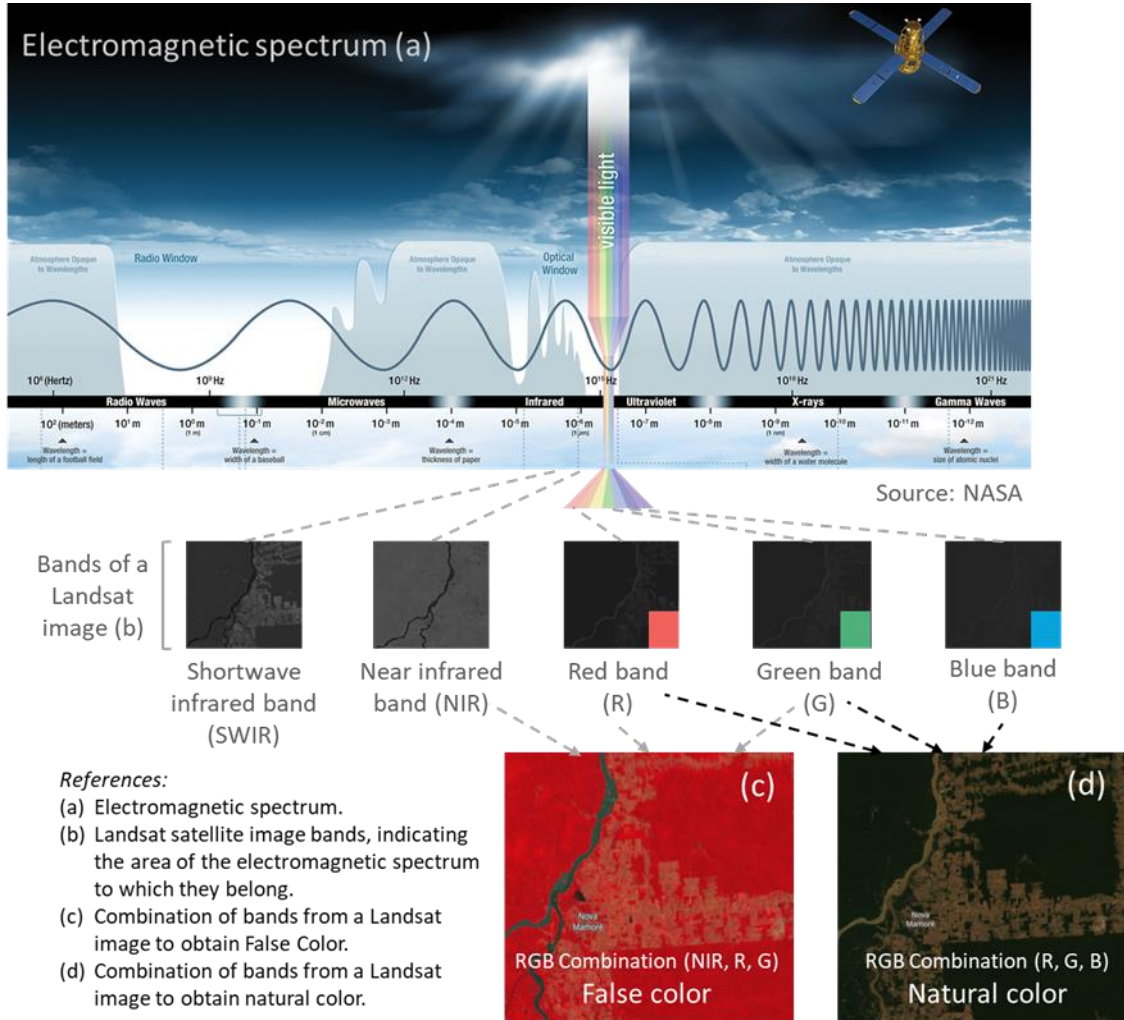


Fig. 5. Combination of Landsat satellite image bands to visualize various aspects. Sources: NASA and Landsat.

As the satellite images are matrices, it is possible to perform calculations to detect other elements not visible with the color combination. The indexes are obtained from calculations with the matrices that form each band of the satellite images. This calculation is performed using specific [software](#), and as a result, a new image is obtained where the pixels related to the parameter, we are measuring are graphically highlighted. E.g., vegetation indices emphasize parameters of vegetation cover: density, leaf area index, chlorophyll activity, and others. For example, details of changes in vegetation cover are easily analyzed by [applying indices](#). The Normalized Difference Vegetation Index (NDVI) is the most commonly used, but several similar indices exist. The [NDVI](#) allows estimating vegetation quantity, quality, and development based on measuring the radiation intensity of some bands of the electromagnetic spectrum that foliage emits or reflects. The bands vary according to the type of satellite. Some images automatically generate the most common indices. High NDVI values indicate healthy vegetation; low



values indicate that the vegetation is drying out (may be due to water stress, disease, fire, etc.) - Fig. 6.

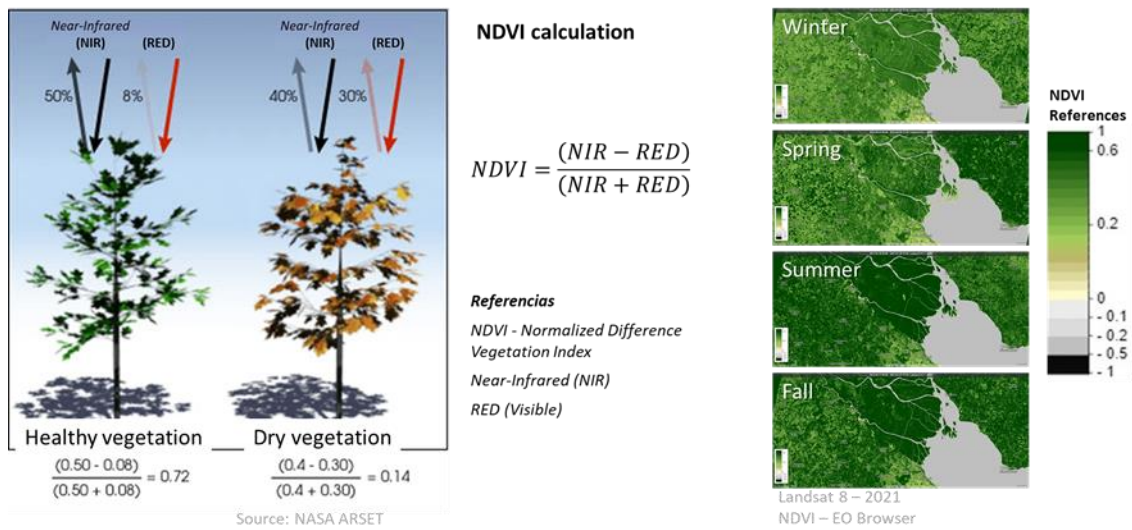


Fig. 6. Calculation and satellite images of the Paraná River Delta processed with the NDVI index. Seasonal changes in vegetation are detected with different color intensities.

