THE CLIMATE IN OUR HANDS

CLIMATE CHANGE AND LAND

Teacher's guide book for primary and secondary school

United Nations
Educational, Scientific and
Cultural Organization

Office for Climate Education

UNDER THE AUSPICES OF UNESCO
AND THE FOUNDATION LA MAIN À LA PÂTE

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THE CLIMATE IN OUR HANDS

Climate Change and Land

A teacher's handbook for primary and secondary schools

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THE NEED FOR CLIMATE EDUCATION

There is an urgent need for collective action to mitigate the consequences of climate change and adapt to unavoidable changes. The complexity of climate change issues can pose educational challenges. Nonetheless, education has a key role to play in ensuring that younger generations have the required knowledge and skills to understand issues surrounding climate change in order to avoid despair, take action, and be prepared to live in a changing world.

The Office for Climate Education (OCE) was founded in 2018 to promote strong international cooperation between scientific organisations, educational institutions and NGOs. The overall aim of the OCE is to ensure that the younger generations of today and tomorrow are educated about climate change. Teachers have a key role to play in this and it is essential that they receive sufficient support to enable them to implement effective lessons on climate change. The OCE has developed a range of educational resources and professional development modules to support them in teaching about climate change with active pedagogy.

THE CONTENT OF THIS EDUCATIONAL RESOURCE

In August 2019, the United Nations Intergovernmental Panel on Climate Change (IPCC) published a Special Report[1], which emphasised the importance of land to humankind and how strongly it is being impacted by climate change.
The four key messages in this report are:

- Land is where we live.
- Land is under growing human pressure.
- Land is a part of the solution.
- But land can't do it all.

This OCE teacher's handbook has been researched and written by the OCE team and the OCE's scientific and education partners. The aim of this guide is to support teachers in implementing a range of activities on climate change and land in their classrooms.
This resource:

- targets students from the **upper primary school to the lower secondary school** (ages 9 to 15 years);
- includes **scientific and pedagogical** overviews, **lesson plans, activities, worksheets** and links to external resources (videos and multimedia activities);
- is **interdisciplinary** with lessons covering areas such as the natural sciences, the social sciences, the arts and philosophy;
- promotes **active pedagogies:** inquiry, roleplay, serious games, debate and project-based learning.

Watch this video to learn more about this guide!

The lessons are divided into two parts:

PART 1 WE UNDERSTAND
This section contains **four sequences** with core and optional lessons, aimed at helping students understand causes and impacts of climate change induced by human activities. They also highlight the importance of land in regulating climate and how it provides essential resources and services to humans. The lessons outline how these services are at risk as a result of climate change. Finally, it provides students with opportunities to reflect on and consider the importance of urgent action.

PART 2 WE ACT
This section presents **seven projects** that students/schools have implemented, all around the world, to take tangible action in mitigating or adapting to climate change. These different projects can be used as ideas to set up your own. Details on possible designs and methodologies to implement a project are also outlined in this section.

The sequences of lessons in this resource are written so that teachers can select lessons that are **suited to their needs or contexts.** However, we advise teachers to maintain a certain **balance between the two main parts:** students will not usually be capable of intelligent, effective action without a proper understanding of the issues involved; understanding without acting is not sufficient, given the urgency of adaptation and attenuation.

Our hope is that this resource will inspire teachers and support them in adopting a creative and effective climate education programme in classrooms.

1 https://www.ipcc.ch/srccl/

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SCIENTIFIC OVERVIEW

Introduction

This background document draws upon the **Special Report on Climate Change and Land (SRCCL)** prepared by scientific experts of the United Nation's Intergovernmental Panel on Climate Change (IPCC), and released in August 2019 (https://www.ipcc.ch/srccl/). It aims to provide a broad overview of the core themes and concepts explored in the accompanying lesson plans. Unless otherwise specified, the information provided here comes from this SRCCL report and from other institutional reports, such as the ones from the Food and Agriculture Organization of the United Nations (FAO).

Note: The definition of the words with an asterisk can be found in the glossary, page 258.

This document provides an overview of climate change across six key themes:

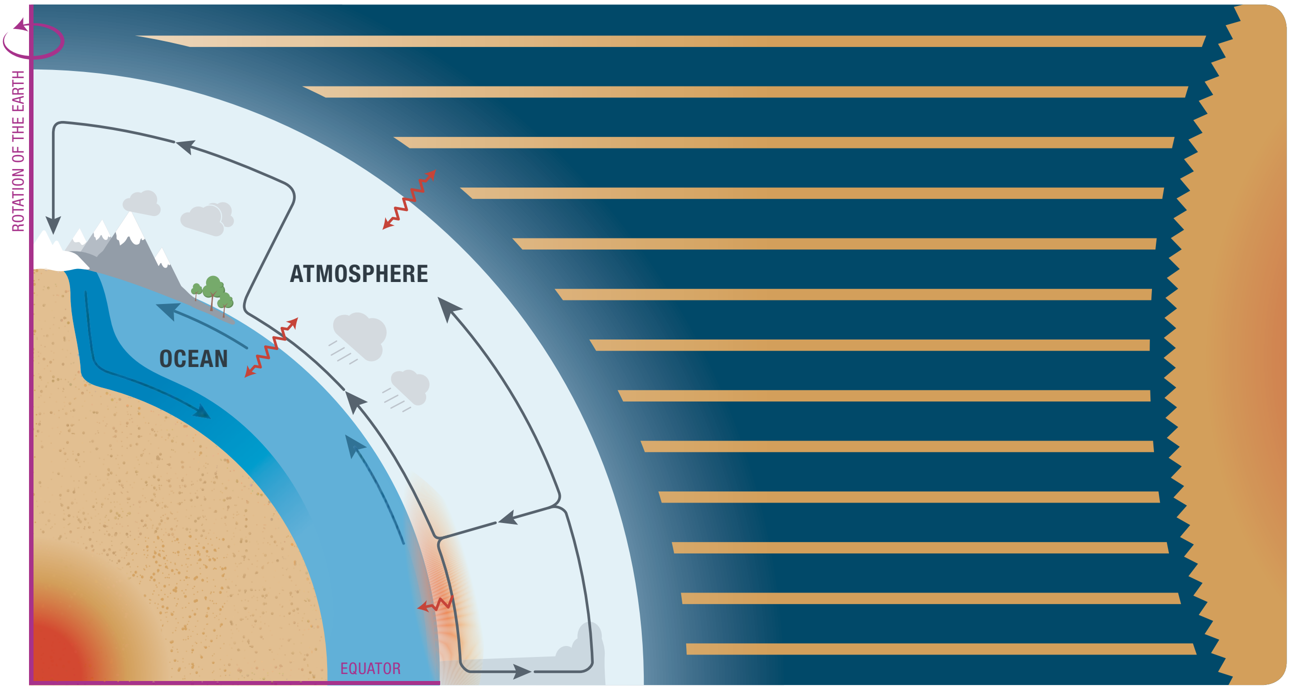
- What the climate is and why it varies
- Why land is important to us
- How the climate is rapidly changing due to human activities
- How land is changing due to climate change and human activities
- What impacts this has on us
- How we can act to mitigate and adapt to climate change

What the climate is and why it varies

THE CLIMATE AND ITS VARIATIONS

The climate* is the time average of weather* over months, years, decades, centuries or more. In the tropics, we expect it to be warm and humid (a tropical climate), although the conditions on any given day will still vary (the weather) around this "average condition". Beyond geography, which explains the different local climates present on Earth, the global climate system is a dynamic entity in which energy, water, carbon and other elements are continuously exchanged between the atmosphere, ocean, cryosphere, land surface and life forms.

The Sun's energy is the main driver of the climate system. Because the Earth is a sphere, the Sun's radiation distributes energy unequally across the planet, with the tropics receiving more energy on average than the poles (see the below figure). The atmosphere and the ocean maintain a stable climate by transporting this additional energy from the tropics towards the poles, acting as climate regulators.



The climate system receives energy from the Sun. The Sun's radiation distributes the energy unequally over the Earth's surface.

To detect changes in the climate and determine their causes, scientists first must understand the mechanisms that affect it. **The climate varies due to both external and internal causes.**

EXTERNAL CAUSES

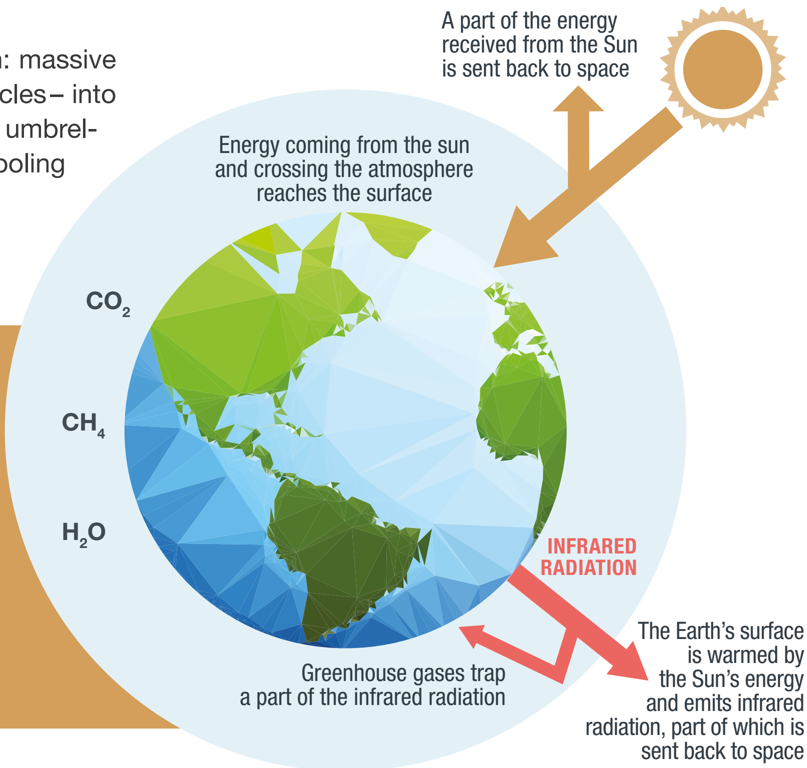
There are three main sources of external climate variations:

- **Changes in the energy received from the Sun** (related to sunspots or variations in the Earth's orbit): for example, the seasons we experience are climate variations caused by differences in the amount of sunlight received at a given location during the year.
- **Volcanic eruptions** occurring on Earth: massive eruptions release aerosols –small particles– into the upper atmosphere, which act as an umbrella blocking the sun's radiation and cooling the planet for up to a few years.
- **Greenhouse gas (GHG)*** emissions.

Greenhouse gases are gases in the atmosphere that have the property of being mostly transparent to visible sunlight, but not to the infrared radiation* emitted by the Earth's surface. These gases (including water vapour, carbon dioxide, methane and nitrous oxide) **trap the infrared radiation and reemit a part of it toward the surface, thus warming the lower atmosphere and the planet's surface.** This phenomenon is known as **the greenhouse effect.** All greenhouse gases do not have the same global warming potential*, which means that they do not have the same "power" to warm the atmosphere.

THE GREENHOUSE EFFECT

This occurs naturally and is essential to life on Earth. Without it, the global mean temperature would be around -18°C, instead of +15°C. However, humans are raising greenhouse gas levels in the atmosphere, causing human-made (anthropogenic) climate change. This is defined as an external cause to the climate system.



INTERNAL CAUSES

The climate also undergoes internal variations of its own accord. **The El Niño phenomenon** is the most active source of internal variations from one year to the next (see the Special Report "The Ocean and Cryosphere in a Changing Climate" summary for teachers). It originates in the tropical Pacific but affects most of the planet. Changes in ocean currents can also drive changes in regional climate over decades. For instance, a colder North Atlantic Ocean in the 1970s and 1980s led to severe droughts in the Sahel (south of the Sahara desert).

SPECIFIC ROLE OF LAND

Land represents the surface of the planet on which people settle, the soil that allows them to produce their food, and an interface with the atmosphere that helps the climate to function properly.

The soil is the upper surface of the land and is composed of a mixture of organic matter and minerals. It interacts with the atmosphere and is also a medium for plant growth and organic matter decomposition, and a habitat for organisms.

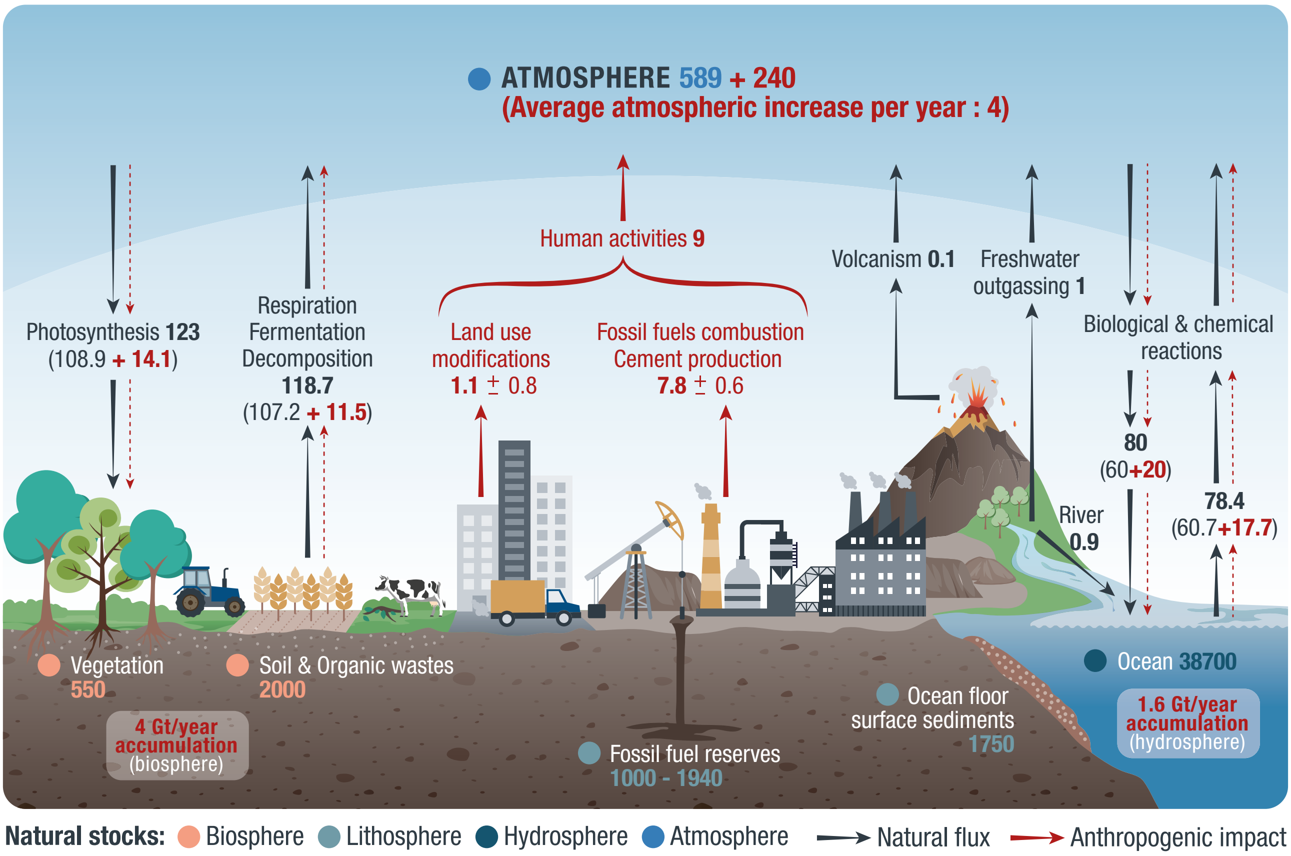
CARBON STORAGE

The land also stores a very large amount of carbon in different reservoirs: soil (in organic matter), biosphere, rocks and fossil fuel resources.

The stored carbon does not stay in its reservoir forever but moves over different timeframes from one reservoir to another, including non-land reservoirs (atmosphere, ocean, oceanic biosphere). These movements are called flows. One example of a flow is photosynthesis*, which transfers carbon from the atmosphere to plants, and eventually into soil storage. The full carbon cycle* is presented in the figure below.

LAND AS PART OF THE CLIMATE SYSTEM

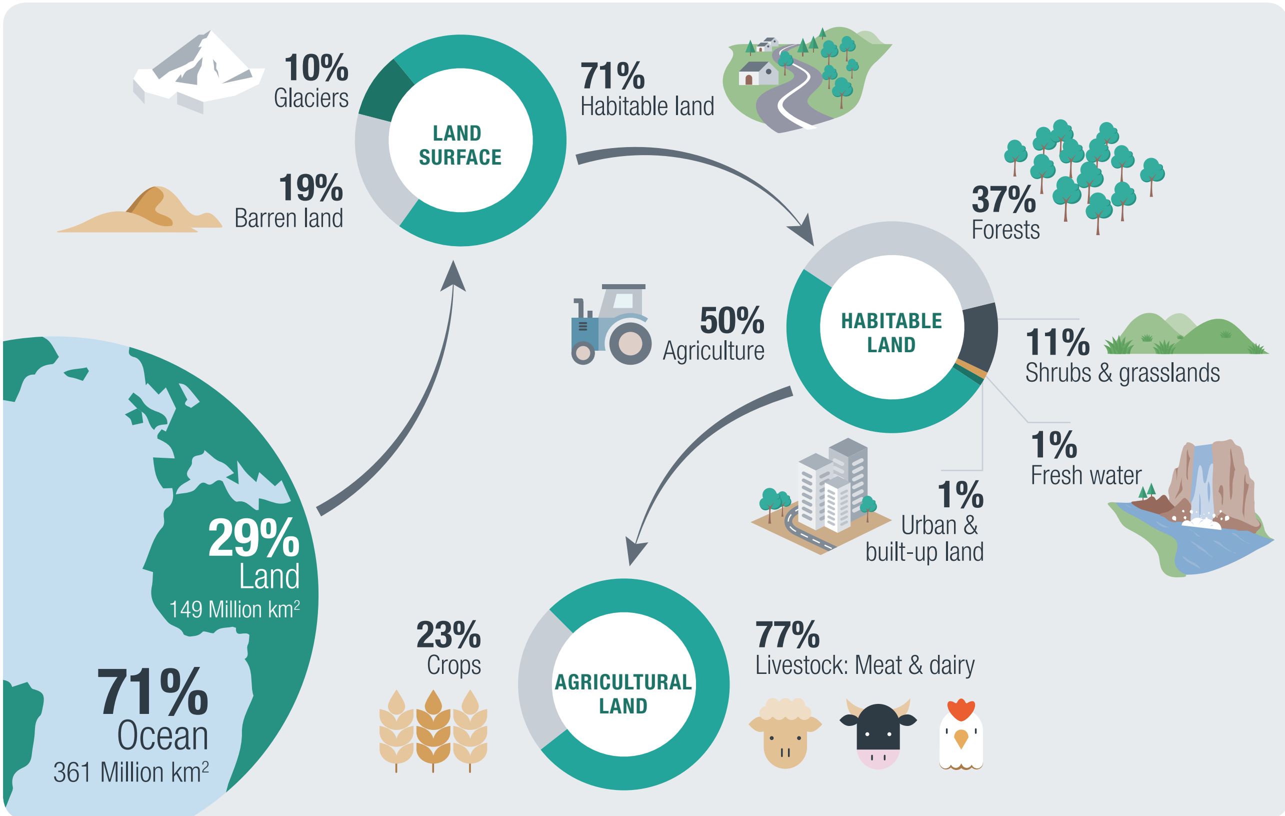
Land exchanges energy, water, aerosols and greenhouse gases with the atmosphere and the ocean. These exchanges are due both to human activity and natural mechanisms. Thus, land plays a central role in the climate system.



The carbon cycle. The amount of carbon in each reservoir is given in gigatonnes (one gigatonne = one billion tonnes).
Source: Adapted from SVT Dijon, data from AR5 IPCC 2014.

Why land is important to us

The land is where we live. It is **essential for our existence and wellbeing,** as it provides most of our **food, feed (food for livestock), fibre, timber and energy.** Today, humans work about three quarters of the global ice-free land surface area (see the figure below).

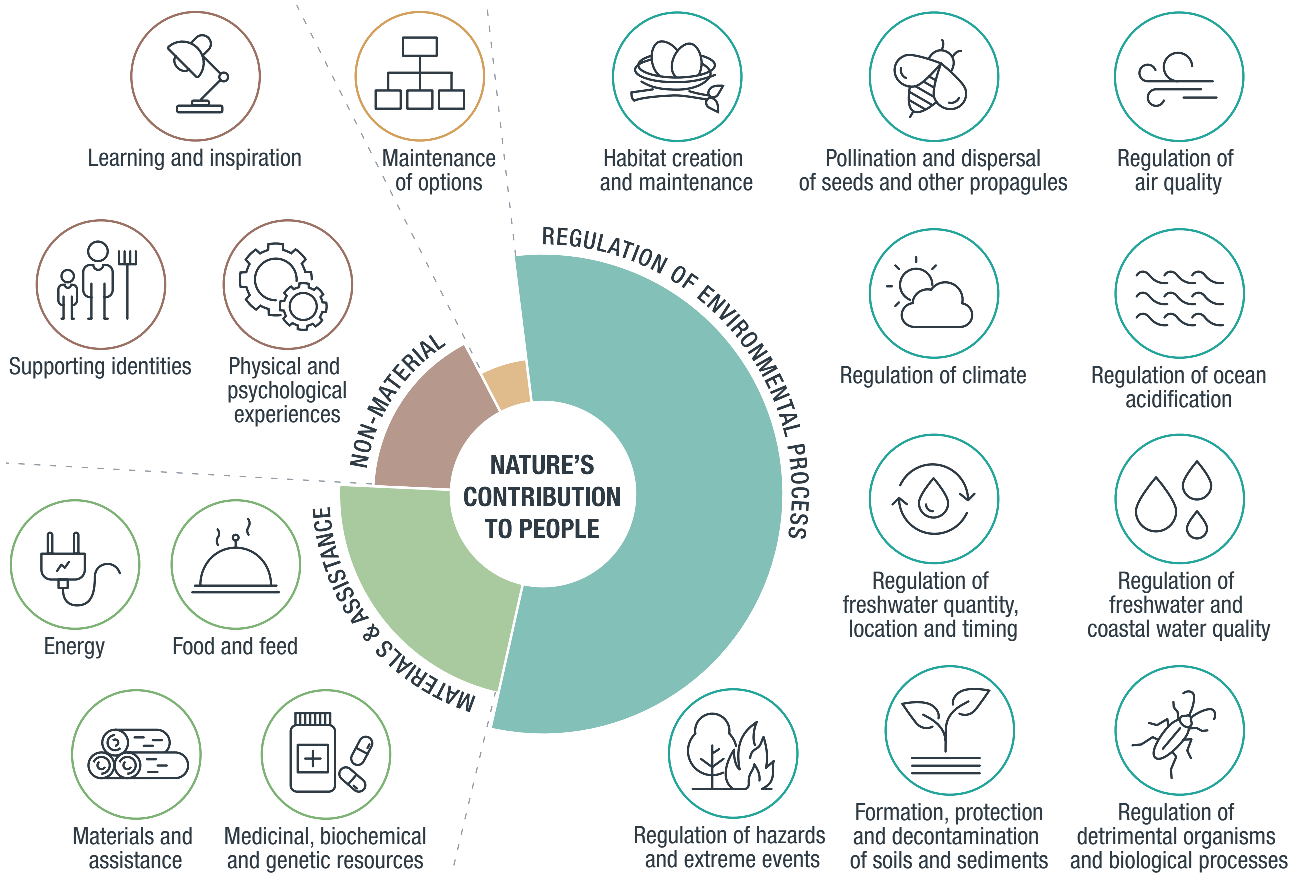


How land is used (~2015). Although human settlements (cities, towns and villages) only take up about 1% of the total ice-free land surface, we use the land for many other purposes.
Source: UN Food and Agriculture Organization (FAO), Licensed under CC-BY by the authors Hannah Ritchie and Max Roser in 2019. Adapted from an infographic by Azote.

LAND IS FINITE

How we choose to manage land not only affects the livelihoods of billions of people but also impacts the natural ecosystems that survive on the land and help maintain ecosystem services like air and soil quality, flood and disease control, or pollination. Some examples of **ecosystem services** provided by land are given in the figure below.

Land is finite, and, as the human population increases, **we rely on land like never before.** When damaged, the resulting losses are substantial and difficult to restore.



Examples of ecosystem services.
Source: IPBES (adaptation). https://ipbes.net/sites/default/files/2020-02/ipbes_global_assessment_report_summary_for_policymakers_en.pdf

BIODIVERSITY

ROLE OF BIODIVERSITY

Biodiversity* literally means the diversity of organisms. It encompasses several levels: **intraspecific biodiversity** (differences between members of the same species), **interspecific biodiversity** (differences between species), and **ecosystem diversity** (differences in various environments and the species that live in it). Biodiversity serves many functions and provides ecosystem* services, such as oxygen production and carbon capture. **Biodiverse ecosystems are also more resilient to climate change**[1]**.**

BIODIVERSITY ON LAND

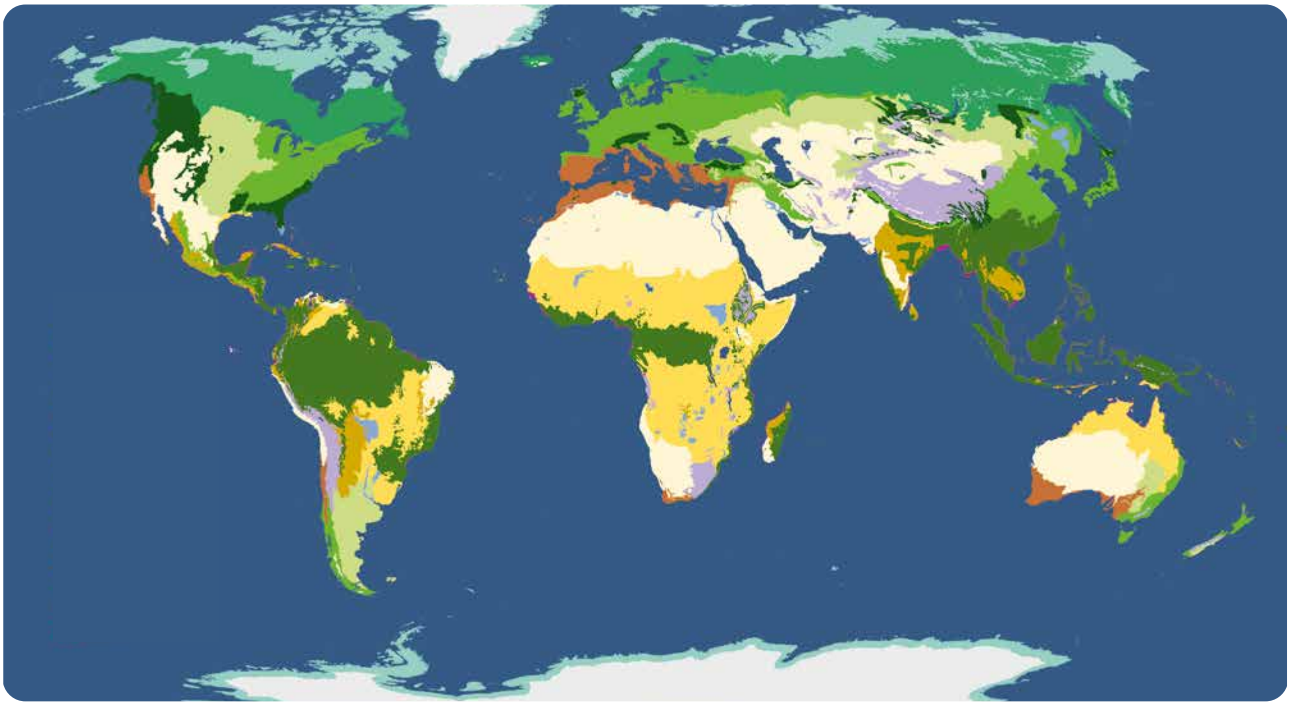
The unequal distribution of the sun's energy received by the Earth's surface, as well as the division of land with respect to the oceans, induces a high variation in climate around the world. These climates, in interaction with the local topography, have led to the development of specific ecosystems in different regions of the planet. All the ecosystems of a similar region are called a biome* (e.g., desert or tropical forest), and land ecosystems are a vast reservoir for biodiversity.

BIODIVERSITY IN SOILS

Not just "visible" land ecosystems, but even soils are a vast reservoir of biodiversity. This includes bacteria, earthworms, insects and fungi. These macro and microfauna play a key role in organic matter decomposition by turning it into mineral matter and thus are called decomposers.

Tropical forests are the ecosystems with the highest biodiversity on land.

1 Epple and Dunning (2014), 'Ecosystem resilience to climate change: What is it and how can it be addressed in the context of climate change adaptation?' UNEP-WCMC technical report.



Biomes of the world

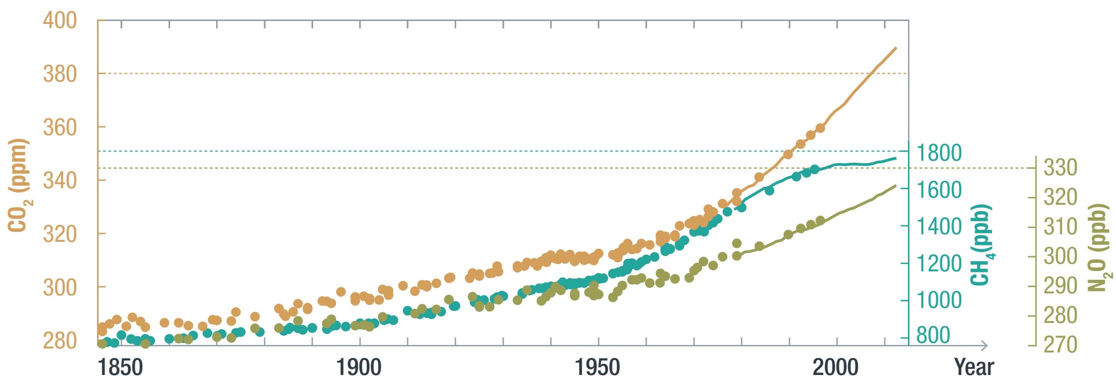
- Tundra
- Taiga
- Montane grasslands & shrublands
- Temperate broadleaf & mixed forests
- Temperate coniferous forests
- Temperate grasslands, savannas & shrublands
- Tropical & subtropical coniferous forests
- Tropical & subtropical moist broadleaf forests
- Tropical & subtropical dry broadleaf forests
- Tropical & subtropical grasslands, savannas & shrublands
- Flooded grasslands & savannas
- Deserts & Xeric shrublands
- Mangrove
- Mediterranean forests, woodlands & scrub

Source: Wikimedia Commons

How the climate is rapidly changing due to human activity

HUMANS AND CLIMATE CHANGE

Since the Industrial Revolution*, humans have been modifying the distribution of greenhouse gases between land, ocean and atmosphere by emitting large amounts of GHG into the atmosphere, mostly **carbon dioxide** (CO_2), **methane** (CH_4) and **nitrous oxide** (N_2O), thus causing an imbalance and leading to climate change.

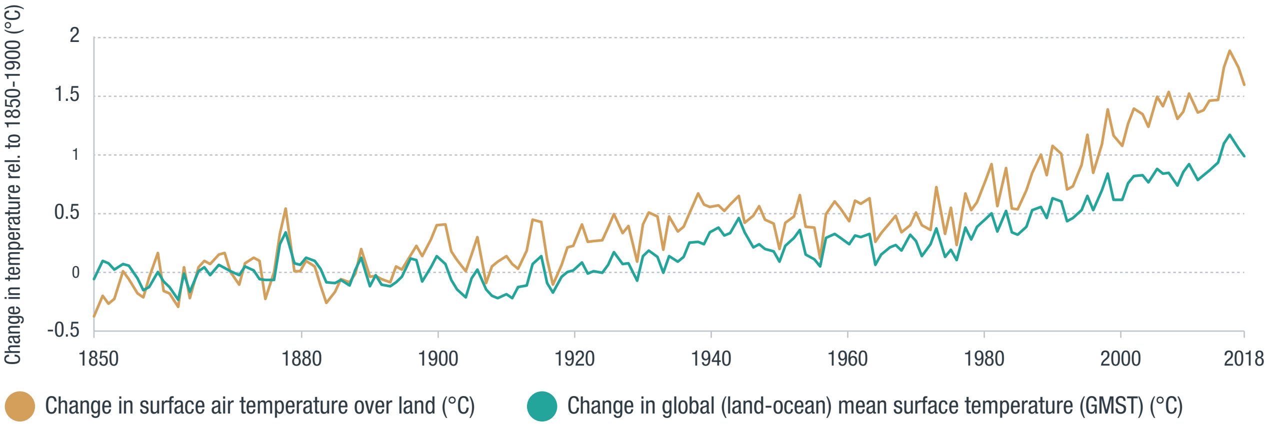


Average global greenhouse gas concentrations.
Source: Adapted from IPCC Assessment Report 5, Summary for Policy Makers.

CLIMATE CHANGE ALTERS THE LAND

Human activities are the cause of global warming. Since the pre-industrial era, the mean temperature over land and ocean has risen, but **the land temperature has risen much more (about 1.59°C since 1850)** than the global mean temperature (about 1.09°C since 1850).

There are two main reasons for the difference between land surface temperature and ocean surface temperature. First, land is mostly made of solid constituents, hence it has a lower heat capacity than the ocean, which is liquid water. Thus, land needs less heat for its temperature to rise. Additionally, when the ocean temperature rises, there is a converse cooling effect when ocean water evaporates. On the land, there is less water, so the cooling effect of evaporation is weaker.

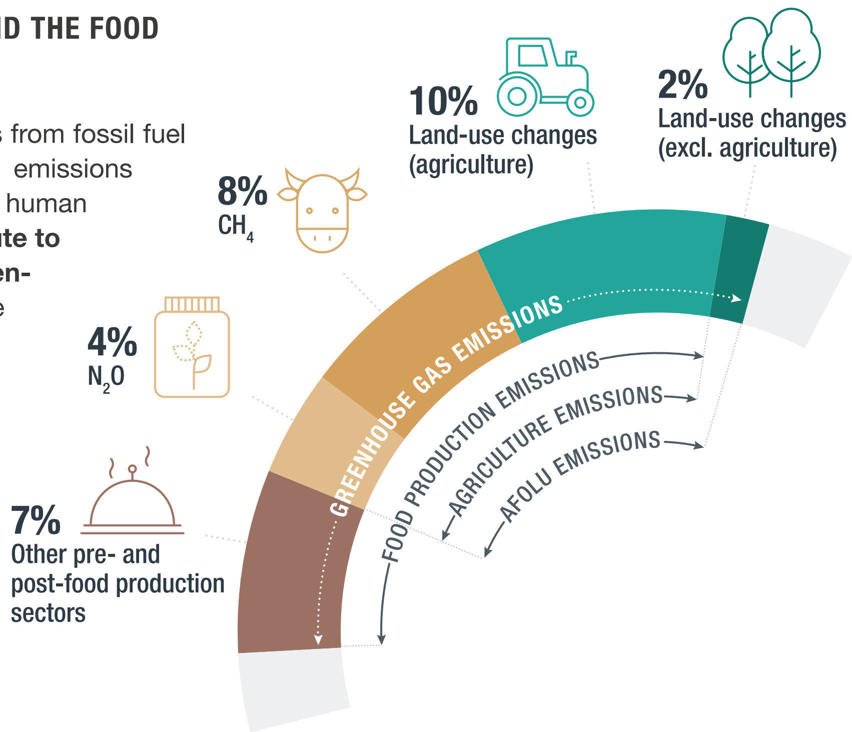


Observed change in surface air temperature over land and in global (land and ocean) mean surface temperature for the period 1850–2018. Since the pre-industrial period (1850–1900) the observed mean land surface air temperature has risen considerably more than the global mean surface temperature (GMST).
Source: Adapted from IPCC, Special Report on Climate Change and Land. Summary for Policymakers.
https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/

THE ROLE OF AGRICULTURE AND THE FOOD SYSTEM

Although greenhouse gas emissions from fossil fuel combustion are substantially larger, emissions from the land are still significant: all human land use activities together **contribute to around 24% of total human greenhouse gas emissions** (see the figure on the right).

The three main greenhouse gases related to land are carbon dioxide, methane and nitrous oxide. Methane and nitrous oxide are closely linked to agriculture and both have a higher global warming potential than carbon dioxide.



Greenhouse gas emissions linked to Agriculture, Forestry and Other Land Use (AFOLU) and food.
Source: Adapted from "Citoyens pour le Climat", summary report based on the IPCC Climate Change and Land report. https://drive.google.com/file/d/17H99ekMQ7j9ErgXTQUKP5s0-qQ4-pJMA/view

The main sources of methane in agriculture are **paddy rice farming and livestock,** whereas nitrous oxide is primarily emitted by the extensive use of **manure and synthetic fertilisers.** Between 2007 and 2016, **the land sector accounted for around 13% of carbon dioxide, 44% of methane, and 81% of nitrous oxide emissions caused by human activities.**

Closely linked to agriculture is the food system* which encompasses food production, transportation, manufacturing, retailing, consumption and waste of food. **The global food system is responsible for 21–37% of total net anthropogenic greenhouse gas emissions,** with future emissions projected to increase due to population and income growth, and changes in consumption patterns and lifestyles.

A GROWING POPULATION AND DIETARY CHANGES

A growing global population and changing lifestyles have increased our consumption of the land's resources. **Currently, agriculture accounts for 70% of global freshwater use and food production has increased by about 240% since 1961.** Not only has the world's population grown, but diets have evolved – especially over the last few decades. This has changed the way we use the land for farming. **Our diets are more energy dense:** high in fat with a large share of vegetable oils, meat and sugar. These dietary changes have contributed to about two billion adults being overweight or obese. Yet, **around 821 million people are still undernourished, despite 25–30% of total food produced being lost or wasted.**

How land is changing due to climate change and human activities

LAND RESPONSE TO CLIMATE CHANGE

Amongst the most damaging impacts of climate change on land are **extreme events*.** By disturbing the water cycle, warming has led to an **increase in the frequency and intensity of extreme meteorological events** like heatwaves, droughts and heavy precipitation. Dust storms are also occurring more often and are more intense – this is mainly due to the expansion of dry areas and desertification.

As more CO_2 is emitted into the atmosphere and the world gets warmer, the land's vegetation responds to these changes. Over the last thirty years, **vegetation greening trends** (increase in vegetation productivity) have been observed in parts of Asia, Europe, South America, central North America and southeast Australia, due to **longer growing seasons: plants have more CO_2 to photosynthesise, plus land management has changed** (different watering mechanisms and fertilisation practices are being used).

In other regions, however, for example, in parts of northern Eurasia, North America, Central Asia and the Congo Basin, the opposite phenomenon has been observed: **vegetation browning*** (decrease in vegetation growth or death of vegetation) is largely due to water stress from climate and land use change, but also from wildfires and climate-related droughts. In fact, in some places, **entire climate "zones" are shifting;** for example, polar climate zones are shrinking and arid climate zones are expanding.

HUMANS ALTER THE LAND

When land loses its soil quality, vegetation, water resources or wildlife then it is said to have been **degraded**. In the twentieth century, land degradation* accelerated partly due to increased extreme events like droughts* and flooding, and also due to human land use change such as urbanisation, deforestation* and intensive agriculture. Today, **about one quarter of the Earth's ice-free land surface is subject to human-induced land degradation.**

Climate change-induced land degradation such as coastal erosion, exacerbated by sea level rise, thawing permafrost or extreme soil erosion, **can result in forced migration, conflicts and poverty.**

An extreme form of land degradation in arid or semi-arid areas is desertification*. **Between 1980 and the 2000s, about 500 million people lived in regions which experienced desertification. Climate change exacerbates this process, impacting people all over the world, especially in South-East Asia, the Sahara, North Africa and the Middle East.**

Deforestation releases CO_2 and eliminates one of the ways by which CO_2 is removed from the atmosphere (photosynthesis) and so does desertification. The FAO estimates that between 1990 and 2019, about 420 million hectares of forest – corresponding to approximately half the area of the United States – have been lost worldwide due to deforestation.

The decrease in vegetation cover increases albedo* and so reflects more heat than land covered with vegetation. This leads to cooling (net effect).

FOOD SECURITY

Climate change has a particular impact on humans through **food security.** Changing precipitation patterns, more frequent extreme events, and warming in general are **reducing crop yields (of maize and wheat, for example) in lower latitude regions.** In Africa, climate change has lowered animal growth rates and productivity in pastoral systems. However, **in some higher latitude regions, some crop yields have increased (such as maize, wheat and sugar beets).**

What impact this has on us

As **a critical resource for the world, land is already under pressure due to competing demands.** Climate change is making a challenging situation worse. Together with a projected growing population and changes in consumption patterns, climate change will result in **increased demand for food, feed and water.** These changes have huge implications, for example, on biodiversity, ecosystem services and, thus, food security and drinking water availability.

Impacts on people will be different depending on regions. With increased warming, the frequency, intensity and duration **of heat-related extreme events** will increase, particularly in the Mediterranean region and Southern Africa. North America, South America, the Mediterranean, southern Africa and central Asia **may be increasingly affected by wildfires*.** In tropical regions, warming could create unprecedented climatic conditions by the twenty-first century, making some areas uninhabitable.
In drylands, climate change and desertification will cause overall **reductions in crop and livestock productivity,** modify the plant species mix and reduce biodiversity. Asia and Africa are projected to have the highest number of people vulnerable to increased desertification. The tropics and subtropics are projected to be most vulnerable to crop yield decline.

Finally, climate change can amplify **environmentally induced human migration** (i.e., from lack of food and water, land degradation, etc.), within countries and across borders, and this increased displacement could exacerbate stressors leading to future conflicts. **Women, the young, elderly and poor people are most at risk from negative climate change impacts.**

How we can act to mitigate and adapt to climate change

There are two ways we can act to reduce the risks and impacts of climate change in the coming decades:

- One is to **limit climate change** by acting on greenhouse gases. We can do this by reducing anthropogenic emissions into the atmosphere or by using methods that actively remove carbon dioxide from the atmosphere (known as CO_2 removal), such as planting trees. Together, these actions are called **mitigation*.**
- A second approach is to **tackle the consequences of climate change** by either limiting the number of people, wildlife and property that might be in harm's way, or by reducing the extent to which they are affected. This is known as **adaptation*.**
- **Some land-related actions contribute to climate change adaptation, mitigation and sustainable development*.**

It is not an either / or situation, though: **both mitigation and adaptation are needed to tackle climate change.** Moreover, both should be considered when taking action. For instance, when designing a new school, we could make the building carbon neutral in both construction and operation (mitigation), while also ensuring it can cope with a range of possible climate futures (adaptation).

MITIGATION

While substantial emission cuts are needed over the next decades to limit climate change, the global population, the demand for energy, and consumption are on the rise. Meanwhile, we need to tackle other major global challenges, including improving access to food, water, jobs and healthcare for those most in need, and reducing inequality.

There are many reasons to be hopeful. Not only is there growing public and political awareness of the need to act fast, but in combination with the rapidly falling cost of renewable energy and the landmark Paris agreement on climate change in 2015, all elements that can support rapid emission reductions are falling into place. There have already been many success stories. In the UK, thanks to a decline in coal use, CO_2 emissions have fallen to levels last seen in 1890[2], while Germany's use of renewables-based electricity has soared from around 6% in 2000, to about 45.4% in 2020[3]. In 2021, 69% of the electricity in Portugal was generated with renewables[4].

However, since the level of warming depends on global emissions, it is not enough for just a few countries to act. It is also not only up to governments, businesses and legislation to reduce emissions, even if their role is central. As we explore below, local organisations and individuals can also play a role.

THE PARIS AGREEMENT

The goal of the UN Paris Agreement[5] is to keep global warming under 2°C while aiming to limit warming to 1.5°C (above pre-industrial levels). To prevent warming exceeding 1.5°C, a 40–60% cut in global CO_2 emissions is needed over the next decade, **to ultimately reach (net) zero emissions by 2050**[6] (see the Office for Climate Education's summary for teachers of the IPCC Special Report Global Warming of 1.5°C for further details).

This is a significant challenge and all levels of society – governments, businesses, local organisations and individuals – can play a role in reducing emissions.

CARBON FOOTPRINTS

Carbon footprint* is usually defined as the total amount of greenhouse gases emitted by a given source of emissions. Carbon footprints can be computed for many different entities, such as a person, country or product. To account for the release of greenhouse gases other than CO_2, these gases are measured in terms of "CO_2 equivalent" (CO_2-eq) – i.e., the equivalent amount of CO_2 emissions.

Calculating a footprint will help you, or the group you belong to, identify which of your activities produce the most emissions, and so are the most critical to target. Rather than trying to get a precise estimate of each contribution to this footprint, the aim is to find a rough estimate of their relative sizes, so you can identify which are the largest and therefore the most important to act on. Bear in mind, though, that there will be limits to what individuals or local groups can do without legislative or other support. Some of these aspects and the measures you can adopt to reduce your carbon footprint are presented in Lesson D1.

THE KEY ROLE OF CONSUMPTION CHOICES

Diversifying food systems reduces the risks from climate change (like promoting the availability of a diversity of seeds or heterogeneous diets). Additionally, diets mainly based on plants, such as grains, pulses, fruits and vegetables, nuts and seeds, contribute to climate mitigation, and at the same time promote good health and wellbeing.

The total mitigation potential of dietary changes is estimated as 0.7-8 Gt CO_2-eq/year by 2050. For comparison: the total greenhouse gas emissions on our planet reached 53.6 Gt CO_2-eq in 2017[7].

Moreover, 25 to 30% of total food produced is lost or wasted nowadays. Reducing food loss and waste can lower greenhouse gas emissions and contribute to climate change mitigation since it reduces the land area needed for food production. Between **2010 and 2016, global food loss and waste contributed to 8–10% of total greenhouse gas emissions from human activities.**

The total mitigation potential in the food sector, from production to consumption, including food loss and waste, is estimated as 2.3-9.6 Gt CO_2-eq/year by 2050.

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2 This does not give the full picture since some of the UK's emissions have been "outsourced" overseas

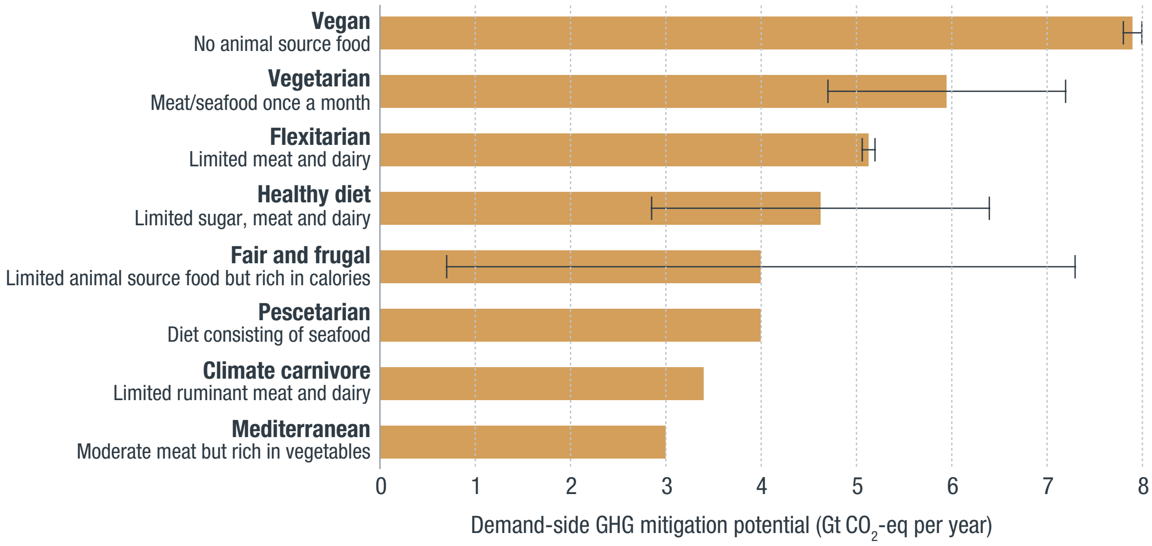
3 German Environment Agency, electricity demand. https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/renewable-energy-sources-in-figures.pdf?__blob=publicationFile&v=3

4 Redes Energéticas Nacionais. https://www.apren.pt/en/march-100-renewable--first-month-of-xxi-century-fully-supplied-by-renewable-electricity-sources/

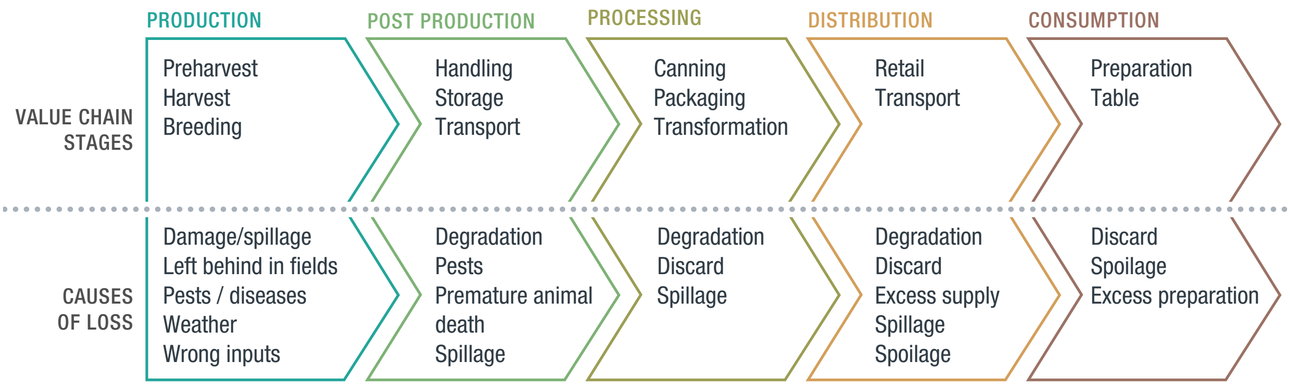
5 https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

6 IPCC Special Report on "Global Warming of 1.5°C": https://www.ipcc.ch/sr15

7 https://www.ipcc.ch/site/assets/uploads/2018/12/UNEP-1.pdf



The greenhouse gas mitigation potential of different diets.
Source: Adapted from IPCC Special Report on Climate Change and Land, chapter 5. https://www.ipcc.ch/srccl/chapter/chapter-5/



Food losses along the food chain.
Source: Adapted from the UNCCD. https://www.unccd.int/sites/default/files/documents/2017-09/GLO_Full_Report_low_res.pdf

BEST PRACTICES IN MITIGATION

While reducing emissions might seem straightforward on the surface, the full story is more complex.

- Land can make a valuable contribution to climate change mitigation. However, there are limits to the deployment of land-based mitigation measures, such as bioenergy crops or afforestation.
- Widespread land use could increase risks for desertification, land degradation, food security and sustainable development.

CLIMATE JUSTICE

While the Paris Agreement does not specify how emissions reductions should be distributed across countries, **ethics suggest that this should be done in an equitable way.** Defining what is equitable is a significant challenge and involves both countries and citizens (in democratic countries) to debate on the best way forward. One approach could be to allocate reductions based on which countries have emitted the most emissions in total, and thus have contributed most to climate change. A limit to this approach is that it does not consider the ability of countries to reduce emissions, given their economic status. The emissions of some populous developing countries, while low per person, can add up to more than the emissions of developed countries with fewer inhabitants. Another dimension of **climate justice*** is the severity of climate impacts experienced by local populations. Indeed, the severest effects will hit the most vulnerable people, most of whom live in the developing world, i.e., those who have contributed the least to global emissions.

ADAPTATION

The extent to which climate change affects a region depends not only on the intensity of the changes in climatic conditions but also on how exposed and vulnerable its population, ecosystems and infrastructure are to those changes.

REDUCING EXPOSURE AND VULNERABILITY

Adapting to climate change involves taking actions to reduce exposure* (things in harm's way) and vulnerability* (their susceptibility to harm). Exposure and vulnerability are often tied to poverty.

Solutions that help adapt to and mitigate climate change, while combating desertification, are site and region specific and include water harvesting and micro-irrigation, restoring degraded lands using drought-resilient ecologically appropriate plants, agroforestry and other agroecological and ecosystem-based adaptation practices.

Afforestation*, or tree planting, can reduce sandstorms, avert wind erosion and contribute to carbon sinks, while also improving micro-climates, soil nutrients and water retention.

EDUCATION AND A HUMAN-CENTRED APPROACH

Education is a core aspect of adaptation and can take many forms, such as getting better acquainted with your local environment, passing on your climate change knowledge to friends and family, and undertaking a career that can contribute to adaptation solutions.

Thanks to their close contact with their environment and their knowledge of the land, **indigenous and local people can contribute through their agricultural practices to overcome the combined challenges of climate change, food security and biodiversity conservation and, hence, combat desertification and land degradation.**

The intersections between climate change, gender and climate adaptation take place at multiple levels: household, national and international. This is why **women play a key role in achieving sustainability but are also especially vulnerable to the impacts of climate change.** Empowering women can bring synergies and co-benefits to households. Such empowerment includes transfer of financial power to women, and investing in their health, education, training and capacity building.

ACTING NOW

The speed at which actions are taken in the land sector directly affects risk and loss reduction. This is because the potential of some response options to limit climate change and its impacts is declining as climate change intensifies. For example, one option to reduce greenhouse gas emissions is to increase the organic carbon content of soils. However, soils have a reduced capacity to act as sinks for carbon sequestration when temperatures rise.

Delaying action will have irreversible effects on many ecosystems, negatively impacting food production and human health.

