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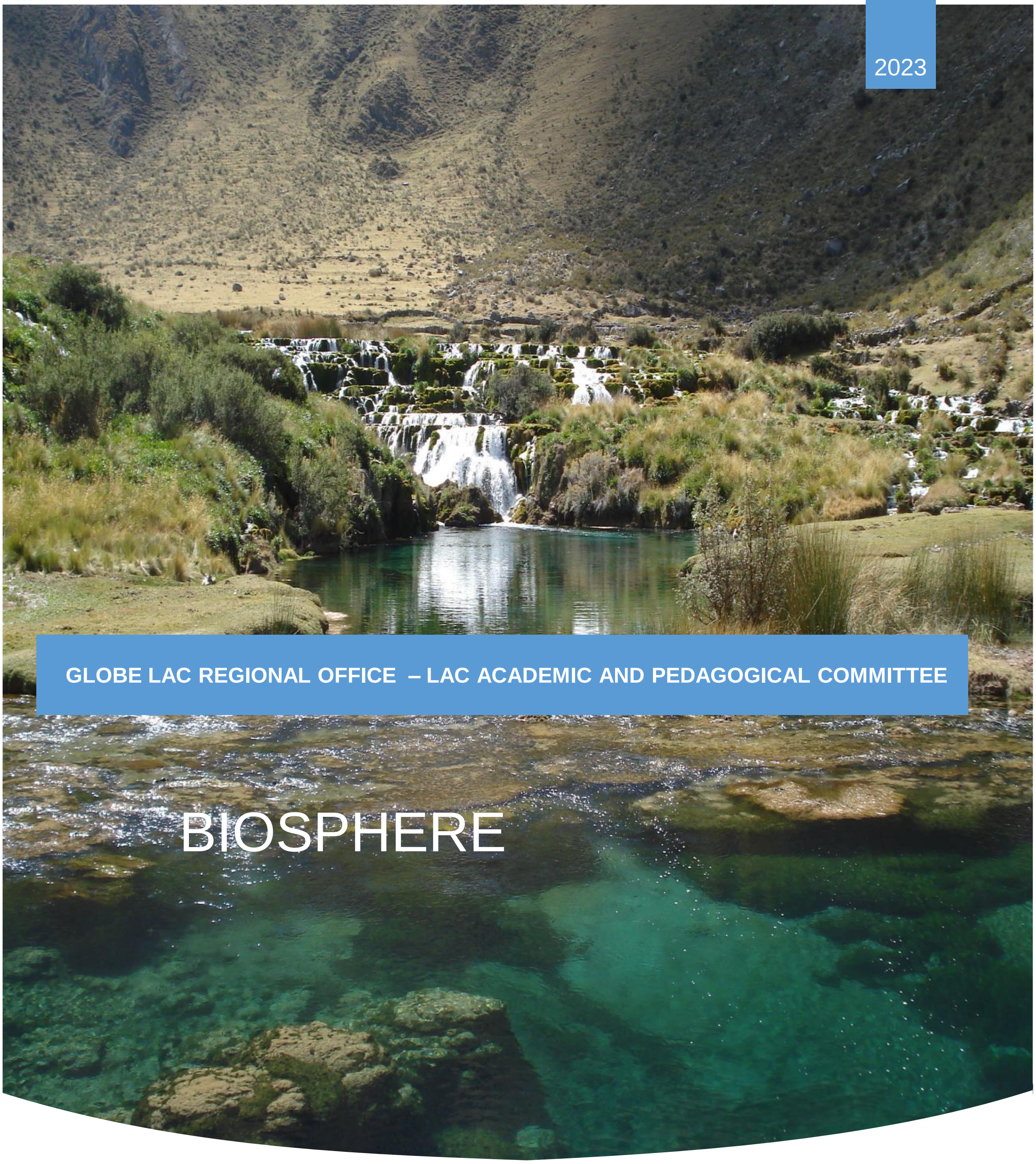

GLOBE LAC REGIONAL OFFICE – LAC ACADEMIC AND PEDAGOGICAL COMMITTEE

BIOSPHERE

Imagen: Claudia Caro Vera

The GLOBE Program
LAC Regional Office

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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Content

PRESENTATION

The Academic and Pedagogical Committee of the Latin America and the Caribbean Region has prepared a series of learning activities to facilitate the understanding of the four research areas of the GLOBE Program. It is expected that, through these activities, teachers will find useful conceptual and practical elements to develop scientific thinking in their students. In this sense, in addition to classroom learning activities, some activities have been designed to explore the science of data, facilitating their interpretation for the generation of useful information. Also, aware of the advancement of the use of technology for research, some learning activities related to the use of remote sensing technologies, have also been included, in order to contribute with the description and analysis of different environmental variables.

One of the GLOBE Program's areas of research is the biosphere, defined as the thin layer of the Earth's surface where life develops. This sphere includes the recognition and description of land cover using biometry and the recognition of seasonal variations in plants. In this sense, the research activities presented in this book cover basic aspects related to the identification of land cover classes, the implementation of some land cover measurements, and the biometric measurements of trees. As well as techniques for the conservation of vegetation and diversity recognition. Also include some techniques of storytelling, land planning and continuous evaluation strategies. As an additional topic, a game has also been proposed to learn more about the GLOBE protocols and their relationship with the Sustainable Development Goals.

We hope that teachers will find in the following pages inspiration and motivation to develop the GLOBE Program research proposals related to the study of the biosphere and that they can include the activities in their daily classes to strengthen the scientific capabilities of their students.

Imagen: Claudia Caro Vera

LEARNING ACTIVITIES

Agricultural calendars and celebrations

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Biosphere	Land Cover Classification Leaf Green-Down Leaf Green-Up	15: Life of on Land 12: Sustainable Consumption and Production 4: Quality Education	Cognitive
Atmosphere	Temperature Precipitation		

Overview

Crop production requires three fundamental factors: fertile soil, water availability and favorable weather conditions. When a crop meets these conditions, it can grow properly. In this sense, agricultural calendars are tools that help farmers visualize the behavior of the weather month by month in a given place, as well as the activities and crops that are favored under those conditions. With this activity, students will learn a little more about agricultural calendars and will create their own to know when to find their favorite fruits and vegetables at the market.

Time

100 minutes

Prerequisites

To know the protocols for assessing temperature and precipitation (optional)

School level

All

Purpose

To create an agricultural calendar with students' favorite foods for each month, associated with temperature and precipitation values, as well as important agricultural celebrations for each location.

Students Outcomes

- Students will identify the main fruits and vegetables offered in your area and where they come from.
- Students will design an agricultural calendar, associating each month with seasonal fruits or vegetables.

Background

Agricultural calendars (Figure 1) provide important information on the appropriate times of the year for each stage of crop development. They are very helpful tools for planning and making decisions on the use and conservation of soils, as they specify month by month when it is time for planting, harvesting, crop marketing and any other task related to food production.

Agricultural calendars are created on the basis of relationships that exist between climate variables and crop phenology. For their elaboration, precipitation (Zid et al., 2022) and the maximum and minimum temperatures of each month (García et al., 2013) are essentially considered. Therefore, climate change and climate variability represent a major challenge for agricultural activities because they usually mean an increase in the frequency and intensity of extreme events such as floods, droughts, frosts, and heat waves, which affect crop production (Yang et al., 2021) and thus the capacity of agroecosystems to meet people's needs (FAO, 2015).

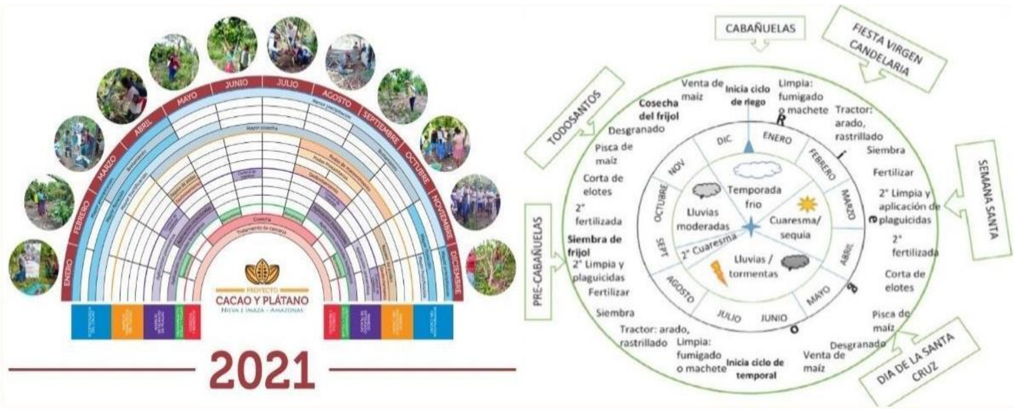

Figure 1: Examples of agricultural calendars
Source: Helvetas, 2020; Alcazar and Gomez-Martinez, 2016.

The knowledge of farmers for the development of agricultural calendars is very important, as they are the ones who have the ability to observe indicators in the environment to detect changes in temperature and precipitation and thus know the times of planting and harvesting of food (Yang et al., 2021). However, even if we are not all farmers, we can recognize the right time to consume certain products, as it is easy to find them in the market. This is how we can identify seasonal fruits.

Through this activity students will identify the appropriate months to consume some of the important fruits and vegetables for nutrition available in markets. In addition, this will serve as a way of approaching agricultural calendars and will allow them to learn more about where their favorite foods are produced and what their growing needs are.

Guiding Research Questions

- Why are agricultural calendars important?
- What is the meaning of seasonal fruit?
- What is the season for apples?
- What is the hottest month in our city and what crops can be harvested in that month?

Scientific Concepts

- Agricultural calendar
- Climate change
- Climate variability
- Phenology
- Agroecosystems

Materials and Tools

- Paper
- Colors
- Monthly temperature and precipitation data for the city

What to Do and How to Do It

- ***Beginning***
    - The teachers ask their students to go to the market and get their favorite fruit and/or vegetable.
    - The teachers ask their students to bring their favorite fruits or vegetables to class. If they can't find them at the market, they are asked to bring a picture of them.
    - Next, the teachers ask their students to use the 4 questions chart, shown in Table 1.

Table 1
4 questions chart to start organizing an Agricultural Calendar

What is my favorite fruit or vegetable?	When can I find it in my local market?	Where does it come from?	What else would I like to know about my favorite fruit or vegetable?

- ***Development***
    - Based on the list of fruits and vegetables obtained from the first column of Table 1 and its relation to column 2, a fruit or vegetable is chosen in the whole class for each month, according to its probability of finding it in the market. From then on that will be the month of the chosen fruit.
    - During the month of the selected fruit or vegetable, students research everything related to the chosen food, answering questions such as: Where does it grow? What is the temperature and precipitation where it grows? What is its market price? How is it consumed?
    - Students will also be able to take temperature and precipitation measurements throughout the month to compare whether the climate conditions in the city where they live are the same as those needed for their chosen crop.

- Finally, students can write down some important holidays on their calendar, find out planting times for some crops or harvest times. They can even put the birthdays of the researcher for each crop. A suggested format for the calendar is shown in Figure 2.

Figure 2: Suggested Agricultural Calendar for the school; the teachers and students will surely do better. Tmin: Minimum temperature of the month, Tmax: Maximum temperature of the month, Tmean: Average temperature of the month, PP: Accumulated precipitation of the month.

- ***Closing***
  - The students present the calendar they have made and discuss ideas to improve it with their group classmates.
  - Finally, they answer this question in a short paragraph: What have I learned by making my agricultural calendar?

Frequently Asked Questions

<u>Do all farmers use agricultural calendars?</u>
All experienced farmers know the times of planting and harvesting crops, even if they do not use a physical calendar. In many countries calendars are very present and have been made by the communities themselves, often using lunar cycles or some other indicators. However, with the challenges of climate change, it is becoming increasingly necessary to work to build and adapt agricultural calendars in the different countries of the world. This is a way to contribute to the food security of our countries.

<u>Instead of going to the market, could we work the calendars based on the plants we grow in a bio garden?</u>
Of course, that would be highly recommended, as well as an enriching experience for the students.

<u>How often is it advisable to make an agricultural calendar</u>?
Students may make a seasonal calendar (spring, summer, fall, or winter) either by school year or by academic semester.

What is the relationship between phenology and agricultural calendars?
Phenology is the study of the life cycle of organisms in response to seasonal changes (mainly temperature, precipitation, and daylight hours) in a given location (Liang, 2019). Plant dynamics includes a series of phases (phenophases) encompassing germination, bud burst, leaf emergence, flowering, fruiting, fruit ripening, seed formation, seed drop and leaf wilting (Caparros-Santiago et al., 2021). Agricultural calendars help to know the appropriate time for each phenophase, recognizing the moments in which products should be sown, fertilized, and harvested in agricultural systems or agroecosystems.

Is climate change the same as climate variability?
No, climate change is the modification of weather patterns, usually temperature and precipitation, over a long period of time on a regional or global scale, while climate variability refers to short-term fluctuations in the prevailing conditions of an area (NASA, 2014). Additionally, the United Nations Framework Convention on Climate Change (UN, 1992) defines climate change as "A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

Suggested Resources

- Canva to Organize Calendars: https://www.canva.com/
- Climate Change Information: Climate Change | United Nations
- Agricultural Calendars and Maps of Peru Calendar (midagri.gob.pe)

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Designing the place where I want to live

GLOBE		Associated SDG(s)	Type of Activity
Sphere	**Protocols**		
Biosphere	Land Cover Classification	15: Life on Land 11: Sustainable Cities and Communities	Application

Overview

Today, more than ever, it is very important to develop cities with sustainability criteria. In order to achieve this goal, it is necessary to work on the basis of adequate planning based on participatory construction. Throughout this activity, students will collaborate to design the city in which they would like to live, incorporating elements that promote sustainable development in the place where they live.

Time

100 minutes

Prerequisites

None

School level

Secondary

Purpose

Students will design the place where they would like to live in a participatory way, incorporating sustainability criteria in their design.

Student Outcomes

- Students will identify the different ways in which the territory where they live is used
- Students will use land cover and land use classification criteria to organize the territory
- Students will design the place where the students would like to live, capturing their ideas on a sheet of paper or model
- Students will present the results of their work and accept suggestions to improve their design
- Students will relate the SDGs to such new design

Background

Our schools, communities and cities are the result of the decisions we make about the use we want to make of each of the spaces we are offered. In this way, we have places destined for gardens, cultivation areas, houses, etc. These spaces are designed to meet people's basic needs, and therefore, they can change depending on what people require for living.

Ecological-economic zoning (EEZ) is a flexible and dynamic process that helps to identify areas of a territory with greater possibilities of offering certain resources in a sustainable manner. To carry out this zoning, the physical, biological, social, economic and cultural characteristics of the areas must be taken into account in order to assign each place the role that corresponds to it (MINAM, 2022). This process can also be considered as a mechanism for designing the territory according to the use of each place.

An adequate design of the space must take into account the type of land cover it has and the use to be made of it. Professionals from various fields work to identify the best way to develop spaces while taking care of the natural areas they contain. In this way, they can recommend the best place to build houses, parks, bridges and other structures without affecting the animals, plants and people living in the area, protecting them from pollution and habitat loss (CU, 2022).

To make a good design of our territory it is important to take into account some aspects. The first one is that we do not live alone, but share the space with other people and other living beings that have needs, just like us. The next is to accept that there are limits in the environment, such as the capacity of the soils to produce food, and the availability of water, as well as the capacity to process the waste we produce, among others.

Designing a space demands a collective action that helps us to focus our attention on the future we would like to see, which implies engaging in a process of collaborative creation, reaching an agreement on what we value about a place, and setting the intentions we have to develop a place that sustains and regenerates itself. This vision will be important because our perspectives will influence our behavior, the technologies we use, and the way we use the natural resources we have, for in design there is intentionality expressed through the interactions of the ecosystem of which humans are a part (Wahl, 2020).

The design of the place we want to live in must be oriented towards regenerating the pattern of interdependencies that maintain the social and natural systems integrated in social-ecological systems, in such a way that allows us to open our senses to observe what is happening around us, adapt to changes and be resilient in the process. This implies working with a system approach, seeing the totality or integrality of a space, recognizing the contexts and the history that has led our communities to be what they are today, identifying the limits of production of a place, the cycles that occur in it and dreaming about the future we want by analyzing the potential we have in order to achieve what we have designed by working collaboratively- all of this with the goal of improving the quality of life of all the inhabitants.

Another issue to be taken into account when redesigning a space is the expansion of cities or populated areas. We must not forget that cities are in permanent growth mainly due to the exodus from rural areas to urban areas due to lack of work, study opportunities, personal growth, etc. In this sense, cities grow in a disorderly manner and generally begin to expand towards the peripheral areas in the form of slums, ghettos or shantytowns. This disorderly growth makes new services, infrastructure and road networks necessary to meet their needs. Population growth can be studied through censuses carried out in each country (for example, the National Institute of Statistics -INE- in Uruguay). The casuistry will depend on each city, since there are many countries with high population growth, others with stable population and some in which population growth has decreased. Such is the case of São Paulo (with 1.8% growth per year in the 1990s) and Montevideo (with an aging population and low birth rate), whose population has decreased and then increased slightly again in the last three population censuses: 1996, 2004 and 2011 (INE, 1996, 2004, 2001).

The decade that runs from 2021 through 2030 has been defined as the Decade for Ecosystem Restoration by the United Nations. The objective is to reverse the degradation of ecosystems over the years in order to recover their functionality, improving their productivity and their capacity to meet the needs of society. This can be achieved by allowing the natural regeneration of ecosystems or with concrete actions that promote reforestation, the cleaning of rivers, lagoons, and the recovery of soils for agriculture, for example. This activity will be important to know the students´ desires in terms of the territory in which they live and to guide the appropriate actions to achieve such desires.

Guiding Research Questions

- Do we like where we live?
- Why do we like the place where we live?
- Could the place we live in be any better?
- What would we like the place where we live to be like?
- What things would we like to enhance or expand and what other things would we like to eliminate or at least take out of town?
- What SDGs can we relate to the new space design?

Scientific Concepts

- Land cover
- Land Use
- Map
- Sketch

Materials and Tools

- Paper
- Colored pencils
- Empty egg shells (optional)
- Playdough (optional)
- Lego applications such as Blockcad and others (Minecraft, etc.)

What to Do and How to Do It

Beginning

- The teacher and students choose either a place in the city or the entire city to redesign. They may also want to create a new space that is not found in their city.

- On a sheet of paper, students make a sketch of the different types of cover that exist in the chosen location. It should be remembered that a sketch is a simplified representation of a place without taking into account proportions or measurements. To draw the sketch, the cover categories in Table 1 can be used. To represent a type of cover, they can draw blocks, paint them with the suggested colors and associate them with a number of the MUC code.

Table 1:
Types of land cover that can be found in a city

Type of Cover	Color	MUC
Houses and residential buildings	Pink	91
Roads and highways	Purple	93
Industrial and commercial areas	Red	92
Agricultural areas	Orange	81
Parks and gardens	Olive green	82
Forests	Petroleum green	0
Seas	Blue	72
Rivers, lakes, lagoons and freshwater wells	Light-blue	71
Pasture areas	Yellow	4
Unvegetated soils or deserts	Gray	5
Farms	Light-brown or beige	813

Development

- Looking at their sketches students individually write ideas on small sheets of paper of how they would like to see their environment. For example:
    - I would like to have more green areas
    - I would like to have chickens at school
    - I wish there were flowers in the courtyard
- Next, the teachers collect all the sheets of paper written by the students, mix them up and distribute a certain number of papers to each student.
- Teachers will place on the board a table (Table 1) to separate the main ideas raised by the students.

Table 1
Students' ideas about where they would like to live

Agreed	Neutral	Disagree

- The students are invited to place the papers under each of the headings.
- Next, the ideas in the column of the "Disagree" statements are discussed, the students are asked why they disagree with the ideas posed, and their opinions are noted for further analysis.
- For a moment, the column of "Neutral" statements is set aside and the statements in the "Agree" column are discussed.
- Based on the first sketch prepared by the students, they are asked to say where they would like to place each statement and seek to justify their answer by appealing to one of the SDGs.

- Next, they are asked to design a new sketch on a poster, adding the new elements. This would be their new space. If they want to do something nicer, they could use eggshells to simulate houses and the playdough to mold their new spaces. This way they can have a 3-D model of their new place to live. They can also design it directly in Blockcad (the older ones), which is an application for designing with legos in a 3D plan, or some other similar estructure.

Closing

- Students are asked to look at their new space and give feedback on whether they like the way it looked.

- Students then decide which space they would like to start redesigning. If there are several ideas, like-minded students should be grouped together and put together a commercial about their chosen location using appropriate language to communicate their decision to the public. They are to imagine that they will communicate their proposal via radio, television or a social network.

- Finally, it is decided which space they would like to start building and how by voting.

- An alternative idea to close the activity is to make a mini school fair exhibiting the work of all the students, socializing with the rest of the educational community and sharing what the imagined school/space/city would be like, using different techniques: posters, models, 3D design, etc.

Frequently Asked Questions

<u>Is a sketch the same as a map?</u>

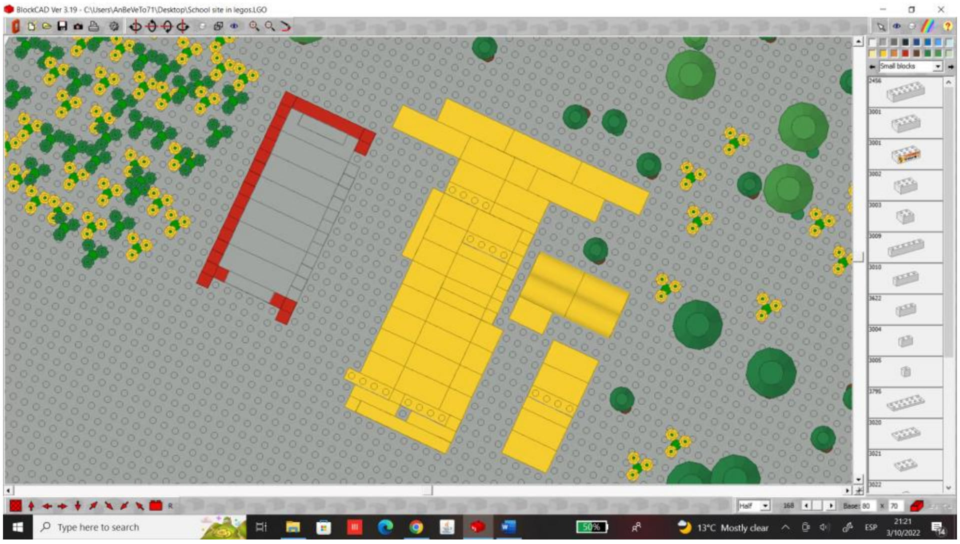
No. On the one hand, sketches are simple representations of a territory, generally made freehand, with simple strokes and usually without very clear proportions or scales, and generally used to highlight some aspects of a place. On the other hand, a map is a two-dimensional representation of a place, respecting the relationships of the elements in space. This means that maps take into account the dimensions and scales of the places that are represented. Maps always have a clear orientation, indicated by the North arrow, a legend and a map scale, and many include coordinates (numbers that represent the latitudinal and longitudinal location of a place). There are some maps that include contour lines to represent the relief of a place.

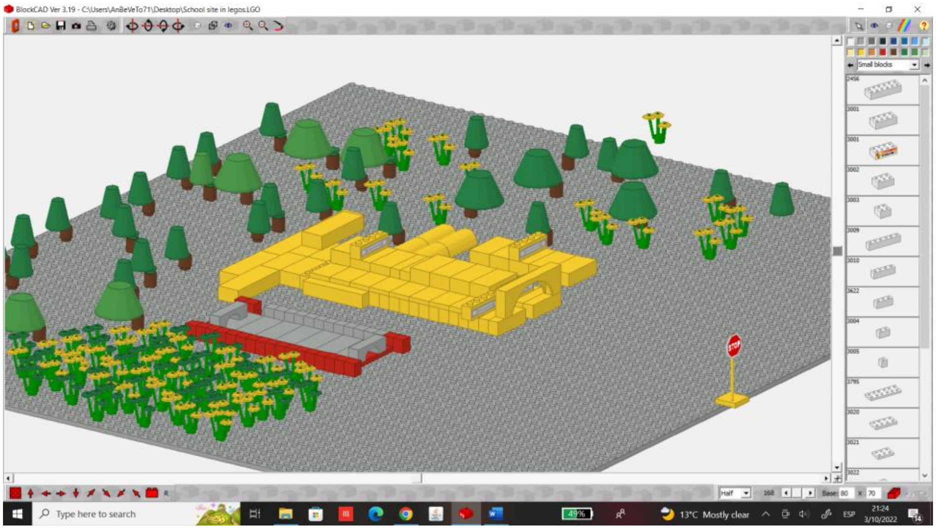
<u>Is land use and land cover the same thing?</u>
No, land cover is everything that covers the surface of the planet, while land use is characterized by the activities that people carry out on a given type of cover to maintain or change it, in order to satisfy their basic needs.

<u>What is the MUC?</u>
MUC stands for the modified land cover classification code of a classification proposal put forward by UNESCO. This system follows international standards with appropriate terms organized in a hierarchical structure of integrating levels that are represented by numbers up to 4 digits. Within this system, each land cover type has a class that is mutually exclusive from another, i.e. there is only one class for each land cover type.

<u>Can we use any color and number to represent the types of cover?</u>
It is advisable not to, since when comparisons with other schools and other countries are to be made, it is important to keep a harmonized or agreed code among all. This is why it is recommended to use the MUC code to classify the different types of cover, while the colors are the result of an adaptation proposed by the European Union's Corine Land Cover program.

Example of a school property designed in BlockCad in different perspectives:





Suggested Resources

- Exploring Earth: Land Cover: This is a page that offers didactic resources to visualize how the different types of land cover interact. https://bit.ly/3qqBcE0
- CORINE Land Cover Color Code proposed by CORINE Land Cover https://bit.ly/3TWeJMC
- GLOBE Program MUC Guide https://bit.ly/3wYkhMV
- Programs for design with Legos: https://blockcad.uptodown.com/windows / http://blockcad.net/proglego.htm
  A Chrome experiment with LEGO: www.buildwithchrome.com

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Development and use of the densiometer

GLOBE		Associated SDG	Type of Activity
Sphere	Protocols		
Biosphere	Biometry Land Cover Classification Tree Height	15: Life on Land 13: Climate Action	Exploratory

Overview

Canopy cover measures the percentage of an area covered by the vertical projection of the tree canopy. There are some techniques that are used to measure this projection, the use of the densiometer being one of the most commonly used. Through this activity a densiometer will be made with elements that are easily found at home and are inexpensive.

Time

30 minutes

Prerequisites

None

School level

Primary and Secondary School

Purpose

To make a densiometer using low-cost materials.

Student Outcomes

- Students will describe a densiometer and explain its uses
- Students will build a densiometer using low-cost materials

Background

Tree canopy cover influences different processes in ecosystems. This is even more evident in forests, where trees influence energy balance, habitat availability and productivity. The measurement of cover is included in many studies describing ecosystems (Newete et al., 2022). There are numerous methods and tools designed to measure canopy cover, each with varying accuracy and precision. Many of the instruments used are based on the assessment of the vertical projection of tree canopy above the trees, so the greater the angle projection, the greater the overestimation of canopy cover may be (Cook et al., 1995).

The most commonly used instruments to measure canopy cover are convex and concave spherical densiometers, which are basically mirrors with about 96 dots reflecting the tree canopy. The number of dots that are over a tree canopy is equivalent to the canopy cover percentage. The GLOBE Program has developed an adaptation of this densiometer to calculate the percentage of dots that are crossed by the tree canopy along a transect or assessment line.

Guiding Research Questions

- How could we measure tree canopy cover?
- What is a densiometer?
- How can a densiometer be made?

Scientific Concepts

- Densiometer
- Tree Canopy

Materials and Tools

- Toilet paper cardboard roll, paper towel or aluminum foil roll
- Dental floss
- Transparent adhesive tape
- Scissors
- ¼" washer or screw (if you don't have any of these items, the ring of a key ring may be used)

What to Do and How to Do It

- ***Beginning***

    - Teachers take their students near a tree and ask them how they can measure the area of the tree canopy. In this part it is important to give the students all the time they need to develop their creativity or to encourage group work.

    - All the ideas put forward by the students are noted and the simplest techniques are selected for implementation.

    - Using the selected techniques, the students are asked to measure the tree canopies.

    - Then, the teachers ask their students whether the results obtained are the same using the different methods selected.

- ***Development***

    - The teacher introduces a densiometer and explains what it is and what it is used for to the students, proposing them to make their own, using the materials in Figure 1 and following the steps below:

        - Every student takes the roll of paper and makes two slight cuts forming an X with the help of the scissors. These cuts should be very small, about 2 mm (Figure 2) and will be used to attach the dental floss that will cross over the top of the cardboard roll.

Figure 1: Materials for making a densiometer

Figure 2: Lateral cuts with the scissors on one end of the cone

- The student takes a piece of dental floss and crosses an X making sure the floss will be secured in the roll cuts (Figure 3).
- The floss is secured with transparent adhesive tape.
- Next, the washer (ring or screw) is attached to a piece of dental floss of about 20 cm long as if it were a necklace, then the ends of the floss are attached to the cardboard roll with adhesive tape.
- Then, the student decorates the outside of the densiometer in any way he/she likes.

Figure 3: Densiometer made by the students. The light blue stripes are the adhesive tap strips that attach the thread to the densiometer.

- ***Closing***

  - The students present their decorated densiometers and then start to use them to measure the tree cover.
    - To measure the cover the students take the densiometer with one hand and raise the arm vertically towards the tree canopies. it is important to make sure that their arm is fully stretched and that the washer is perpendicular (straight) towards the observer's face (Figure 4).

Figure 4: For the use of the densiometer the observer's arm must be fully stretched and the washer must remain perpendicular to the observer's face.
Source: GLOBE Program

    - The observer can see through the paper roll and find the X mark as a point of intersection that has been made with the dental floss.
    - If tree branches or leaves meet in the point of intersection, a positive sign (+) for cover is marked.
    - If the branches or leaves of the trees are only on one side of the densiometer , a negative sign (-) for cover is recorded (Figure 5).

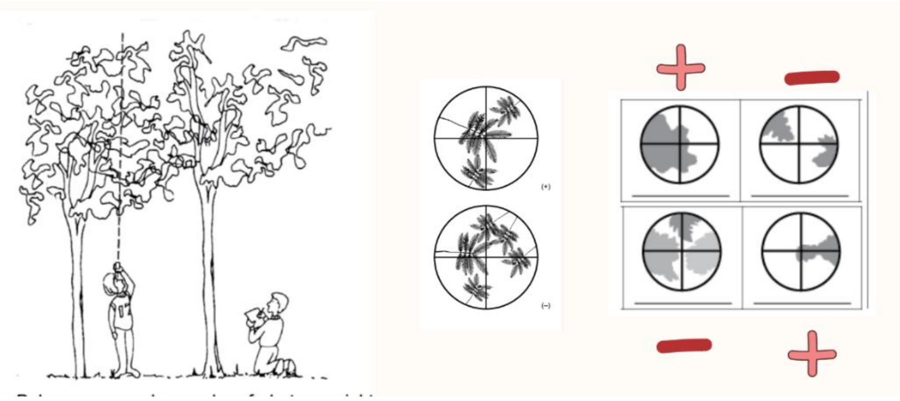

Figure 5: Observations with the densiometer; attention needs to be paid to when it is marked positive (+) and when it is marked negative (-) for cover.
Source: GLOBE Program

  - At the end of the activity the students discuss the experience with the densiometer and can also set up a small art exhibition to display the decoration of their densiometers and the pictures of the trees they evaluated.

Frequently Asked Questions

Is it possible to use something more durable than the cardboard paper roll to make the densiometer?
Of course it is; you could use a 2" diameter plastic tube for more durability and rigidity.

What if I don't have floss or washers at home?
These materials can be replaced by a piece of very fine wool, embroidery thread and any hoop that is not too big.

Suggested Resources
Video to make the densiometer: https://bit.ly/3R4ramL

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Ecosystem doctors

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Atmosphere	Temperature Precipitation	15: Life on Land 12: Responsible Consumption and Production 4: Quality Education	Exploratory
Biosphere	Green-Up Green-Down Land Cover Classification		
Pedosphere	Soil pH Soil Fertility		

Overview

Ecosystems present different characteristics according to the place where they are located, depending on the influences they receive from biotic, abiotic and social elements at a given time. When the composition or the relationship among these elements is altered, environmental problems can occur that often result in an alteration of the services provided by the ecosystems to meet the needs of people. Through this activity, students will describe an ecosystem and identify potential alterations in the elements that compose them.

Time

60 minutes

Prerequisites

To have completed at least two of the protocols related to this activity.

School level

Secondary

Purpose

To identify all the elements of an ecosystem and diagnose the existence of potential environmental problems

Students Outcomes

- Students will explore an ecosystem in order to identify the main elements that make up the ecosystem and recognize problems that have arisen in them
- Students will define the concept of ecosystem in their own words
- Students will elaborate a diagnosis of their ecosystems
- Students will make a proposal to improve or maintain the conditions of their ecosystems

Background

Ecosystems are spatial and temporal units where we can find living beings interacting with each other and with the environment that surrounds them (Mazparrote and Romero, 2020). Have you ever heard of ecosystem doctors? Well, this is the name given to the group of scientists who are dedicated to conserving and restoring ecosystems to ensure that plants, animals, water, soil and many other elements of the environment are in good condition; that is, functioning properly.

Many ecosystems have been modified by human activities, which end up causing environmental problems. In this regard, environmental problems can be defined as the negative conditions that have occurred in the environment, either by the alteration in the composition of any of its variables or by a bad relationship of humans with the environment. In this sense, it is important to identify the environmental problems that have occurred in an ecosystem in order to plan the steps to follow for their solution.

When we go to the doctor, the first thing he/she does is ask his/her patients for their name, their age and why they have come to visit him/her. In the same way as ecosystem doctors, the first activity will be to identify the ecosystem, where it is and what are the "symptoms" it presents to need the doctor. We hope that this activity will be useful to begin to have contact with the environment that surrounds the students.

Guiding Research Questions

- What is the type of ecosystem in which we live?
- What are the problems with our ecosystem?