Spectral indices have been developed to analyze various aspects of satellite images that have applications in ecology, agriculture, disasters (floods, fires, etc.), aquatic resources, geology, etc. All of them use calculations using different bands of satellite images.

Guiding Research Questions

- How has land cover changed due to the expansion of cities and crops?
- How can the proportion of green spaces in cities be analyzed through satellite images?
- What aspects of seasonal changes are easily identifiable through satellite imagery?
- How valid are band combinations and indices for analyzing satellite information?

Scientific concepts

- Ecosystems. Forests. Meadows. Deserts. Crops.
- Land cover
- Waves and the electromagnetic spectrum.
- Graphics. Histograms
- Satellite images

Materials and tools

1. ArcGIS StoryMaps <https://storymaps.arcgis.com/>
2. Worldview <https://worldview.earthdata.nasa.gov/>
3. EO Browser App <https://apps.sentinel-hub.com/eo-browser/>

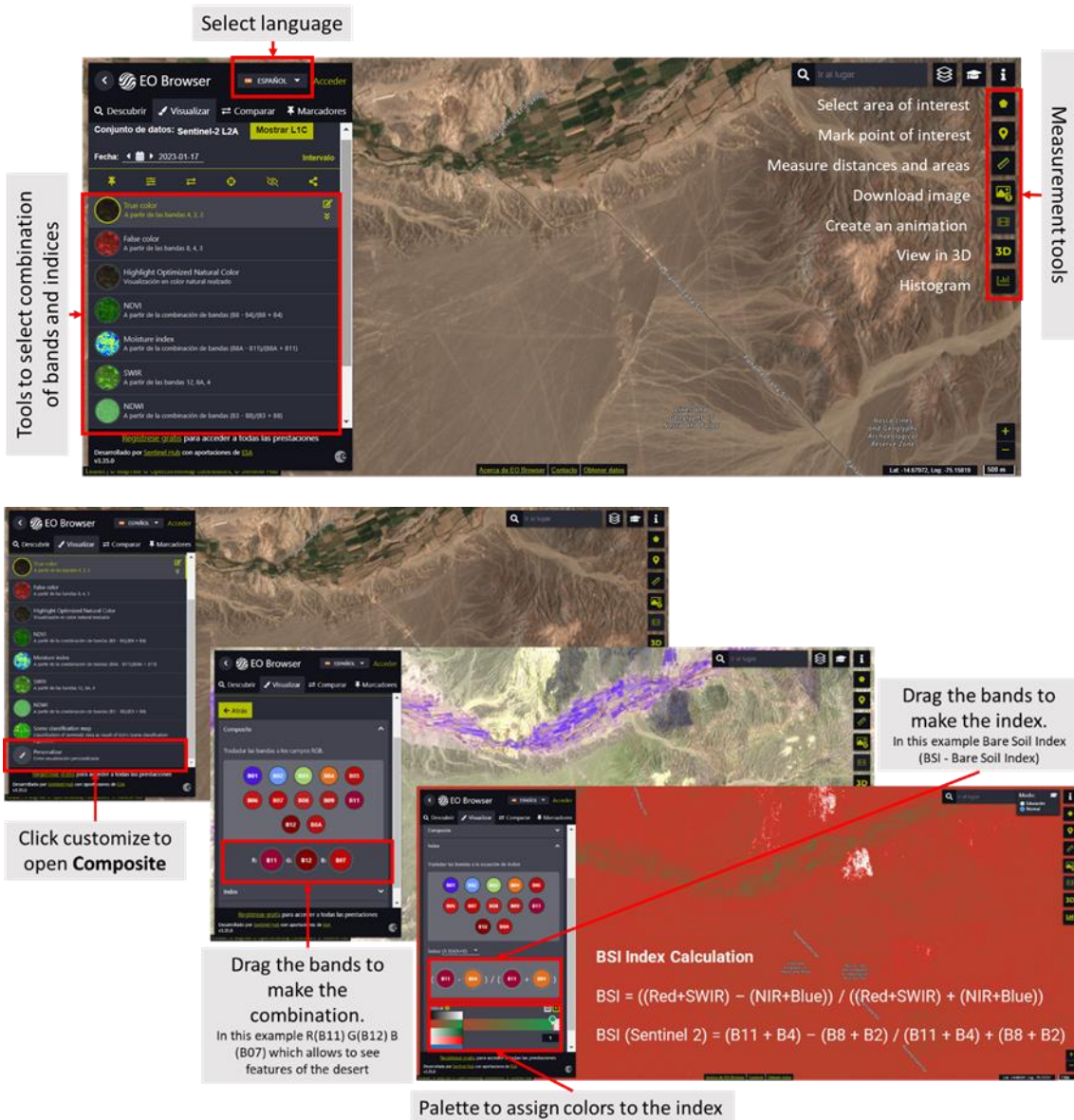


Fig. 7. Infographic of EO Browser App tools.

Case analysis:

Case 1: Urban growth. Cities of Asunción, Paraguay, and Clorinda, Argentina.

- Google Map - [Location](#)
- [Climate graph](#) Weather by Month of the average temperatures and rainfall.