Wrap-up

Land is an **essential component of the climate system** as it contributes to the global cycles of heat, water and carbon. Land also provides food, feed, fiber, fuel and freshwater to human society and its economy. But this provision is **under threat,** as a consequence of unprecedented rates of land and freshwater exploitation in recent decades (agriculture, deforestation and other land uses) and exacerbated by rising global temperatures and changing rain patterns.

Properly managing the use of land can contribute significantly to mitigating and adapting to climate change, including through the promotion of sustainable management of forests and ecosystems.

Land can be conserved, restored and used sustainably while other global societal goals are simultaneously met through concerted efforts fostering transformative change.

The lesson plan which follows explores the concepts introduced here in more detail. It also empowers students to consider the role they, as future citizens, their local communities and their nations can play in tackling the great twenty-first century challenge of climate change.

PEDAGOGICAL OVERVIEW

BACKGROUND FOR TEACHERS

PEDAGOGICAL OVERVIEW

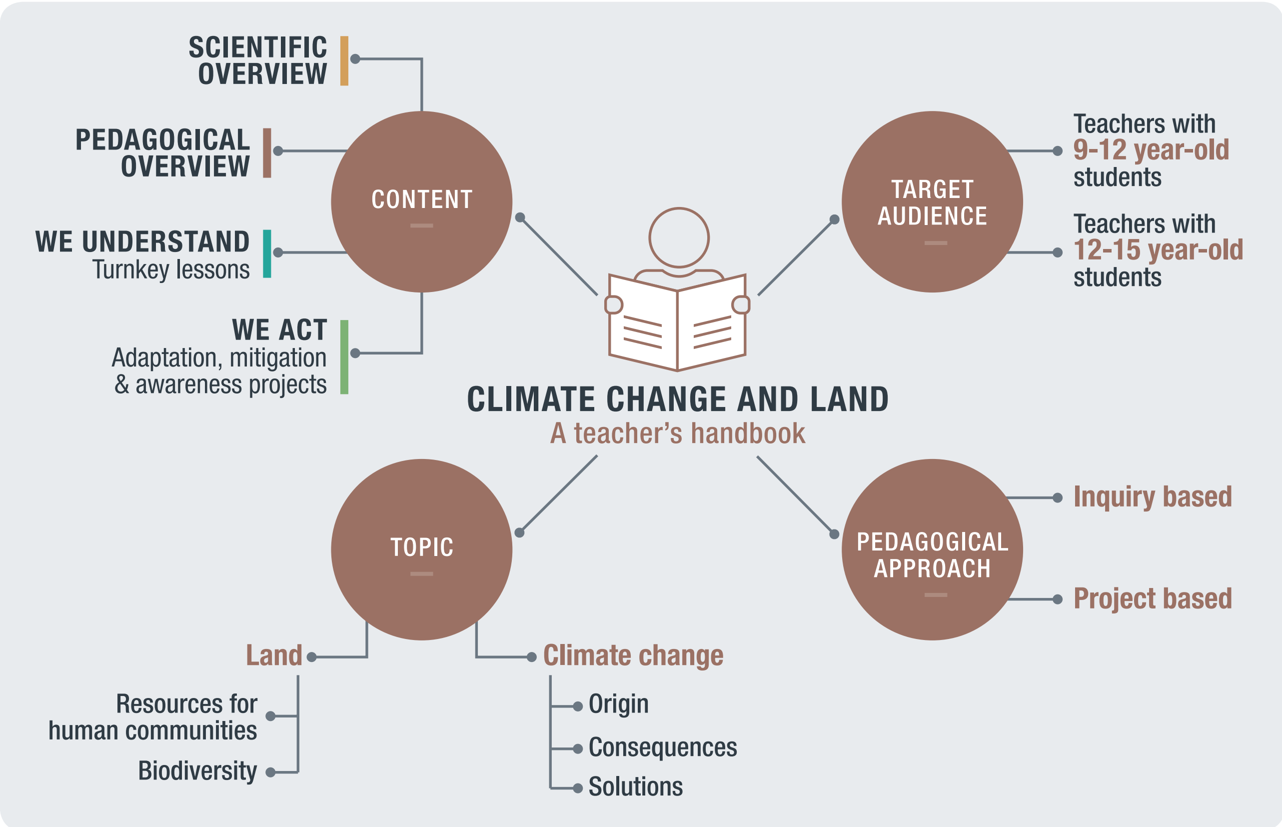
Introduction

We strongly recommend reading the scientific and pedagogical overviews before engaging with the lessons so that you will know enough about climate science and other related topics, as well as active pedagogies, to be able to teach these subjects.

This pedagogical overview is organised around the following topics:

- Mindmap of this guide for teachers
- How to use this guide to plan your progression through the lessons?
- How to use this guide to prepare a lesson?
- How to teach about climate change?
- Toolbox

Mindmap of this guide for teachers



How to use this guide to plan your progression through the lessons?

HOW ARE THESE ACTIVITIES DESIGNED?

This teacher's handbook provides detailed guidelines on how to teach **9 to 15-year-old students** about climate change and land. The structure of each lesson helps teachers to encourage their pupils to engage with the investigations and activities.

"The Climate in our Hands – Climate Change and Land" consists of two different parts, both of equal importance: "We understand" and "We act".

PART 1 WE UNDERSTAND

In the first part, the lessons are organised in four consecutive sequences, following a coherent pattern. These sequences include:

- A – What is climate change?
- B – Why is land important to us?
- C – Land and climate change
- D – What can we do?

PART 2 WE ACT

This part is not a lesson plan. Instead, the class is encouraged to implement concrete adaptation or mitigation project(s). We provide examples of actual, successful projects for inspiration. The sample projects differ in terms of duration (from a few hours to a few years!) and type (adaptation, mitigation, raising awareness, research).

HOW TO USE THIS GUIDE IN YOUR PROGRESSION THROUGH THE LESSONS

In this handbook, you will find eighteen lessons (and one review session), some of which are designed for 9–12 year-old students, whereas others are more suitable for 12–15 year-olds.

Considering the amount and the variety of the lessons, keep in mind that you need not follow the whole programme: it is up to you to choose which ones are best suited to your students' level of ability and the time you have.

We suggest three examples of progression below, depending on the topics you would like to focus on:

RECOMMENDED LESSONS

- **A1** – Evidence of climate change on land — 1h
- **A2** – The greenhouse effect: understanding with an analogy — 1h15
- **B2** – Different soil types and land use — 2h
- **C1** – Making choices: How do your food habits impact climate change? — 1h
- **C2** – Climate change and agriculture — 1h30
- **D2** – Emotions and climate change — 1h

Total 7h45 + 1 "We act" project

FOOD HABITS

- **C1** – Making choices: How do your food habits impact climate change? — 1h
- **A2** – The greenhouse effect: understanding with an analogy — 1h15
- **C2** – Climate change and agriculture — 1h30
- **C4** – Climate change, human activities and biodiversity — 1h
- **B3** – The soil is a major resource — 2h

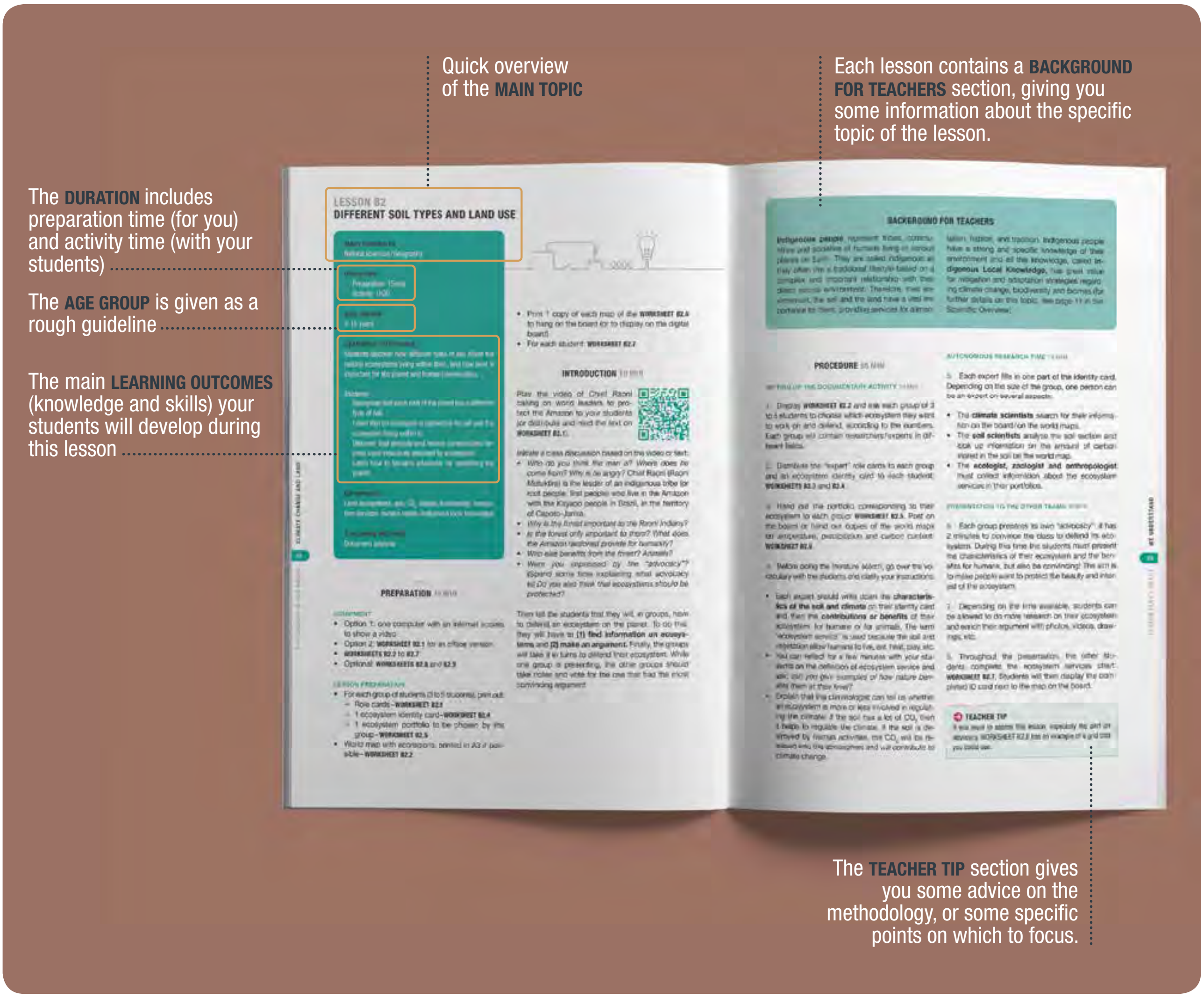
Total 6h45 + 1 "We act" project

CONSEQUENCES OF CLIMATE CHANGE

- **A1** – Evidence of climate change on land — 1h
- **D2** – Emotions and climate change — 1h
- **A2** – The greenhouse effect: understanding with an analogy — 1h15
- **C2** – Climate change and agriculture — 1h30
- **C3** – Extreme events and land degradation — 1h
- **D1** – Our carbon footprint — 1h

Total 7h + 1 "We act" project

How to use this guide to prepare a lesson?



LEVELS

In each lesson, **the targeted age group** will be mentioned. Of course, this does not mean that you cannot conduct this lesson with another age group, but it gives you an idea of the ability level of the activities involved. The age groups are mentioned as follows:

- 9–12 years
- 12–15 years
- 9–15 years

LEVEL OF DOCUMENT DIFFICULTY

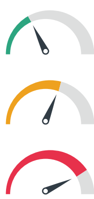
For some lessons, we include a variety of **documents requiring differing levels of ability;** thus, you will find some documents that are easier to understand and others that are designed for more advanced students.

Keep in mind that **this is only a recommendation:** you are the only one able to choose the documents most suitable for the level of your class. The different levels are illustrated as follows:

TRAINEE

CURIOUS

EXPERT



YOUR STUDENTS FIRST!

All the suggestions for experiments and conclusions that you will find in this lesson plan are provided merely as examples. They were compiled during class tests and are scientifically correct. Nevertheless, we strongly encourage you to **follow the experimental protocols, ideas and conclusions proposed by your own students.**

How to teach about climate change?

In this teacher's handbook, it is our objective to allow students to actively participate in class, through questioning, experimentation, observation, trial and error, debate and the implementation of local, concrete solutions to address climate change issues. This "active learning" can take different forms. **The two approaches that we strongly promote throughout this resource are inquiry-based learning and project-based learning.**

Some activities are aimed at developing students' scientific education and expanding their critical-thinking skills. These adopt **inquiry-based approaches to learning,** which are frequently used in STEM education. Other activities focus specifically on implementing real adaptation or mitigation projects, which can be carried out by the students, the school and even local communities. **These follow a project-based approach.**

WHAT IS INQUIRY-BASED LEARNING?

While it would be an oversimplification to use a fixed model of inquiry-based learning, this approach generally has three phases:

1. **Questioning:** initiated by the teacher or the students, it helps to formulate hypotheses.
2. **Formulating a hypothesis and carrying out research:** this may be carried out through experiments, investigations, observations or documentary studies.
3. **Structuring knowledge** (discussion on information/data collected or produced): the purpose of this is to draw some broad conclusions, which in turn can lead to more questioning, more research, etc.

PHASE 1: QUESTIONING

The aim of this phase is to **provide students with opportunities to ask questions about different phenomena in their environment.** The processes of questioning, drawing comparisons and highlighting discrepancies will not only capture the students' attention and engagement but it will also lead to introducing a problem that the students must solve. The teacher's role during this phase is to **guide the discussion,** allowing the students to become aware of a problem and to discuss ways in which they can address it. The teacher should ask open-ended questions to support students in developing their scientific and critical-thinking skills.

PHASE 2: FORMULATING A HYPOTHESIS AND CARRYING OUT RESEARCH

Using their experience and/or knowledge, students are encouraged to provide **plausible explanations, which in turn, will lead to the students' hypotheses.** To enable students to accept or reject their different hypotheses, they are given opportunities to carry out specific experiments and/or documentary research. The research phase starts when the credibility of a theory needs to be tested.

Students can develop ideas or theories (use what they think they know, what they think they understand to explain a certain phenomenon).

During this phase, the students work alone or in a group to investigate solutions to the problem raised. This involves testing the hypothesis they have chosen.

If experimenting, modelling or direct observation are not possible, documentary research and even interviewing an expert will enable the students to validate or dismiss their hypothesis.

Sometimes students need to alternate between questioning and research before finding a solution and constructing new knowledge. **Class and group discussions play a key role in structuring the students' knowledge.** During discussions, the teacher's role is to support dialogue between the students.

PHASE 3: STRUCTURING KNOWLEDGE

It is important that **students summarise their key findings.** We recommend that the teacher allows the students to draw their own conclusions, based on the work they did in class. The class conclusion, emerging after the discussion of the different interpretations, should ideally be a consensual conclusion. The teacher may act as a facilitator to reach this conclusion, if needed. An essential step in an inquiry-based approach, which is all too often skipped, is to compare the knowledge created in class (the class conclusions) with established knowledge.

Examples of inquiry-based learning in the present teaching resource:

- **Experimentation:** in lesson **A2**, the students carry out an experiment to study how a greenhouse works (they will then make an analogy with the greenhouse effect).
- **Observation:** in lesson **B4**, the students observe a forest, collect samples, record sounds, etc.;

these observations are then used to study the biodiversity of the place.
- **Documentary research:** in lesson **C2**, students learn how modern agriculture is impacted by climate change and how agricultural practices worldwide are affecting the climate.
- **Serious game:** in lesson **B1**, the students play a game similar to "bingo" in order to understand how we depend on land and its natural resources.
- **Roleplaying:** in lesson **D3**, two roleplaying games help students to comprehend the inequalities between countries with respect to wealth, greenhouse gas emissions, and vulnerability to climate change.

WHAT IS PROJECT-BASED LEARNING?

Project-based learning is a fully fledged type of active learning. First described in the early twentieth century (initially by John Dewey, who also introduced inquiry-based learning), it was long confined to primary education before gradually spreading to secondary and higher education. Project-based learning has evolved as a method of instruction that addresses core content through rigorous, relevant and hands-on learning. The projects are typically framed with open-ended questions that push students to investigate, research and construct their own solutions. For example: *How can we reduce our school's carbon footprint?*

The second part of this teaching resource ("We act", page 234) presents some concrete actions to address climate change that have already been implemented in classrooms, schools or communities. All these actions adopt project-based learning so that students can engage in real-world problem solving.
- The purpose of project-based learning is to enable students to **manage a project from beginning to end,** including a variety of different tasks, to solve a particular problem.
- Students carry out **practical investigations and conduct desk-based research** to establish different points of view on a particular issue.
- Sufficient time should be allocated to enable students to **overcome challenges and implement projects in the field.**
- It is important to understand that the project is managed by students as a class group and **not by the teacher alone.**
- **Breaking up complex tasks into more basic ones,** where students have a high degree of independence and are actively involved, is to be encouraged.

The main benefits of project-based learning are that students are learning within **contexts that are meaningful to them.** Moreover, the practical aspect of the project usually motivates them even further. They acquire cross-functional skills, such as decision-making or planning. They realise that making errors and failed attempts are part of the learning process, and that cooperating is the key to success.

Finally, the outcome of the project can inspire other classes, families and the community as a whole. For further details on this topic, see the introduction to "We act", page 234.

THE TEACHER'S ROLE IN PROJECT-BASED LEARNING

Like inquiry-based learning, project-based learning focuses on **student activity.** The teacher's role is to help define the project and make sure that its objectives are achievable. The teacher refocuses the activity or discussion on the objectives, if necessary, supervises discussions and may act as an expert if asked by the students. The teacher also might have to deliver lessons to help students gain relevant knowledge before they start the project. Lesson plans, hence, are essential.

INTERDISCIPLINARY APPROACH

Teaching about climate change means taking into consideration all its dimensions, and this requires a multidisciplinary approach. This is a major challenge, as most school programmes are designed in a single disciplinary approach, especially in secondary school. This teacher's handbook provides an interdisciplinary progression, intended to encourage a thematic and project-based approach and collaboration between teachers from various disciplines.

While "traditional" scientific disciplines (physics, chemistry, biology and geology) are essential to understand the mechanisms of climate change and its consequences, the humanities and social sciences (history, geography, economics, etc.) allow students to understand the issues of sustainable development and climate justice. The arts and language disciplines are also valuable for encouraging students to express their feelings and engage with certain forms of action (such as public awareness). Engineering and practical disciplines (agriculture, technology, etc.) are of use in developing solutions.

POSITIVE THINKING

Worldwide, climate change issues have led to a strong mobilisation of young people, often marked by extreme emotion, especially amongst the youngest, who talk of civilisation collapse, the end of planet boundaries, biodiversity loss, etc. The term **"solastalgia"** (the nostalgia of the ongoing disappearance of the natural environement as we know it) has been coined to describe this climatic anguish, or eco-anxiety* (the fear, in anticipation, of the impacts of climate change).

Here, we suggest managing this anxiety by:

- **Raising awareness on climate change:** not denying its seriousness and challenging aspects, but focusing on scientific facts instead of on catastrophic speech (see Sequences A and C). This approach is important, but not sufficient, considering the high emotional charge of climate change consequences.
- Encouraging students to **acknowledge their emotions and feelings,** and to connect with others rather than remaining in isolation (see Lesson D2 which is devoted to this topic).
- Realising that it is necessary, and still possible, **to act at different levels:** the individual, school, community, etc. (see Sequence D).
- Encouraging students to take part in a **concrete plan of action,** through projects (see the "We act" section) that will lead to mitigation or adaptation.

TOOLBOX

CONDUCT AN EXPERIMENT

For each experiment in this handbook, you will have to prepare some equipment beforehand; this mainly consists of affordable and accessible materials. **Keep in mind the safety rules before letting your students conduct experiments.** During the experimentation itself, take some time to discuss with your students what each element of the experiment represents in reality, as it will help them to draw conclusions at the end.

COLLABORATIVE WORK WITH ROLEPLAYING GAMES

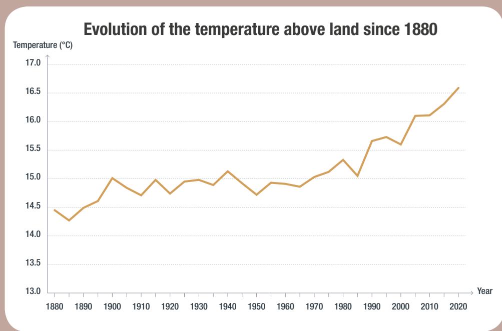
In several lessons, we suggest dividing your students into groups, in order to encourage **collaborative work.** In these lessons, roles with specific objectives are often given to maintain student motivation. The roles are only suggestions; feel free to pick your own.

STUDENT REPORTS

We suggest some type of creative work for your students to produce at the end of the lessons. The general idea is to **let them be as imaginative as possible:** you may consider having them make a video, a small podcast, a poster, a slideshow... depending on your classroom equipment.

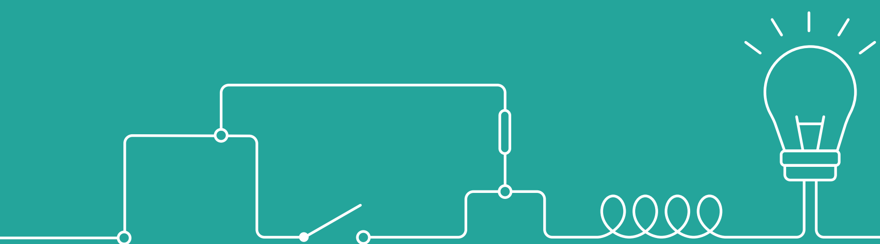
GRAPH ANALYSIS

In order to correctly analyse a graph, you will first have to explain **the significance of the x and y axes:** what do they represent? You will then have to express y in terms of x: in the example below, the graph represents the evolution of the temperature above land over time. Avoid using terms such as the curve goes "up" or "down": use precise vocabulary instead, for instance, *"we can observe that the temperature has increased over the last 140 years".*



STAY IN TOUCH WITH YOUR EMOTIONS!

We have not mentioned emotions in every lesson, but please bear in mind that after some lessons, **some of your students may express their feelings regarding climate change** and its consequences. One lesson is specifically dedicated to this aspect but you may want to consider regularly asking your students how they are feeling and allow time to take this factor into account.



WE UNDERSTAND

LESSON PLAN – PART I

WE UNDERSTAND #LESSONS

The first part of this lesson plan is called "We Understand". As its name indicates, it is aimed at providing the students with the **essential knowledge** necessary to understand:

- The **basis and evidence** of climate change.
- The **physics** involved in climate change and the role of greenhouse gases.
- How **land and the climate system** are interconnected, and consequently how climate change is affecting land.
- The impacts of climate change on **land ecosystems and human communities** that depend on them.
- The importance of **resources provided by land** for human livelihood and how climate change may impact them.
- The possible **measures** for mitigating and adapting to climate change.

All the lessons proposed are based on **scientifically sound and up-to-date knowledge** provided at a **primary and/or secondary school level of understanding.** The sequences have been designed to correspond to the **student mind and how they think**, and the lessons include a wide range of activities: experimentation, documentary analysis, roleplaying games, debating, use of multimedia animations and short videos. The overall progression follows an **inquiry-based teaching method.** As climate change issues are intrinsically **multidisciplinary,** so too are the lessons proposed, which include subjects from the natural sciences, such as physics, chemistry, biology and geology, the social sciences, such as history, geography, economics and sociology, and the visual arts.

The order of lessons proposed is one amongst many possible orders, and **you can adapt it** depending on your students' needs, ages, backgrounds, etc.

Some lessons, called the **"core lessons"**, are those that we consider to be essential for students to acquire a comprehensive and easy-to-understand picture of the phenomenon explored. **If you have limited time to work on this education project, we suggest you start by working on the core lessons.**

"Optional lessons" are aimed at delving further into the students' understanding of the different subjects and gaining a wider view of the overall issue of climate change impact on land. Some of these optional lessons are suggested for advanced students only.

Some of the core lessons also include variations (worksheets with different levels) in order to facilitate their adaptation to students at various levels of advancement. In both cases, **you, as the teacher, are best equipped to know how to adapt this lesson plan to your students' abilities.**

SEQUENCE A

WHAT IS CLIMATE CHANGE?

In order to teach and to understand climate change, two essential aspects must be addressed: the **scientific evidence** that the climate has changed (and is still changing) and the **mechanisms** of this change. The first one is essential to acquire scientific knowledge about this phenomenon, and the second one is paramount in acknowledging that humans are responsible for climate change.

The two first lessons in this sequence constitute the basis for all of the following sequences. Without this prior knowledge, the context of the other lessons will be much harder for students to grasp. The optional lesson A3 addresses the human activities responsible for greenhouse effect. These lessons are mainly based on documentary analysis and experimentation.

Lessons A4, A5 and A6 take a deeper look into the link between land and climate, focusing on the carbon cycle and its disturbance due to human activities. They are more suitable for older students, especially because lessons A5 and A6 require handling some specific equipment.

LESSON LIST

◉ Core lesson ○ Optional lesson

LESSON A1
EVIDENCE OF CLIMATE CHANGE ON LAND

MAIN SUBJECTS
Natural sciences / Geography

DURATION
~ Preparation: 5-10 min
~ Activity: 1h

AGE GROUP
9-15 years

LEARNING OUTCOMES
Students collect various types of evidence showing that the world climate has been changing over the last decades (global warming, sea level rise, the melting of glaciers, droughts, extreme events, etc.).

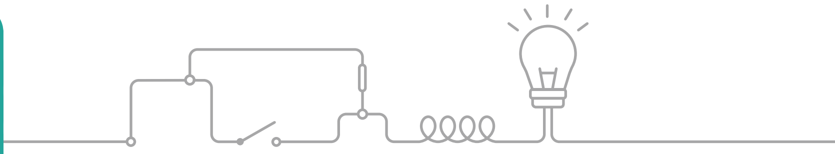
They learn that:
- ~ Climate and weather are two different phenomena.
- ~ The climate is an average of the prevailing weather pattern for a particular region. It depends primarily on latitude, altitude and distance from the ocean.
- ~ The weather is the state of the atmosphere at a particular place and time. Temperature and humidity are among the variables that characterise the weather.
- ~ The temperature of the whole planet has been increasing for a century, especially on land. This has led to different impacts, such as melting ice (glaciers and sea ice) and sea level rise.
- ~ Frequency and/or intensity of extreme events – such as floods, storms, and droughts – is increasing.

KEYWORDS
Climate, weather, global warming, extreme weather events, long timescales, scientific data

TEACHING METHOD
Documentary analysis

PREPARATION 5-10 MIN

EQUIPMENT
- **WORKSHEET A1.1** (one for each student).
- **WORKSHEETS A1.2, A1.3, A1.4, A1.5, A1.6, A1.7, A1.8, A1.9.**



TEACHER TIP
In these worksheets, we have included documents catering to different levels of ability. They are sorted into three categories: **"trainees"** is the most accessible level, suitable for 9-10 year olds; the **"curious"** tag gathers documents for 10-11 year olds; whereas the **"expert"** level is suggested for 12+ year-old students. These age ranges are provided for information only. For the youngest students, one worksheet comes with one document only. For more advanced students, several may be given to the same group.

LESSON PREPARATION
1. Consider groups of 4 students and pick the most suitable documents for their level.
2. Print copies of **WORKSHEETS A1.1** (one for each student), **A1.2, A1.3, A1.4, A1.5, A1.6, A1.7, A1.8** and **A1.9** (one for each group).

TEACHER TIP
During this lesson, you should take into account two potential obstacles to student understanding:
- → **The timescale of climate change:** The large timescales involved with climate change can be difficult to conceive for a young student, for whom fifty years may seem an eternity. For them it is not easy to comprehend the idea of change on these timescales. Moreover, some changes will be gradual and thus difficult to perceive.
- → **The fact that climate change is a worldwide phenomenon:** Even in the era of globalisation and social media, young (and often old!) people will tend to merely perceive events that are directly related to their personal life. Changes and events that occur in other parts of the world are too far away to be real. As a teacher, you can start with events that the students can relate to, events that occur locally and today. Subsequently, you can progressively introduce more global and long-lasting changes. This is why starting with concrete examples brought by the students may help.

Some documents require basic skills in the interpretation of graphs and percentages. Do not hesitate to spend more time on this lesson if the students are confronted with this kind of task for the first time.

BACKGROUND FOR TEACHERS

CLIMATE VERSUS WEATHER

The difference between **climate** and **weather** is related to the length of time considered: climate is the average state of the atmosphere over months, years, decades, centuries or more, whereas weather is the state of the atmosphere at a particular place and time and can change hourly, daily or, on average, from one season to another (see page 8 of the Scientific Overview for more detailed definitions).

WHAT ABOUT CLIMATE CHANGE?

The term **"climate change"** is now commonly used as a synonym to anthropogenic climate change, meaning changes to the climate system resulting from human activities since the Industrial Revolution (see page 13 of the Scientific Overview for further details on anthropogenic impact). Climate change can manifest in several ways and on different timescales: through **changes in the nature of single, short-lived, extreme weather events,** like dust storms or heatwaves, to **incremental changes that build up over decades,** such as sea level rise. These can interact and reinforce one another (*e.g.* the impact of more intense or frequent heatwaves is compounded/aggravated by increasing desertification in dry and desert areas). When talking about climate change, people also refer to one of its consequences for our planet, **global warming**. By global warming we mean an increase in the average surface temperature of the whole planet.

Scientists use different types of **evidence** to track climate change and its consequences. In this lesson, we provide a few examples, focused on land. These examples are just some of the different types of evidence that tens of thousands of scientists from all over the world and from all disciplines use to observe, measure and understand climate change and conclude that it is due to **human activity,** and in particular the release of CO_2, a greenhouse gas (see lesson A2).

INTRODUCTION 15 MIN

Case 1: If you live in a region of the world that has a seasonal climate (summer/winter or wet/dry): Start by asking the students: *How are you dressed today? Are you wearing a t-shirt or a sweatshirt? Shorts, skirts or trousers? Sandals or shoes? Were you wearing the same type of clothes yesterday? What do you carry to school, other than your schoolbooks, lunch box, etc.?* (a cap, raincoat or umbrella) *What about the week before, last month, or during the last holidays? What guides your choice of clothes/equipment?* They will probably state that it depends on whether the day is sunny or rainy, cold or warm; that it depends on the weather.
What is it like outside? Was it the same yesterday, the day before, last week, etc.? What about different regions of the world? What temperatures and humidity prevail there? How can you distinguish climate from weather?

Case 2: If you live in a place without a seasonal climate: *Is the weather the same all year round? Is the weather the same as everywhere else in the world? Do other regions have the same temperature and rainfall? How can you distinguish climate from weather?*

1. In order to get a better understanding of the difference between weather and climate, we suggest you do a "moving debate". Divide the classroom space into two parts: "Weather" and "Climate".

2. On the whiteboard, write one of the sentences suggested on the next page. Then, the students can move across the classroom according to whether they think it refers to the climate or the weather (for each sentence, you will find the correct category in brackets). Ask why they have chosen one part of the classroom over the other.

3. Choose another sentence and repeat this several times.

4. Then ask your students to explain the difference between climate and weather: they have to understand that **weather is a state of the atmosphere (including temperatures and precipitations),** at a particular place and time, whereas **climate is an average pattern.** For a given climate, the weather varies daily (even during the day!), whereas the weather on a given day does not describe a given climate: *The climate tells you which clothes to buy and the weather tells you what to wear.*
You may now consider asking your students to give an example of other statements concerning climate or weather.

SUGGESTED STATEMENTS

Look out the window; the sun is shining through the clouds and it looks lovely. (Weather)

My granny says it always snowed in the winter when she was a child. Sometimes she couldn't get to school because of the snow. (Climate)

I wish I lived in New York where it's cold in winter and hot in summer. We could have snowman-building competitions in winter or races in summer. (Climate)

It's going to be cold this weekend. You will have to put on a scarf to go outside. (Weather)

We could dress up as our favourite film characters. There's no way I am dressing up; it's way too cold. (Weather)

My friend in Australia had a water fight at her school fair, but it's always hot there. (Climate)

It rained on May 8. (Weather)

Germany is a cold country. (Climate)

It rains during the monsoon season. (Climate)

TEACHER TIP
These statements are only suggestions: you should adapt them according to your local conditions.

PROCEDURE 40 MIN

1. From the previous activity, students should have noticed that the weather may change quickly. Ask: *Do you think that the climate has changed? Quickly or not? How can we prove it since climate occurs over a long period of time?* They will have to conduct a documentary analysis.

2. Show **WORKSHEET A1.1** to the whole class and distribute one copy to each student: they will have to fill it in at the end of the lesson.

3. Place the students into groups of no more than 4 (you may have different groups working on the same documents) and explain that they are going to be experts on one type of evidence for climate change. Distribute the **WORKSHEETS A1.2** to **A1.9** (one for each group). Using their document(s), they will have to write a short sentence that summarises what they learned (for instance, "The Earth has been getting warmer over the last XX years"). Then, they will have to write this sentence within the corresponding frame of **WORKSHEET A1.1**.

Students analysing data showing the change in annual precipitation.

4. After each group has analysed and discussed its document(s), one member of each group writes the sentence on the whiteboard or presents the findings to the other groups orally, so each student can complete **WORKSHEET A1.1**, gathering evidence that the climate is changing.

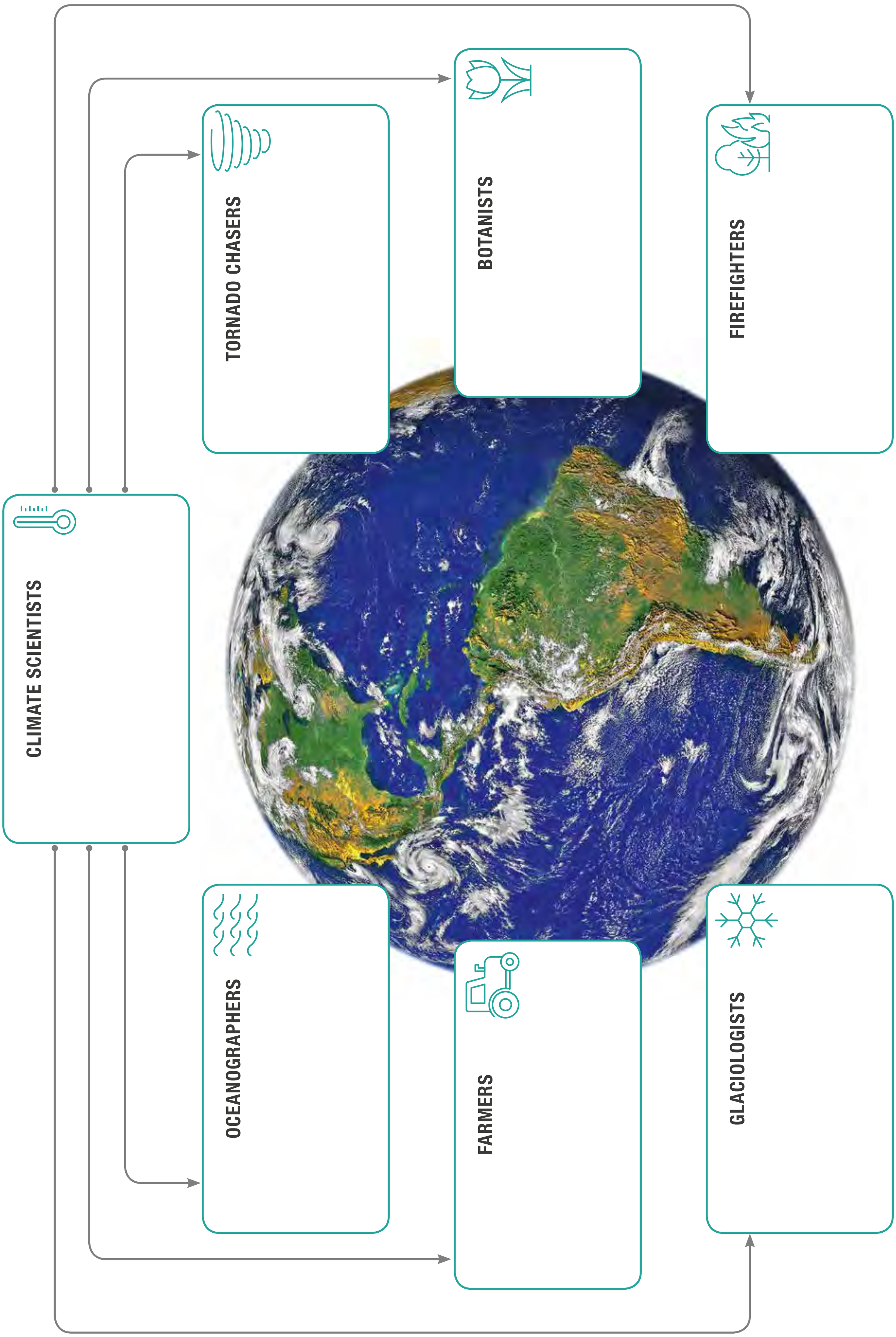
WRAP-UP 5 MIN

Conclude by pointing out that just as the weather varies, so too has the climate over the past century: this is climate change. There is solid scientific evidence that the climate is changing (droughts, early blooming, wildfire frequency increase, glaciers melting, higher temperatures, etc.) in various regions of the world. You can mention the IPCC as one of the most reliable sources of information on climate change.

TEACHER TIP
You can find teacher-friendly summaries of the latest IPCC reports on the Office for Climate Education website.

WORKSHEET A1.1

CLIMATE CHANGE EVIDENCES

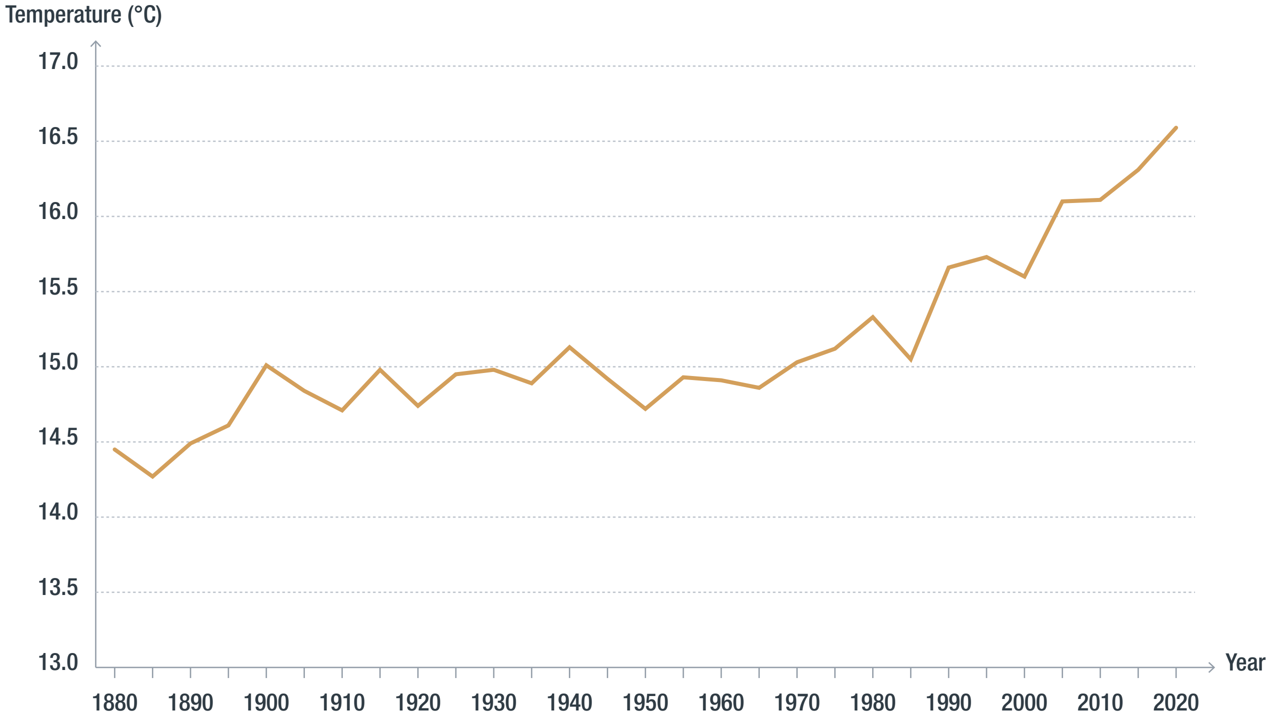


CLIMATE SCIENTISTS

Your mission: As climate scientists, you would like to know how the temperatures have changed over the last century. Using the graph below, describe in a couple of sentences what you notice about the temperature change on Earth since 1880.

This graph shows the change in the Earth's temperature above land since 1880. These measurements come from the NASA website and were obtained using different weather stations across the globe.

EVOLUTION OF THE TEMPERATURE ABOVE LAND SINCE 1880



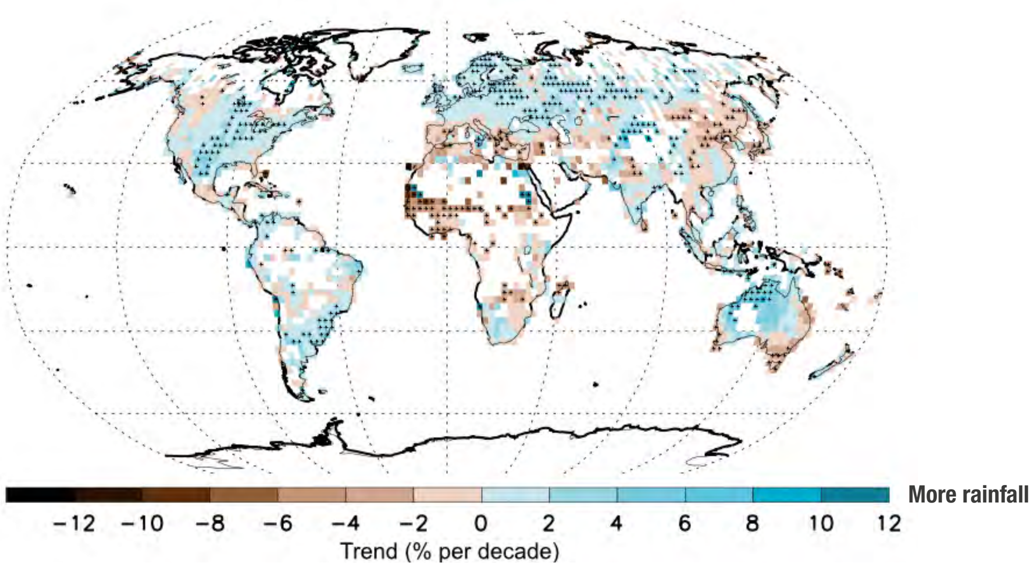
Source : https://data.giss.nasa.gov/gistemp/graphs_v4/

EXPERT CLIMATE SCIENTISTS

➔ Your mission: As expert climate scientists, you would like to know how climate has changed over the last century. Using the figures below, describe in a couple of sentences what you notice about precipitation and temperature changes on Earth since 1950.

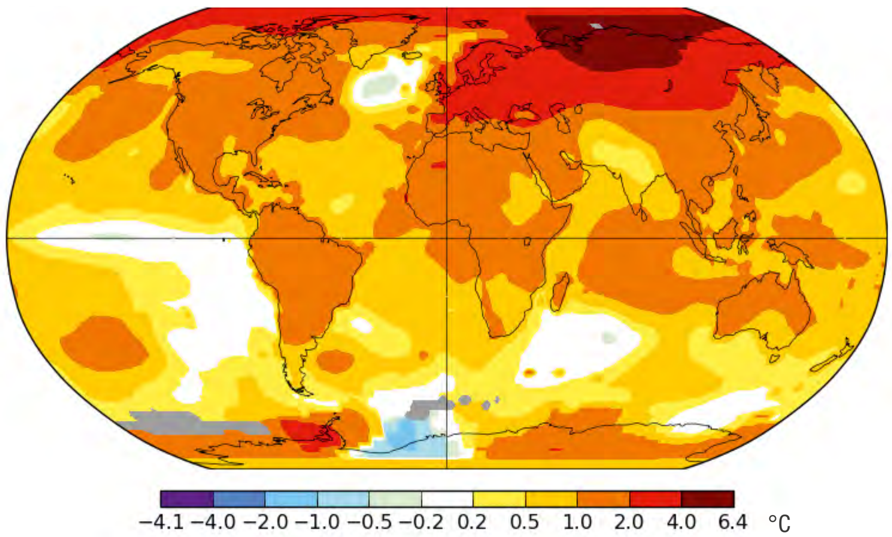
The two figures illustrate the evolution of precipitation between 1951 and 2010 and the changes in temperature between 1950 and 2020.

TRENDS IN PRECIPITATION OVER LAND BETWEEN 1951 AND 2010



Source: IPCC Assessment Report 5 – WG1

CHANGES IN MEAN ANNUAL SURFACE TEMPERATURE IN 2020 COMPARED TO THE PERIOD 1950–1980



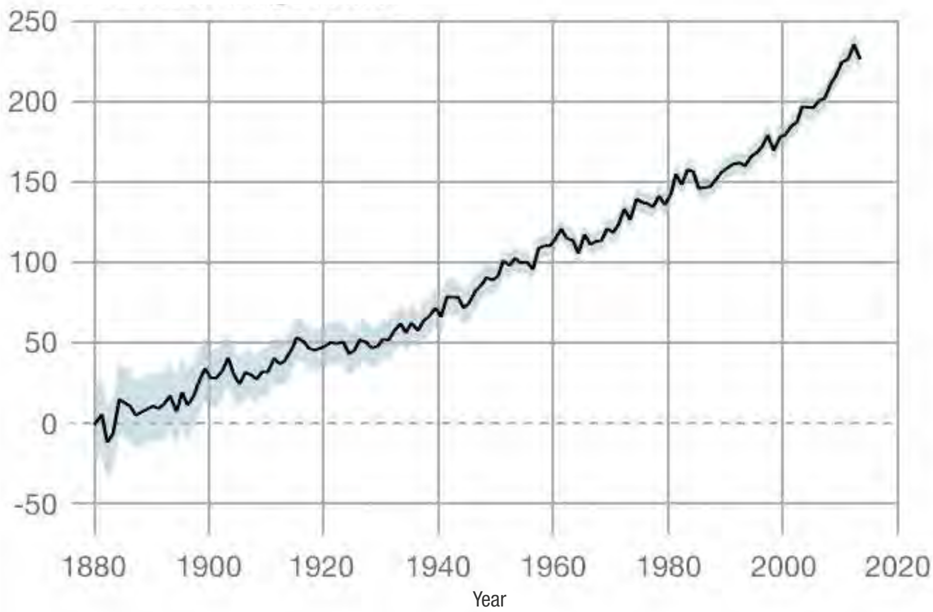
Source: NASA – https://data.giss.nasa.gov/gistemp/maps/index_v4.html
A NASA video is also available to help visualise the increase in temperature since 1880: https://svs.gsfc.nasa.gov/4882

OCEANOGRAPHERS

Your mission: As oceanographers, you would like to know how sea level has changed over the last century. Using the graph below, describe in a couple of sentences what you notice about the change in sea level since 1880.

This graph shows sea level variations since 1880. Recent measures were obtained using satellites revolving around the Earth and continuously recording the sea level, whereas the oldest ones come from littoral sea gauges[1].

SEA LEVEL CHANGE IN MM



Source: data from NASA – https://climate.nasa.gov/vital-signs/sea-level/

1 A sea gauge is a recording device that measures the sea – or river – level in a specific place and for a certain amount of time.

FARMERS

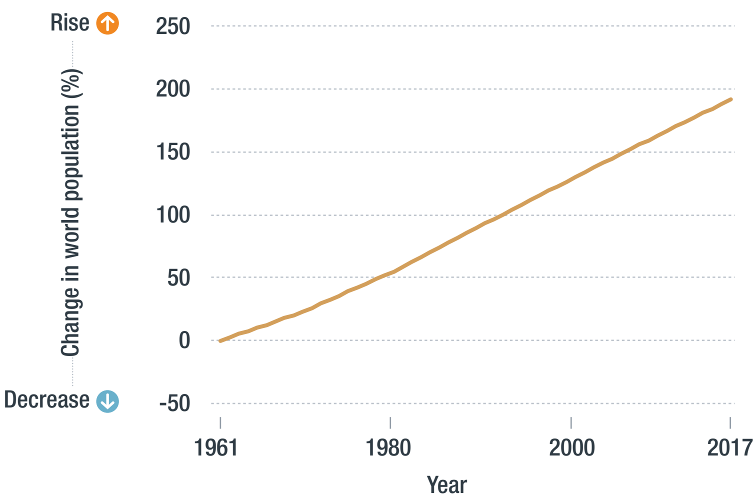
Your mission: As farmers, you are concerned about climate change. Using the following information, write a couple of sentences explaining what a drought is and how the number of people affected has changed since 1960.

The first part describes what a drought is and its consequences. The second focuses on the amount of population experiencing desertification. Desertification occurs when the land is damaged in a dry area; it then becomes more and more arid and looks like a real desert.

WHAT IS A DROUGHT?

Drought occurs when there is less precipitation (rain) than usual or when the temperature is so high that groundwater reserves begin to run out.
Plants, like all living things, need water to survive and grow. When there is a drought, farming becomes very difficult.
If the drought lasts too long or is very severe, it can lead to desertification.

CHANGE IN WORLD POPULATION EXPERIENCING DROUGHT RELATIVE TO 1960



Source: Adpated from the IPCC's Special Report on Climate Change and Land.

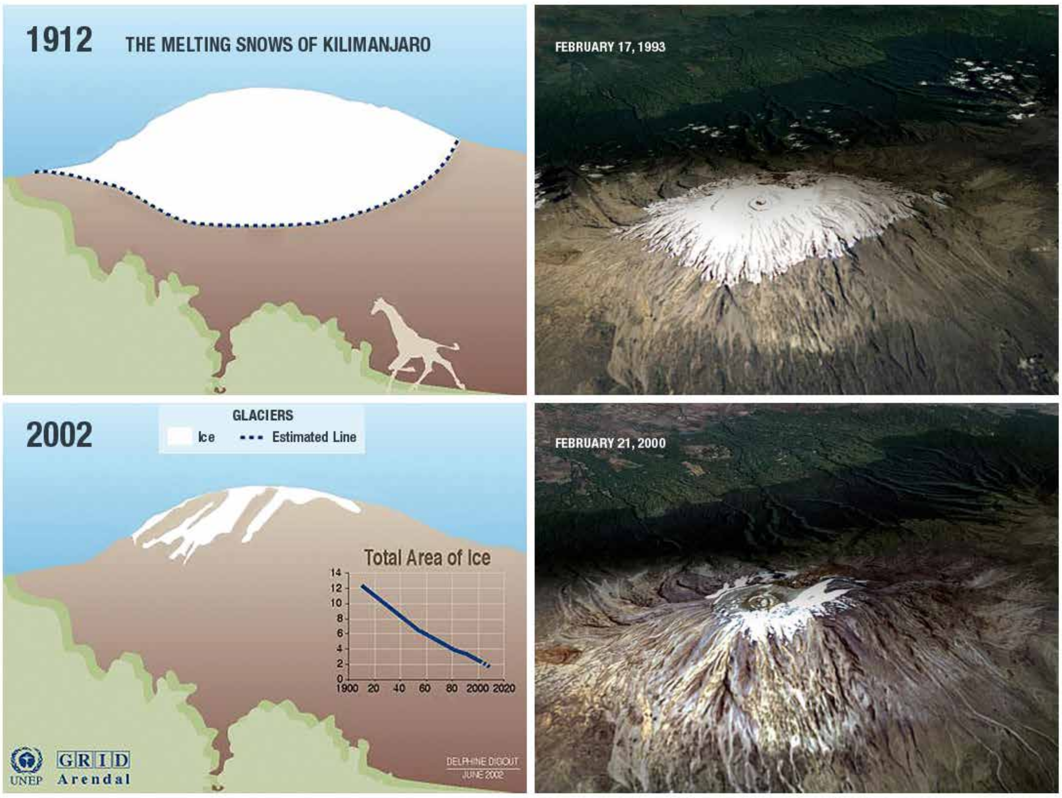
GLACIOLOGISTS

Your mission: As glaciologists, you are concerned about climate change, wondering if it will still be possible for you to study glaciers in the future. Using the following article, write a couple of sentences explaining what has happened to the Kilimanjaro glaciers since 1912.

The following article describes how the Kilimanjaro glaciers have changed between 1912 and 2002.

KILIMANJARO IS DYING!