Scientific Concepts

- Ecosystems
- Conservation
- Environmental problems

Materials and Tools

- Pencils
- Color Pencils
- Paper

What to Do and How to Do It

- ***Beginning***

    - Students, with the help of their teacher, pick an ecosystem of their choice that is close to their school so that they can visit it.

    - Working in groups, the students make a list of everything they like about the selected place and what they would like to improve.

    - Then, the students go to the selected location.

- ***Development***

  - Once the students are at the selected location, they describe all the types of cover it has in a range of approximately radius 30 m around it, considering the 4 cardinal points. Figure 1 can be used as a guide to complete Table 1.

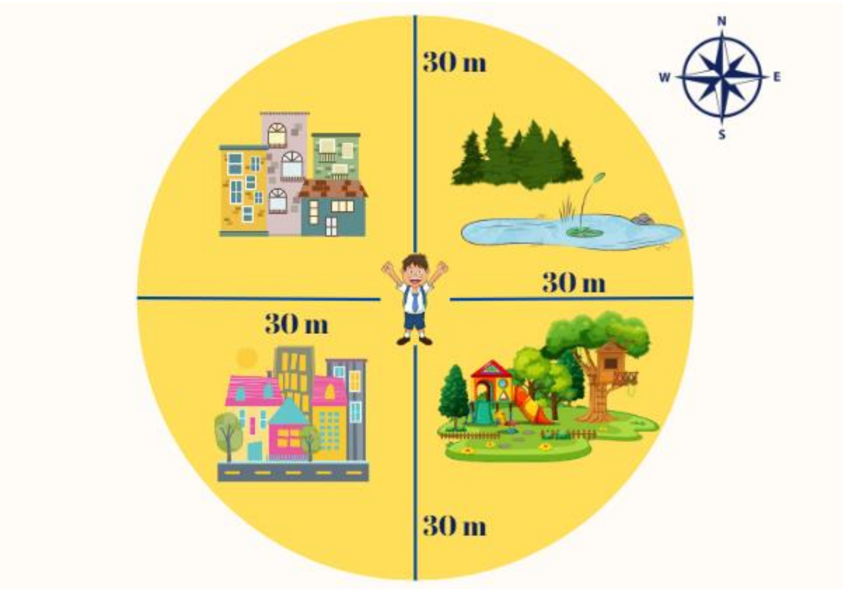

Figure 1: Representation of an ecosystem to be assessed

Table 1 Description of the main elements of the Ecosystem

NE	SE	SW	NW	Elev	Lat	Long	Average T of the place (warmest and coldest month)	Annual cumulative rainfall
Trees	Park	Houses	Houses					
Lagoon								

Note: NE, SE, SW and NW are the cardinal points that can be seen in Figure 1. Alt. represents the altitude at which the ecosystem is located, while Lat. is the altitude and Long. represents the longitude.

  - With the description derived from Table 1, students can detect the type of ecosystem they are describing based on its cover type. To do this they can use the MUC code, or at its simplest level, the Table 2 as a guide.

Table 2
Description of the types of cover according to the GLOBE Program

Type of cover	Description	MUC Code
Closed forests	Trees with an average height of 5 m, with intertwined canopies covering at least 40% of the area	0
Closed evergreen forests	When the leaves never fall off the trees	01
Closed deciduous forests	When the leaves of more than 50% of the trees fall off at some time during the year	02
Wooded area	Trees whose canopies never touch are also called open forests	1
Evergreen wooded area	When the leaves never fall off the trees	11
Deciduous wooded area	When the leaves of more than 50% of the trees fall off at some time during the year.	12
Dry forests	When trees grow in arid areas	13
Shrubland	When the shrub canopies (small woody plants whose branches grow from the base) cover at least 40% of the space. Consider shrubs taller than half a meter.	2
Dwarf shrubland	When shrubs less than 50 cm in height cover at least 40% of the space.	3
Herbaceous vegetation	When more than 60% of the space cover is covered by grasslands and herbs	4
Small grasses	Dominance of graminoid plants, or grasses (elongated leaves and parallel veins) less than 50 cm high.	43
Broadleaf weed	Dominance (more than 50%) of broad-leaved herbaceous plants where a midrib and secondary veins can be recognized. Many of the flowers fall into this classification.	44
Soil without vegetation	Soil with less than 40% vegetation cover with a limited capacity to support life (often due to lack of water). It is common to find fine soil, sand or rocks.	5
Wetlands	At least 40% of the area covered by estuaries, marshes, mangroves, wetlands. These are areas saturated with water	6
Riparian wetlands	Wetlands adjacent to a freshwater channel	61
Estuaries	Wetlands adjacent to a intertidal zone	63
Lake wetlands	Wetlands surrounding open water (e.g. ponds and lakes) which have a size greater than 1 hectare in size and more than 2 meters deep.	7
Open water	Lakes, ponds, rivers and oceans. All these bodies of water are more than 2 m deep and more than 1 ha in size.	71
Lakes, lagoons and rivers	It includes fresh open water	72
Sea	Salty open water	8
Green areas	When the soil is covered with more than 60% of non-native cultivated species. These are areas developed by people	
Agricultural areas	When the soil is used for different crops	81
Non-agricultural areas	When the soil is destined for gardens, parks, golf courses, etc.	82
Urban areas	When more than 40% of the land is allocated to areas developed for residential, commercia, industrial or transport uses.	9

- Then, based on the temperature and precipitation data, the location of the site and the literature review, students will be able to detect the climate type of the site. They could also use the Köppen-Geiger climate map (Figure 2).

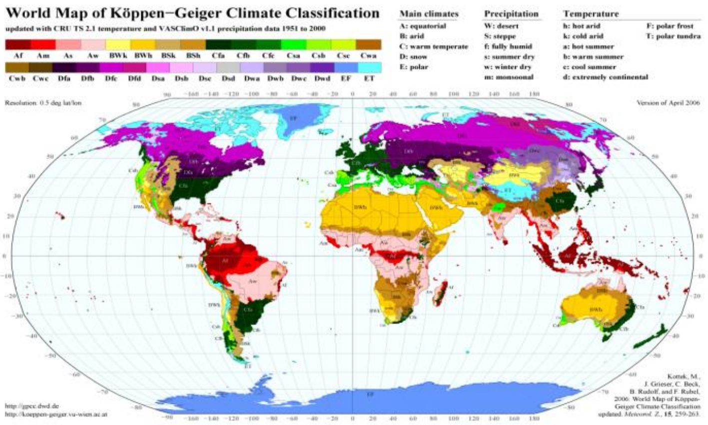

Figure 2 Köppen-Geiger global climate classification.
Source: http://koeppen-geiger.vuwien.ac.at/

- Students describe the state of the ecosystem based on a quick diagnosis by filling in Table 3. Analyzing their observations, they communicate their evaluation result in their own words. With their analysis, students should deduce whether the ecosystem is in good condition or whether some aspect of the ecosystem needs to be improved.

Table 3
Ecosystem Diagnosis

Plants found	**Animals observed**	**Check all that apply and comment**							
		Houses	Solid waste	Clean water	Traffic and noise	Clean plant leaves	The birds can be heard singing	There are insect sounds	There is sewage or bad smells
Evaluation Result									

- ***Closing***
  - Based on their diagnosis, students make a proposal to improve or maintain the analyzed ecosystem in good condition (Table 4).

Table 4
Proposal to maintain or improve the ecosystem

<table>
<tr><td colspan="5">Name of the ecosystem doctor:

Ecosystem Type

Type of climate:</td></tr>
<tr><td colspan="5">Diagnosis: Do you think the ecosystem is in good condition or does it need improvement?</td></tr>
<tr><td>Causes of the problems encountered:</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Prescription: What do we think could be done to improve the ecosystem?</td></tr>
<tr><td colspan="2">Additional analysis</td><td colspan="3">Treatment time</td></tr>
</table>

Frequently Asked Questions

For a more detailed determination of the ecosystem, can we follow the GLOBE Program Classification protocol?

Of course, that would help a lot to have a proper classification of the type of ecosystem the students are describing.

Can we apply the GLOBE protocols we know to improve our description?

This would be the most advisable. For example, you could apply atmosphere protocols such as temperature or precipitation, and you could also use water transparency and soil pH and fertility protocols, for example.

Suggested Resources

- GLOBE Program MUC Field Guide: https://bit.ly/3wYkhMV

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Ecosystems tell us stories

GLOBE		Associated SDG	Type of Activity
Sphere	Protocols		
Biosphere	Land Cover Classification Phenology	15: Life on Land 13: Climate Action	Communication

Overview

Stories are remembered, stories connect and that is why they can be a very good educational tool to improve students' understanding of facts or aspects that we would like them to know. Reconstructing the history of a place helps to understand why it is the way it is and, based on that, to design the future that is expected. With this activity, students will reconstruct the history of a place and dream its future using local observations and techniques such as storytelling and stop motion.

Time

60 minutes

Prerequisites

None

School level

All

Purpose

With this activity, students will detect the changes that a place has gone through to become what it is today and will document the changes that are happening today to dream the future scenarios they would like to see in the selected site.

Student Outcomes

- Students will describe the most important historical events in their community
- Students will record the changes that some element of their ecosystem goes through over time
- Students will construct a story from real events in their ecosystem and observed changes to plan for the future they would expect to see in the place where they live

Background

In general, scientific topics are usually difficult to understand. Most of the times this happens because they are presented as a collection of facts with a lot of information that must be analyzed at the same time. This does not facilitate learning on the part of the student, since a great memory and reasoning capacity would be necessary for many elements in a short time (Negrete and Lartigue 2004).

According the above mentioned, storytelling is considered a powerful educational tool because it improves the understanding of a series of facts, transforming reality into a sequence of events (with cause-effect analysis) that includes emotion (Rowcliffe,2004). Writing stories... "helps the writer consolidate ideas and stimulates creativity, encouraging the development of new hypotheses and the creation of new challenges"... (Mantas, 2016).

In this regard, a story could be defined as.... "a narrative unit that can fix the affective meaning of its component elements... by orienting our feelings about its content" ... (Peterat and Egan, 1988). This emotional connection to the facts makes a story easier to remember and therefore helps to enhance the learning of what is told.

Storytelling and science have things in common: they both need a narrator (observer), a story (connecting the facts through cause-effect analysis about the most important observations, facilitating their incorporation within a context) and an ending (results and conclusion). Good stories allow us to connect things and to discover what is going to happen in the future step by step (scene by scene), something that is interesting for our memory. Stories are not only facts, they are also creation, inspiration and fun. It is important to remember that some facts stay in our mind longer depending on how exciting they are.

Ecosystems, defined as spatial and temporal units where living beings interact with one another, as well as with the abiotic environment that surrounds them, are characterized by a constant flow of energy and a cyclical movement of nutrients. An ecosystem is an open system in which there are inputs and outputs of energy that ensure its stability and permanence over time (Starr & Taggard 2004; Odum & Barret, 2006). Energy flow and nutrient cycling make it possible for ecosystems to change over time. Sometimes these changes are gradual and sometimes they occur from one moment to the next (Folke, 2006). Recording these changes reveals a lot about a place and helps us know what we might do to redesign the space we would like to live in. Ecosystems tell us stories and that is why the technique of storytelling can be of great help to connect us more with the environment in which we live.

Guiding Research Questions

- What are the changes that the place where we live has gone through in the last 10 years?
- How long does it take to change some aspect of the ecosystem in which we live?
- What changes would we like to see in our ecosystem?

Scientific Concepts

- Ecosystem
- System
- Stability
- Emergency
- Resilience
- Transformability
- Adaptability

Materials and Tools

- Paper
- Pencils
- Camera
- Photographs of the place from any period
- Color Pencils
- Books of the local area

What to Do and How to Do It

- ***Beginning***
  - Teachers ask their students to bring in pictures or images they can find of the place where they live.
  - The students in groups share opinions about the photos they brought, analyzing whether the locations remain the same or have changed over time.
  - Next, the class identifies a place in the school or city that they like best and justifies their choice.

- ***Development***
  - The students ask their parents and grandparents about what the chosen place was like before and take notes on what they gather from older people.
  - Students then assemble a story of the place they chose. The following sequence of steps is suggested for this purpose (Richie et al., 2008; Norris,2020).
    - <u>To decide what they want to achieve with their story</u>: What is their goal?
      - To motivate?
      - To persuade listeners to do something?
      - To report?
      - To entertain?
    - <u>To identify the most important message they want to convey and the main characters of the story.</u>
      - What relevant information did they find about the place?
      - What important data supports the information?
      - Will the main characters represent local people? Or will they be local plants or animals?
    - <u>To identify the audience for the story:</u> Who are they? What do they do? Where do they spend most of their time? What places do they visit to entertain themselves?
      - Schoolmates?
      - City neighbours?
      - All of them?
    - <u>To design the plot of the story:</u> For this they can use a story arc (see suggested resources), which is the basis of many of the stories known.

- The beginning: In this part it is very important to connect with the audience. For this the students can start with the motivation to tell the story, involving the audience "...Remember when..." starting with something known by everyone will help, it will set the stage for what follows. In the beginning it is important to say where the story takes place, that is to describe the setting.
- Presentation of the issue: To tell the audience what is happening with the place they are presenting. What has happened to it in the last few years? Has it changed? How has it changed? "... over time this place stopped having green areas and now there are not enough plants...". Data can be used here. Data to be meaningful must be compared to things the audience can understand.
- Failed attempts: To say if there have been any problem-solving initiatives that did not work well. Some metaphors can be used here to categorize, associate or infer information.
- The solution: Based on the story put together, to converse with the audience about what they would like this place to be like, contrasting the ideas with some facts or examples from other places. This process enhances metacognition.
- The end: The students can establish some agreement about how to start transforming their selected place the way they want.

- As students tell their stories, they can use photographs of the place or images to help them give more meaning to their words. To work on their images, students can use the stop motion technique. This is a technique that allows them to make static objects appear to move by making a sequence of photographs. Through this technique they can create stories.
  - The students choose a special place and create a photo shooting station '.
  - The students take photographs of any element of the ecosystem at the same time every day and from the same angle for a month.
  - They animate the photographs using video programs. Some are suggested in the Resources section.

- ***Closing***
  - The students present their stories using a socio-drama. They need to remember that socio-dramas are performances to showcase an aspect of reality using gestures, actions and words. For the socio-drama they only need to choose the topic to be represented and have the group members talk about the topic, what they know about it and how they live and understand it. Finally, they create the plot by assigning roles to each person in the group.
  - The students make an exhibition of sequential photos and/or videos to show the changes they captured of the ecosystem.

Frequently Asked Questions

What if we don't identify a place to take pictures anywhere near the school to record changes?

You can plant some seedlings in pots and take photographs to see how they grow over time, document the changes they go through from germination, and tell their story.

Why do we talk so much about stability in ecosystems and why is it so important?

Above all, ecosystems are systems: a set of biotic and abiotic elements that related to each other in a coherent way help to form a whole. All these elements must have the ability to regulate each other, so that they can cope with disturbances and keep functioning properly (this is stability).

Do ecosystems always remain stable?

Ecosystems always tend to be stable. However, this does not mean that they stay the same. Stability is dynamic with small changes that allow for novelty. When new components appear in the system, often times as a result of human actions, the possibility of new properties emerging in the ecosystem is greater. These properties can be positive or negative. The good news is that ecosystems are resilient (maintain their essence) to a certain level of disturbance.

What is resilience?

Resilience can be defined as the capacity of an ecosystem to absorb disturbances and reorganize itself as it undergoes change. The resilience of an ecosystem ensures that it continues to hold the same function, structure, identity and feedback as before the disturbance (Walker et al., 2004). If disturbances are very large, then ecosystems are transformed and, in the face of these transformations, the only thing left for living things to do is to adapt to the changes.

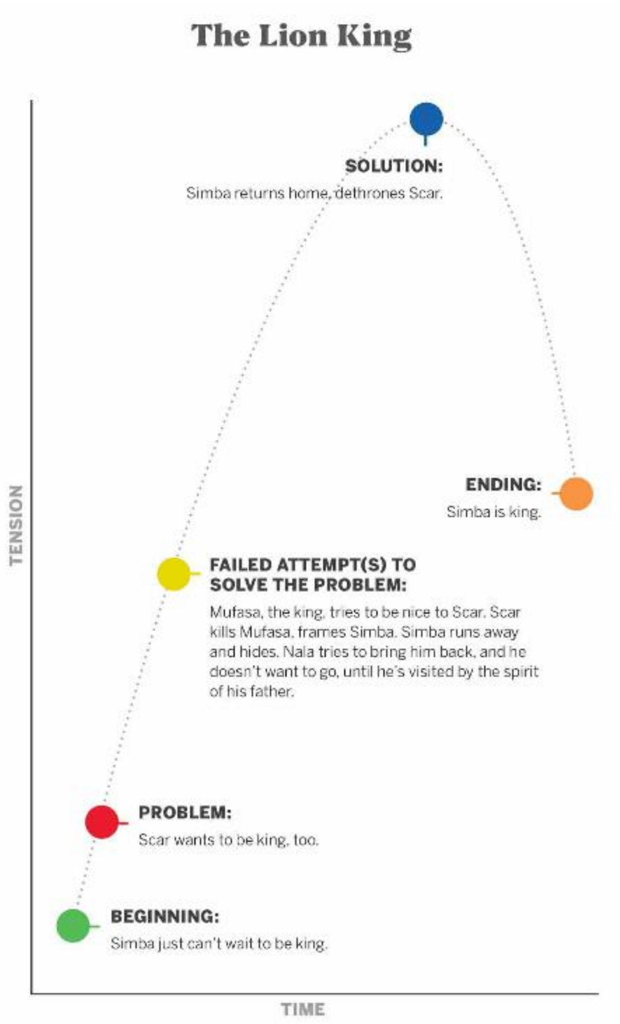
There are several activities proposed, do we have to do them all?

Of course not. A few options have been presented so that you can select the one that best fits your reality. On the one hand, maybe you just want to document the change of some aspect of your ecosystem, such as the growth of a flower, On the other hand, maybe you just want to reconstruct the history of a place by interviewing the elderly or, as a third option, you have decided to talk about the future you would like to see in the place where you live.

Resources

- Stop motion animation app: Stop Motion Studio - Apps on Google Play

- ***Plot Type Arc to elaborate stories***



Source: Norris, 2020

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Embroidering my pixel

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Biosphere	Land Cover Classification Biometry	15: Life on Land	Motivation

Overview

A pixel is the smallest homogeneous unit that is part of an image. We have probably heard the phrase: "The image is pixelated," when such image is not very clear and small blurry squares appear in it. Satellites capture images of the Earth's surface that are made up of pixels, which must later be described in detail by anyone studying land cover. Using the cross-stitch embroidery technique (or painting), students will be able to understand how an image is composed, applying what they have learned at their study site.

Time

50 minutes

Prerequisites

- To identify the cardinal points
- To know how to embroider or paint

School level

Last year of elementary school and high school

Purpose

Students will recognize that images are made up of a series of small squares called pixels that they will represent on canvas or paper, applying the concept learned to describe their study site.

Student Outcomes

- Students will explain the concept of pixel.
- Students will associate art with science to embroider (paint) an image composed of pixels on canvas or paper.
- Students will apply the concept of pixel to identify dominant image elements in a selected area.

Background

People often take photographs to remember special moments. Many of these photographs are taken when we travel somewhere, and we want to remember the landscapes we have visited. Our cameras can take pictures with a lot of detail, when we are only a few meters away from the photographed object; but they can also capture very distant images that barely allow us to recognize some elements of the landscape. The more distant the image we capture, the less detail of the landscape we can see.

If we enlarge a picture a lot, or zoom in on it, we can notice how it is composed of small squares that are losing resolution every time (sharpness). If we zoom in on them, we will only see squares of one color. These squares or squares of a single color (homogeneous image composition) are called pixels, minimum units of information in an image with a certain value (ESRI, 2022).

Earth observation (EO) is the collection of information about the Earth's physical, chemical and biological systems through remote sensing technologies, typically with satellites carrying imaging devices (EU Science Hub, 2022). In this regard, it is important to remember that, although we may not be very aware of it, we are being photographed from space by satellites that are on average at an altitude of 500 km or so.

The information generated by satellites is very important because it allows to study the climate (Fick et al., 2017), the land cover (Merlotto et al., 2012), the state of corals in the sea (Hedley et al., 2016), the surface temperature (Mantas & Xiam, 2021), among many other applications.

Land cover is one of the most studied variables. This is everything that covers the surface of the Earth, which can be natural or artificial (man-made) elements. The coverage of a place is generally expressed as a percentage. There are several studies that allow a classification of the type of cover found in a place, assigning it a code that allows its comparison through space and time. One such code is what we will call the MUC code (Modified UNESCO Classification), which will be applied throughout this activity to characterize pixels (homogeneous image elements) within a study site.

Guiding Research Questions

- What is the landscape like near our school?
- What elements dominate the landscape?
- How many pixels are in a photograph?
- What is the importance of pixel size?
- Is everything really the same inside a pixel?

Scientific Concepts

- Pixel
- Remote sensing
- Satellite
- Cover

Materials and Tools

- Fabric for cross stitch embroidery
- Color threads
- Needle

- Image to embroider in cross stitch
- Sheets of graph paper
- Pencils
- Colors or crayons
- Camera (you can use your cell phone)
- Compass (optional)

What to Do and How to Do it

- ***Beginning***

    - The teacher will ask the students to choose a figure to be embroidered in cross stitch or may show the student an embroidery that has already been made. From this image, the teacher will explain to the student how an image is made up of small squares (pixels) that add up to form a complete image.

    - Then, the students will recognize the elements of the image. For example, how many different colors there are and what structures make it up. If it were a flower, it would be made up of petals, stems and leaves. Each part takes up some space in the embroidery, representing a percentage of it. From this point you can better understand what the cover is.

    - Next, the students will explain what a pixel is and what cover means in their own words.

    - The teacher will show students a landscape and ask them to identify all the elements they can find in it.

    - Based on the students' answers, the teachers will explain that there are different types of elements that cover the surface of the earth: buildings, houses, lakes, pastures, forests, fields, etc.

- ***Development***

    - In a field visit, the students select a square area that will represent a pixel, this can be 10m*10m if the terrain is small, and placing themselves in the center of it, they will locate the cardinal points: N, S, E and W.

    - Using a camera, the students will take a picture towards each of the cardinal points, as well as towards the ground. Then, they will draw two diagonals in a SE and SW direction as if marking an X point on the ground.

    - From one corner of the square the students will walk along the diagonals and every two steps they will record their findings on a sheet of graph paper.

    - In order to record their findings, the students will use a numerical and color code, suggested in Table 1, which results from a simplification of the MUC code, while the colors have been standardized to the system used by the CORINE inventory for the land cover types. It is important to mention that there may be points with more than one number because they have more than one type of land cover.

Table 1
Land cover types according to and MUC code and suggested colors for its representation.

Cover	MUC Code	Color
Trees	0	Dark green
Shrubs	2	Light green
Grassland	4	Yellow
Barren lands	5	Brown
Water	7	Light blue
Cultivates lands	8	Orange
Built-up areas	9	Red

- ***Closing***
  - The students will analyze their drawings and identify which numbers are most common in the diagonals and which color dominates.
  - The teachers will ask the students what color they think their pixel would look like at 500 km altitude and consequently, they will be able to identify that that will be the dominant color.
  - The teachers will explain to the students that the element that stands out most is the one seen on satellite images.
  - Finally, teachers will ask students to evaluate the activity using the CASH (Conceptual, affective, surprising and helping) effective learning technique, which can be translated as follows: C (what concepts they learned), A (what they felt while doing the activity), S (what surprised them the most) and H (what they think will be most useful to them at the end of the activity).

Frequently Asked Questions

<u>What is remote sensing?</u>

It is the acquisition of information about an object without being in direct physical contact with it (at a distance) by measuring the radiation it reflects and emits at a certain distance. Remote sensors provide a global perspective and data on Earth systems to guide decision-making on the current and future state of the Earth (NASA, 2022).

<u>What is a pixel?</u>

The word pixel comes from the English word "picture element". It is the smallest element shown in an image that can be attributed some characteristics such as dimension, color, and intensity. A pixel is represented in a remotely sensed image as a cell in an array of data values (ESRI, 2022).

What are satellites?

Satellites are objects that orbit around a planet. These can be natural like the moon, but there are also many artificial man-made satellites observe our planet. The latter measure the amount of energy reflected from the Earth's surface, this information is recorded by special sensors and converted into images composed of "picture elements" arranged in columns and rows, called pixels. Each satellite has different pixel sizes. Satellites can have different pixel dimensions, which can be for example 30m x 30m for Landsat, 250m*250m for MODIS and 10m*10m for Sentinel. This means the smallest image unit in the area. However, we all know that in the field there are many smaller elements that occupy a percentage within that area, something that we can only see if we visit a certain area.

Can I work in smaller squares if I don't have large natural areas of 30 m x 30 m or 10 m x 10 m around my school?

Of course, what is important is to do the activity to allow the students to become familiar with their environment and know what a pixel is.

What if my students are very young and I don't want them to use embroidery needle and thread?

You can do the activity regardless, using colors and graph paper to simulate cross stitch patterns.

Resources

- USGS Satellite Imagery Page: EarthExplorer (usgs.gov)
- How to embroider a cross stitch step by step: guide to cross stitch - YouTube
- Suggested cross stitch gallery: bit.ly/3DY

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Herborizing plant diversity

GLOBE		Associated SDG	Type of Activity
Sphere	Protocols		
Biosphere	Land Cover Classification Biometry Green-Down Green-Up	15: Life on Land	Research

Overview

When you walk through a place, a great diversity of animals and plants can be found. In order to describe this diversity, there are several techniques. One of the best known is the collection of plant samples to preserve them in a herbarium and later determine their taxonomic classification. This activity presents a simple way to make a herbarium with the main plant species found in the study site selected by the students.

Time

50 minutes for species collection
10 minutes every other day to dry the plants.
100 minutes to set up the herbarium and determine species.

* The time may change depending on the number of species to be placed in the herbarium

Prerequisites

None

School level

All

Purpose

Students will collect plant species found around the school to create a herbarium and preserve a sample of the biodiversity around the school.

Student Outcomes

- Students will observe the variety of plants that exist in the environment
- Students will collect a sample of the plants found and preserve them for later determination
- Students will determine the genera and/or species to which the plant species found belong
- Students will create a herbarium with additional information that may be useful for further research

Background

The dictionary of the Royal Spanish Academy defines herborization as the process through which plants, leaves, fruits or seeds are sought and collected for later study (RAE, 2022). For this purpose, the collected plants must be properly dried and identified with their scientific name and common name. In addition to the name, it is important to record other information about the plants such as the place of collection, the date, the uses given and the name of the individual who made the collection. All species that have this information are placed in an orderly manner in a herbarium. In other words, a herbarium is a catalogue of the diversity of plants in a given place.

Determining the identity of collected plant samples is done on the basis of the characteristics of a group that shares a common ancestor. This group is called a taxon. The Table 1 shows how the taxonomy of the Kingdom Plantae or plant kingdom is organized, with its different groups and taxa.

Table 1
Taxonomy of the Kingdom Plantae

Taxon	Termination	Example
Kingdom		Plantae
Division	Phyta	Magnoliophyta
Class	Opsida	Magnoliopsida
Order	Ales	Magnoliales
Family	Aceae	Magnoliaceae
Genre	Always in *italics*	*Magnolia*
Species	Always in *italics*	*Magnolia grandiflora*

When a plant is found and its identity is not known, what is done is to determine it. Determination is the scientific process through which we come to know the scientific name of a species unknown to us but which was studied by taxonomists at some point in the past. Often times this term is confused with classification, which is the process through which a plant is placed in a certain taxon based on common characteristics. Classification is only done once for those species that are new to science, whereas determination is something that is done many times when researchers encounter species that they personally do not know. In order to determine the identity of a species, scientists use dichotomous keys (Alvaro-Alba, 2006) or images from other herbaria to compare the species found.

Through this activity, students will learn and practice plant collection and conservation techniques. At the same time, they will recognize the diversity of plants in their study site, thus improving their appreciation of the ecosystem around them.

Guiding Research Questions

- How many plant species are there in the school?
- What are the most common plants in the school?
- How can a plant sample be preserved?
- How does the name of a plant get to be known?

Materials and Tools

- A wooden press
- Cardboard, old newspapers and paper towels
- Jute cord or thick thread
- A pair of scissors
- A pencil
- Sheets of paper
- A needle
- Thread
- Cardboard paper
- Local plant guides

What to Do and How to Do It

- ***Beginning***
    - Teachers take their students out into the field and ask them to walk around the space and look carefully at the plants around them.
    - Then, the teachers ask their students if they recognise all the species. They will probably say no and this will lead the teachers to explain that it is important to have a collection of plant samples where the diversity found in that place is appreciated.

- ***Development***
    - The students will put together a herbarium and the first step will be for the teachers to explain to their students how to make a good collection of plants. To do this, the following should be taken into account:
        - To take old newspaper sheets and scissors to the field
        - To take a sample from the plants. They need to make sure to collect a sample that is as complete as possible. This should have leaves arranged along a branch and, if possible, keeping the flower, as for many species the flower is key to determining species (Figure 1)
        - It is recommended to make the cut with scissors and diagonally so that the plant heals the stem as well as possible. It is recommended to include the flower and fruit (if any, in the sample).
        - All collected samples should be placed between newspaper sheets for pressing later on.
        - For determination purposes, it helps a lot to take pictures of the whole plant and the environment where it grows.
        - Always remember to take a small notebook and a pencil to the field to record some data about the species collected and to establish a code to relate the sample with the environment where the plant was collected.

Figure 1: Herbarium plant sample
Source: Brazil REDFLORA

- Once the plants have been collected, the next step is to press the samples. For this it is recommended to use a wooden press. The press can be made with wood that comes in fruit crates, nailing the pieces of wood together, forming a grid and placing two sheets of cardboard inside them (Figure 2). Often times, when a wooden press is not available, thick books can be used instead.

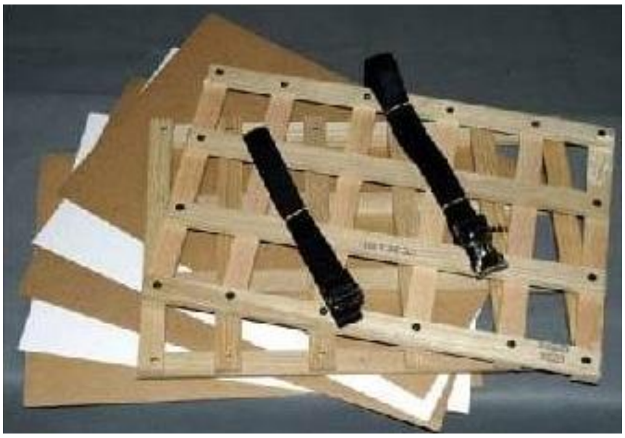

Figure 2: Wooden press for drying plants. These are usually 30 cm wide and 45 cm high.

- Next, the sheets of newspaper with the collected samples are placed inside the press and with the help of a rope, they are tied to the press to ensure that they will dry properly. This press can be placed on a heater (if available) or simply placed in the sun.

- Before tying the press, it should be checked that the plants inside the newspaper sheets are in good condition. The leaves should not be wrinkled and the flowers should be kept in paper towels to prevent them from being damaged.

- The paper should be changed every day or maximum every other day until the plants are dry.

- Once the plant samples are dry, they are removed from the press and sewn with needle and thread to a sheet of cardboard 30 cm wide and 45 cm high. For sewing it is important to secure the stems and branches. The leaves can be fastened with small strips of paper with rubber bands at the ends. Often times fishing line is used for sewing so that it is invisible. The plants are never glued directly onto the cardboard paper, as it is important that the plant can be given the opportunity to be replaced if the cardboard becomes damaged (Figure 3).

- Once the sample has been affixed to the cardboard, a determination label is attached. The label should contain basic information such as the scientific name of the plant, the name of the person who made the collection, the date, and some other information shown in Figure 4. To determine the species of the plant, botanical books, dichotomous keys, virtual herbaria, cell phone applications, or consultation with an expert can be used. Some suggestions for determination are given in the Resources section.

- Drawings made by the students can also be included in the herbarium to help them become familiar with the characteristics of the plants. This would be an activity that can be linked to art classes.

Figure 3 A sheet containing a plant sample, showing that the plants are attached by small strips of paper. At the bottom right is the label and to the left is usually an envelope with the florers placed inside.

Figure 4 Herbarium label

- ***Closing***
  - When finished, students place all the plant sheets in an album and make sure to keep it in a dry place, out of reach of moths.
  - Finally, the teachers give their students pieces of paper in the shape of leaves and ask them to write down what they liked best about making a herbarium. They might also ask them to write the name of their favorite plant species on the leaves.
  - The leaves written by the students are displayed as tree branches in the classroom. This will be the plant knowledge tree. Each time the students learn something new about plants, they can place new leaves on the tree.

Frequently Asked Questions

What happens if the plants are filled with fungus?
Change the leaves more frequently to prevent fungus. It helps a lot to place the press in the sun.

Could we complement the herbarium activity with the MUC Cover Classification protocol to describe the context in which the plant grows?
Please, do this! It would be a great activity and would help students understand the context in which plants develop.

Resources

Applications to determine plants***:***
- PlanNet: PlantNet Plant Identification - Apps on Google ***Play***
- iNaturalist: iNaturalist
- Google lens: Google Lens: Find what you see

Guides for making a herbarium:
- Manual of Curation and Preservation Techniques for a Weed Herbarium https://bit.ly/3eDYe7A
- Developing a Local Herbarium: A Basic Guide https://bit.ly/3BDpeNX

Dichotomous keys:
- Dichotomous keys for common ornamental species https://bit.ly/3ewxhCN
- Dichotomous key containing information about plants for primary https://bit.ly/3RT9uM0

Virtual herbarium:
- Herbarium of the National Autonomous University of Mexico. https://bit.ly/3cWHA2V
- Herbarium of the National Commission for the Knowledge and Use of Biodiversity https://bit.ly/3DhHXj5
- Herbarium of the Missouri Botanical Garden https://bit.ly/3TZPuco
- REDFLORA Herbarium - Brazil https://bit.ly/3xdxYaC

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Introduction to Phenology

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Biosphere	Land Cover Classification Green-Down Green-Up	15: Life on Land	Research
Atmosphere	Temperature Precipitation		

Background

Phenology studies the life cycle of organisms and how they respond to changes in environmental conditions, especially temperature, precipitation and light intensity. Phenology studies are very important because they are closely linked to the seasons of the year and the appropriate times to plant and harvest food. With this activity, students will analyze the stages of the life cycle (phenophases) in which plants are found, making an association between this information and the temperature and precipitation of a place.