Worldview

- Compare the growth of the cities of Asunción and Clorinda ([between 1988 and 2022](#)). Use the ruler (right, below the screen) to measure each city's distances and areas on different dates.
- Analyze the extent of both cities in 2022 (with night lights) and population density. Measure the areas with the highest population density.



- Download the most representative images of the data consulted.

EO Browser (see tools in Fig. 7):

1. Image Sentinel (1/12/2022): [True Color](#), [False color](#), [False Color \(Urban\)](#) ,
2. Sentinel Image (2022-06-12): [True Color](#), [False color](#), [False Color \(Urban\)](#)
 - Use the ruler (on the right of the screen) to measure distances and areas.

In EO Browser images, do the following:

1. See the images in actual color (True Color), and false color (False color) and False Color (Urban), and note the differences between the cities of Asunción and Clorinda. Compare both images (summer and winter)
2. Select the NDVI index (on the left of the screen) and then the histogram (on the right of the screen). Compare the results of the images. Measure the area of the cities, reselect the histogram, and compare the results.
 1. Do the same for NDMI (Moisture Index) and SWIR (to know the water present in vegetation and soil).
 2. Check the **histogram** (on the right of the screen), and open the menu of the index you are looking at (on the left) to see the reference of the colors. Analyze the histogram by comparing the values with those in the reference.
3. To make a new **combination of bands**, go to customize (left below) and select **composite**.
 1. Drag the bands to the circles to make the RGB combination: (R) 11, (G) 8, and (B) 3. Also, try the RGB combination: (R) 12, (G) 11, and (B) 4.
 2. Compare the sharpness with which you see vegetation cover concerning previous visualizations.
4. **Generate an index.** It is difficult to differentiate between urban areas, farmland, or bare soil, particularly in arid areas. For this reason, several indices have been developed. The Normalized Difference Tillage Index (**NDTI**) is sensitive to differences between buildings and farmland. Also, the indices of Normalized Built Difference - **NDBI** and the urban **UI**.
 1. Go to Customize (left below) and select **Index**. The formula for placing the bands appears.

For NDTI at site A (locate band B11) and site B (locate band B12) corresponding to the following calculation:

$$\text{NDTI} = (\text{SWIR } 1 - \text{SWIR } 2) / (\text{SWIR } 1 + \text{SWIR } 2)$$

$$\text{NDTI (Sentinel 2)} = (\text{B11} - \text{B12}) / (\text{B11} + \text{B12})$$

For NDBI at site A (locate band B12) and site B (locate band B8) corresponding to the following calculation:

$$\text{NDBI} = ((\text{SWIR2-NIR}) / (\text{SWIR2+NIR}))$$

$$\text{NDBI (Sentinel 2)} = ((\text{B12-8}) / (\text{B12+B8}))$$

For UI, at site A (locate band B11) and site B (locate band B8) corresponding to the following calculation:



$$(IU) = ((SWIR1-NIR) / (SWIR1 + NIR))$$

$$UI \text{ (Sentinel 2)} = ((B11-B8) / (B11+B8))$$

1. In each index, go to the **threshold** and select a color palette to color the image.
2. Refer to the histogram on each index to compare the different indices.
3. Analyze which color scheme or index you can best visualize cities with.
5. Make a presentation comparing the results obtained in summer and winter for both cities.

Case 2: Analysis of agricultural fields in central Argentina.

- Google Map - [Location](#)
- [Climate graph](#) Weather by Month of the average temperatures and rainfall.

Worldview:

- Compare Landsat images (years [2001 and 2022](#)). Use the ruler (right, below the screen) to measure each city's distances and areas on different dates.
- Analyze the sizes and shapes of the plots between the different years. Record the changes they observe.
- Download the most representative images of the data consulted.

EO Browser (see tools in Fig. 7):

1. Sentinel Image (2022-07-20): [True Color](#) and [False color](#)
2. Sentinel image (2022-12-02): [True Color](#) and [False color](#)
 - Use the ruler (on the right of the screen) to measure distances and areas.

In the images in EO Browser, do the following:

1. See images in True and False colors. Analyze changes between winter and summer.
2. Select the NDVI index (on the left of the screen) and then the histogram (on the right of the screen). Compare the results of the images. If you want to measure a specific area, you can draw the area and then select the histogram.
 1. Do the same for NDMI (Moisture Index), NDWI (to detect water bodies), and SWIR (to know the water present in vegetation and soil).
 2. Check the **histogram** (on the right of the screen), and open the menu of the index you are looking at (on the left) to see the reference of the colors. Analyze the histogram by comparing the values with those in the reference.
 3. You can draw an area and do the same analysis for that particular sector.
3. To do the **band combination**, go to customize (left below) and select **composite**.
 - a. Drag the bands to the circles to make the merge to make the RGB combination: (R) 8A, (G) 11, and (B) 2.
 - b. Compare the sharpness with which you observe the urban area and the vegetation for the previous visualizations.
4. **Generate an index.** There are many vegetation indices, some with greater complexity in the calculation. The best known and used is the NDVI, but other indices are also used to know other aspects of the crop (e.g., GNDVI has greater sensitivity to detect different chlorophyll concentration rates). Select the



NDVI index, the Green Normalized Difference Vegetation Index (**GNDVI**). Also, the indices: Modified Normalized Difference Water Index - **MNDWI (Normalized Difference Water Index)** and Normalized Burn Ratio - **NBR** (Calcination Index).

- a. Go to Customize (left below) and select Index. The formula for placing the bands appears.
For GNDVI at site A (locate band B8) and site B (locate band B3) corresponding to the following calculation:

$$\text{GNDVI} = (\text{NIR} - \text{GREEN}) / (\text{NIR} + \text{GREEN})$$

$$\text{GNDVI (Sentinel 2)} = (\text{B8} - \text{B3}) / (\text{B8} + \text{B3})$$

For MNDWI at site A (locate band B3) and site B (locate band B11) corresponding to the following calculation:

$$\text{MNDWI} = (\text{Green} - \text{SWIR}) / (\text{Green} + \text{SWIR})$$

$$\text{MNDWI (Sentinel 2)} = (\text{B3} - \text{B11}) / (\text{B3} + \text{B11})$$

For NBR at site A (locate band B8) and site B (locate band B11) corresponding to the following calculation:

$$\text{NBR} = (\text{NIR} - \text{SWIR}) / (\text{NIR} + \text{SWIR})$$

$$\text{NBR (Sentinel 2)} = (\text{B8} - \text{B11}) / (\text{B8} + \text{B11})$$

- b. In each index, go to the **threshold** and select a color palette to color the image.
 - c. Refer to the histogram on each index to compare the different indices.
 - d. Analyze with which color combination or index you can best visualize the cities.
5. Make a presentation comparing the results of winter and summer in the crops. Also, compare the visualizations you get with the different indexes.