The glaciers of Mount Kilimanjaro, the highest peak in Africa, which have covered the top of the mountain for the past 11,700 years, are rapidly disappearing: *"[…] in 1912, there were about 12.1 square kilometers of ice on the mountain, but a map in 2000 showed only 2.2 sq km of ice remained on the mountain – a loss of 80% of ice since then. […] Kilimanjaro's location […] places it in the tropics. Here, ice fields are particularly susceptible to climate change, and even the slightest temperature fluctuation can have devastating effects."*



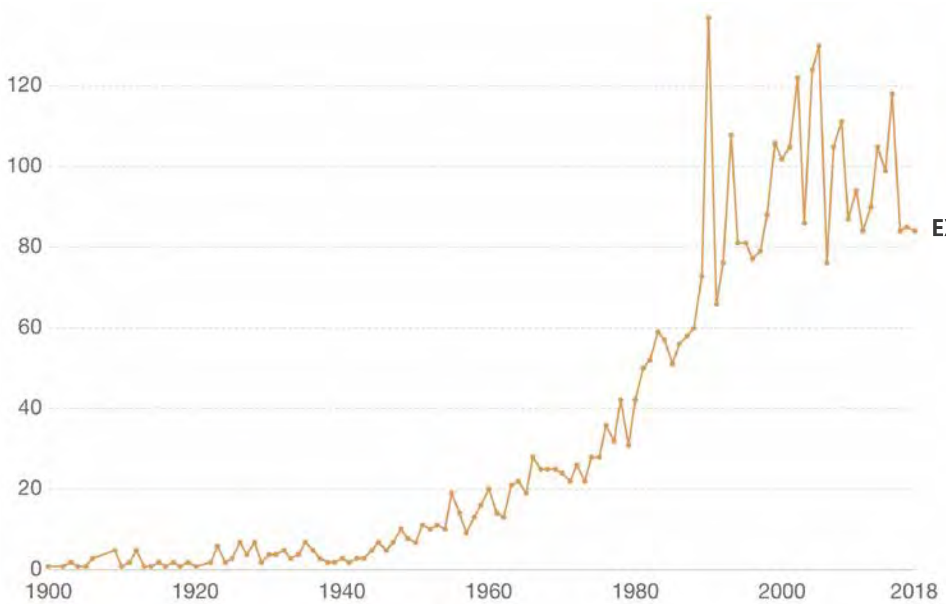
Source: Adpated from http://www.earthkam.org

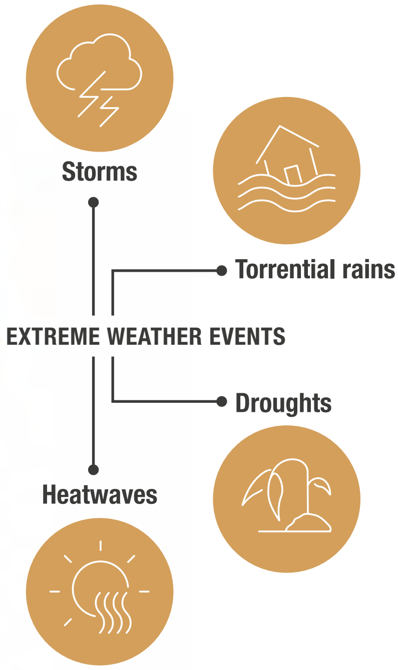
TORNADO CHASERS

➔ **Your mission: As tornado chasers, you wonder if it will still possible to take pictures of tornadoes, despite climate change. Using the following graph, write a couple of sentences on what extreme weather events are and how their number has changed since 1900.**

The following graph shows the change in the number of extreme weather events occurring since 1900. Extreme weather events are those that are out of the ordinary, often because they are more powerful (*e.g.* tornadoes, torrential rains, droughts or heat waves). They can lead to forest fires or floods and cause a lot of damage.

NUMBER OF EXTREME WEATHER EVENTS RECORDED ON THE PLANET





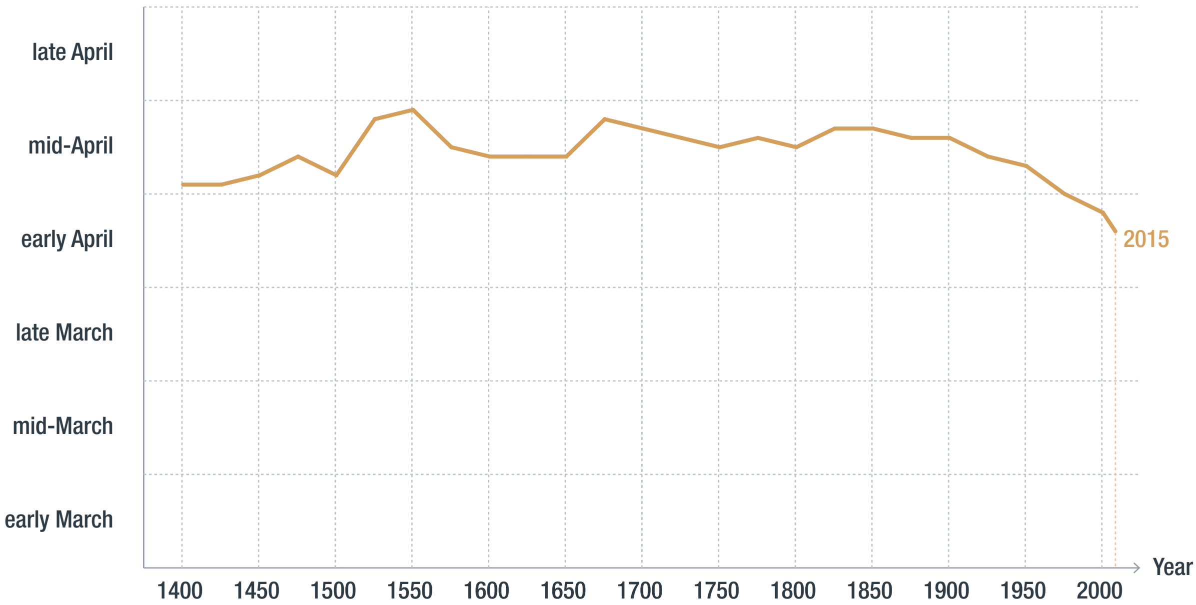
Source: EMDAT (2019): OFDA/CRED International Disaster Database, Université catholique de Louvain, Brussels, Belgium. https://ourworldindata.org/natural-disasters – CC BY

BOTANISTS

Your mission: As botanists, you wonder how plants will react as the global temperature increases. Using the following graph, write a couple of sentences explaining how the blossoming date has changed over the last 600 years, and how this is related to climate change.

The following graph shows the evolution of the blossoming date of cherry trees in Japan over a period of 600 years. The blooming occurs when temperatures are high enough.

EVOLUTION OF THE BLOSSOMING DATE



Source: Aono and Kazui, 2008; Aono and Saito, 2010; Aono, 2012; Chikyu Kankyo (Global Environment), 17, 21–29
http://atmenv.envi.osakafu-u.ac.jp/aono/kyophenotemp4/

FIREFIGHTERS

Your mission: As firefighters you are concerned that forest fires may become more frequent with global warming. Using the maps below, write a sentence explaining how the fire season has changed and how it relates to climate change.

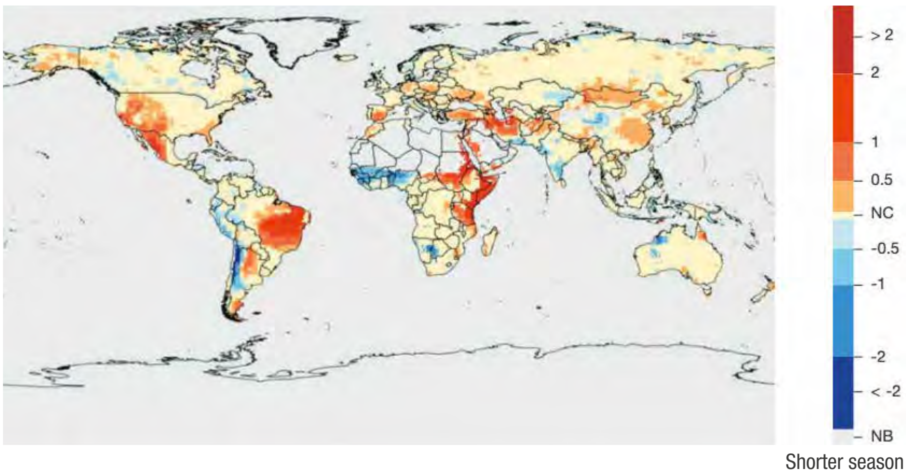
The following maps show the evolution of fires worldwide between 1996 and 2013 compared to 1979-1996. The first one shows the change in the length of the fire weather season, whereas the second shows the change in the frequency of fire events. Wildfires may be caused by humans – willingly or otherwise – but are also more frequent in the case of droughts or heatwaves.

GLOBAL PATTERNS OF FIRE WEATHER SEASON LENGTH CHANGES FROM 1979 TO 2013

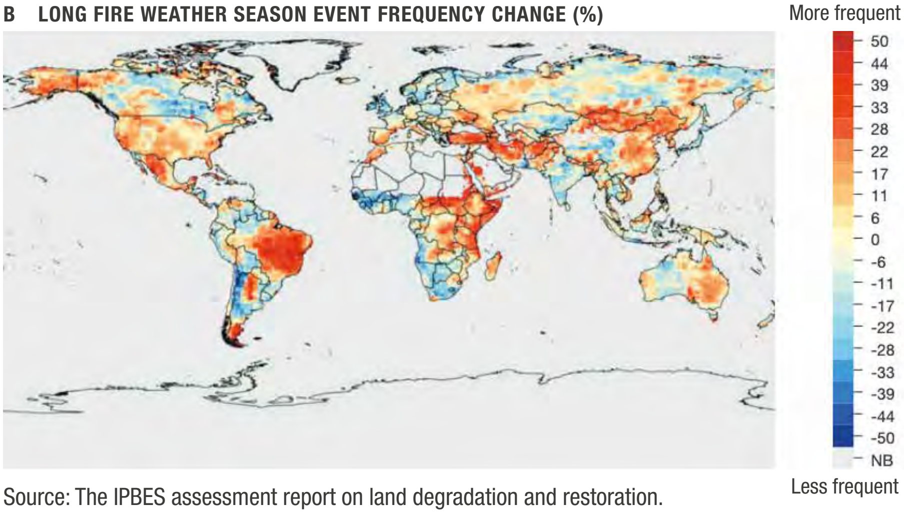
A. Areas that show modifications in fire weather season length

B. Regions that have experienced changes in the frequency of long fire weather seasons

A FIRE WEATHER SEASON LENGTH CHANGE (DAY PER YEAR)



B LONG FIRE WEATHER SEASON EVENT FREQUENCY CHANGE (%)



Source: The IPBES assessment report on land degradation and restoration. https://ipbes.net/sites/default/files/2018_ldr_full_report_book_v4_pages.pdf

LESSON A2
THE GREENHOUSE EFFECT: UNDERSTANDING WITH AN ANALOGY

MAIN SUBJECTS
Natural sciences / Physics

DURATION
~ Preparation: 5-10 min
~ Activity: 1h15

AGE GROUP
9-15 years

LEARNING OUTCOMES
Students build a greenhouse model as an analogy to greenhouse gases in the atmosphere.

They learn that:
~ All objects emit infrared radiation; the warmer they are, the more infrared radiation they emit.
~ When the Earth's surface is warmed by the sun, it emits infrared radiation.
~ Greenhouse gases act like a blanket, absorbing infrared radiation emitted by the Earth's surface.
~ Only part of this infrared radiation escapes into space and the rest is sent back to the surface. This explains global warming.

KEYWORDS
Greenhouse effect, greenhouse gas, infrared radiation, global warming

TEACHING METHOD
Experimentation, documentary analysis

PREPARATION 5-10 MIN

EQUIPMENT

For each group of 3 to 4 students:

- 1 light bulb (at least 60 W, if possible 100 W; use incandescent or halogen bulbs rather than energy-saving ones) mounted on a stand.
  Note: If the weather is sunny, the light bulbs are optional, and the experiments can be carried out in the sun.
- 2 electronic thermometers – or chocolate squares, or butter.
- 1 transparent container made of glass or transparent plastic (as thin as possible), or a container sealed with plastic wrap.
- Optional: modelling clay, which can be useful for sealing the container.

INTRODUCTION 20 MIN

In the previous lesson, students have learned that the temperature of the atmosphere is increasing, and that this global warming has several impacts on the land.
Key questions to guide discussion:

- *What do you think are the causes of the temperature increase?* Write all the students' suggestions on the whiteboard: they may mention some kind of pollution, variations in the "power" of the Sun, heat, etc.
- *How can you demonstrate which one of the suggestions is correct?* They will need to know if the Earth is becoming more and more "polluted", or if the Sun's light is more powerful.
- Explain that in order to find these answers, they will have to compare the Earth with another element located as far away as the Earth is from the Sun, but uninhabited: *which one?* Show students **WORKSHEET A2.1**: they should notice that the Moon fits this description.
- *By comparing the Moon and Earth's characteristics, can you reject some of your hypotheses?* The Moon hasn't experienced any warming over the last century despite its distance from the Sun, which is the same as that of the Earth: thus, global warming is not linked to a variation in the Sun's light or power.
- *How can you explain the global warming we have observed on Earth?* The only difference between the Earth and the Moon is the presence of an atmosphere on Earth. *What in the atmosphere may explain this warming?* Tell the students they will study the role of the gases in the atmosphere that are responsible for increasing temperatures: these are called "greenhouse gases".

TEACHER TIP
If the students are not familiar with the "greenhouse effect", we suggest you show this video, by NASA Space Place: What is the Greenhouse Effect?

PROCEDURE 50 MIN

1. Ask the students to think of an experiment they could carry out in the classroom in order to show the role of the atmosphere in global warming. Have them think about what might represent the Sun (a lamp, or even the Sun itself if it is possible to go outside), the atmosphere surrounding the Earth (a transparent bowl), and how they can record the temperature. Building a greenhouse model should be the most realistic proposal that emerges (see figures below).

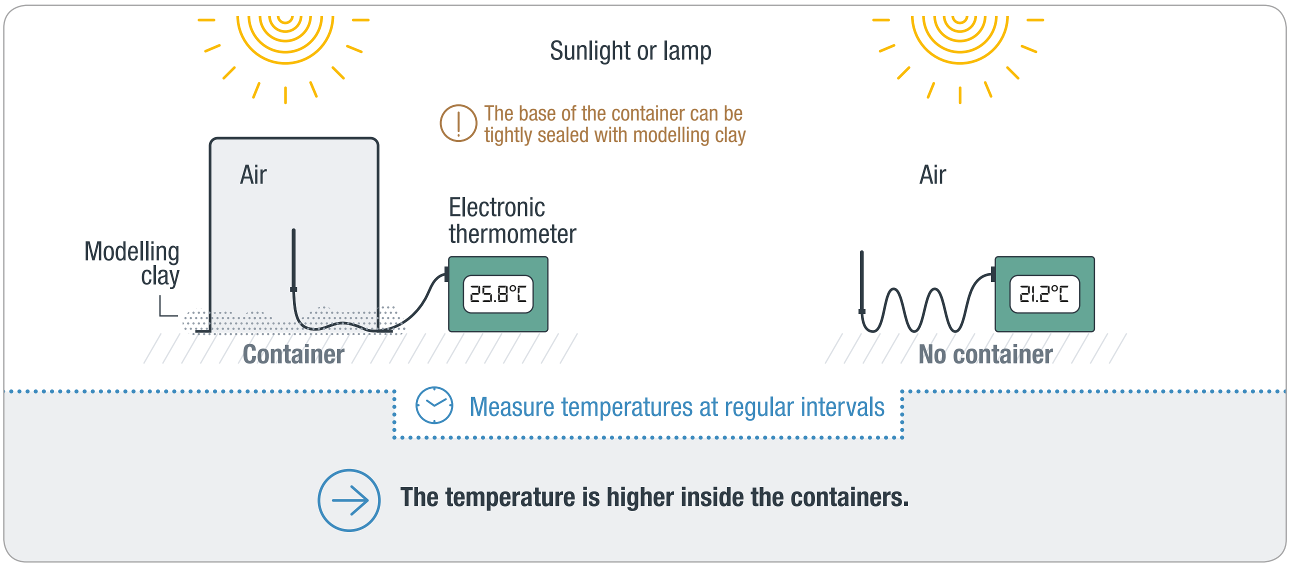
> **TEACHER TIP**
> For noticeable results, do the experiment in the sun, in the middle of the day. You can expect a temperature difference of up to 4 degrees. The use of electronic thermometers is not required, but make sure that your thermometer allows you to notice the change in temperature. If you do not have a thermometer, you can use chocolate squares instead to observe the effect of heat (melting of the chocolate).

2. Each group builds a basic greenhouse model with the provided container and puts a thermometer – or chocolate square – inside. Another thermometer/chocolate square should be kept outside as a control (see figures below).

3. Ask the students to measure the temperature at regular intervals and write down the measured values in a table, or to check regularly the piece of chocolate to observe its consistency.

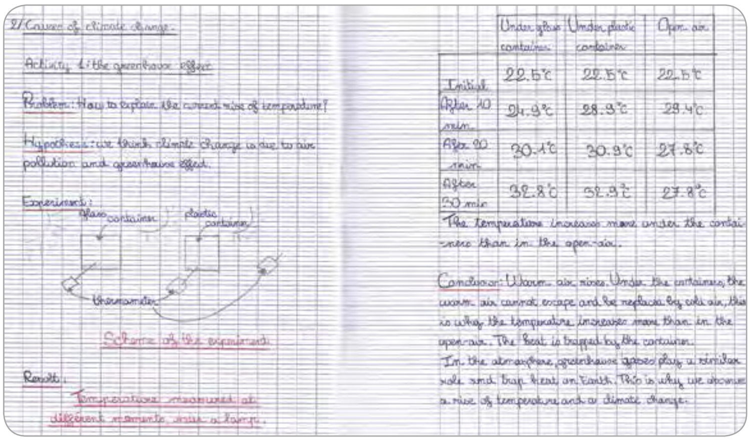
4. Meanwhile, give the students **WORKSHEET A2.2** to analyse in groups. Discuss the sources of greenhouse gases in the atmosphere, especially the ones associated with land use (e.g., farming, agriculture).

5. Ask the students what they think is making the temperature rise. Explain that the greenhouse is being used as an analogy.



The greenhouse experiment in a plastic or glass container.

Measuring the temperature inside and outside the greenhouse.



Student notes on the experiment.

BACKGROUND FOR TEACHERS

THE GREENHOUSE EFFECT

Sunlight crosses the atmosphere and warms the Earth's surface, generating the upward emission of **infrared radiation** (heat). Some of this heat is trapped on its return to space by **greenhouse gases** in the atmosphere and sent back towards the Earth's surface. Greenhouse gases thus act like a blanket, absorbing some of the heat emitted from below and re-emitting part of it back towards the Earth. The temperature of the lower atmosphere is therefore warmer than it would otherwise be.

In fact, without greenhouse gases, the average temperature of the Earth's surface would be about -18°C rather than the present average of 15°C.

The concentration of greenhouse gases can change, either because of natural causes, as in the past, or due to human activities, as in the present. This alters the Earth's energy equilibrium and the average surface temperature (see figure on page 9 of the Scientific Overview).

MOON AND EARTH

The Moon and the Earth are located at the same distance from the Sun and receive the same amount of energy. It would be easy to think they have the same temperature, **but it is colder on the Moon!**

How can we know the temperature on the Moon? On the Earth, we can measure the temperature of the Earth using the agitation of the particles of atmospheric gases. For the Moon, scientists measure **the infrared radiation,** which gives us an idea of its temperature. The surface of the Moon warms up because of the Sun's light and cools down in its absence, by emitting infrared radiation. The amount of this infrared radiation is the same as that of a black body with a temperature of -150°C (for the parts of the Moon that are not exposed to sun): this is how we can say that the temperature of the Moon is around -150°C.

Because of the **Earth's atmosphere and the greenhouse gases it contains,** the temperature is higher on Earth, even if it receives the same amount of sunlight as the Moon.

TEACHER TIP

In a greenhouse, two main factors contribute to the increase in temperature: the greenhouse effect and the containment. Without a cover, the hot air rises by convection and is replaced by colder air. This is prevented when you use a cover. Containment effect prevents the warm air from escaping from the greenhouse. The thermometer therefore displays a lower temperature outside than inside. Moreover, when comparing a glass greenhouse (where, in theory, there is a greenhouse effect, resulting from the absorption of infrared radiation) with a polyethylene (plastic) greenhouse (where there is no greenhouse effect), it turns out that there is no noticeable difference in temperature increase. Even though the dominant effect here is containment, in reality the greenhouse effect caused by greenhouse gases in the atmosphere leads to rise in temperature.

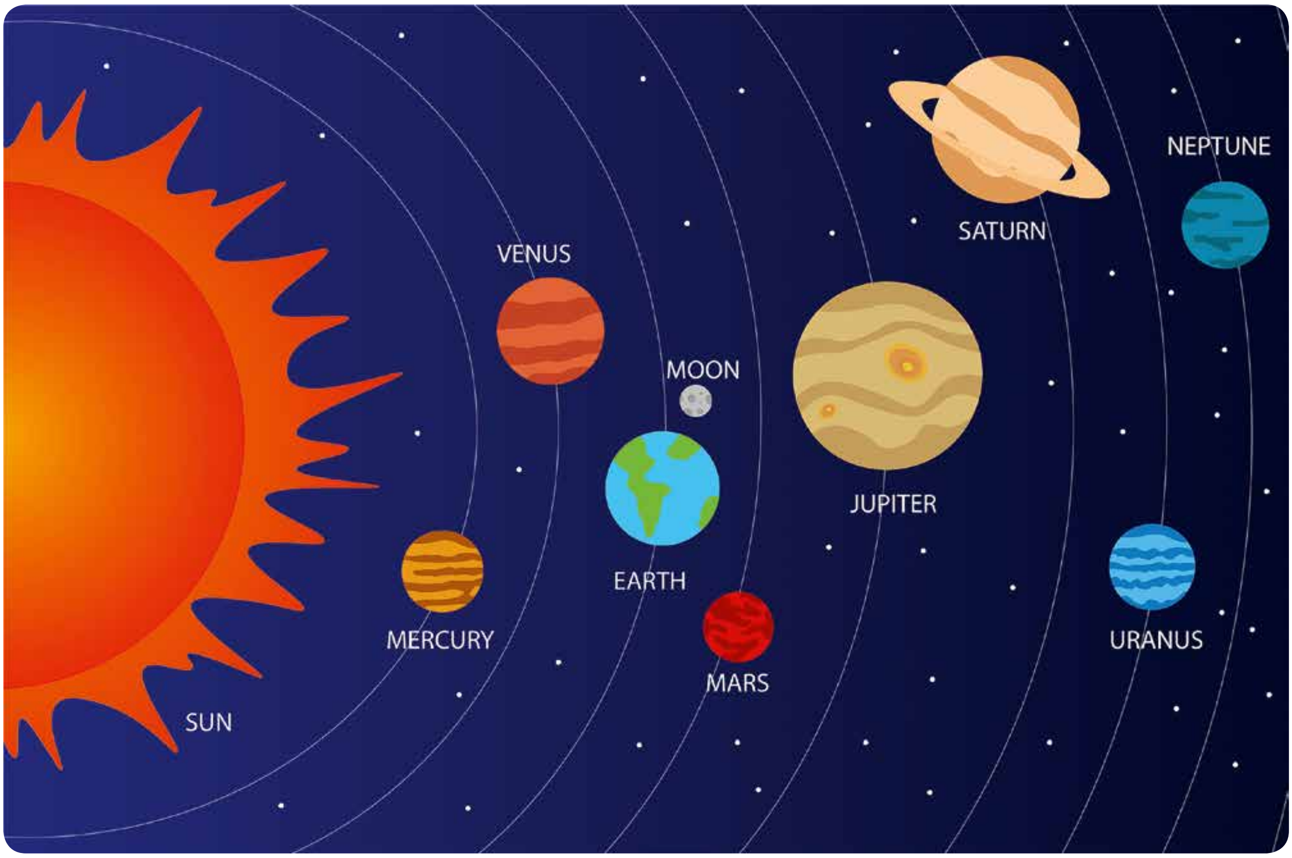
6. There are gases in the atmosphere that play the same role as the greenhouse roof. These are therefore called greenhouse gases. Such an analogy, if presented and taken as such, is entirely acceptable in the classroom.

WRAP-UP 5 MIN

Discuss the link between the experimental results and the greenhouse gas effect that is causing global warming. The greenhouse gases act like a greenhouse, "trapping" the invisible infrared radiation emitted by the Earth's surface (and also directly by the Sun), thus, leading to warming "inside" the greenhouse (the Earth's surface and the lower atmosphere). These greenhouse gases are naturally present in the atmosphere and useful for establishing a temperature suitable for life; but due to human activities their concentration has been rising for the last century, leading to global warming.

WORKSHEET A2.1

THE SOLAR SYSTEM



Source: Hatice EROL on Pixabay

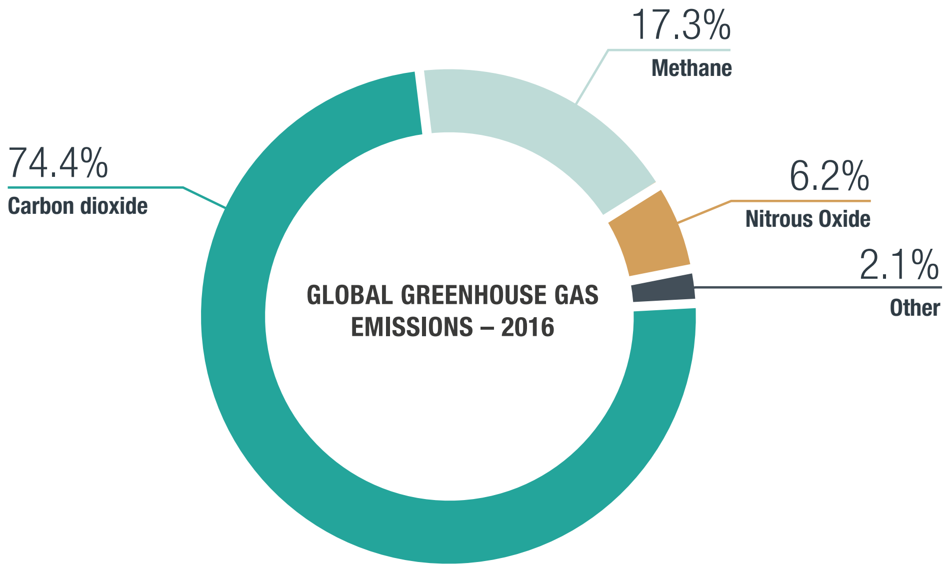
EARTH VERSUS MOON	EARTH	MOON
Distance from the Sun	150 million kilometres	150 million kilometres
Atmosphere	Present, with different gases: nitrogen, water vapour, oxygen, carbon dioxide, methane	No atmosphere
Surface temperature	+15°C, rising for a century	Between -150°C and +150°C, stable since its formation 4.5 billion years ago

Look at the figures below and answer the following questions:

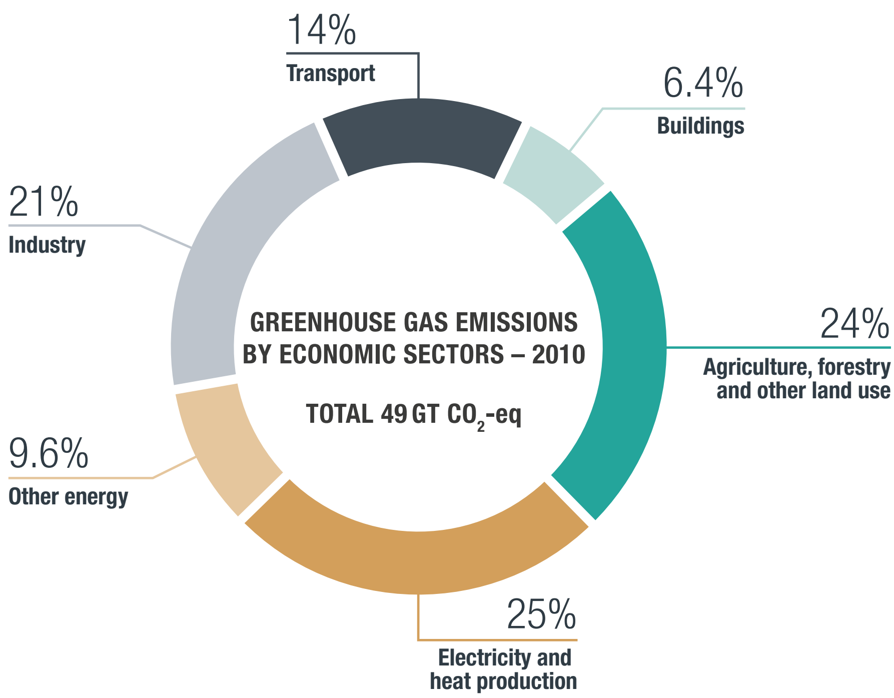
- How can you explain the recent global warming?
- Which gas contributes most to global anthropogenic greenhouse gas emissions?
- Which sectors of human activity contribute the most to greenhouse gas emissions?

A greenhouse gas is an atmospheric gas that acts as a "cover", preventing heat from escaping into space and retaining it in the atmosphere. For the last century, human activities have kept adding greenhouse gases into the atmosphere, which has resulted in a thicker cover and in temperature rise.

The following chart presents the different greenhouse gases that were emitted due to human activities in 2016.



Source: Adapted from https://ourworldindata.org/uploads/2020/08/Global-GHG-Emissions-by-gas.png (data from WRI, 2016).



Source: Adapted from IPCC AR5 WG3.

LESSON A3
THE GREENHOUSE EFFECT AND HUMAN ACTIVITIES

MAIN SUBJECTS
Natural sciences / Physics

DURATION
- Preparation: 5-10 min
- Activity: 1h

AGE GROUP
9-15 years

LEARNING OUTCOMES
This activity[1] explores the greenhouse gases in both their natural and enhanced state and the effect they have on the Earth's climate. Students make a presentation about the gases.

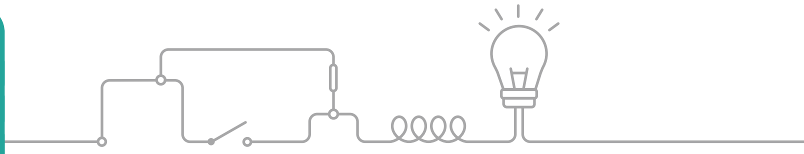
They learn that:
- Global warming can be explained by an increase in greenhouse gas concentration.
- The greenhouse effect is due to atmospheric greenhouse gases.
- Greenhouse gases are produced by various human activities.

KEYWORDS
Greenhouse effect, greenhouse gas, anthropogenic emissions

TEACHING METHOD
Card game, documentary analysis

PREPARATION 5-10 MIN

EQUIPMENT
- **WORKSHEET A3.1** (one copy for the whole class). Each greenhouse gas has a "good side" and a "bad side". These need to be cut out and stapled together, with a total of 6 pairs, or they can be laminated if you would like to reuse them.
- 7 large sheets of paper, if asked for by the groups.
- Optional: **WORKSHEET A3.2** one for each group (see question 5 below).



INTRODUCTION 10 MIN

After lessons A1 and/or A2, ask your students how we can explain the increase in the Earth's surface temperature (they should mention the excess of greenhouse gases). Then, ask if they know which gases are responsible for it. Record their responses. *How can you know if your list is correct/complete? How can you know where those gases come from?* They should suggest conducting a documentary analysis.

PROCEDURE 40 MIN

1. Divide the class into 6 groups asking each to choose a leader.

2. Holding the 6 pairs of cards (**WORKSHEET A3.1**) so the children can't see them, ask the leaders to come up and select a pair of cards, explaining they have to keep the name of the greenhouse gas that is on their cards to themselves.

3. Explain to the groups that they have 10 minutes to create a 1-2 minute presentation, with the aim of teaching the rest of the class about both the good and the bad sides of their greenhouse gas. Explain they can use various forms of expression to get the main points across. This could include props, acting, presenting, dance, etc. The only thing they can't do is read directly from their card!

TEACHER TIP
During each group's presentation, it may be a good idea to give the other students a quick survey in order to get them more involved: *What gas are we talking about? Where does it come from? Why is it a problem?*

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1 This activity is inspired by the "Climate Change" Teacher curriculum of New Zealand of Future Curious Limited. The OCE would like to warmly thank the authors.
https://nzcurriculum.tki.org.nz/content/download/168449/1243903/file/Climate%20Change%20Learning%20Programme%20%E2%80%93%20Teacher%20Resource_updatedJune2020.pdf

4. At the end of each presentation, they ask the rest of the groups what are the key learnings about their greenhouse gas. These can be recorded on a large piece of paper to refer to later.

5. If you or your students would like to explore this further, you can distribute the **WORKSHEET A3.2** for a stronger focus on scientific documents.

WRAP-UP 10 MIN

Going back to the introductory questions, ask the students about their understanding on the role of greenhouse gases and discuss everyone's responsibility with respect to those emissions and climate change, emphasising the link with land use.

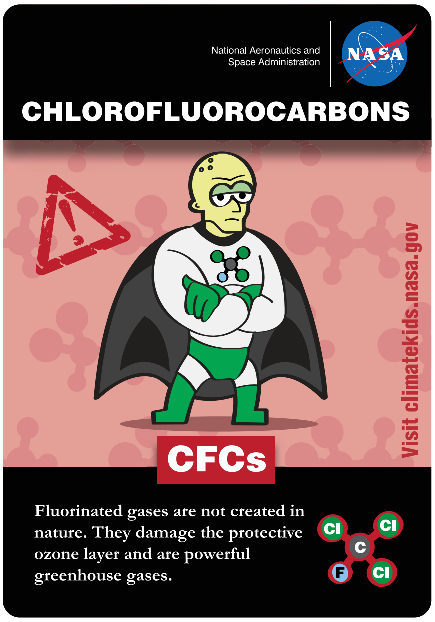
OPTIONAL EXTENSION: BUILD YOUR OWN EARTH 1H
To extend this lesson, students can use the "Build your own Earth" online software (http://www.buildyourownearth.com) that will enable them to explore different greenhouse gas emission scenarios and their impacts on the Earth's climate and system (atmosphere, ice, land and ocean). If you are working with high school students, you can also use the C-ROADS or the En-ROADS software (https://www.climateinteractive.org/tools/c-roads/and https://www.climateinteractive.org/tools/en-roads/).

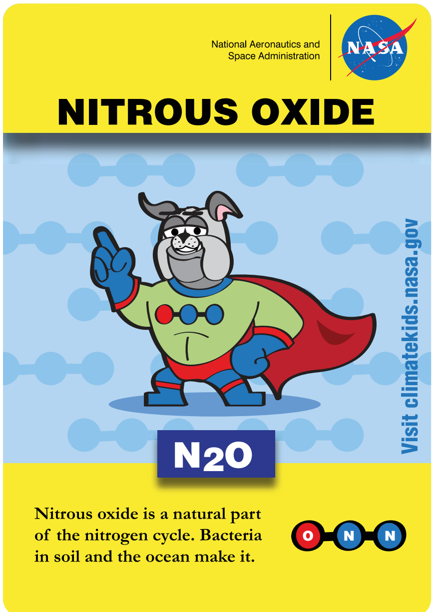
BACKGROUND FOR TEACHERS

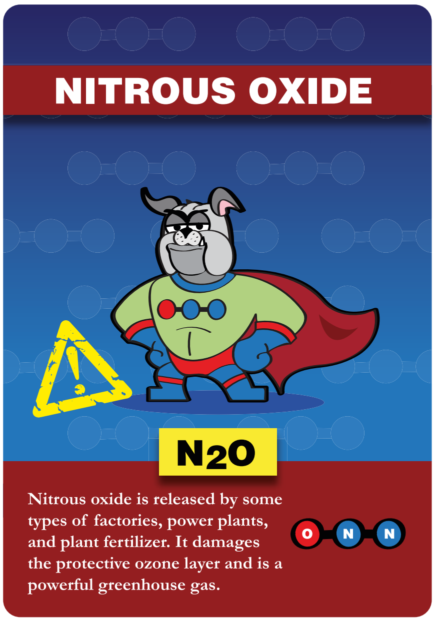
HUMANS AND GREENHOUSE GASES
The **Industrial Revolution** brought with it unprecedented changes affecting all sectors of human societies and leading to new living standards (starting with Europe and North America). These changes occurred at the same time as a considerable growth in the human population. The increasing use of fossil fuels as an energy source, together with a quickly growing population, led to today's vast exploitation of natural resources (such as fossil fuels) and the associated emission of **greenhouse gases.** Burning of any fuel produces carbon dioxide (CO_2), which disperses in the Earth's atmosphere. Other greenhouse gases are produced by human activities, such as methane (CH_4) or nitrous oxide (N_2O).

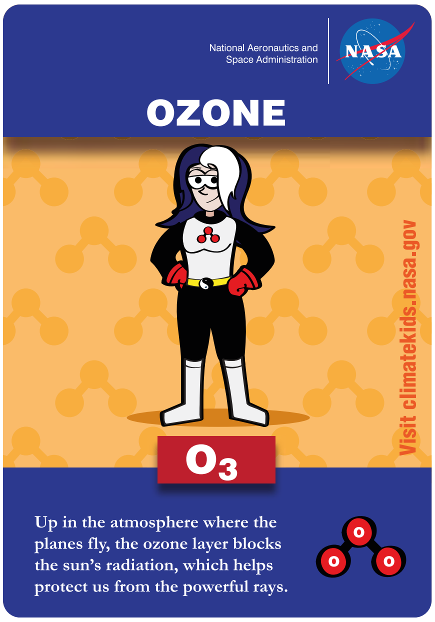
The different greenhouse gases have different Global Warming Potential (GWP), which is the amount of radiation that the emissions of that gas will absorb over a given period of time, in comparison to how much radiation one ton of CO_2 would be able to absorb (in the same period of time, usually considered over 100 years).

For further details on greenhouse gas emissions and their GWP, see the definition in the glossary, page 259.

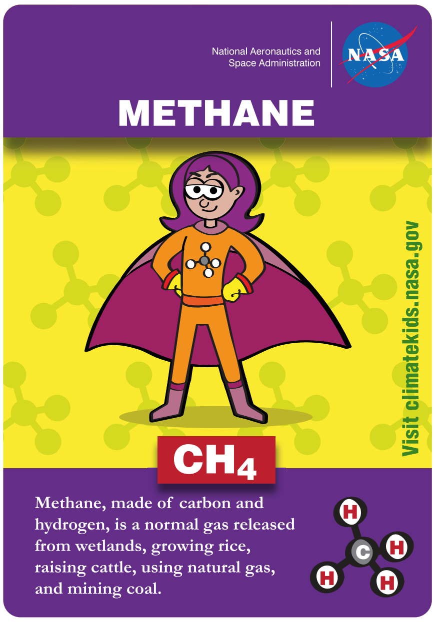


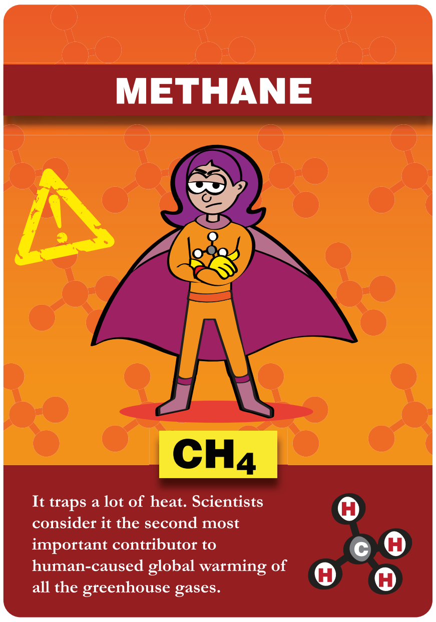


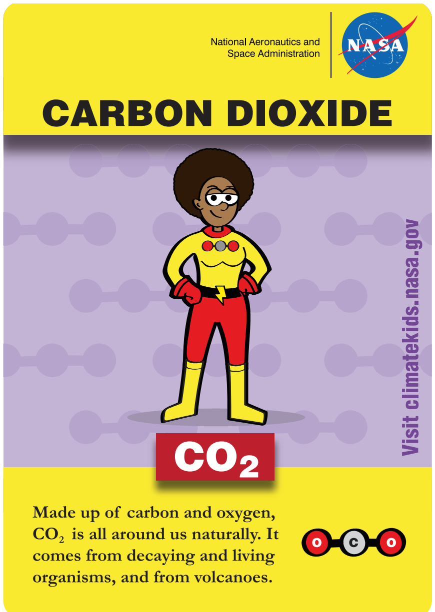


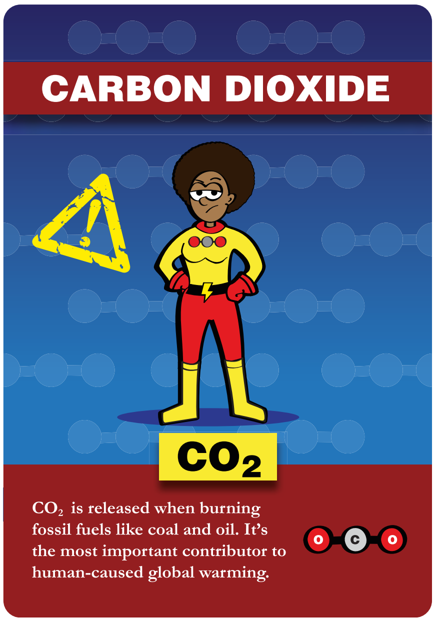


Source: These cards are from the Climate Kids NASA website: https://climatekids.nasa.gov/greenhouse-cards/









Source: These cards are from the Climate Kids NASA website: https://climatekids.nasa.gov/greenhouse-cards/

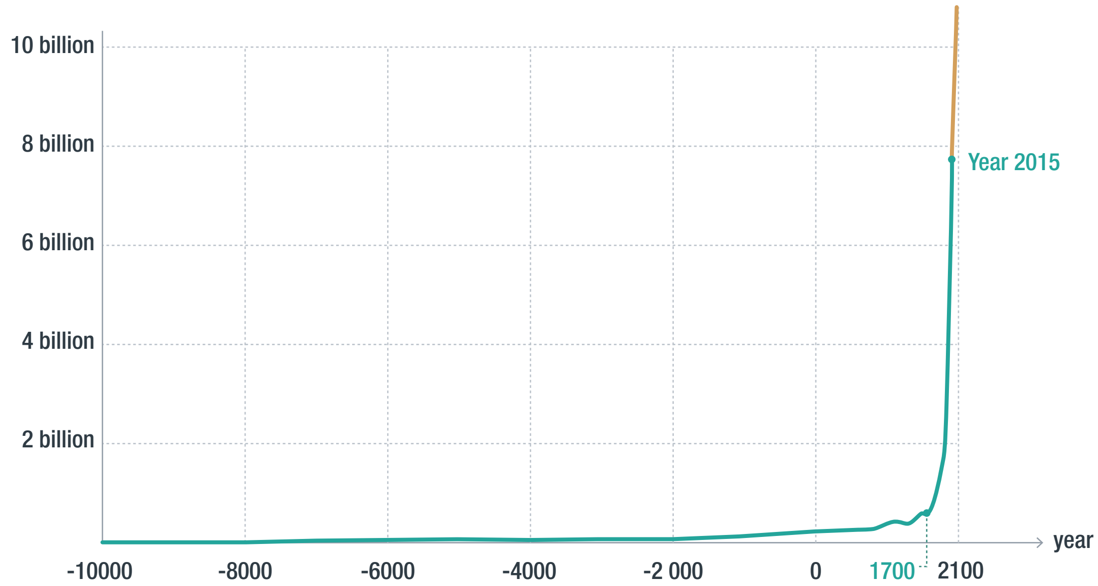
WORKSHEET A3.2

EXPERT

Technical progress since the Industrial Revolution is not only related to the steam engine, but also to unprecedented scientific, technological, economic and political changes affecting all sectors of human societies. All these developments have contributed to an unparalleled increase in the human population. More people and greater energy consumption have led to increased greenhouse gas emissions. Observe the two figures below and answer the following questions:

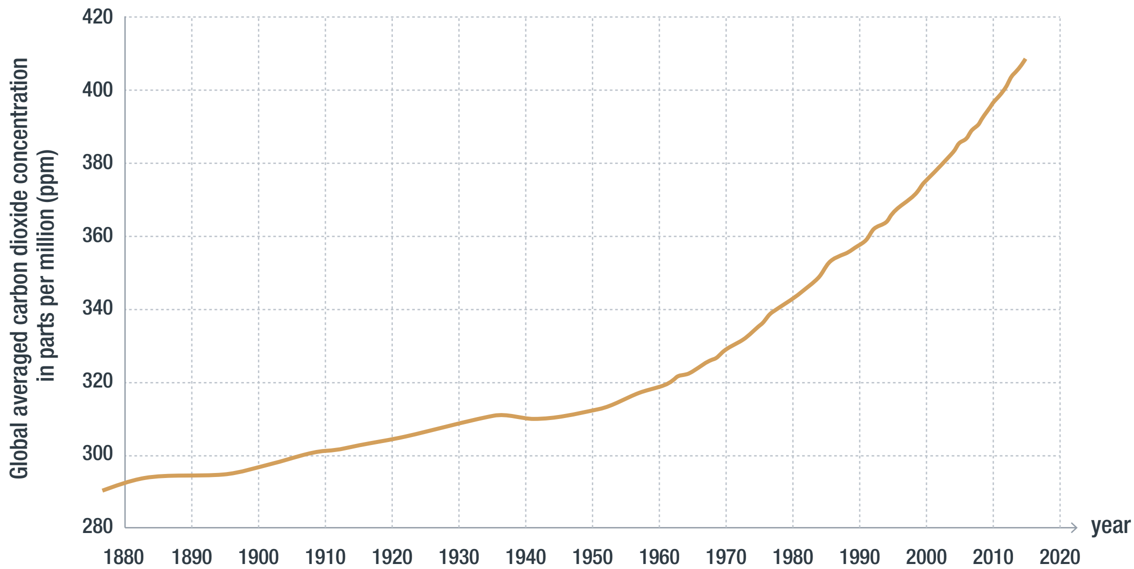
- **How has CO_2 concentration in the atmosphere evolved since the industrial revolution?**
- **Name two factors that can explain this evolution.**

WORLD POPULATION OVER THE LAST 12,000 YEARS AND UNITED NATIONS PROJECTION UNTIL 2100



Source: https://ourworldindata.org/world-population-growth#population-growth

EVOLUTION OF THE ATMOSPHERIC CARBON DIOXIDE CONCENTRATION SINCE 1880



Source: NOAA – Earth System Research Laboratory – Global Monitoring Division
https://www.climate.gov/media/13560

LESSON A4
CARBON CYCLE: LAND IS PART OF THE CLIMATE SYSTEM

MAIN SUBJECTS
Natural sciences / Physics / Chemistry

DURATION
~ Preparation: 15 min
~ Activity: 1h15

AGE GROUP
12-15 years

LEARNING OUTCOMES
While playing a board game about the carbon cycle, students will learn that:
~ Carbon circulates in the carbon cycle and that human activities disturb it.
~ Soil is an important carbon reservoir.
~ Fossil fuels are important underground reservoirs.
~ Fossil fuels need a lot of time to be formed (several millions of years).
~ Their use releases CO_2, previously stored in the soil, into the atmosphere.
~ Through photosynthesis, plants capture CO_2 from the atmosphere and store it in organic matter.
~ Through fermentation, respiration and decomposition of organic matter, land vegetation releases CO_2 into the atmosphere.
~ Vegetation and land play a key role in the carbon cycle.

KEYWORDS
Carbon, CO_2, photosynthesis, biosphere, respiration, erosion, combustion, sedimentation, outgassing, dissolution

TEACHING METHOD
Board game and / or multimedia animations

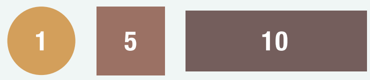
PREPARATION 15 MIN

EQUIPMENT

TEACHER TIP
This activity can be carried out using either multimedia animation or the role-play card game, or both of them.

- 69 plastic tokens representing carbon – you may also use small pieces of cardboard (for each group of 5 students).
- One triangle-shaped small piece of paper (0.5 cm each side) that will be used as a cursor to mark the temperature (for each group).

TEACHER TIP
The tokens should be light and small enough to be easily moved across the board. You can choose different sizes and shapes to represent 5 and 10 carbon atoms, and smaller ones to represent 1 atom of carbon.
Here is an example:



- **WORKSHEET A4.1**.
- Gameboard: **WORKSHEET A4.2** (one for each group—you can laminate it in order to reuse it), preferably on an A3 sheet
- **WORKSHEET A4.2** may also be printed in small versions (2 copies on one page) to be used during wrap-up.
- Carbon cycle play cards (one batch per group): **WORKSHEETS A4.3** to **A4.4**.
  Note: WORKSHEETS A4.4 are only needed for the second part of this lesson.
- Optional: Computers / tablets (at least one for each pair of students) to use the Multimedia resource "Carbon cycle".

LESSON PREPARATION

1. Gather 69 tokens for each group.
2. Print **WORKSHEET A4.2**, preferably on an A3 sheet – it will be used as a board for the game.
3. Print **WORKSHEET A4.2** in small versions, one for each student.
4. Print **WORKSHEETS A4.3** and **A4.4**. You can print them double-sided. We suggest laminating the cards in order to reuse them. Put aside the cards from **WORKSHEET A4.4** (they will be used in Part 2) and shuffle all the others.
5. Divide students evenly into groups of 5 or 6. Each group will have its own board, set of cards and tokens.

INTRODUCTION 15 MIN

Before starting this activity, ask your students to recall what they learned from the previous lesson – that current anthropogenic greenhouse gas emission is responsible for climate change and that global CO_2 emissions have increased since the Industrial Revolution (you can use the second graph on **WORKSHEET A3.2**).

Conduct a classroom discussion:

- *How do you think this situation will evolve over the next decades?* (carbon dioxide emissions will probably increase)
- *How do you think we could limit this increase?*
- *Do you know any natural processes that are part of / that influence the carbon cycle?* List them on the board.

In order to learn more about these processes, the students will have to investigate where they can find carbon on Earth. For this, they must study the carbon cycle to understand how carbon flows from one place to another on Earth, and that it does not disappear but is being exchanged between different types of storage. To do so, explain that they will play a board game about the carbon cycle.

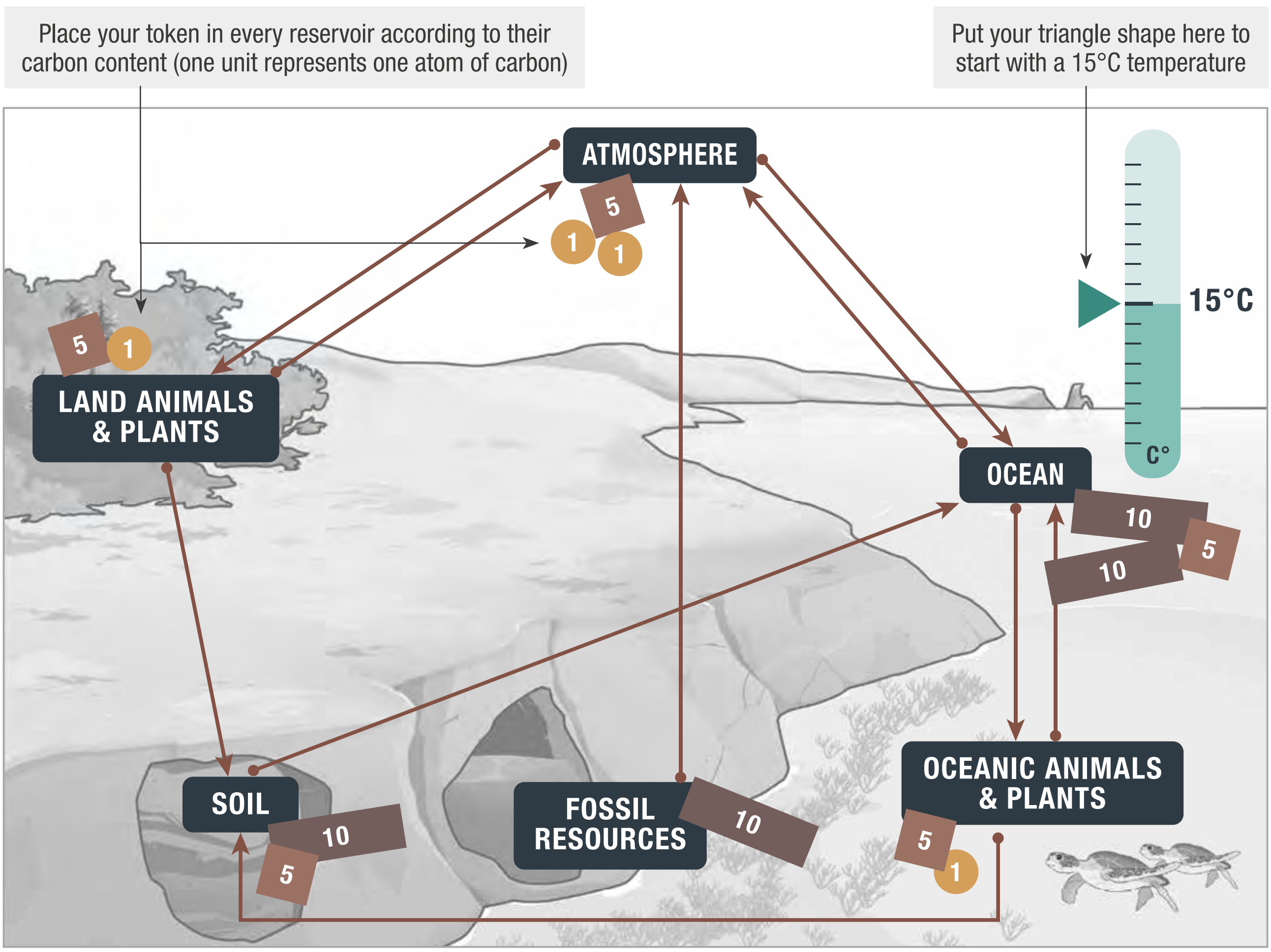
Discuss how carbon is a common element on earth. Have students recall some of the things or living beings in their daily lives that they think contain carbon. Make a list of these items on the board.

Explain that the carbon contained in any one thing does not stay there forever. The carbon atoms move from one thing to another in what is called **the carbon cycle**. Some parts of the carbon cycle happen very quickly, as when plants absorb carbon dioxide from the atmosphere for photosynthesis. However, some other parts of the carbon cycle proceed very slowly, like the conversion of carbon-containing organic matter to fossil fuels.