Time

15 minutes per week for one year

Prerequisites

To be familiar with the GLOBE Program Air Temperature and Precipitation protocols.

School level

Last year of elementary school and high school

Purpose

To assess the qualitative changes of plants throughout their life cycle, considering the phases of flowering, fruiting, seeding and foliation, finding a relationship of these changes with weather variables.

Student Outcomes

- Students will explain the importance of climate elements (temperature and precipitation) in plant development.
- Students will evaluate plant phenophases.
- Students will compare the effect of climate on the development of different plant species.
- Students will infer the effect that climate has on plants in other latitudes, different from those of your school.

Background

Phenology is the study of the life cycle of organisms in response to seasonal changes (mainly temperature, precipitation and daylight hours) in a given location (Liang, 2019). The cycling of phenological events, or phenophases, such as flowering, fruiting, bird migration or animal reproduction is frequently used to define annual seasonal sequences (Bradley et al., 1999) For example: leaves fall in autumn, animals are born in spring, birds migrate in winter.

Phenology studies are critical to better understand the response of our ecosystems to climate change (Menzel et al., 2006). In this sense, monitoring the length of the growing and maturing season for many species is very important for society, as crops can be better planned to take advantage of the most productive seasons (Hatfield & Prueger, 2015). This is because the seasons of the year affect food production, the production of supplies for medicine and industry, having consequences on the economic development of a place (Rademacher-Schulz et al., 2014; Liang et al., 2017).

Throughout their life cycle, plants go through different phenophases, which can occur in a plant at the same time in different proportions. Studying the phenophases is important because it allows us to know the best time for pollination, the production of some food, when it is not good to go to the field in the case of pollen allergy, or what is the relationship among the phenophases of plants and their ability to regulate temperature, among other things, (Jochner et al., 2013).

The phenophase observation is enriched when it is accompanied by the observation of meteorological variables such as radiation, temperature, precipitation, humidity, wind speed and cloudiness, so the direct effect of some variables on others can be seen. With this activity, students will understand how to make observations of plant phenology and infer about the potential applications of their investigation results.

Guiding Research Questions

- In which month of the year do plants bear fruit?
- Do all plants flower at the same time?
- What is the fruit of the month?

Scientific Concepts

- Phenology
- Seasonality
- Phenophases

Materials and Tools

- Pencil
- Data sheet
- Camera
- Permanent markers
- Ruler
- GLOBE Plant Color Guide
- Marker tape or color wool

What to Do and How to Do It

- ***Beginning***

  - The teachers take the students to visit the plants in the school; if there are none, they can be encouraged to bring a pot or to plant some local plants.
  - The teachers discuss with their students about what time of the year they think the plants will have flowers or be able to bear fruit.
  - Each student adopts a plant that he/she will have to monitor to describe its different phenophases. When adopting a plant, the student must give it a symbolic name, which he/she will write down on an adoption certificate that will be given to him/her along with Table 1 to record his/her observations.

Table 1

Plant Phenophases Data Sheet

Phenophase	Yes	No
Leaf buds: (mention if dormant, swollen or opening)		
First leaves 25 - 50 % of the plant has new leaves		
Leaf growth: 50 - 100 % of the plant has mature leaves		
Color leaves: 25% or more of leaves changing color from green to yellow, red or brown		
Leaf fall: There is evidence that leaves are falling		
Flower buds: There are flower buds on plants		
Flower opening: 50% - 100% of flowers are open		
End of flowering: 95% of the flowers have fallen		
Green fruits: First fruits appear on plants		
Ripe fruit: 50 - 100% of the fruit is ripe		
Presence of seeds in plants		
Seed dissemination: There is evidence of seed dispersal in soils		

- ***Development***

  - The plant phenophases are evaluated every 15 days, taking into account the following indications:

Leaves

- Identify the leaf buds, marking some points on 3 or 4 different buds, if observed (Figure 1). Take into consideration that the buds can have the following conditions:

  - Dormancy (state of stopped metabolism and growth)
  - Swollen buds (the bud starts to grow)
  - Budburst (small leaves start to show in the bud)

Figure 1: Buds marked to assess their condition (top). Buds in a state of dormancy (bottom - right), swollen buds (bottom - center) and budburst (bottom - left).

- Once the leaf buds have opened, the length of each leaf can be measured using a ruler, not including the petiole (Figure 2).

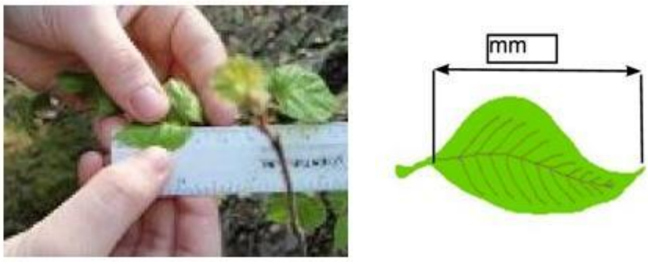

Figure 2: Measuring the leaves

- Measure the leaves until they stop growing. On the same plant, leaves stop growing on different dates; measure at least three leaves per plant.

- You can follow the growth of the leaves with the analysis of the coloration acquired over time; for this you can use the GLOBE Plant Color Guide (Figure 3).

Figure 3: Leaf color assessment according to the GLOBE protocols

- Assess the whole plant and determine the percentage of leaves that are in the following phenophases:
    - New leaves: 25 - 50 % of the plant has new leaves.
    - Leaf growth: 50 - 100% of the plant has mature leaves.
    - Wilted leaves: 25% or greater percentage of the plant has leaves that are turning from green to yellow, red or brown.
    - Leaf fall: There is evidence that leaves fall or come off easily with the wind.

Flowers

- The flower is the reproductive structure of angiosperm plants and is the main source of food for many insects. For this reason, it is very important to observe their presence; for this you can follow the following steps:
    - Observe the presence of flower buds
    - Check if 50% - 100% of the flowers are open.
    - Observe whether approximately 95% of the flowers have fallen or not.

Fruits

- It is the part of the plant that derives mainly from the ovary of the flower. The fruit is responsible for containing the seeds until they ripen and plays an important role in the dissemination of the seeds. Note the following:
    - Presence of green fruits
    - Presence of ripe fruits: 50 - 100% of the fruits present on the plant are ripe.

Seeds

- The seed is the part of the plant that houses the embryo of a plant. Note the following:
    - Presence of the first seeds on the plant
    - Seed Dissemination: Check for evidence of seed dispersal (seeds dropped on the ground).

- ***Closing***
    - The students discuss the results and compare the different phenophases their plants have gone through. It is important that they discuss whether the phases last the same length of time for all plants, and that, based on their results, they can come up with some research questions.

Frequently Asked Questions

- What if I don't notice changes in my plant with every measurement?
  Continue measuring, as many times plants are in a dormant or resting state waiting for the best time to develop at a faster rate.

- What exactly are phenophases?
  Phenophases are the different phenological stages or observable stages that animals and plants go through during the year in response to climate conditions. The most common phenophases in plants are:
    - Presence of leaves: green and dry
    - Presence of flowers: flower buds or fully open flowers
    - Presence of fruits: green or ripe
    - Presence of seeds: on the plant or dispersing
- Can I measure temperature and precipitation together with phenophases?
  Of course you can. This would be ideal and if you do not have a weather station, we invite you to record the temperature and precipitation data from the nearest weather station.

Suggested Resources

- Phenology Explained (in English) https://bit.ly/3xPH3qE
- Handbook of Phenological Observations https://bit.ly/3C718en

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Party of colors

GLOBE		Associated SDG	Type of Activity
Sphere	Protocols		
Atmosphere	Temperature	15: Life on Land 14: Life below Water 13: Climate Action	Cognitive
Biosphere	Biometry Land Cover Classification		

Overview

The energy that drives ecosystems comes from the sun. It encompasses a range of electromagnetic waves from shorter to high-frequency ones, such as gamma rays, to longer and lower-frequency waves, such as the radio ones. An important part of this electromagnetic spectrum that comes from the sun is the light waves. Visible light makes it possible for us to see and for plants to use photosynthesize to make food. Through simple activities, students will understand how solar energy reaches the Earth and analyze the electromagnetic spectrum as a source for satellite imagery.

Time

From 50 to 100 minutes depending on the experiments that are selected

Prerequisites

To know the basic elements of energy

School level

Secondary

Purpose

Students will understand what the electromagnetic spectrum consists of and will perform some simple experiments to recognize the reflection of light, as well as the processes that allow color vision and the generation of heat.

Student Outcomes

- Students will observe the visible light waves of the electromagnetic spectrum
- Students will demonstrate the processes of light reflection and absorption, as well as the effect of color on heat generation
- Students will explain the effect of light on different types of land cover
- Students will develop an experiment to observe the effect of color on plant growth

Background

Solar radiation reaching the Earth's surface has three main components: visible light (45%), shorter wavelength ultraviolet radiation - UV (10%), and longer wavelength infrared radiation (45%). Radiation is attenuated as it passes through the atmosphere layer surrounding the Earth. For example, UV radiation decreases in the ozone layer, while visible radiation is attenuated to a lesser degree as it passes through clouds and water (Odum & Warret, 2006; Audesirk, 2013). Infrared radiation, which emits heat, is absorbed and reflected back to the Earth's surface by greenhouse gases. Figure 1 presents the spectrum of electromagnetic radiation. Of all these wavelengths, the human eye perceives only a fraction between 360 and 760 nanometres, which corresponds to the visible spectrum (Mazparrote et al., 2020).

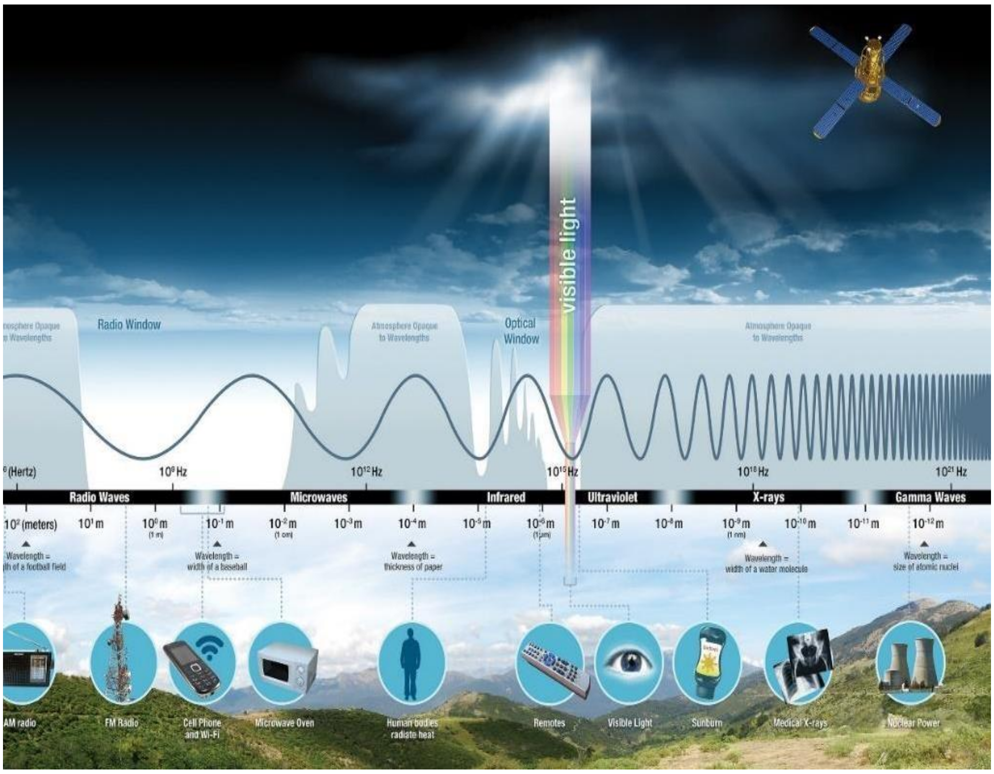

Figure 1: Electromagnetic spectrum
Source: NASA

Of the visible light spectrum, vegetation strongly absorbs blue and red light waves, as well as far infrared waves. However, plants do not have much affinity for green and near infrared, so the latter two waves are reflected and allow us to see green vegetation (Odum & Warret, 2006). On the other hand, a white surface reflects equal amounts of radiation from all wavelengths of visible light, similar to what happens with Newton's disk experiment.

Colors are also related to temperature. For example, white reflects 100% of radiation and absorbs 0% heat, while black reflects 0% radiation and absorbs 100% heat. Water also absorbs visible radiation along a depth gradient. For this reason, the deeper a water source is, the darker the surface looks.

In conclusion, it can be said that electromagnetic radiation from a surface is either a reflection (reflected light) or an emission (radiation emitted from the same surface) of light. The reflected light can only be measured during the day, while the emission can be measured at any time. Different types of surfaces, such as water, bare ground or vegetation, reflect radiation differently. This is a property utilized by remote sensing to obtain information about the Earth's surface from satellites. The reflected radiation as a function of the wavelength is called the spectral signature of the surface. The capability of satellites to distinguish among various spectral signatures is vital for their use in mapping, where the distinction among the different types of surface covering the Earth is essential (Brown & Harder, 2016)

Guiding Research Questions

- How does color affect plants?
- Which color absorbs the most heat?
- How do satellite images use colors?
- How can the way in which the light is reflected be verified?

Scientific Concepts

- Electromagnetic spectrum
- Light reflection
- Light absorption
- Remote detection

Materials and Tools

- Water
- Plastic bags or coloured cellophane paper
- Cardboard
- A stopwatch
- A mirror
- White, black, green, red, yellow, blue balloons
- 2 white sheets of paper
- A flashlight
- A magnifying glass
- Candle wick or thread
- Pens or indelible markers
- Acrylic paint
- 1 water thermometer
- Scissors
- A tub or small container
- Colored painted glasses: white, green, red, black, blue, yellow, black
- What to Do and How to Do it

- ***Beginning***

  - Teachers present a color palette and students choose the color they like best.

  - Each student communicates to his/her classmates what his/her favorite color is, associating it with elements observed in the environment. For example: "my favorite color is blue as in the color of the sky and the sea" , "my favorite color is green as the color of the leaves".

- Then, students are then given an explanation of the electromagnetic spectrum and decide which of the experiments presented in the following paragraphs they want to perform.

- ***Development***

a. *Reflection of Solar Radiation:*

- A tub of water is placed in an open space, preferably on a sunny day, and then a mirror is placed inside, as shown in Figure 2. The sun will reflect off the mirror and then project the light onto a sheet of paper, which the students place in front of the mirror. Students should then write down or draw the colors they see on the sheet of paper. This way the students will be able to see how the light is reflected with a spectrum of colors.

Figure 2: Experiment to observe the reflection and decay of light.
Source: Barrientos and Martinez, 2011

- Next, a mirror is placed in the container with water as in Figure 2, only this time the mirror needs to be covered with a colored transparent surface, such as cellophane paper, or a painted plastic bag with colored markers. If there is no sunlight, the students can use their cell phone flashlight as a source of light energy. Then students observe the color reflected in the mirror and make notes. The students change the color of the paper covering the mirror to see the effect of this change in light reflection.

- Then, it will be interesting to combine the colors of the electromagnetic spectrum of light to obtain white light. For this purpose, a simple version of Newton's Disk will be used (Figure 3). Newton's Disk consists of a circle painted with the colors of the rainbow in sections. This circle is spun at high speed so that the colors are visually combined, with the white light being observed at the end. This experiment helps to understand that white light reflects all colors.

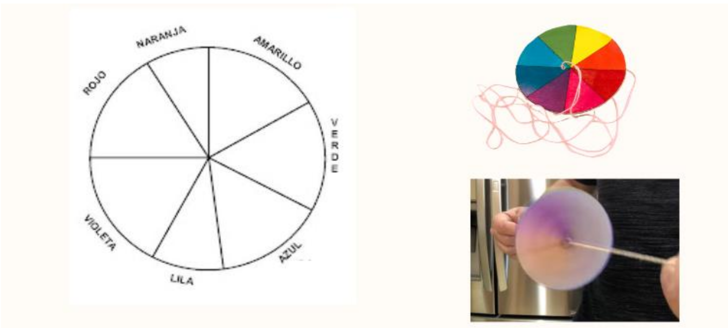

Figure 3: Newton's Disc

b. *Color and Heat*

- The way the electromagnetic spectrum is reflected and absorbed is important not only because it gives us a range of colors on our planet, but also because there is an effect of colors on temperature. Here are two simple experiments on this effect.

- The students place different colored plastic cups with water in the sun. After 40 minutes of exposure, they measure the water temperature in each cup, record the data and discuss the effect of color on the water temperature. They can also use the same material and color of cups, paint the water with different colored baking dyes for each cup, and see the same effect of color on the water temperature.

- On a sunny day, students blow up colored balloons (white, black, green, yellow, blue and red) and point a magnifying glass at them. With the help of a stopwatch, they count the seconds it takes to pop each balloon (Figure 4).

Figure 4: Color and Heat experiment

c. Light and Satellite Imagery

- Figure 5 shows a satellite image. Although it is in black and white, it can be seen that there are surfaces of the terrain that absorb all the light, and therefore appear dark, and other lighter surfaces that reflect the light. Dark surfaces are usually associated with water, while bare ground, rocks or buildings reflect light to a greater extent. The teachers show this image to students and ask them to differentiate surfaces that have water (the darker, the better). The more bare or built-up the ground, the lighter the surface will appear.

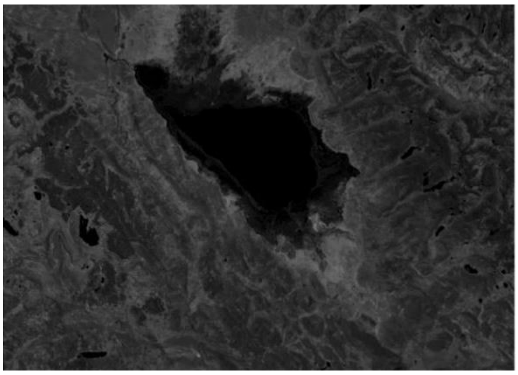

Figure 5: Satellite image of Junín National Reserve

- It is important to mention that satellite images are taken with sensors (cameras) that capture different wavelengths that are reflected by the Earth's surface, so the superposition of these images allows to see a color image as shown in Figure 6.

Figure 6: True-color satellite image of the Junín National Reserve - Peru. In the center and occupying most of the area, Lake Junín.

- Using a color identifier on their cell phone such as Color Grab (https://bit.ly/3eDF7ux) , students can point their phones at any surface and collect data on the colors around them. This application identifies colors based on HSV values (Hue, Saturation, and Value). These values are the result of the transmission, absorption, and reflection of light that sensors, such as the human eye, perceive. The hue recognizes the dominant wavelength, the saturation defines how pure or intense the dominant wavelength is, and the value refers to the lightness or darkness of a color. The Color Detector application (https://bit.ly/3xgBm4C) , in addition to recognizing color by HSV composition, provides values for the RGB one (red, green and blue), which are primary colors from the combination of which the rest of the so-called secondary colors are obtained (Figure 7).

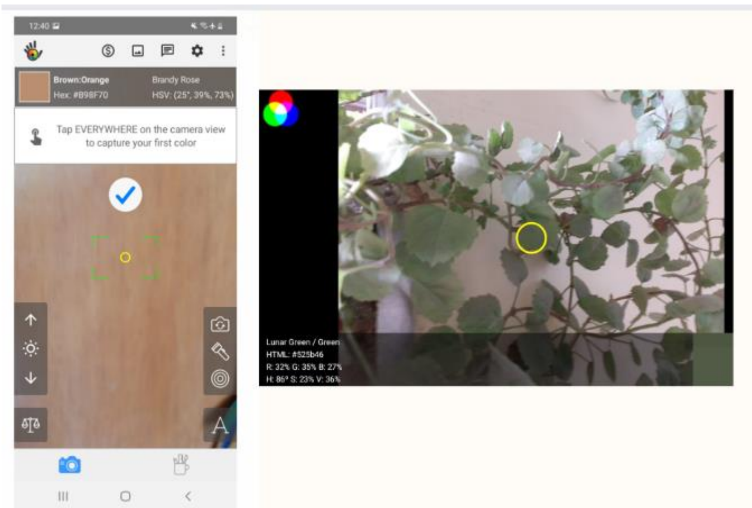

Figure 7: Image of the Color Grab application (left) showing the HSV percentage for each color and the Color Detector application (right) showing the RGB composition.

d. The effect of Color on Plants:

- Using the principles of the scientific method, the students try to answer the suggested question: How does color affect plant growth? To do this, they can do a germination experiment with seeds at hand, taking into account the following suggestions:
    - To test that the seeds contain embryo and therefore will germinate; it is very important to soak the seeds in water and discard those that float. Only those that sink should be sown.
    - In small trays the seeds are placed on soil, paper towel or cotton wool with water.
    - The important thing is then to place cellophane or translucent colored paper (red, green, transparent and blue) over the trays of the germinated seeds, arranged like a roof.
    - To evaluate the growth of the small plants with a ruler for one week after germination and analyze the effect of colors on the growth.
    - Remember that it is important that all the trays are in about the same place in the house and that there should be three repetitions per color.

- ***Closing***

    - When doing the suggested activities, teachers ask students to write down everything they have learned through their experiments on a sheet of paper.
    - All such sheets of paper will be placed in a container that will be called the chest of knowledge.
    - Once the students have placed all their sheets of paper in the chest, their teachers will read some of them in class to reinforce learning and to recognize what has amazed students the most about the experiments performed

Frequently Asked Questions

<u>That's a lot of experiments, do we have to do them all?</u>
Of course not, we just want to give you some ideas so that you can choose some that will help your students better understand how light is composed and its importance for living things and for the satellite imagery generation.

<u>What seeds can we use for the germination experiment?</u>
You can try any seeds you have at home. However, it might be interesting to try flaxseed, lentils, wheat, corn, or radishes.

<u>What if I can't find balloons in the colors you ask for, can we try other colors?</u>
Of course, the important thing is that they are different colors.

Suggested Resources

- Explanation of the electromagnetic spectrum: https://bit.ly/3qszKRJ
- Worldview: EOSDIS Worldview (nasa.gov)
- Introduction to the electromagnetic spectrum. NASA: https://go.nasa.gov/3xfZ0hT
- Newton's Disk: https://bit.ly/3qsBDxl
- Light reflection experiments: https:***//bit.ly/3eKlkbT***
- Preparation of a germination: https:***//bit.ly/3REmiG2***

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Set of scales

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Biosphere	Land Cover Classification Tree Height Biometry	15: Life on Land	Cognitive
Bundle	Study Site Definition		

Overview

When a map is observed, it is very common to see the scale in its description. In this regard, the scale is a proportional measurement of the actual size of a place adequately represented on paper. Many times it is easy to understand a scale, but at other times it may be necessary to do some abstraction exercises to better understand this concept. With this activity, students will reflect on the different ways of perceiving the environment from different spatial perspectives and will understand the concept of scale by applying it to the interpretation of maps.

Time

50 min

Prerequisites

None

School level

Last two years of primary and secondary school

Purpose

Through the use of classroom elements, students will understand the concept of scale and apply this concept to understand and draw maps to scale.

Student Outcomes

- Students will infer about how different living things perceive the environment in which they live.
- Students will analyze maps represented with different scales
- Students will draw a scale map

Background

Every living being is important in our ecosystem and not all of them occupy the same space, nor do they perceive it the way we do. For this reason, it is important to learn to put ourselves in the place of others. For example, an ant could take up to 15 minutes to move a very short distance, seeing the leaves as big obstacles, while the same space for a mouse will represent other challenges, and perhaps almost none for people or birds (Arango et al., 2009). It is all a matter of scale.

Scale is defined as the relationship between actual distances measured in the field and their representation on paper. Therefore, scale is a ratio between two linear quantities. It can also be said that scales are multiplication factors of linear measurements that are measured with the same units (IGN & UPM, n.d.; Serrano, n.d.).

Scale = The Linear measurement of the drawing/ The Linear measurement of reality

Within the scales we can consider those that are called natural scales when the proportion is 1:1 and they take place when the spaces are represented with their real measurement. When the objects to be represented are very small, enlargement scales are used, represented by N: 1. On the other hand, when we want to represent a large object in a smaller space, reduction scales are used, whose proportion is 1: N (Serrano, sf).

When spaces are represented in maps, what is used are reduction scales, being the most common proportions 1:2,5; 1:5; 1:10; 1:100; 1:500; 1:100.000, etc. When you have a scale 1:500, what is interpreted is that 1cm on paper represents 500 cm. in reality. It can also be understood as follows: A tree with a scale 1:100 equals that the tree is actually 100 times the size represented on the paper. Figure 1 will help to better understand this idea.

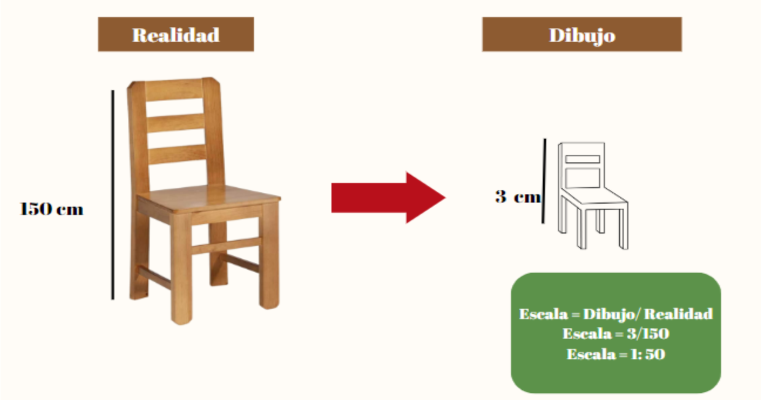

Figure 1: Representation of a scale

When viewing drawings or maps made using a reduction scale, it is important to keep in mind that there is less space on paper to represent a real image. Therefore, what is represented are more general views of a space, losing details. The amount of detail that is lost in a representation will depend on the scale that is used. The scale representation can be numerical, verbal and graphical. For example, Figure 2 presents a numerical scale that represents a road with a length of 8 km. Remember that on paper, it is better to use cm as a unit of measurement for representations; therefore, 8 km would be 800.000 cm. As it is a reduction scale, the proportion should be 1:N (1cm on paper is equal to X cm in reality).

Figure 2: Scale of a road 1: 200.000 is equal to say that 1cm on paper equals 20.0000 cm or 2 km in the real world. If the road measures 4cm on paper, then in the real world it measures 8 km applying a simple rule of 3: Scale = Drawing/reality.

The vebal scale is expressed in writing; for example, in figure 2 the verbal scale would be: "1 centimeter represents two kilometers". Finally, the graphic scale is the one you can see on the maps when you look at a ruler placed at the bottom of the map. Thanks to this ruler the real dimension on the map can be measured with the help of a real ruler or compass. Figure 3 presents the same map with different graphic scales to verify the importance of proportions in the representation of details.

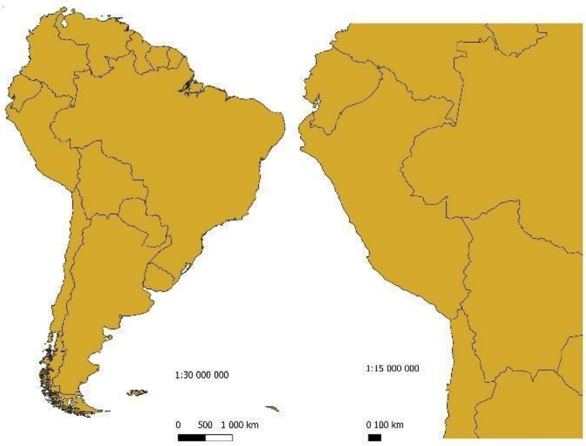

Figure 3: Maps at different scales

It is important to remember that a map is a simplified representation of a space on a plane. Maps have elements that must be present on it, such as scale, legend, orientation indicators and geographic coordinates, as well as a title. Figure 4 shows a map with all its components. Sketches are simpler than a map; they generally only want to highlight some basic ideas of the space and it is not necessary that they keep proportionality with reality.

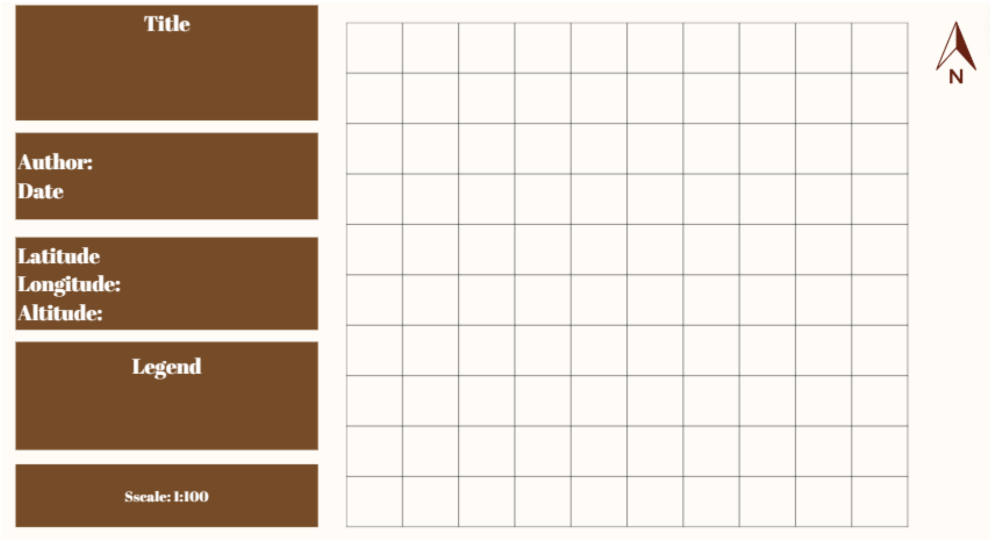

Figure 4: Representation of a map with all the elements it should contain. In this case the scale represented means that 1 cm on paper represents 100 cm (1m) in reality.

Guiding Research Questions

- Who will take longer to travel 10 meters: an ant, a mouse or a pigeon?
- How do scales influence our understanding of the impact on the environment?
- Is making a croquis map/sketch the same as making a map?
- How can the schoolyard be represented on a scale map?

Scientific Concepts

- A scale
- A map
- A croquis map/sketch

Materials and Tools

- Drawing paper
- Color Pencils
- A Ruler
- A pencil

What to Do and How to Do It

- ***Beginning***

  - The teachers divide the students into 3 groups and assign a small animal to each group: This way we will have the group of ants, mice and birds.

  - Then they all go out into the courtyard and the teachers ask the students to draw a certain space, as ants, mice and birds in flight would see it. Their students are asked to use their imagination to depict, for example, how an ant would see the leaves of a plant and how the same plant would look from above as a bird flies.

- The groups share their drawings and realize that there are animals that capture a larger area such as birds, losing some details, while ants will probably see more details of a small space, losing sight of the horizon.

- ***Development***

  - Once the reflection on the importance of scales has been done, an exercise is done to represent the observation of something real on paper.

  - Students measure a chair in the classroom and decide that each meter they find on real objects is equivalent to 1 cm on paper. This is called drawing to scale, they can review Figure 1 for more detail and represent a chair to scale on paper.

  - They then go out into the field and draw a map of an area of 10 meters on the sheet of paper, locating the most important resources. For this they can use Figure 5. It is recommended to draw the map with a scale of 1:100, that is, each square of the map of 1 cm will represent 1m in reality. Remember that the maps should have some important elements that are also shown in Figure 4

  - Table 1 can be used as a reference to represent the different types of land cover found in a place. That is, the representation of the real world can be done by painting the squares with colors or placing the suggested numbers to identify the different types of land cover they observe.

Table 1
Types of cover according to MUC code

Cover	MUC Code	Color
Trees	0	Dark green
Shrubs	2	Light green
Grasses and herbs	4	Yellow
Area without vegetation	5	Brown
Water	7	Light-blue
Crops	8	Orange
Buildings	9	Red

- ***Closing***

  - The students share their maps and discuss how different perspectives can include or leave out certain terrain features.

  - Finally, they display their maps to scale on a classroom or school mural.

Frequently Asked Questions

Can we use other animals for perceptual perspectives?

Of course, the idea is that they are different species to have different perspectives.

Suggested Resources

- QGIS: Mapping software: Download QGIS
- Practice on Khan Academy scales: https://bit.ly/3U4ylyj

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Succession and diversity

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Biosphere	Land Cover Classification Biometry Biomass	15: Life on Land	Research

Overview

Heraclitus said 2500 years ago that "the only constant is change" and it is precisely the observation of changes in ecosystems that has attracted the attention of scientists over time. With this activity, students will describe the successive changes that occur in the vegetation of an ecosystem over a period of time determined by them.

Time

Once a week for 3 months to 1 school year, depending on the teacher and the student goals

Prerequisites

None

School level

Secondary

Purpose

Students will describe the general characteristics of a process of secondary succession of soil vegetation in a square of 1 meter of side to see the changes that its composition and diversity undergo after removing all the vegetation.

Student Outcomes

- Students will recognize the main species of plants in their environment
- Students will calculate the abundance and diversity of plants in their environment
- Students will analyze the changes that occur in ecosystems over time

Background

Succession is the process through which the ecosystem undergoes a series of changes and organizes itself from an initial state, called pioneer, to an advanced state, called climax (Odum & Barret, 2006). As succession occurs, certain ecosystem characteristics increase, such as diversity, resistance to disturbances (stability), connections among elements, species specialization, the amount of organic matter accumulation and biomass (Rodríguez, 2010).