What to do and how to do it

– **Beginning**

Show your students the following videos: a) [NASA Remasters Nearly 20 Years of Global Rain](#), b) [Climate Change Could Affect Global Agriculture Within 10 Years](#) y c) [Introduction to the Electromagnetic Spectrum](#) Also, the websites: a) [Eyes on the Earth](#), b) [Sentinel 2 Bands and Combinations](#)

Then share ideas about the usefulness of satellite information for making decisions in daily life. Also, about using different waves of the electromagnetic spectrum to obtain information about cities, crops, and other features of the Earth.



– **Development**

1. Ask students to read the introduction to this activity and make a concept map with the information. (*The introduction provides the basic fundamentals of remote sensing with links to expand the information or clarify aspects if necessary*).
2. Divide the class into groups and assign a case to each group for analysis.
 - a. Look at the current satellite image on Google Maps. What do you see in that image (forest, desert, crops, cities, roads, rivers, etc.)?
 - b. Analyze the climograph of the average rainfall and temperatures of that place.
 - c. See the differences between old and 2022 images in Worldview. Measure distances and areas to establish differences.
Note: In WorldView, you can change month and year, bottom left
 - d. Check out EO Browser images from different seasons. Discuss band combinations and indexes. Use the combinations and indexes listed (you can try different bands and analyze the visualization if you wish).
3. Ask your students to give a presentation about the case under discussion. They can make a story with maps (ArcGIS StoryMaps), a slide show, or a video.
4. Gather all the groups and ask them to explain the cases analyzed.
5. Complete the concept map with the main characteristics of each case analyzed.

– **Closing**

Due to the relevance of both events, it is essential to develop dissemination materials. Students can create a story with maps ([Story Map](#)), a video, or flyers to post on social networks summarizing the cases analyzed.

Frequently asked questions

- Where do I find satellite images? – Worldview – Google Earth – Google Map
- Where do I find information on global environmental conditions and population? [ResourceWatch](#) gathers information from different sources.

Suggested resources

As an extension of this activity, students can consult satellite images of different dates and places to explore other places of interest and even different events. You can use the GLOBE Program protocols to make manual measurements in your environment or download data from measurements made by other people. You can also perform environmental measurements to complement research based on satellite images.

Websites

- UN-Habitat (2023) Earth Observations Toolkit for Sustainable Cities and Human Settlements. <https://eotoolkit.unhabitat.org/>
- NASA. (2023) Eyes on the Earth. <https://eyes.nasa.gov/apps/earth/#/> (satellites that take images of Earth)
- USGS (2021) Common Landsat Band Combinations. <https://on.doi.gov/3wAKJvd> (Band combinations with Landsat images)



- USGS (2022) What are the best Landsat spectral bands for use in my research? <https://on.doi.gov/3HEMdLf>
- GISGeography (2022) Sentinel 2 Bands and Combinations. <https://gisgeography.com/sentinel-2-bands-combinations/> (Band Combinations with Sentinel Imagery)

Videos:

- NASA Climate Change (2021) *How NASA Satellites Help Model the Future of Climate*. Youtube: <https://youtu.be/iAUFVUzZlhl>
- NASA Climate Change. (2021) *NASA's Earth Minute: Dishing the Dirt*. Youtube: <https://youtu.be/hgsIFyITvJE?si=zBZXPYvjRbi5wlvv>
- NASA Climate Change. (2021) *NASA's Earth Minute: Earth Has a Fever*. Youtube: <https://youtu.be/nAuv1R34BHA?si=AJHU9ZxNf6qDu2pj>
- NASA Climate Change. (2021) *NASA's Earth Minute: Cloudy Forecast*. Youtube: https://youtu.be/UCVn_IODEys?si=jyecSHoKZHf-w0WK
- NASA Climate Change. (2021) *NASA's Earth Minute: Blowin' in the Wind*. Youtube: https://youtu.be/UCVn_IODEys?si=jyecSHoKZHf-w0WK
- NASA Climate Change. (2021) *NASA's Earth Minute: My Name is Aerosol*. Youtube: https://youtu.be/4eh6IKahbok?si=QISVr_NmynXoqWQm
- NASA Climate Change. (2021) *NASA's Earth Minute: Mission to Earth?*. Youtube: https://youtu.be/R8hh_I3l9Ao?si=WBOWlpw23UkhyREB
- NASA Climate Change. (2021) *NASA's Earth Minute: Gas Problem*. Youtube: <https://youtu.be/K9kga9c0u2l?si=cRSJ8nkzkBaWvRSW>
- NASA (2019) *Two Decades of Rain, Snowfall from NASA's Precipitation Missions*. <https://youtu.be/qNIRQgACTFg?si=c95YgYXQ3yXQDb-P>
- NASA en Español (2021) *Climate Change Could Affect Global Agriculture Within 10 Years*. Youtube: <https://youtu.be/-NZlvvhGIR0?si=av2opPTE48KSuwCT>
- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 3. Microwaves*. Youtube: <https://youtu.be/UZeBzTI5Omk> [Español. Traducido por: Antenas y Salud (2015) *El espectro electromagnético 3. Microondas*. Youtube: https://youtu.be/OCxFv_KDdZE]
- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 4. Infrared Waves*. Youtube: <https://youtu.be/i8caGm9Fmh0> [Español. Traducido por: Dpto. Electricidad Electrónica (2017) *El espectro electromagnético 4. Infrarrojo*. Youtube: <https://youtu.be/DqZKWfRRxKw>]
- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 5. Visible Light Waves*. Youtube: <https://youtu.be/PMtC34pzKGc> [Español. Traducido por: Dpto Electricidad Electrónica (2017) *El espectro electromagnético 5. Luz visible*. Youtube: <https://youtu.be/BVbbkzyqf94>]
- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 6. Ultraviolet Waves*. Youtube: <https://youtu.be/QW5zeVy8aE0> [Español. Traducido por: Eldador (2011) *El espectro electromagnético 6. Luz ultravioleta*. Youtube: <https://youtu.be/IOKEbZgB2lI>]



- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum. Introduction 1*. Youtube: <https://youtu.be/lwfJPc-rSXw> [Español. Traducido por: Antenas y Salud (2015) *El espectro electromagnético. Introducción 1*. Youtube: <https://youtu.be/K-up0o96Vhw>]

Other resources:

- Data and maps of environmental conditions and crops by countries and agricultural production districts - NASA HARVEST – Earth data for informed agricultural decisions. <https://cropmonitor.org/tools/agmet/>
- Global expansion of cropland in the 21st century - Global Land Analysis & Discovery (GLAD) (2000 to 2019) <https://bit.ly/3eKcooe>
- Crop Explorer – Crop Explorer <https://ipad.fas.usda.gov/cropexplorer/>
- FAO Earth Observation Map (Environmental conditions and crops: Global and by country) <https://www.fao.org/giews/earthobservation/index.jsp?lang=es>
- Global Agricultural & Disaster Assessment System (GADAS) Map <https://geo.fas.usda.gov/GADAS/>
- Tutorials: Worldview ([short video](#), [Complete video](#), [Website](#), [ideas for the classroom](#)) EO Browser ([Website](#) o [video](#), [infographic](#)), [Story Map](#)
- Automatic translation: [Videos](#), [Website](#)

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Volcanoes

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Atmosphere	Wind direction and speed. Aerosols. Rainfall. Relative humidity	13 (Climate action) 15 (Life on land)	Exploratory
Biosphere	Land cover. Biometrics. Phenology		
Pedosphere	Soil characterization. Fertility. Humidity. pH. Temperature		
Package	Soil Agriculture Air Quality Soils		

Overview

Satellite images and maps are analyzed to understand volcanic activity's negative and positive impacts, especially the effect of increased soil fertility. Students analyze cases of different volcanic eruptions in Latin America and the Caribbean. Extensions of activity are suggested by making field measurements to complement satellite information.

Time

3 or 4 classes

Prerequisites

Basic knowledge of volcanoes, location of volcanoes, types of eruptions. ICT management. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School level

Final years of elementary, secondary, and university students

Purpose

Understand the negative impacts of volcanic eruptions and the long-term positive effects on increasing soil fertility and developing commercially essential crops.

Student Outcomes

- Identify the significant impacts of volcanic eruptions in nearby areas and at great distances.



- Know the changes caused by volcanic ash deposits in soils.
- Analyze the predominant soil type around volcanoes and changes in natural vegetation and crops following weathering of volcanic ash.

Introduction

Volcanoes are openings in the surface crust of a planet or moon where lava or other materials that are hotter than their surroundings (ash, rocks) come out, causing an eruption. In addition to the numerous volcanoes on Earth, volcanoes have been found on other planets (e.g., Mars has the largest volcano in the solar system, called Olympus Mons, almost three times higher than Mount Everest) and also on moons (e.g., Mars has the largest volcano in the solar system, called Olympus Mons, nearly three times higher than Mount Everest) and also on moons (e.g., Mars has the largest volcano in the solar system, called [Olympus Mons](#), almost three times higher than Mount Everest) and also on moons (e.g., [On Io](#), one of Jupiter's moons, volcanic eruptions have been detected.)

According to the [Global Volcanism Program](#), there are currently approximately 1,350 active volcanoes in the world, and about 500 erupted in the last 100 years. Volcanoes that have shown activity in the last 10,000 years are considered active. The Smithsonian Institution's [map of active volcanoes](#) shows that most are in the Pacific Ring of Fire and associated with [seismic zones](#). Most of these volcanoes are located in Latin America and the Caribbean.

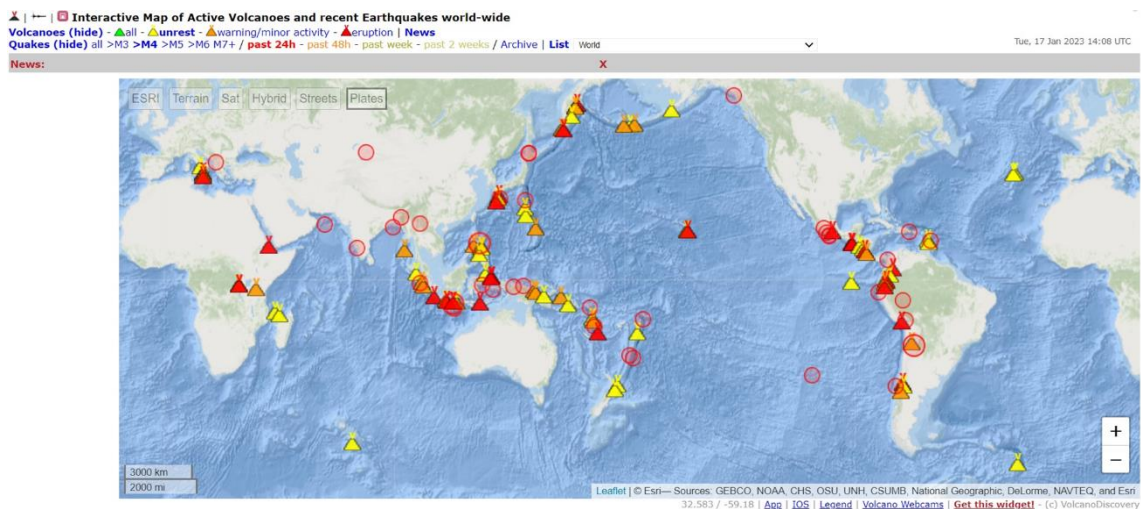


Fig. 1. Location of active volcanoes and recent earthquakes.