PROCEDURE 50 MIN

PART 1: THE NATURAL CARBON CYCLE 30 MIN

1. Explain to your students that the tokens represent the carbon that can be found on Earth and that this carbon is stored in what we call "reservoirs". There are 6 major reservoirs on Earth: atmosphere, ocean, aquatic organisms, terrestrial organisms, soil and fossil fuels. Write these words on the board.



The gameboard at the starting point.

2. Divide students evenly into groups. Give each group a board (**WORKSHEET A4.2**), a batch of tokens, and the triangular cursor – they will have to place it in the middle of the thermometer so they start with a 15°C temperature (see the diagram before).

3. Show the table in **WORKSHEET A4.1**: the students will have to put the correct number of tokens on each reservoir. Point out that the reservoirs on land are diverse and contain much carbon.

4. Explain that they will have to make their carbon move, mimicking some natural phenomenon. Distribute the "Natural cycle" cards (**WORKSHEETS A4.3 only**): they will have to flip cards one by one and move a token according to the description on the card. Each time they add a token to the atmosphere, they will have to make the temperature rise using the triangular cursor; each time they remove a token from the atmosphere, the temperature will decrease.

5. Once the stack of cards is empty, ask: *How many tokens are now left in each reservoir? Are there as many as at the beginning? How has the temperature changed? How can you explain this?* At the end of the game there should be the same number of tokens in each reservoir as at the beginning because students can only move tokens around, rather than removing them. Explain that in this way **the cycle is perfectly balanced**. Point out that carbon only flows from one reservoir to another but never disappears and that some processes allow carbon to be "extracted" from the atmosphere. This is the reason why the temperature is still 15°C at the end of the natural cycle.

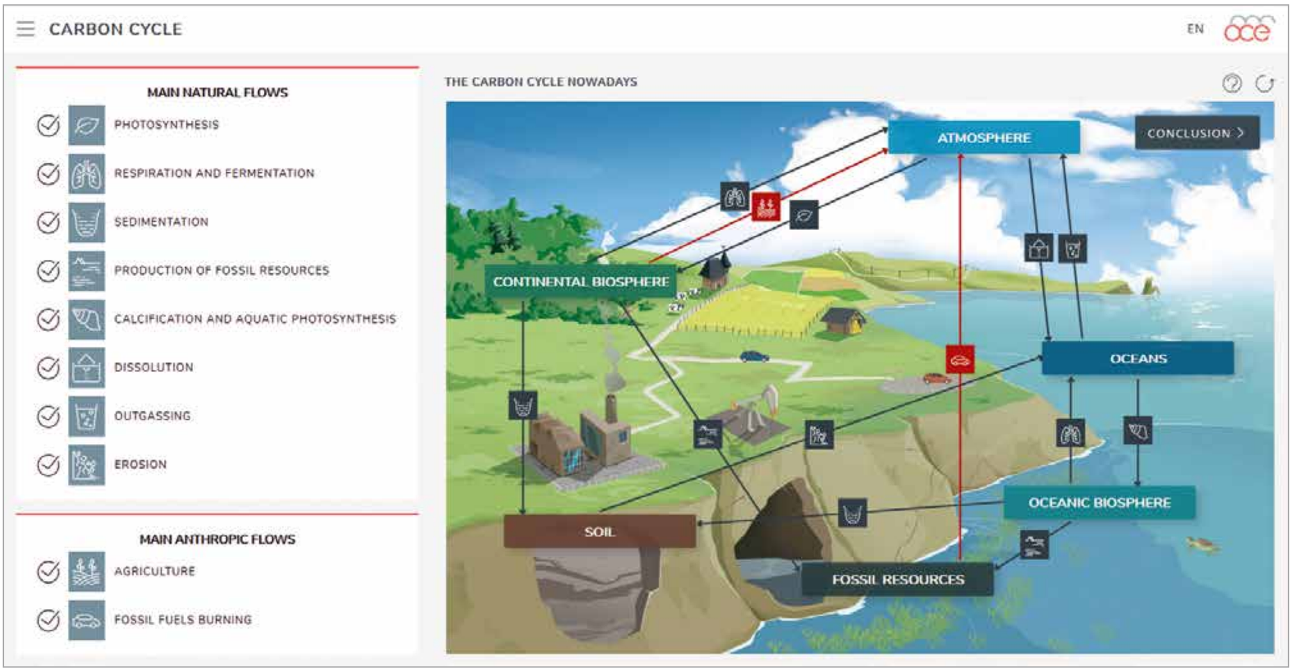
TEACHER TIP
For more advanced students, you can also discuss the speed of these processes, represented here by the number of cards: for example, the carbon moves associated with photosynthesis or respiration are much faster than sedimentation (there are more cards for these).

PART 2: HUMAN IMPACTS ON THE CARBON CYCLE 20 MIN

6. Explain to your students that they have just performed the carbon cycle **without human intervention,** but that humans greatly influence this carbon cycle with some of their activities.

7. Distribute the "human activities" deck of cards (**WORKSHEETS A4.4**) and ask the students to shuffle the two decks. Play recommences with the same rules as before, moving the temperature cursor. This time, the students should pay particular attention to what happens – in terms of carbon moves – when the "human activities" cards are drawn.

8. Once the stack of cards is empty, ask them about the carbon content in each reservoir and about the temperature change: *How can you explain these results? Why is the temperature higher this time? How could you limit this increase?* Human activities have increased the amount of carbon dioxide in the atmosphere, by adding the carbon which was previously stored in fossil resources: **this has led to the temperature rise.**



Screenshot of the multimedia animation "Carbon cycle"

WRAP-UP 10 MIN

Hold a classroom discussion to review the previous activity using the **WORKSHEET A4.2** (small version) as a template. Work with your students to draw arrows demonstrating all of the carbon flows they discovered. They can mark the impact of human activities with a different colour. In this way explain that humans have not created more carbon on Earth, but that we move carbon from one place to another more quickly than would naturally happen, and that this has consequences for the climate of the planet.

Encourage students to provide explanations for the processes underlying each of the arrows, focusing on the content appropriate for your grade level. Emphasise the fact that many human activities impact the cycle by reinforcing carbon movement towards the atmosphere. However, we can also act to capture this atmospheric carbon: for example, this is what happens in the case of reforestation.

TEACHER TIP

You may notice a slight difference between the carbon cycle in the gameboard and the one in the multimedia animation programme. We have chosen not to represent the flow between the biosphere and fossil resources ("fossil resource production") in our boardgame because of the huge timescale of this phenomenon, which occurs over several million years. It would not be accurate to represent this flow in the game.

BACKGROUND FOR TEACHERS [1]

Carbon is found in both living and non-living parts of the planet, as a component in organisms, atmospheric gases, water and rocks. It is usually bound to other elements in compounds, such as carbon dioxide, sugars and methane.
Carbon moves from one sphere to another in an ongoing process known as the **carbon cycle,** which is influenced by crucial life processes such as photosynthesis and respiration, contributes to fossil fuel formation, and **impacts the Earth's climate.** For further details on the carbon cycle, see page 10 of the Scientific Overview.

THE CARBON CYCLE IS BOTH FAST AND SLOW

In general, the **short-term carbon cycle** encompasses photosynthesis, respiration and predator–prey transfer of carbon. The **long-term carbon cycle** involves more lithospheric (=rocks) processes. This includes the weathering and erosion of carbon-containing rocks, the accumulation of carbon-rich plant and animal material in sediments, and the slow movement of those sediments through the rock cycle. Despite the diversity of the processes involved, **the natural carbon cycle is balanced.**

HUMANS AFFECT THE CARBON CYCLE

There are natural fluctuations in the carbon cycle, but humans are now changing the carbon flows on earth at an unnatural rate. The major human-induced changes have resulted in an **increase of carbon dioxide in the atmosphere and in an imbalance of the carbon cycle.**
The largest source of this is **burning fossil fuels** but other actions, such as **deforestation and cement manufacturing,** have also contributed to this change in the carbon cycle. Understanding the carbon cycle is especially important at this time in human history because of the dramatic changes we are making to the cycle.

1 This background is inspired by the "Carbon Cycle Roleplay" of the Calacademy. https://www.calacademy.org/educators/lesson-plans/carbon-cycle-role-play

WORKSHEET A4.1

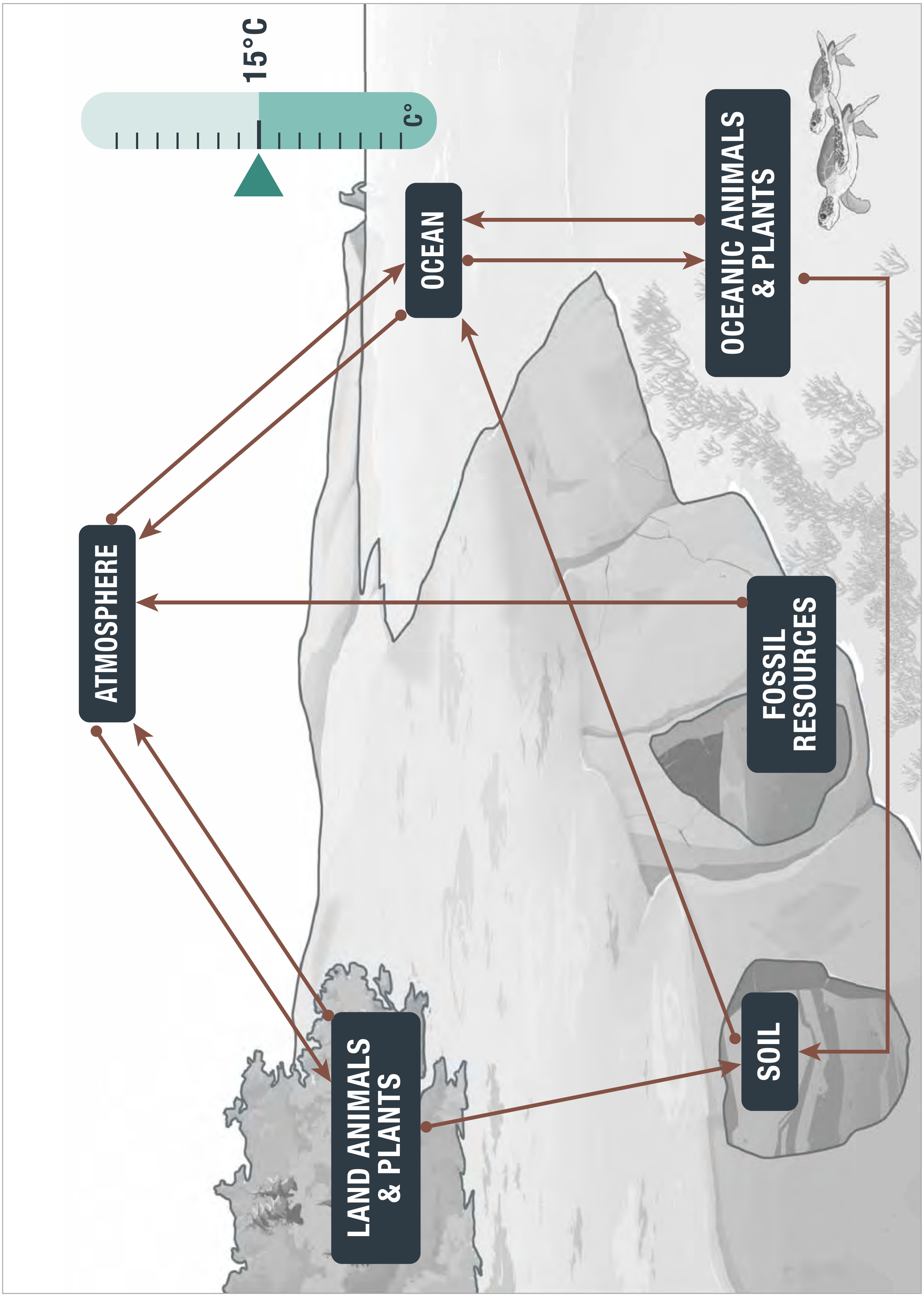
DIVISION OF THE CARBON TOKENS BETWEEN EACH RESERVOIR ACCORDING TO THEIR STOCK

RESERVOIR	STOCKS (GIGATONNES OF CARBON)	NUMBER OF TOKENS TO PUT ON THE GAMEBOARD
Ocean	38,700	25
Atmosphere	829	7
Biosphere: Oceanic animals and plants	about 400	6
Biosphere: Land animals and plants	about 200	6
Soil, rocks and sediments	3750	15
Fossil fuels	1000 - 2000	10

The number of tokens is given as approximate, but it cannot exactly represent the stocks as the ocean stock is ten times higher than the one for soil, for example.

The estimations of the different stocks are taken from the IPCC reports.

WORKSHEET A4.2



LAND PHOTOSYNTHESIS

In sunlight, through photosynthesis, plants produce their organic matter and grow by absorbing carbon dioxide from the atmosphere and taking in water using their roots.

NATURAL CYCLE

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NATURAL CYCLE

CONTINENTAL SEDIMENTATION

Continental sedimentation is the accumulation of mineral, plant or animal deposits in the soil, on land. Their carbon content is then stored in the soil.

NATURAL CYCLE

OCEANIC SEDIMENTATION

Oceanic sedimentation is the accumulation of mineral, plant or animal deposits in the soil, at the bottom of the ocean. Their carbon content is then stored in the soil.

NATURAL CYCLE

WORKSHEET A4.3 PAGE 2/8

EROSION

Soil and rocks are permanently exposed to wind, rain, or frost. They break into smaller pieces, rich in carbon, which will then be transported by rivers to the ocean. This is called erosion.

NATURAL CYCLE

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NATURAL CYCLE

RESPIRATION, FERMENTATION, DECOMPOSITION

Many living things release carbon dioxide by breathing or during fermentation, allowing them to produce energy, and also during decomposition. This carbon dioxide will then pass into the ocean or the atmosphere.

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NATURAL CYCLE

OCEAN OUTGASSING

The ocean releases carbon dioxide into the atmosphere when it warms up: this is called outgassing.

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NATURAL CYCLE


CARBON CYCLE
NATURAL CYCLE


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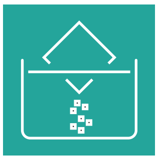
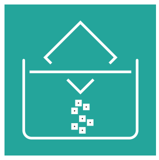


DISSOLUTION

Carbon dioxide from the atmosphere dissolves in water, more easily in cold areas of the ocean.

NATURAL CYCLE



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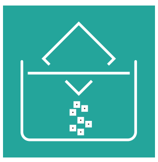

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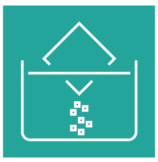

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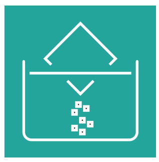

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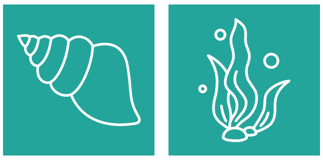
NATURAL CYCLE

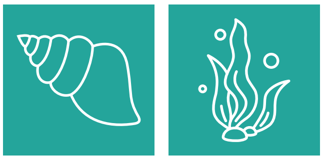
WORKSHEET A4.3 PAGE 6/8



CALCIFICATION & OCEANIC PHOTOSYNTHESIS

Some organisms form shells using carbon dioxide in the water. This carbon dioxide is also consumed by aquatic species who perform photosynthesis in presence of light.

NATURAL CYCLE



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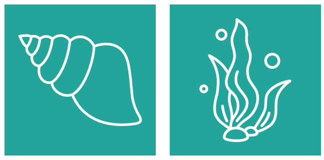

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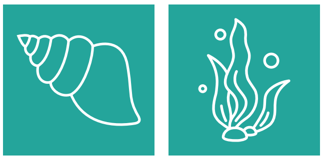

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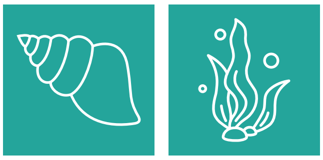

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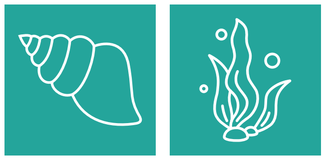

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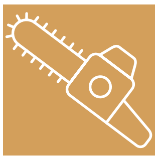
NATURAL CYCLE

WORKSHEET A4.3 PAGE 8/8



DEFORESTATION

Deforestation occurs when humans cut down trees to use wood, or burn them to plant crops. Burning causes the release of carbon dioxide into the atmosphere.

HUMAN ACTIVITIES

REFORESTATION

Reforestation is the planting of new trees in areas where they have been removed. The new trees then capture carbon dioxide from the atmosphere through photosynthesis.

HUMAN ACTIVITIES

INDUSTRIES

The industries that manufacture our everyday objects release large quantities of greenhouse gases into the atmosphere, such as carbon dioxide, because they burn fossil resources (coal, oil).

HUMAN ACTIVITIES

TRANSPORTATION

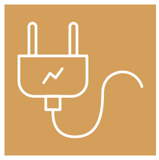
The transportation sector (trucks, cars, boats, airplanes) consumes fossil resources (oil) through combustion. The carbon dioxide produced is then released into the atmosphere.

HUMAN ACTIVITIES

AGRICULTURE

Agriculture requires fossil resources (coal, oil, gas) to produce our food. Livestock, especially cattle, also produce large quantities of methane. This adds carbon to the atmosphere.

HUMAN ACTIVITIES

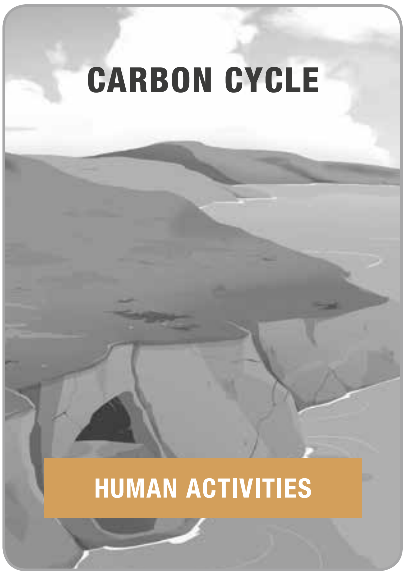


ENERGY

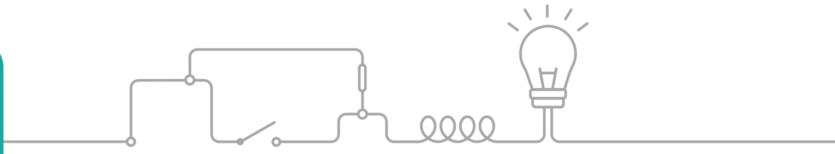
To produce energy, many power plants on Earth use fossil resources. When they are burned, the carbon dioxide that is produced is released into the atmosphere.

HUMAN ACTIVITIES

WORKSHEET A4.4 PAGE 2/2



LESSON A5
LEARNING MORE ABOUT CARBON CYCLE TRANSITIONS – PHOTOSYNTHESIS AND RESPIRATION



MAIN SUBJECTS
Natural sciences / Physics / Chemistry

DURATION
~ Preparation: 30 min
~ Activity: 1 h (+ a few hours to let the experiments run)

AGE GROUP
12-15 years

LEARNING OUTCOMES
After the introduction to the carbon cycle provided by the last lesson, this worksheet illustrates, through experiments, how carbon moves between two reservoirs – plants and atmosphere.

During this lesson, students will learn that:
~ Plants capture CO_2 from the atmosphere through photosynthesis, and release CO_2 into the atmosphere through respiration.
~ Photosynthesis occurs only in the presence of light, while respiration occurs in both light and darkness.
~ Photosynthesis plays a major role in the carbon cycle at a global scale.

KEYWORDS
Photosynthesis, respiration, carbon cycle

TEACHING METHOD
Experimentation

PREPARATION 30 MIN

TEACHER TIP
This optional lesson focuses on some flows of the carbon cycle: photosynthesis and respiration. It is better if this lesson follows the previous one on the carbon cycle, and it can be given along with lesson A6, which focuses on other carbon flows.

EQUIPMENT
- Test tubes or small bottles with plugs or corks (2 for each group of 4 students).
- Water.
- Red cabbage juice (used for measuring the pH; can be replaced by a pH metre if available). See the background for teachers on next page.
- Limewater.
- Lamp or sunlight.
- Aluminium foil or a cupboard to put some of the test tubes in darkness.
- Small aquatic plants (seaweed, for example).
- Large sheets of paper (one for each group).

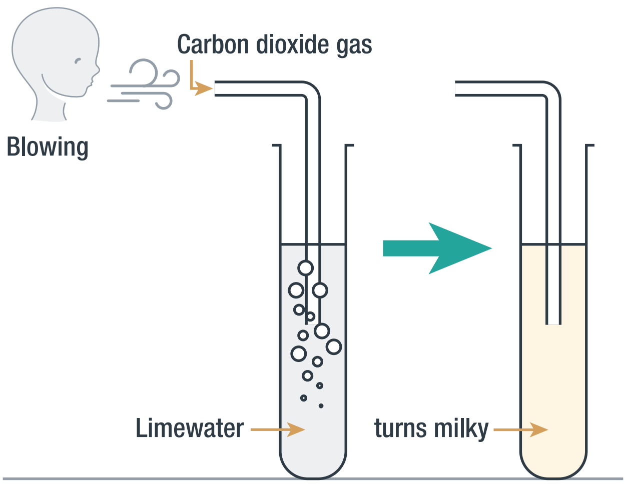
INTRODUCTION 10 MIN

1. During the previous lesson, students learned how carbon atoms are exchanged between different reservoirs on Earth. Ask students to discuss what they learned about carbon reservoirs and the flows between them. Hold a classroom discussion on the movement of carbon between plants and the atmosphere.

Some questions to guide the discussion:
- *How do you think carbon moves from the atmosphere to plants (both land and aquatic)?*
- *Do you think these atoms can move the other way round? How?*
- *What conditions do you think are necessary for plants to take carbon from the atmosphere and to release it back into the atmosphere?*

2. Write the students' responses on the board. Common answers include the requirement of light for photosynthesis and oxygen for respiration. The students may also mention carbon dioxide as the gas that is exchanged.

- *How can we demonstrate the presence of CO_2 even though it is invisible?* Students will probably mention the use of limewater, as shown in the picture on the next page. Ask the students to blow with a straw into red cabbage juice, so they can see there is a colour change. In the next experiment, the students may consider that the colour change is due to an alteration in the CO_2 concentration.



REACTION BETWEEN LIMEWATER AND CARBON DIOXIDE

Adapted from http://solomonsnow.weebly.com/carbon-dioxide.html

PROCEDURE 45 MIN

1. Once students have understood the link between carbon dioxide and the colour changes of the red cabbage juice, you can let them conduct the experiments. Divide the class in half (two broad groups), and then into teams of 4 students. Teams in one group will conduct the experiment in the light-exposed setup, and teams in the other group in the setup placed in darkness.

2. Distribute the equipment and give the students some instructions:

- In one of the bottles, put a few leaves/twigs of seaweed and then seal both bottles.
- Pour the same amount of red cabbage juice into the 2 tubes or bottles (enough for your seaweed to be fully immersed).
- Put both the bottles in sunlight or in the darkness, depending on which group you belong to, as shown in the figure next page.

BACKGROUND FOR TEACHERS

For the experiments in this lesson, you will need to put one aquatic plant in darkness for a few hours, up until the point of use, to remove any residual reactions of photosynthesis and ensure that gas exchange occurs only through respiration for that duration.

TO MAKE RED CABBAGE JUICE

→ Chop the red cabbage into small pieces, place them in a container and put the container in the freezer for at least 3 hours. This will break up the cell walls of the red cabbage and give an even more intense colour to the juice.

→ Pour boiling water onto the red cabbage pieces. The water turns dark purple. Pass this red cabbage juice through a strainer.

TO TEST THE RED CABBAGE JUICE

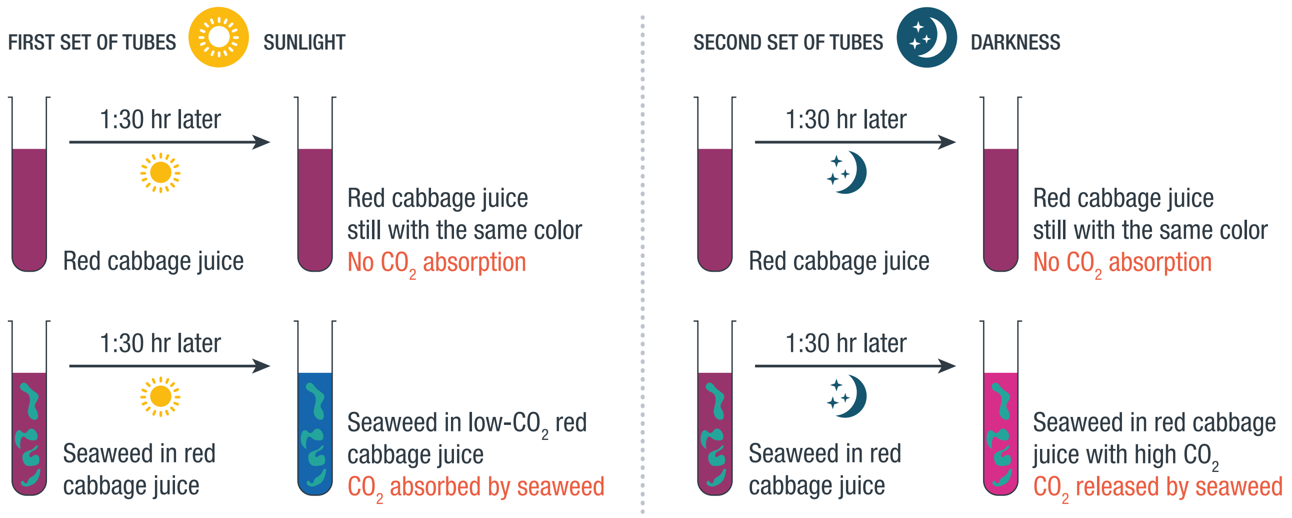
Blow through a straw into a glass with some juice, and check whether the **colour changes** from a dark violet to a more pinkish violet. If you add **vinegar** the solution should turn a bright magenta colour, whereas adding **sodium bicarbonate** (baking soda) makes the solution greenish blue. You should test the red cabbage juice in advance to make sure it works. It works best if it is fresh and not stored for too long before using (one day). If you store it in the freezer, it can last for months. Make sure your container is tightly sealed to avoid oxidation.

Source: Académie de Nantes.

pH	2	4	6	8	10	12
Colour	Red	Purple	Violet	Blue	Blue green	Greenish yellow

OUTCOME OF THESE EXPERIMENTS

In the **light-exposed setup,** you will see that the colour of the red cabbage juice containing the seaweed will turn **more bluish** (alkaline), suggesting that **carbon dioxide has been absorbed.** On the other hand, in the setup placed in **darkness,** the colour of the red cabbage juice containing the seaweed will turn **pinkish violet** (acidic), indicating that **carbon dioxide has been released.**
In both light and dark situations without the seaweed, the colour of the juice will remain the same, showing that there is no change in the pH (and no addition or removal of carbon dioxide).



EXPERIMENT ON PHOTOSYNTHESIS AND RESPIRATION

TEACHER TIP

It is important to emphasise the influence of light on these experiments. If the students have put the plant in the dark, they will see the effect of respiration; whereas if they place it in sunlight, the effect of photosynthesis will be observed. Students should also consider proper controls for this experiment, which will demonstrate that the change in colour is due to plant activity. This can be done using the bottles containing only juice. Please note that for better results, **these experiments may have to sit for a few hours.**

3. Once the students have set up the experiments, ask them to take photographs of the bottles and record their predictions about what will happen.

- In the bottles containing only red cabbage juice, the colour should stay unchanged in both light and dark conditions.
- For the plant placed in sunlight, the colour should change to a more bluish shade, showing that some CO_2 has been consumed.
- For the plant placed in darkness, the colour should change to a more pinkish shade in the same way as it did when the students blew into the juice, showing that some CO_2 has been released into the water.

4. After each group has completed their experiments, ask the students to form new teams of 4, composed of 2 students from the "light" group and 2 from the "dark" group, so they can explain to each other what they found. Provide each group with one large sheet of paper so they can draw a diagram/poster to represent their understanding of the movement of carbon during photosynthesis and respiration.

5. After a few minutes, come back to the suggestions that they made at the beginning of the lesson about the movement of carbon between plants and their environment (the ones written on the board) to see if they need to be changed.

WRAP-UP 5 MIN

To conclude, you may show a video about the impact of photosynthesis at a global scale to emphasise the importance of this process (for example, you can use this one[1]). You may also add that plants, because they only need mineral carbon (CO_2), are always at the beginning of the food web. You may then show some examples of aquatic and land food webs, like the ones available on our website.

Whole class discussion:

- *How do plants exchange carbon with the atmosphere?* If exposed to light, plants use the carbon dioxide from their environment (atmosphere or water) to carry out photosynthesis; in both light and darkness, they carry out respiration leading to the production of carbon dioxide.
- *How do you think these processes impact the whole planet?* At a global scale, vegetation may be considered as a carbon sink since it removes carbon from the atmosphere or the oceans.

1 Timelapse: Photosynthesis Seen from Space (Educator version) California Academy of Sciences. https://www.youtube.com/watch?v=Nsmdzd2NSjQ

BACKGROUND FOR TEACHERS

Plants, both aquatic and terrestrial, exchange carbon dioxide with their environment (water or atmosphere) through two major mechanisms: **respiration and photosynthesis.** In daylight, plants use the sun's energy to transform carbon dioxide into organic molecules, a process called **"photosynthesis"**. They produce a sugar (glucose), which is stored in the cells in the form of a bigger molecule called **starch** (which we find in huge quantities in potatoes). This chemical reaction **needs water and produces oxygen.** Photosynthesis only occurs in the green parts of plants – the only parts able to convert light energy into chemical energy which is stored in the form of carbohydrates.

$$\underbrace{6\,CO_2}_{\text{carbon dioxide}} + \underbrace{6\,H_2O}_{\text{water}} \xrightarrow{\text{Light (energy)}} \underbrace{C_6H_{12}O_6}_{\text{glucose}} + \underbrace{6\,O_2}_{\text{dioxygen}}$$

At the same time, plants also carry out **cellular respiration:** their cells use **oxygen and sugars** (which they produce through photosynthesis) to **extract energy.** This also leads to the **production of carbon dioxide,** which is released into the atmosphere or in the water.

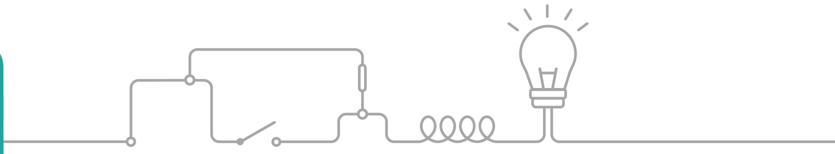
During the day, both processes occur simultaneously. But since photosynthesis takes more carbon dioxide from the atmosphere than is released by respiration, the result is a **net removal of atmospheric carbon dioxide.**

Conversely, during the night or when the plant is kept in darkness, photosynthesis cannot take place while cellular respiration continues to happen. This results in a **net carbon dioxide influx into the atmosphere.**

At a global scale, photosynthesis is the process that allows mineral matter (carbon dioxide) to turn into organic matter (sugar) that may then be used by animals as a source of food.

Some mitigation measures are also based on this process, using the plant's capacities to extract atmospheric carbon dioxide and to store it in their trunks or in the soil (see lesson B4, page 126 to explore this further).
Photosynthesis always lies at the base of any food web (see lesson C4, page 182 to explore this further).

LESSON A6
LEARNING MORE ABOUT CARBON CYCLE TRANSITIONS – COMBUSTION AND ENERGY – HUMAN ACTIVITIES



MAIN SUBJECTS
Natural sciences / Physics / Chemistry

DURATION
- Preparation: 10 min
- Activity: 1h30

AGE GROUP
12-15 years

LEARNING OUTCOMES
After previously introducing the carbon cycle, this lesson illustrates by experiential learning, how carbon moves from one reservoir (fossil fuels and land animals) to another (atmosphere).

During this lesson, students will learn that:

- Sources of energy can be classified as renewable and non-renewable.
- Combustion of fossil fuels or wood produces energy and releases CO_2 into the atmosphere.
- Fermentation occurring in the stomach of cattle produces methane, which gets released into the atmosphere.
- This methane can be used instead of fossil fuel as a cheap source of energy.
- Gases released into the atmosphere through combustion and fermentation contribute to the greenhouse effect and therefore to global warming.

KEYWORDS
Carbon, methane, fermentation, non-renewable and renewable energy

TEACHING METHOD
Experimentation, documentary analysis

PREPARATION 10 MIN

TEACHER TIP
This optional lesson focuses on some flows of the carbon cycle: combustion and fermentation. It is better if this follows the previous lesson on the carbon cycle, and it can be given alongside lesson A5, which deals with other carbon flows.

EQUIPMENT

- **WORKSHEETS A6.1** and **A6.2** (can be showed to the whole class).
- **WORKSHEETS A6.3, A6.4** and **A6.5** (one copy for each pair of students).
- Two small glass jars with lids, preferably with a spout to prevent the CO_2 from coming out too quickly.
- A little piece of charcoal (well burned) or wood or a cork, small enough to easily fit into the jar - consider taking samples of the same weight. You can also use different materials, depending on what you choose or your students' suggestions (diesel, peat, etc.)
- Fire protection gloves.
- A lighter or matchbox.
- A clamp to hold the piece of coal / wood.
- Limewater. (To make this: dissolve some calcium hydroxide in water, allow it to stand for some time and then pour out the clear solution on top into a fresh container, ensuring that the undissolved precipitate remains behind. Make sure that the container is tightly closed. Use the clear limewater solution for your experiment).

INTRODUCTION 10 MIN

Ask students to discuss what they have already learnt in the previous lesson about the Earth's carbon reservoirs and the flows of carbon atoms between them. Explain that this lesson is going to focus on human activities that play a part in the carbon cycle. In order to study these activities, they will have to help a farmer who raises cattle and who wants to reduce his impact on the environment. He currently uses fossil fuels as his main energy source, but he just saw the documents in **WORKSHEET A6.1** and is a bit sceptical about the link between fossil-fuel use and carbon dioxide emissions. Your students will have to convince him that fossil fuel use is responsible for carbon dioxide emissions and to persuade him to use an alternative source of energy.

PROCEDURE 1H10 MIN

PART 1: COMBUSTION 40 MIN

Here are some key questions to lead a whole class discussion about energy. Record your students' responses on the whiteboard.

1. Distribute or show to the whole class **WORKSHEET A6.1**, and have your students analyse it. *What can you observe about fossil fuel related CO_2 emissions since 1850? How can you explain it?* (human activities: transport, electricity production, industries, etc.)

> **TEACHER TIP**
> In this worksheet we provide two levels of difficulty: the first graph is for younger students, whereas the second one may be used with more advanced pupils. The latter focuses on the five countries that are responsible for most of the CO_2 emissions and may be used to address climate justice issues. It is up to you to choose which one is best suited to your students' level.

2. If you choose to use the second part of **WORKSHEET A6.1**: first ask the students to analyse the graph in order to identify which countries contribute most to CO_2 emissions, and also how the proportions have changed over the past decades. Next, conduct a debate in your class on whether all countries should cut their emissions equally or the cuts should be in proportion to contributions to CO_2 emissions. *Should any other factors such as development index, quality of life, etc. be considered?* Ask them to justify their responses.

3. Explain that many major human activities rely on energy, and mostly on fossil fuels for supplying that energy. *Since fossil fuels are burned in order to be used, how can you prove to the farmer that fossil fuel combustion generates carbon dioxide? Can you think of an experiment?*

4. Here is the kind of experiment you might set up (you can either choose to do this experiment as a teacher demonstration or the students could carry it out themselves in groups).

- Light the piece of coal or wood.
- Put it in a jar and close it immediately, to allow the coal/wood to burn inside. Wait until the coal/wood stops burning.
- Taking care that the air inside the jar, containing carbon dioxide, does not escape, quickly and carefully remove the wood/coal (wearing protective gloves) and pour in some limewater.
- Secure the lid of the jar and shake it. If the students have performed experiments using limewater before, have them recall how it reacts with carbon dioxide; if not, explain the reaction.
- As a control, pour the same amount of limewater into another empty jar and shake.
- Place the two jars next to each other and observe.
- The students will observe that the limewater becomes cloudy in the first jar but not in the second, indicating that CO_2 has been produced during combustion.

> **TEACHER TIP**
> If this experiment is carried out by groups of students, have them test different combustible substances of the same weight to see if all of them produce CO_2 and which ones produce more CO_2 (measured indirectly by how cloudy the limewater gets).

5. Have all the groups share and compile their results to draw conclusions from collective data: the combustion of different materials (including fossil fuels) produces CO_2, and the amount of CO_2 that is produced depends on the material. By using fossil fuels, humans increase carbon movement into the atmosphere.

6. Explain to your students that now the farmer is convinced that fossil fuel use leads to CO_2 emissions, and they will have to help him to find an alternative source of energy. *Which sources of energy do you know?* You may show or distribute **WORKSHEET A6.2** in order to have them identify different sources of energy. *What are the differences between renewable and non-renewable energy?* Renewable energy comes from sources that do not run out or that can be replenished within a short period of time, such as wind, water, sun, biomass and geothermal. On the other hand, non-renewable energy comes from sources that cannot be restored within a short period of time, such as oil, coal, natural gas and nuclear energy.

PART 2: FERMENTATION 30 MIN

1. Explain to your students that they will now focus on a renewable source of energy which is called "biomass" – meaning it is made up of organic matter produced by living beings. In our farmer's case, one thing he can do is develop a process that uses "biogas". In order to explain to the farmer how he could use this kind of energy, tell your students that they will work together in groups of 6, each pair of students focusing on one aspect of biogas use.

Altogether, as a group, they will have to find the answer to the following questions:

- *What is biogas?*
- *Where does it come from?*
- *How could it be used?*
- *Why is it a good idea to use biogas instead of allowing methane to escape into the atmosphere?*
- *Why can we consider it as a renewable energy?*

2. In order to do this, each pair of students will have a specific role in their group—distribute **WORKSHEETS A6.3** to **A6.5**, according to their role:

- *Veterinarian:* **WORKSHEET A6.3**
- *Environmental activist:* **WORKSHEET A6.4**
- *Engineer:* **WORKSHEET A6.5**

3. Each pair of "experts" has to analyse their documents to find the information needed.

BACKGROUND FOR TEACHERS

Combustion and fermentation are parts of the carbon cycle that produce carbon dioxide, which is then released into the atmosphere.

COMBUSTION

Combustion– also called "burning" –consists of a chemical reaction between a **combustible material** (e.g., wood) and an **oxidiser,** generally oxygen. Combustion of fossil fuels involves burning of organic carbon (coal, oil, natural gas, etc.) which liberates carbon dioxide and water, according to the chemical reaction:

$$\underset{\text{methane}}{CH_4} + \underset{\text{dioxygen}}{2\,O_2} \xrightarrow{\text{combustion}} \underset{\text{carbon dioxide}}{CO_2} + \underset{\text{water}}{2\,H_2O} + \text{heat}$$

This equation indicates that combustion of methane releases carbon dioxide (CO_2), which formed 65% of the total GHG emissions in 2010[1]. Thus, combustion leads to global warming by producing CO_2. Methane is only one example amongst many–wood or coal combustion also releases carbon dioxide, as follows:

Coal combustion:

$$\underset{\text{coal}}{C} + \underset{\text{dioxygen}}{O_2} \xrightarrow{\text{combustion}} \underset{\text{carbon dioxide}}{CO_2} + \text{heat}$$

Wood combustion:

(if we consider that it contains only cellulose):

$$\underset{\text{wood cellulose}}{C_6H_{10}O_5} + \underset{\text{dioxygen}}{6\,O_2} \xrightarrow{\text{combustion}} \underset{\text{carbon dioxide}}{6\,CO_2} + \underset{\text{water}}{5\,H_2O} + \text{heat}$$

FERMENTATION

Fermentation occurs naturally in living animals; in cows' stomachs, for example, numerous methanogenic bacteria generate methane from molecules found in the grass chewed by the cow. The difference with combustion lies in the nature of carbon molecules produced, since **fermentation releases methane (CH_4) and not carbon dioxide.** This methane is then released directly into the atmosphere from the cows passing wind (farts and burps), and even from their dung, contributing to the greenhouse effect.

This is a good example to demonstrate that tackling climate change does not necessarily involve only the elimination or reduction of CO_2 emissions because there are also other greenhouse gases involved. Moreover, **methane is even worse for global warming than carbon dioxide** because the "warming capacity" of one ton of methane is 28 times greater than the same amount of CO_2.

Recently, a method called **"methanisation"** has been developed for using methane to produce energy. In this process, biogas (which contains methane) is produced from food wastes and cow dung through fermentation. This biogas is stored in a closed container and distributed through pipelines with valves at different points. It is then used for various purposes like cooking, producing hot water or heat for houses, etc. This is an efficient way to both reduce waste and produce cheap energy. This method is used in some countries and represented 14% of the total energy consumption of the world in 2014[2].

1 https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data
2 https://www.worldbioenergy.org/uploads/WBA%20GBS%202017_hq.pdf

WRAP-UP 10 MIN

In groups of 6, students can now present what they learned (how does methane form, why it may present a threat to climate, and how some waste may be used as a source of renewable energy), in the form of a digital presentation or a giant drawing or poster.

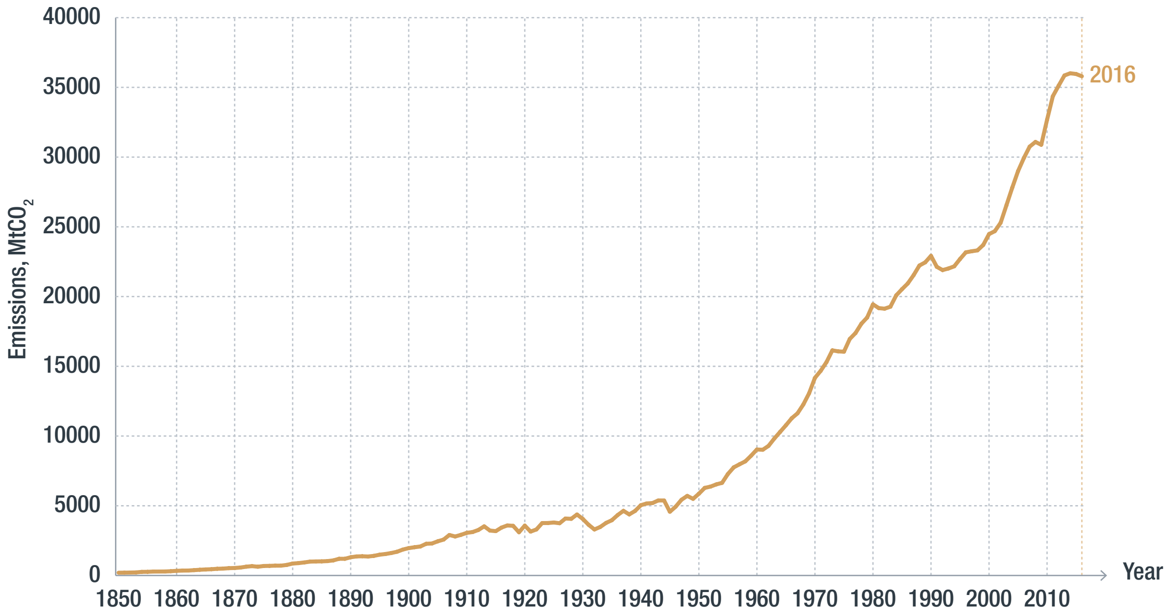
Their presentation should explain:

- The link between fossil fuel use and carbon dioxide emissions and its impacts on the atmosphere (the combustion produces carbon dioxide that moves quickly from fossil fuel reservoirs to the atmosphere).
- The link between cattle breeding and temperature rise (cattle produce methane during fermentation that warms up the atmosphere).
- The use we – as humans – make of these processes (both processes produce energy; methane emissions could be reduced by turning methane produced by cattle into biogas, leading to energy production).
- The pros and cons of the use of these processes (combustion is the most used and produces a huge amount of energy, but it is not renewable; biogas is a cheap and easy way to obtain energy in many parts of the world, but is currently underdeveloped and needs infrastructure).

TRAINEE

DOCUMENT 1: FOSSIL FUEL RELATED CO_2 EMISSIONS IN THE WORLD, BETWEEN 1850 AND 2016

This document shows fossil fuel related CO_2 emissions worldwide since 1850.

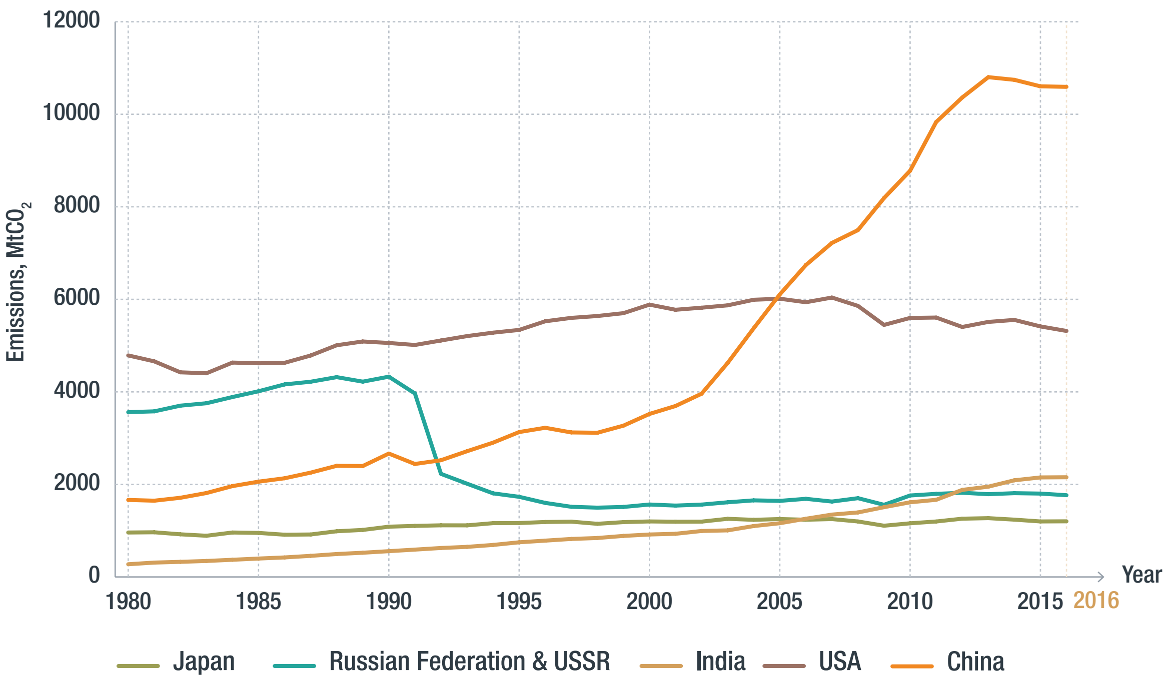


$MtCO_2$ means "million tonnes of carbon dioxide".
Source: US EIA Historical Statistics for 1980-2016. US Energy Information Administration, World Bank, Gampinder.org, via: https://www.theshiftdataportal.org

CURIOUS

DOCUMENT 2: CO_2 EMISSIONS FROM FOSSIL FUELS BETWEEN 1980 AND 2016

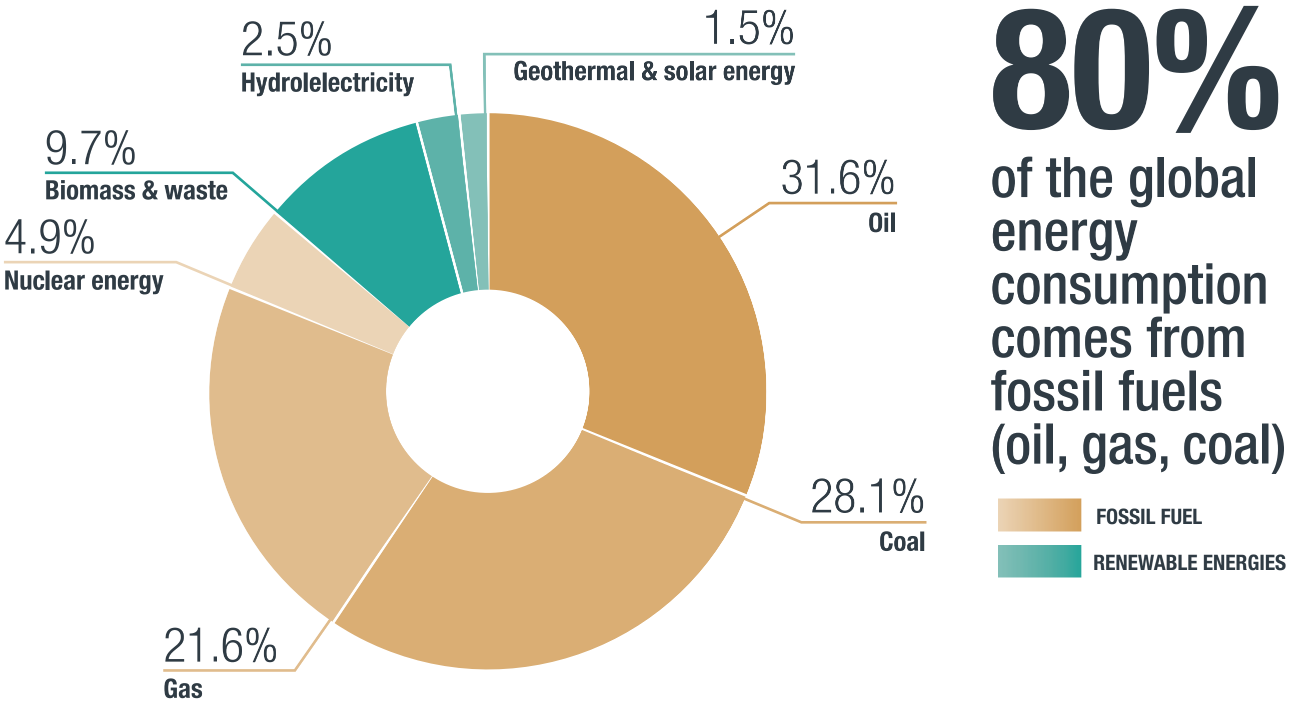
This document presents the CO_2 emissions from fossil fuels for 5 countries since 1980.



$MtCO_2$ means "million tonnes of carbon dioxide".
Source: US EIA Historical Statistics for 1980–2016. US Energy Information Administration, World Bank, Gampinder.org, via: https://www.theshiftdataportal.org

This document shows the distribution of energy used according to the source:

- What is the main source of energy in the world today?
- Is it a renewable or non-renewable resource?



In 50 years, the **global population** has increased **2.5 times** but the **energy consumption** has increased **5 times!**

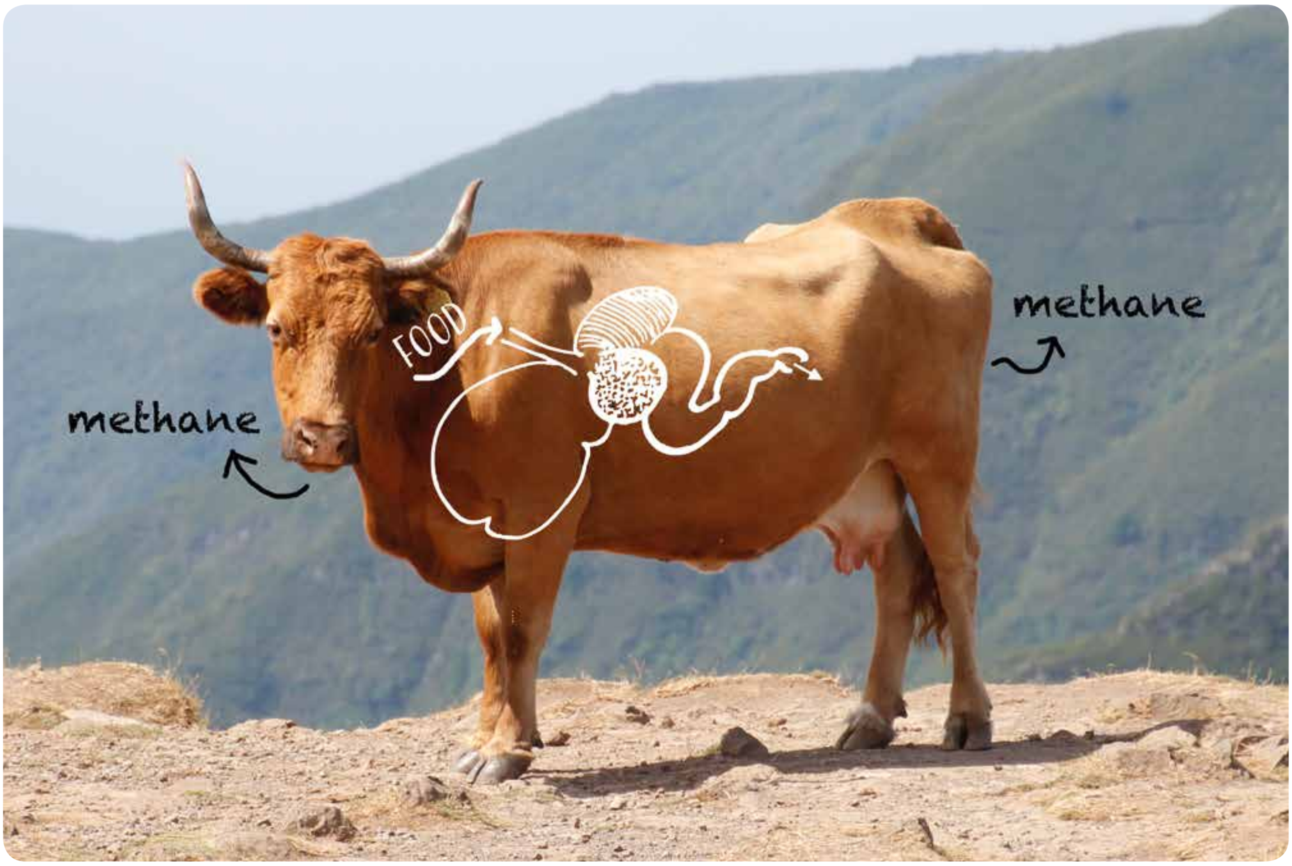
Source: Adapted from the guide "Comment agir pour la planète?", ADEME.