Within the succession process, some types of succession can be recognized, for example (Mazparrote and Romero, 2020):

- Primary succession: The process that involves the formation of soil and the constitution of the ecosystem as a whole.
- Secondary succession: The process that occurs when an already formed ecosystem suffers a disturbance that alters its structure and dynamics. Through a secondary succession, the structure of an ecosystem is restored.
- Autotrophic succession: It generally takes place in the early stages of succession and occurs when there is a surplus of production (plants photosynthesizing) in relation to respiration.
- Heterotrophic succession: It starts from a situation in which there is a large amount of not-respired, produced material, therefore, there is an excess of decomposing and disintegrating organisms (an excess of respiration). It is like the process of disintegration that takes place in a fallen tree trunk.

Throughout the successional process an ecosystem goes through a series of stages in a cycle, called an adaptive cycle (Figure 1). The adaptive cycle consists of phases of ecosystem development in which long periods of resource accumulation and transformation alternate with short periods that create opportunities for new elements to emerge. When studying the succession of an ecosystem, it is possible to identify in which phase of the cycle it is by considering the following:

- Exploitation phase or r: This is when the system has begun its development. It is characterized by very few species, called pioneers, which grow rapidly, taking advantage of the soil, water, nutrients and light resources available to them.

- Conservation or K phase: This is when the system has accumulated many species, several of which have established close relationships. In this phase diversity and biomass are very high.

- Release phase u Ω: This is the phase in which a system has experienced some disturbance that has caused the system to lose resources, e.g. when all existing vegetation has been removed from a space.

- Reorganization phase or α: This is when the system begins to reorganize itself after having suffered a disturbance. This will be the process of the succession that will be studied with this activity.

Knowing in which stage of succession a system is and the characteristic diversity of each phase is useful for applying management methods that guarantee the sustainability of ecosystems.

Guiding Research Questions

- What is succession?
- How does the plant community change in my environment?
- What is the biological biodiversity value of the species present in an experimental plot?
- What are the pioneer species of succession?
- What are the most common species in the ecosystem?

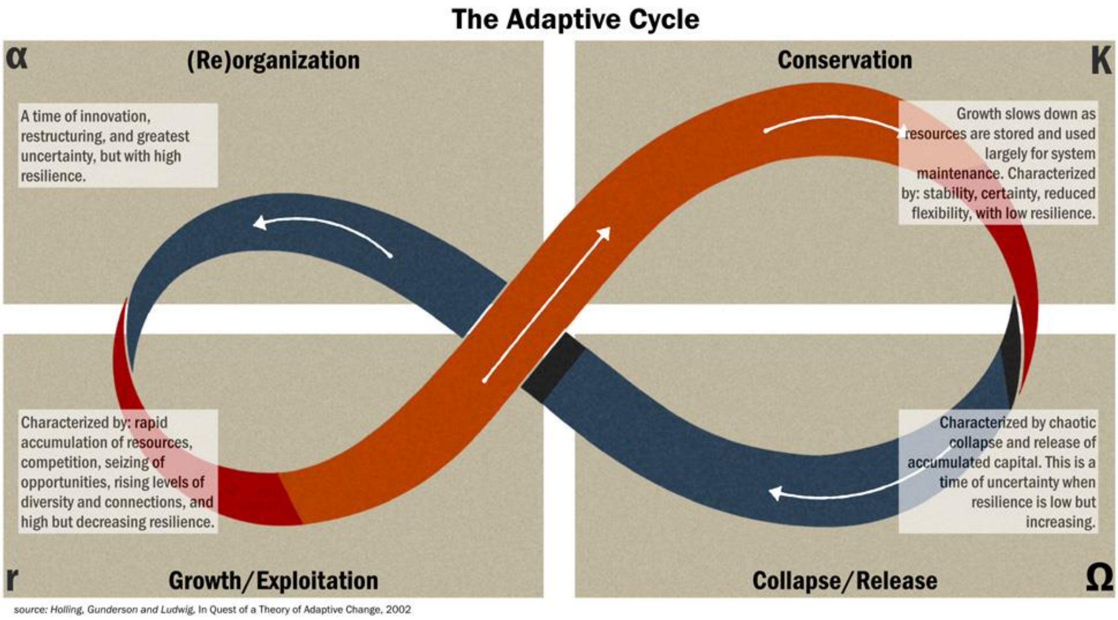

Figure 1: Adaptive cycle of ecosystems. In this image, potential can be used as a synonym for accumulated resources. Connectivity refers to the relationships among resources, and resilience is the ability of system elements to maintain their fundamental structure and functions despite disturbances.
Source: Vilchis-Mata et al., 2018.

Scientific Concepts

- Succession
- Adaptive Cycle
- Biodiversity
- Cover
- Stability
- Wealth
- Biomass
- Production
- Productivity
- Resilience
- Equity

Materials and Tools

- A roll of candle wick or thread to build a net of 1 m2 with 25 cm reticules
- 4 wooden stakes
- 1 small flag or bright color ribbon to put on a sign
- A small wooden stick or knitting stick
- Paper
- Pencils

What to Do and How to Do It

- ***Beginning***

  - The teacher asks the students to bring in photos of when they were younger and of different times when they were growing up, then he/she asks them to analyse some of the changes they have undergone over time. The teachers take this opportunity to explain to students that ecosystems also change over time and that this process of change is called succession.

  - The teacher can also show the students photographs of the same place at two different times so that they can see the similarities and differences between the two images. Perhaps they can see new buildings, plants that are no longer there, etc.

  - Then, the students are told that they will be studying the succession of a small area, of one meter on each side, near the school and that they will have to build a wick or thread net with small squares, within 25 cm, as a key tool to make their measurements (Figure 2).

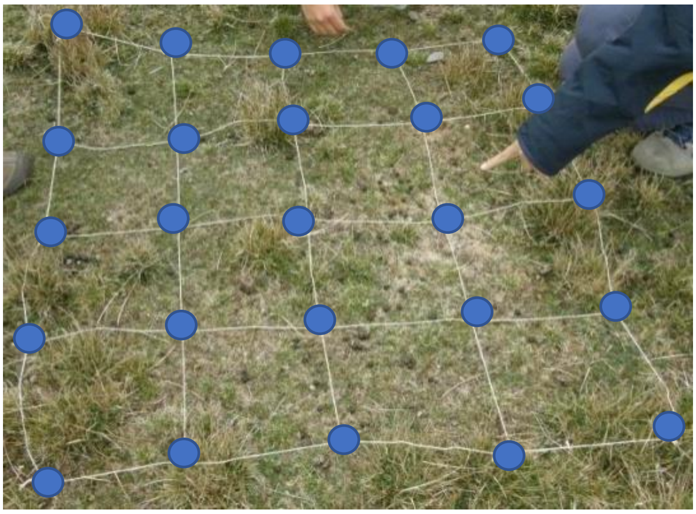

Figure 2: Wick grid constructed to assess vegetation cover. The net should measure one meter on each side (sample) and the squares in the middle are made every 25 cm so the number of points to be assessed (sample units) will be 25. This means that the sample units are composed of the intersections of the squares (blue dots).

- ***Development***

  - A location in the school is selected where to set up the net, this place should have vegetation on the ground, it would help a lot to follow the GLOBE Cover Classification protocol and determine the MUC Code of the study site.

  - Using four wooden stakes, the net is set up on the ground and should be stretched out as far as possible (Figure 2).

- Measure the plant cover in the square. To make the cover measurement it will be necessary to use a wooden stick or a knitting stick and place it perpendicularly at each point, recording the species that is touched with it (Figure 3).

- Record the species present at each given point. The number of points where the species is present with respect to the total number of points will be equivalent to the cover (C) of the species, for which this formula is used:

$$\%C= (ni/25) * 100$$

Where:

C is the percentage of cover
ni = Number of points where a species is recorded.

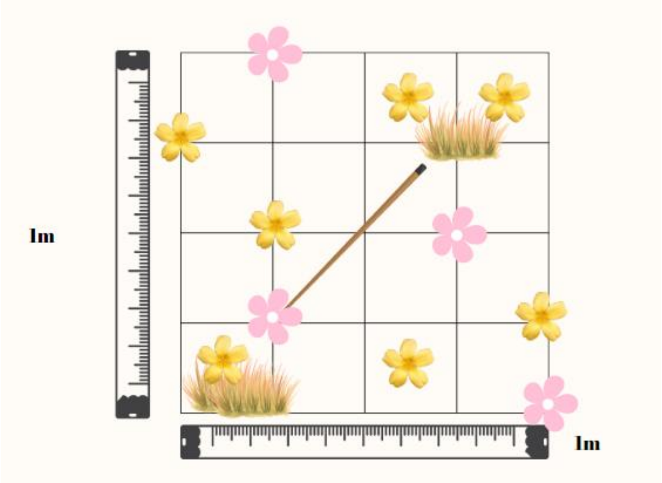

Figure 3: Measurement of the vegetation cover using the square method. It is important to remember to record species that fall only at the intersections of the squares. In this case we have pink flowers in 4 points out of 25, for example, so the cover value of pink flowers would be 16%.

The information from the points is very important, as both the species richness (number of different species) and diversity (a measurement that helps to know the variety of species according to their richness and equal abundance) can be calculated. As an example to make these calculations we will use the data in Figure 3, presented in Table 1. It is important to remember that only the number of intersection points where the plants are located is taken into account.

Table 1
Data for the calculation of plant diversity based on Figure 3

Species	ni
Pink flower	4
Yellow flower	3
Brown grass	2
Total	9

- The richness according to Table 1 would be 3, three different species (pink flower, yellow flower and brown grass). The richness is usually represented by the letter S, for the word species.

- The calculation of diversity is done with indexes. Indexes are numerical values that synthesize a lot of information in a single number and have a scale that helps to interpret its meaning.

- Using the data in Table 4, diversity will be calculated using the complement of an index known as Simpson's index, which is calculated on the basis of probabilities (Table 5). The probability is the chance we have of finding a certain element within a group.

Table 5
Calculation of diversity based on the data in Table 4

Species (S) It helps to determine the identity of each species	ni Number of points where the species is found	Pi The probability of finding the species within the set of species	Pi^2 Simpson's index needs the probability to be squared
Pink flower	4	4/9	$(4/9)^2$
Yellow flower	3	3/9	$(3/9)^2$
Brown grass	2	2/9	$(2/9)^2$
Total sum	9	1	**0,36**

The diversity of the site will then be 1- 0.36 = **0.64**. This is the value of Simpson's diversity index, where 0 means that all species are the same and 1 means that all species are different and each could be found in approximately the same number of points. The formula is presented below:

$$\text{Simpson's Diversity Index} = 1 - \sum_{1}^{S} Pi^2$$

- After measuring richness and diversity, remove all plants from the square, leaving only the soil. This will have the effect of a disturbance on the ecosystem.

- Then, take the same measurements as the first time, once a week. This will help to identify the species that grow first and see how the community is changing over time.

- Calculate cover and wealth every time you go to the field, at least once a week.

- ***Closing***

  - Analyzing the data and the results, it is especially important to know which are the first species that appear in the square after the vegetation has been removed, how the diversity value changes and which are the plants that appear later in the succession process.

  - Teachers will assess the knowledge learned, using the target shooting technique, as shown in Figure 4.

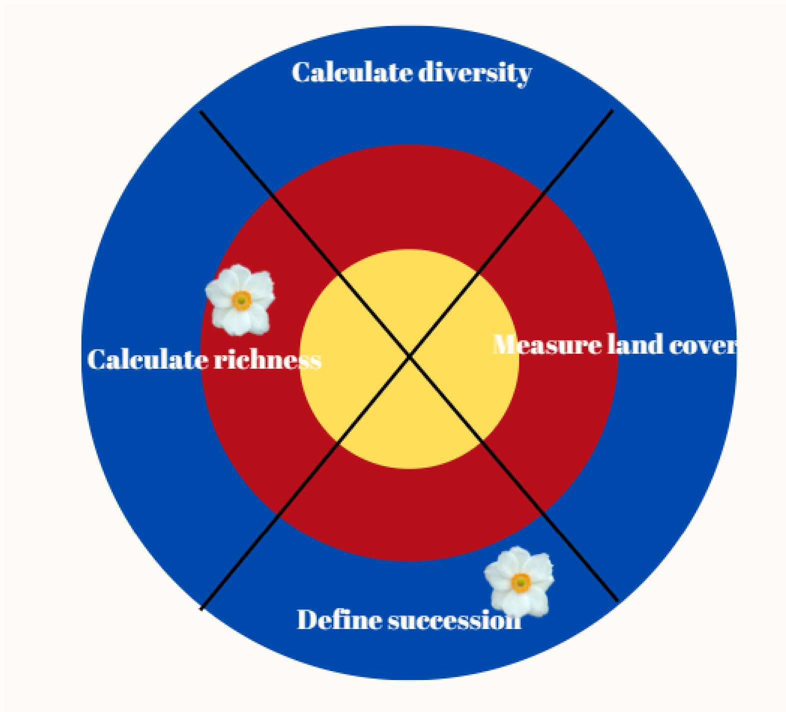

Figure: 4 Students should place a point according to how well they know some of the skills the teacher wants to assess.

Frequently Asked Questions

- <u>What if we can't follow the succession for a long time, will one month be enough?</u>
  Of course, the time is to be decided by the students with the teacher. It will depend on the project objectives.

- <u>Some of the calculations seem complicated, could you limit the activity to just taking measurements in the field and recognizing species by calculating cover?</u>
  You can adapt the activity to what you think is convenient and manageable for your group of students.

Suggested Resources

- MUC Guide to the GLOBE Program
  https://bit.ly/3wYkhMV

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Trees cover us

GLOBE Sphere	GLOBE Protocols	Associated SDG	Type of Activity
Biosphere	Biometry Land Cover Classification Tree Height	15: Life on Land 13: Climate Action	Research
Atmosphere	Air temperature Surface Temperature Precipitation		

Overview

When studying vegetation, one of the most important measurements made in the field is plant cover, as this is a good indicator of the abundance of species in a given location. This activity aims to investigate tree cover at a site selected by students and teachers.

Time

50 minutes

Prerequisites

- To know the Pythagorean Theorem
- To know how to calculate percentages
- To identify the cardinal points with and without a compass.
- To know how to use the densiometer
- To know the distance of your steps (not essential)

School Level

- Secondary

Purpose

Students will determine the percentage of an area that is covered by trees and identify the dominant tree species in a 10m X 10m square plot.

Student Outcomes

- Students will delimit a square of an area of 10m X 10m in their study site, using their own steps and will draw two diagonals in a NE-SW and NW-SE direction.

- Students will calculate the distance of the diagonals of the square they drew using the Pythagorean Theorem.

- Students will use a densiometer to record tree cover at the established study site.

Background

Canopy cover is defined as the percentage of the sampled area that is covered by the vertical projection of trees. This measure is very important because trees influence many ecosystem processes. For example, they are involved in the regulation of light, temperature and the percentage of rainfall reaching the ground. They are also involved in carbon capture, oxygen release and the provision of habitats for many other species, such as birds. For example, it has been studied that a larger tree canopy causes changes in the light and precipitation received on the ground. The latter, in turn, affects the availability of water in the soil. The canopy and branch structure channel rainfall and create drip points that can cause more intensity of local effective precipitation (Suqui et al., 2021).

Trees act as the "lungs and kidneys of cities", helping to curb air and water pollution, and reducing noise in cities as well as urban heat island effects (Newete et al., 2022). Therefore, it is important to have adequate tree cover in our cities and fields, as well as to recognize which trees are most common in our environments.

Tree canopy cover can be assessed in terms of the number of times a person can find the tree canopy in a given area. This is also called density, so the instrument that helps assess tree canopy cover, or canopy, is called a densiometer. With this activity a simple version of a densiometer will be used to assess tree canopy density and, therefore, infer tree canopy cover.

Scientific Concepts

- Canopy
- Cover
- Density
- Dominance
- Biodiversity

Guiding Research Questions

- What is the tree cover we have near the school?
- What is the dominant tree in our study site?
- What is the relationship between cover and precipitation?
- What is the relationship between temperature and tree cover?
- Does tree cover change throughout the year?
- At what time of the year is tree cover the highest?
- What animals species use trees to live?

Materials and Tools

- Densiometer
- 50 m tape measure
- Calculator
- Paper
- Pencil

What to Do and How to Do It

- ***Beginning***
    - Students draw or take pictures of trees they can find near their school and share any information they have about them.

- Teachers help students identify the canopy of trees they have drawn or photographed.

- The students choose the tree with the largest canopy and the tree with the smallest canopy and infer about the effects of canopy cover on the soil, aided by the following questions:

    - Which of the trees provides the most shade, and why?
    - Which of the trees is best to protect us from the rain? Why?
    - Where could we find more birds? Why?

- ***Development***

- The students visit the nearest place where they can find trees and in groups of 4 they draw a square of 10m x 10m. Then, they stand in the middle of that square and locate the cardinal points, drawing two diagonals in a NE-SW and NW-SE direction covering the whole area.

- Using the Pythagorean Theorem, the students calculate the distance of the diagonals in meters.

- In teams of two, the students go to the south end of the square.

- Using the densiometer the students observe the canopy cover along each of the diagonals by following the steps below:

    - They point the densiometer vertically towards the canopy cover (see activity of construction and use of the densiometer).
    - Every two steps one (a) of the students observes the canopy cover, while his/her partner (b) writes down the data on a sheet of paper. If cover is observed through the densiometer, a plus sign (+) is placed on a sheet of paper.
    - If the result of the cover observation is positive, i.e. there are trees, the name of the species is noted. If they do not know the tree, it is recommended that they take a photograph and then ask an expert to help determine the name of the species. They need to make sure that the photograph shows the branches and flowers, if there are any. The fruits and bark also help in determining the species.
    - The students follow the same procedure along the two diagonals drawn.
    - At the end the total number of observation points is added up (remember it is every two normal steps).
    - The number of points where tree canopies were found is added up.
    - The total number of points where there was tree cover by species is added up.

- Repetitions are always important for science so it is necessary that each square is evaluated at least 3 times.

- ***Closing***
    - Using a calculator, the students calculate the percentage of canopy cover in the square. For more detail on the percentage calculation, see the "Cover: The Value of Percentages" activity.
    - Based on the results, the students discuss which diagonal has the most cover.

- The dominant species is identified (the one with the most positive observations in the square).
- The students discuss what the effect is of having more or less cover.
- A decision is made as to whether or not more trees are needed on the investigated site and a discussion is held on how this cover can be improved.
- Further research is proposed. This may relate cover to the amount of precipitation received, the amount of light or temperature, for example.

Frequently Asked Questions

Can I work on squares smaller than 10m x 10m?
Of course, they can be 5m x 5m squares if it is in a small area. In this case, only two students per square will be enough to do the work.

What if I don't have fields near the school, can I still apply this activity?
You could work with a satellite image and points every 0.5 cm, and still have your students calculate percentages of plant cover and find out which areas of your city have the most plant cover.

Resources

Application of the GLOBE program to measure tree height: *https://bit.ly/3QA3kiJ*
Guide for using the application to measure tree height:
https://bit.ly/3Bx3IdB

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Walking with the SDGs and GLOBE

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Atmosphere	All	All	Exploratory
Biosphere	All		
Pedosphere	All		
Hydrosphere	All		
Bundle	All		

Overview

The Sustainable Development Goals (SDGs) are a call to action to end poverty and human inequality, taking into consideration the limits of the planet. These goals become a common aspiration for all member countries of the United Nations, who must include them in their national agendas and policies until 2030. The GLOBE Program, through its scientific-educational proposal, contributes to achieve the goals of sustainable development in different ways. For this reason, this activity is aimed at learning more about the SDGs and GLOBE protocols in order to improve students' understanding of the connection between these proposals that seek to learn more about our socio-ecological systems to achieve their sustainability.

Time

70 minutes

Prerequisites

None

School level

All

Purpose

Through the game, students will learn about the Sustainable Development Goals and their relationship to the GLOBE Program to improve their understanding of the Earth system and propose solutions to environmental problems in their environment.

Student outcomes

- Students will name some of the SDGs set by the United Nations
- Students will explain the concept of sustainable development in their own words
- Students will stablsh links between SDGs and GLOBE protocols to answer research questions and solve problems in the environment.

Background

The year 2022 the world population reached a total of eight billion inhabitants (UN, 2022), a figure that translates into a record not only for what the number means for the planet, but also for the challenge of ensuring that all people enjoy an adequate quality of life, while maintaining the stability of critical processes for the planet (O'Neil et al., 2018).

The above mentioned implies ensuring that human activities remain within a safe operating space (Figure 1), which on the one hand has a ceiling demarcated by nine biophysical processes called planetary boundaries (Steffen et al., 2015), and on the other hand had a social basis that recognizes the right of all people to meet their basic needs, on the other (Raworth, 2017).

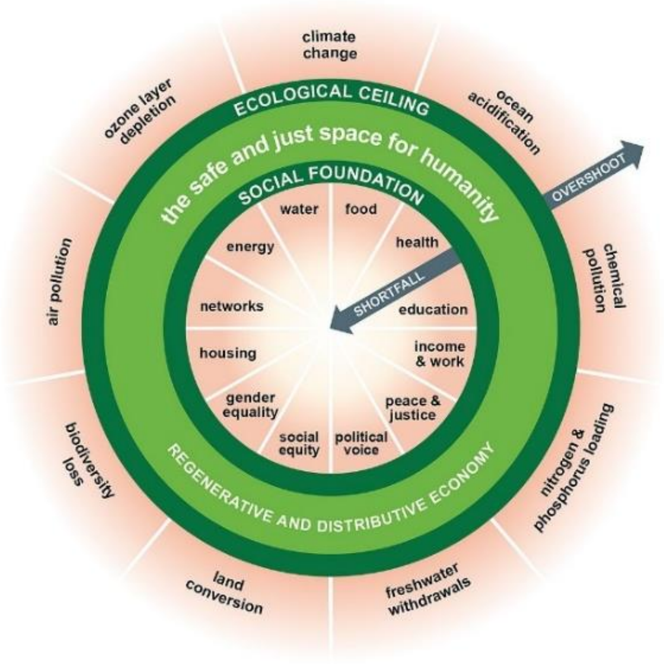


Figure 1: Safe operating space for human activities (in green) demarcated by planetary boundaries as the ceiling and societal needs as the basis.
Source: Doughnut Economy Action Lab, 2022

Maintaining human activities within a safe operating space demands that the sustainability of the actions carried out be guaranteed. In this sense, sustainability can be defined as the fact that we can all enjoy a good quality of life within the limits of our planet's resources, ensuring that this condition will be maintained over time. . It is important to emphasize that the sustainability should not be understood as a fixed state, but rather as a process of change in which the resources used, the way investments are made, technology and institutions are consistent with the present and future needs of people. Therefore, this fact demands that the natural processes of the planet be taken into account at all times. Figure 2 shows how sustainability can be understood and what is necessary to achieve it.

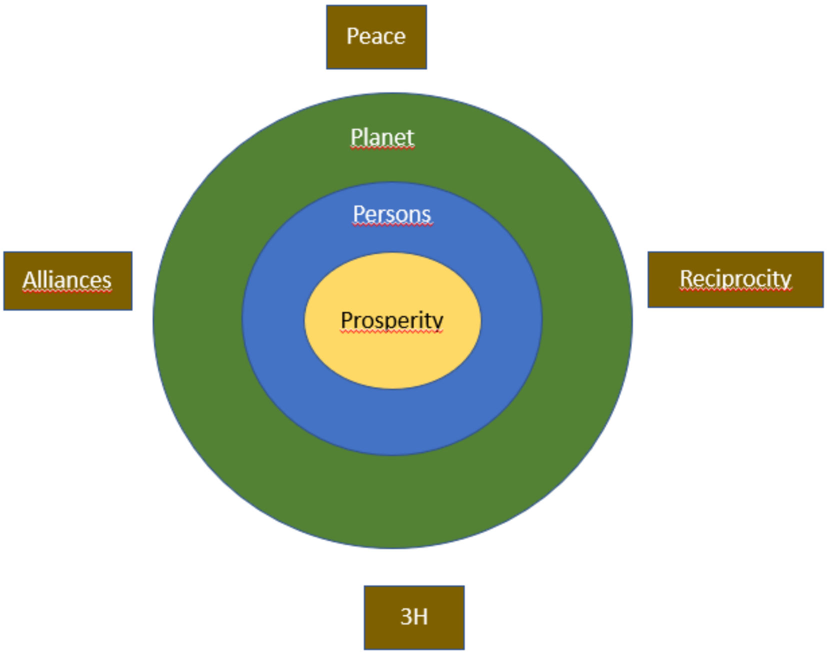


Figure 2: Sustainability is only possible if three components are taken into account: i) the planet, respecting planetary boundaries, ii) people and the conditions in which their basic needs are met and iii) prosperity or improvement in the economy. In order to achieve this sustainability, these conditions are necessary, like the existence of peace, alliances, reciprocity and environmental awareness represented by the 3 H (Head – to know; Hands – to do, and Heart -to feel).

As a way to achieve sustainability, as of January 1, 2016, the member countries of the United Nations adopted 17 sustainable development goals, which were agreed upon at a meeting held on September 25, 2015 in New York. These goals are part of a global action plan that seeks to make this world a better place by 2030 (UN, 2019).

The proposed goals (Figure 3) outline the path to achieve the sustainability of the planet and, therefore, should be applied in all countries in the world. They are based on values and principles of equity and respect for human rights, seek collaboration and the well-being of society, and ensure the proper functioning of ecosystems.

Figure 3: Sustainable Development Goals

Importantly, the Sustainable Development Goals are interrelated (Stafford-Smith et al., 2017) and have an integrative structure that encompasses the three components of sustainability (planet, people and prosperity). Likewise, there is a goal focused on how society must work together to achieve all the other goals (Goal 17: Partnerships). Figure 4 shows how the goals are organized in a systemic way to contribute to the sustainability of the planet.

Figure 4: Integrative Approach to the Sustainable Development Goals

The GLOBE Program has a scientific and educational proposal oriented to train the new scientists of the planet, who will contribute to improve the knowledge of the Earth system with their work, as well as to propose solutions for the environmental problems that arise. The scientific proposal of the Program revolves around 4 research spheres: Atmosphere, hydrosphere, pedosphere and biosphere. Each area includes a series of protocols that ensure the scientific suitability of the Program and serve to improve the students´ skills. Through the following activity, students will be able to establish the relationship between GLOBE and the SDGs.

Guiding Research Questions

- What are the Sustainable Development Goals?
- What does it mean for any activity or product to be sustainable?
- Do you know any of the Sustainable Development Goals? Which one?
- Do you think the GLOBE Program can help to be sustainable? How?

Scientific Concepts

- Sustainability
- Sustainable development
- Sustainable Development Goals
- Protocols
- Environmental problems
- Environmental projects

Materials and Tools

- Paper
- Pens
- A Game board
- 17 SDG cards
- 43 GLOBE protocols cards
- Small stones that serve as a bargaining chip
- 2 dice
- 5 chips that can be made of cardboard, or any other token may be used

What to Do and How to Do It

- ***Beginning - Rules of the Game***

- The game aims for students to obtain 1 card from any SDG representing the planet (goals 6; 13; 14 and 15), 1 representing the people dimension (goals 1; 2; 3; 4; 5; 7; 11 and 16), and 1 from the prosperity dimension (goals 8; 9; 10 and 12). For more details on these cards see Figure 3. Possessing these 3 SDG cards will earn you the SDG 17 card, related to partnerships that help implement all the Sustainable Development Goals. Therefore, the first person to get the SDG 17 card wins the game.

- In the game it is important to choose one of the players as the 2030 agent. This person will be in charge of guarding the SDG cards and GLOBE protocols, as well as handing out the stones or currency at the start of the game.

- ODS are obtained at the players' choice (from 1 to 16). Each ODS is obtained by exchanging two GLOBE protocol cards plus 3 small stones. The stones or currency will be given to the players at the beginning of the game by the 2030 agent.

- The GLOBE protocol cards are obtained by 3 small stones each and by the statement informing where the player´s chip should be placed. In this regard, it must be considered that any protocol is valid as long as it serves to study what is mentioned in the statement. However, for example, it is not possible to obtain a soil pH protocol to assess clouds. It is important for the 2030 agent to be attentive to this process of obtaining GLOBE protocol cards.

- ***Development***

- Up to 5 participants can take part in each game

- Agent 2030 is the custodian of protocol cards, sustainable development goals and small stones that serve as coins.

- Each player receives 15 small stones to be able to obtain protocol cards with them.

- All players roll the dice and the player with the dice highest number is the first one to start.

- Each time a player falls on a statement he must obtain a protocol that allows to investigate what is mentioned in the statement. This card must be acquired from agent 2030 for 3 stones. To do this the player must mention which protocol he wants to obtain.

- If the player lands on box 5 he automatically receives 3 stones from agent 2030. If he lands on box 9 he receives a random protocol that he can use later or exchange it with another player. If he lands in box 13 he must take a piece of paper and formulate a research question that he will leave in the center of the board. If he lands on box 17 he should consider himself lucky because he wins a SDG card selected by the 2030 agent at random and if he lands on box 22 he pays 3 stones to the 2030 agent.

- If players land in boxes 11 and 24 they may acquire 3 protocols at once or do it in parts, one each time they pass through numbers 10; 11 and 12 or 23, 24 and 25, respectively.

- Immediately a player has collected two protocols, he/she can add 3 stones and exchange them with the 2030 agent for an SDG card of his/her choice.

- ***Closing***

- The first player to collect 1 SDG card from each level (planet, people and prosperity) according to Figure 3 wins, immediately earning the SDG 17 card. The 2030 agent must verify the cards are correct before ending the game and declaring the winner.

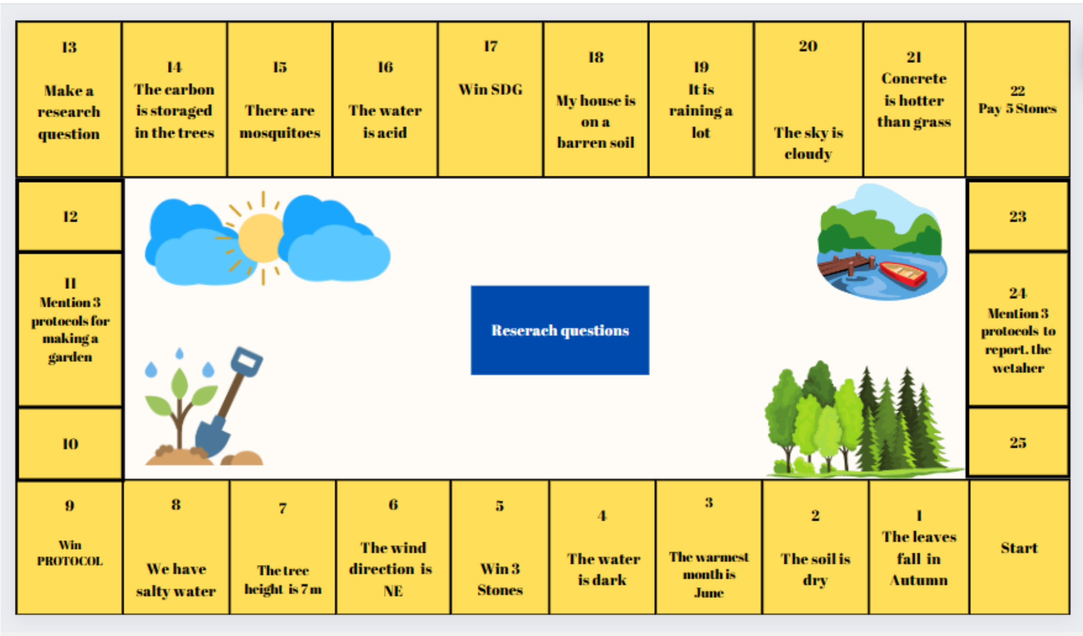
Frequently Asked Questions

<u>If we don't want to print the cards, can we make them from materials available at school?</u>
Of course, you can use whatever materials you have at home; the idea would be to use what you have at hand to learn about the SDGs.

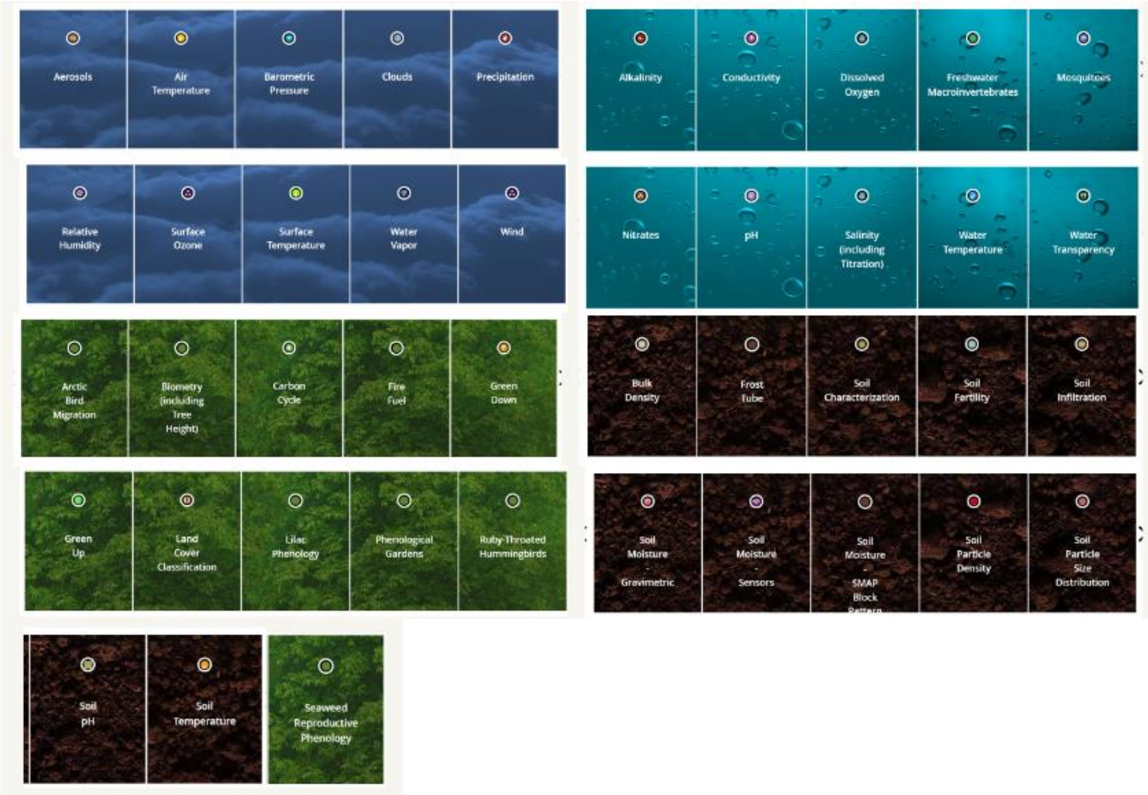
<u>Can the small stones be replaced by another material?</u>
Yes, students could cut out pieces of paper, or use bottle caps or bits of cardboard, for example.