<https://earthquakes.volcanodiscovery.com/>

It is now possible to monitor volcanic and seismic activity in near real-time worldwide (Fig. 1). Volcanic activity is highly variable. The Smithsonian Institution reported that 54 volcanoes erupted in 2022 and 75 in 2021. Some volcanoes have near-permanent activity, while others erupt after prolonged periods of inactivity. For example, in the case of the [Chaitén](#) volcano, it is estimated that the last eruption would have occurred 9,000 years ago before erupting in 2008. Latin America and the Caribbean are home to some of the world's most active Volcanoes. (See [map](#)). This variability makes it challenging to



investigate, especially when no volcano exists, as happened in Mexico when the [Paricutín volcano](#) was formed in 1943. This event was surprising; a fissure appeared in the ground in the middle of a corn plantation (according to the [accounts of villagers](#), the owner of the field noticed an area where the corn dried, the soil had a higher temperature, and heard a sound coming from the ground that looked like a stream of water). From the fissure in the field, volcanic material began to emerge for nine years and 11 months, forming a [cone 240 meters high and a lava field of 25 km²](#) that buried the cities of Paricutín and San Juan Parangaricutiro. Table 1 shows more examples, with satellite images, of some of the latest volcanic eruptions in Latin America and the Caribbean.

Volcanoes are formed (Fig. 2) when tectonic plates separate (at divergent edges), as occurs on the seafloor. Magma rises and rises, filling space and forming submarine volcanoes. Also, when tectonic plates move over each other, forcing one to penetrate the interior (convergent plate edges), pressure, friction, and heat melt the crust and can form volcanoes. For example, the Nazca plate in the Pacific Ocean, which enters below the South American plate, has formed numerous volcanoes in the Andes Mountains. Other volcanoes form far from the edges of plates in [volcanic hot spots](#) resulting from magma plumes rising to the surface, as underwater volcanoes can form islands. For example, the [Galapagos Islands](#).

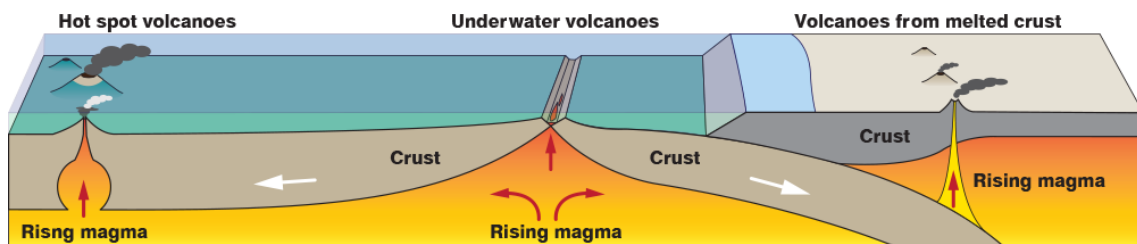


Fig. 2. Formation of volcanoes on the earth's surface: a) Hot spot volcanoes, b) Submarine volcanoes, and c) Melted crust volcanoes. Source: <https://spaceplace.nasa.gov/volcanoes2/en/>

Volcanic eruptions are shocking natural phenomena. During eruptions, lava flows, pyroclastic flows, and lahars are released, posing a risk to nearby people. Large explosive eruptions can cause long-term effects by filling the atmosphere with volcanic ash and [gases](#), disrupting air transport. E.g., the 2011 eruption of the Puyehue Cordón Caulle Volcanic Complex released a large amount of ash, which was dispersed by the wind (See Table 1). Ash from [the Calbuco volcano](#) reached Uruguay, Brazil, and Australia. To alert the population and reduce risks, earthquakes generated in volcanoes are [monitored](#), [webcams](#) are used (to monitor the volcano on the ground), satellite images (to study the deformation or release of volcanic material), and other [technologies](#).

But volcanic eruptions also bring benefits, from creating new land areas on coasts to entire islands in the middle of the oceans. Andisols are soils derived from volcanic ash, pumice, or other volcanic material. According to the [Soil atlas of Latin America and the Caribbean](#), this soil type is widely distributed in the region, particularly in the Andean area. These soils are very productive for [coffee cultivation](#). Another property of volcanic ash is that chemical weathering absorbs carbon dioxide from the atmosphere and incorporates it into the ground. For this reason, several scientists recommend using volcanic ash in crop areas to store more carbon in soils and mitigate the climate crisis. However, they warn that more research is required to optimize the process. Weathering



of volcanic ash releases nutrients that have positive effects on plant growth. Volcanic ash also retains moisture in the soil. Positive impacts of volcanic ash have been documented in many cases: a) after the eruption of the Puyehue Cordón Caulle Volcano in 2011, scientists found that *Plumillo Nothofagus* trees located near the volcano had significantly higher than average growth because the ash layers increased water retention in the soil, The ash facilitated the plants' access to nutrients and reduced the attack of herbivores. (b) after the eruption of the Hudson volcano in 1991, in the long term, the soil in the orchard and cherry production area that had received volcanic ash increased its fertility (chemical and physical changes were recorded), especially in those using irrigation. Knowing the type of soil in your environment, if you have had volcanic ash deposits in the past, the type of use of that soil, if it is soil with tillage for crops, the variation in the number of nutrients and humidity throughout the year, the pH, is important for proper management.

Guiding Research Questions

- Has my locality received volcanic ash in the past? When? What volcano did they come from?
- How do aerosols and ash produced by volcanoes influence natural ecosystems, crops, and human activities?
- How are ash and aerosols dispersed? Why does the direction of ash rain change on different days?
- How far is my town from the nearest volcanoes? If any of them erupt, could the winds deposit the volcanic ash in my locality? What wind direction prevails in my locality?
- What factors affect plant growth in my locality? Is the soil of volcanic origin? Do you have volcanic ash deposits?
- Why is coffee grown very close to volcanoes?
- What crops are important in my area? Does it have any relation to volcanic activity?