VETERINARIAN

Your mission: You are a veterinarian and you have to explain to the farmer how he may 'use' his cows as a source of energy. Using the following document, explain what happens when cows graze and how this could be used as a source of energy.

Cows – like other ruminants – have a peculiar stomach: in fact, they have 4! Each "pocket" of the stomach contains millions of microbes that break down grasses into useable energy for the cow. During this process, **they also produce methane** – a gas rich in carbon – that is released into the atmosphere through cows' burps, farts and dung. If we can't collect the **methane** from burps and farts, maybe we can at least use the portion coming from dung?

The natural gas that is used as a source of energy in some housing or industries is composed of 90% methane, and can be produced by the **decomposition of cow dung** and other organic matter.

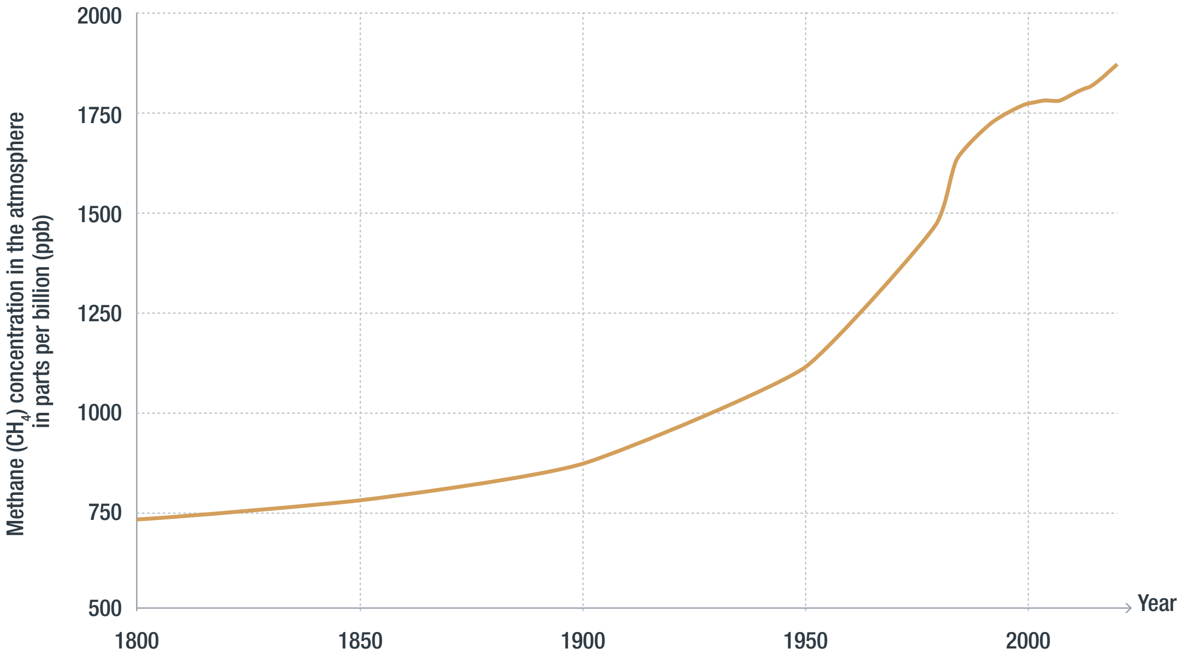


ENVIRONMENTAL ACTIVIST

Your mission: You are an environmental activist and you have to explain to the farmer why cows may constitute a threat to the climate. Using the following document, explain how methane levels have evolved over the last century and why it may represent a problem.

This document shows the changes in methane (CH_4) levels in the atmosphere, since 1800.
Methane is a **greenhouse gas** that is produced in agriculture. It is more powerful than carbon dioxide, since it warms the atmosphere up to **30 times more than CO_2!**

EVOLUTION IN GLOBAL CH_4 LEVELS SINCE 1800



Source: Adapted from https://www.methanelevels.org

WORKSHEET A6.5

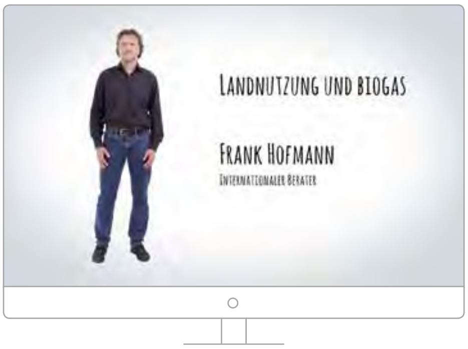
EXPERT

ENGINEER

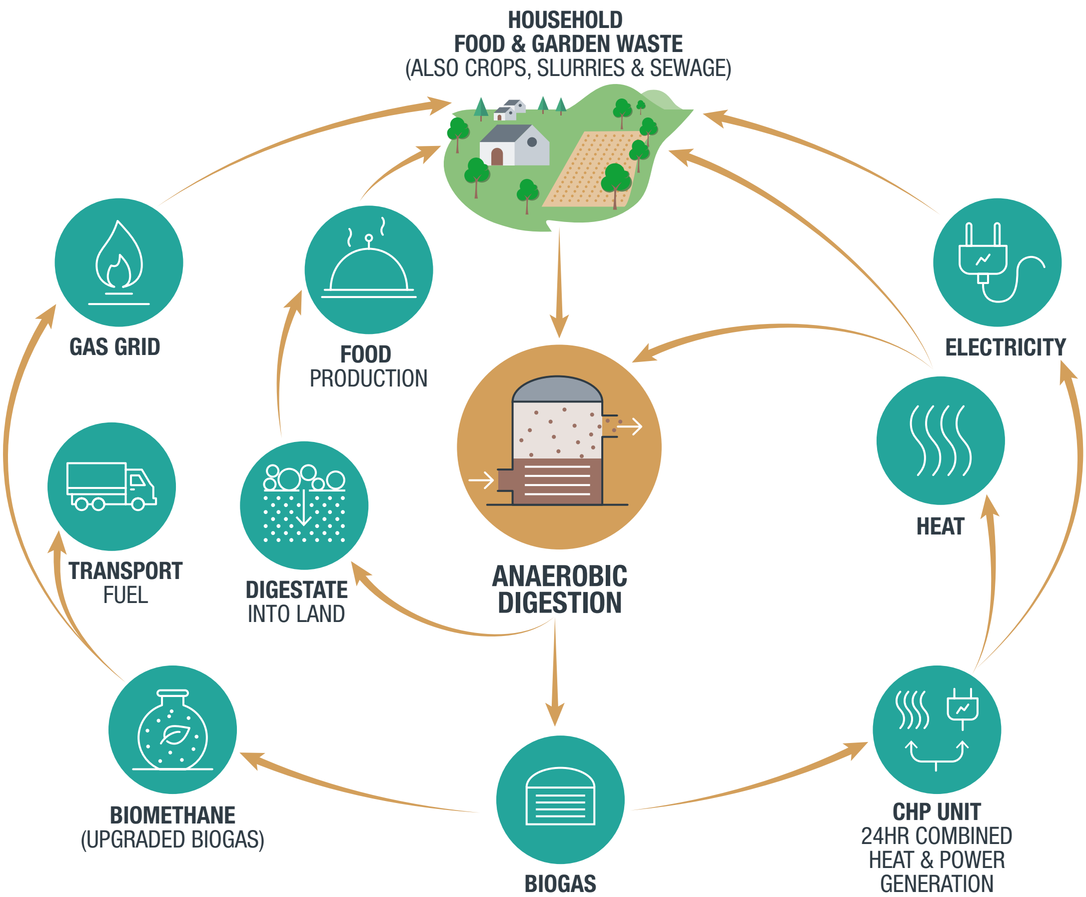
➔ Your mission: You are an engineer and you have to explain to the farmer how he can use his cow dung to produce energy. Using the following documents, explain how it is possible to produce biogas from waste and why it can be considered as a renewable energy source.

DOCUMENT 1: VIDEO ABOUT METHANIZATION

https://qrco.de/bcdqPr



DOCUMENT 2: THE DIFFERENT USES OF BIOGAS



Source: Adapted from https://adbioresources.org/about-ad/

SEQUENCE B
WHY IS LAND IMPORTANT TO US?

Acknowledging that humans are responsible for climate change is the first step in understanding this phenomenon. The next step is to study **the link between land and climate change.** By acquiring knowledge about the different roles of land for humans, awareness about the necessity of protecting land from the impact of climate change grows. Depending on their culture and origins, human communities use land and its resources in different ways, and the two first lessons focus on this aspect. Lesson B3 highlights issues concerning the soil and lesson B4 discusses forests.

This sequence involves a roleplaying game and a boardgame, experimentations and a field trip.

LESSON LIST

◉ Core lesson ○ Optional lesson

◉	B1	Ages 9-12	**Our natural resources** Natural sciences / Geography Students become aware of how much humans depend on the land and the valuable resources it provides.	page 85
◉	B2	Ages 9-15	**Different soil types and land use** Natural sciences / Geography Students discover how different types of soil affect the natural ecosystems living within them, and how land is important for the planet and human communities. They learn how to become advocates for protecting the planet.	page 96
○	B3	Ages 9-15	**The soil is a major resource** Natural sciences In order to prevent soil degradation, students conduct experiments to study the properties of different soils and their cover. They also study their biodiversity and the role of this biodiversity.	page 115
○	B4	Ages 9-15	**Forests, humans and climate change** Natural sciences / Geography On a field trip, students learn about the important role of trees and forests for living beings and the link with climate change.	page 126

LESSON B1
OUR NATURAL RESOURCES

MAIN SUBJECTS
Natural sciences / Geography

DURATION
- Preparation: 15 min
- Activity: 55 min to 1h15

AGE GROUP
9-12 years

LEARNING OUTCOMES
Students become aware of how much humans depend on land and the valuable resources it provides.

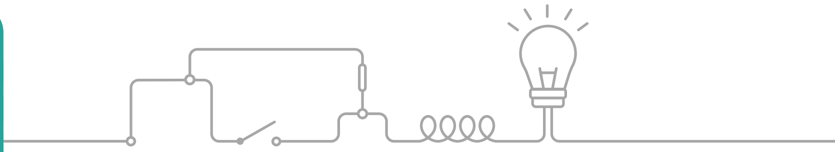
Students:
- Learn that the Earth is composed of many natural resources, including plants, animals, rocks, fossil fuels and water.
- Learn that materials important for humans are made from these natural resources.
- Classify objects that we use in our daily life according to the natural resources used to create them.
- Identify objects that need more resources than others.
- Learn that due to land, humans can eat, drink, live in a house, wear clothes, and enjoy many forms of entertainment.

KEYWORDS
Land use, ecosystem services, human needs, natural resources

TEACHING METHOD
Boardgame

PREPARATION 5-10 MIN

EQUIPMENT
- A set of “natural resources” cards (1 set per group) – **WORKSHEET B1.1**
- A set of “I,T,E,M,S” cards (1 set per group) – **WORKSHEET B1.2**
- A gameboard (1 per student, every student within a group must have a different one) – **WORKSHEETS B1.3** to **B1.7**
- A dozen little stones or something similar to tick the item boxes (optional)
- A laminator (optional)
- Markers



LESSON PREPARATION

TEACHER TIP
This is a version of the game “Bingo” and the rules are quite similar. To give the students more autonomy, the game can be played in groups.

Print out the “natural resources” set of cards, the “I,T,E,M,S” cards and the gameboards. If you have a laminator, you can laminate the gameboards in order to play several times.

INTRODUCTION 15 MIN

Announce the objectives of the activity to your students: By playing this game, we are going to learn:
- That the Earth is composed of many natural resources.
- That objects important for humans are made from natural resources.
- To classify everyday objects according to the natural resources used to create them.

Before starting the game, take a nearby object (for instance, your shoe or a piece of clothing): *What is the object made of? Fabric? Where does the fabric come from? From a plant? From an animal, etc.?* After a few objects you can write down on the board the different materials used and the origins of these materials. You end up with 5 main categories of natural resources from which these materials come from:
1. **Plants**
2. **Animals**
3. **Mineral matter** (from which we obtain glass, cement, etc.)
4. **Water**
5. **Fossil resources** (from which we obtain plastic, oil, etc.)

Continue this discussion to find out in more detail what your pupils think: *What objects do you use on a daily basis? What do you need them for? Which raw materials are these objects made from?*

PROCEDURE 30 TO 50 MIN

1. Divide your students into groups and hand out different gameboards per group.

2. In order to become familiar with everyday objects, you are going to sort the object cards into categories according to their usefulness. To do this, the groups can cut out the pictures from the board and place them in categories, then share the different categories with the whole class. Here are some examples of categories: housing, drinking, eating, health/hygiene, living, having fun, getting around, clothing. To help you, use **WORKSHEET B1.8**.

3. The rules of the game are similar to bingo. First, present the materials: Each student has 1 grid with drawings organised in 5 columns that form the word ITEMS: *What do the drawings on the grid represent?* Each group also has two piles containing resource cards and the letters that form the word ITEMS.

4. Then, explain the rules of the game: A game master (in turn) draws 1 "letter" card and 1 "natural resource" card. You must mark with a pencil 1 space in the letter column that contains 1 object made from this natural resource.

For instance, in the picture bellow, the game master of the group draw the card N and the card "Vegetable": the student can either make a mark under the apple (which comes from a plant) or in painting (which are made out of wood, vegetable and pigments – mineral and fossil fuel).

Students are filling their grid.

There are different ways to win:

- Easy: the winner is the player who fills a row or a column or a diagonal first (with at least 1 resource ticked per object).
- Easy: the winner is the player who fills in at least 1 item from each category with at least 1 resource per item.
- Medium: the winner is the player who fills in all the resources for the 5 objects.
- Medium: the winner is the player who completes at least 1 item in each category with all resources per item.

5. The whole class plays a test game with the teacher as the game master. Each group receives the same grid to compare/discuss before giving possible answers orally.

6. The game is played using groups of tables with a game master who rotates them for each new draw. Shuffle the grids between the groups. Encourage discussion amongst students, with your help, to identify the raw materials used. Students can either put a pebble or a coloured mark on each resource pictogram on the grids for each object.

WRAP-UP 10 MIN

Hold a classroom debate on natural resources. This should lead to a discussion on sustainable and non-sustainable resources.

- *Which resources are used most frequently?*
- *Why is it important to conserve natural resources?* Because we need resources for so many things in our daily lives, such as food, habitation, transportation, etc. If we use them up, we will not have the things we need, or subsequent generations will not have the things they need.
- *What do you think would happen to the Earth if we used more resources than it provides?* We would run out of the things we need to live.
- *What is the difference between needs and wishes?*
- *Do you think we need new objects all the time? Why/why not?*
- *How do you think natural resources in our daily lives could be protected?* Reducing, reusing, recycling and composting.

BACKGROUND FOR TEACHERS

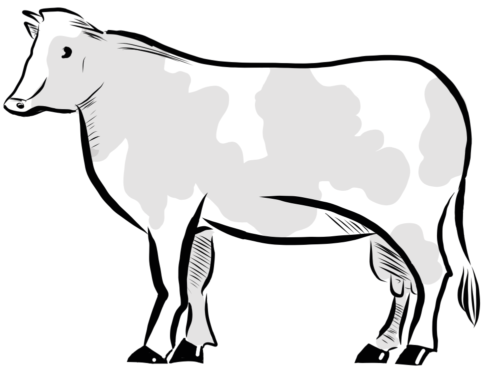
Natural resources are materials from nature that are used to support life and people's needs. The environment, and here, specifically, the land, provides natural services for humans; they are called **"ecosystem services"**.

All societies benefit from the natural resources of land to produce objects needed in every arena of daily life (habitation, clothing, medicinal products, games and art, food and beverages, and so on).

We can classify natural resources into 5 categories:

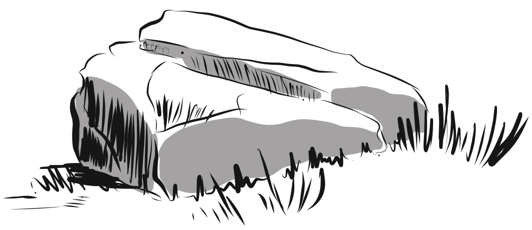
- **Water** (fresh water that is stored underground in groundwater tables).
- **Mineral resources** (from rocks and sand, such as concrete, glass, metals).
- **Fossil resources** (petrol, plastics and other chemical products, as well as medicinal products).
- **Animals** (animal products, either based on animal organisms, such as meat, wool and leather, or animal production, namely, honey and milk).
- **Plants** (for fibre, to make wood, paper, cotton, etc.; for food, such as vegetables, fruits).

ANIMALS

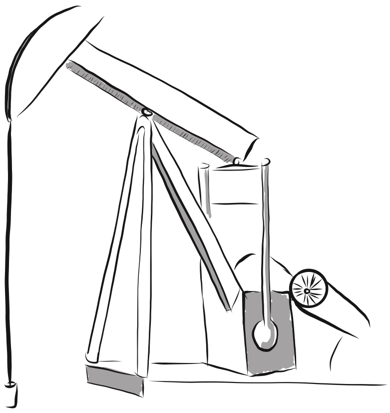


PLANTS

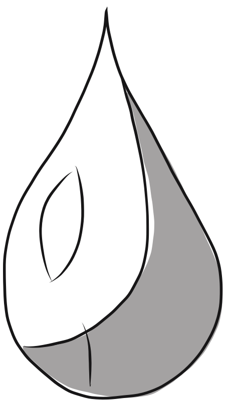
MINERAL RESOURCES



FOSSIL RESOURCES



WATER



HOW TO WIN

The first person to complete a row, column or diagonal (5 objects) wins.
The first person to complete an object in each category wins.

I

T

E

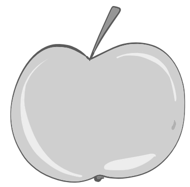
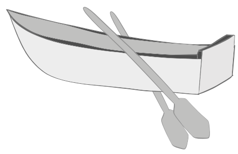
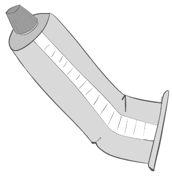
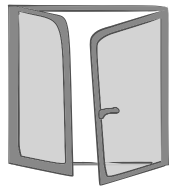
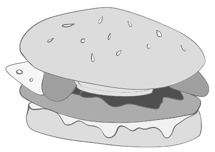
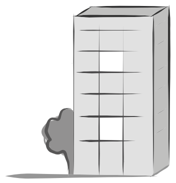
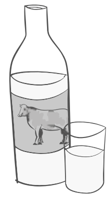
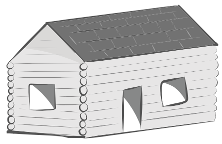
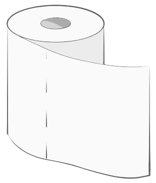
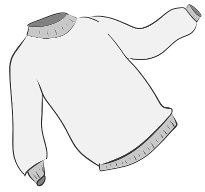
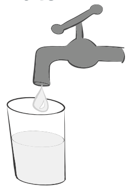
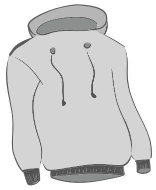
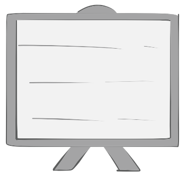
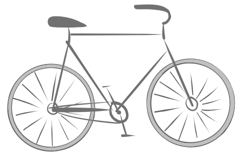
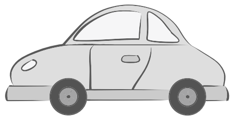
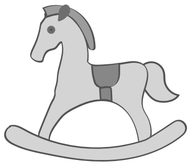
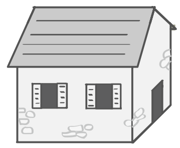
M

S

RULES OF THE GAME

In turn, a game master draws a letter card and a resource card. The players mark an object that requires this resource in the column corresponding to the letter drawn. The game master puts the letter and the resource back into the pile, shuffles and passes to their neighbour who becomes the new game master.

ITEMS

Apple 	Aspirin 	Ball 	Wooden boat 	Soda 
Shoes 	Painting 	Tooth paste 	Window 	Cake 
Hamburger 	Building 	Milk 	Wooden house 	Honey 
Toilet paper 	Wool jumper 	Water 	Jumper 	Television 
T-shirt 	Bike 	Car 	Wooden game 	Stone house 

ITEMS

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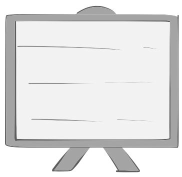
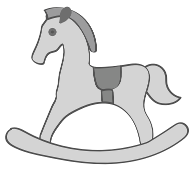
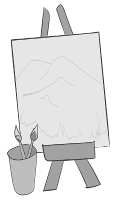
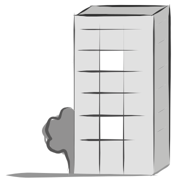
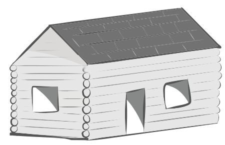


Wooden game


Painting


Building


Wooden house


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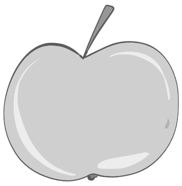
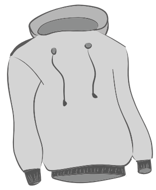
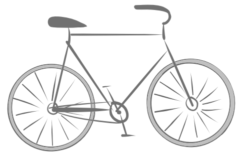


Jumper


Soda


Shoes


Bike


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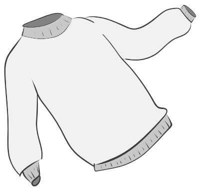

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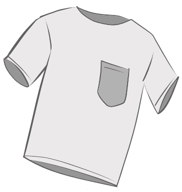

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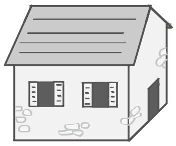

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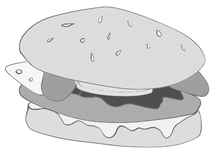
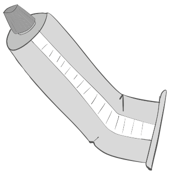


Ball


Tooth paste


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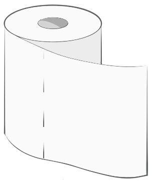
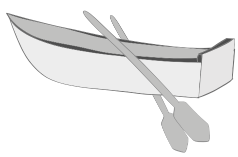


Wooden boat


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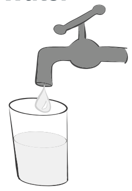
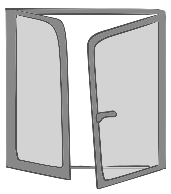
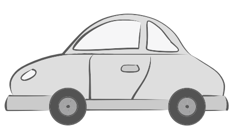
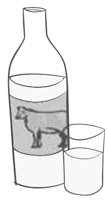


Honey


Window


Car


Milk


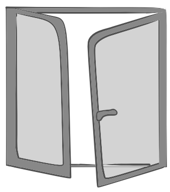
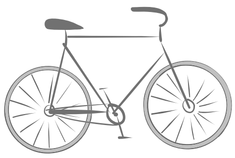
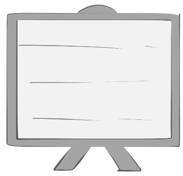
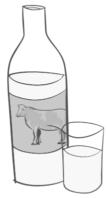
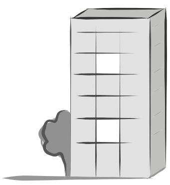
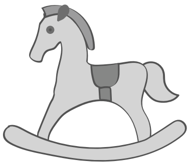
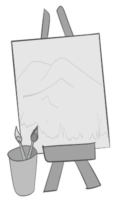
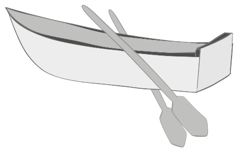
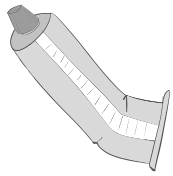
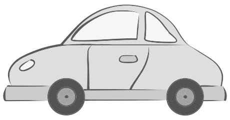
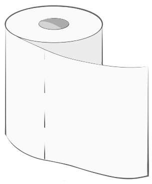
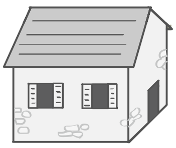
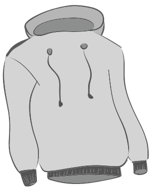
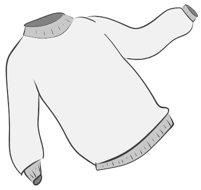
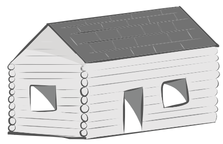
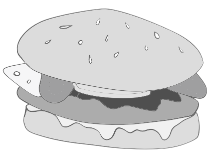
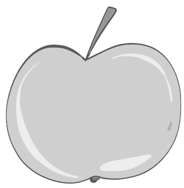
Aspirin


Cake



ITEMS
Wooden game
Soda
Building
Toilet paper
Milk
Stone house
Shoes
Wooden house
Car
Wooden boat
Honey
Tooth paste
Apple
T-shirt
Cake
Water
Television
Aspirin
Hamburger
Wool jumper
Jumper
Painting
Bike
Window
Ball

I T E M S

Window 	Bike 	Honey 	Television 	Milk 
Building 	Wooden game 	Painting 	Wooden boat 	Tooth paste 
Car 	T-shirt 	Cake 	Toilet paper 	Water 
Stone house 	Jumper 	Aspirin 	Wool jumper 	Wooden house 
Soda 	Hamburger 	Ball 	Shoes 	Apple 

WORKSHEET B1.7

TRAINEE

WORKSHEET B1.8

GET A PLACE	Building	Window	Wooden house	Stone house
GET DRESSED	T-shirt	Wool jumper	Shoes	Jumper
HAVE FUN	Painting	Wooden game	Ball	Television
EAT	Apple	Hamburger	Cake	Honey
DRINK	Milk	Water	Soda	
MOVE AROUND	Car	Wooden boat	Bike	
TAKE CARE OF YOURSELF	Toilet paper	Tooth paste	Aspirin	

LESSON B2
DIFFERENT SOIL TYPES AND LAND USE

MAIN SUBJECTS
Natural sciences / Geography

DURATION
- Preparation: 15 min
- Activity: 1h20

AGE GROUP
9-15 years

LEARNING OUTCOMES
Students discover how different types of soil affect the natural ecosystems living within them, and how land is important for the planet and human communities.

Students:
- Recognise that each part of the planet has a different type of soil.
- Learn that an ecoregion is defined by its soil and the ecosystem living within it.
- Discover that animals and human communities depend upon resources provided by ecoregions.
- Learn how to become advocates for protecting the planet.

KEYWORDS
Land ecosystems, soil, CO_2 uptake, biodiversity, ecosystem services, human needs, indigenous local knowledge

TEACHING METHOD
Documentary analysis

PREPARATION 10 MIN

EQUIPMENT
- Option 1: one computer with an internet access to show a video
- Option 2: **WORKSHEET B2.1** for an offline version.
- **WORKSHEETS B2.2** to **B2.7**
- Optional: **WORKSHEETS B2.8** and **B2.9**

LESSON PREPARATION
- For each group of students (3 to 5 students), print out:
  - → Role cards – **WORKSHEET B2.3**
  - → 1 ecosystem identity card – **WORKSHEET B2.4**
  - → 1 ecosystem portfolio to be chosen by the group – **WORKSHEET B2.5**
- World map with ecoregions, printed in A3 if possible – **WORKSHEET B2.2**
- Print 1 copy of each map of the **WORKSHEET B2.6** to hang on the board (or to display on the digital board)
- For each student: **WORKSHEET B2.7**.

INTRODUCTION 10 MIN

Play the video of Chief Raoni calling on world leaders to protect the Amazon to your students (or distribute and read the text on **WORKSHEET B2.1**).

Initiate a class discussion based on the video or text:
- *Who do you think the man is? Where does he come from? Why is he angry?* Chief Raoni (Raoni Metuktire) is the leader of an indigenous tribe (or root people; first people) called Kayapo, which lives in the Amazon forests in Brazil, in the territory of Capoto-Janira.
- *Why is the forest important to the Raoni Indians?*
- *Is the forest only important to them? What does the Amazon rainforest provide for humanity?*
- *Who else benefits from the forest? Animals?*
- *Were you impressed by the "advocacy"?* (Spend some time explaining what advocacy is) *Do you also think that ecosystems should be protected?*

Then tell the students that they will, in groups, have to defend an ecosystem of the planet. To do this, they will have to **(1) find information on ecosystems** and **(2) make an argument.** Finally, the groups will take turns to defend their ecosystem. While one group is presenting, the other groups should take notes and vote for the one that had the most convincing argument.

BACKGROUND FOR TEACHERS

Indigenous people represent tribes, communities and societies of humans living in various places on Earth. They are called indigenous as they often live a traditional lifestyle based on a **complex and important relationship with their direct natural environment.** Therefore, their environment, the soil and the land have a vital importance for them, providing services like **food, habitat, and tradition.** Indigenous people have a strong and specific knowledge of their environment and all this knowledge, called **Indigenous Local Knowledge,** has great value for mitigation and adaptation strategies regarding climate change, biodiversity and biomes (for further details on this topic, see page 19 of the Scientific Overview).

PROCEDURE 55 MIN

SETTING UP THE DOCUMENTARY ACTIVITY 10 MIN

1. Display **WORKSHEET B2.2** and ask each group of 3 to 5 students to choose which ecosystem they want to work on and defend, according to the numbers. Each group will contain researchers/experts in different fields.

2. Distribute the "expert" role cards to each group and an ecosystem identity card to each student: **WORKSHEETS B2.3** and **B2.4**.

3. Hand out the portfolio corresponding to their ecosystem to each group: **WORKSHEET B2.5**. Post on the board or hand out copies of the world maps for temperature, precipitation and carbon content: **WORKSHEET B2.6**.

4. Before doing the literature search, go over the vocabulary with the students and clarify your instructions:

- Each expert should write down the **characteristics of the soil and climate** on their identity card and then the **contributions or benefits** of their ecosystem, for humans or for animals. The term **"ecosystem service"** is used because the soil and vegetation allow humans to live, eat, heat, play, etc.
- You can reflect for a few minutes with your students on the definition of ecosystem service and ask: *can you give examples of how nature benefits you at your level?*
- Explain that the climatologist can tell us whether an ecosystem is more or less involved in regulating the climate: if the soil has a lot of CO_2 then it helps to regulate the climate. If the soil is destroyed by human activities, the CO_2 will be released into the atmosphere and will contribute to climate change.

AUTONOMOUS RESEARCH TIME 15 MIN

5. Each expert fills in one part of the identity card. Depending on the size of the group, one person can be an expert on several aspects:

- The **climate scientists** search for their information on the board/on the world maps.
- The **soil scientists** look up information on the amount of carbon stored in the soil on the world map.
- The **ecologist, zoologist and anthropologist** must collect information about the ecosystem services in their portfolios.

PRESENTATION TO THE OTHER TEAMS 30 MIN

6. Each group prepares its own "advocacy": it has 2 minutes to convince the class to defend its ecosystem. During this time the students must present the characteristics of their ecosystem and the benefits for humans, but also be convincing! The aim is to make people want to protect the beauty and identity of the ecosystem.

7. Depending on the time available, students can be allowed to do more research on their ecosystem and enrich their argument with photos, videos, drawings, etc.

8. Throughout the presentation, the other students complete the ecosystem services chart: **WORKSHEET B2.7**. Students will then display the completed ID card next to the map on the board.

TEACHER TIP

If you want to assess this lesson, especially the part on advocacy, WORKSHEET B2.8 has an example of a grid that you could use.

WRAP-UP 10 MIN

After listening to all the advocacies and filling in the summary table, ask the class to vote for the most convincing group, both on the basis of the content of the ecosystem, but especially on the quality of the presentation.

End with a global discussion: all ecosystems on the planet are different and all deserve protection without exception. To help with the global discussion, you can use the questions in **WORKSHEET B2.7**.

Think about the place of humans in nature. *Do humans necessarily have a negative influence on nature? What do you think of the customs of the peoples presented in each ecosystem?* To further explore the importance of the local and ancestral knowledge of indigenous peoples, you can watch the OCE video on this topic (duration 3 min).

What all these terrestrial ecosystems have in common is that they are linked to a soil, which has an importance for the climate, but also allows plants to grow. *Do you know how soil is formed and what is in it?* They can look at this in a future session.

OPTIONAL EXTENSION

To explore the link between soil and vegetation, you and your students can create some terrariums that will represent the different ecoregions you can find on Earth. Some guidelines are provided in **WORKSHEET B2.9** and in the OCE video.

WORKSHEET B2.1

CHIEF RAONI IS ADVOCATING

"To everyone who is watching me, I want to say that my commitment to protecting the forest must be heard by all of you because after our generation, others will come, our grandchildren will grow up and we must take care of what remains of the forest so that they too can benefit from it."

Raoni Metuktire, the indigenous leader of Brazil's Kayapó people, has defended the Amazon rainforest for over 4 decades. He's now urging world leaders to protect it from an alarming rise in threats by farmers, loggers, miners, and fires.

"At the rate we're going, we'll soon destroy all of the forest's resources, which will be tragic. How will we breathe? How will future generations breathe? I'm therefore asking all of you who are listening to protect our natural resources so that our grandchildren can continue to live here too. To live, we need nature."

Brazil's 1988 Constitution established the demarcation of indigenous lands. But Chief Raoni is calling on the international community to stop the current encroachment on tribal lands.

CHIEF RAONI IS CALLING FOR MORE ACTION

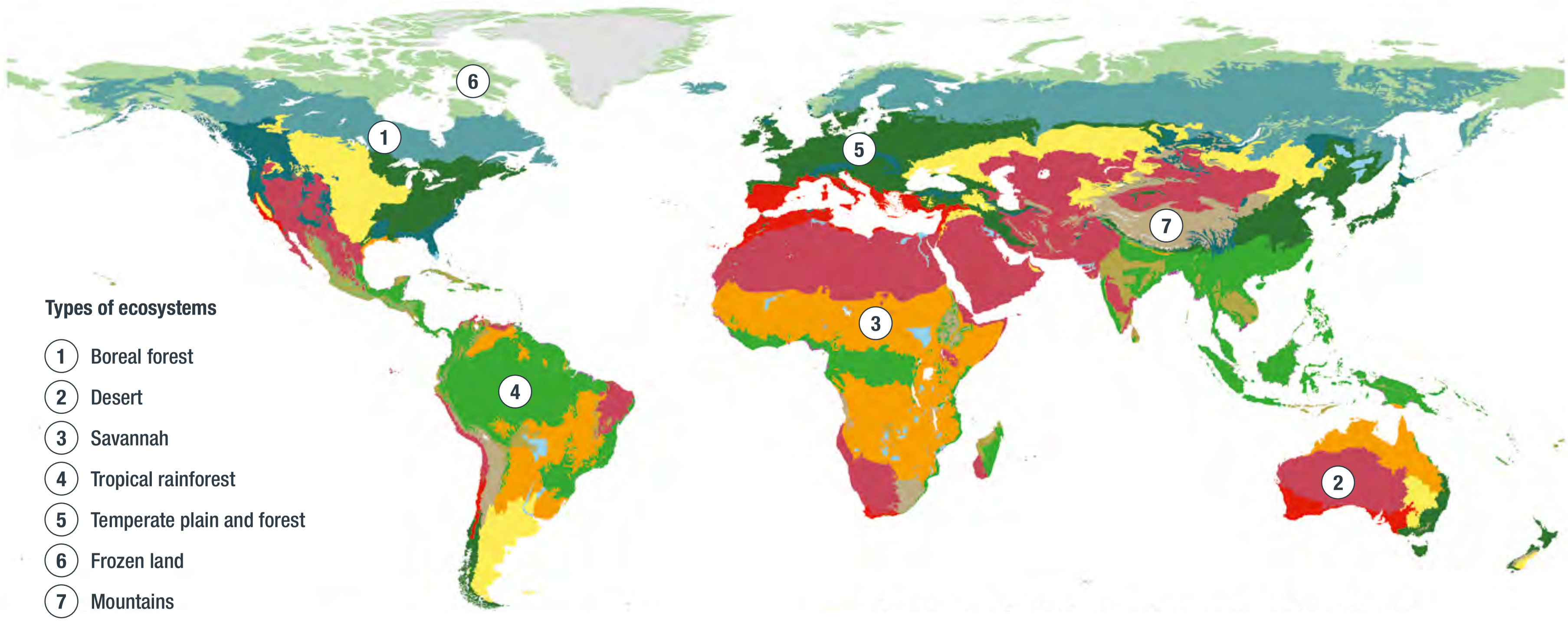
"I thought about it and concluded that I should ask the international community to help us establish the physical borders of our land so that we can continue to protect it. Many communities live on the banks of the Xingu River, and we want to protect it. This is my message today: we need the support of international leaders to establish the borders of our land."

Extract from the video of Chief Raoni.

WORKSHEET B2.2

CURIOUS

MAP SHOWING TERRESTRIAL ECOREGIONS OF THE WORLD



Types of ecosystems

1. Boreal forest
2. Desert
3. Savannah
4. Tropical rainforest
5. Temperate plain and forest
6. Frozen land
7. Mountains

Biome

- Tropical & subtropical moist broadleaf forests
- Tropical & subtropical dry broadleaf forests
- Tropical & subtropical coniferous forests
- Temperate broadleaf & mixed forests
- Temperate conifer forests
- Boreal forests / Taiga
- Tropical & subtropical grasslands, savannas & shrublands
- Temperate grasslands, savannas & shrublands
- Flooded grasslands & savannas
- Montane grasslands & shrublands
- Tundra
- Mediterranean forests, woodlands & scrub
- Deserts & Xeric shrublands
- Mangrove
- Rock & ice

Source: Adapted from Olson et al., Terrestrial ecoregions of the world: A new map of life on Earth. BioScience, Volume 51, Issue 11, November 2001, Pages 933–938

WORKSHEET B2.3

ANTHROPOLOGIST

Study the habits of human societies in relation to the environment.

ZOOLOGIST

Study animal biology and behaviour.

CLIMATOLOGIST

Study the climate (rainfall, temperature...) of an environment.

ECOLOGIST

Study the functionning of an ecosystem (link between soil, plants and animals).

SOIL SCIENTIST

Study soil composition.

Note: here the ecologist and the soil scientist can be the same person.

WORKSHEET B2.4

CURIOUS

Group name: ....

Ecosystem number: ....

Name of the ecosystem: ....

Location: ....

SOIL SCIENTIST

SOIL CHARACTERISTICS

- Name of the soil:
- Carbon stored (in tonnes of carbon per hectare):

CLIMATOLOGIST

CLIMATE

- Temperature (°C):
- Rainfall (mm):

ECOLOGIST

- Describe the ecosystem and identify the benefits it brings

ZOOLOGIST

- Describe the key species and how it interacts with the ecosystem

ANTHROPOLOGIST

- Name the local community. How is it benefiting from the ecosystem?

ECOSYSTEM 1
BOREAL FORESTS IN QUÉBEC, CANADA

The boreal forests, or taiga, grow on *podzol*. They are coniferous forests with many lakes, used for various purposes, for instance, to produce the majority of Quebec's electricity. There is also a lot of mining and wood industry in the boreal forests.

Caribous are large mammals that live in Canada. They migrate between different ecosystems and spend the winter in the boreal forests, where they feed on lichens.

INDIGENOUS PEOPLE AND THE BOREAL FORESTS

"From large game like moose and caribou to smaller mammals such as beaver and rabbit, many common boreal mammals continue to provide food, clothing, and tools for the Indigenous Peoples that reside in the forest. Fish and waterfowl make up significant portions of the diet of many remote communities as well, which are often only accessible by small aircraft. Native trees, shrubs, grasses, lichens, and fungi also feature prominently within Indigenous cultures by providing food, medicine, shelter, and materials."

Source: Boreal Songbird Initiative.
http://www.borealbirds.org

ECOSYSTEM 2
AUSTRALIAN DESERT

The Australian desert is a part of its vast Outback. Its soil is very poor in organic matter and is called *regosol*.
Uluru (or Ayer's rock) is an isolated mountain in the middle of Australia. It is considered sacred by the local tribes and is an important spiritual part of the Aboriginal cultural heritage.
The outback is very rich in minerals like iron, aluminum, manganese and uranium, leading to a lot of mining in the region.

In the very hot Australian desert, honey pot ants find shelter underground, where they build their large colonies. Only a few forager ants go out to collect food (nectar from the scarce vegetation) in the dry, hot weather. Nectar brought by the foragers is then stored in the abdomen of other ants that have stayed behind in the colony. Thus, the ant colony can survive using their honey stocks, even when it is too hot to go outside.

THE ABORIGINAL PEOPLE IN AUSTRALIA
"Although spinifex country is relatively abundant in kangaroos and emus, in Western Desert areas further north, large game is a more seasonal food source following summer rains. As well as hunting with spears and boomerangs, animals were also caught with elaborate nets strategically placed in feeding and watering habitats. Other favored animal foods included lizards and some snakes.
Insects, especially witchery grubs (the larvae of wood-boring beetles and cossid moths), were a valuable source of protein. Honey ants and the honey of stingless bees were sought after for sweetness."

Source: Australian geographic.
https://www.australiangeographic.com.au/australian-geographic-adventure/adventure/2017/07/surviving-in-the-desert/

ECOSYSTEM 3
SAVANNAH OF THE SERENGETI NATIONAL PARK, TANZANIA

The Serengeti National Park is located in Tanzania, at its border with Kenya. The dry savannah there grows on *lixisol*. Many animals live in the park, which attracts a lot of tourists. Local populations use the wood, soil and water for construction and agriculture, and the land for hunting and fishing, further increasing the pressure on the wildlife.

African elephants from the savannah are the biggest mammals on earth. They eat foliage from trees. In areas with high elephant density, they can cause damage to local agriculture.

THE MAASAI IN TANZANIA

"The Samburu and the Laikipia Maasai have developed traditional/customary natural resource management strategies that they have used to assess, manage and restore ecological zones or regions.
For years, the two communities have used different and unique observations and interpretations such as stars, livestock milk productivity and skin quality, "reading" the intestines of slaughtered animals, wildlife migratory patterns, plant species etc. to predict changes in weather patterns as well as to determine how healthy the environment is. This traditional weather forecasting is still relevant to date and does contribute to drought coping strategies for the pastoralists."

Source: Knowing our lands and resources: indigenous and local knowledge of biodiversity and ecosystem services in Africa.
https://unesdoc.unesco.org/ark:/48223/pf0000247461

ECOSYSTEM 4
TROPICAL RAINFOREST OF THE AMAZON, BRASIL

The Amazon rainforest grows on *acrisols*. The soil is very rich in iron and has an orange colour. Because of the large number of trees in this very dense rainforest, the Amazon valley influences and regulates the climate.

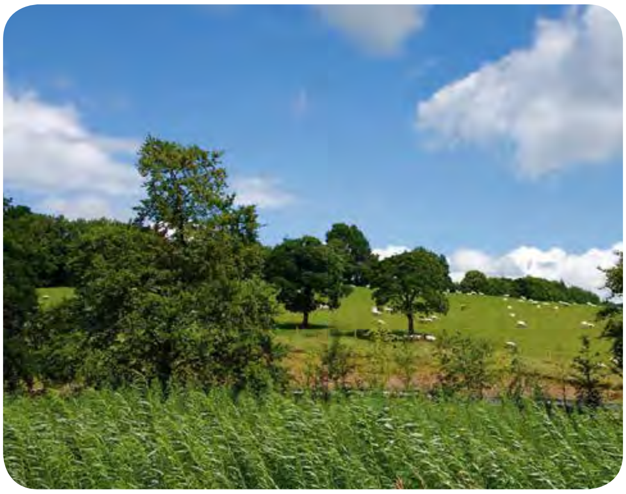
Poison frogs are very common in the Amazon forest. They are poisonous to their predators, and feed on various species of flies that are abundant in the forest. Local communities use the poison of some frogs to make weapons for hunting. It is also used by the pharmaceutical industry to make medicines.

THE WAJAPI IN BRAZIL

"The Wajapi indigenous people live in an area of well-conserved forests, close to the springs of some tributaries of the Jari River in northeastern Brazil. According to the Wajapi, animals in the forest, despite their appearance, are actually human beings with souls. They live in societies that are similar to ours. The trees and most plants are also recipients of human souls, but only the healers or shaman are able to communicate with them. Many of the Wajapi's cultural traits and skills needed for survival in the forest have been passed to them by animals. This perception of the world is the basis of Wajapi knowledge of ecological processes."

Source: WWF.
https://wwf.panda.org/knowledge_hub/where_we_work/amazon/about_the_amazon/people_amazon/

ECOSYSTEM 5
TEMPERATE PLAINS AND FORESTS OF IRELAND



Irish forests and open fields grow on *luvisol*. *Luvisols* are rich in organic matter and are fertile soils that provide nutritious grass for wild and farmed animals.

Wild bees, such as this bumble bee, live in the temperate forests and open fields of Europe, Asia and Northern America. They collect nectar from flowers and transfer pollen from one flower to another, providing the very crucial service of pollination that permits the fertilisation of flowers and, thereby, the production of fruits.

FARMING IN IRELAND

"The country also has a rich tradition of stockmanship and crop husbandry, with farming skills handed down through at least 200 generations. The Ceide Fields on the north Mayo coast contain the remains of a 5,000 year old Stone Age farming landscape of stone walled fields, preserved beneath the growing blanket bog. Research has shown that they were a highly organised community of farmers who worked together on clearing hundreds of acres of forest and dividing the land into fields for cattle rearing."

Source: Ask about Ireland.
http://www.askaboutireland.ie/enfo/sustainable-living/farming-in-ireland-overvi/

ECOSYSTEM 6
THE FROZEN LANDS OF NUNAVUT (CANADA)

Nunavut is covered with snow for a large part of the year. The soil, called *cryosol*, can be frozen and contains permafrost. This permafrost holds a large reserve of natural gas.

Arctic foxes are present in areas of the far north, like Greenland, Iceland and the polar circle. They feed on lemmings, eggs, birds and carcasses left by bears. Their fur changes colour according to the season to help them blend in with their surroundings.

THE INUIT IN THE ARCTIC

"The bowhead whale is the most culturally significant resource harvested on the North Slope. The Inupiat have hunted the bowhead whale for thousands of years and knowledge of subsistence whaling continues to be taught to our children beginning at an early age. These skills include preparing the umiaq, or traditional skin boat, and coping with the dangers while traveling on sea ice to the whaling camps. Preparing the umiaq begins in summer with the harvest of bearded seals and caribou. The women spend much time preparing the bearded seal skins to be used to cover the boat's wooden frame. Caribou sinew are stripped and dried, then later made into thread, which is used to sew the seal skins to cover the umiaq. Passing on this and other knowledge helps to assure the continuation and survival of the Inupiat culture."

Source: Cultural Survival .
https://www.culturalsurvival.org/publications/cultural-survival-quarterly/subsistence-hunting-activities-and-inupiat-eskimo

ECOSYSTEM 7
THE MOUNTAINS IN TIBET

The Himalayas are the largest mountain range in the world. The *leptosol* that is present in that environment is quite poor in organic matter. Himalayan mountains contain many freshwater lakes. Numerous rivers arising from the Himalayan glaciers supply water, and sometimes electricity, to a large population in southern Asia.

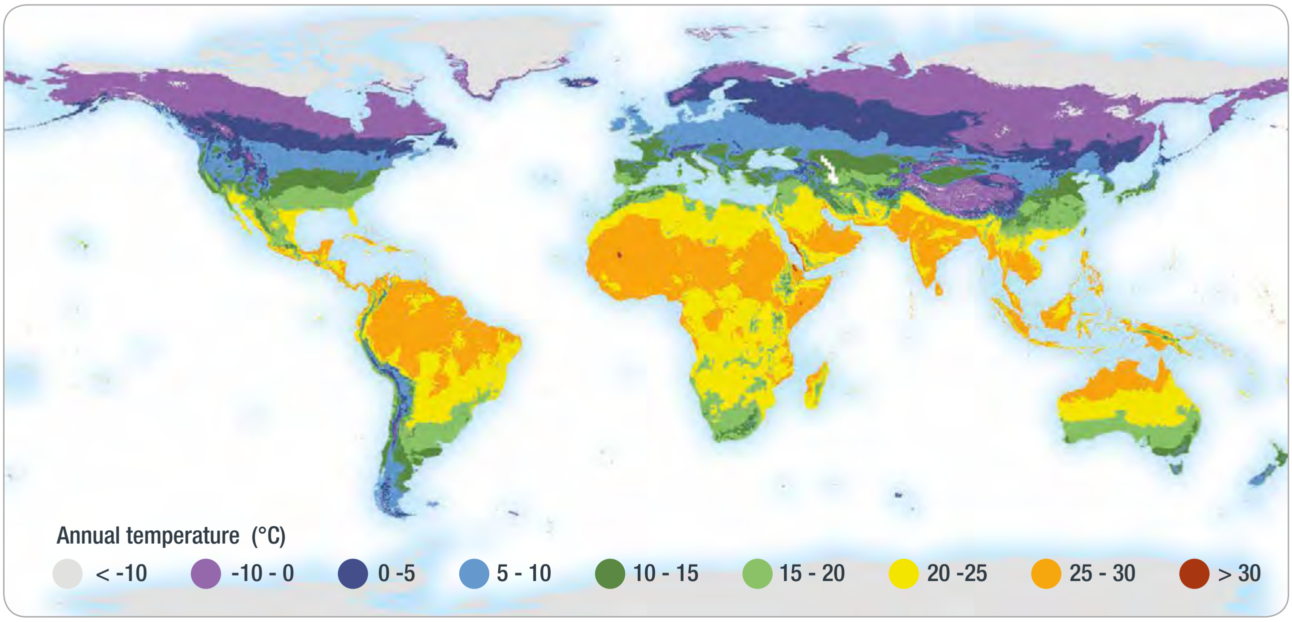
The snow leopard is a top predator of the Himalayan mountains. It eats wild ungulates (such as tahrs, argalis or markhors), but also farmed animals such as sheep.

THE CHEPANG PEOPLE IN NEPAL

“Chepang is one of Nepal’s most backward indigenous groups. They were originally nomads, but are now embracing a semi-nomadic lifestyle. Chepangs are known for shifting cultivation practice (slash-and-burn agriculture), which is their main source of livelihood. Farming alone is not enough for them to sustain their families, so they also depend on hunting, fishing and collecting Githa and Vyakur (shoots and roots), wild yams, and catching bats and wild birds. [. . .] They worship nature. Their main festival is “Bhui Jyasa”/”Bhumi puja” (a prayer to the land). They also worship Chiuri trees. They extract butter from seeds produced by these trees. Butter trees are often gifted to Chepang daughters when they get married.”