Suggested Resources
Activities to work on the SDGs in class: ***https://bit.ly/3xl80SB***

Board Game:



SDGs and Protocol cards to cut out:



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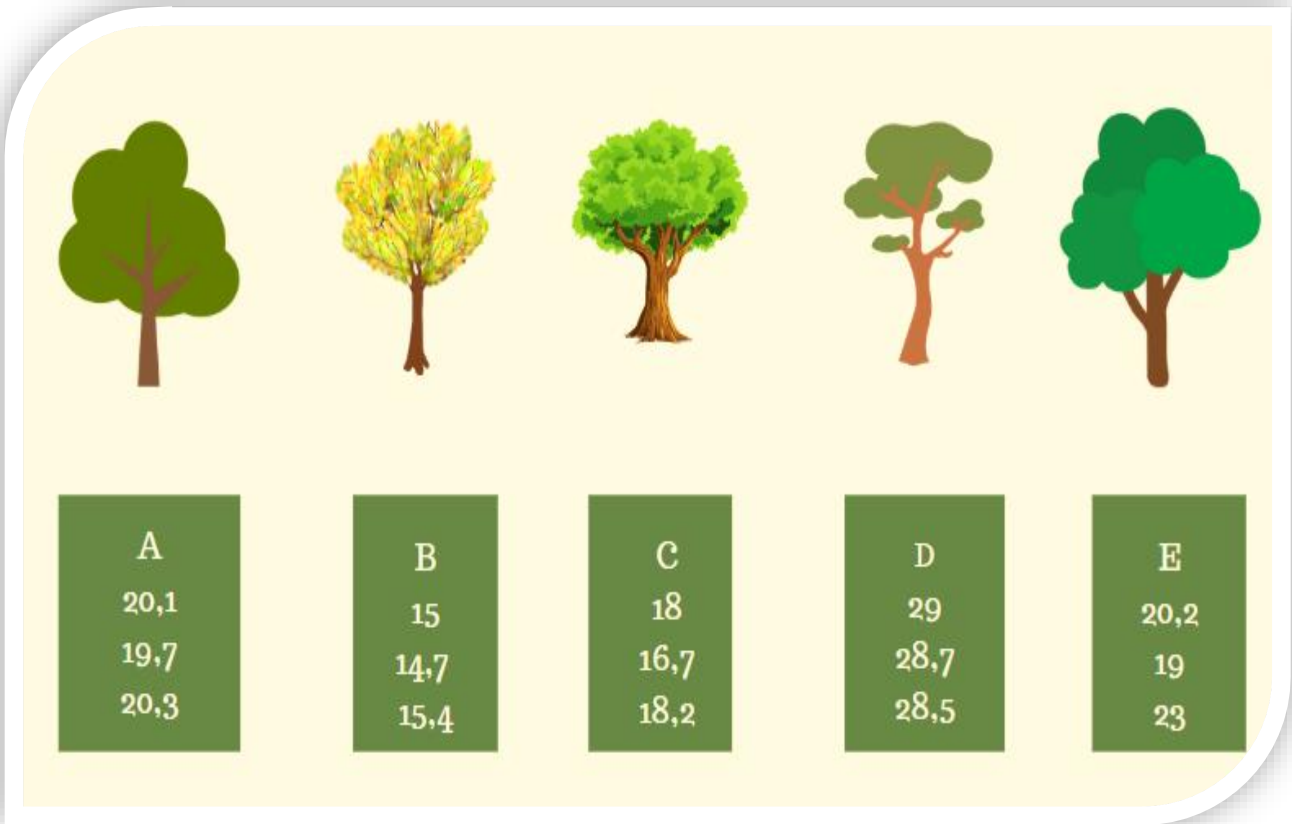

DATA LITERACY LEARNING ACTIVITIES

The GLOBE Program

LAC Regional Office

Cover: The value of percentages

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Biosphere	Land cover classification Biometrics	15: Life on Land 4: Quality Education	Cognitive

Overview

The surface of the planet is covered by different types of structures that can be natural or man-made. In this sense, it can be said that everything that covers the surface of the planet is called land cover. This term is also used by scientists to express the abundance of some structure on the planet and is expressed in terms of percentage. With this activity, students will understand the importance of land cover, practice its classification, and calculate percentages of different types of land cover.

Time

50 minutes

Prerequisites

None

School level

Secondary

Purpose

At the end of the activity, students will explain the concept of land cover and identify the different types of existing land cover of a place, calculating their percentage through simple exercises.

Students Outcomes

- Students will explain the concept of land cover.
- Students will describe the main types of the land cover they observe.
- Students will determine the percentages of different types of land cover.

Background

Every day we observe different types of structures around us. Plants, buildings, lakes, rivers, houses, farmland, etc. All this is part of what is called land cover. Land cover is defined as the biophysical cover found on the surface of the planet (FAO, 2022). The term land cover is closely associated with the term land use, which is characterized by the activities that people carry out on a given land cover type, either to maintain it or to change it in order to meet their basic needs.

To better describe the different types of land cover and the uses that people make of it, it is important to classify it according to common characteristics and using some agreed terms to name each classification category. There are some proposals for classifying land cover, which are used worldwide, such as the COPERNICUS classification system, used to map the distribution of land cover in different countries of the world (COPERNICUS, 2022). Although this system is widely used, it is also quite advanced. Therefore, the GLOBE Programme recommends using a more user-friendly system to start getting familiar with the different land cover types. This is the Modified UNESCO Classification System (MUC).

When describing a given area, it is possible to find different types or classes of cover. If someone were to ask us what we observe in that area, the most appropriate response would be something like: "Half (50%) is water and the other half is divided into forest (25%) and pasture (25%)". The description of the cover of an area is expressed as a percentage and therefore it is important to learn both the terms for its classification and the procedure for determining the percentages of each class of cover within an area. This is something we hope to achieve through this activity.

Guiding Research Questions

- What is the dominant land cover class in the school?
- What is the percentage of the school's dominant land cover class?
- How many classes of cover are there in my favorite landscape?
- How can we best describe the cover of a place?

Scientific Concepts

- Land cover
- Percentage
- Land use

Materials and Tools

- Paper
- Pencil
- Calculator
- Colors

What to Do and how to Do It

- **Beginning**
    - The teachers ask students to draw their favorite landscapes.
    - The students will form groups and share their drawings with their classmates, describing what elements they like most about them.
    - After sharing as a group, the teachers ask a representative from each group to present the landscapes of their classmates, highlighting the elements that have caught their attention the most.
    - The teachers will write down the list of all these elements on the blackboard. For example: trees, lagoon, sand, sea, etc. Then they will explain to their students that each of these elements is a type of land cover.
    - Next, the teachers will ask their students what they understand by land cover.

- **Development**

  - Once the concept of cover has been defined and the classes of cover that students like the most have been described, the teachers will proceed to classify some of them according to the basic level of the MUC code. To do this, they will show Figure 1 in class.

Figure 1: Types of cover according to MUC code level 1

  - The next step will be to explain to the students how to calculate the cover percentage using Table 1.

Table 1

: Matrix for calculating percentages. The total consists of 100 units which would be equivalent to 100%. Note that there are some squares representing the cover classes in Figure 1.

81	81	81						81	81	81
81	81	81					81	81	81	81
81	81	81					81	81	81	81
						81	81	81	81	81

- According to Figure 2, there are 25 squares, out of 100 in total, with cover class 81 corresponding to agricultural fields and 50 squares corresponding to cover 72 representing the sea. Therefore, it can be said that there are 25% agricultural fields and 50% sea in this Figure.
- It is important to remember that the percentage is the proportion of one class of cover to 100 units, which would be equivalent to the total. The calculations for the example in Figure 1 would be, for instance:

Total = 100
Range of coverage 81 = 25

So: 100 is 100%, 25 is what percent of 100?

100 -------------------------100%
25 ____________________X?

Using a simple rule of three, the following would be reached:

$$X = \frac{25 \times 100\%}{100} = 25\%$$

- Table 2 is shown below so that students can practice calculating percentages.

Table 2
: Representation of the cover of a site that has classes 81 (agricultural area), 82 (non-agricultural green areas created by people, such as parks and gardens), 1 (wooded area), 0 (forests where trees are very close to each other), 4 (grasslands), and 9 (urban areas).

						1	**1**	**0**	**0**
						1	**1**	**0**	**0**
						1	**1**	**0**	**0**
						1	**1**	**0**	**0**
82	**82**					**1**	**1**	**0**	**0**
82	**82**					**1**	**1**	**1**	**0**
82	**82**				**1**	**1**	**1**	**1**	**0**
82	**82**				**1**	**1**	**81**	**81**	**81**
82	**82**			**1**	**1**	**1**	**81**	**81**	**81**
82	**82**	**82**		**1**	**1**	**1**	**81**	**81**	**81**

- **Closing**
    - To end the activity, teachers ask students to make one-sentence summaries of what they have learned on chart paper, answering the questions:
        - What is a percentage?
        - How is a percentage calculated?
        - What is land cover?
        - What are my favorite classes of land cover?

Frequently Asked Questions

Can I use colors instead of numbers?
Yes, together with the students you can choose a specific color for each class of cover or, if you prefer, you can see the activity "Designing the place where I want to live" where there is a suggestion of colors for each class of cover that has been agreed upon.

How can we learn more about the different classes of cover the GLOBE Program uses?
To practice with the different classes of cover, you can download the GLOBE Observer App and work through the Cover Protocol or consult the MUC Program Guide.

What exactly is the MUC Code?
MUC stands for the Modified Land Cover Classification Code of a classification proposal put forward by UNESCO. This system follows international standards with appropriate terms organized in a hierarchical structure of integrating levels that are represented by numbers up to 4 digits. Within this system, each land cover class has a class that is mutually exclusive from another, i.e., there is only one class for each land cover class.

Suggested Resources

- MUC Guide to the GLOBE Program: https://bit.ly/3wYkhMV

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Data storytelling

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Biosphere	Carbon Cycle Biomass	15: Life on Land 13: Climate Action 4: Quality Education	Cognitive

Overview

Data are punctual records of a reality. Data alone are not useful for decision making. Therefore, they must be processed and interpreted appropriately to become information that helps answer a question or solve a problem. This activity will show some ways of interpreting a set of data to generate important information to guide decision making.

Time

30 min

Prerequisites

None

School level

Secondary

Purpose

Students will use a piece of data and convert it into useful information by interpreting it appropriately and communicating it to their peers.

Students Outcomes

- Students will identify the importance of interpreting data to generate information.

Background

Data alone does not tell us much, it needs to be transformed into information so that it can help us make decisions and generate knowledge. In this sense, data can be defined as a collection of facts or a record of something observed at a particular time, which by itself has no meaning. On the other hand, information has meaning (relevance and purpose) and is the result of placing data in context. Finally, knowledge can be defined as information plus experiences, values and the know-how to incorporate new experiences and information useful for action (UNAM, 2022).

Data represents variables (something changing in space or time) at a particular time and place. It can be qualitative or quantitative. Qualitative data is used to describe the quality of something or qualify the appearance of something, which can be opinions or thoughts that are usually described in words. Quantitative data is that obtained from figures, numerical values that can be analyzed using the tools provided by mathematics.

The set of data stored and classified, according to some criteria, constitutes what is called databases that, when subjected to analysis, generates information that can be understood and explained to guide decision making. Through this activity, students will practice how to convert data into information that can be properly communicated to their peers.

Guiding Research Questions

- What is a piece of data?
- Does the data provide information on its own?
- How can the data be interpreted to generate meaningful information?

Scientific Concepts

- A piece of Data
- Information
- Carbon Cycle
- Biomass

Materials and Tools

- Writing paper
- Pencil
- GLOBE Program Visualization Tool

What to Do and How to Do It

- ***Beginning***
    - The teachers present Table 1 to the students and ask them to identify the data by reading the text.
    - Once the data has been identified, the teachers explain that data alone has no information unless it is part of a context.

Table 1
Text to identify data

Text: To reduce fossil fuels (Borunda, 2021)	***Data***
The **1.1 degrees Celsius** that the planet has warmed since the pre-industrial period has pushed the Earth towards irreversible changes, some of which are inevitable. The ice melting in both Greenland and Antarctica is already causing faster sea level rise than at any other time in the last 3,000 years. Recent work has found that limiting warming to 1.5°C would reduce sea level rise by half in this century.	***1.1 ºC***

- The students are then asked to share some facts they know about any topic and to analyse whether they are sharing facts or information. Remember that information has meaning to the listener, while data alone does not convey anything special unless it is analysed and interpreted.

- The teachers present students with Figure 1, which contains data on the carbon storage capacity of a tree, and ask if the data in the red box means anything to them.

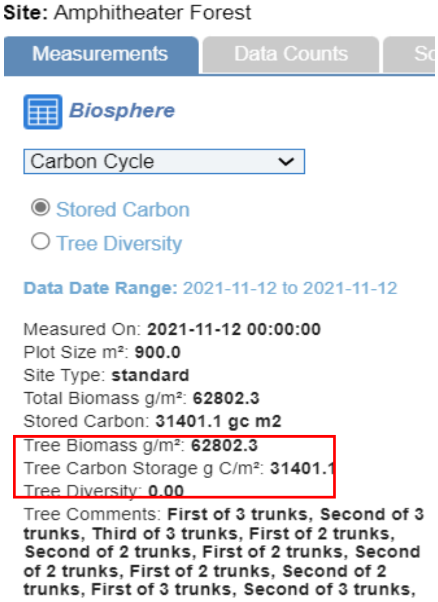

Figure 1: Elkhom Slough National Preserve GLOBE Program Carbon Cycle Protocol Data

- ***Development***

  - After listening to the students' answers, the teachers ask the students to write down the total biomass of the tree in g/m2 and the amount of carbon stored by the tree in g C/m^2.

  - Then the students are explained that the biomass of the tree is the total weight of the tree and that the amount of carbon stored is the weight in grams of carbon contained in the tree that has been produced as a result of the process of photosynthesis.

  - The students are then asked to contextualize the data. This involves creating a story that connects the data to a known reality or explaining the context of the data. For example, something along these lines could be said:
    - The amount of Carbon that was generated in the world in 2021 was more than 2000 million tons (UNFCCC, 2022).
    - The accumulation of carbon in the atmosphere is responsible for the fact that the temperature of the planet has increased by 1.1 ºC since the end of 1800 (NU,2022).
    - Plants need Carbon to produce glucose, a type of sugar needed to live. To produce one molecule of glucose, 6 molecules of carbon dioxide are needed.

  - The next step will be to ask students to create a representation for the data that would give meaning to it. For example:
    - A tree with a biomass of 62802,3 g/m2 stores 31401,1 g of C/m2, that is to say, that <u>half of the biomass of a tree is Carbon</u> (this underlined sentence would be the representation of the data that offers a meaning for the listener).

  - As a third step, it is necessary to make the data relevant, i.e. to explain why it is important. For example:

  - Some studies suggest that each person contributes 4 million grams of carbon per year due to their activities. If 31401.1 g of C/m2 is stored by one tree in the Elkhom Slough National Reserve, it takes approximately 133 trees to offset the carbon produced by one person per year.

- Finally, with the context, representation and relevance of the data, the teachers ask their students to construct a story to tell the biomass and carbon storage data. This will help transform the data into information. For example:

  - Imagine you are walking through the forest and you find a very big tree. Then you wonder: what is the tree made of? After investigating you discover that the basic building molecule is glucose, which is made from CO_2 and water, in the presence of solar energy. In other words, the tree we are observing is capable of storing carbon. This element so important for life in excess is also responsible for the increase of the temperature of the planet that since the end of the 14th century has increased by 1.1 ºC according to the United Nations. It is then that the curiosity arises to know how much carbon the tree that we have found is able to store. After applying a series of procedures we discovered that the tree has the capacity to store carbon equivalent to half its weight. If the tree weighs 62802.3 g/m2 then it stores 31401.1 g of C/m2 so it would take approximately 133 trees like the one we found to offset the amount of carbon produced by one person per year.

- ***Closing***
  - The students share the stories they created with their classmates.
  - The teachers explain to their students that their stories told have more meaning than data alone, because the story presents a context, represents the data in a way that makes it understandable and shows why the data is relevant to a reality. Therefore, with stories, data is no longer data but information.
  - Finally, students are asked to explain what is data and what is information in their own words.

Frequently Asked Questions

If I don't know how to give context to the data and represent it, what can I do?
At this level it is important to look for information in books or on the Internet about the topic to which our data refers in order to find more data that can be used to build our story.

What if the biomass and carbon capture data are still too complex for my students, can I still do the activity with other data?
Of course, this activity seeks to tell the data through a story that shows the context of where or why it was taken, that represents the values in a way that is easily understood, and that shows the relevance of the data. This applies to any type of data.

Suggested Resources

- GLOBE Data Visualization System: GLOBE Science Data Visualization

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Facts & trends: I have a question for you

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Biosphere	Green-Up	15: Life on Land 4: Quality Education	Communication

Overview

After reviewing the importance of research questions to motivate curiosity and learning, teachers guide students to pose and select their own research questions. This activity further seeks to enable students to understand the importance of gathering various data to answer their question. At the end of the activity, students will be able to identify trends over time.

Time

50 minutes

Prerequisites

None

School level

Secondary

Purpose

Through this activity the students will select a research question and interpret a trend graph to answer it.

Students Outcomes

- Students will propose research questions on which to work collaboratively.
- Students will explain the importance of collecting multiple pieces of data to answer a research question
- Students will interpret trend graphs

Background

Curiosity is a natural characteristic of all people and the first step to build knowledge. Knowledge without curiosity is not possible. So if you want to understand what is going on around you it is very important to have the ability to ask questions about everything that fills us with wonder.

Many times the answers to the questions we ask are in books or on the Internet. However, there are questions whose answers we cannot find and this is when the adventure of the scientific process begins. In this sense, science is nothing more than the generation of knowledge through an orderly and coherently connected process called the scientific method, which guides us through a series of steps that lead us through a process of reflection to produce knowledge (Figure 1).

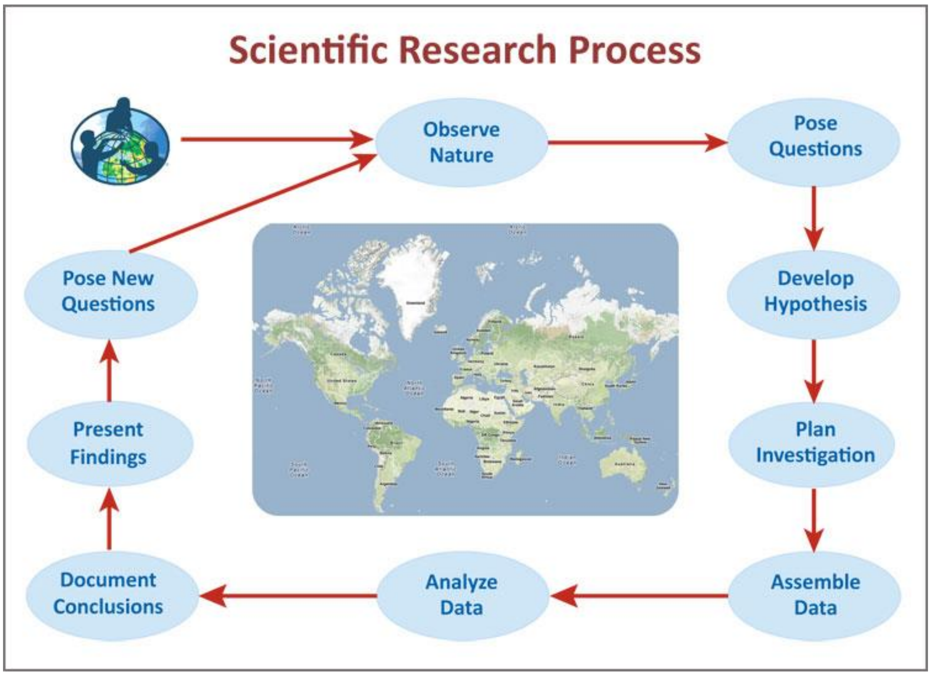

Figure 1: Steps of the Scientific Method

The scientific method begins with a question that arises from something we have observed that has filled us with wonder. These questions are motivating, and as Rachel Carson mentions in her book "The Sense of Astonishment" (1956) it is important to keep the senses open to the perception of the environment for the amazement to occur. It is then that we go after the discovery of cause-effect relationships.

By asking ourselves questions, we carefully gather and examine the evidence, looking for all available information to combine it into a logical answer supported by data that can be qualitative (words that qualify something) or quantitative (numerical values). Questions such as What, How, When and Where are the most common ones to be asked after observing something interesting. At this point, it is important to emphasize that the observation experience is what guides us to formulate questions that help us to explain what we perceive. Therefore, to enhance our observation experience it is important to: i) experience the environment with all our senses (this is why outdoor activities are very successful); ii) identify what is most interesting to the observer, what fills us with wonder, excitement or curiosity; iii) ask questions, as many as possible about what has caught our attention, and iv) take notes or data about the things that have captured our attention.

The discovery begins with a question

The research question is the driver or guide for knowledge generation. This is where the importance of finding a question that has not been previously answered lies, which also implies that a good research question is worthy of being answered or is worth the effort to answer. The following are some characteristics of a good research question, which can be summarized in one name: OSCAR (Table 1).

Table 1
Characteristics of a Research Question

O **Original**	**S** **Students´ own interest-based question**	**C** **Clear**	**A** **Accessible**	**R** **Relevant**
Questions should be creative and not just copies of similar questions.	A good question should start with something that interests students.	It should be clear and simple enough to be understood by different types of audiences.	The questions should be able to be answered, preferably quantitatively, with the resources we have and in a reasonable amount of time.	They should be aimed at understanding important issues.

In order to answer the research questions that are formulated, it is important to return to the observed reality and collect data, through field evaluations, in order to obtain evidence. Utilizing appropriate equipment and methods, it will be possible to arrive at an answer through the analysis and interpretation of the data collected, for which, many times, statistics are used.

Statistics can be defined as the science of data. This science uses mathematics to make sense of a set of data, converting them into useful information that supports decision making, answering research questions or solving problems (PUCP, 2022). One branch of statistics is in charge of reducing a data set to a small number of descriptive values that allow characterizing the main properties of the data set initially obtained to be easily transmitted and understood. This branch is called descriptive statistics (ESAN, 2016).

Descriptive statistics summarizes, analyzes and represents a set of data to describe a reality. In other words, it can be said that it explores the data to present them in an easily understandable way, and to achieve this it is necessary:

- To group the data belonging to the same category
- To sort the data from highest to lowest or you can also sort the identified categories.
- To calculate measures that summarize information for each category.
- To represent the data found in tables or figures.

Among the main measurements taken to summarize a data set, the following can be considered (Orellana, 2001)

- Frequency: It indicates the number of times data fall into a certain category and can be presented as percentages.
- Average: This is the most frequent position measure into which the data fall.
- Median: It is the data that occupy the central position of a set of data sorted from highest to lowest.
- Mode: It is the data that occur most frequently in the data set.

The main ways of representing data are (ESAN, 2016):

- Bar charts or pie charts: Generally they present the frequencies found. Bar graphs are also often referred to as histograms.
- Scatter plots: They show the relationship between two variables, an independent (X) and a dependent (Y) ones.
- Trend graphs: It is the representation of the data obtained over a defined period of time to observe their behavior over time.

Guiding Research Questions

- What is a research question and what characteristics should it have in order to generate knowledge?
- Are the data necessary to answer a research question? Why?
- Is it possible to summarize a data set to better understand it? How can this be achieved?
- Do the data obtained in the environment change over time?
- How can the behavior of the data be represented over time?
- Why is it important to analyze data over time?

Scientific Concepts

- Scientific Method
- Research Question
- Statistics
- Trend
- Phenology

Materials and Tools

- Paper
- A pencil
- GLOBE Program Visualization Tool

What to Do and How to Do It

- #### *Beginning*

  - Teachers take their students to a place where they can be in contact with plants and ask them to observe the plant leaves carefully.

  - Then, they ask them to ask questions about what they have observed on the leaves. They can start by using some kind of game so that all the questions begin with: What, Why, When, When and Where?

  - All questions are written down on pieces of paper to make a big list, the more questions you have, the more chances you will have to find the right research question, which we will call EUREKA QUESTION. All questions are important so it is necessary that the students have time to think about all possibilities.

  - Next, the students return to the classroom.

- ***Development***
  - In the classroom, teachers divide the board into two parts and ask their students to place their research questions in the category of their choice (Table 2).

Table 2
First Brainstorming Classification of Research Questions

Very interesting questions	Uninteresting questions

  - The students are then asked to place the very interesting questions distributed as in Table 3.

Table 3
EUREKA Question Selection

	Very interesting questions
Already answered - the information can be found in books or on the Internet.	To check this question the teacher's guide or the Internet is needed to check if the questions are already answered.
There is no information to answer the question	EUREKA: The questions that are in this box are what can be considered research questions.

  - Once the EUREKA questions are found, it is important to plan whether it will be suitable to be answered. To do this the students can complete Table 4 with the help of their teachers.

Table 4
Planning from a research question

It takes a long time to answer it	It takes many teams to answer it	It takes a large area and many people to answer it.	It is possible to manage the answer to the question with our resources: people, equipment and time.
			Question chosen

  - Next, the teachers present their students with Figures 2 and 3, obtained from the GLOBE Program Data Visualization System. When presenting the figures, the teachers explain that these are data on the changes that the tree leaves, commonly called birch, have undergone over time.
  - Presenting them with the figures, the teachers ask their students to look at them carefully and describe them as best they can. What data is on the horizontal axis (X) and what data is on the vertical axis (Y). They should remember that the variable X is independent and the variable Y is dependent because it changes as a function of X.
  - Then, students are asked to compare the two figures and explain if they see changes over time in the size of the leaves (Y-axis). What changes are these? When do they start? Do they see if the changes show the green dotted line going up or down (explain that this is the trend)?

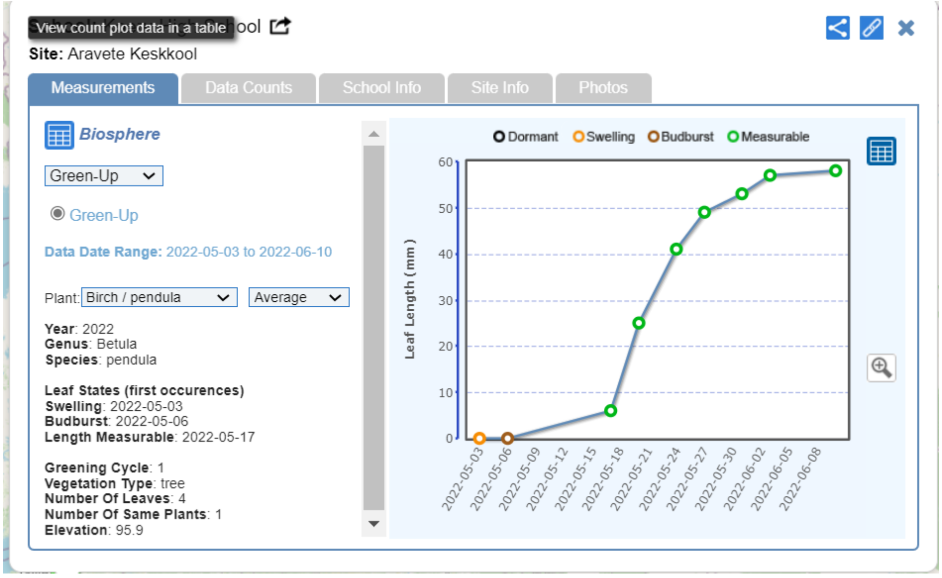

Figure 2 Green-Up data for *Betula sp* in Estonia, 2022

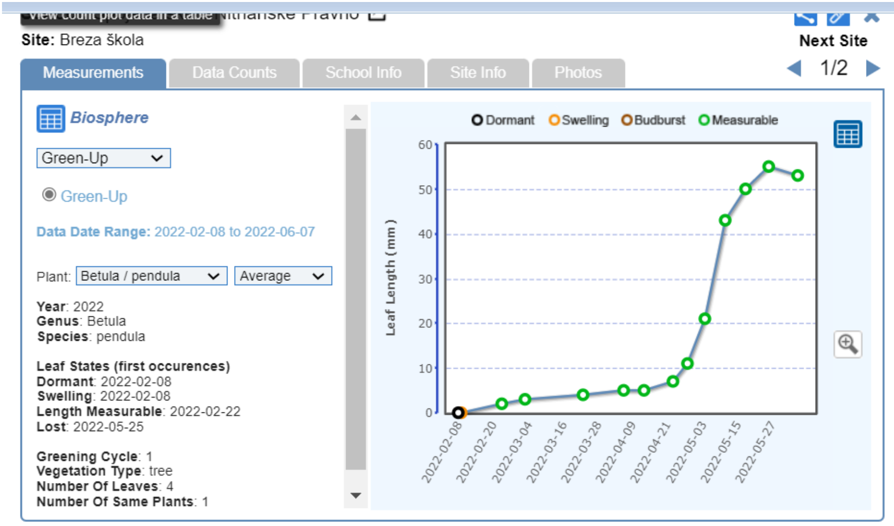

Figure 3 Green-Up data for *Betula sp* in the Czech Republic, 2022

- ***Closing***

  - The teachers form groups with students to discuss what they observed in the figures and to explain what a trend is in their own words and whether the trend between Figures 2 and 3 is the same.

  - Each group of students will designate a classmate to present their findings to the rest of the group.

  - The students propose an investigation based on the observations made on the plant leaves they saw at the beginning of the activity. They may decide to do the Green-Up protocol to have their own trend line.

Frequently Asked Questions

Can other figures be used to show trends?
Of course, the GLOBE Program offers a large database on different variables that can be used for this exercise. For example, you can try with temperature and precipitation trends, which are common and well-known variables.

Can we create our own trend lines?
Yes, you only need to take data for the variable of your choice over a certain period of time, for example, every day for a month for climate variables or once a week for 3 months for phenology variables. The longer you take the measurements and record the data, the better trend lines you will be able to observe.

What exactly is a trend?
A trend is the direction a set of data takes over time, either up or down. To view a trend, the data is plotted on a Cartesian plane where time is the independent variable (X) and the other variable "Y" depends on time moving along it.

Suggested Resources

- GLOBE Program Green-Up and Green-Down Protocol: Green-Up / Green-Down - GLOBE.gov
- GLOBE Data Visualization System: GLOBE Science Data Visualization

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Tree height: Averages, medians, and modes

GLOBE		Associated SDG	Type of Activity
Sphere	Protocols		
Biosphere	Biometry - Tree Height	15: Life on Land 13: Climate Action 4: Quality Education	Cognitive

Overview

When scientific measurements are made, to be sure that the data taken are as close as possible to reality, they should be repeated at least 3 times. This number of repetitions helps to reduce the error. The data obtained are then summarized using some statistical tools such as averages, modes or medians. Through this activity, students will calculate averages and find the median and mode of a set of data related to tree height.

Time

50 minutes

Prerequisites

None

School level

Secondary

Purpose

Considering tree height data, students will learn the importance of repetitions, calculate averages, and identify the median and mode of a data set.

Students Outcomes

- Students will recognize the importance of replicates when taking scientific data.
- Students will organize a data set to obtain summary statistical measures.
- Students will calculate summary statistical measures of a data set such as mean, median, and mode.

Background

When field measurements are made to obtain data on some observed characteristic, it is important to have confidence in the measurements taken, as only then can the data be properly contextualized and given meaning. The confidence in the measurements depends on some factors such as the state of the instruments used (therefore, the calibration of the equipment is fundamental), the place where the measurement is made, the conditions in which the data are obtained and the subjectivity (experience) of the observer.

The first step for an adequate measurement is to identify the variable to be evaluated, to select the appropriate instrument, to calibrate it and to follow a set of established steps to take the measurement in such a way that it can be repeated on successive occasions. This process is called measurement protocol.

Confidence in the measurements implies recognizing that each time a measurement is repeated, the values obtained will be very close to each other, being within a range or confidence interval. To make sure that the data we obtain are reliable, it is always recommended to make at least 3 measurements of each variable under study to reduce the error. For example, when measuring the height of trees using the GLOBE Observer App, or a clinometer, it is recommended to measure each tree 3 times and make sure that the difference of these three measurements is less than 1 m in height (this meter would be the confidence interval).

Repeating the measurements generates a large amount of data, which often times is not known how to handle, which is why the data from the repetitions are organized and summarized in some measurements that have greater meaning. Within these measurements are the means (averages), medians and modes, which are part of what is known as descriptive statistics.

Statistics can be defined as the science that makes sense of data using mathematics. In order to properly interpret the data on a given reality, it is important to be clear about some concepts, such as the following (INEI, 2006):

- Population: The set of units or elements defined in space or time in which the researcher is interested.
- Sample: The representative subset of the population.
- Sampling unit: The unit that is selected to construct the sample and from which the data is obtained.
- Error: The difference between the population real value and the sample estimated value.
- Average: A measurement of central tendency obtained by adding the values of the data and dividing the result by the number of them.
- Median: A measurement of central tendency that divides a set of sorted data into approximately two parts, 50% higher and 50% lower. To calculate the median, the data are sorted from smallest to largest. If the number of data is odd, the median is the central value. If the number of data is even, there are two central terms, and the median is the semi sum of these two values.
- Mode: A measurement of central tendency that presents the value of the variable that has the greatest frequency. That is, which is the value that is most repeated.
- Data: Value of a variable that in itself has no meaning if it is not properly analyzed.
- Variable: A characteristic of an object that can be observed, measured and analyzed.

Guiding Research Questions

- What is an average?
- Why is it important to calculate averages?
- Is the mean or average the same as the median and the mode?
- Why do the measurements have to be repeated?
- What calculations can be done with the data to better understand it?