Scientific concepts

- Ecosystems. Tropical, subtropical, and temperate forests
- Land cover
- Soils
- Carbon cycle
- Satellite images

Materials and tools

1. ArcGIS StoryMaps <https://storymaps.arcgis.com/>
2. Satellite information data from some recent volcanic eruptions:



Table 1. Recent eruptions in Latin America and the Caribbean

Volcanoes	Eruptions
Chaitén Volcano Chile	<p><i>Eruption 2 May 2008</i></p> <p>Satellite images: 03/05/08 – 05/05/08 - 06/05/08 – 26/05/08 (city of Chaitén) – 26/05/08 - 28/05/08 – 31/05/08 – 31/05/08 (caldera) – 18/06/08 - 18/06/08 - 01/07/08 – 07/09/09 - 03/03/10 (Chaiten Volcano Erupts Lava dome) – 18/01/22</p> <p>Ashes: 02 and 03/05/08</p> <p>Aerosols and gases: 03/05/08</p>
Llaima Volcano Chile	<p><i>Eruption 4 April 2009</i></p> <p>Satellite images: 04/04/09 – 08/04/09 – 16/04/09 - 15/01/23</p>
Puyehue-Cordón Caulle Volcanic Complex Chile	<p><i>Eruption June 4, 2011</i></p> <p>Satellite images: 04/06/11 – 06/06/11 – 04-06/06/11 – 11/06/11 – 13/06/11 - 13/06/11 (ash in Australia and New Zealand) 14/06/11 – 20/06/11 – 02/07/11 – 31/07/11 – 14/08/11 – 18/08/11 - 21/08/11 – 30/08/11 – 17/09/11 – 09/10/11 – 22/10/11 – 4/11/11 – 16/11/11 – 23/12/11 – 26/01/12 – 10/02 y 07/03/12 - 08/01/23</p> <p>Aerosols: 05/06/11 – 5-13/06/11 (ash in Australia and New Zealand)</p>
Calbuco Volcano Chile	<p><i>Eruption April 22, 2015</i></p> <p>Satellite images: 23/04/15 – 03/05/15 (ash in suspension) – 24/04/15 - 08/01/23</p> <p>Gases: 23-26/04/15</p>
Villarrica Volcano Chile	<p><i>Eruption March 3, 2015</i></p> <p>Satellite images: 05/03/15 – 18/03/15</p>
Tungurahua Volcano Ecuador	<p><i>Eruption</i></p> <p>Satellite images: 17/07/06 - 24/07/06 – 17/08/06 – 25/10/06 - 20/02/22</p> <p>Aerosols: 17/08/06</p>
La Cumbre Volcano Ecuador (Galapagos)	<p><i>Eruption 11 April 2009</i></p> <p>Satellite images: 11/04/09 – 14/04/09 – 27/04/09 - 07/12/22</p> <p>Gases: 14/04/09</p>



Wolf Volcano Ecuador (Galapagos)	<i>Eruption May 25, 2015</i> Satellite images: 28/05/15 – 11/05/15 – 13/01/23 <i>Eruption January 7, 2022</i> Satellite images: 07/01/22 (night and day) – 14/01/22
Montserrat Volcano Montserrat Island	<i>Eruption 29 August 2006</i> Satellite images: 29/08/06 – 01/09/06 – 12/09/06 – 14/02/07 - 27/12/22
Colima Volcano Mexico	<i>Several eruptions in February 2003 and June 2005</i> Satellite images: 21/05/05 – 07/06/05 – 22/01/11 – 12/01/23
Momotombo Volcano - Nicaragua	<i>Eruption December 2015</i> Satellite images: 04/12/15 - 02/03/16 - 04/12/22

Case 1. Puyehue-Cordón Caulle Volcanic Complex - Chile:

- Google Map - [Location](#)
- WorldView – [Comparison](#) Eruption vs. image after several years
- NDVI and False Color during the eruption – [NDVI](#) and [False Color](#) after several years
- [Current state](#) of the volcano
- [Atlas of soils](#): Andosols near the volcano (page 105 and legend page 59) and organic carbon in the soil (page 138)

Case 2. Calbuco Volcano - Chile:

- Google Map - [Location](#)
- WorldView – [Comparison](#) Eruption vs. image after several years
- NDVI and False Color during the eruption – [NDVI](#) and [False Color](#) after several years
- [Current state](#) of the volcano
- [Atlas of soils](#): Andosols near the volcano (page 105 and legend page 59) and organic carbon in the soil (page 138)

Case 3. Cotopaxi Volcano - Ecuador:

- Google Map - [Location](#)
- WorldView – [Comparison](#) Eruption vs. image after several years
- NDVI and False Color during the eruption – [NDVI](#) and [False Color](#) after several years
- [Current state](#) of the volcano
- [Atlas of soils](#): Andosols near the volcano (page 83 and legend page 59) and organic carbon in the soil (page 138)



Case 4. Volcán de Fuego - Guatemala:

- Google Map - [Location](#)
- WorldView – [Comparison](#) Eruption vs. image after several years
- NDVI and False Color during the eruption – [NDVI](#) and [False Color](#) after several days
- [Current state](#) of the volcano
- [Atlas of soils](#): Andosols near the volcano (page 73 and legend page 59) and organic carbon in the soil (page 138)

Note: The [false color](#) highlights vegetation in red. [NDVI](#) (Normalized Difference Vegetation Index) indicates the state of health of the vegetation; it is good when the green is more intense.

What to do and how to do it

– **Beginning**

Show your students the [location of volcanoes](#) in Latin America and the Caribbean, the following videos: a) [Volcanic explosions Where does all that destructive force come from?](#) b) [How the Parícutín volcano buried two villages in Mexico](#) c) [Parícutín Volcano, destruction and rebirth](#) and d) [Tracking Volcanic Ash with Satellites](#).

Discuss the impact of volcanoes in nearby areas and at great distances. Ask if they know of any eruptions that have caused significant impacts.