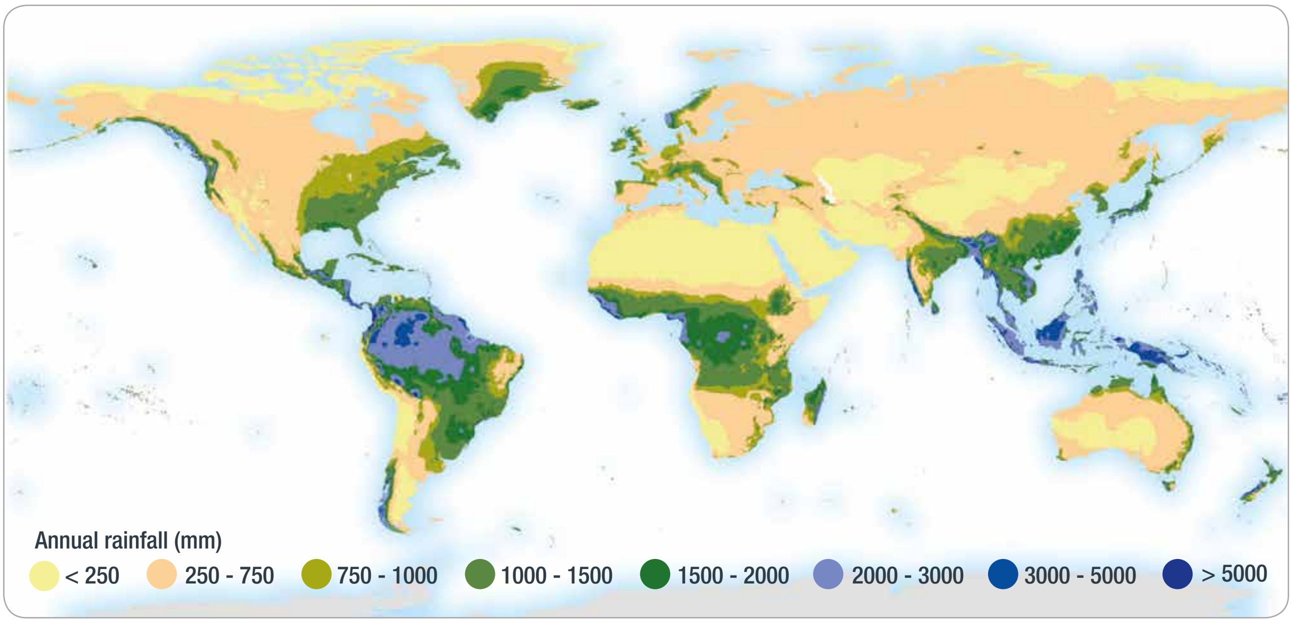
Source: Indigenous voice.
https://www.indigenousvoice.com

MAP SHOWING THE MEAN ANNUAL TEMPERATURES ACROSS THE EARTH (IN °C)



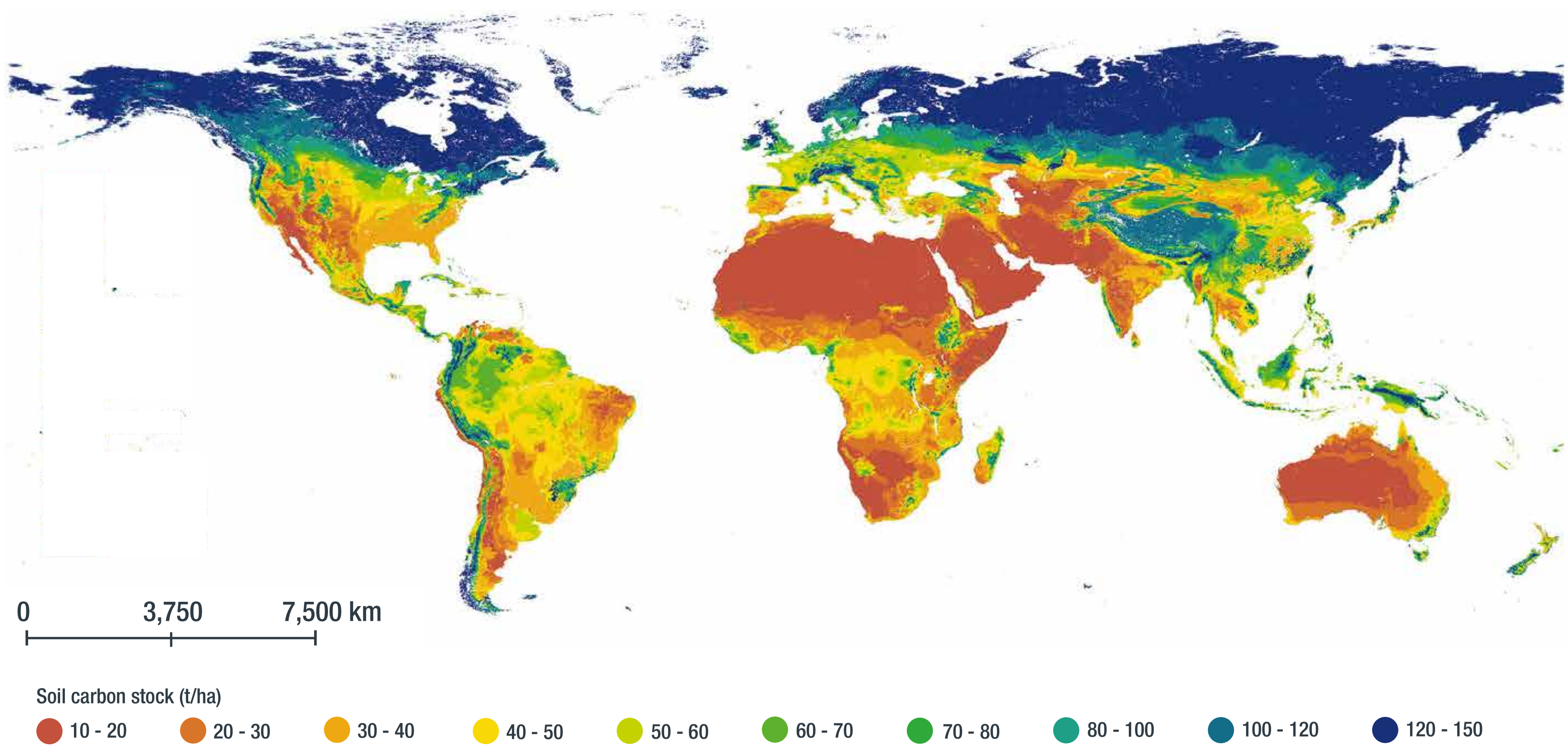
Source: Global Soil Biodiversity Atlas
https://esdac.jrc.ec.europa.eu/public_path/shared_folder/Atlases/JRC_global_soilbio_atlas_high_res-2019-06-13.pdf

MAP SHOWING THE MEAN ANNUAL PRECIPITATION ACROSS THE EARTH (IN MM)



Source: Global Soil Biodiversity Atlas
https://esdac.jrc.ec.europa.eu/public_path/shared_folder/Atlases/JRC_global_soilbio_atlas_high_res-2019-06-13.pdf

WORLD MAP SHOWING THE SOIL CARBON STOCK ACROSS THE EARTH (IN TONNE PER HECTARE)



Source: Soil carbon 4 per 1000, Minasny et al., Geoderma, 2017: https://www.sciencedirect.com/science/article/pii/S0016706117300095

WORKSHEET B2.7

CURIOUS

	ECOSYSTEM NAME	CARBON STORED	BENEFITS OF THE ECOSYSTEM	VOTES FOR THE ADVOCACY
1				
2				
3				
4				
5				
6				
7				

Examples of questions:

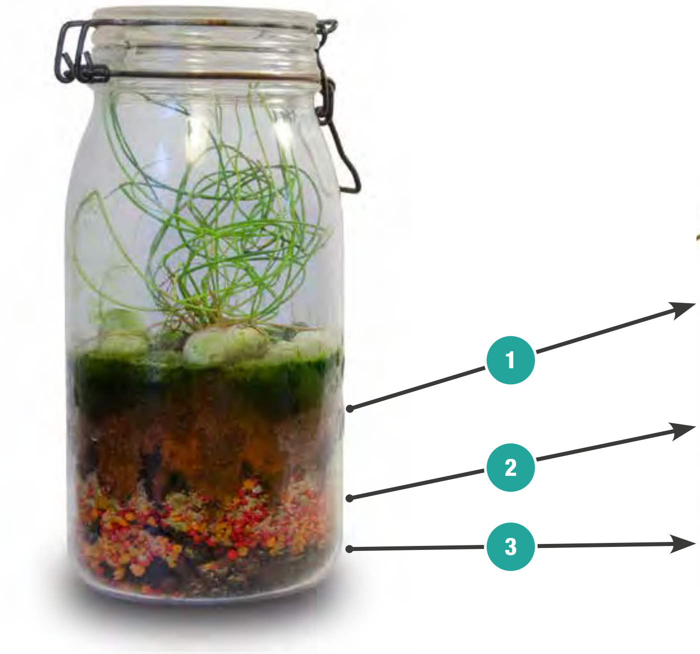
- Name the ecosystems and their associated soils.
- Which soil stores the most CO_2?
- Where are the warmest and coolest regions on the planet?
- Which region has the most rainfall? And the least?
- What are the ecosystem services for animals found in your ecoregion?
- What are the ecosystem services for human communities found in your ecoregion?
- Are there any environmental services or aspects really specific to one ecosystem that are not found in the others?
- Which advocacy did you like best and why?

WORKSHEET B2.8

OPTIONAL: GRID TO ASSESS THE QUALITY OF THE DIFFERENT ADVOCACIES

This grid is given for your information only – you are free to give your own marks.

	SCIENTIFIC CONTENT	WAS THE ADVOCACY ENGAGING?	WAS THE PRESENTATION CLEAR?	ORIGINALITY AND HUMOUR	TOTAL
1					
2					
3					
4					
5					
6					
7					



Source: United State Department of Agriculture (adaptation)

1 **Potting soil (mixture of compost and soil):** rich in organic matter, analogous to litter and humus. This is where the roots will develop. It contains the soil macrofauna (earthworms can be added, for example).

2 **Gravel, sand, clay or coal:** poor in organic matter, allows aeration and contains water. Analogous to clay or sandy soil. Charcoal is not mandatory but it helps to reduce odours.

3 **Pebbles, rock, slate, coarse sand:** mainly minerals and rock. Analogous to bedrock and to the weathered part of bedrock that turns into soil.

ECOREGION	SOIL	PLANTS	COMMENTS
Boreal forest	Poorly developed acidic soil (e.g. heathland), sand and slate	Lichens, mosses (sphagnum), carnivorous plants, fir shoots	Often acidic, wet and cold soils. A bog can be created (mosses and carnivorous plants). Moisten well but do not leave in the heat
Desert	Sand, pebbles and gravel	Cacti and succulents	Little watering, keep warm
Savannah	Potting soil, sand, clay and pebbles	Grasses, small bushes, peanuts	Medium watering, keep warm
Tropical rainforest	Potting soil, humus, gravel	Mosses, epiphytic plants, pothos, orchids	Constant moistening, best is a closed terrarium, keep warm
Temperate forest	Potting soil, sand, gravel	Mosses, lichens, ferns, tree shoots	Medium heat, medium moistening
Arctic zone	Rocks, sand, gravel	Lichens and mosses	Closed terrarium, keep it cold
Mountain	Rocks, acid soil	Little mountainous plants, lichens, mosses	Keep it cold

LESSON B3
THE SOIL IS A MAJOR RESOURCE

MAIN SUBJECTS
Natural sciences

DURATION
~ Preparation: 30 min
~ Activity: 1h20

AGE GROUP
9-15 years

LEARNING OUTCOMES
Students conduct experiments to study the properties of different soils, to find ways to prevent their degradation. They also study their biodiversity and the role of this biodiversity.

They learn that:
~ Soil health is a major concern since it supports human settlements (buildings, agriculture, roads, etc.).
~ Soil contains a rich biodiversity which contributes to food production, through agriculture.
~ Some human activities may lead to soil degradation, such as fertiliser and pesticide use, overcultivation or deforestation. Inherent biodiversity of soil can reduce the need for fertilisers and pesticides.
~ Erosion may represent a threat for soil stability, and thus for human activities. It may be reduced if grasses grow on the soil.

KEYWORDS
Soil, humus, organic matter, biodiversity, decomposers, mineral matter, erosion, soil degradation

TEACHING METHOD
Experimentations, documentary analysis

PREPARATION 30 MIN

EQUIPMENT

- **WORKSHEETS B3.1, B3.2, B3.3, B3.4, B3.5, B3.6** and **B3.7.**
- Several soil samples (they could be brought by your students or you could bring them yourself–try to pick some from different places); see the lesson preparation below.
- Transparent plastic bags–freezer bags, for example–one for each student.
- Optional: computers/smartphones/tablets with internet access–one for each group.
- **For the teams of "biologists"** (for each group of 4):
  - → Magnifying glasses, if possible, binocular microscopes.
  - → Funnels (1 for each soil sample–you might build one using a folded sheet of paper, or a plastic bottle that has been cut in half and placed upside down–see the document in the **WORKSHEET B3.4**).
  - → One plastic bottle cut in half (1 for each soil sample or you can reuse the same one – see **WORKSHEET B3.4**).
  - → Sieves or metal/plastic grids (1 for each soil sample or you can reuse the same one).
  - → Denatured alcohol (70%).
  - → One lamp with incandescent bulbs (no LED–the experiment needs heat).
  - → One black paper to cover the setup.
- **For the teams of "agricultural engineers"** (for each group of 4):
  - → 2 plastic bottles cut in half vertically.
  - → 2 plastic cups.
  - → Strings.
  - → A 15cm x 10cm rectangle of grass (with roots and soil intact) OR some mulch OR dead leaves.
  - → A bottle of water or a watering can.

LESSON PREPARATION

! MANDATORY! TO DO A FEW DAYS OR A WEEK BEFORE THE LESSON.

- **You need to collect soil samples.** Depending on time you can either do it with the students during a dedicated activity (i), ask the students to do it at home (ii), do it by yourself (iii).
  In all cases, you should pick several samples from at least two different areas: from a forest, for example ("natural" soil), and from a cultivated area or near a road ("artificial" soil). Thus each group of students should have a minimum of two soil samples ("natural" and "artificial").
  Make sure your samples are big enough (approximately two to three cups for each group of students) to conduct several experiments.
  You can collect it up to 3-4 days before the experiments, but no longer, so that it remains fresh.

i. Print and distribute **WORKSHEET B3.1** (one for each student). Go outside with your students, examine soils and sample soil following instructions from the worksheet. Take pictures of where you take the soil from.
ii. Print and distribute **WORKSHEET B3.1** (one for each student). Ask your students to sample soil in their home or local environment and to bring samples to the classroom for the day of the activity. Ask them to follow **WORKSHEET B3.1** for instructions. Ask them to take pictures of where they took the soil from.
iii. Collect samples for the classroom, take pictures of where you took the soil from. On the day of the soil analysis activity: print and distribute **WORKSHEET B3.1** (one for each student).

- For the teams of “agricultural engineers”, you will also need, for each group, a 15 cm x 10 cm rectangle of grass (with roots and soil intact). If you cannot get one, consider bringing some mulch and dead leaves instead.
- Print **WORKSHEET B3.3** (one for each student).
- Optional: Print **WORKSHEET B3.2** (one for each group of 4 – you can also show it to the whole class instead of printing it out).
- Print **WORKSHEETS B3.4** and **B3.5** (one for each group of “biologists”) and **WORKSHEETS B3.6** and **B3.7** (one for each group of “agricultural engineers”).

INTRODUCTION 10 MIN

In previous lessons, students have learned that the temperature of the atmosphere is increasing and that this global warming impacts land, which is indispensable for humans in many different ways, including agriculture. Start this lesson by asking your students: *What is the top layer of land that supports every human activity?* The answer is the soil.

Here are some key questions to guide a classroom discussion – write their answers on the board:
- *In your opinion why is soil important?*
- *What does soil contain?*
- *Are all soils the same around the world?*
- *Do you think human actions affect the soil? In what way?*
- *How might you find out the answers to these questions?* They should suggest carrying out research and/or carefully examining the soil.

PROCEDURE 1H

PART 1: A HEALTHY SOIL 15 MIN

1. First, collect the samples brought by the students and place the different bags on a table in a corner of your classroom, with a list of the locations they have been collected from. Have them take a quick look at the samples, but without opening the bags. *What do they notice?* They should notice that the samples look different.

2. Once the students have returned to their seats, divide the class into groups of 4 and give one soil sample to each group. Let them observe it and describe it, using the senses of sight, hearing, touch and smell, in order to complete the table in **WORKSHEET B3.1**. Each group will then have to present to the others what they have discovered. Write the words they used on the board. You can also draw a word cloud, for example, using https://worditout.com/word-cloud/create. This should help your students notice the commonalities *(which words appear the most?)* and differences between the samples. They will also be able to complete the two last rows of the table.

3. Comparing different samples, ask them: *Can you explain the differences you see between the samples?* Actually, the ratio of each component varies with the location of your sample: the one from a garden will be richer in organic matter than the one taken from near a pathway. *According to you, which one might be more suitable for agriculture / plants to grow?* Some samples may contain more rocks and not much organic matter; these may be qualified as “poor” soils.

4. Your students should be able to give a general definition of what constitutes soil: it is a mix of organic (coming from living beings) and mineral (coming mostly from rocks) matter. Some soils contain more organic matter than others. Ask about the differences between “natural” soils and artificial ones.

PART 2: SOIL-UTIONS! 45 MIN

5. For the following activity, explain to your students that they have been asked by a farmer whether or not her professional activities are “harming” the soil as she wishes to be able to continue to cultivate on it; she wonders what are the best practices to adopt in her fields. She has therefore called on a team of biologists (to learn more about soil biodiversity and its use in agriculture) and a team of agricultural engineers (to discover how to develop her plot of land): your students will be assigned to either the biologist team or the agricultural engineer team.

6. Distribute or show **WORKSHEET B3.2** and explain that soil degradation is the decline in soil condition, meaning it may no longer be able to carry out its role. Ask your students: *What do you observe on this map? What might be the consequences of soil degradation for populations living in these regions? According to you, what might be the causes of soil degradation?* They may mention physical causes (such as droughts or floods) or human-related ones (such as fertiliser and pesticide use, overcultivation, deforestation, etc.).

7. Distribute **WORKSHEET B3.3** for them to complete using what they have learned during this activity. Ask them to sort the different causes of soil degradation mentioned into human causes and climate-related ones. If they cannot think of any causes, here are some: floods, overgrazing, droughts, pesticide and fertiliser use, deforestation and torrential rainfall.

8. Then, give each group of 4 a role, either as biologists or agricultural engineers. Make sure that you have about the same number of groups for each role and ask them to carefully read **WORKSHEET B3.4** or **B3.6** to discover what their mission will be.

TEACHER TIP

For younger students, we suggest your class only performs the "biologist" role and thus only conducts one of the two experiments – the one with the Berlese funnel. If you have enough time, then students can conduct both experiments, but one at a time, so it is easier for you to ensure they are following the protocols correctly. It may even be appropriate for you to set up the experiment for your students, so you can be sure they do not harm themselves and that the instructions are carried out properly.

9. Distribute the equipment for each group, listed at the beginning of this lesson.

10. Hand out **WORSKHEET B3.5** to the biologists, and **WORKSHEET 3.7** to the agricultural engineers. The biologists will learn about the role of soil fauna, whereas the engineers will discover that some human activities (palm oil crops, for example) are causes of deforestation, which degrades the soil.

WRAP-UP 10 MIN

Conduct a classroom discussion based on the diagram in **WORKSHEET B3.3** in order to summarise the following elements:

- Soil contains both mineral and organic matter, in varying amounts.
- Soil degradation may be induced by various factors, including human activities and climate-related phenomena.
- Soil is a full-fledged ecosystem, including living beings called decomposers. They play a key role in the decay of organic matter, providing minerals for plant roots through these processes.
- Deforestation linked with human activities makes the soil more vulnerable to degradation.
- A vegetation cover is a good way to prevent soil erosion and degradation. It also makes soil more resistant to floods or torrential rainfall.

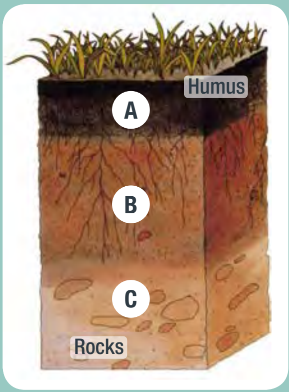
BACKGROUND FOR TEACHERS

Soil can be defined as the material on the surface of the ground in which plants grow: this doesn't take into account human constructions, such as pavements.

SOIL ORGANISATION

From a structural point of view, 3 layers can be distinguished:

→ The first horizon **(A) is the litter layer.** This is made up mainly of dead plant and animal organic material called humus. This horizon is relatively poor in minerals due to washout.



Source: USDA (adaptation)

→ The second one **(B) is a mixture of organic and mineral matter,** as well as the roots of plants. We can also observe small pieces of rocks.

→ The last one **(C), the deepest, consists of bedrock** (calcareous, granite, volcanic rock, etc.) and is called the substratum.

It is also possible to establish a classification based on the size of the different materials – what we call **the soil texture.** Particles can be classified into three groups: sand, silt and clay (the smallest). Soils are generally a combination of these three types, and their relative percentage is used to describe the soil's texture. You can also observe different sized pieces of rock.

SOIL FORMATION

Soil is made up of both **mineral and organic matter,** suggesting there needs to be interaction between bedrock and living organisms in order for it to be formed. This formation is a long process which can take hundreds to thousands of years, and is influenced by many different factors:

1. The first is **climate:** temperature and moisture have a strong influence on soil formation because of their capacity to determine the speed of chemical reactions and provide good living conditions for organisms. Thus, a soil in cold and dry regions will need more time to form than in warm and moist ones.
2. As mentioned before, **living organisms** play a key role in soil formation, in particular, by breaking up rocks into small pieces and producing carbon dioxide that wears away rock.
3. The **topography of the region** is also an important factor, leading to different sun exposure and water retention capacities.
4. The **nature of the bedrock** has a strong influence: this leads to different chemical compositions – for instance, limestone bedrock will provide more calcium to the soil than a granite one.
5. The last factor is, of course, **time!** The older a soil is, the more it is exposed to weathering.

These five factors are enough to explain the diversity in soil we can observe worldwide.

SOIL BIODIVERSITY

One of the main factors involved in soil formation are the decomposers that live within and above the soil. These living beings interact with the other soil organisms in a giant food web which starts with plants: their dead organic matter is then used by the decomposers who turn it into mineral matter that is used as nutrients for plants, leading to a never-ending cycle (see lesson C4, page 182, for more details on this topic). If this biodiversity is threatened, so too is the cycle.

SOIL AND CLIMATE CHANGE

The soil is also a major reservoir of carbon (see lesson A4, page 55) and is considered **both as a sink and a source of carbon.** This carbon is linked with the decomposition process: the soil is mainly made up of organic matter and carbon dioxide is released during decomposition. Soil also plays a role in infrastructure and the stability of buildings; because of the increase in extreme-event frequency and intensity due to climate change, **this stability may be threatened if soil erosion is widespread.**

SOIL DEGRADATION

Many processes affect the soil and thus its role. The IPBES[1] defines **land degradation** as "the many human-caused processes that drive the decline or loss in biodiversity, ecosystem functions or ecosystem services in any terrestrial and associated aquatic ecosystems". In this lesson, we also include climate, soil erosion, deforestation and intensive farming as examples.

1 The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://www.ipbes.net/sites/default/files/spm_3bi_ldr_digital.pdf

WORKSHEET B3.1

TRAINEE

HOW TO OBTAIN A GOOD SOIL SAMPLE

EQUIPMENT

- → Shovel
- → Transparent plastic bag, for example, a freezer bag
- → Marker pen
- → Map or a GPS system
- → Camera or sheet of paper and some pencils
- → Ruler or tape measure

METHOD

1. Record the place of your sampling on a map or use a GPS.
2. Make a drawing or take a picture of the place you choose, e.g., garden, forest, roadside, etc.
3. In order to get a good sample of soil, you have to dig a hole of at least 20 cm in depth and 20 cm wide, using a shovel.
4. Put your sample in the bag and write your initials on it.

WHAT DOES MY SAMPLE LOOK LIKE?

Become familiar with your sample by touching and smelling it and take notes in order to fill in the table below. You may use the following information:

HOW DO I DESCRIBE MY SAMPLE OF SOIL?

If there are stones in the soil as big as the ends of your fingers, this is called 'gravel'. Smaller particles of rock are called sand and you can see them with your eyes. Very small particles are called silt, and you need to use a lens to see them. Silt feels smooth between your fingers. The smallest particles of rock are called clay: you must use a big microscope to see them and they feel slippery in your fingers.

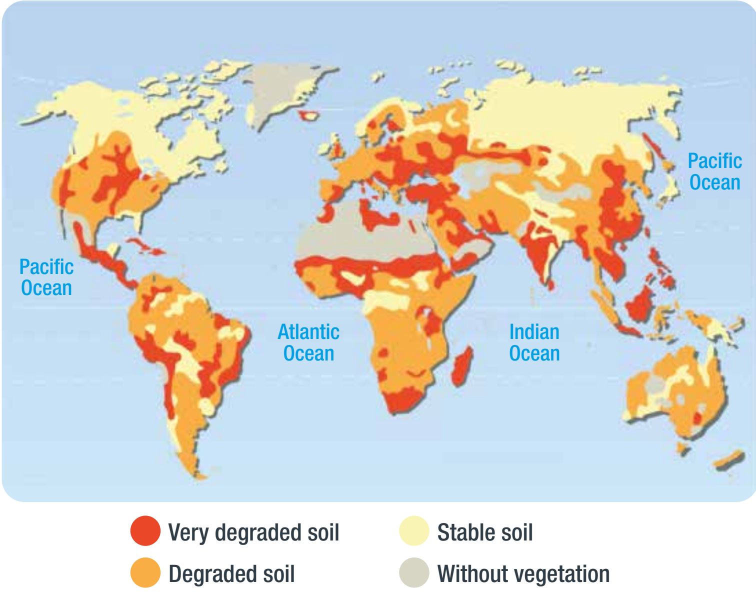
The best soil for agriculture is half sand, some silt and a little clay.

MY SOIL SAMPLE

Where does it come from?
What colour is it?
How does it smell?
What elements can I identify?
What are the commonalities between all the samples?
What are the differences?

You may also see some elements that come from living beings: roots, small pieces of wood, insects, leaves, etc.
Try to identify them as much as you can!

WORLD MAP OF SOIL DEGRADATION



Source: Adapted from an infographic by Philippe Rekacewicz, UNEP/GRID-Arendal. https://www.grida.no/resources/6338

WORKSHEET B3.3

TRAINEE

BIOLOGISTS

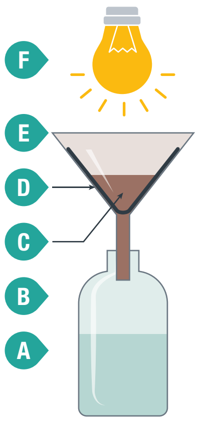
You are a team of biologists and you have to study **soil biodiversity** and understand why a soil with good biodiversity is **useful for agriculture.** You have just received a sample of soil that you have to analyse, as well as some documents to learn more about the role of the living beings you found.

Your mission:

- Using the following protocol, conduct an experiment to collect soil biodiversity.
- Identify as many living beings as you can, using the identification key.
- Compare what you find with other groups that have worked on different samples of soil.
- Using **WORKSHEET B3.5**, explain the role of these living beings and why they are important for agriculture.

DOCUMENT 1: EXPERIMENT – THE BERLESE FUNNEL

In order to trap soil insects, use the following procedure or watch this video.



METHOD

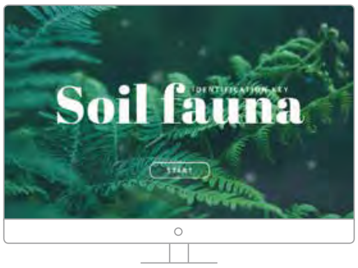
1. Pour a small amount of alcohol into the bottle.
2. Place the filter inside the funnel and fill with some soil.
3. Cover the whole setup with a black paper (optional).
4. Place the lamp above your soil sample and switch it on.
5. Wait a few minutes: you should see some living beings falling into the alcohol.
6. Turn the lamp off and collect the organisms to observe them with your binocular microsope or your magnifying glass.
7. Using **WORKSHEET B3.5**, try to identify as many living beings as you can!

A Liquid for conservation (70° alcohol) B Bottle C Soil sample
D Filter E Funnel F Lamp (source of heat)

BIOLOGISTS' CONCLUSIONS

- List of living beings in my soil sample:
- List of living beings in another group's soil sample:
- How can you explain the differences?
- What is the role of living beings in soil?
- Why are they important for agriculture?

DOCUMENT 2: IDENTIFYING SOME OF THE SOIL FAUNA



Here you can find an interactive identification key that will help you to know which animals are in your soil sample. You just have to click on the correct description on each page, and that will lead you to your animal!

DOCUMENT 3: THE ROLE OF THE SOIL FAUNA

Source: Wim van Egmond 2017. https://youtu.be/Mxp1nnrUG0Q

These pictures present the results of an experiment carried out to study the role of fauna in decomposition of organic matter to turn it into minerals that **are useful for plant growth. The fauna that is involved in organic matter decay are called "decomposers".** The contents of the left compartment were heated in an oven, removing the fauna, but some microscopic mushrooms survived. In the right one, all the faunawas kept intact, including earthworms, isopods, etc.
The results are shown after a fifteen-week period. The leaves on the right side are almost completely incorporated into the soil at the end of the experiment, whereas the ones on the left side are still almost whole, as they were beforehand.

DOCUMENT 4: INTERACTIONS BETWEEN PLANTS' ROOTS AND MICROORGANISMS

This picture shows several structures, called "nodosities", that can develop on the roots of some plants from the legume family, including peas, lentils, soya beans, etc. Nodosities look like small buttons and they appear because some microorganisms (bacteria) associate with the roots, **allowing plants to absorb more minerals from the soil.**

Some roots are associated with other microorganisms, belonging to the mushroom family. These are invisible to the naked eye, but we can observe them in this picture (the white 'mantle' around the tip of the roots) because it has been taken using a microscope. This kind of association between a root and a fungus is called mycorrhiza and **it enhances the plant's capacity to absorb water from the soil.**

AGRICULTURAL ENGINEERS

You are a team of agricultural engineers and you have to study how soil cover may prevent erosion. You have just received two samples of soil: one of just soil and one covered with grass or mulch. You will have to determine which one is the "best" for preventing soil degradation by erosion. **Your mission:**

- Understand the process of erosion by water.
- Using the following instructions, carry out an experiment to compare the reaction of the two different soil samples to watering.
- Compare your results with those of the other groups.
- Using the documents below, explain why human activities may cause deforestation.
- Explain how deforestation may affect the soil as a support and think about a solution for the farmer so she can maximise her yields and preserve the soil.

DOCUMENT 1: WHAT IS EROSION?

When it rains, water that is not used by plants, dried up by the sun, or absorbed by the ground, slowly **flows through the topsoil** downhill into nearby water basins (lakes, rivers, streams, etc.). This water **may transport materials** in the soil from one place to another: this process is called **erosion**. If the water flow is slow, erosion occurs very slowly. If the water flows quickly, then this may lead to a rapid removal of topsoil and can sometimes also cause a **landslide**.

Source: Encyclopædia Britannica, Inc.

DOCUMENT 2: BUILD AN EROSION MODEL [1]

1. Fill two vertically cut bottles with soil.
2. Cover one soil sample with grass OR mulch OR dead leaves and leave the other bottle of soil bare.
3. Suspend the bottles over the 2 cups (you can use string to keep the cups attached to the bottles) at a 25 to 40° angle with the necks facing downward. Get creative in finding ways to accomplish this!
4. Pack the soil in each bottle.
5. Run water over the top of the soil in each bottle (if your soil hasn't had time to settle, you should discard the first few centimetres from each cup).
6. Use your rain simulator (or watering can) to apply equal amounts of water to each bottle.

Watch this video to see the model.

1 This experiment is based on the one from the Soils4Teachers website, available here. The OCE warmly thanks the authors.

AGRICULTURAL ENGINEERS' CONCLUSIONS

- Compare the differences in the clarity of the water in each cup and with other groups (especially if they have different equipment):
- How can you explain the differences?
- Observe the soil surface before, during and after the 'rain event'; which soil is best suited to limit landslides?

WORKSHEET B3.7

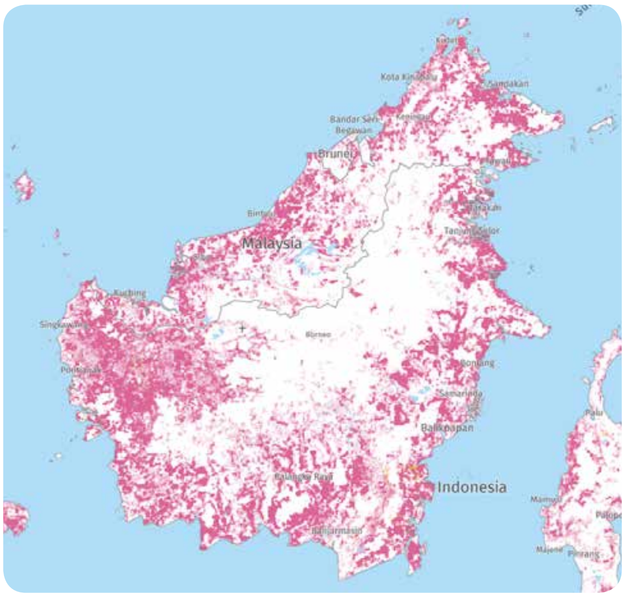
EXPERT

DOCUMENT 3: DEFORESTATION EVOLUTION

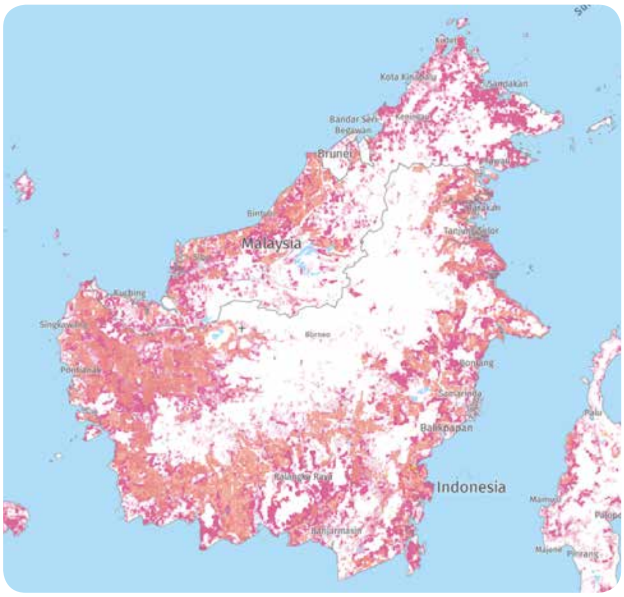
If you have internet access, go on the Global Forest Watch website: https://www.globalforestwatch.org/map.
If not, look at the following maps.

Zoom in on the Southeast Asian islands of Malaysia and Indonesia.

In the menu on the left, click on "Forest change", select only the **"deforestation alerts"** and observe the pink stains: the pinker they are, the more deforestation is present.



Then, click on "land use" and activate the **"palm oil concessions"** button. Observe where the concessions (appearing in orange) are located with reference to the deforestation rate.

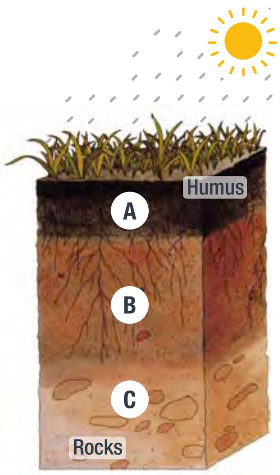


DOCUMENT 4: WHAT MAY BE THE PROBLEM WITH DEFORESTATION?

The soil is structured in different layers. As you can see in the picture, the topsoil (layer A) is where roots start to grow and where we can find the largest biodiversity. The roots play a key role in stabilising the soil.

The topsoil is thus the soil layer with the highest content of minerals and nutrients. These minerals and nutrients are essential for plants to grow. If the topsoil gets flushed away because of torrential rainfall, then it will be harder for the next generation of plants (or crops) to flourish. **With an unfavorable soil, erosion is easier and yields and productivity are more affected.**

The increasingly high demand of a growing population for commodities, such as coffee, soybean, palm oil and wheat, has resulted in the widescale clearing of land for agriculture. Unfortunately, clearing "indigenous" or "native" trees and replacing them with new tree crops that don't necessarily hold onto the soil increases the risk of soil erosion. Over time, as topsoil (the most nutrient-rich part of the soil) is lost, **agriculture is put under threat.**



Source: USDA (adaptation)

LESSON B4
FORESTS, HUMANS AND CLIMATE CHANGE

MAIN SUBJECTS
Natural sciences / Geography

DURATION
~ Preparation: 10 min
~ Activity: 1h (preparatory activity) + ½ day of field trip + 1h of debriefing

AGE GROUP
9-15 years

LEARNING OUTCOMES
On a field trip to the forest, students learn:
~ To get to know their local environment and its resources, using a sensorial approach.
~ To collect samples in a scientific way.
~ To define what is a tree and a forest based on certain criteria.
~ The needs of a tree.
~ That forests are home to a large biodiversity .
~ The impact of climate change on forests and how forests can limit climate change.

KEYWORDS
Forest, tree, photosynthesis, carbon storage, ecosystem, wood, biodiversity, deforestation

TEACHING METHOD
Outdoor teaching, experimentation, documentary analysis

PREPARATION 10 MIN

This lesson focuses on the forest. The activities listed below are only suggestions, to be applied according to your context. The idea here is to allow students to really ‘feel’ the forest in all its dimensions.
It could be appropriate to link this lesson with the previous one on soil.

THINGS TO CONSIDER PRIOR TO THE FIELD TRIP

- Gather information about nearby accessible forests or, if not possible, an urban park rich in a variety of plants and trees.
- Plan how to get there safely.
- Ensure that the legal aspects and requirements for such an activity are fulfilled.
- Ask parents, field experts or colleagues to help out.
- According to the weather forecast, remind students to wear appropriate clothes.
- Establish the safety and behaviour rules, such as no throwing, no sticks, no touching of stinging, sharp or poisonous plants, etc.
- Agree on a signal for the class to gather around you.

EQUIPMENT FOR THE FIELD TRIP

- **WORKSHEET B4.1** (one for 2 groups of 4; you may laminate them to be reused).
- **WORKSHEET B4.2** (one for each student).
- **WORKSHEET B4.3** (one for each group; each topic must be cut out along the dotted lines).
- **WORKSHEET B4.4** (one for each group of 4; you may laminate them to avoid damage).
- Plastic bags to collect samples.
- Camera and/or dictaphone machine and/or smartphone (to record forest noises).
- Gloves (to avoid being in direct contact with specimens that might be toxic).
- Thermometer to measure the air temperature.
- Luxmeter or a similar smartphone application.
- Tape measure or pieces of string and a metre stick/metre wheel – one for each group.
- Calculator or smartphone for each group.
- Books/internet access to answer your students’ questions (you may also use the “Background for teachers”).

EQUIPMENT FOR THE CLASSROOM

- **WORKSHEET B4.5** (one for each pair of students).
- Computer with internet access (one for each pair of students); if not available, print **WORKSHEET B4.6**.

FIELD TRIP PREPARATION 1H (ONE WEEK BEFORE)

In the previous lessons, students learned that many objects they use in their daily life come from natural resources, including plants. Explain that you are going to focus on forests. Tell your students that first of all you will ask them a couple of questions on this subject for their individual reflection. Secondly, a discussion with the whole class will take place and their ideas will be written on a class chart: *Do forests play a part in climate change? How?* (They may mention that the temperature is colder under trees, that trees store CO_2 or that trees provide us with renewable and sustainable raw materials) *How does climate change transform forests?* (Students may mention the impact of droughts or species losses).

To answer the previous questions, you must explore these ones first:

- What is a forest?[1]
- Why is it important?
- How do forests grow?

1. To find out what they think, ask them to draw a forest. Then, keep the drawings and use them after the field trip to see if their thoughts have changed.

2. Split the class into small groups (4 students maximum) and give each group a large sheet of paper. Let them draw and discuss without interruption for about 15 minutes.

3. Bring the students together for a short discussion on the three questions above.

4. Tell them that a good way to find out more about forests is to go on a field trip but they must first prepare well.

5. Ask them: *How will you discover what a forest is? How will you gather samples in the forest?*[2] *Which tools should you use to collect, observe and recognise organisms? How can you keep track of your observations?*

6. Split them again into groups to plan the field trip. Help them out with hints and questions about how:

- **To collect:** your bare hands, gloves, butterfly net, transparent box.
- **To observe or recognise:** the naked eye, magnifying glass, goggles, a ruler, book or identification keys[3].
- **To conserve:** boxes, bottles, bags, marker pens.
- **To take notes or illustrate:** notebook, pencil, eraser, camera, smartphone.

> **TEACHER TIP**
> For a week – until the day of the field trip – a box can be left in the classroom where students can put objects they may find "useful" for their mission.

7. Each group chooses a spokesperson and the whole class decides on a list of equipment, discussing the use and the relevance of each object. Some missing ones might be suggested using questions – *what if you want to observe from a remote place?* or *what if you want to record an observation without hurting yourself / the animal/the plant?* Once this has been agreed on, the list is written in the notebook of each student.

8. Explain that each of the group members will have a specific role and make sure you clarify each one of them:

- The cartoonist
- The photographer
- The scientist
- The sound recorder

9. Together, you can discuss the rules, so the field trip takes place in the best possible way. Make the students note them down.

10. If relevant, set up a list of questions for the expert, if you have contacted one.

FIELD TRIP OBSERVATION HALF A DAY

PART 1: GETTING FAMILIAR WITH TREES AND FORESTS

1H30

1. On the day of the field trip remind the students that they have a common group objective: to gather answers to the questions raised in class through pictures, drawings, samples and recordings.

2. Announce that each group leader is an accompanying adult and is in charge of distributing helpful material, including **WORKSHEET B4.3**. Explain that if they have any questions they can ask you or the other adults to give them a helping hand.

3. Distribute **WORKSHEET B4.2** to each student. Verify their understanding.

4. Invite a few students to recall the field trip rules.

5. Promote sharing of their interesting discoveries to the class after their exploration.

6. Ask the students to rejoin their groups and to randomly draw the roleplay cards (**WORKSHEET B4.1**). Give them the equipment needed and let them explore for 45 minutes.

1 This part of the lesson is largely inspired by module 1 of the FAO, Discovering forests: Teaching guide, Rome, 2018, p. 64; available here: https://www.fao.org/3/i6208e/i6208e.pdf

2 This part of the lesson is based on a resource from *La main à la pâte* about biodiversity by Gabrielle Zimmermann, available here: https://www.fondation-lamap.org/fr/page/20221/la-biodiversite

3 One example in the UK: https://www.nhm.ac.uk/content/dam/nhmwww/take-part/identify-nature/tree-identification-key.pdf

> **TEACHER TIP**
> During a previous visit you made in the area, you may have noticed something interesting for your class: for example, a stump where we can observe tree rings, an anthill, or a noteworthy plant. Once you have gathered your students together, this should be the perfect moment to show it!

7. Once the time is up, gather the whole class together and allow each group 5 minutes to present what they found. They can show samples and pictures, play sounds, or give an explanation about something.

8. Hold a general discussion to check what they have learned:

- *What is a forest?* The idea behind this questioning is to lead the students to the understanding that the forest is an ecosystem in itself. It is indeed made up of trees, but also of smaller trees (shrubs), grasses, mosses and animals.
- *What are trees made of? What are the 4 main parts?* Trunk, branches, leaves and roots. *What are their functions?* Leaves react to light, the trunk conducts the sap, branches allow the leaves to spread out in space to get more light, and roots absorb minerals and water.
- *Why are forests useful for human purposes?* Trees produce oxygen which we need to breathe; wood for..., fruits for..., leaves may also be useful; trees are associated with some cultural/religious beliefs. *And for other living beings?* Have them notice the biodiversity around them.

> **TEACHER TIP**
> You can ask your students to pick one element that may be useful to humans; they will have to present it to the class and explain its utility.

PART 2: FORESTS AND CLIMATE CHANGE 1HR (ON THE FIELD)

9. Once they have become familiar with their environment, explain that you are going to focus on the link between climate change and forests. Have them recall the main facts about climate change. They should mention the major role of carbon dioxide (see lesson A3, page 50). Reiterate some key carbon facts:

- Carbon exists in the Earth's atmosphere mainly as carbon dioxide, but in a very small proportion (circa 0.04%).
- Carbon is an essential building block of life – about half of the dry weight of most living organisms is carbon.
- Forests store 86% of the planet's above-ground (as opposed to in the oceans) carbon, and 73% of the planet's soil carbon.

10. Hold a class discussion: *How do trees handle carbon dioxide? Where is it stored? How much carbon can a tree store?*

11. Explain that they will become scientists; they have developed a quick carbon calculator which allows us to get a rough measure of the amount of carbon stored in trees. Give a copy of **WORKSHEET B4.4** to each group so they have a fact sheet to answer the first question.

12. Ask the students to read the carbon calculator conversion chart. If they do not understand the headings, explain it to them. *How are they going to measure the dry weight of the tree?* They need to find out the circumference. *Where are they going to measure the circumference?* Use the diagram to explain chest height circumference. Demonstrate how to measure a tree. *Is one measure enough? How many times should we measure? Should it be the same way/at the same place each time? How do we make sure no measurement is lost?* Record on a table. Each group collects a tape/piece of string and a metre stick, selects a tree, and starts measuring.

13. Ask them to calculate the average circumference for their tree and estimate the dry weight and carbon stored in the tree. *How will this carbon finally be released from the tree?* By respiration, chopping down and burning, rotting or decomposing.

> **TEACHER TIP**
> To help your students realise the amount of carbon "their" tree can store, you can ask: *How many 1kg sugar packages would they have to pile up to represent this?*

14. Have them gather around you and ask: *How can forests help us with climate change?* Trees can store carbon in their trunk, roots and leaves and use it to manufacture their food – as sugars; in this way they can help us reduce the concentration of greenhouse gases and, thus, climate change.

WRAP UP 5 MIN

Before departing join in a circle and ask the students what they have learned from this activity. *What surprised you and what did you enjoy most? What did you learn about trees, forests and climate change? What did you like about working in small groups?*

BACK IN THE CLASSROOM 1H

1. Once you are back in the classroom, each group can gather what they collected and put pictures, drawings, sounds and / or videos on this collaborative wall: https://digipad.app/p/62197/a489296342453. Before posting, ask them to describe precisely what their pictures, sounds, videos, etc. represent and where exactly they found them in the forest.

2. If some questions remain unanswered, ask your students: *How can you answer these questions? Experiments? Documentary analysis?* etc.

3. Ask them: *Do you think every forest in the world looks alike? How can you explain their differences?* Distribute **WORKSHEET B4.5**.

4. If you have internet access, tell your students to go on the Global Forest Watch website (https://www.globalforestwatch.org/map/) so you can see the impact of deforestation on a global scale. If you do not, you can distribute **WORKSHEET B4.6**.

TEACHER TIP
On the Global Forest Watch website, you can tick / untick different options. We suggest focusing on Forest Changes > Deforestation alert, and untick all the others.

5. Discuss how forests, even ones far away in other countries, are still very important to your community. They serve as large "carbon sinks", accumulating carbon and giving back more than 20% of the oxygen for the whole planet.

- *What would it be like if there were no trees or forests?*
- *How would our lives be different?*
- In groups, or as a class, have students discuss how they knowingly – and unknowingly – may contribute to deforestation of the world's forests. Ask: *How can you help prevent or solve such issues in your own community and the world?*

WRAP UP 5 MIN
Hold a classroom discussion allowing your students to summarise what they learned during these sessions:
- *What is a tree / forest?*
- *What are their needs?*
- *How can forests help tackle climate change?*

Take a moment to acknowledge their feelings: *Did you enjoy going outside? Which memories will you keep about this experience?*

BACKGROUND FOR TEACHERS

WHY GO ON A FIELD TRIP?
This lesson gives you an opportunity to teach outside the classroom, on a field trip. The idea is to give some disciplinary input: a forest isn't only an association of trees, but also contains many different types of organisms and represents an ecosystem in itself. Trees need light to grow and use carbon dioxide in order to do so; thus, they play a key role in climate change mitigation.

This lesson also allows **the development of various skills,** including the recognition of forest sounds, collecting samples in a scientific way, and working in groups.

But the most important aspect of a field trip is **to make students aware of their local environment:** by allowing them to link their knowledge with a concrete local place, they will be more involved in the protection of this forest and more likely to engage in action to tackle climate change.

TREES AND CLIMATE CHANGE
Trees differ from most other plants by their perennial (long-lived) woody trunk. They can be classified as deciduous trees, which lose their leaves seasonally, such as oaks, or as evergreens, like pines. Trees grow both in height and in diameter. Some tree species have visible rings that facilitate the study of their growth, as they represent the inner living layers under the bark that have aged and become inactive. These growth rings reflect seasonal changes (including changes in climate). The leaves have a large surface area: they capture both light and gases for respiration and photosynthesis. The trunk is solid and gives height to the tree. The roots grow far and wide beneath the soil to obtain water and nutrients.

Trees play a key role in climate change since they turn high amounts of atmospheric carbon into sugars (see lesson A5, page 71) or store this carbon in the soil. On the other hand, deforestation and wood burning lead to the release of carbon that was previously stored, increasing the atmospheric level and thus contributing to climate change.

WORKSHEET B4.1

CARTOONIST

My role
I make drawings of everything I can to describe how the forest is organised, the different trees, the leaves, the animals, etc.

SCIENTIST

My role
I pick up samples of leaves, branches, dead insects, etc. I try to identify them and put them in small bags to bring back to the classroom. I can also use some measuring tools (size, temperature, luminosity, etc.)

I have to wear gloves!

PHOTOGRAPHER

My role
I take pictures to have a clear vision of what is a forest, what is a tree, which animals I can observe, and the results of the experiments the scientist conducts.

SOUND AND VIDEO RECORDER

My role
I record the sounds of the forest and I try to identify them. I can also make some small movies of what I see.

CARTOONIST

My role
I make drawings of everything I can to describe how the forest is organised, the different trees, the leaves, the animals, etc.

SCIENTIST

My role
I pick up samples of leaves, branches, dead insects, etc. I try to identify them and put them in small bags to bring back to the classroom. I can also use some measuring tools (size, temperature, luminosity, etc.)

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SOUND AND VIDEO RECORDER

My role
I record the sounds of the forest and I try to identify them. I can also make some small movies of what I see.

WORKSHEET B4.2

TRAINEE

My name: ....

My role: What will I have to do?

Write down the questions about forests that have been raised in class
e.g. What is a tree and how does it take in nourishment? What is a forest? Why is it important?

How do you feel being among trees? Use your senses...

Is the forest different from what you imagined?

Describe the elements that you gathered to answer these questions.

Which questions remain unanswered?

On the back of this sheet, make a labelled sketch which represents the exchanges between a tree and its environment (soil and atmosphere). On your sketch, you should use these terms: leaves – trunk – branches – roots – oxygen – carbon dioxide – soil – atmosphere – sunlight – water – minerals.

WORKSHEET B4.3

TRAINEE

HELPING HAND

To be explained to the students when they need it... but not too early!

WHAT IS PHOTOSYNTHESIS?

Photosynthesis is a chemical reaction that takes place in the **leaves of trees and plants.** When leaves are exposed to sunlight, **they can use this light to turn carbon dioxide from the atmosphere into sugars.** This is how they can make their own food! During this process, plants and trees also need water absorbed from the soil by their roots and they release oxygen that goes into the atmosphere.

Note: **Plants also breathe!** In sunlight, they perform both photosynthesis and respiration but only respiration in darkness.

WHAT IS A TREE?

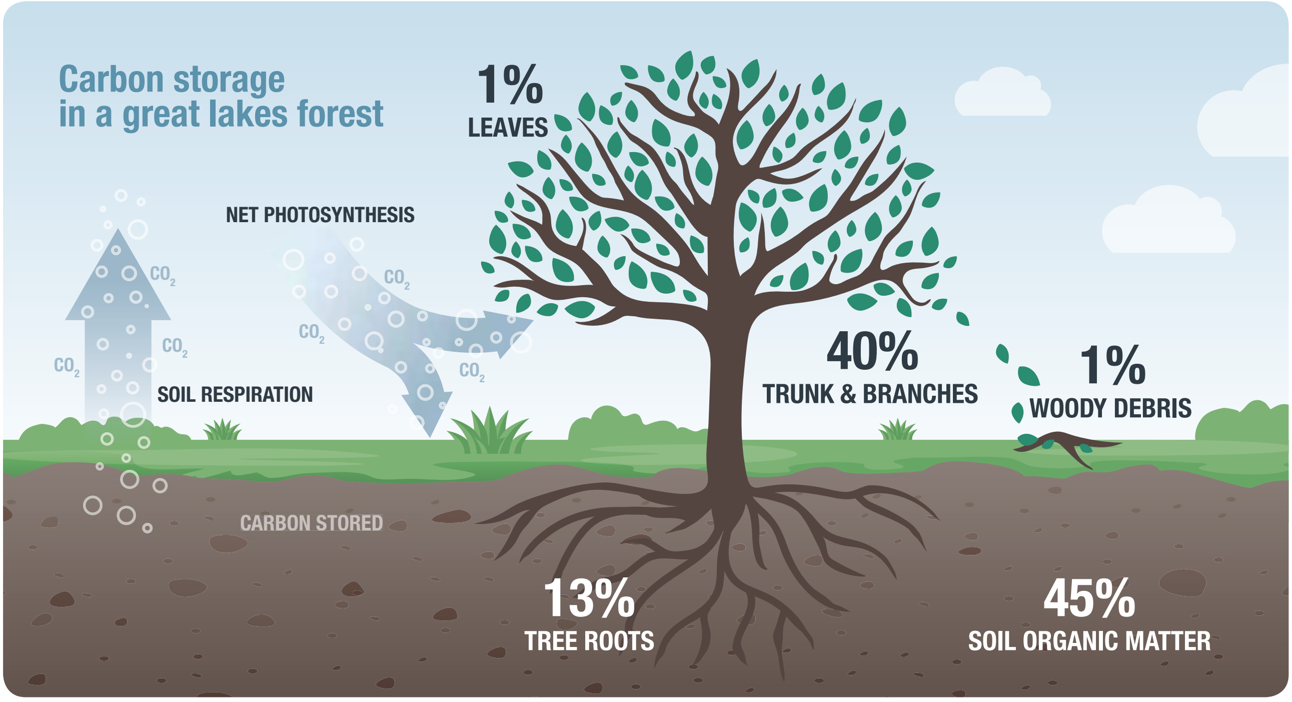
A tree is a plant that grows wood in its trunk. This wood contains **conducting vessels** which act in the same way as your veins carry blood: instead of blood, trees have sap that transports sugar, minerals and water, just as your blood does!

WHAT ARE THE DIFFERENT PARTS OF A TREE?

A tree consists of four visible parts, and one hidden under the ground:

- → **The leaves,** in presence of light and contact with the atmosphere, absorb carbon dioxide and release oxygen.
- → **The branches** to which the leaves are connected.
- → **The trunk** contains wood and is surrounded by bark.
- → **The flowers, fruits and seeds:** during the flowering season, flowers bloom and once pollinated, transform into fruits that contain seeds.
- → **The roots,** which are hidden in the soil, that absorb minerals and water.

WHAT BECOMES OF THE CARBON DIOXIDE IN PLANTS?