Scientific Concepts

- Mean
- Median
- Mode

Materials and Tools

- GLOBE Observer App – Tree Height
- Paper
- A pencil
- A calculator

What to Do and How to Do It´

- ***Beginning***
  - Teachers go into the field with their students and assess the height of the trees they find. It is important to tell the students to select random trees to be measured and to take three measurements of each tree.
  - If they do not have time to go out in the field, students can use Figure 1, which shows some tree measurements.
- ***Development***
  - The teachers present Figure 1 and ask their students to identify the trees with reliable data to calculate the average height. Each tree has been measured three times and it is important to remember that to have confidence in the data, the data must be within one meter of each other.

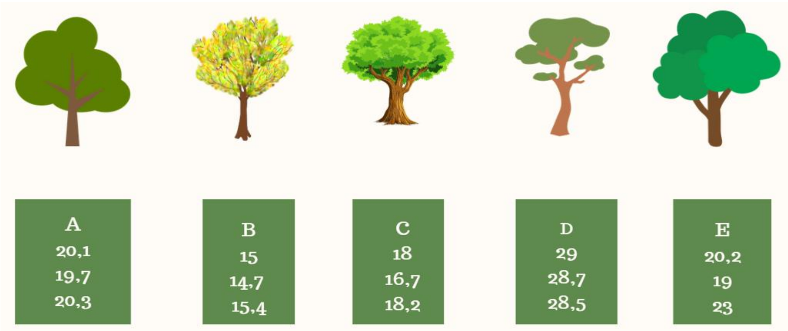

Figure 1: Measurements in meters taken from five trees. It can be seen that trees A, B and D have data with a difference from each other lesser than 1 meter apart, so the data are reliable. In tree C the difference between the first and second data is greater than 1 meter, so one more measurement should be taken. On the other hand, in tree E, the three data among them have differences greater than 1 meter, so at least two new tree E measurements should be taken.

  - Once the trees with reliable data have been identified, the students are asked to calculate the average height (Table 1). It should be remembered that, to calculate the average, the three data are added together, and the result of the sum is divided by 3 (because there are 3 measurements).

Table 1
Tree Height Average Calculation

Tree	**A**	**B**	**D**
Datum 1	20,1	15	29
Datum 2	19,7	14,7	28,7
Datum 3	20,3	15,4	28,5
Average			

- Next, the students are asked to look at Figure 2, which shows the average measurement of a series of trees and are asked to calculate the mode and median of the values shown.

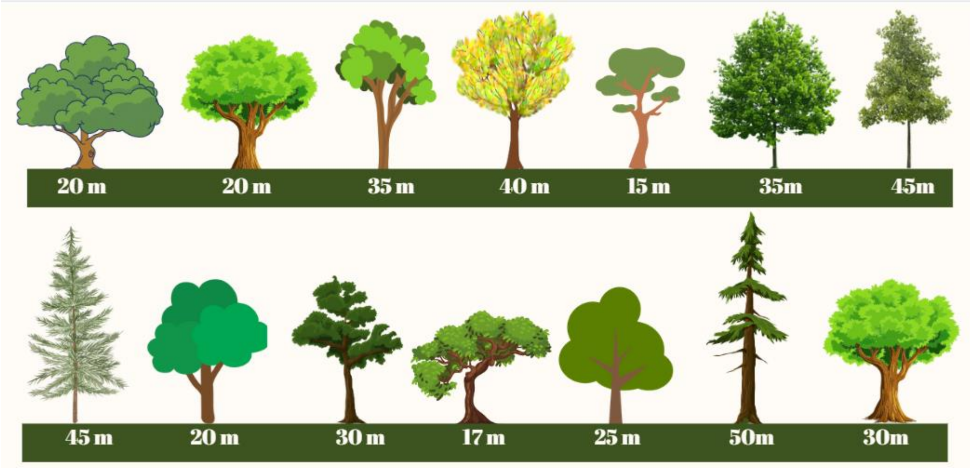

Figure 2: Average of the measurement of a set of trees

- To calculate the mode, it is important to sort the data from smallest to largest and count the number of times that value is repeated- this is called frequency. Therefore, the value of the mode will be the number that appears most frequently, as shown in Table 2. In this example, the mode is the 20 m trees. If there is a tie in the number of times a value appears, it is possible to consider that there are two modes.

Table 2
Mode Calculation

Tree size	15m	17m	20m	25m	30m	35m	40m	45m	50m
Frequency Number of trees with the same size	1	1		1			1		1

- Next, the median of the values is calculated. For this purpose, the tree height sorted data from table 2 is considered, which can be seen in Figure 3. To calculate the median, the middle value of the data set is considered. In this case, if there are 9 tree heights, the median will be the value that is in a central position (middle value). To its left there will be the 4 low values and to its right there will be the 4 high values.

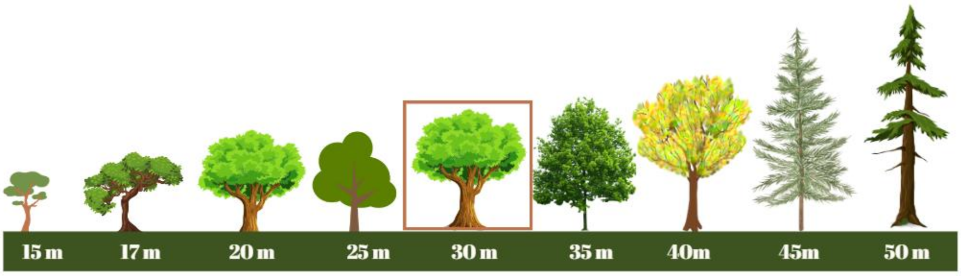

Figure 3: Trees are sorted by height, from shortestt to tallest, with the median shown in a square.

  - In Figure 3 the median of an odd set of data has been calculated. What would happen if the data set were even is that there would be two central values so the median would be the average of the two central values.

- ***Closing***
  - The students explain why it is important to repeat a measurement in their own words.
  - Working in groups, the students create a poster to explain what they understand by mean, median and mode, and why these values are important for generating information from data collected in the field.

Frequently Asked Questions

<u>Is it possible to work with other elements in class, if we don't have trees nearby?</u>
Of course, you can use plant leaves that students can bring to class and use a ruler to measure them. You can also have different students measure the same leaf so that they can see for themselves if there is a difference among the measurements.

<u>What exactly is a variable?</u>
The variable is something that can change, adopting different values. These can be qualitative (generally opinions that describe attributes or qualities) or quantitative (numbers that present some dimension of the variable being studied). In turn, quantitative variables can be continuous or discrete. They are called continuous variables when they are described with real numbers showing intervals, for example, height of the trees: 5.53 m or 4.21 m. Discrete variables are those that are represented by natural numbers, such as the number of trees in the yard: 15 or 20 (INEI, 2006).

Variables can also be classified as independent and dependent. Independent variables are those that directly influence the characteristics being studied, for example, time. Dependent variables are those that are measured in each repetition to see how the independent variable influences its values, it can also be said that it is the response variable, for example, the height of the trees, which changes over time (Florian, 2008).

Suggested Resources

- GLOBE Observer [Trees Overview - GLOBE Observer - GLOBE.gov]
- Students can use Canva to make their posters. [Home - Canva]

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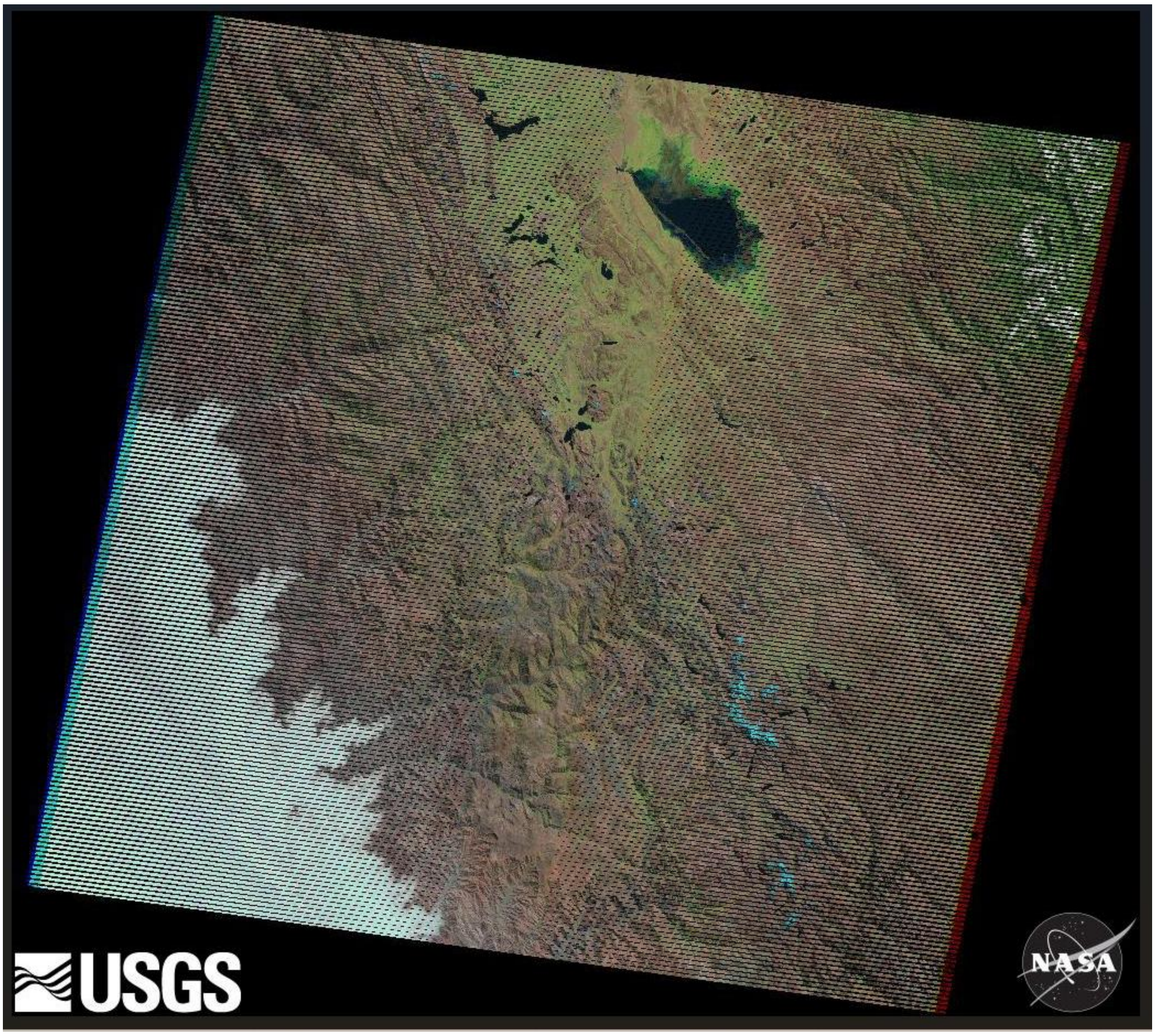


LEARNING ACTIVITIES USING SATELLITAL INFORMATION

The GLOBE Program

LAC Regional Office

Deforestation

GLOBE		Associated SDG	Type of Activity
Sphere	Protocols		
Atmosphere	Air Temperature. Surface Temperature. Wind Direction and Speed. Precipitation Relative Humidity	6 (Clean Water and Sanitation) 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 Air quality Water Cycle Water Quality Soils		

Overview

Satellite images and maps are analyzed to determine deforestation impacts and trends over the last 30 to 40 years. A series of Landsat images are compared to detect changes in land cover, hot spots (which can lead to fires) and seasonal changes. Students analyze cases of deforestation to establish crops (soybeans, palm oil, etc.), cattle raising, mining, urbanization, etc. They also analyze the impact of fires on forests.

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 large-scale deforestation and changes in the interrelationship among the spheres of the Earth System

Student Outcomes

- Students will identify deforestation patterns associated with different human activities.
- Students will identify the main types of land cover in satellite images.
- Students will analyze land cover changes through the use of satellite images.
- Students will analyze the impact of human activities and fires on land cover.

Background

According to FAO's 2020 assessment, almost one third of the planet's surface is covered by forests. The greatest extension corresponds to tropical forests. Forests have a high biodiversity, many endemic species are specialized in microhabitats within the forest and can only be found in very restricted areas. Their specialization makes them vulnerable to extinction.

Forests provide products for global consumption such as latex, cork, fruits, nuts, wood, fibers, spices, oils, natural resins, and medicines, among others. Forests are a huge carbon sink because trees capture CO_2 from the atmosphere, they also absorb and emit water vapor through transpiration and even get to form their own clouds. Forests provide other services to society such as water regulation, soil formation and conservation, biodiversity conservation and climate regulation. They also purify the air, provide food and water, are sources of energy, recreational areas and preserve the cultural identity of the people who live in them, etc. In Latin America, the largest expanse of forests corresponds to the Amazon River basin, which covers about one third of South America, encompassing eight countries.

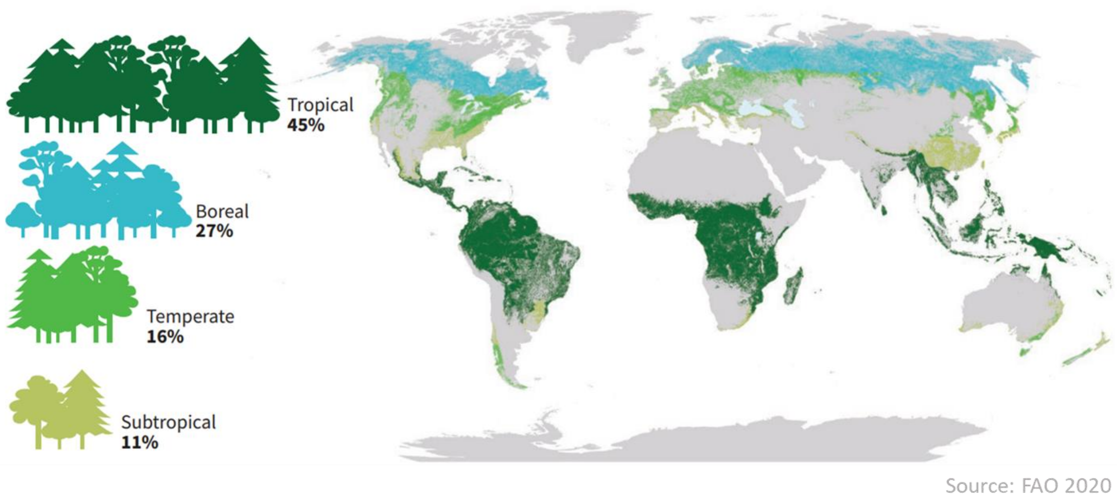
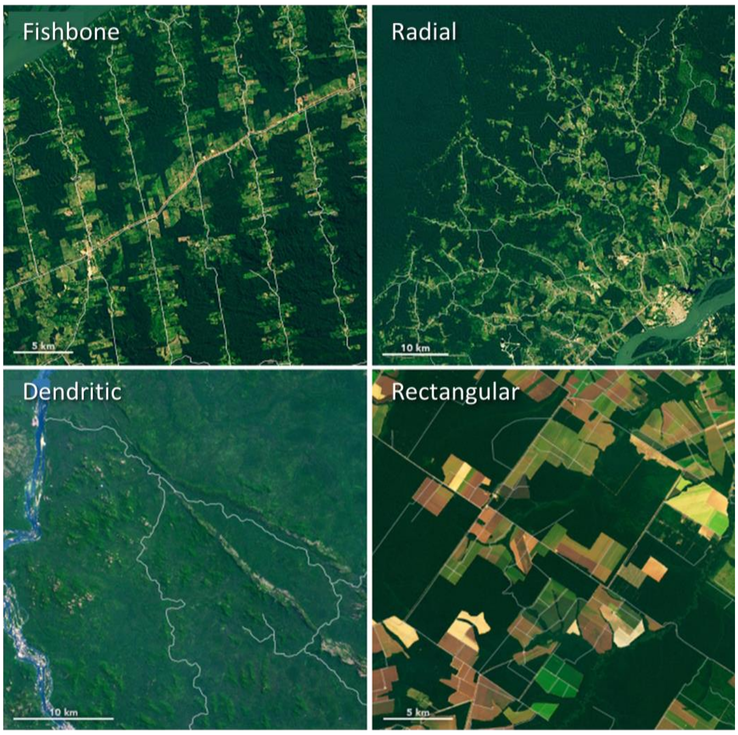


Figure. 1. Global forest area by climate zones, 2020. Source: FAO 2020

In the last 20 years, satellites have shown forest cover change and rapid decline in some places. In addition to the species that are lost when a sector of the forest is deforested, the remaining forest fragments are increasingly vulnerable. When a forest becomes fragmented, the edges begin to change rapidly due to exposure to increased solar radiation, winds, etc.



Source: NASA Earth Observatory (2022)

Figure 2 Deforestation patterns observed in the Amazon basin.

Human activity is responsible for the generation of major impacts on forests. From the analysis of satellite images, different patterns of deforestation have been detected: 1) *Fishbone*: from the construction of roads the deforestation process began, set up in a perpendicular direction, to establish crops and form later urbanizations. E.g. Rondonia in Brazil. 2) Radial: In some sectors deforestation began by starting from a center and extending radially. E.g. Santa Cruz de la Sierra, Bolivia. 3) *Ramified*: A large-scale, rapid deforestation was started to replace it with pastures that provide food for cattle. E.g. São Félix do Xingu, Brazil. 4) *Rectangular*: deforestation occurs through burning to establish crops, such as soybeans. E.g. Salta, Argentina. In recent years, soybean cultivation has spread throughout most of the tropical and temperate zones of Latin America, causing deforestation in many places. Another similar case occurs with palm oil plantations. E.g., Yurimaguas, Peru. Small-scale gold mining produces another type of deforestation, leaving a *pattern of water-filled prospecting pits* where mercury is used to amalgamate with gold. E.g., Madre de Dios, Peru.

Another type of disturbance caused by deforestation is fire. In dry periods, fires cause major changes in forest cover spreading smoke to almost the entire continent, for example, the number of hot spots increased in the Caribbean region in early 2020 and in South America from August 2020. Combined images of the hot spots and smoke generated by the 2019 fires that some days darkened the sky in the city of São Paulo, Brazil, can be seen in Worldview.

Similar events occurred in Corrientes, Argentina. The 2020 drought affected the flows of the Paraná River creating large fires in this river delta vegetation. Forest modification has environmental, economic, social and political implications on a local, regional and global scale.

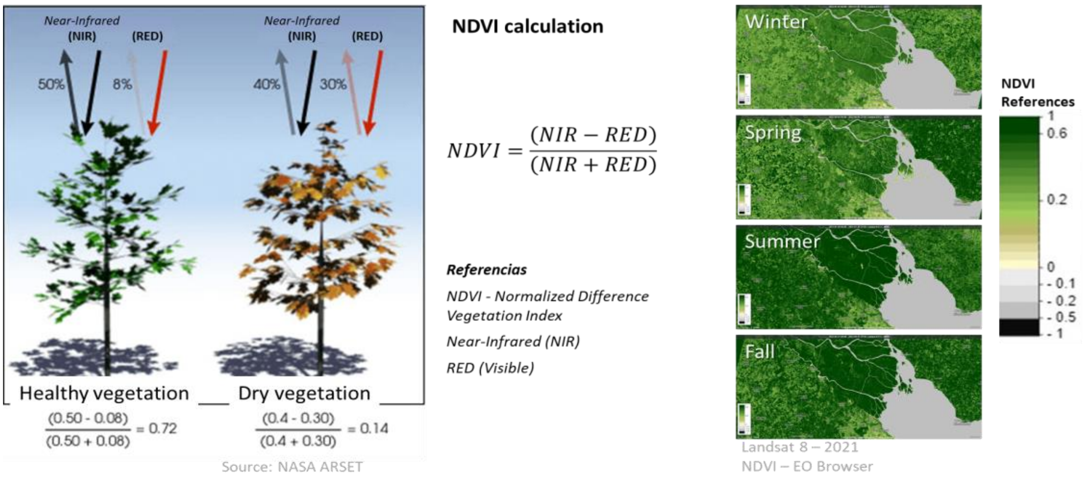


Figure. 3. Calculation and NDVI processed satellite images of the Paraná River Delta

Changes in forest cover are easily detected by looking at a satellite image, but more detail can be analyzed by applying indices. The Normalized Difference Vegetation Index (NDVI) is the most commonly used, but there are several similar indices. The NDVI allows estimating the quantity, quality and development of vegetation based on the measurement of the radiation intensity of some bands of the electromagnetic spectrum that vegetation emits or reflects. The bands vary according to the type of satellite, but some imagers automatically generate the 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.).

Knowing and monitoring land cover change is the first step in understanding and designing mitigation measures to prevent impacts.

Guiding Research Questions

- What is the impact of deforestation on ecosystems and people's lives?
- What human activities impact large-scale deforestation?
- How do fires impact deforestation? How far does smoke from fires spread and how does it impact other ecosystems and nearby cities?
- How can deforestation and fires be monitored?
- How does NDVI vary in forest patches and other areas (crops, urbanization, etc.) during different seasons of the year?
- How does land cover change in the short and long term?

Scientific Concepts

- Ecosystems
- Deforestation
- Land cover
- Crops
- Electromagnetic spectrum
- Satellite Images - Spectral Bands - NDVI Index

Materials and tools

- ArcGIS StoryMaps https://storymaps.arcgis.com
- Copernicus Global Land Cover (Land Cover - 2015 to 2019)
- Satellite images of:

Case 1. Rondônia, Brazil:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- GFW tree cover loss (2001 to 2021)
- Wordview (1984 and 2022 comparison)
- EO Browser - NDVI (seasonal changes): Spring, Summer, Autumn, Winter
- GFW fire alerts (3-month periods)
- NASA FIRMS - latest fire alerts (hot spots)
- Wordview (Smoke and heat sources) 9 Aug. 2021

Case 2. Santa Cruz de la Sierra, Bolivia:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- GFW tree cover loss (2001 to 2021)
- Wordview (comparison 1986 and 2021)
- EO Browser - NDVI (seasonal changes): Spring, Summer, Autumn, Winter
- GFW fire alerts (3-month periods)
- NASA FIRMS - latest fire alerts (hot spots)
- Wordview (Smoke and heat sources) 26 Sep. 2021

Case 3. São Félix do Xingu, Brazil:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- GFW tree cover loss (2001 to 2021)
- Wordview (1984 and 2022 comparison)
- EO Browser - NDVI (seasonal changes): Spring, Summer, Autumn, Winter
- GFW fire alerts (3-month periods)
- NASA FIRMS - latest fire alerts (hot spots)
- Wordview (Smoke and heat sources) 23 Aug. 2022

Case 4. Salta, Argentina:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- GFW tree cover loss (2001 to 2021)
- Wordview (comparison 1986 and 2022)
- EO Browser - NDVI (seasonal changes): Spring, Summer, Autumn, Winter
- GFW fire alerts (3-month periods)
- NASA FIRMS - latest fire alerts (hot spots)
- Wordview (Smoke and heat sources) 21 Aug. 2022

Case 5. Yurimaguas, Peru:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- GFW tree cover loss (2001 to 2021)
- Wordview (comparison 1985 and 2022)
- EO Browser - NDVI (seasonal changes): Spring, Summer, Autumn, Winter
- GFW fire alerts (3-month periods)
- NASA FIRMS - latest fire alerts (hot spots)
- Wordview (Smoke and heat sources) 15 Sep. 2016

Case 6. Madre de Dios, Peru

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- GFW tree cover loss (2001 to 2021)
- Wordview (comparison 1986 and 2022)
- EO Browser - NDVI (seasonal changes): Spring, Summer, Autumn, Winter
- GFW fire alerts (3-month periods)
- NASA FIRMS - latest fire alerts (hot spots)
- Wordview (Smoke and heat sources) 22 Aug. 2022

Case 7. Paraná River Delta, Argentina - Fires:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- GFW tree cover loss (2001 to 2021)
- Wordview (comparison 1986 and 2021)
- EO Browser - NDVI (seasonal changes): Spring, Summer, Autumn, Winter
- GFW fire alerts (3-month periods)
- NASA FIRMS - fire alerts (hot spots 30 Dec. 2021)
- Wordview (Smoke and heat sources) 19 Aug. 2022

What and how to do it

- ***Beginning***

  - Show your students the GFW map of forest loss in Latin America and the Caribbean.

  - Show the changes from 2001 to 2021 (by clicking on the years in the legend on the left of the screen).

  - Ask your students to note the years of greatest forest loss. They can zoom in on the map to see some sites in more detail.

  - Ask your students to suggest hypotheses about possible causes of deforestation.

- ***Development***

  - Ask your students to read the introduction to this activity and make a concept map with the information.
  - Divide the class into student groups and assign one case study to each group. Tell your students:

    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 cover do they correspond to (Urban, Suburban, Roads, Forest, Grasslands, Crops, Bare Soil, Water, etc.)?
    b. Refer to the Copernicus Global Land Cover to characterize the land cover type. Are there any changes between 2015 and 2019 for the analyzed region?
    c. Open the Google Earth sequence and observe the changes in each year. Note the changes. What pattern of deforestation do you observe for that location?
    d. Analyze the same in the GFW (Global Forest Watch) sequence. In which years did the most deforestation occur? What do you suppose was the cause (establishing areas for agriculture and urbanization, cattle raising, gold prospecting, fires, etc.)?
    e. Compare Landsat images (old and current). Record the observed changes.
    f. What seasonal changes are observed in EO Browser images processed with the NDVI index? Consider crops and forest patches.
    g. Consult fire occurrences in GFW, NASA FIRMS and Wordview. Has the area under analysis had fire alerts? Do they intensify at any time of the year? What is the fire trend at this site? Has it suffered large fires at any given time? Is it affected by smoke from nearby fires?

  - 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.

  - Bring all the groups together and ask them to explain the cases they analyzed and compare the similarities among such cases.

  - Complete the conceptual map with the impacts observed in each case and their ecological effects.

  - If there are forests in your area, you can use the same tools to analyze their condition and changes over the last few years. You can get more information and statistics from GFW (Global Forest Watch) and supplement it with field measurements.

- ***Closing***

  - Due to the relevance of this problem, it is important to develop outreach activities. Students can develop a story with maps (Story Map), a video, or flyers to post on social networks summarizing the analyzed cases and highlighting the importance of their conservation.

Frequently Asked Questions

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 consult satellite images from different dates and locations to explore other sites where large-scale deforestation has occurred. Worldview and Google Earth store images dating back to the 1980s. In addition, Global Forest Watch collects a wealth of information on forests and the problems of deforestation, fires, plantations, etc. that can be used to supplement research.

Other Resources:

Tutorials for: Worldview, EO Browser, Story Map

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NASA Earth Observatory (2018) *Deforestation in Paraguay.* https://go.nasa.gov/3TMbSG0
NASA Earth Observatory (2019) *South American Fires in 2019.* https://go.nasa.gov/3KPdvyE
NASA Earth Observatory (2019) *Tracking Amazon Deforestation from Above.* https://go.nasa.gov/3QkUvcr
NASA Earth Observatory (2019) *Tracking Peruvian Forest Loss from Space.* https://go.nasa.gov/3RFKJCH
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NASA Earth Observatory (2022) *Patterns of Forest Change in Bolivia.* https://go.nasa.gov/3KSIkmb
NASA Earth Observatory (2022) *The Spread of Soy in South America.* https://go.nasa.gov/3D4fbma
The GLOBE Program (2022) *GLOBE Protocol Bundles.* *https://www.globe.gov/es/web/earth-systems/*

Forests

GLOBE		Associated SDG	Type of Activity
Sphere	**Protocols**		
Atmosphere	Air Temperature Surface Temperature Wind Direction and Speed Precipitation Relative Humidity	6 (Clean Water and Sanitation) 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 Air quality ENSO Water Cycle. Water Quality Soils		

Overview

Satellite images, satellite data and maps are analyzed to characterize forests (tropical, subtropical, temperate and mangrove forests) and urban parks, and to establish differences and similarities. Students analyze cases of different types of forests and parks in Latin America and the Caribbean. Extensions of the activity are suggested by taking field measurements to supplement the satellite information.

Time

4 or 5 classes

Prerequisites

Basic knowledge of ecosystems, photosynthesis, 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

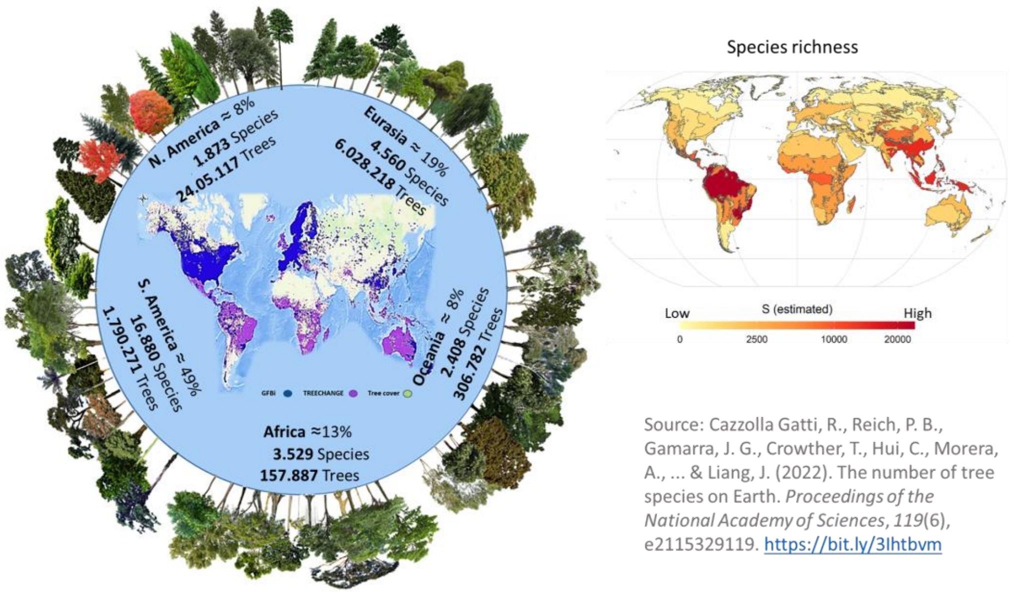
To understand the environmental conditions that allow the development of different types of forests, and the trends of short- and long-term changes in the interrelationship among the spheres of the Earth System.

Student Outcomes

- Students will identify the main types of forest cover in satellite images.
- Students will characterize the environments where different types of forests grow and compare them with urban parks.
- Students will analyze changes in forest cover and tree height through the use of satellite images.

Background

Currently, almost a third of the planet's surface is covered by forests. The 2020 FAO report indicates that the greatest extension is occupied by tropical forests with high biodiversity, followed in extension by the boreal forest, then the temperate forest and finally, the subtropical forest. The Latin America and the Caribbean forests are megadiverse and, according to the latest estimates, are home to approximately 49% of the world's tree species diversity (Cazzolla Gatti, et. al, 2022). Figure 1.



Source: Cazzolla Gatti, R., Reich, P. B., Gamarra, J. G., Crowther, T., Hui, C., Morera, A., ... & Liang, J. (2022). The number of tree species on Earth. *Proceedings of the National Academy of Sciences*, *119*(6), e2115329119. https://bit.ly/3lhtbvm

Figure. 1. Tree species richness

Conducting forest inventories to know the existing biodiversity in forests is useful because: a) It helps to infer the evolutionary mechanisms that generated the diversity and to predict how these same mechanisms will develop in the future. 2) It helps to evaluate which systems can be more resistant to global change. 3) It allows us to know the rare species and their vulnerability to extinction risk in order to manage biodiversity preservation. 4) It allows understanding total species assemblages to quantify the impacts of regional conservation efforts and improve the ability to predict extinctions.

People who live far from forests are not likely to think of them when they pour themselves a glass of water or watch the rainfall in city parks. But forests near and far affect daily life far more than most people realize. In large cities, the benefits of urban trees in reducing stress, sequestering carbon, cleaning and cooling the air are increasingly recognized, but the benefits of distant forests (in regulating global climate, water quality and availability, biodiversity benefits essential to health, people's quality of life, and others) are not always considered. The Cities4Forests initiative summarizes the benefits that forests provide to cities at three scales: internal, near and distant to help cities conserve, restore and sustainably manage their forests. Figure. 2. In addition to the services mentioned above, forests provide global consumer products such as latex, cork, fruits, nuts, timber, fibers, spices, oils, natural resins, and medicines, among others.

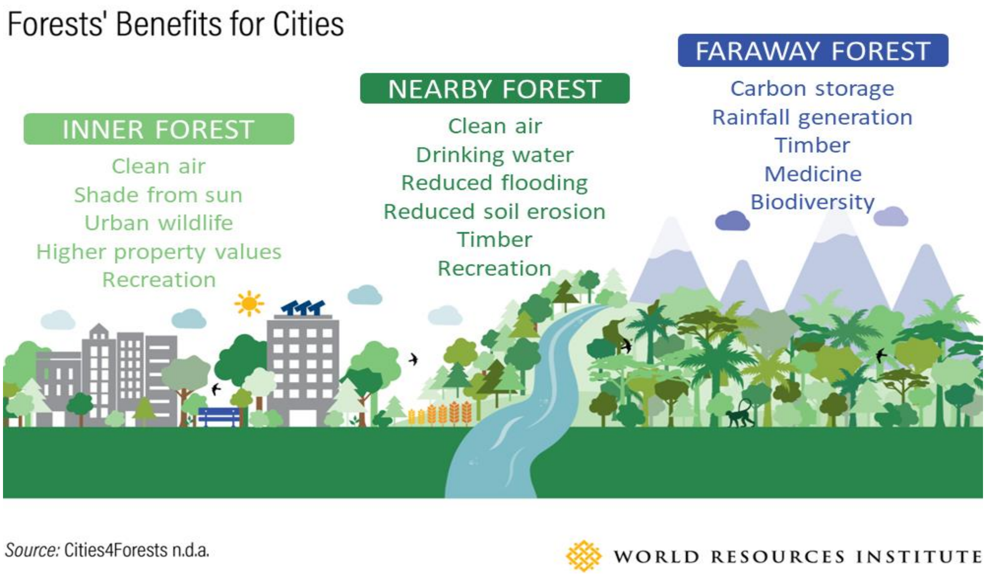


Figure 2. Benefits provided to cities by the three levels of forests and their contribution to the achievement of the SDGs. Source: Cities4Forests (Wilson, et. al, 2022) https://www.wri.org/insights/forests-benefit-cities

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The trees in the cities, with their shade, help to reduce the heat island effect. Many trees are used in parks and plazas, in some cases with artistic and recreational designs such as the labyrinths found in most of Latin America and the Caribbean: Labyrinth of Apaneca, El Salvador, Labyrinth in Ancon, Peru, Labyrinths Borgeano, Patagonian and Las Toninas, Argentina. But there are also other designs that can only be seen from the air, such as the Guitar-shaped park built with 7,000 trees near the city of General Levalle, Argentina. Another curiosity about trees is their height and, especially, their long life. Some forests are home to very old trees that have managed to survive diseases, fires, droughts, etc. In the Andean-Patagonian forests live the araucaria (*Araucaria araucana*) with some specimens that are over 1000 years old. In the city of Santa María del Tule, Oaxaca, Mexico, there is the Tule Tree, a specimen of Montezuma Cypress (*Taxodium mucronatum*) whose estimated age is close to 2000 years.