– **Development**

1. Ask students to read the introduction to this activity, consult the links and make a concept map with the information.
2. Divide the class into groups and assign a case to each group for analysis.
 - a. Look at the current satellite image on Google Maps. What do you see in that image (volcano, forest, crops, roads, cities, etc.)?
 - b. Considering the concept map, what cities and economic activities would it affect if that volcano were to erupt again?
 - c. Compare Worldview images during and after the eruption.
 - d. After an eruption, several scientists reported that after a while, the soils have greater fertility and favor the growth of plants. One way to detect it is to measure the intensity of green with the NDVI index or red with the false color combination. Analyze this volcano if changes are observed.
 - e. What is the state of this volcano today? Have alerts been issued to the population? See the monitoring report.
 - f. Consult the Soil Atlas on the indicated pages and analyze the soil type around the volcano and the organic carbon stored.
3. Ask your students to give a presentation about the case under discussion. They can make a story with maps (ArcGIS StoryMaps), a slide show, or a video.
4. Gather all the groups and ask them to explain the cases analyzed.
5. Compare eruption intensity between volcanoes analyzed and impacts on soil and carbon sequestration. (In this case, consider that there are other volcanoes near the one you are analyzing, which also influence the variables analyzed)
6. Complete the concept map with the main characteristics of each case analyzed.



7. If volcanoes are nearby in your locality or you are in the direction of the prevailing winds and volcanic ash could arrive, you can use the same tools to study it.

– **Closing**

Because of the relevance of this problem, it is important to develop dissemination materials. Students can create a story with maps ([Story Map](#)), a video, or flyers to post on social networks summarizing the cases analyzed and highlighting the importance of volcanoes in soil formation and plant growth.

Frequently asked questions

Where do I find satellite images? – Worldview – Google Earth – Google Map

Where do I find information about volcanoes? [Global Volcanism Program](#) gathers all the information about volcanoes and has a [map](#) of active volcanoes. Volcano Discovery has an interactive map with a [report of the latest eruptions](#) in the world. The websites listed in the materials are also recommended.

Suggested Resources

As an extension of this activity, students can consult the list of recent eruptions in the region and satellite images of different dates and places to explore other sites of interest. Complement this analysis with the [Soil Atlas](#) and seek information on the type of crops in the region they are analyzing. Guiding research questions can help analyze volcanic activity at other sites not covered by this activity.

You can use GLOBE Program protocols to make measurements in your environment and query program data to compare volcanic data. If your locality is far from volcanic areas, you can analyze satellite imagery and search for field measurement data in the GLOBE Program database.

Websites

- Volcanic Soil Research Center CISVO <https://www.cisvo.cl/>
- Global Volcanism Program. Smithsonian Institution. NMNH. <https://volcano.si.edu/> (Volcano Information Sources, Eruption Reports, Monitoring, etc.) - Volcano Information Sources by Country. https://volcano.si.edu/resource_infosources.cfm
- Google Earth. 10,000 Years of Volcanoes. (Location of volcanoes) <https://bit.ly/3GSL959>
- My NASA Data. Volcanic Eruptions Story Map. <https://bit.ly/3H3x30H>
- NASA. ACDL (2023) Global Sulfur Dioxide Monitoring. <https://so2.gsfc.nasa.gov/>
- Volcanic Magazine <https://www.jvolcanica.org/ojs/index.php/volcanica/issue/view/9>
- SegemAR <https://oavv.segemar.gob.ar/monitoreo-volcanico/> - Questions about [volcanoes](#)
- Seismic Monitor (global earthquake monitoring) <http://ds.iris.edu/seismon/index.phtml>
- Sernageomin <https://rnvv.sernageomin.cl/>
- The Caribbean GeoPortal <https://www.caribbeangeoportal.com/>



- Volcano Active Foundation <https://volcanofoundation.org/es/>
- Volcano discovery <https://earthquakes.volcanodiscovery.com/> - Interactive Map of Active Volcanoes and recent Earthquakes worldwide
<https://earthquakes.volcanodiscovery.com/>
- Volcanology Chile. <https://www.volcanochile.com/joomla30/>

Videos:

- BBC News Mundo (2019) *Cómo el volcán Parícutín sepultó dos pueblos en México*. Youtube: https://youtu.be/-TYXiD7U_tg
- Conexión Milenio (2022) *Volcán Parícutín, destrucción y renacimiento*. Dailymotion: <https://www.dailymotion.com/video/x89pokr>
- GeologyHub (2020) *The Active Volcano which Grew from a Farmer's Field: Parícutin*. Youtube: <https://youtu.be/M7pLDDMXSXQ?si=DDQWrvsud4xAf9L1>
- IRIS SAGE (2021) *Hotspot Volcanism: Thermal Plume*. Youtube: https://www.iris.edu/hq/inclass/animation/hotspot_volcanism_thermal_plume#
- IRIS Earthquake Science (2017) *Volcano seismicity at long-dormant stratovolcanoes*. Youtube: https://youtu.be/RxPrHy8RBj0?si=GIYub_WtTDHfkEYZ
- National Geographic (2018) *Explosiones Volcánicas ¿De dónde proviene toda esa fuerza destructiva?* Youtube: <https://youtu.be/MmwQKpzMSHc>
- SVS (2016) *Tracking Volcanic Ash with Satellites*. Calbuco. Youtube: <https://youtu.be/lmyjh3t3c7g> Artículo: <https://svs.gsfc.nasa.gov/12221>

Infography:

- National Geographic (2023) *Forces of nature. Volcanoes*. <https://www.nationalgeographic.org/forces-nature/volcanoes.html> (Graphics: parts of a volcano, volcano formation, types of volcanoes, types of eruptions, types of lava, etc.)

Articles:

- National Geographic. (2022) *Volcanes: qué son y cómo se forman*. <https://bit.ly/3iEKNqt> - *Erupciones volcánicas* <https://bit.ly/3H7bbmu>
- OpenMind BBVA (2021) *Ciencia para 'domar' volcanes*. [En español] *Science for Taming Volcanoes* [En Inglés]
- Perfect Daily Grind (2020) *¿Por Qué se Cultiva Café Cerca de Volcanes Activos?* [En español] *Why Do Some Producers Grow Coffee Near Active Volcanoes?* [En Inglés]



Other Resources:

Tutorials de: [Worldview](#), [Story Map](#)

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