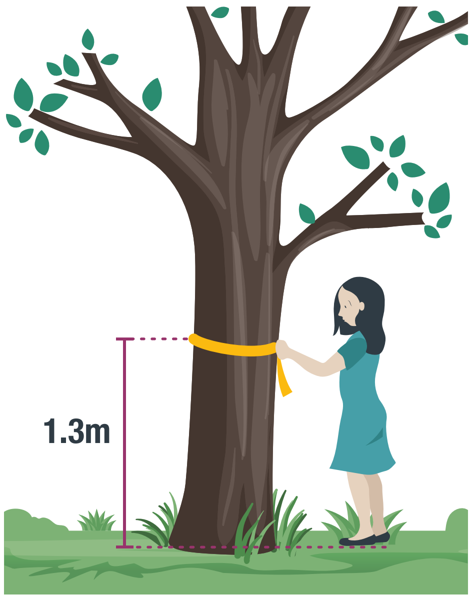


Source: Adapted from an infographic on http://climategreatlakes.com/feature-accounting-for-carbon/

INSTRUCTIONS FOR MEASURING THE TREE AND CARBON STORED

1. Measure the circumference of the tree at the standard chest height (1.3m) with a tape measure. Record the measure in centimetres. Repeat at least tree times, at the same height, and calculate the average measure.
2. When you've got your average circumference, look at the table to convert this to dry weight. Use the nearest value in the table to your value.
3. Because half of the dry weight of the tree is carbon, you then need to divide your answer by two. This tells you how much carbon is stored in the tree.
4. You can also calculate how much carbon dioxide was absorbed to create this carbon store, by multiplying your figure for carbon by 3.67.

CIRCUMFERENCE (CM)	TREE DRY WEIGHT (KG)
50	106
100	668
150	1,1964
200	4,221
225	5,771
250	7,641
275	9,842
300	12,410
325	15,350
350	18,700
400	26,674



These values, provided by Forest Research, are for an individual hardwood tree in Westonbirt Arboretum. They can be used as an example. Trees will grow at different rates across the world depending on, for example, the species, soil, drainage, slope aspect and climate conditions.

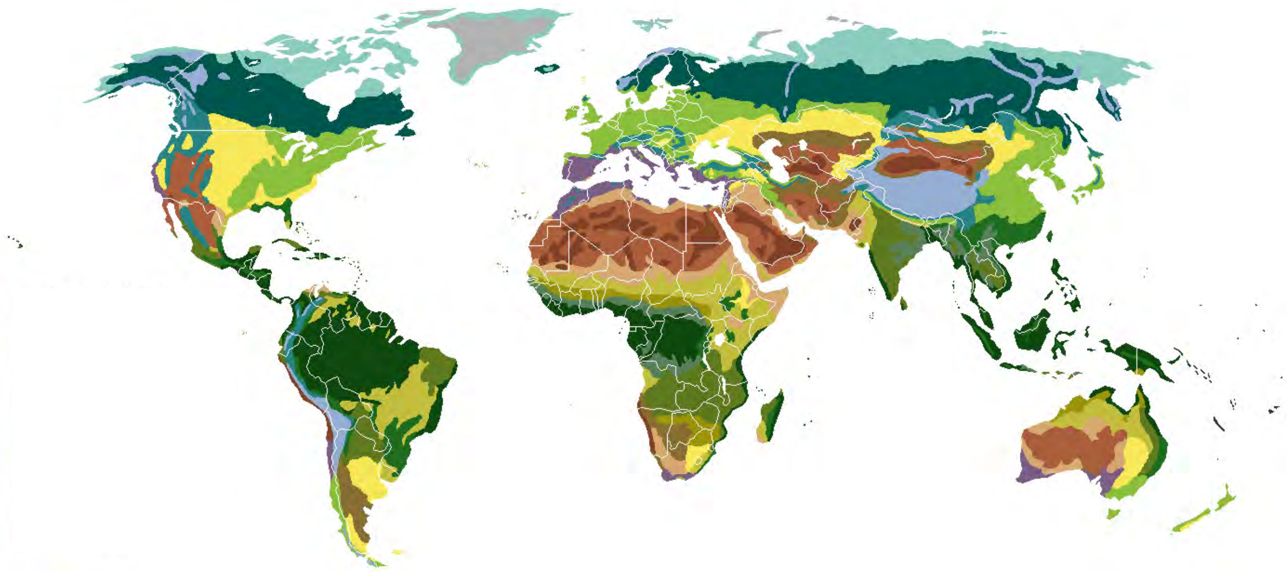
WORKSHEET B4.5

CURIOUS

These two maps represent the different types of vegetation and climates around the world.

- Make a list of the different types of forests.
- Which type corresponds to the one you visited on your field trip?
- How can you explain the distribution of these forests?
- What may be the consequences of climate change on these forests?

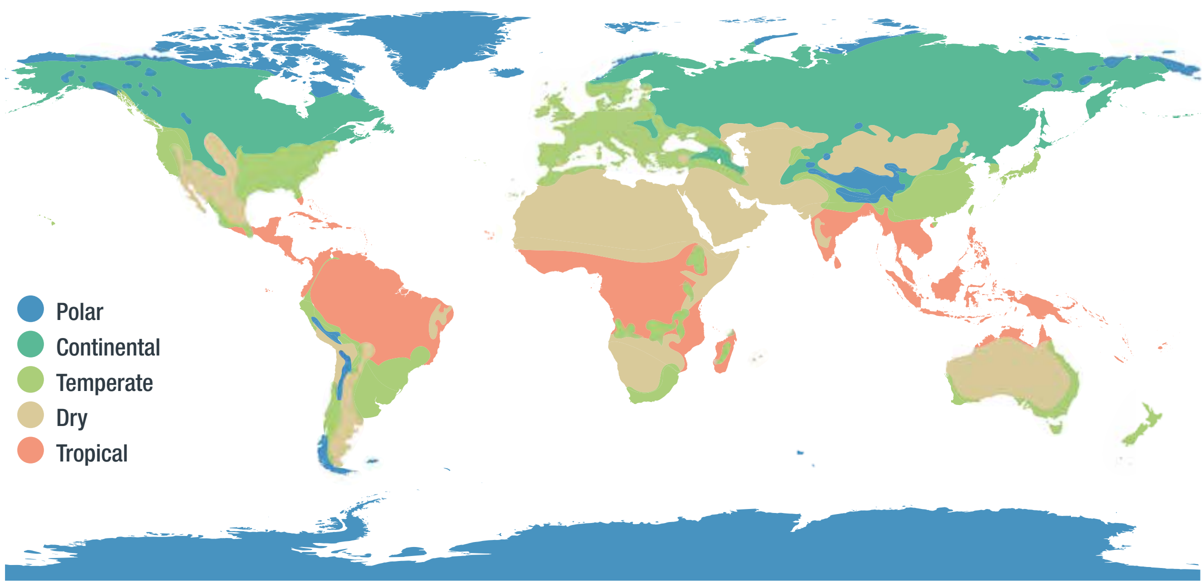
MAP OF THE VEGETATION TYPES AROUND THE WORLD



- Ice sheet and polar desert
- Tundra
- Taiga
- Alpine tundra
- Grass savanna
- Tree savanna
- Montane forest
- Temperate steppe
- Subtropical rainforest
- Tropical rainforest
- Subtropical & tropical dry forest
- Monsoon forest
- Arid desert
- Xeric shrublands
- Dry steppe
- Semiarid desert
- Mediterranean vegetation
- Temperate broadleaf forest

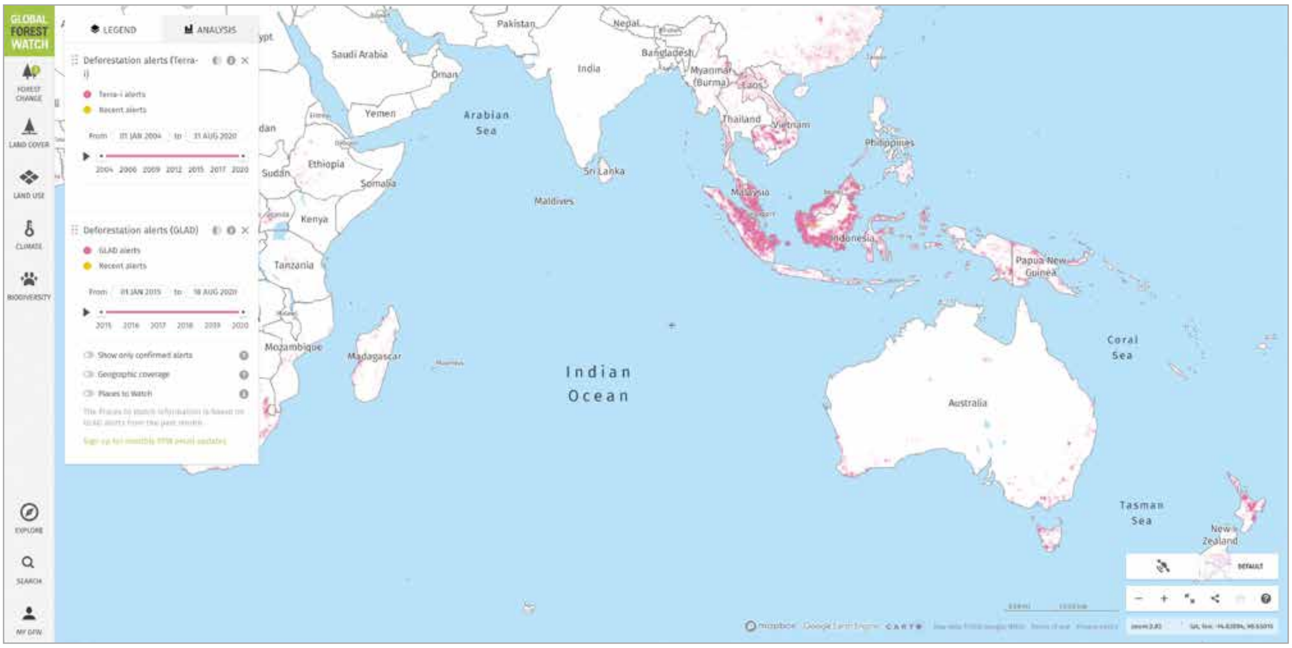
Source: Wikipedia

MAP OF CLIMATE CLASSIFICATION



These two maps represent the progression of deforestation – using deforestation alerts – between 2004 and 2020. The pinker the stains, the more deforestation present.

MAPS OF DEFORESTATION ALERTS



Source: https://www.globalforestwatch.org/map

SEQUENCE C

LAND AND CLIMATE CHANGE

The Earth is a complex system where everything is interconnected and in equilibrium; thus, climate **change necessarily affects the whole system, and its repercussions are very diverse.**
In this sequence, four lessons focus on the climate regulation that land can provide and the consequences of climate change on land. While directly affecting land, the impacts of climate change are also observed in key ecosystems and human communities, and the issues involved are also explored here. These lessons are based on documentary analysis and games (roleplay and cards).

LESSON LIST

◉ Core lesson ○ Optional lesson

LESSON C1
MAKING CHOICES: HOW DO YOUR FOOD HABITS IMPACT CLIMATE CHANGE?

MAIN SUBJECTS
Natural sciences / Geography

DURATION
~ Preparation: 10 min
~ Activity: 1h (Part 1), 1h30 (Parts 1 & 2)

AGE GROUP
Part 1: 9-15 years
Part 2: 12-15 years

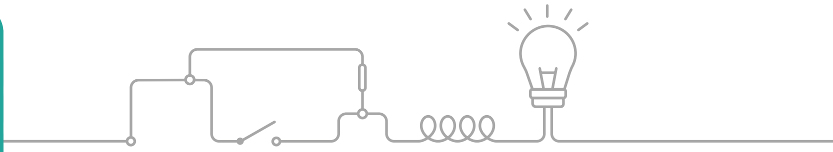
LEARNING OUTCOMES
Students explore the link between food security and climate change by playing a multimedia animation game or a card game.

Students learn that:
~ As the human world population is growing, the demand for food and land is growing as well.
~ The way we produce food has an impact on climate change.
~ The way we consume food also has an impact on climate change since agriculture is a major greenhouse gas (GHG) emitter. Changes in diet have a significant impact on reducing GHG emissions.
~ A certain amount of food is lost or wasted with significant regional differences.

KEYWORDS
Carbon footprint, water footprint, soil surface, dietary choices, inequalities, food security, food resources, food lost / wasted

TEACHING METHOD
Card game / Multimedia animation game, documentary analysis

TEACHER TIP
This lesson is designed for two levels of student ability: Part 1 is more suitable for 9-12 year-old students, whereas Parts 1 and 2 are geared towards 12-15 year olds.



PREPARATION 10 MIN

EQUIPMENT
- The day before this lesson takes place ask your students to bring in food packages with nutritional / processing information about the product. Clarify that you would like to have different categories of food (noodles, rice, fruits, yoghurts, vegetables, biscuits, etc.).
- For under 12 year-old students: **WORKSHEET C1.1** (one for each group).
- For 12 to 15 year-old students: **WORKSHEETS C1.1, C1.2** and **C1.3** (one for each group).
- Optional: **WORKSHEET C1.4** (one for each student).
- Option 1: Computers (at least one for each pair of students) to use the online multimedia animation game: The impact of our food.
- Option 2: Card-game version (**WORKSHEETS C1.5 AND C1.6**): The impact of our food.

LESSON PREPARATION
1. Print the worksheets you need, according to your students' level of ability (**WORKSHEETS C1.4** and **C1.6** are optional – see point 2 below and the wrap-up section).
2. The multimedia animation game can be used either online or offline (you may download it beforehand). If no computers are available in the school, this session can also be done as an "unplugged activity" (**WORKSHEETS C1.5** and **C1.6**) or at home (if the students have an internet connection at home).

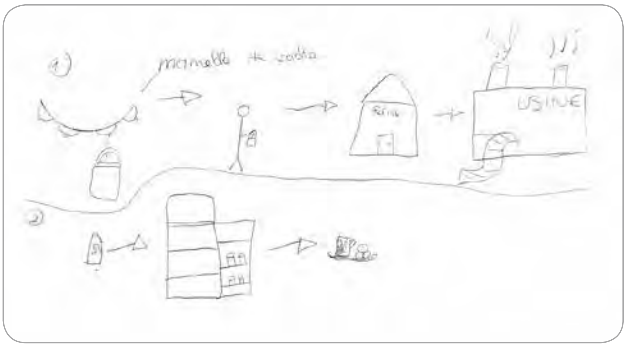
INTRODUCTION 5 MIN

In the previous lessons, the students learned that soils may be used in different ways for human life purposes, including resource production. Discuss with your students the importance of agriculture for humans. They will mention production of food and you can then move the discussion towards the link between food and climate change.

PROCEDURE 45 MIN (PART 1), 1H15 (PART 1+ 2)

PART 1: DIETARY CHOICES[1] 45 MIN

1. Pick one of the food packages your students brought to school and draw a diagram that shows the different processing steps this food went through until it reached their plate. Let them define the interconnected web of resources, systems, activities and people that gets the food on to their plate, and the country it comes from. *What parts of the system use fossil fuel energy, transportation and water? Look at your diagram. Are there any other elements missing?* Explain that this diagram can give us some idea about **the ecological footprint of this food:** in this case, it measures the natural resources that humans require to produce this type of food and the associated pollution (due to transportation and energy consumption associated with processing), including land, water and fossil fuel use.



One example of diagram: cow's udder → farm → factory → fridge

2. Then, distribute or show to the whole classroom **WORKSHEET C1.1** and ask: *Do you think every family's diet has the same impact on the planet? Why? How can you prove this?* Let them take a look at the packages they brought: *Can you find any information about such an impact on these packages?* They probably won't be able to.

3. In order to compare the impact of different foods on the planet – and thus on climate – explain that they will have to rank different foods according to either their carbon footprint[2], their water footprint, or the soil surface which is needed to grow and deliver them – from farm to fork.

> **TEACHER TIP**
> The multimedia animation can be used with these three different parameters (carbon footprint, water use and land use). We suggest you and your class choose the one you would like to start with, and then focus on the others after the game – the students may even restart it to try the game using another parameter.

4. Allow your students to go online to the website, follow the instructions to play the animation game, and discuss it with their group.

> **TEACHER TIP**
> Two levels of difficulty are available for this game: on the "easy level", students only have 10 cards to rank. On the "hard level", they have 20. We recommend you start with the easy level so they can become familiar with the game. For younger students, we recommend doing a short game with the whole classroom:
> - → Show 2 cards and ask them to sort them. They may write their answer on a blackboard.
> - → When you clap your hands, they have to show their answer.
> - → Discuss the results together and give the correct answer.
> - → Repeat the steps a few times.

5. Once the game is over – depending on the time left – ask them to compose their favourite meal using the cards and let them calculate the associated carbon footprint. They can then discuss it with their classmates.

6. Compare the carbon footprint results and have them take a look at the other parameters – water footprint and soil surface: *Will the ranking be the same with these?* They should notice that some foods need a large amount of land surface, meaning many trees need to be cut down; that some cause much pollution by using fossil fuels; and that others require a large amount of water. Thus, it is not so easy to choose the foods that have the lowest impact on the planet.

7. Ask your students: *How can you explain that meat "pollutes" more than vegetables or fruits?* Answer: because when we eat beef, we have to feed the cattle we eat with crops, whereas we can eat the crops directly if we eat soya, for instance.

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1 Some parts of this lesson have been inspired by the "Interactive Guide: Understanding Food and Climate Change", from the Center of Ecoliteracy, available here: https://foodandclimate.ecoliteracy.org/interactive-guide/page_0002.xhtml. The OCE would like to warmly thank the authors.

2 Lesson D4 in this handbook takes a deeper look at carbon footprints, including not only the one associated with food but also many other human activities.

TEACHER TIP
Keep in mind that the greenhouse gas emission values, as well as the water and soil surface values provided in this lesson are merely indicative, since they depend on multiple factors, such as the country considered, the agricultural practices used, etc. You may try to find more precise values for your own country / region if you wish.

8. By taking another look at the pictures on **WORKSHEET C1.1** and at their answers to the questions in point 2 above, your students should be able to see if they were right about which family has the biggest/lowest footprint and to justify their choices based on what they have just learned. They may also think about other consequences of dietary choices on the environment.

TEACHER TIP
For students under 12, we suggest you stop the lesson here. For more advanced students, you can continue with the next questions.

9. Using **WORKSHEET C1.2**, ask students to justify their answers and to suggest some solutions in order to reduce the impact of our dietary choices on the environment. They should see that one option to reduce this impact is choosing a more plant-based diet.

PART 2: FOOD WASTE AND LOSS 30 MIN

10. Have your students take a closer look at the pictures on **WORKSHEET C1.1**, asking them to compare the quantities of food eaten by the different families, and encourage them to think about this statement: *We are buying and eating more food than we used to and more than we need to. What might be the consequences?* They will certainly mention food waste and loss. Explain the differences between these two terms.

11. Ask them if they consider whether all countries are equally responsible for food waste and loss and have them analyse **WORKSHEET C1.3** to answer this question and explain the results.

WRAP-UP 10 MIN

After this lesson, your students should be able to establish the link between our dietary choices and the consequences for climate change, by keeping in mind that the more plant-based our diet, the better it is for the environment. Discuss with them any potential actions they could take to reduce the greenhouse gas emissions associated with food.
If you wish to go further, distribute **WORKSHEET C1.4** so they can tick the actions they are willing to do. This may also be a way for them to discuss this subject with their families and friends. You can even let them debate the different propositions and their willingness – or unwillingness – to take some of these practical steps: this could lead to reflecting on the “social weight” of such decisions.

OPTIONAL EXTENSION: GLOBALISATION

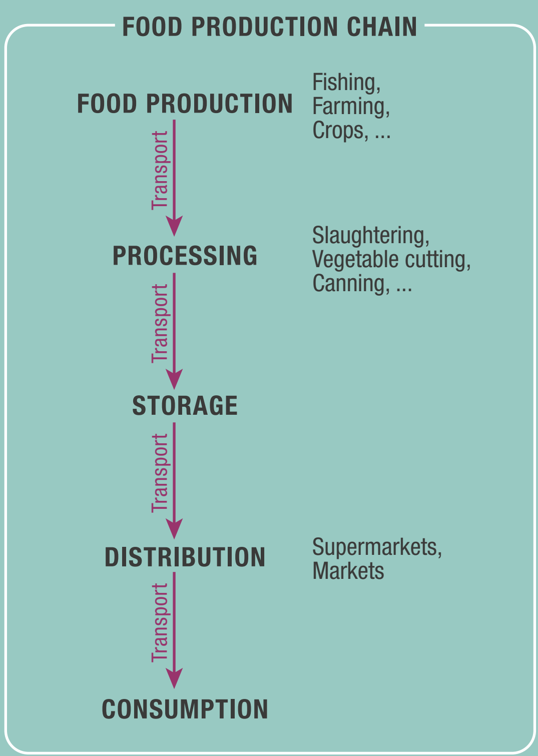
Globalisation refers to worldwide, interconnected cultures and economies and the exchange of products and ideas. For instance, the food in your supermarket may have been caught or grown in Japan, Mexico, Canada or Spain. Sushi is a global food that’s eaten around the world with consequences for fish stocks. Have students take on different roles (fisherman, restaurant owner, consumer, economist, wildlife biologist, government trade official, etc.) and debate the pros and cons of globalisation. Some questions to consider: *What is globalisation? What has led to globalisation? Does everyone benefit? Are there negative effects?*

BACKGROUND FOR TEACHERS

THE LINK BETWEEN FOOD AND CLIMATE CHANGE

Food and climate change are linked in many ways: deforestation–to make room for farms and livestock–which releases carbon dioxide during wood combustion, ruminant digestion (mainly burps), rice paddies which produce methane, and fossil fuels used during the whole farming and shipping process are all sources of greenhouse gases.

The world's food system is responsible for about **one quarter of the greenhouse gas emissions** that humans generate each year[1]. This includes every step that our food goes through, from farm to fork. The diagram below illustrates these different steps:



Each step will almost certainly require fossil resources–to produce electricity, for example, or to power a tractor–unless renewable energy is used. The final stage of transportation to the place of consumption may not require fossil resources if one goes shopping on foot or by bicycle.

However, not all stages will have the same carbon footprint, or the same water or soil surface requirements: thus, a livestock farm will always emit more greenhouse gases (mainly methane and N_2O) than a crop farm, and will also consume more water, over a larger surface area. Hence, meat and dairy account for around 14.5% of the world's greenhouse gases each year.

Moreover, **it is this stage of production that will have the most significant impact on the environment, and not the transport,** as one might think. Thus, it appears that reducing your meat consumption and choosing seasonal products will have a greater impact on reducing your carbon footprint than eating locally or going shopping on foot or by bicycle. You can get a better idea of the impact of each step from the examples on **WORKSHEET C1.3**.

DIET CHANGE: WOULD THIS HELP?

Changes in your diet would certainly help. The IPCC, using different studies, has concluded that some diets are clearly more climate friendly than others. If everyone on the planet became vegan, this could reduce greenhouse gas emissions related to land use by up to one third (of the reference "business-as-usual" scenario for 2050), and even lead to forest regeneration. However, if you do not want to go "that far", you can still consider eating less meat and dairy products–this would still reduce your emissions. Some climate-friendly recipes can be found in The new climate focus cookbook available online.

FOOD LOSS AND WASTE

According to the FAO, food loss is defined as the reduction of edible food during production, postharvest handling and processing, whereas food discarded by consumers is considered as food waste[2]. Cutting food loss and waste may then also be a way to reduce your footprint, even if some options for the reduction of food loss do not depend on our personal choices as consumers–harvesting techniques or infrastructure, for example (see the Scientific Overview, pages 17-18, for more details on this topic).

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1 Reducing food's environmental impacts through producers and consumers, J. Poore and T. Nemecek, Science, June 1, 2018. https://www.science.org/doi/10.1126/science.aaq0216

2 https://www.fao.org/platform-food-loss-waste/flw-data/en/

WORKSHEET C1.1 PAGE 1/2

TRAINEE

Peter Menzel is an American photographer who travelled across twenty-four countries to study the way people eat around the world. He asked different families to pose with the food they bought for one week.

MALI Food expenditure for one week: $26.39 USD

CHAD Food expenditure for one week: $1.23 USD

USA Food expenditure for one week: $341.98 USD

GERMANY Food expenditure for one week: $325.81 USD

ITALY Food expenditure for one week: $260.11 USD

MEXICO Food expenditure for one week: $189.09 USD

JAPAN Food expenditure for one week: $317.25 USD

EQUADOR Food expenditure for one week: $31.55 USD

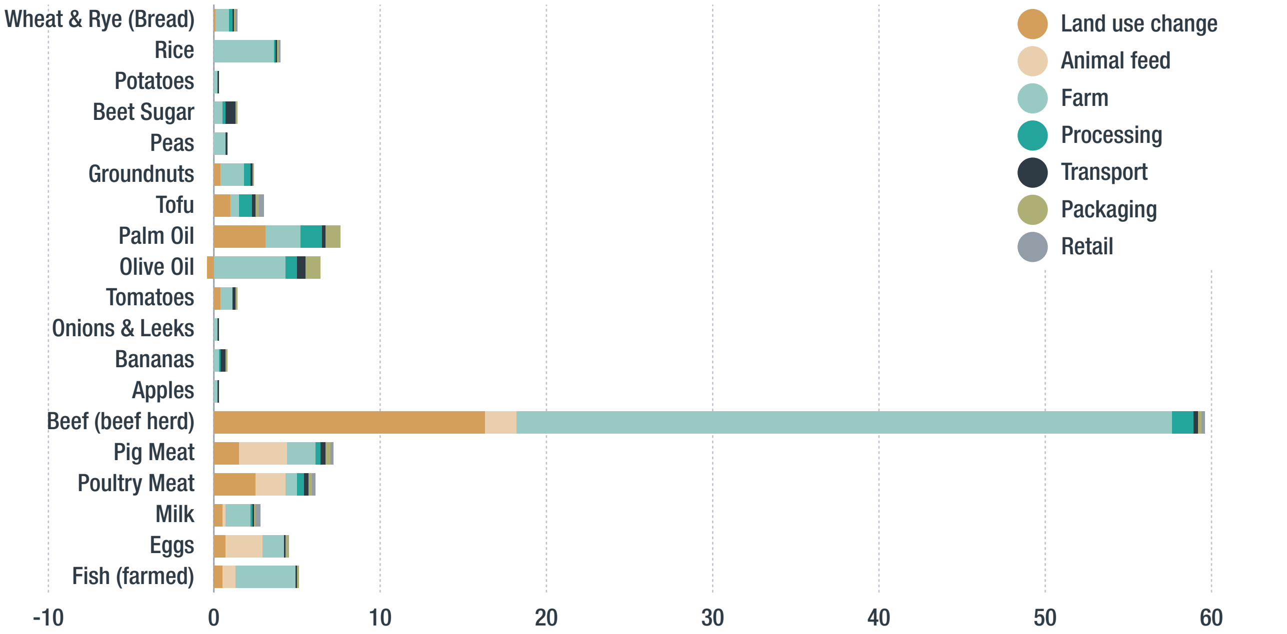
WORKSHEET C1.2

EXPERT

The graphs below explore the consequences of food production on the planet, depending on the food we eat and our diet. They present the GHG emissions (in kg CO_2 equivalent) for different foods.

- Using the emissions associated with the different lifecycle stages of food products, how can you explain that a diet change will be more efficient than buying local food, in reducing GHG emissions?
- By comparing the GHG mitigation potential of different diets, explain which one may be the best to provide every human with food in the future as well as to limit climate change.

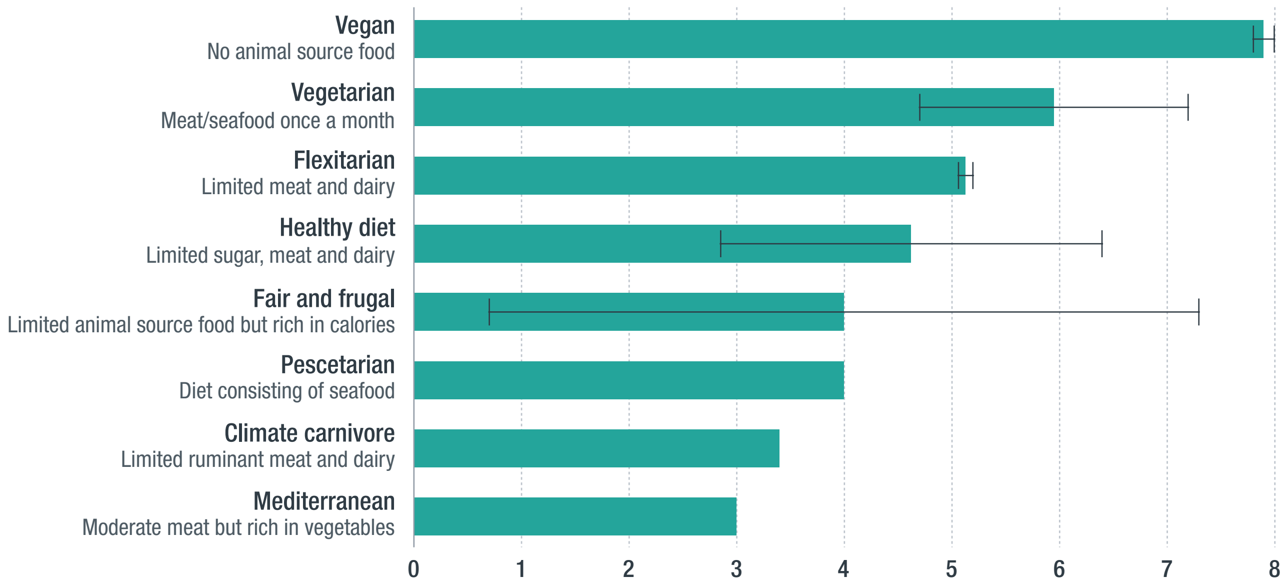
GHG EMISSIONS BY LIFECYCLE STAGE FOR DIFFERENT FOOD PRODUCTS (KG CO_2 EQUIVALENT PER KG PRODUCT)



Source : https://ourworldindata.org/environmental-impacts-of-food

GHG MITIGATION POTENTIAL OF DIFFERENT DIETS (GT CO_2 EQUIVALENT PER YEAR)

Mitigation potential means the capacity of a diet, in this case, to reduce GHG emissions: the higher the potential, the less the diet is responsible for GHG emissions. According to some studies, if a vegan diet is followed worldwide, this may lead to a reduction in land areas allocated to food production, allowing forest regeneration and reducing land-based GHG emissions by one third.



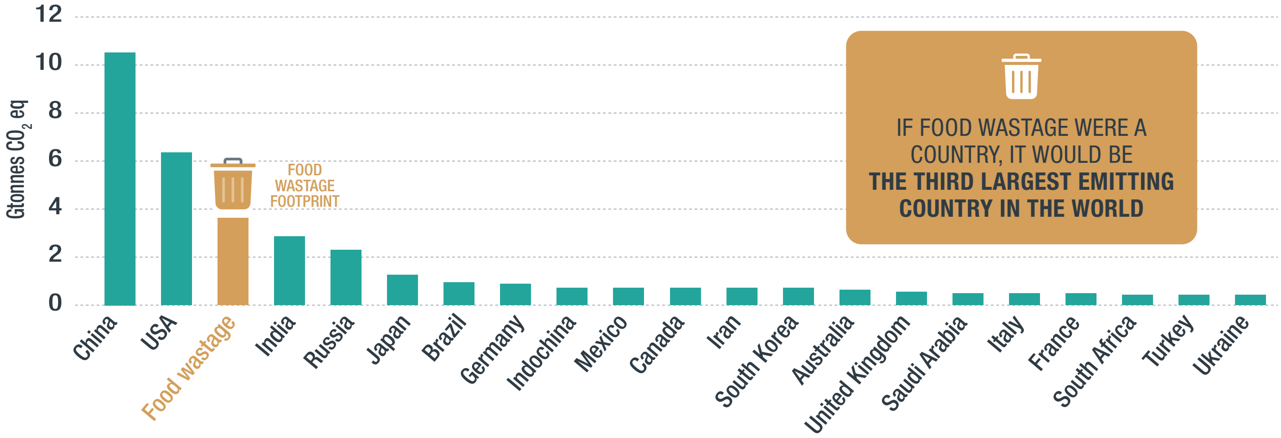
Source : IPCC Special Report on Climate Change and Land, Chapter 5.
https://www.ipcc.ch/site/assets/uploads/sites/4/2021/02/08_Chapter-5_3.pdf

WORKSHEET C1.3

EXPERT

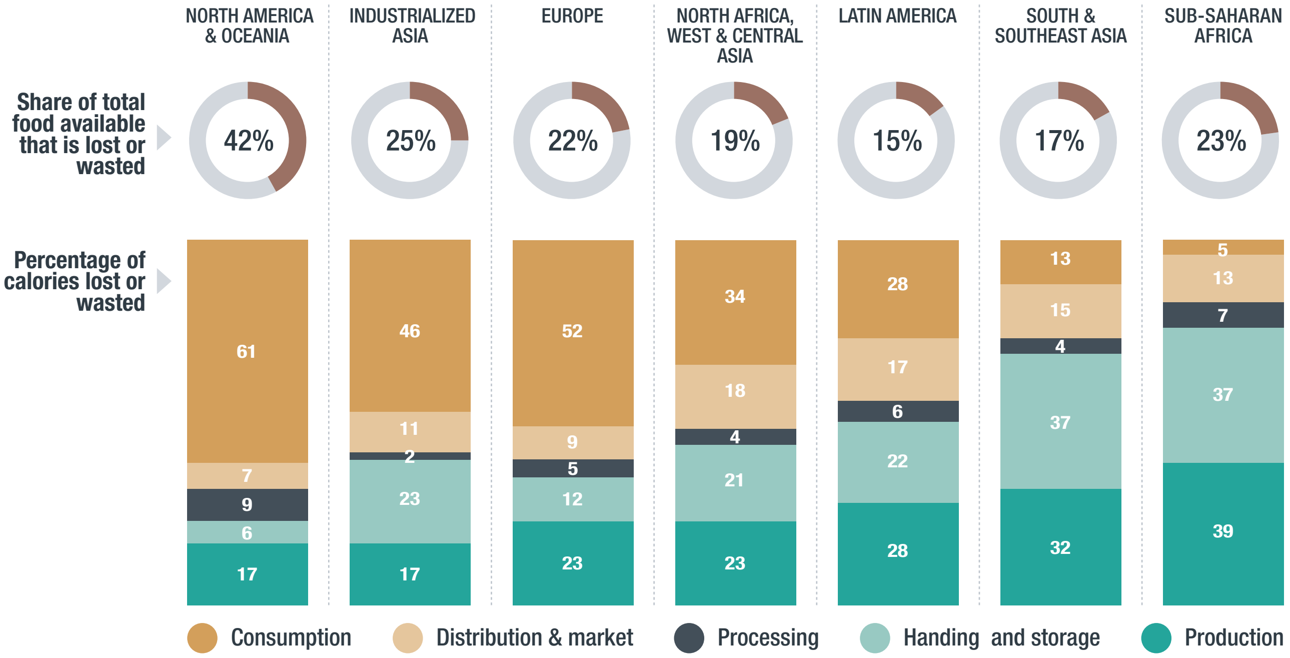
CARBON FOOTPRINT OF GLOBAL FOOD WASTAGE

The results represent the total GHG emissions of each country, in gigatonnes CO_2 eq (1 gigatonne = one billion tons).



Source : Data from WRI's Climate Data Explorer. Adapted from Food and Agriculture Organization of the United Nations, 2011, Food wastage footprint & Climate Change. Reproduced with permission. http://www.fao.org/3/bb144e/bb144e.pdf

WHERE FOOD LOSS AND WASTE OCCURS ALONG THE FOOD SUPPLY CHAIN VARIES AMONG REGIONS



Note: Numbers may not sum to 100 due to rounding. Data are from the year 2009.
Source : Data from WRI analysis based on FAO (2011c). Adapted from Creating a Sustainable Food Future. https://research.wri.org/sites/default/files/2019-07/C_REP_Food_Course1_web.pdf

What does each step represent?

- **Production**: damage to fruits and vegetables due to farming equipment; spills and attacks by insects and other diseases; loss of animals resulting from disease and death during breeding; fish discards.
- **Handling and storage**: loss resulting from handling of fruits during harvesting, storage and transportation from farms to the processing centres; animal loss at the slaughterhouses; rotting meat and fish at storage centres.
- **Processing**: food product waste associated with: juices, canned food and pastry production; food peeling, slicing, boiling and sorting; loss of milk during pasteurisation; fish canning, smoking and salting.
- **Distribution**: at the market centres, lots of fresh food rots and is thrown away; in wholesale and retail shops, foods reach their expiry date and are thrown away.
- **Consumption**: Lots of pastries, milk, juices and food are thrown away because they are spoilt or not eaten.

WORKSHEET C1.4

CURIOUS

In the table below is a list of changes you or your family could consider making. You may already be doing some of them. Others may be straightforward to adopt. Each one has a star rating against it: The greater the number of stars, the greater impact the action is likely to have.

		I'M ALREADY DOING THIS	I WOULD CONSIDER THIS	THIS WOULD BE REALLY HARD
Reduce meat consumption by 50%	★★★	☐	☐	☐
Stop eating meat	★★★★★	☐	☐	☐
Reduce cheese and butter consumption by 50%	★★	☐	☐	☐
Stop eating cheese and butter	★★★	☐	☐	☐
Reduce milk and yoghurt consumption by 50%	★	☐	☐	☐
Stop drinking milk and yoghurt	★★	☐	☐	☐
Cook vegetarian meals twice a week	★	☐	☐	☐
Cook vegetarian meals four times a week	★★	☐	☐	☐
Eat only seasonal fruits and vegetables	★★	☐	☐	☐
Join a local organic box scheme	★	☐	☐	☐
Grow some of my own vegetables, salads or fruit	★	☐	☐	☐
Buy air-freighted food only on special occasions	★	☐	☐	☐
Stop buying all air-freighted food	★★	☐	☐	☐
Buy 75% of food produced locally or in my country	★★	☐	☐	☐
Eat frozen food only on special occasions	★	☐	☐	☐
Reject all frozen food except produce gathered from the garden	★★	☐	☐	☐
Reject all frozen food and ready meals and get rid of the freezer	★★★	☐	☐	☐
Reduce amount of processed food by 50%	★★	☐	☐	☐
Reduce amount of ready meals and fast food by 50%	★★	☐	☐	☐
Reject all aluminium cans	★	☐	☐	☐
Reduce food waste by 50%	★★	☐	☐	☐
Give up drinking bottled water and soft drinks	★	☐	☐	☐

Source : This table is taken from In Time for Tomorrow? The Carbon Conversations Handbook by Rosemary Randall and Andy Brown, 2015.

WORKSHEET C1.5

RULES FOR PLAYING THE GAME OFFLINE

The cards on WORKSHEET C1.6 need to be printed out, preferably on thick paper or cardboard and laminated. **Every group needs to have a full set of cards.**

We suggest playing this game in small groups, with a maximum of 4 students in each group.

GOAL OF THE GAME

The first player who no longer has any cards is the winner.

SET-UP

a) All the players sit around a table.

b) The first card is randomly drawn, and all the players choose the game's parameter (this could be carbon footprint, water use or land use).

c) The cards are shuffled.

d) Three cards are dealt to each player, which they place in front of them with the side bearing the information facing downwards. **They must, under no circumstances, check the reverse side of the card.**

e) A draw pile is formed with the remainder of the cards and is placed in the middle of the table, with the information-bearing side down.

f) The first card of the deck is placed in the middle of the table and is flipped so that its information is showing.

LET'S PLAY!

The players play in turn, in a clockwise direction.

The first player must place one of their cards next to the first card, already on the table:

→ If they think that the ecological footprint of the food on their card is less than that of the food on the first card, they place their card to the left of the first card.

→ If they feel that their card's ecological footprint is greater than that of the food on the first card, they place their card on the right side.

Once played, the player flips the card over to confirm whether its value does correspond to the space it occupies in the line:

→ If the card is properly placed, it remains where it is, information-bearing side up.

→ If the card isn't properly placed, it is returned to the draw pile. The player must then take the first card from the draw pile and place it, information side down, alongside their other cards.

The second player:

→ If the first player has properly played their card, then the second one can place their card to the left or right of the two cards already in play, or between them.

→ If the first player hasn't placed their card correctly, the second player then has to place their card to the right or left of the card.

→ If this card is properly placed, then it remains in place with the information-bearing side up. The line is reorganised so that there's always a space between each card.

Then it is the next player's turn, and the game continues until one player has correctly placed all of their cards.

Note: **If two cards present the same value, the order in which they have been placed does not matter.**

WORKSHEET C1.6 PAGE 1/8

This chart shows all the foods available in the game. You can print them on both sides.

BEET SUGAR
7g

CARBON FOOTPRINT
0.013 kg CO_2-eq

WATER USE
1.53 L

LAND USE
0.013 m^2

NUTS
30g

CARBON FOOTPRINT
0.02 kg CO_2-eq

WATER USE
138.34 L

LAND USE
0.43 m^2

CANE SUGAR
7g

CARBON FOOTPRINT
0.022 kg CO_2-eq

WATER USE
4.34 L

LAND USE
0.014 m^2

PEAS
90g

CARBON FOOTPRINT
0.03 kg CO_2-eq

WATER USE
13.47 L

LAND USE
0.26 m^2

MAIZE
75g

CARBON FOOTPRINT
0.04 kg CO_2-eq

WATER USE
5.33 L

LAND USE
0.08 m^2

SUNFLOWER OIL
10ml

CARBON FOOTPRINT
0.04 kg CO_2-eq

WATER USE
10.08 L

LAND USE
0.18 m^2

RAPESEED OIL
10ml

CARBON FOOTPRINT
0.04 kg CO_2-eq

WATER USE
2.38 L

LAND USE
0.11 m^2

OLIVE OIL
10ml

CARBON FOOTPRINT
0.05 kg CO_2-eq

WATER USE
21.42 L

LAND USE
0.26 m^2

ONIONS
100g

CARBON FOOTPRINT
0.05 kg CO_2-eq

WATER USE
1.40 L

LAND USE
0.04 m^2

CANE SUGAR
7g

THE IMPACT OF OUR FOOD

NUTS
30g

THE IMPACT OF OUR FOOD

BEET SUGAR
7g

THE IMPACT OF OUR FOOD

SUNFLOWER OIL
10ml

THE IMPACT OF OUR FOOD

MAIZE
75g

THE IMPACT OF OUR FOOD

PEAS
90g

THE IMPACT OF OUR FOOD

ONIONS
100g

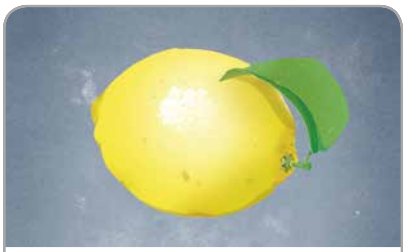
THE IMPACT OF OUR FOOD

OLIVE OIL
10ml

THE IMPACT OF OUR FOOD

RAPESEED OIL
10ml

THE IMPACT OF OUR FOOD



LEMONS
130g

CARBON FOOTPRINT
0.05 kg CO_2-eq
WATER USE
10.79 L
LAND USE
0.12 m^2

GROUNDNUTS
20g

CARBON FOOTPRINT
0.06 kg CO_2-eq
WATER USE
36.43 L
LAND USE
0.18 m^2

CARROTS
150g

CARBON FOOTPRINT
0.06 kg CO_2-eq
WATER USE
4.20 L
LAND USE
0.05 m^2

PALM OIL
10ml

CARBON FOOTPRINT
0.07 kg CO_2-eq
WATER USE
0.06 L
LAND USE
0.02 m^2

APPLES
180g

CARBON FOOTPRINT
0.07 kg CO_2-eq
WATER USE
32.40 L
LAND USE
0.11 m^2

LEEKS
150g

CARBON FOOTPRINT
0.08 kg CO_2-eq
WATER USE
2.10 L
LAND USE
0.06 m^2

BROCCOLI
150g

CARBON FOOTPRINT
0.08 kg CO_2-eq
WATER USE
17.85 L
LAND USE
0.09 m^2

POTATOES
150g

CARBON FOOTPRINT
0.11 kg CO_2-eq
WATER USE
15.19 L
LAND USE
0.23 m^2

BANANAS
180g

CARBON FOOTPRINT
0.11 kg CO_2-eq
WATER USE
13.80 L
LAND USE
0.23 m^2

CARROTS
150g

—

THE IMPACT OF OUR FOOD

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GROUNDNUTS
20g

—

THE IMPACT OF OUR FOOD

Office for Climate Education

LEMONS
130g

—

THE IMPACT OF OUR FOOD

Office for Climate Education

LEEKS
150g

—

THE IMPACT OF OUR FOOD

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APPLES
180g

—

THE IMPACT OF OUR FOOD

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PALM OIL
10ml

—

THE IMPACT OF OUR FOOD

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BANANAS
180g

—

THE IMPACT OF OUR FOOD

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POTATOES
150g

—

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BROCCOLI
150g

—

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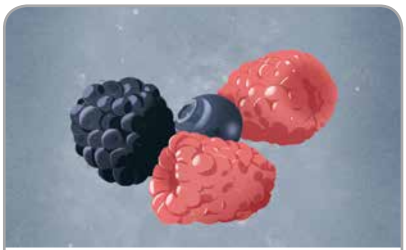
WHEAT AND RYE (BREAD)
75g

CARBON FOOTPRINT
0.15 kg CO_2-eq
WATER USE
61.35 L
LAND USE
0.35 m^2



BERRIES AND GRAPES
120g

CARBON FOOTPRINT
0.18 kg CO_2-eq
WATER USE
50.40 L
LAND USE
0.29 m^2

SOY MILK
200ml

CARBON FOOTPRINT
0.2 kg CO_2-eq
WATER USE
5.60 L
LAND USE
0.14 m^2

TOFU
100g

CARBON FOOTPRINT
0.2 kg CO_2-eq
WATER USE
9.28 L
LAND USE
0.22 m^2

EGGS
1 egg

CARBON FOOTPRINT
0.26 kg CO_2-eq
WATER USE
32.30 L
LAND USE
0.35 m^2

RICE
75g

CARBON FOOTPRINT
0.32 kg CO_2-eq
WATER USE
163.33 L
LAND USE
0.21 m^2

TOMATOES
180g

CARBON FOOTPRINT
0.32 kg CO_2-eq
WATER USE
55.50 L
LAND USE
0.12 m^2

CHEESE (COW)
20g

CARBON FOOTPRINT
0.37 kg CO_2-eq
WATER USE
85.62 L
LAND USE
1.35 m^2

COFFEE
1 cup

CARBON FOOTPRINT
0.4 kg CO_2-eq
WATER USE
Insignificant
LAND USE
0.30 m^2

SOY MILK
200ml

THE IMPACT OF OUR FOOD

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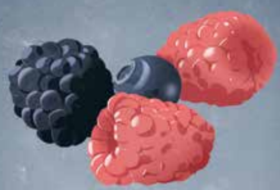


BERRIES AND GRAPES
120g

THE IMPACT OF OUR FOOD

Office for Climate Education

WHEAT AND RYE (BREAD)
75g

THE IMPACT OF OUR FOOD

Office for Climate Education

RICE
75g

THE IMPACT OF OUR FOOD

Office for Climate Education

EGGS
1 egg

THE IMPACT OF OUR FOOD

Office for Climate Education

TOFU
100g

THE IMPACT OF OUR FOOD

Office for Climate Education

COFFEE
1 cup

THE IMPACT OF OUR FOOD

Office for Climate Education

CHEESE (COW)
20g

THE IMPACT OF OUR FOOD

Office for Climate Education

TOMATOES
180g

THE IMPACT OF OUR FOOD

Office for Climate Education

WORKSHEET C1.6 PAGE 7/8

CASSAVA
200g

CARBON FOOTPRINT
0.45 kg CO_2-eq

WATER USE
Insignificant

LAND USE
0.61 m^2

DARK CHOCOLATE
1 square

CARBON FOOTPRINT
0.46 kg CO_2-eq

WATER USE
5.40 L

LAND USE
0.68 m^2

MILK (COW)
200ml

CARBON FOOTPRINT
0.64 kg CO_2-eq

WATER USE
125.60 L

LAND USE
1.80 m^2

FISH (FARMED)
100g

CARBON FOOTPRINT
0.98 kg CO_2-eq

WATER USE
265.52 L

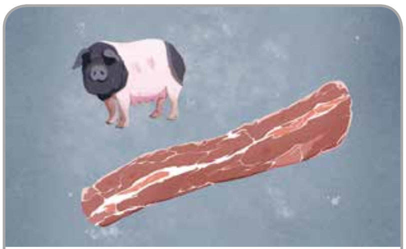
LAND USE
0.61 m^2

POULTRY
100g

CARBON FOOTPRINT
0.99 kg CO_2-eq

WATER USE
66.45 L

LAND USE
1.24 m^2



PORK
100g

CARBON FOOTPRINT
2.11 kg CO_2-eq

WATER USE
308.58 L

LAND USE
3.06 m^2

LAMB & MUTTON
100g

CARBON FOOTPRINT
3.31 kg CO_2-eq

WATER USE
149.21 L

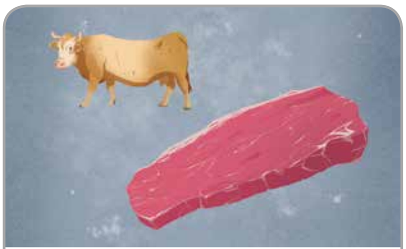
LAND USE
30.64 m^2

CRUSTACEANS (FARMED)
100g

CARBON FOOTPRINT
3.62 kg CO_2-eq

WATER USE
478.38 L

LAND USE
0.40 m^2



BEEF
100g

CARBON FOOTPRINT
8.72 kg CO_2-eq

WATER USE
126.96 L

LAND USE
28.60 m^2

MILK (COW)
200ml

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DARK CHOCOLATE
1 square

THE IMPACT OF OUR FOOD

Office for Climate Education

CASSAVA
200g

THE IMPACT OF OUR FOOD

Office for Climate Education

PORK
100g

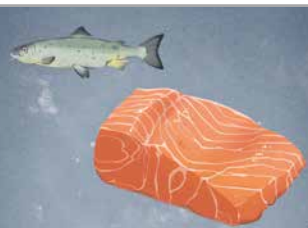
THE IMPACT OF OUR FOOD

Office for Climate Education

POULTRY
100g

THE IMPACT OF OUR FOOD

Office for Climate Education



FISH (FARMED)
100g

THE IMPACT OF OUR FOOD

Office for Climate Education

BEEF
100g

THE IMPACT OF OUR FOOD

Office for Climate Education

CRUSTACEANS (FARMED)
100g

THE IMPACT OF OUR FOOD

Office for Climate Education

LAMB & MUTTON
100g

THE IMPACT OF OUR FOOD

Office for Climate Education

LESSON C2
CLIMATE CHANGE AND AGRICULTURE

MAIN SUBJECTS
Natural sciences / Geography

DURATION
~ Preparation: 5 min
~ Activity: 1h15

AGE GROUP
12-15 years

LEARNING OUTCOMES
In this activity, through documentary analysis students learn how modern agriculture is affected by climate change and how agriculture worldwide is influencing the climate.

Students learn that:
~ Modern agriculture is very diverse.
~ Agriculture is affected by climate change.
~ Extreme events affect the ability to grow crops or to farm animals.
~ Modern agriculture increases deforestation.
~ Modern agriculture impacts biodiversity.

KEYWORDS
Land, agriculture, deforestation, extreme events

TEACHING METHOD
Documentary analysis

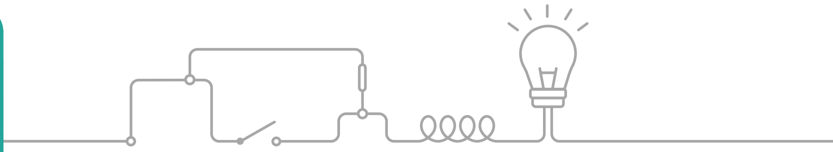
PREPARATION 10 MIN

EQUIPMENT

- Optional: computers with internet access, to use the multimedia animation Agriculture diversity.
- If no computers are available: **WORKSHEET C2.1**.
- **WORKSHEETS C2.2** and **C2.3** (one per student).
- **WORKSHEETS C2.4, C2.5, C2.6, C2.7** and **C2.8** (one or two copies, depending on the number of groups you have).

LESSON PREPARATION

The documents have two levels of difficulty– “curious”, the most accessible level for students aged 11 to 12 years, and “experts”, for students aged 12 and over. These levels are of course merely indicative.
Print out the worksheets.



INTRODUCTION 30 MIN

In the previous lesson, students worked on the link between eating habits and climate change. Ask them where their food comes from and how it is produced (from their garden? from the supermarket? from the farm?)

- *What is a farm? Why is it useful?*
- *How does a farm work?*

Possible answers: A dairy farm produces milk. The cows eat grass (or are fed in their cowshed with hay, and soya, corn, etc.) and are milked every morning and evening. The milk can be processed to make cheese, yoghurt or butter, which can be sold on the farm.
A famer grows vegetables in a greenhouse or in fields. They need to add nutrients to the soil, using manure or compost or fertilizers, and to water their plants.

- *Are all farms the same?*
- *How can these questions be answered?*

In order to answer them, students should suggest that they carry out research on how a farm operates. Then ask: *How can this be done? Take a tour? Have a farm in the school?* Initiate a discussion on this topic and then explain that you can see a farm from the air, using a website, or you can carry out a documentary analysis.

1. If you have access to the internet, your students can explore this topic using multimedia animation. Otherwise, distribute **WORKSHEET C2.1**.

2. Also hand out **WORKSHEET C2.2**; fill in the table with your students based on the information presented from a bird’s eye view.