In the Los Alerces National Park in Argentina is the larch (*Fitzroya Cupressoides*) called "El Abuelo" (The Grandfather) with 2600 years old. In Brazil, near Sao Paulo, there is Jequitibá-rosa (*Cariniana legales*) also called "Patriarca da Floresta", approximately 3,020 years old. Although it seems incredible, these trees have been widely surpassed by another larch (*Fitzroya cupressoides*), even older, called "El Gran Abuelo" (The Great Grandfather) which is found in the Alerce Costero National Park in Chile and its estimated age is of 5484 years. Old trees are extremely useful because they allow us to know the environmental conditions of the site where they grow, such as temperature, precipitation, and competition with others. Valuable environmental records and past events remain in their growth rings. If they have survived a fire, marks are left between the rings. The formation of a growth ring begins in spring and ends when temperatures drop again in the fall. In the growth period, a wide light ring remains, and, in the cold stage, a narrow, dark ring remains. By counting these rings it is possible to know the age of the tree, but also the changes in the thickness of the rings indicate a response to climate variability; for example, if there is water scarcity, the growth ring will be narrow, and in wet years, it will show wide rings. Climatology uses tree rings to study interannual variability in past climates and large-scale climate forcings such as ENSO (El Niño-Southern Oscillation) and PDO (Pacific Decadal Oscillation). In hydrology they are used for reconstructions of river flows, floods and water tables. In ecology, they are used to study population dynamics, age structure in a forest, temporal and spatial patterns of species establishment and disturbances, such as fires. In geomorphology, they are used to date glacial retreat, landslides, volcanic eruptions and earthquakes. Forests that lived in earlier geological eras and are now petrified have provided important information for reconstructing the Earth's past at some sites. Petrified forests have been found in Argentina, Peru, Brazil and even in Antarctica.

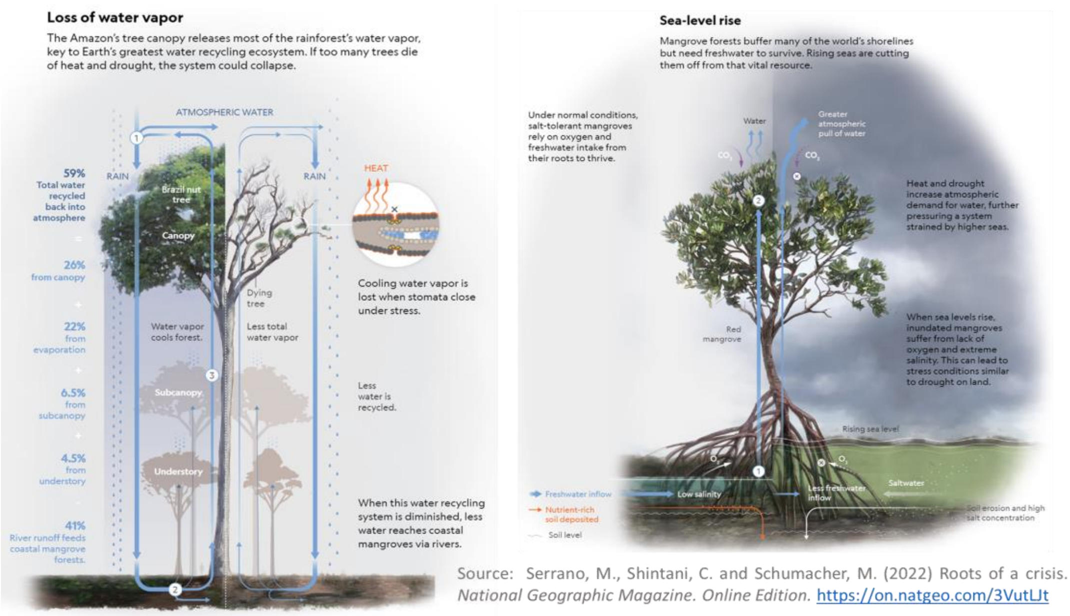

Figure 3. Impact of water vapor loss and sea level rise on trees.

Climate change is currently affecting the growth of trees; for example, heat waves and droughts cause greater water loss through transpiration, stomatal closure, and requires greater demand from the soil. The dry soil retains moisture and stresses trees that are unable to access it, even causing death. Under stress conditions, trees are more vulnerable to diseases caused by pathogens, and offer little resistance to insect pest attack. In the Amazon, tree transpiration creates clouds that produce precipitation of more than half of the water in the same place. The loss of water vapor due to prolonged droughts could cause this system to collapse. Mangroves need freshwater to survive and sea level rise is affecting them (Figure 3).

Forests are capable of storing significant amounts of carbon in their biomass, as well as in dead wood, litter and soil. Monitoring tree health and the changes in: a) forest cover (whether gradual by species succession or abrupt by fire, deforestation), b) biomass density, its response to seasonal changes (such as green intensity, impacts of droughts and floods), c) its growth in height and diameter allows detecting trends and establishing management plans to conserve them in the future. Field measurements combined with the use of satellite data improve knowledge of forest conditions, the changes in forest cover, the anthropogenic impacts and those caused by climate change, among others. For example, measuring tree height improves the estimates of how much carbon is stored in large forests, and field measurements help to verify data and improve models. In addition, field measurements can detect causes of changes such as tree mortality, degradation due to diseases or insect attacks, etc.

Guiding Research Questions

- Why are/aren't there trees in my local environment (perhaps because the environmental conditions are optimal, or on the contrary, the place is too dry, cold or windy)? Are the trees native or exotic?
- What animals use the trees around me?
- What factors affect tree growth in my locality? Are environmental conditions changing in my environment? How will tree growth be affected in the future?
- What is the impact of the trees in your city: how does the surface temperature decrease in the shaded area under the tree? How much does the brightness change in the shade and in the sun?
- Is the approximate age of the trees in your locality known?
- Were there forests in your locality? Are there fossils of petrified trees?

Scientific Concepts

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

Materials and Tools

- ArcGIS StoryMaps https://storymaps.arcgis.com/

- State of conservation of natural World Heritage sites

- FAO (2020). *Global Forest Resources Assessment 2020. Key findings*. - Map: Global Forest area by climate zones, 2020. P. 3

- Consult satellite information data of different types of forests:

Case 1. Tropical forest. State of Amapá, Brazil:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month.
- Surface temperature - Monthly average

- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data

- Overall tree height 2020
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Protected areas
- Biodiversity

Case 2. Subtropical forest. Araucárias National Park, Santa Catarina, Brazil:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data
- Overall tree height 2020
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Protected areas
- Biodiversity

Case 3. Temperate forest. Corcovado National Park, Chile:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data
- Overall tree height 2020
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Protected areas
- Biodiversity

Case 4. Mangrove forest. Panama City:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Mangrove cover 2016
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Protected areas
- Biodiversity

- Consult satellite information data of urban parks.

Case 5. José Enrique Rodó Park, Montevideo, Uruguay

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Biodiversity

Case 6. Simon Bolivar Central Park, Bogota, Colombia

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Total precipitation per month
- Surface temperature - Monthly average
- Soil moisture. Monthly average - 0 to 10 cm.
- Tree cover. Gain and loss.
- Tree canopy height - GEDI Data
- Changes in tree height between 2000 and 2020.
- Biomass density of tree canopy cover
- Biodiversity

What and how to do it

- ***Beginning***

  - Show your students the following videos: a) *The Sustainable Development Goals need forests*, b) Forests and sustainable cities and visualization of the height of the world's trees in 3D (with data collected by the GEDI instrument on board the Satellite Space Station).

  - Ask your students to record the places in Latin America and the Caribbean with the tallest trees. Then make a list of the benefits that these trees offer them in their daily lives considering the distance they are from them.

- ***Development***

  - Ask your students to read the introduction to this activity and make a concept map with the information.

  - Divide the class into student groups and assign one case study to each group. Tell your students:
    - Look on Google Map at the current satellite image. What do you see in that image (forest, parks, plantations, roads, rivers, lakes, etc.)? Is the forest/park near a city or within a city?

- Considering the conceptual map, analyze what ecosystem services the forest or park provides to nearby cities. How could they be influencing your locality?
- Open the Google Earth sequence and observe the changes in each year. Note the changes you observe, or if the area remains unchanged.
- Consult environmental data (precipitation, temperature and soil moisture) and record the most common values for the analyzed site to understand why trees grow in that location.
- *Note: In WorldView you can change the month and year, bottom left*
- Analyze the tree cover- gain or loss. Compare years of tree cover loss and sudden changes in height with environmental conditions. Record the coincidences- if any.
- Analyze the tree cover at different heights. Are there very tall trees in the analyzed site? What are the predominant heights? Have the trees grown, remained stable or decreased in height between 2000 and 2020?
- *Note: Layers are available in GFW for the years 2000 and 2020, and of tree heights. ≥3, ≥4, ≥5, ≥7, ≥10, ≥15 y ≥20 m*
- How is the biomass density in the site analyzed? What is the predominant percentage of tree canopy density?
- *Note: In GFW, layers are available for tree canopy densities > 10%, > 15%, > 20%, > 25%, > 30%, > 50%, and > 75%.*
- Is the site under analysis a protected area?
- What is the predominant percentage of biodiversity?

- Ask your students to develop a presentation on their case study. They can make a story with maps (using ArcGIS StoryMaps), or a slide presentation. To develop the presentation, consider the following questions: How do forests change over time, did they observe long-term changing trends? What changes are seasonal?

- Bring all the groups together and ask them to explain the analyzed cases and compare the similarities among them: Tropical Forest, subtropical forest, temperate forest and the analyzed city parks.

- Complete the conceptual map with the main characteristics of each case study.

- If there are forests in your area or if you have a square or park nearby, you can use the same tools to analyze their condition and changes in recent years. ~

- ***Closing***

- Due to the relevance of this problem, it is important to develop outreach activities. Students can develop a story with maps (Story Map), a video, or flyers to post on social networks summarizing the analyzed cases and highlighting the importance of their conservation.

Frequently Asked Questions

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

Where can I find forest cover information? Global Forest Watch (GFW) has a wealth of information on forests. ResourceWatch gathers information from different sources.

Suggested resources for further information

As an extension of this activity, students can consult satellite images from different dates and locations to explore other sites of interest. Global Forest Watch collects a wealth of information on forests that can be used to supplement the research. The OpenAltimetry site, which collects data from NASA's ICESat-2 satellite, provides highly accurate terrain and vegetation heights (data are only available for some sites).

You can use the GLOBE Program protocols to take manual measurements in your environment. You can visit a forest, a park, a city square to study species diversity, take measurements of tree height (using a clinometer or the GLOBE Observer Trees App), surface temperature, precipitation (or consult nearby weather service records or Wundermap, which gathers particular weather stations). You can also take measurements of trees near your environment (school or home) to characterize the type of tree cover and the environmental services it provides. You can supplement this information with other biosphere measurements such as phenology (measuring the green-up or green-down), or atmosphere, pedosphere and hydrosphere measurements.

Websites

- Cities4Forests https://cities4forests.com/
- FAO. Global Forest Resources Assessments https://www.fao.org/forest-resources-assessment/en/
- GFW Tree canopy height (2000-2020) ≥ 3m to ≥ 20m https://bit.ly/3u6h2Ba
- GFW Tree canopy changes https://www.globalforestwatch.org/map
- GFW Biomass density in trees > 10% to > 75% https://bit.ly/3ARcXV0
- GFW Biodiversity slides https://bit.ly/3Z8rgzd
- Global Tree Canopy Height 2020. 0 to ≥ 50m https://bit.ly/3VdP1mT
- OpenAltimetry https://openaltimetry.org/data/icesat2
- World Natural Heritage https://worldheritageoutlook.iucn.org/es
- Protected Planet (Map of Protected Areas) https://www.protectedplanet.net/en
- ResourceWatch 2000 - 2020 Tree Height Change https://bit.ly/3IgX1Qo
- SERVIR AMAZONIA: https://www.servirglobal.net/Regions/Amazonia
- SERVIR GLOBAL: https://www.servirglobal.net/
- UN Biodiversity Lab https://unbiodiversitylab.org/es/
- *Videos:*
- FAO (2018) *The Sustainable Development Goals need forests*. Youtube https://youtu.be/EoxB5IxTig8
- FAO (2018) *Forests and sustainable cities.* https://youtu.be/ucXz3EqzRLo
- GLOBE Observer Trees https://observer.globe.gov/de/toolkit/trees-toolkit
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- SVS (2021) GEDI Forest Height. https://svs.gsfc.nasa.gov/4950 (3D Map of World Tree Height)

Infographics:

- National Geographic (2022) Roots of a crisis: heat and drought [In English] [In Spanish] - pests and pathogens [In Spanish] - loss of water vapor and sea level rise. [In Spanish]

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Other resources:

- Tutorials by: Worldview, Story Map

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Mangroves

GLOBE		Associated SDG	Type of Activity
Sphere	Protocols		
Atmosphere	Air Temperature Surface Temperature Wind Direction and Speed Precipitation Relative Humidity	6 (Clean Water and Sanitation) 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	Air Quality Oceans Rivers and Lakes Water Cycle Water Quality Soils		

Overview

Satellite images and maps are analyzed to determine the impacts of mangrove loss and their replacement by agriculture, aquaculture, urbanization, etc. over the last 20 to 30 years. Cases of mangrove restoration are also analyzed. Landsat and Sentinel image series are used to detect changes in land cover and seasonal changes.

Time

3 or 4 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 assess the importance and vulnerability of mangrove ecosystems to different natural and anthropogenic impacts

Student Outcomes

- Students will identify the main impacts that cause mangrove loss.
- Students will understand the relevance of mangroves in the fight against climate change.
- Students will analyze changes in mangrove cover through the use of satellite images.
- Students will analyze the impact of human activities and hurricanes on mangrove reduction.
- Students will learn about and analyze cases of mangrove ecosystem restoration

Background

Mangroves are coastal ecosystems, located in tropical and subtropical zones, formed by several species of trees and shrubs that have special salt resistance adaptations (halophytes) to live in saline intertidal environments.

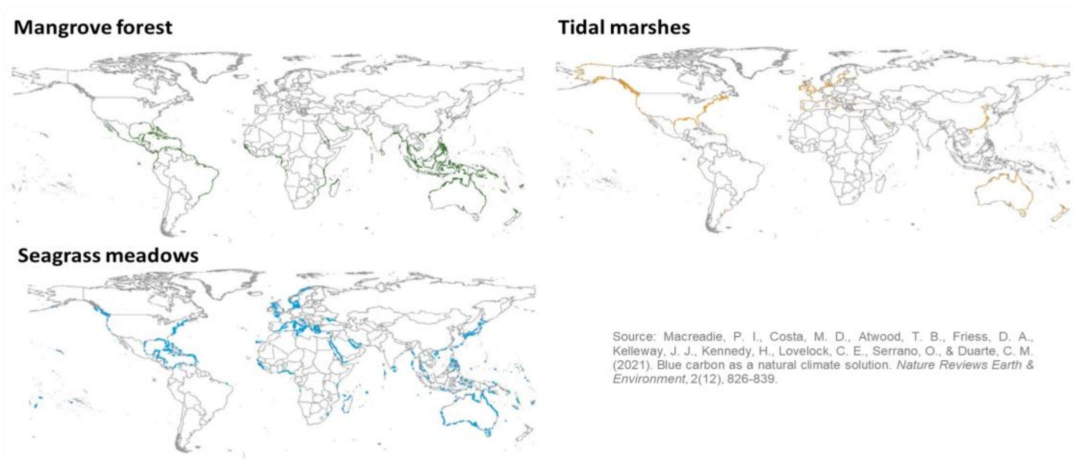


Figure 1. Global Distribution of Blue Carbon Ecosystems (Mangroves, Marshes and Seagrasses)

Mangroves are found on sheltered coasts and estuaries north and south of the Equator between isotherms of 20°C. (Figure 1) This distribution can be locally extended by warm ocean currents or diminished by cold currents. Mangroves are sensitive to temperatures below 0°C and also suffer from storm damage (e.g. damage in the Yucatan Peninsula in 2020). In latitudes with cold temperatures mangroves are often replaced by tidal marshes. Mangroves are widely distributed, but globally they cover less than 1% of the world's tropical forests. Limiting factors in the distribution of mangrove plants are salinity and sediment inundation. To cope with high salinity, mangrove species have a number of mechanisms to remove or exclude salt from their tissues, and some species have developed the ability to actively secrete salt through their leaves. Waterlogged anaerobic soil represents another challenge that mangrove plants have overcome by developing aerial roots to transport oxygen to roots below ground or underwater.

Mangroves are part of the Blue Carbon Ecosystems (BCE), along with tidal marshes and seagrass meadows. This designation is due to their capacity to capture and store carbon.

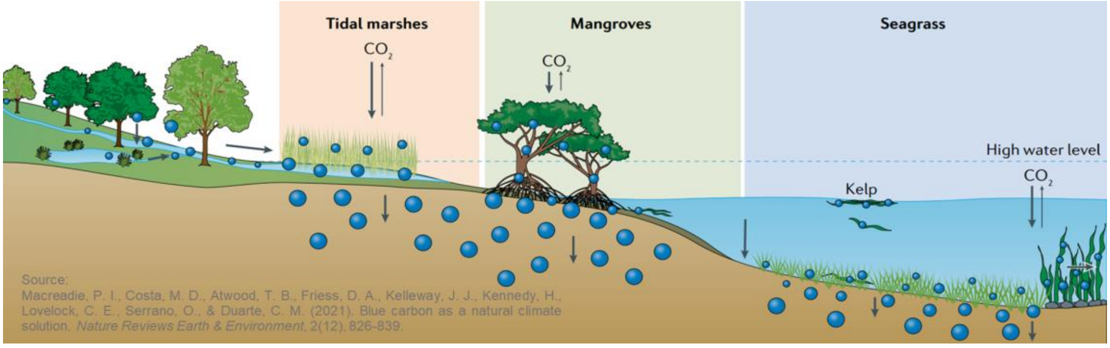
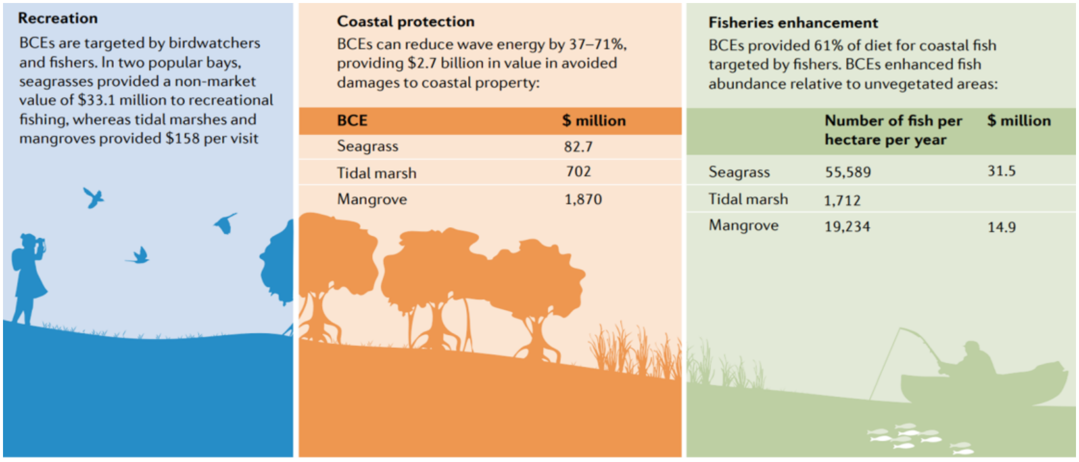


Figure 2. Comparison of carbon sequestration capacity. Blue carbon ecosystems fix large amounts of indigenous carbon and their position at the land-sea interface allows them to accumulate sediment and allochthonous carbon produced in other ecosystems.

The concept of blue carbon is defined by [UNEP's REDD Programme] as the mass of carbon that is stored, sequestered or released from coastal vegetation ecosystems. Mangroves help mitigate climate change because they are very effective carbon sinks for large amounts of carbon (Fig. 2).



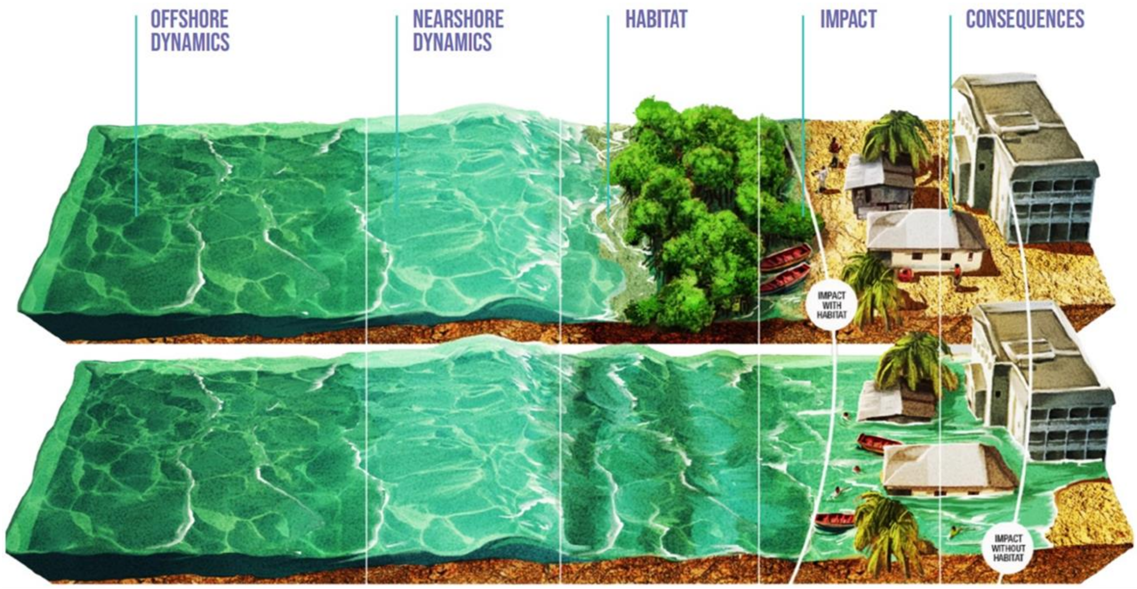
Source: Macreadie, P. I., Costa, M. D., Atwood, T. B., Friess, D. A., Kelleway, J. J., Kennedy, H., Lovelock, C. E., Serrano, O., & Duarte, C. M. (2021). Blue carbon as a natural climate solution. *Nature Reviews Earth & Environment*, 2(12), 826-839.

Figure 3. Co-benefits provided by blue carbon ecosystems. Co-benefits, sometimes called ecosystem services, contribute to the economy and well-being of coastal communities. This example includes Australian dollar (AU$) values for fisheries, coastal protection, and recreation.

Mangroves contribute to the well-being, food security and protection of coastal communities around the world. (Fig. 3) Mangroves are ecosystems rich in biodiversity because they support complex communities with multiple interactions among the species that inhabit them. (They provide habitat for fish and crustaceans, are a source of food for many species of mammals, birds, insects, etc.).

The United Nations has declared July 26 "[International Mangrove Ecosystem Conservation Day]" to highlight the importance and need for mangrove management and restoration, noting that it is a viable and cost-effective way to ensure food security for many coastal communities. Mangroves are a natural coastal defense system against storm surges (tidal waves), tsunamis and sea level rise, control flooding, maintain coastal stability and prevent erosion (Figure 4).

Mangrove ecosystems support fisheries, the production of medicines, fibers, wood, and fuels. They also filter the water that flows into the oceans and reef systems contributing to improve their quality, help stabilize the climate, among other environmental services. In addition, they have a cultural, recreational and educational component that makes them vital on many levels.



Source: Spalding, M. D. and Leal, M. (editors) (2021) *The State of the World's Mangroves 2021*. Global Mangrove Alliance.

Figure 4. Mangroves prevent erosion and reduce the force of waves, storm surges and flooding

According to the UNESCO Director-General Audrey Azoulay:

> *"Mangroves are in danger: it is estimated that more than three-quarters of mangroves in the world are now threatened, and with them all, the fine balances that depend on them. This is why UNESCO is acting to protect them, along with other valuable blue carbon ecosystems, through its geoparks, World Heritage sites and biosphere reserves*"

Climate change is affecting mangroves due to the increase of extreme events such as hurricanes, droughts, coastal erosion, sea level rise, increased sediment discharge from large rivers, etc. Human activities (like logging, agriculture, aquaculture, and coastal development) impact mangrove loss through deforestation or pollution. For example, many mangrove areas were converted into shrimp farms, which impacted water quality and reduced fish breeding habitat, affecting fishing. Shrimp farms can pollute the surrounding environment with excess nutrients, waste and drug residues.

Some mangroves are in protected areas, but because of their importance, partnerships have been established among technical experts, civil society organizations, governments, local communities, businesses, funding agencies and foundations to accelerate a global, comprehensive and coordinated approach to large-scale mangrove conservation and restoration. Through these partnerships, satellite monitoring and on-the-ground sampling are conducted to know the state of mangroves around the world. As a result of this monitoring, different aspects of mangroves have been mapped. Mangroves have great relevance at local and global scales for decision making. Monitoring the state of mangroves, water, air and soil quality is important to learn more about these ecosystems, detect changes that may affect them and establish restoration programs where necessary.

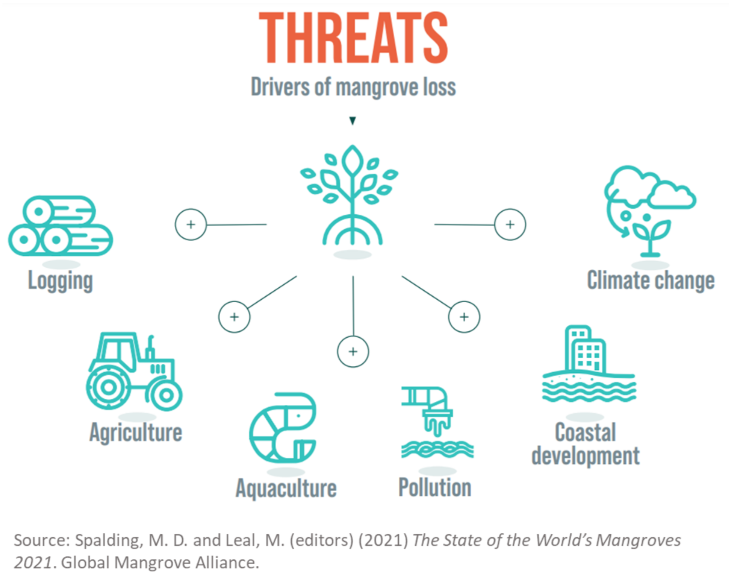


Fig. 5. Climate change and anthropogenic activities contributing to mangrove loss

Guiding Research Questions

- What is the impact of mangrove loss on ecosystems and people's lives?
- Why have mangroves disappeared in many places?
- What is the relationship between fishing and mangroves?
- In what ways do mangroves protect the coasts?
- How can mangrove areas be restored?
- How can the state of mangroves be monitored?

Scientific Concepts

- Ecosystems
- Deforestation
- Land cover
- Agriculture
- Aquaculture
- Electromagnetic spectrum
- Satellite images - False color images

Materials and Tools

- ArcGIS StoryMaps https://storymaps.arcgis.com/
- Satellite images of:

Case 1. Impact of aquaculture on mangroves:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Wordview (comparison 1986 and 2022)
- EO Browser - False color (seasonal changes): March - July
- Global Intertidal Change - (changes in the mangrove) Activate different layers, top right

Case 2. Impact of hurricanes in 2020:

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Wordview (comparison 1986 and 2021)
- EO Browser - Changes due to hurricanes. False color (before - after) - NDVI (before - after). *See explanation of NDVI in Deforestation activity.*
- Trajectory of hurricanes Delta and Zeta
- Global Intertidal Change - (changes in the mangrove). Activate different layers, top right

Case 3. Changes in the mangroves of The Esmeraldas River Estuary Mangrove Wildlife Refuge.

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Wordview (comparison 2000 and 2022)
- EO Browser - False color (seasonal changes): January - April
- Global Intertidal Change - (changes in the mangrove). Activate different layers, top right

Case 4. Changes in The Gulf of Nicoya Mangroves with rehabilitation programs.

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Wordview (comparison 1986 and 2022)
- EO Browser - False color (seasonal changes): March - June
- Global Intertidal Change - (changes in the mangrove) Activate different layers, top right)
- Story Map: 1) Land use, 2) Rehabilitation

Protected Planet (Map of protected areas)

World Natural Heritage (State of conservation)

What and how to do it

- ***Beginning***
  - Watch the videos: International Mangrove Ecosystem Conservation Day and Protecting Mangroves. Then ask your students to make a list of the most important items about mangroves.
- ***Development***
  - Read the introduction to the activity and show your students the global maps of mangrove distribution, protected areas, World Natural Heritage areas and compare the state of protection of mangroves in different regions of Latin America and the Caribbean.
  - Divide the class into student groups and assign one case study to each group. Tell your students:

- Look at the current satellite image on Google Map. What do you see in that image (mangroves, cities, shrimp ponds, crops, roads, rivers, forest, etc.)?
- Open the Google Earth sequence and note the changes in each year. Note the changes: What happened to the mangroves, did they remain intact, did they shrink, did they grow, were they replaced by aquaculture (shrimp farming), agriculture, growth of cities, or coastal development of tourism infrastructure, etc.?
- Compare the two Landsat images (old and current). Record the observed changes.
- Compare EO Browser Sentinel images and record seasonal changes.
- Check Global Intertidal Change to see if the mangrove site you are analyzing has remained intact, grown, or lost mangrove areas.
- Note: for case 4 look at the Story Maps describing soil use and ecosystem rehabilitation.

- 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.
- Bring all the groups together and ask them to explain the cases they analyzed and compare the similarities among such cases.
- Discuss the threats to mangroves and the state of protection and conservation in different locations. Explore the map of restoration areas and activate the different layers such as population density, droughts, etc. Which would be the best sites to restore? On what criteria do you base your decision?
- If you live near mangrove areas, you can use the same tools to analyze their condition and changes in recent years. You can also visit the site and take land cover and tree height measurements to characterize the mangrove. Atmosphere, pedosphere and hydrology measurements will help to understand the role of mangroves in the ecosystem (with respect to air quality, water quality, soil type and the biodiversity supporting the mangrove).

- ***Closing***
  - Due to the relevance of this problem, it is important to develop outreach activities. Students can elaborate a story with maps (Story Map), a video, or flyers to post on social networks summarizing the cases they analyzed and highlighting the importance of their conservation.

Frequently Asked Questions

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

Where do I find information on the status of mangroves? Global Mangrove Alliance - Global Mangrove Watch - Save Our Mangroves Now!

Suggested resources for further information

As an activity extension, more variables can be analyzed by making comparisons in the information of the different maps listed in the resources. You can also consult satellite images from different dates and locations. Worldview and Google Earth store imagery from the 1980s. The mappings listed in the resources gather information on mangroves.

Other Resources:

- Global Mangrove Alliance https://www.mangrovealliance.org
- Mangrove Science https://mangrovescience.org
- Protected Planet (Map of protected areas on the planet) https://www.protectedplanet.net/en
- World Natural Heritage https://worldheritageoutlook.iucn.org/es
- Save Our Mangroves Now! (Mangrove restoration projects and educational resources) https://www.mangrovealliance.org/save-our-mangroves-now
- UNESCO - International Day for the Conservation of the Mangrove Ecosystem. July 26. https://www.unesco.org/es/days/mangrove-ecosystem-conservation

Tutorials of: Worldview, EO Browser, Story Map

Mangrove mapping

- Mangrove Distribution. Global Distribution of Mangroves https://data.unep-wcmc.org/datasets/4
- Mangrove height and biomass. Global Mangrove Height & Biomass Explorer. Earth Engine Apps https://bit.ly/3yATbMF (Select layers from menu)
- Global Mangrove Loss Drivers. Global Mangrove Loss Drivers. https://bit.ly/3yGSykm (Some cases. Select layers from menu)
- Mangrove dataset. Mangrove Dataset Selector https://bit.ly/3D8jVa1 (Select layers from menu)
- Comparison of Mangrove Extent. Comparison of Mangrove Extent. https://bit.ly/3MzN9S1 (Select layers from menu)
- Global Mangrove Watch. Global Mangrove Watch (1996 - 2020). https://data.unep-wcmc.org/datasets/45
- Global Mangrove Watch (Mangrove information and maps of the world's mangroves) https://bit.ly/3CUD5jw (Select from the menu below)
- Map of mangrove restoration projects. Mangrove Restoration https://maps.oceanwealth.org/mangrove-restoration
- Map of mangrove restoration, adaptation, livelihood, research, policy, climate projects. Global Mangrove Alliance - Initiatives https://www.mangrovealliance.org/initiatives
- Global Intertidal Change - Global Intertidal Change https://www.globalintertidalchange.org

Videos

UNDP PANAMA (2018) *Protection of Mangroves.* Youtube: https://youtu.be/Z4jiJLaVQI0

UNESCO (2019) International Day for the Conservation of the Mangrove Ecosystem. Youtube: https://youtu.be/DHwlVzSYTL8

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Corrales, L., Pineda, J., Torres, D. and Guerrero, A. (2022). *Mangrove rehabilitation in the Gulf of Nicoya-Costa Rica.* CATIE. Story Map: https://bit.ly/3TmCAUH

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NASA Earth Observatory (2012) *Tiny Shrimp, Big Changes.* https://go.nasa.gov/3MxtK4c

NASA Earth Observatory (2014) *Notes from the Field Mangroves, Mud, and More.* https://go.nasa.gov/3eleZoF

NASA Earth Observatory (2020) *2020 Hurricanes Damage Vulnerable Mangroves.* https://go.nasa.gov/3g2VaCX

NASA Earth Observatory (2021) *A Closer View of 2020 Hurricane Damage.* https://go.nasa.gov/3TjtVT4

NASA Earth Observatory (2021) *Shrimp Farms Spread in Sinaloa.* https://go.nasa.gov/3Cqk1rH

NASA Goddard (2021) *NASA Finds Cause of Florida Mangrove Forests Die-off*. Youtube: https://youtu.be/M0tYfMjxeAM

Spalding, M. D. and Leal, M. (editors) (2021). *The state of the world's mangroves 2021.* Global Mangrove Alliance. https://bit.ly/3Sb2V7

Tang, W., Zheng, M., Zhao, X., Shi, J., Yang, J., & Trettin, C. C. (2018). Big geospatial data analytics for global mangrove biomass and carbon estimation. *Sustainability*, *10*(2), 472. https://www.mdpi.com/2071-1050/10/2/472/htm

The GLOBE Program (2022) *GLOBE Protocol Bundles.* *https://www.globe.gov/es/web/earth-systems*

UNESCO (2022) *International Day for the Conservation of the Mangrove Ecosystem. July 26th.* UNESCO. UNESCO International Days. https://www.unesco.org/es/days/mangrove-ecosystem-conservation

WWF (2022) *Incredible mangroves. Discover these forest wonders from around the world.* World Wildlife Fund. https://wwf.to/3seVJMV

Remote sensing – The forests from satellite

GLOBE		Associated SDG	Type of Activity/ies
Sphere	**Protocolos**		
Atmosphere	Air Temperature Surface Temperature Wind Direction and Speed. Precipitation. Relative Humidity	6 (Clean Water and Sanitation) 13 (Climate Action) 14 (Life Below Water) 15 (Life of Land)	Exploratory
Biosphere	Land Cover Biometry Phenology.		
Pedosphere	Soil characterization. Fertility. Moisture. pH. Temperature.		
Bundle	Agriculture Air Quality Soils Meteorology Water cycle		

Overview

Basic concepts of remote sensing are explained for their application in the analysis of satellite images of various types of forests (tropical, subtropical, temperate, and mangroves). Processed satellite images using band combinations and indices are utilized. Additionally, students can experiment with different band combinations and apply specific indices to highlight certain features.

Time

Four or five classes

Prerequisites

Basic knowledge of ecosystems, photosynthesis, meteorology, waves, electromagnetic spectrum, and ICT. Analysis of bar, line, and histogram charts. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School Level

High school and university students

Purpose

To understand the application of wave properties, using sensors in satellites and satellite images to gather information about the Earth process it to observe changes, trends, and interrelationships between the biosphere, atmosphere, hydrosphere, and pedosphere.

Student Outcomes

- Understand the types of electromagnetic waves satellite sensors use to gather information about the Earth's system.
- Identify changes and trends in satellite images.
- Apply combinations of bands by assigning the colors Red (R), Green (G), and Blue (B) to identify specific features on the terrain.
- Apply specific indices to analyze information from satellite images.
- Recognize different types of forests in satellite images.
- Use multispectral images to analyze changes in forests.Conocer los tipos de ondas electromagnéticas utilizadas por los sensores de los satélites para obtener información del sistema Tierra.

Background

Remote sensing

The process of acquiring information from a distance using remote sensors is known as remote sensing. For example, a photographic camera is a sensor that enables the retrieval of data from an object at a distance (when we take a photograph); our eyes also serve as sensors that allow us to obtain information about our surroundings when we look at something. Sensors placed on satellites, the International Space Station, airplanes, drones, balloons, and other platforms detect, and record reflected or emitted energy—figure 1.

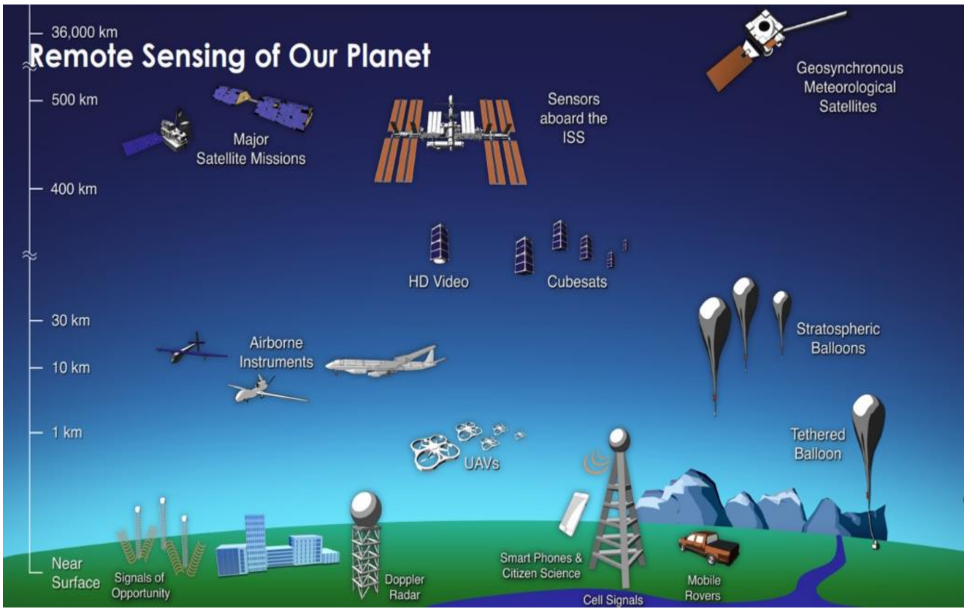


Figure. 1. Types of remote sensors that gather information from Earth. Source: https://svs.gsfc.nasa.gov/30892

Remote sensors provide a global perspective and a wealth of data on the atmosphere, hydrosphere, pedosphere, and biosphere, enabling the understanding of the current state, studying trends through historical information (for example, a 20-year record of rainfall and snow), and using them for data-driven decision-making. NASA has its fleet of satellites orbiting Earth and also operates satellites in collaboration with other countries (several of which belong to the Latin American and Caribbean regions). An example of this is the International Afternoon Constellation, consisting of a coordinated group of satellites from different countries that follow an orbit synchronized with the sun, passing at approximately 13:30 local solar time, with differences of seconds to minutes between them (hence the name Afternoon Constellation). This constellation of satellites conducts nearly simultaneous observations with a wide variety of highly useful sensors for conducting research, issuing alerts, making decisions, etc. Figure 2.

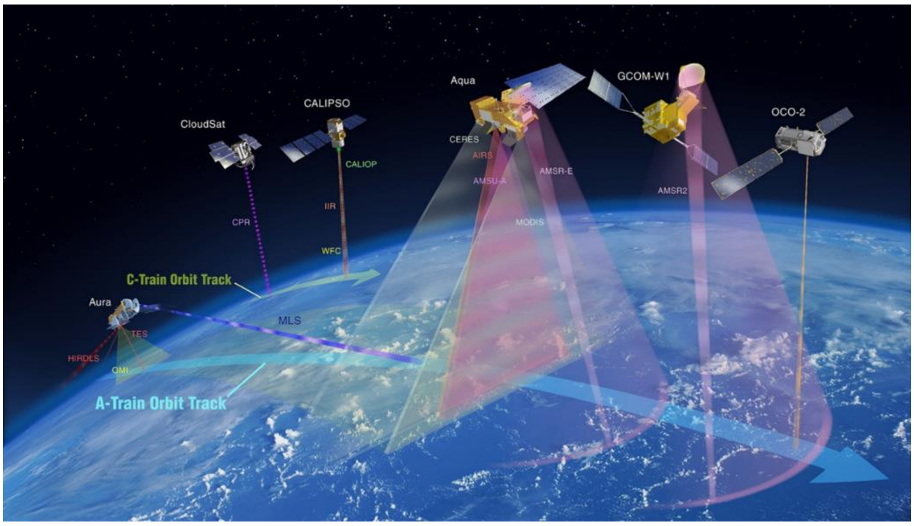


Figure 2. International Afternoon Constellation. Source: https://atrain.nasa.gov/

Some sensors are passive, meaning they detect the electromagnetic waves reflected by 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 the temperature of land and sea surfaces, vegetation properties, cloud characteristics, aerosols, soil moisture, and others. However, they have limitations as they cannot penetrate the dense layer of clouds that regularly cover the tropics. On the other hand, active sensors emit waves that bounce off the Earth's surface and return. Most of them operate in the microwave band of the electromagnetic spectrum, which gives them the ability to penetrate the atmosphere (e.g., radar). These sensors measure vertical profiles of aerosols, forest structure, precipitation, winds, and sea and ice surface topography, among others.

The Sun is the primary source of energy observed by satellites. Different types of surfaces reflect varying amounts of solar energy. The property of reflecting incident radiation is called albedo. For instance, snow is a bright surface with high albedo (reflecting up to 90% of incoming solar radiation). The dark ocean has a low albedo (reflecting only around 6% of incoming solar radiation and absorbing 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 reflect, sponge, or transmit varies based on the wavelength.

Spectral Bands and Signatures

Since reflected energy varies according to the surface type, it can be used to identify different features of the Earth, functioning similarly to our fingerprints and referred to as a [spectral signature.](#) The spectral signature makes it possible to identify various types of rocks and minerals, clear and turbid water, soil moisture, vegetation, vegetation health, etc. Figure 3.

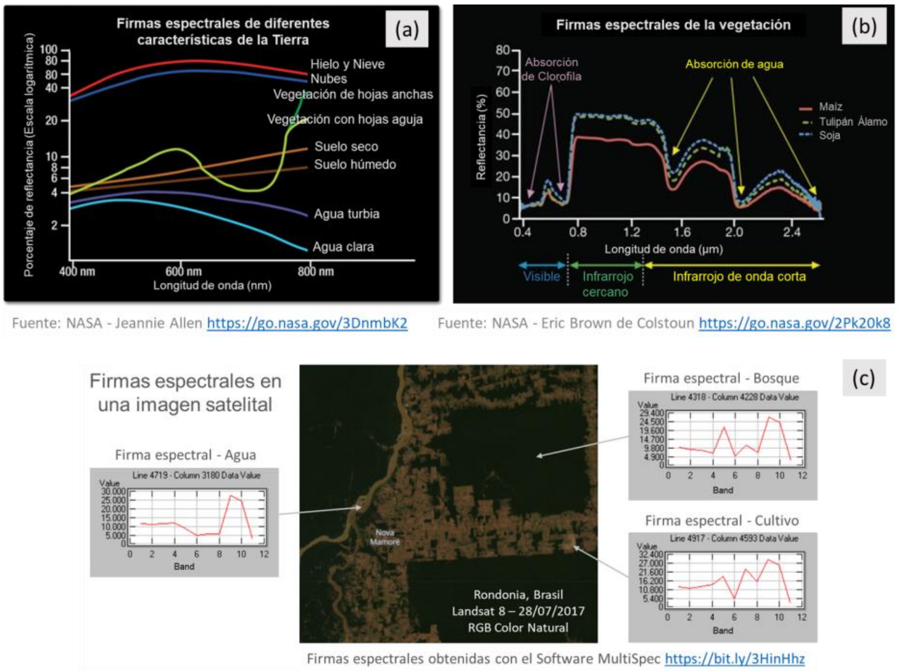
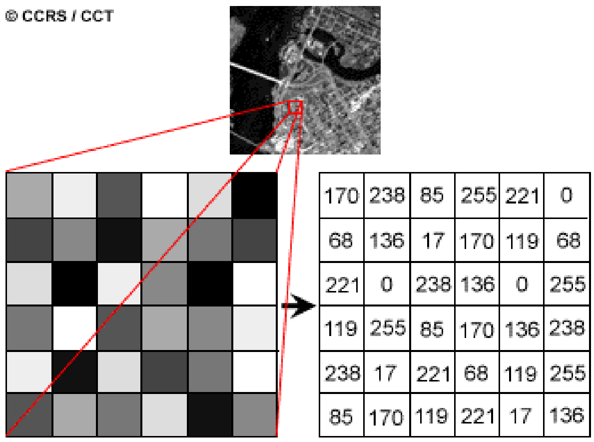


Figure 3. Spectral Signatures: (a) of different Earth features. (b) of vegetation. (c) Examples of spectral signatures in other pixels of the satellite image of Rondonia, captured by the Landsat 8 satellite on 07/27/17.

A digital image comprises pixels (or squares), each representing a number corresponding to its color. Therefore, a picture is a matrix of grayscale numbers ranging between 0 (white) and 255 (black). Any other value within this range represents a shade of gray. (Figure 4)



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

Figure. 4. Satellite Image and Numeric Matrix of a Landsat 7 Satellite Image Band. Each pixel (or square) represents a land surface 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 [Figue 5 (a)]. Sensors on most satellites utilize wavelengths ranging from infrared to ultraviolet, including visible light. The bands represent data from visible regions and the infrared spectrum (shortwave infrared, near infrared, and mid-infrared). [Figure 5 (b)] When we combine the bands into an RGB image to obtain natural-looking colors, we work with three matrices, one for each color channel: Red, Green, and Blue. [Figure 5 (d)] Similar to grayscale images, 0 represents the complete absence of color, while 255 represents the entire presence of the hue corresponding to a particular channel. To observe other aspects reflected in infrared bands or wavelengths, which our eyes cannot perceive, they are assigned one of the RGB colors, resulting in false color images. [Figure. 5 (c)]

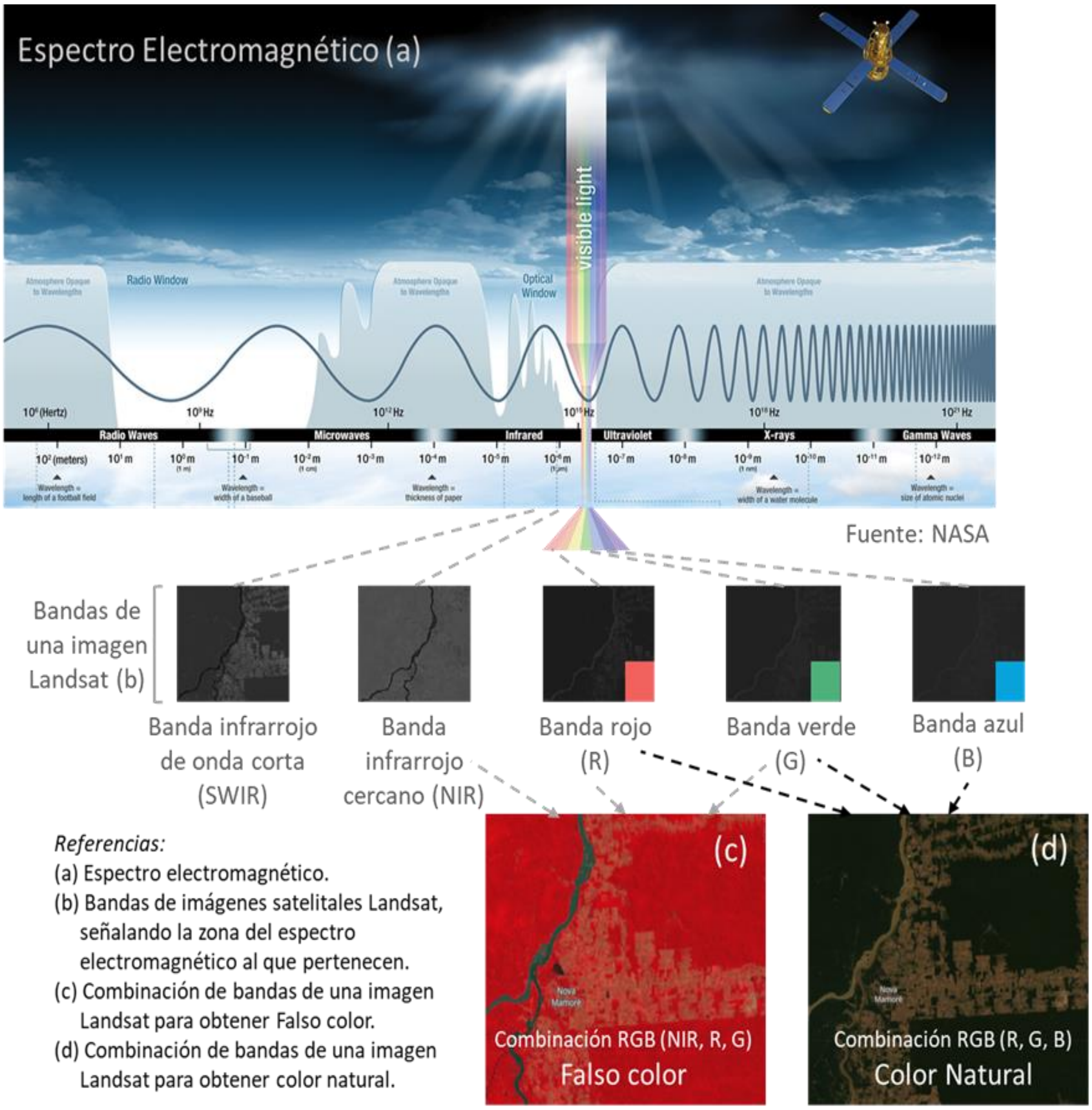


Figure. 5. Combining bands from Landsat satellite images to visualize different aspects. Sources: NASA and Landsat

Index

As satellite images are matrices, it's possible to perform calculations with them to detect other invisible aspects through color combinations. Indices are obtained through analyses using the matrices that form each band of satellite images. This calculation uses specific software, resulting in a new image where pixels related to the measured parameter are graphically highlighted. For instance, vegetation indices emphasize parameters of vegetation cover, such as density, leaf area index, chlorophyll activity, and more. 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. NDVI allows estimating vegetation quantity, quality, and development based on measuring the radiation intensity in specific bands of the electromagnetic spectrum that vegetation emits or reflects. The bands vary depending on the type of satellite. Some visualization tools automatically generate the most common indices. High NDVI values indicate healthy vegetation, while low values indicate vegetation is drying out (due to water stress, diseases, fires, etc.)—Figure. 6.

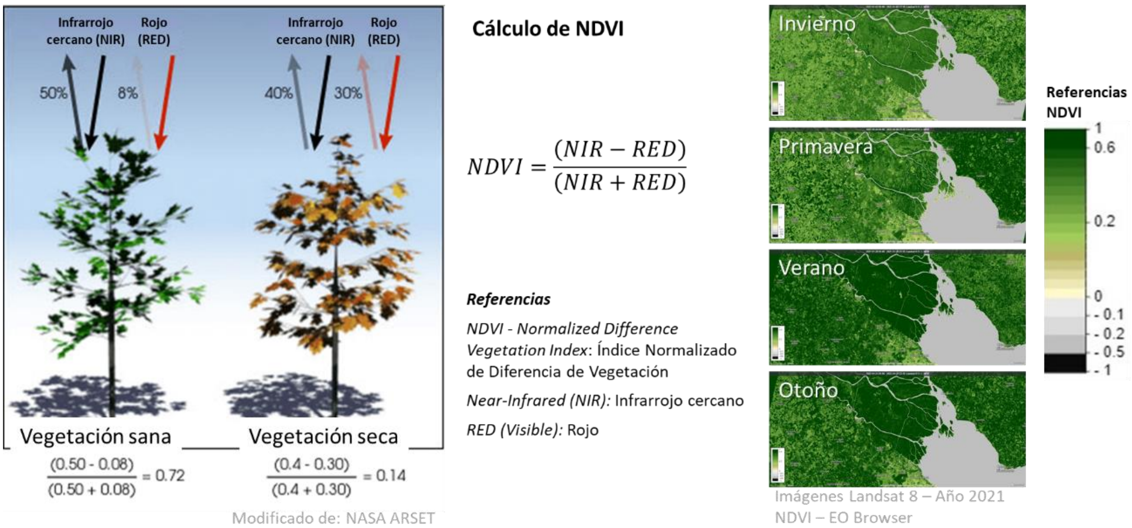


Figure 6. Calculation and satellite images of the Paraná River Delta processed with the NDVI index. Seasonal changes in vegetation are detected with varying color intensities.

Spectral indices have been developed to analyze various aspects of satellite images, with applications in ecology, agriculture, disaster management (such as floods, fires, etc.), aquatic resources, geology, and more. All of these indices utilize calculations involving different bands of satellite images.

Guiding Research Questions:

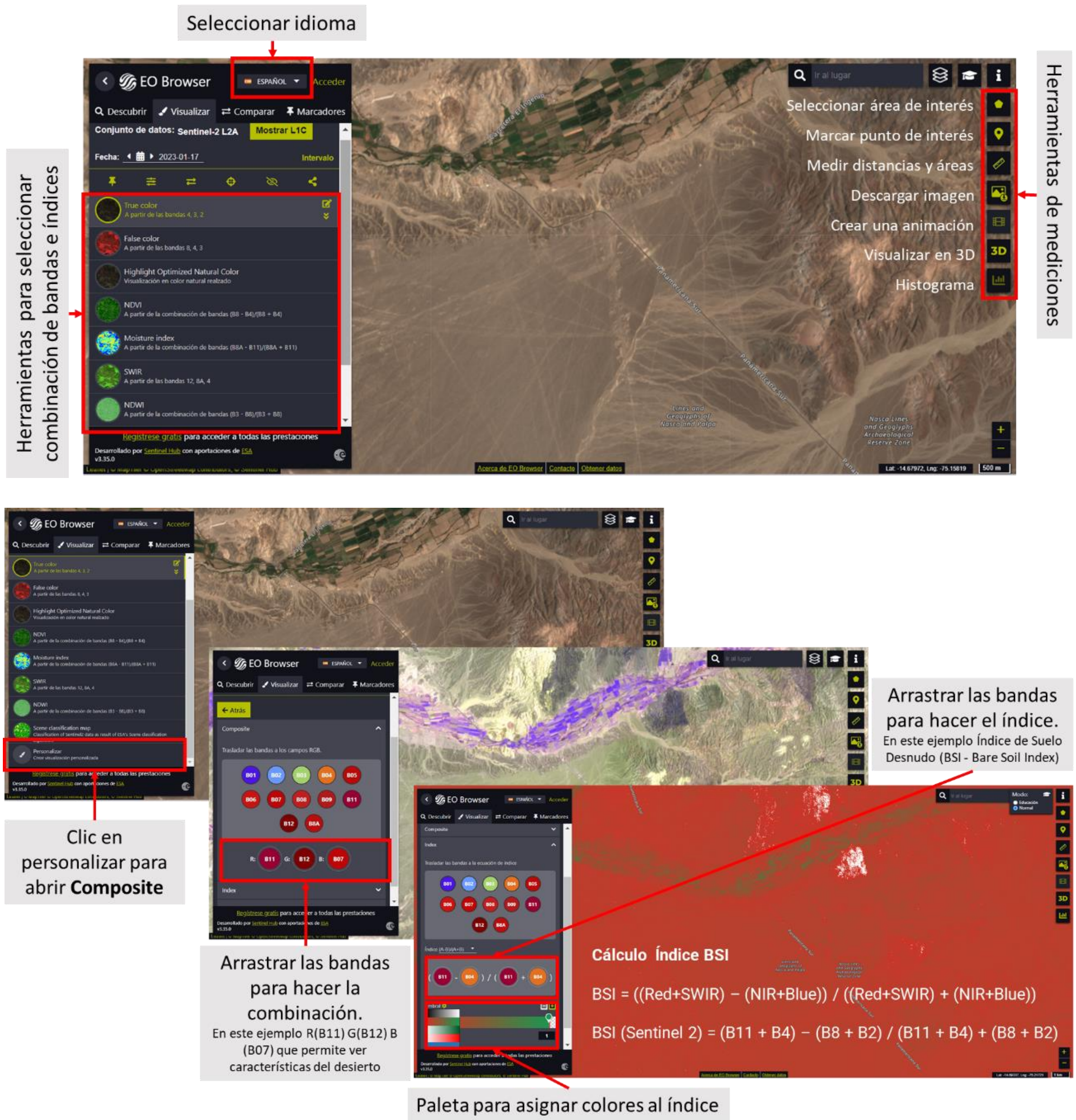
- Where are the different types of forests located in Latin America and the Caribbean?
- What is the relationship between precipitation and vegetation types? What kind of vegetation exists in my local environment, and how are precipitation patterns distributed throughout the year?
- What happens when precipitation patterns change in my surroundings? Are there any local/regional consequences related to the El Niño-Southern Oscillation (ENSO) phenomenon?
- Why is it important to monitor forests?

Scientific Concepts:

- Ecosystems. Forests. Grasslands. Deserts.
- Land Cover
- Waves and the electromagnetic spectrum.
- Graphs. Histograms.
- Satellite images.

Materials and Tools:

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



Figue 7. EO Browser App Tools Infographic:

Caso 1: Tropical Forest: Cordillera Azul (Peru)

- Google Map – Location
- Climate chart showing average temperatures and precipitation.
- Tree Cover. Gain and Loss.
- Google Earth (Sequence 1985 to 2020)

Worldview

- Image Comparison (12/09/2001 – 12/09/2022)
- Total Precipitation by Month
- Surface Temperature - Monthly Average
- Generate a Video in Worldview with Each Group of Consulted Data.

EO Browser (refer to tools in Figure 7 and guide at the end of the cases):

1. Imagen Sentinel 12/09/22 – True color, False color
2. Imagen Sentinel 25/01/23 - True color, False color

- Use the ruler (on the right side of the screen) to measure areas and distances.

Caso 2: Subtropical Forest: Palmares (Argentina)

- Google Map - Location
- Climate chart showing average temperatures and precipitation.
- Tree Cover. Gain and Loss.
- Google Earth (Sequence 1985 to 2020)

Worldview

- Image Comparison (12/09/2001 – 12/09/2022)
- Total Precipitation by Month
- Surface Temperature - Monthly Average
- Generate a Video in Worldview with each group of consulted data.

EO Browser (refer to tools in Figure 7 and guide at the end of the cases):

3. Imagen Sentinel 2/7/2022 – True color, False color
4. Imagen Sentinel 29/12/22 - True color, False color

- Use the ruler (on the right side of the screen) to measure areas and distances.

Caso 3: Mangrove Forest, Dominican Republic

- Google Map - Location – (Global Mangrove Map)
- Climate chart showing average temperatures and precipitation.
- Tree Cover. Gain and Loss.
- Google Earth (Sequence 1985 to 2020)

Worldview

- Image Comparison (13/01/2001 – 13/02/2022)
- Total Precipitation by Month.
- Temperatura de superficie – Promedio mensual
- Generate a Video in Worldview with each group of consulted data.

EO Browser (refer to tools in Figure 7 and guide at the end of the cases):

1. Imagen Sentinel 18/01/2022 – True color, False color
2. Imagen Sentinel 29/12/22 - True color, False color
    - Use the ruler (on the right side of the screen) to measure areas and distances.

Caso 4: Bosque templado, Argentina and Chile

- Google Map – Location
- Climate chart showing average temperatures and precipitation.
- Tree Cover. Gain and Loss.
- Google Earth (Sequence 1985 2020)

Worldview

- Image Comparison (01/12/1999 – 01/12/2022)
- Total Precipitation by month.
- Surface Temperature - Monthly Average
- Generate a Video in Worldview with each group of consulted data.

EO Browser (refer to tools in Figure 7 and guide at the end of the cases):

1. Imagen Sentinel 29/07/2022 – True color, False color
2. Imagen Sentinel 29/12/22 - True color, False color
    - Use the ruler (on the right side of the screen) to measure areas and distances.

In the EO Browser, images perform the following:

1. Refer to the images in actual or false color and record seasonal changes.
2. Select the NDVI index (on the left side of the screen) and then the histogram (on the right side of the screen). Compare the results of the images. You can draw the site and then select the histogram to measure a specific area.
    a. Do the same for NDMI (Soil Moisture Index) and SWIR (for water present in vegetation and soil).
    b. Refer to the **histogram** (on the right side of the screen), open the menu of the index you are observing (on the left side of the screen) to see the color reference. Analyze the histogram by comparing the values with those of the reference.Puede dibujar un área y hacer el mismo análisis para ese sector en particular.
3. To make a new **band combination,** go to customize (left below) and select **composite**.

    a. Drag the bands to the circles to make the RGB combination: (R) 8A, (G) 11 and (B) 2.
    b. Compare the sharpness with which you observe the vegetation and compare it with previous visualizations.
4. **Generate an index**. There are many vegetation indices, some of which are more complex to calculate. The most known and used is the NDVI. Still, other indices are also used to understand other aspects of the crop (e.g., GNDVI has higher sensitivity to detect different chlorophyll concentration rates). The Green Normalized Difference Vegetation Index (**GNDVI**) and the Normalized Burn Ratio (**NBR**).

    Go to Customize (bottom left) and select **Index**. The formula for placing the bands will appear.

For GNDVI at site A (place band B8) and at site B (place band B3), corresponding to the following calculation:

GNDVI = (NIR-GREEN) /(NIR+GREEN)
GNDVI (Sentinel 2) = (B8 – B3) / (B8 + B3)

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

NBR = (NIR – SWIR) / (NIR + SWIR)
NBR (Sentinel 2) = (B8 – B11) / (B8 + B11))

b. In each **index**, go to the threshold and select a color palette to colorize the image.

c. Analyze with which color scheme or index you can best visualize the cities.

5. Make a presentation comparing winter and summer results on crops. Also, compare the visualizations you get with the different indices.

What to do and how to do it

- ***Beginning***

  - Show yours students the following videos: a) NASA: Misión a la Tierra b) La NASA muestra dos décadas de nieve y lluvia *y c) El espectro electromagnético*. Also the web sites: 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, it is about using different electromagnetic spectrum wavelengths to gather information about the Earth.

- ***Development***

  - Ask the students to read the introduction to this activity and create a concept map with the information. *(In the introduction, the basic principles of remote sensing are provided, along with links to expand on the news or clarify aspects if necessary).*

  - Divide the class into groups and assign a case to each group for analysis.

    - Look at the current satellite image on Google Maps. What do you see in that picture (forest, desert, cities, roads, rivers, etc.)?
    - Analyze the climogram of rainfall and temperature averages for that location.
    - Query changes in tree cover (gain and loss over the last 20 years) and look at the sequence of images from 1985 to 2020 in Google Earth. Record the changes and trends you find.

    - Consult the environmental conditions of the last year and make a video in Worldview.
        - *Note: In WorldView, you can change the month and year at the bottom left*
    - Consult the EO Browser images to analyze the band combinations and indices. Use the blends and indexes given (if you wish, you can try different bands and examine the display).

- Ask the students to create a presentation about the analyzed case. They can create a story with maps (using ArcGIS Story Maps), a slideshow presentation, or a video.

- Gather all the groups and ask them to explain the analyzed cases.

- Complete the conceptual map with the main characteristics of each analyzed case.

- ***Closing***
    - Due to the relevance of both events, it is essential to elaborate promotional materials. Students can develop a story with maps (Story Map), a video, or flyers to post on social media summarizing the analyzed cases.

Frequently Asked Questions

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

Where can I find information forest cover information? Global Forest Watch (GFW) has a wealth of information about forests.

Where can I find information about the global environmental conditions and population? ResourceWatch gathers information from different sources.

Suggested Resources

As an extension of this activity, students can access satellite images from different dates and locations to explore other points of interest and even various events. They can use the protocols of the GLOBE Program to conduct manual measurements in their environment or download measurement data collected by others. They can also perform environmental measurements to complement the research based on satellite images.

Web Sites

- GISGeography (2022) *Sentinel 2 Bands and Combinations.* https://gisgeography.com/sentinel-2-bands-combinations/ (Combinaciones de bandas con imágenes Sentinel)
- NASA. (2023) Eyes on the Earth. https://eyes.nasa.gov/apps/earth/#/ (satélites que toman imágenes de la Tierra)
- USGS (2021) *Common Landsat Band Combinations.* https://on.doi.gov/3wAKJvd (Combinaciones de bandas con imágenes Landsat)
- USGS (2022) *What are the best Landsat spectral bands for my research?* https://on.doi.gov/3HEMdLf
- *Videos:*
- NASA Climate Change (2021) *How NASA Satellites Help Model the Future of Climate*. Youtube: https://youtu.be/iAUFVUzZIhI

- NASA Climate Change. (2021) *NASA: La humedad de la Tierra.* Youtube: https://youtu.be/YPgmdRYrvjU
- NASA Climate Change. (2021) *NASA: La Tierra tiene fiebre.* Youtube: https://youtu.be/R5RcCc3qWMY
- NASA Climate Change. (2021) *NASA: Las nubes.* Youtube: https://youtu.be/R5YYdEATivg
- NASA Climate Change. (2021) *NASA: Los vientos oceánicos.* Youtube: https://youtu.be/MJSaIFY0CsE
- NASA Climate Change. (2021) *NASA: Me llamo Aerosol.* Youtube: https://youtu.be/Dr4Dkm1Ud1E
- NASA Climate Change. (2021) *NASA: Misión a la Tierra.* Youtube: https://youtu.be/M0HHZ9vRlpk
- NASA Climate Change. (2021) *NASA: Problema de gas.* Youtube: https://youtu.be/4ZvAEQLWDTs
- NASA en Español (2020) *La NASA muestra dos décadas de nieve y lluvia*. Youtube: https://youtu.be/HVxosovHInw
- NASA en Español (2021) *El cambio climático podría afectar la agricultura mundial en 10 años*. Youtube: https://youtu.be/hSOMnPJom50
- 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/DgZKWfRRxKw]
- 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/BVbbkzygf94]
- 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 ultraviolet*. Youtube: https://youtu.be/IOKEbZgB2II]
- 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:

- Tutoriales de: Worldview (video corto, video completo, sitio web, ideas para el aula) EO Browser (sitio web o video, infografía) , Story Map
- Traducción automática: Videos, Sitios web

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