3. Lead a whole class discussion to compare their results, using the questions below. The idea here is to get them to see a link between agriculture and climate change:

BACKGROUND FOR TEACHERS

Agriculture is one of the biggest emitters of GHG in the atmosphere worldwide (in 2014, it represented 24% of total emissions — source IPCC). Industrial agriculture is a major contributor for various reasons: fertilisers used for crop production emit large quantities of N_2O into the atmosphere; cow, sheep and goat farming produces methane (CH_4).

In many cases, crop production — mainly cereals to feed cattle — encourages **deforestation**, resulting in the accumulation of CO_2 in the atmosphere.

But agriculture is also directly impacted by climate change: the increase in intensity and frequency of extreme events, such as flooding, heatwaves, bushfires, land erosion and drought, are already jeopardising food production and causing malnutrition in many regions.

You can learn more about these aspects and the link between climate change and food (lesson C1, page 137) by watching this video (in French but with English subtitles).

- *Which farm is bigger?*
- *For each farming system, how do you think this type of farming affects the environment (pollution, water, land use) or the climate?*
- *How do you think the climate may affect these farms?*
- *Do you think that some farms affect the environment more than others? What about climate change?*

PROCEDURE 30 MIN

4. Explain to your students that they need to advise a farmer on the best way to set up a business (you can play the role of the farmer yourself). In teams, they must consider the problems that one can encounter as a farmer and the possible solutions.

- First of all, they will understand the role of one expert as a group (we advise groups of 3; there may be several groups working in the same role): they will have to analyse a portfolio, answer the questions, and fill in a short conclusion (one sentence) in the corresponding box on the summary sheet (**WORKSHEET C2.3**).
- Afterwards, each group of experts will mix together in larger groups of 5, which will have 1 expert from each category. This is the advisory board. Together, they will fill in the summary sheet, bringing together all their conclusions, and in this way they can help the farmer in his decision.

5. Hand out to each student the sheet summing up the conclusions of all the experts: **WORKSHEET C2.3**.

6. Divide the class into 5 groups (3 students per group):

- Meteorologists (expert level) – **WORKSHEET C2.4**
- Beekeepers (expert level) – **WORKSHEET C2.5**
- Veterinarians (expert level) – **WORKSHEET C2.6**
- Forest rangers (easy level) – **WORKSHEET C2.7**
- Journalists (easy level) – **WORKSHEET C2.8**

7. Each group answers the questions in their case study and puts down the conclusion of the study in one sentence on the summary sheet.

WRAP-UP 10 MIN

Each group presents their conclusion to the rest of the class and the students can discuss. Give feedback to the whole class asking, for example, what can be done as a student, as a parent or even at school to encourage better farming. Encourage local agriculture – visit a farm, have a vegetable garden in the school, have vegetarian menus in the canteen, etc.

TO GO FURTHER

You can take a trip to a local farm with your class.
You can propose to the class to work on a project on planting vegetables in the school or at home (see We Act, Project #5, page 245).

BEEF

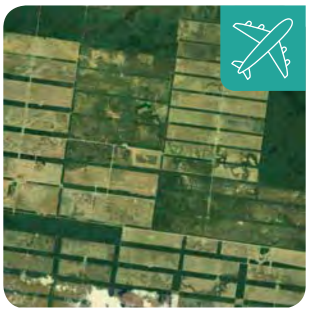
FRANCE: NORMANDY BOCAGE

Normandy, in France, still has small-scale agriculture, with family-run farms. The meadows are small and delimited by hedges forming what is called the "bocage". This contains a very rich biodiversity, especially in terms of insects and birds, which benefit from the many trees and shrubs. The traditional way of farming is to breed Normandy cows for milk (to make Camembert, for example), but also for meat. Cattle release methane into the atmosphere, which is a powerful greenhouse gas.

BURKINA FASO: THE BEEF OF THE FULANI

The Fulani people have large herds of humped zebus, related to the cow. They mainly get milk from the females and use the males for draught power. In some cases, on special occasions, they eat the meat. Cattle release methane into the atmosphere, which is a powerful greenhouse gas. The animals graze on large, very arid areas and drink from big watering holes created by humans. Intense and increasingly frequent droughts linked to climate change are causing yield losses and herd mortality.

PARAGUAY: CATTLE FARMS

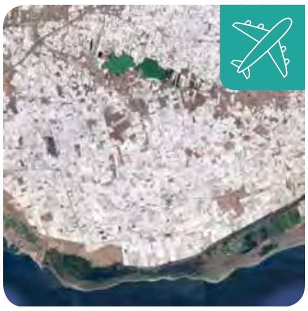


In Brazil and Paraguay, farmers cut down the forests to create space to raise cows. Cows live in dense groups in giant corrals to provide food for the local population and for export outside South America. Cows are the main emitters of methane, a major greenhouse gas. Deforestation also contributes to climate change.

Plane view | Drone view | Pedestrian view

TOMATOES

ALMERIA: THE SEA OF PLASTIC



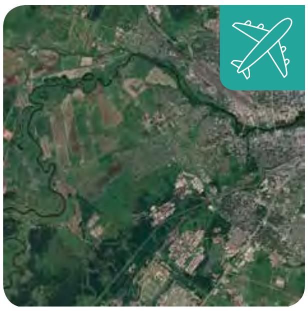
This large region in southern Spain was once a desert. Today, it is covered with greenhouses where tomatoes, amongst other products, are grown all year round to supply supermarkets throughout Europe. The fruit and vegetables grown here are often used in the preparation of industrial processed food. The highly intensive production requires a lot of water, fertilisers and pesticides. The greenhouses use a lot of plastic in their manufacture and frequent repair as the region is very windy. The use of so much fertiliser and plastic, and the transportation required to distribute the tomatoes all over Europe increases the emission of greenhouse gases into the atmosphere.

TUNISIA: THE DRIED TOMATOES OF CAP BON



Close to the sea, in the north of Tunisia, traditional family tomato-growing enterprises remain. The tomatoes are grown in open fields and picked by hand by family members. They are then either dried on large racks in the sun, or made into tomato puree or concentrate. These small crops benefit from a favourable environment for tomato production that climate change and rising water levels could disrupt.

RUSSIA: THE RUSSIAN GARDEN COLLECTIVE



Russia offers an example of large-scale collective peri-urban agriculture. Many residents of Russia's large cities cultivate a garden for food purposes; they are called gardener-inhabitants (or datchniki). In these groupings of flower gardens, kitchen gardens, orchards and cottages, there are many crops grown such as fruit (strawberry and raspberry) or vegetables, such as cabbage, carrots, potatoes and tomatoes. In addition to making a significant contribution to the country's agricultural production, this "parallel circuit" makes it possible to be less affected by climate change.

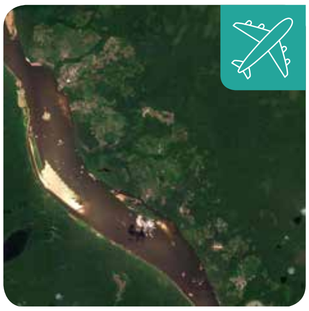
Plane view   Drone view   Pedestrian view

MAIZE

MEXICO: THE MAYAN TRADITIONS OF CORN CULTIVATION

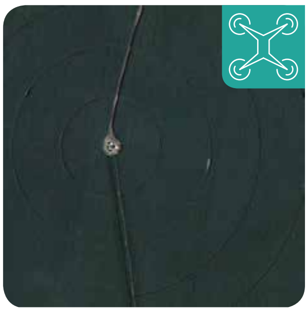
In the Yucatan region, there is a strong Mayan tradition. This translates into a very diversified diet and, in particular, the use of corn as a cereal base (as in the famous tortilla). In many villages, maize is grown by families on small plots of land, in divided farms that also grow fruit trees, fruit or vegetables. The land is often worked by hand. These farming practices have a low impact on the climate, as they require little transport and fertiliser.

VENEZUELA: SLASH-AND-BURN



Along the Orinoco River, the Piaroa root people have practised traditional slash-and-burn agriculture for centuries. Farmers burn a part of the Amazonian forest, then cultivate successive assemblages of plants and trees for their consumption (maize gardens, then cassava gardens, fallow land, then a forest of palm trees and fruit trees). On a small plot of land, they burn, cultivate, and then plant a forest. This type of agriculture is very respectful of the environment and has a low impact on the climate and biodiversity.

UNITED STATES: CIRCULAR FIELDS OF CROPS



In semi-arid regions, to obtain fertile soil to grow crops such as maize (mainly used to feed animals), farmers use a watering system (irrigation) creating giant circular fields of crops. These crops use a lot of space and water. In addition, they are often linked to the use of fertilisers and pesticides (which have a very negative impact on the climate) as well as to the cultivation of GMOs. These structures are visible from space, giving the impression that the landscape is pixelated.

Plane view   Drone view   Pedestrian view

PALM OIL

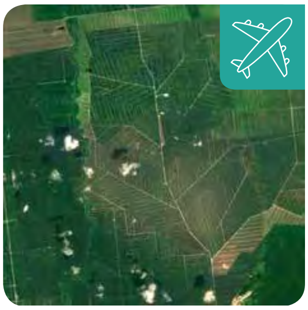
SRI LANKA: AGROFORESTRY

Tea and palm oil plantations are combined with other plants to mimic the local ecosystem, and have more disease- and weather-resistant crops than monocultures. These family productions have a low impact on the climate and the local environment, and promote biodiversity.



MALAYSIA: INTENSIVE PALM OIL PRODUCTION

In Sarawak, on the island of Borneo, the palm oil industry is very strong. Large tracts of rainforest are burnt down every year to make way for palm oil plantations. These endless palm groves are a disaster for the local ecosystems: the monoculture of these trees leads to a depletion of the previously rich local biodiversity (this is the land of the famous orangutans). In addition, deforestation contributes to climate change. Almost all the palm oil produced is exported from Malaysia.



BENIN: TRADITIONAL PALM OIL PRODUCTION

In West Africa, farmers practice agroecology, harvesting the fruits of the palm tree in the wild or on small farms for local consumption, as they have done for generations. The traditional palm oil remains an essential part of the local culture, economy and diet. Its artisanal production is generally carried out by women farmers. These crops have a very low impact on the climate, as they do not require transport or the use of fertilisers.



Plane view Drone view Pedestrian view

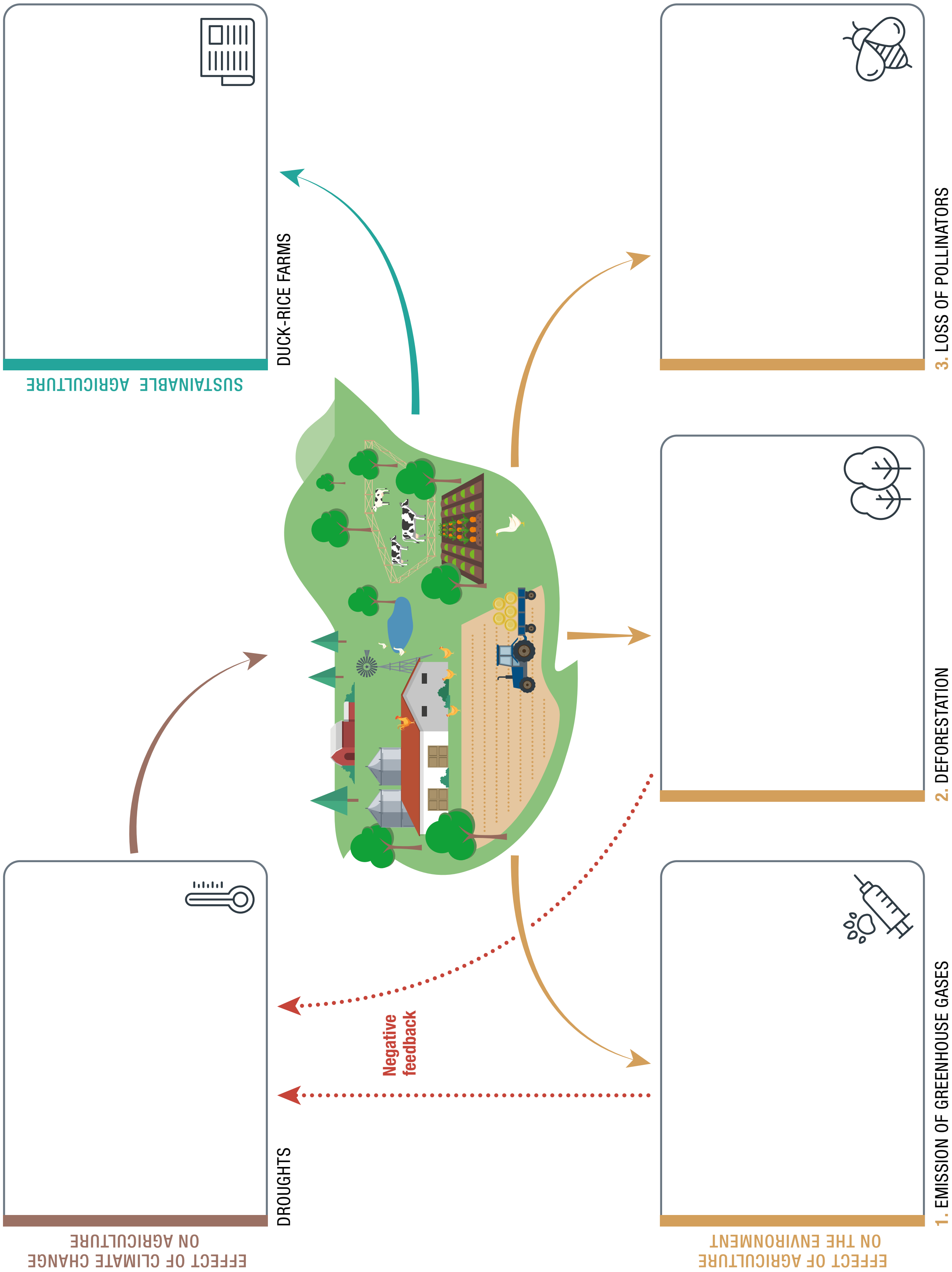
WORKSHEET C2.2

DIFFERENT TYPES OF FARMING IN THE WORLD

	LOCATION / CLIMATE	TYPE OF FARMING AND PRODUCTION	APPROXIMATE SIZE
BEEF			
TOMATOES			
MAIZE			
PALM OIL			

WORKSHEET C2.3

SUMMARY SHEET



METEOROLOGISTS

You are a group of meteorologists (you study the temperature and rainfall at a given time). You are sent to Australia to discover what happened in 2015: animals were starving to death and it was very dry.

- Where and when were the photos in DOCUMENT 1 taken? Explain the differences between the "before" and "during" pictures. From the "before" picture, describe what you can see: humans, animals, plants, water? What does the sky look like? Cloudy or sunny? What aspects do you think are good for food production from what you see in the picture? Now look at the picture taken during the drought: what do you think is different?
- How does the weather influence agricultural activity? Can you explain in some detail (you can do some research online).
- Describe the two graphs in DOCUMENTS 2 and 3: in each case, what information is on the x and y axes? What type of data is represented here and how does it change over time? How does this relate to the images in DOCUMENT 1? Do you think this is related to climate change? Why do you think so? How do you think this will change over time?
- Answer in one sentence the following question (write your answer on the summary sheet): **What is the impact of climate change on agriculture in Australia? What are the resulting problems for the farm?**

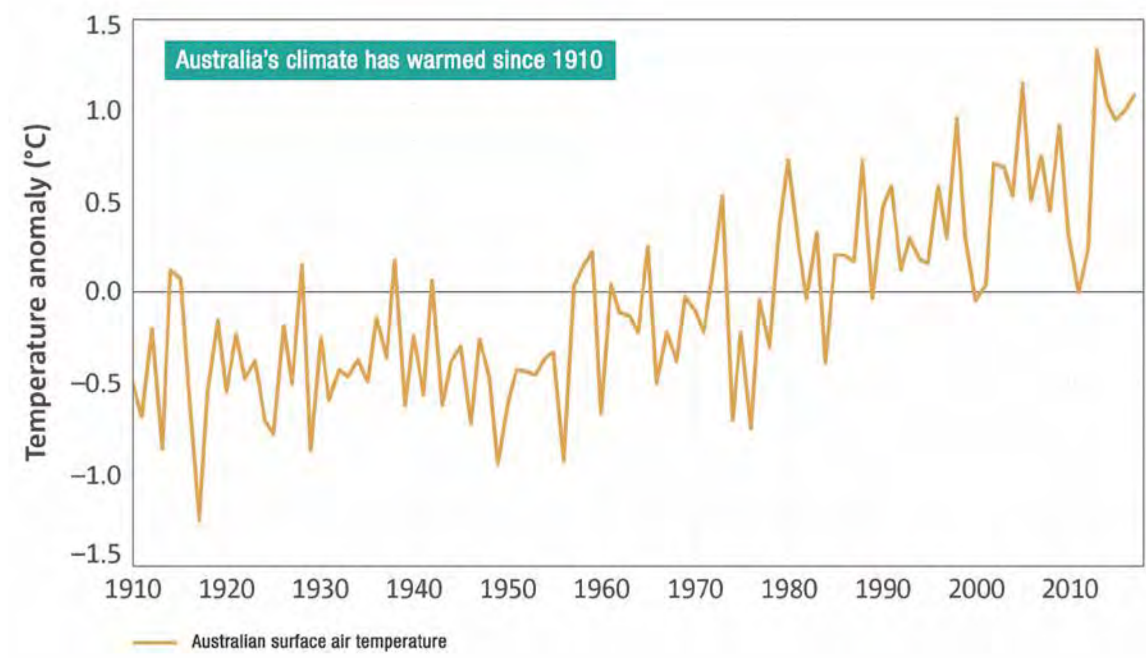
DOCUMENT 1: BEFORE AND AFTER DROUGHT IN AUSTRALIA

If you have internet access, go to the following website and study the "before" and "after" pictures of drought on Australian farms.
https://www.abc.net.au/news/2015-12-17/queensland-drought-photos-before-after/7035610?nw=0

2012: Rearing healthy cattle at Catumnal Station.

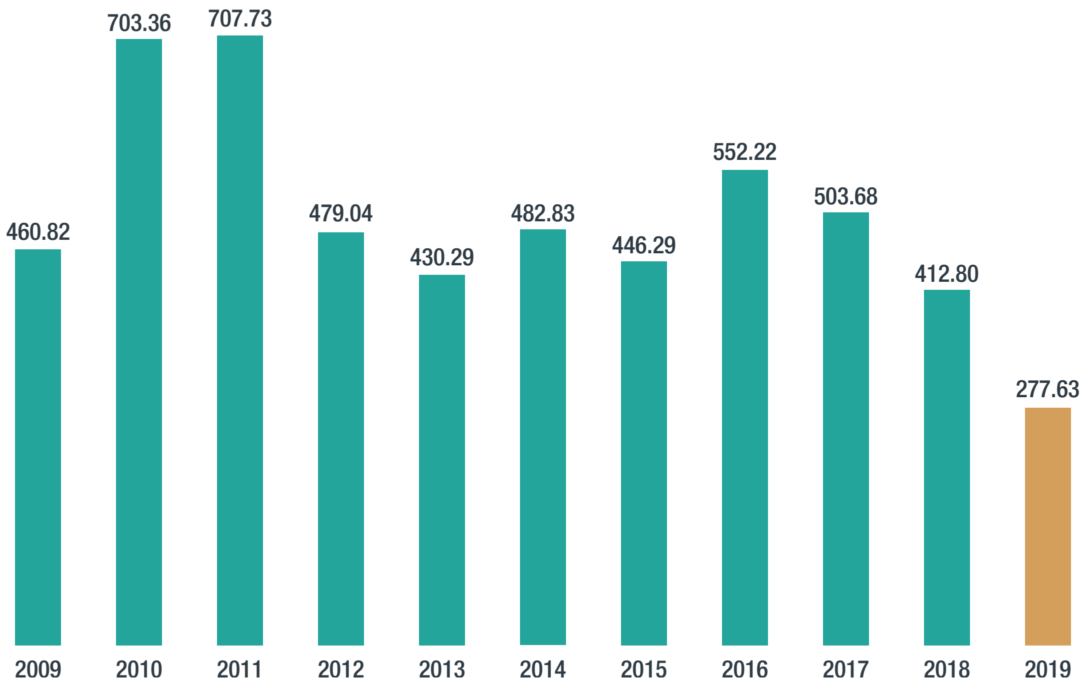
2015: This paddock at Catumnal Station can now only support about 20 cows.

DOCUMENT 2: CHANGE IN AUSTRALIA'S MEAN TEMPERATURE OVER A HUNDRED-YEAR PERIOD, FROM 1910 TO 2010



Source: © Copyright CSIRO Australia, data from Bureau of Meteorology.
https://www.csiro.au/en/research/environmental-impacts/climate-change/state-of-the-climate/previous/state-of-the-climate-2018/australias-changing-climate

DOCUMENT 3: AVERAGE RAINFALL IN AUSTRALIA BETWEEN 2009 AND 2019, IN MILLIMETRES



Source: Statista, data from Bureau of Meteorology.
https://www.statista.com/chart/20525/australia-wildfires-drought-rain/

BEEKEEPERS

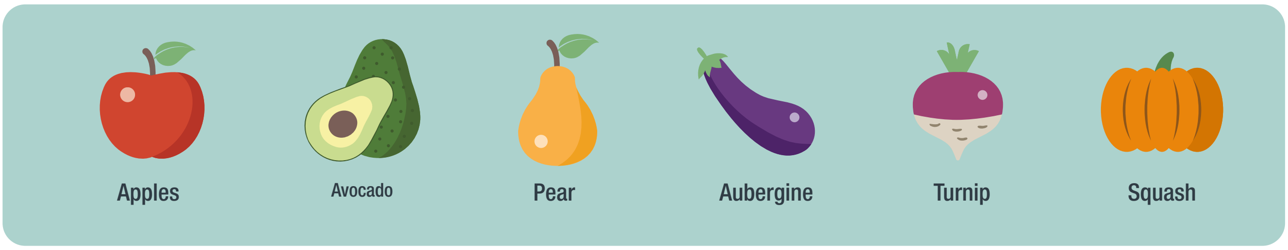
You are a group of beekeepers and your job is to look after hives, which contain bees that produce honey. You are experts on the environmental role of bees and you have been asked to study the following documents to find the link between the disappearance of bees and falling agricultural yields.

- With reference to the **DOCUMENT 1** and to the first paragraph of the article in **DOCUMENT 2**, explain why bees and other pollinators are important for food production.
- Read the whole article and explain, in your own words, what is happening to pollinators. What might this be due to? How is modern agriculture also a problem for bees?
- ***"Climate change interferes with the relationship between bees and the plants on which they feed."*** What do you understand from this sentence? What do you think is happening? You can do some research on the internet about how climate change affects flowers and bees.
- Write a one-sentence answer to this question on the summary sheet: **What is happening to pollinators around the world? Why is this a problem for farms?**

DOCUMENT 1: THE ROLE OF INSECT POLLINATION

LOSING OUR POLLINATORS MEANS LOSING OUR FRUIT AND VEGETABLES

About a **third** of crops are **pollinated by bees**



INSECT POLLINATION VERSUS OTHER TYPES OF POLLINATION

Fruits can **vary greatly in size and quality** if insect pollination is taken out of the equation

DOCUMENT 2: WHAT IS HAPPENING TO THE WORLD'S BEES?

If you have access to the internet you can read the entire article:
https://theconversation.com/ten-years-after-the-crisis-what-is-happening-to-the-worlds-bees-77164

THE CONVERSATION

Academic rigour, journalistic flair

Ten years after the crisis, what is happening to the world's bees?

Ten years ago, beekeepers in the United States raised the alarm that housands of their hives were mysteriously empty of bees. What followed was global concern over a new phenomenon: Colony Collapse Disorder.

Since then we have realised that it was not just the US that was losing its honey bees; similar problems have manifested all over the world. To make things worse, we are also losing many of our populations of wild bees too.

Losing bees can have tragic consequences, for us as well as them. Bees are pollinators for about onethird of the plants we eat, a service that has been valued at €153 billion (US$168 billion) per year worldwide.

In a recently published review, we argue that modern agriculture and industry have created a host of sublethal stressors that damage bees' cognition. For example, diesel fumes and neonicotinoid pesticides both reduce bees' foraging efficiency by disturbing chemical communications in their brains. Modern intensive agriculture disturbs bee nutrition, which impairs their brain. Climate change interferes with the relationship between bees and the plants on which they feed.

VOCABULARY

HIVE bee house.

COLONY COLLAPSE DISORDER the name given to a global phenomenon where honey bee populations are dramatically declining.

SUBLETHAL STRESSORS impacts from the direct environment that affect the behaviour or the health of an individual, without killing it directly (as opposed to a lethal stressor that kills the individual).

COGNITION functions of the brain, such as memory, choice, movement, senses, etc.

DIESEL FUMES air pollution coming from cars, trucks and tractors.

NEONICOTINOID PESTICIDES a type of chemical used on crops, and fruit and vegetable farms, to kill insects.

FORAGING pollinators, when they "forage", are collecting pollen and nectar from flowers to feed their larvae.

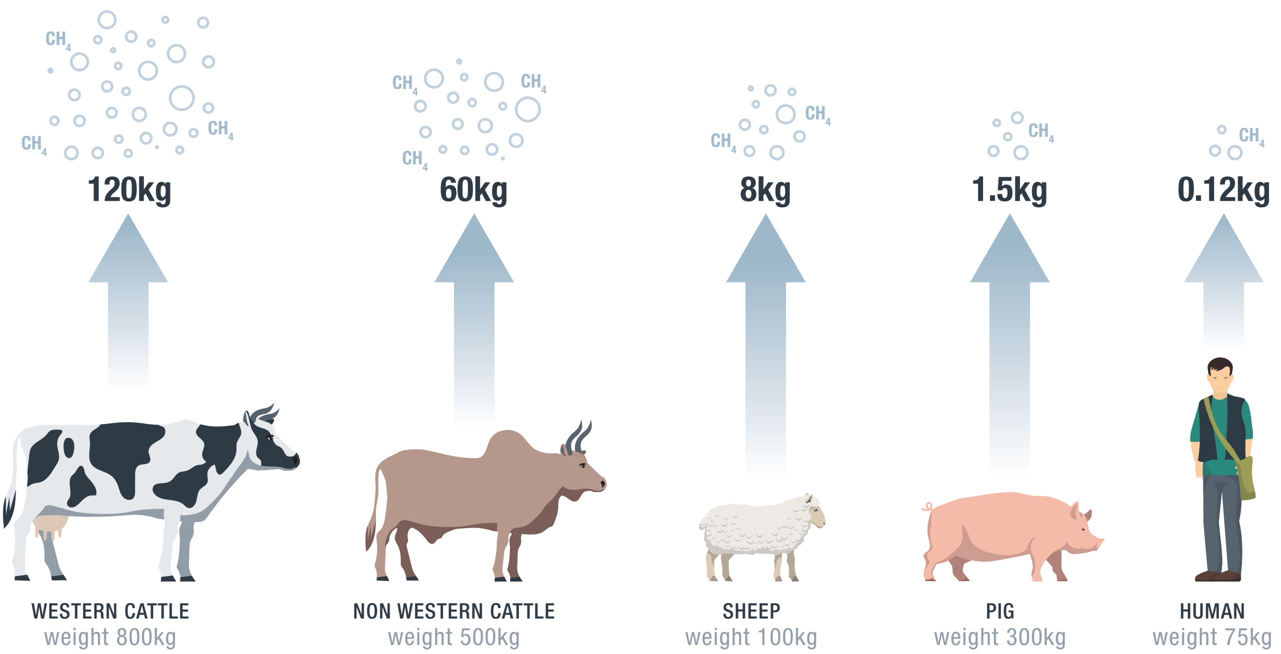
VETERINARIANS

You are a group of veterinarians and you mainly take care of farm animals (cows, horses, pigs, chickens, etc.). You are experts on these animals and today you have been asked to describe their impact on the production of greenhouse gases.

- Using DOCUMENT 1, compare the amount of methane emitted in a year by a farm animal to what you (a human) emit over the same period. To estimate the amount produced by one kilogram of animal, divide methane emissions by animal weight. This will help you to find out which species emits the most CH_4 in relation to its weight.
- With your results, explain how farm animals have an impact on climate change.
- Take a look at the map (DOCUMENT 2), and compare the different regions. In your region, are there a lot of livestock? Do you think this affects the climate? What can you do about it?
- Write a one-sentence answer to this question on the summary sheet: **How do farm animals affect the climate? What solution(s) exist to limit the impact of agriculture on the climate?**

DOCUMENT 1: FARM ANIMALS AND METHANE EMISSIONS (PER ANIMAL/HUMAN PER YEAR)

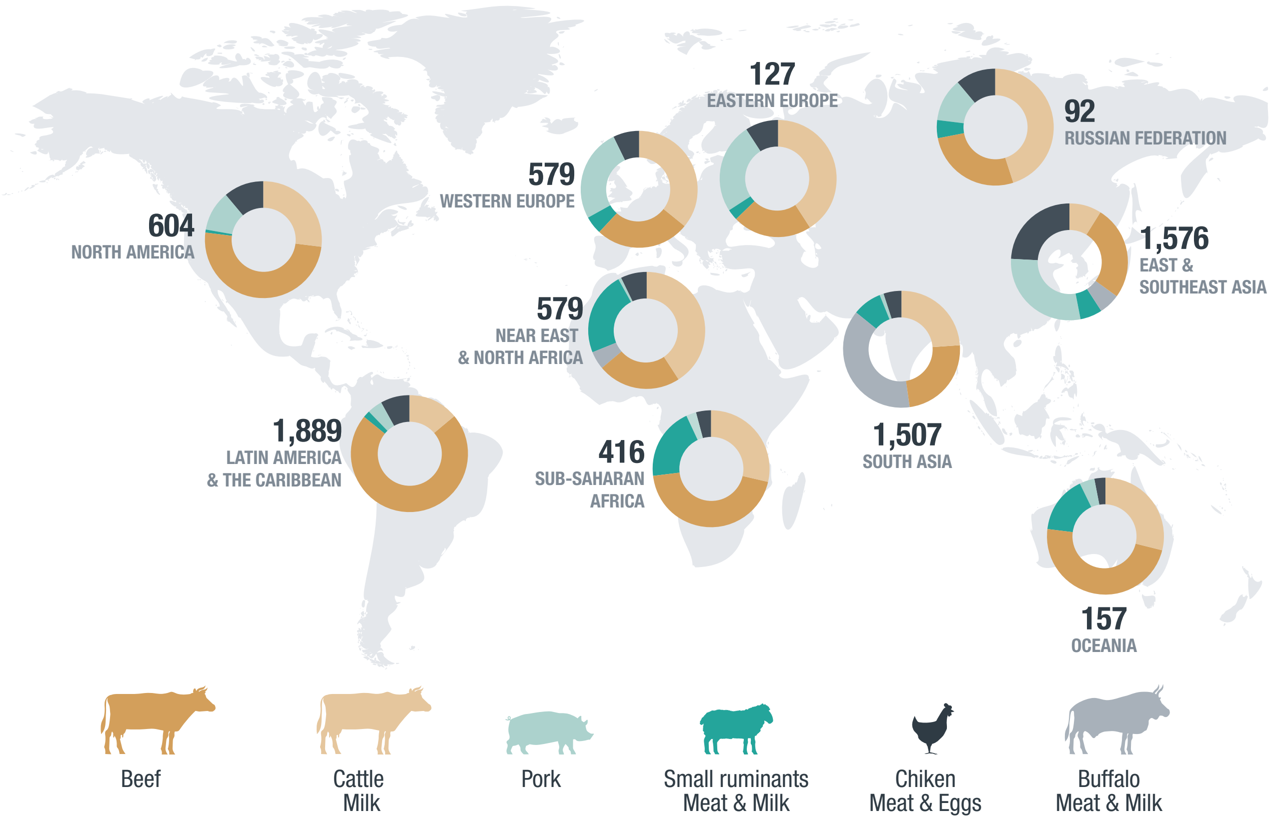
Cows—like other ruminants, such as buffalos or sheep—have a peculiar stomach: in fact, they have 4! Each "pocket" of the stomach contains millions of microbes that break down grasses into useable energy for the cow. During this process, they also produce methane, a greenhouse gas that contributes to global warming, which is released into the atmosphere through cows' burps, farts and dung.



Source: Adapted from Nasa's Goddard Institute for Space Science.

DOCUMENT 2: REGIONAL EMISSIONS OF ALL GREENHOUSE GASES IN MILLION TONNES CO_2-EQ, BY SPECIES, IN 2010

"CO_2-eq" means "carbon dioxide equivalent". It is useful to compare the impact of different greenhouse gases, because they do not have the same "warming power": for instance, a given amount of methane heats the atmosphere 28 times more than the same amount of CO_2!



Source: Adapted from FAO (2017); Global Livestock Environmental Assessment Model (GLEAM). http://www.fao.org/gleam/results/en/#c303617

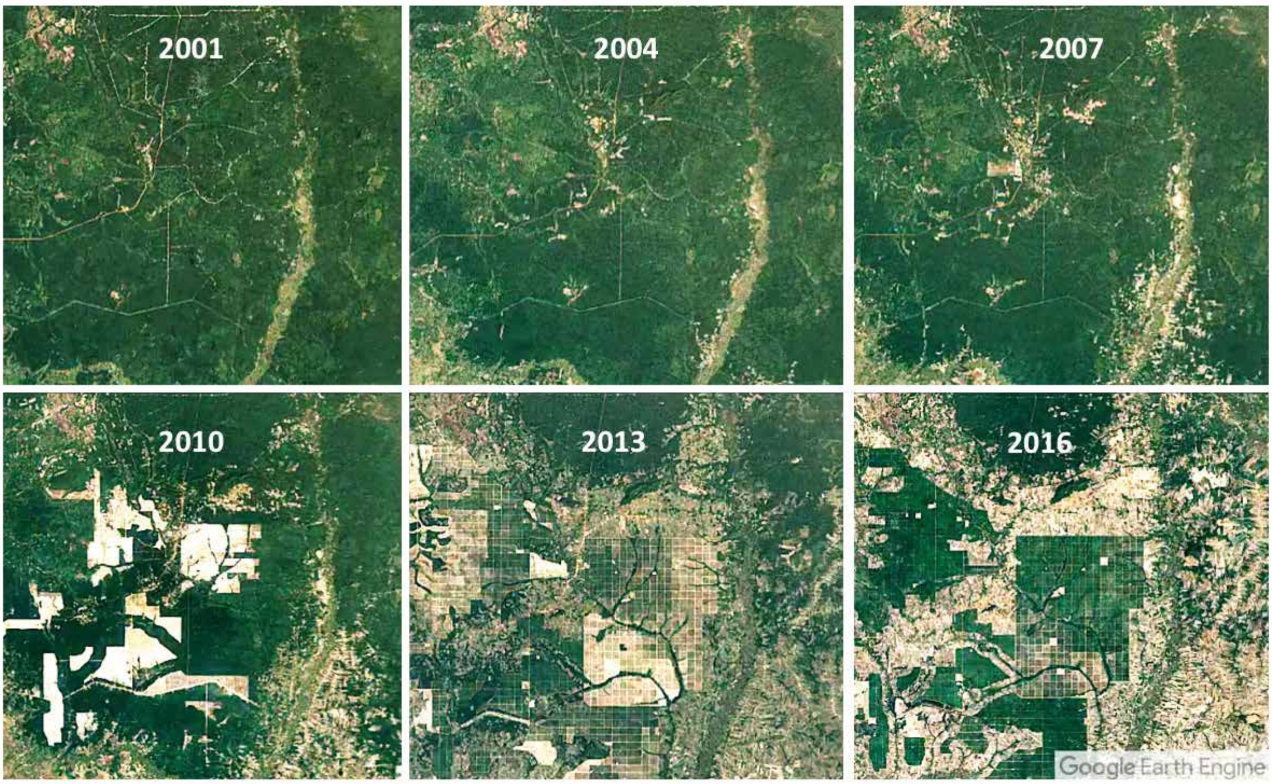
FOREST RANGERS

You are a group of forest rangers. You know the forest well and understand that trees capture CO_2 from the atmosphere, so the forest is good for fighting climate change. You are sent to Cambodia to study the link between forests, agriculture and climate change.

- **DOCUMENT 1:** When you look at the photographs, what do you see? What has happened to the forest over time?
- **DOCUMENT 2:** Why are vegetation, trees and forests important for the climate? Can you explain why it is important to conserve the forest?
- In this case, how does agriculture affect the climate? Is it a direct (affecting the temperature, or the rain) or indirect effect?
- Answer this question in one sentence and write it on the summary sheet: **Why are large farms/plantations problematic for forests? Why are they a problem for the climate?**

DOCUMENT 1: DEFORESTATION IN BENG PER WILDLIFE SANCTUARY, CAMBODIA, FROM 2001 TO 2016

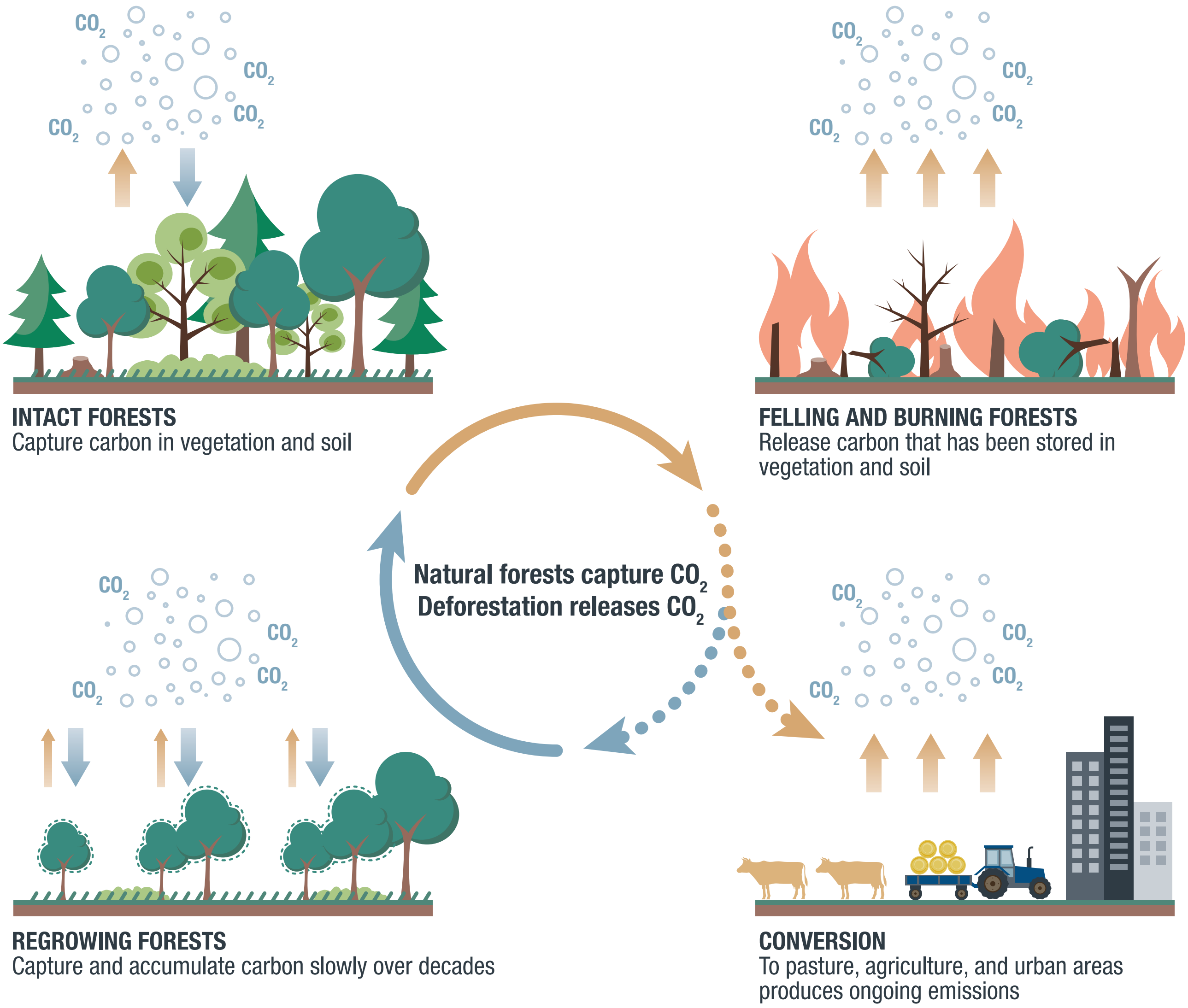
Trees have been cut down to make furniture, or to facilitate agricultural plantations producing products such as rubber, rice, bananas and cashew nuts, which are then exported all over the world. In these pictures, the forest has been replaced by rubber plantations.



Source: Google Earth Engine. https://earthengine.google.com/timelapse/

Note: if you have access to the internet, you can go on Google Earth and build up your own timeline looking at changes in land use in your own regions of interest.

DOCUMENT 2: CARBON DIOXIDE CAPTURE AND RELEASE BY FORESTS



Source: Adapted from Center for Global Development
https://www.cgdev.org/page/infographics-why-forests-why-now

WORKSHEET C2.8

JOURNALISTS

You are a group of journalists and you are interested in reporting on environmentally friendly agricultural methods. You go to visit a special farm in Japan, which has found an interesting way to ensure its methods have a very low impact on the climate.

- In your own words, can you describe this agricultural practice and where it comes from? Then make a diagram that summarises the text.
- From the short text and picture below, explain why this farming practice is good for the environment.
- Answer this question in one sentence and write it on the summary sheet: **How is this farming practice good for the environment and the climate?**

WHY RICE-DUCK FARMING IS GOOD FOR THE ENVIRONMENT [1]

Takao Furuno, a Japanese farmer, has developed a method for growing rice that mimics natural ecosystems. He puts ducks in his paddies (flooded parcels of land used to grow rice) to eat weeds and insects. The ducks' waste provides nutrients, which then nourish the crops, and allows the farmer to save money ordinarily used for pesticides and fertilisers. They earn extra money by selling duck meat and duck eggs. Furuno's system also uses fish in the paddies, which is another source of income. Industrial rice farmers have discontinued this latter practice because the pesticides they use in their system kill their fish. The Furuno system yields 20 percent more rice than conventional systems, which grow rice exclusively.

Note: Pesticides are chemicals used in fields (or rice paddies) to protect crops from being eaten by insects or to control diseases. Pesticides are dangerous for two reasons: they kill many insects that do not eat the crops; and they emit greenhouse gases when they are produced and when they are used in the fields. So pesticides make climate change worse.

1 Adapted from FoodSpan lesson plan, John Hopkins Center for a Livable Future. https://www.foodspan.org/lesson-plans/unit-2-farmers-factories-and-food-chains/

LESSON C3
EXTREME EVENTS AND LAND DEGRADATION

MAIN SUBJECTS
Geography

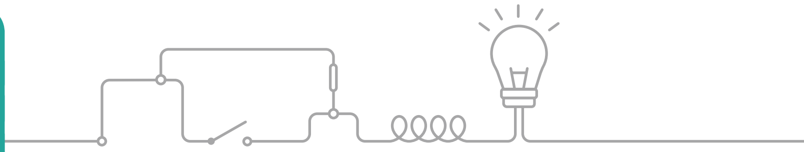
DURATION
~ Preparation: 5 min
~ Activity: 1h

AGE GROUP
12-15 years

LEARNING OUTCOMES
In this lesson, students learn that:
~ There are various climate-related extreme events, such as heatwaves, wildfires, flooding, drought, etc.
~ Extreme events negatively affect human populations and ecosystems.
~ The frequency and intensity of extreme events have been recently increasing.
~ Human populations are able to reduce the impact of such events (adaptation).
~ Extreme events are linked to climate change.

KEYWORDS
Extreme events, heatwave, wildfire, flooding, desertification, drylands, land degradation, drought

TEACHING METHOD
Documentary analysis



TEACHER TIP
During this lesson, you should take into account three potential obstacles to student understanding:
→ **Confusion about all catastrophic events as being related to the climate or weather;** some are (heatwaves, flooding, wildfires, etc.) but others are caused by different mechanisms (earthquakes, tsunamis, etc.).
→ **Confusion between the natural variability of the weather and the "deep-rooted trend" caused by climate change.** It is very difficult to attribute any individual event to climate change but we know that climate change tends to increase the frequency and intensity of some events (like heatwaves, wildfires and flooding). This "statistical" aspect of the question is important: we do not have to focus only on individual "stories" or examples, but rather demonstrate their multiplicity.
→ Some documents require **basic skills in the interpretation of graphs.** Do not hesitate to spend more time on these if students are confronted with this kind of task for the first time.

PREPARATION 5 MIN

EQUIPMENT
- **WORKSHEETS C3.1, C3.2, C3.3, C3.4** and **C3.5** (one for each group)

LESSON PREPARATION
1. To be carried out in advance: ask your students to collect "evidence" for climate-related extreme events that have recently happened in your country or elsewhere (press, social media, etc.).
2. Print out the worksheets, one for each group.

INTRODUCTION 10 MIN

Ask the class:
- *What is an extreme weather event?*
- *What kind of extreme weather events do you know about? That you have learnt about? That you have seen in movies, books or stories? That you have witnessed on the news? That happened in your life?*
- You can list the different events on the board and see which ones are the most common.
- *Do you think extreme events occur more often now?*
- *Do your older relatives tell you that there are more extreme events today? Was it different when your parents were your age, for instance?*
- *How can you explain this increase in extreme events?*

BACKGROUND FOR TEACHERS

Extreme weather events are events that fall outside the normal weather patterns for a given location (e.g., super powerful hurricanes, torrential precipitation, droughts, heatwaves). Extreme weather events are, in themselves, debilitating, **but the after-effects of such extremes can be devastating.**

With climate change, **an increase in extreme events' frequency and/or intensity has been observed.** Climate change may also worsen the impacts of some extreme events. For example, sea level rise increases the impact of coastal storms and warming can place more stress on water supplies during droughts. Scientists have published more than 150 attribution studies looking at weather events around the world.

You may access an overview of these studies by visiting this website.

The predictions about extreme events within the context of climate change for the years to come **remain uncertain for some of these events** (for example, monsoons, because there is only limited consensus in climate models regarding future changes). **However, there is strong evidence that the increase in frequency and intensity of extreme events over the past few years is due to human activities and to greenhouse gas emissions.**

PROCEDURE 45 MIN

1. Divide the class into 4 groups.

2. Ask each group to analyse the documents available on the worksheets (including the evidence they brought to class).

3. After each group has studied and discussed its document(s), one member of each group presents the findings to the other groups. You can choose the way they present their work to the other groups depending on your class level and the time you have available.

4. The students should notice that the various articles and graphs they studied were provided by different information sources. The first worksheet explores the general trend, while the others focus on specific events, in different regions of the world. The combination of these sources of information will help students to see a global "trend" and realise what such events mean for populations all over the world.

5. Take some time to address issues that may cause anxiety. Speaking about extreme or catastrophic events can be stressful for students. It is important for them to realise that, despite the strong increase in extreme events during the last one hundred years, the number of deaths due to these events has decreased (see **WORKSHEET C3.1**). Today, societies are better prepared to cope with such events (advances in medicine, better infrastructure, international solidarity, etc.).

WRAP-UP 5 MIN

Conclude by saying there is solid evidence that climate change is leading to an increase in some extreme events, such as heatwaves, wildfires and flooding. These events tend to be more frequent and more intense, which has many consequences on land (degradation, desertification), agriculture, health, etc.

To wrap up, you can lead a discussion based on these key questions:

- *What are the different extreme events?*
- *Do they all have similar consequences?*
- *How do you think these events will change in 10, 20 or 50 years' time?*
- *Do you think you or your community are more or less vulnerable to such events?*
- *What would you do if there were an extreme event in your area?*
- *Why do you think we did not talk in depth about earthquakes, tsunamis or volcanoes? Are they related to climate change? Are they also becoming more and more frequent?*
- *How can populations adapt to extreme events?*
- *What kind of consequences do these extreme events have on land? Do they cause land degradation?*

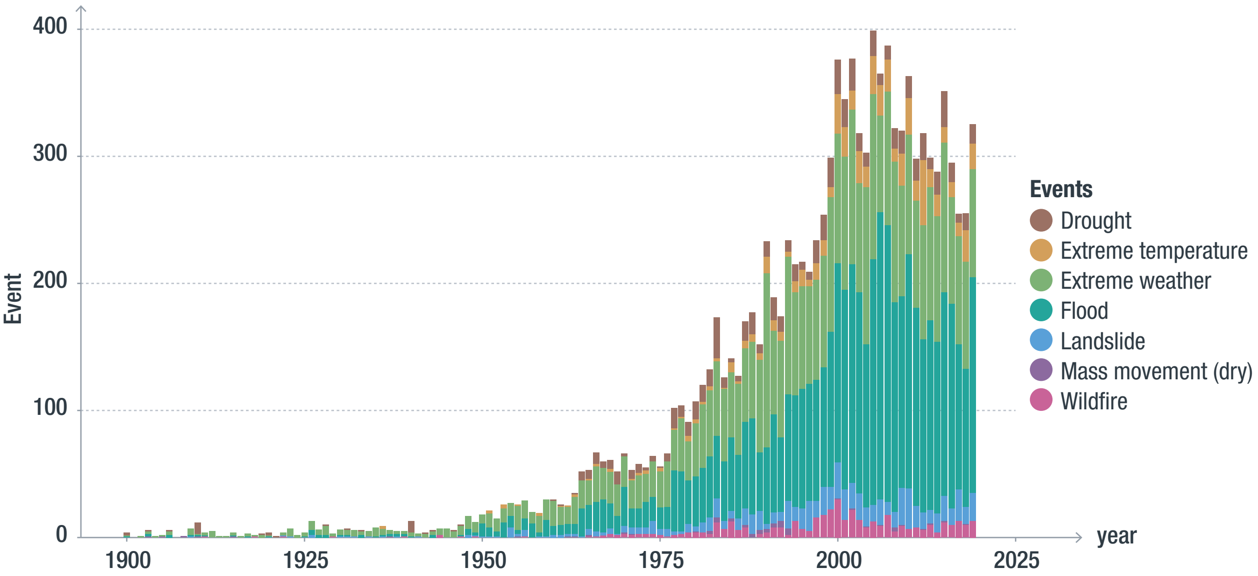
WORKSHEET C3.1

CURIOUS

Look at the documents below and answer the following questions:

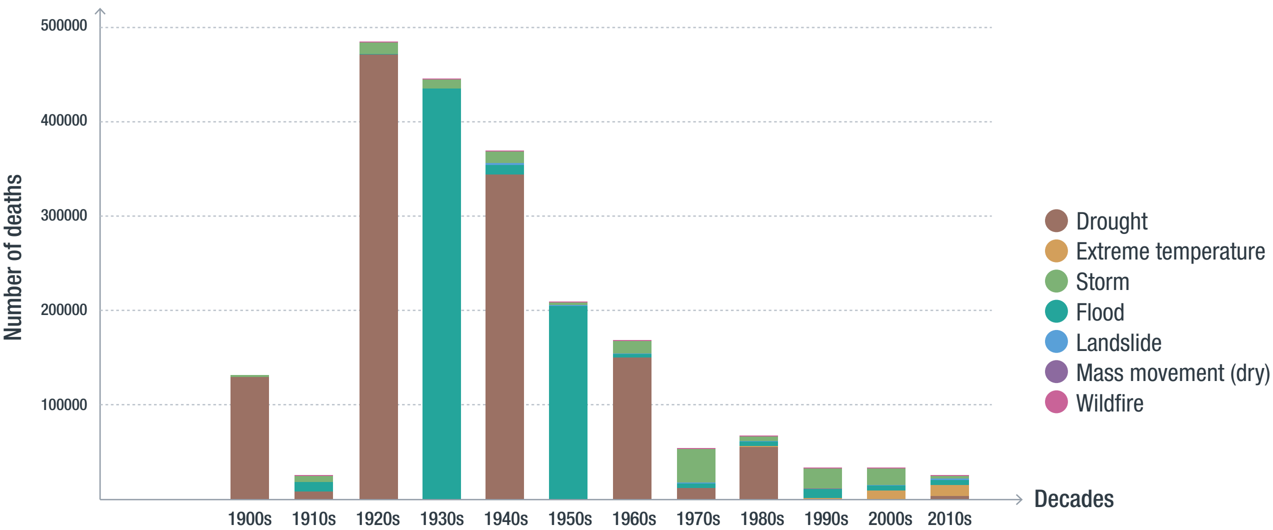
- What kind of documents are they? When were they published?
- What are the sources of these documents? Are these sources reliable?
- Describe the graphs: what is represented by the x and y (horizontal and vertical) axes? What are the units? What patterns do you see?
- What type of extreme events are shown?
- How have extreme weather events changed over the last 120 years?
- What can you say about the change in the number of deaths due to extreme events during the same period?
- Can you explain why some of the disasters have decreased and others increased over time?
- Can you explain why some types of deaths have decreased over time?
- Have you or people you know ever experienced such extreme events? How did you feel? What did you do to protect yourself? You can share a story.

DOCUMENT 1: CHANGE IN THE NUMBER OF EXTREME EVENTS FROM 1900 TO 2019



Source: Adapted from the EM-DAT (2019) – OFDA/CRED International Disaster Database, Université catholique de Louvain, Brussels, Belgium.

DOCUMENT 2: CHANGE IN GLOBAL ANNUAL DEATHS FROM NATURAL DISASTERS, FROM THE 1920s TO THE 2010s



Source: Adapted from EM-DAT (2019) – OFDA/CRED International Disaster Database, Université catholique de Louvain, Brussels, Belgium.

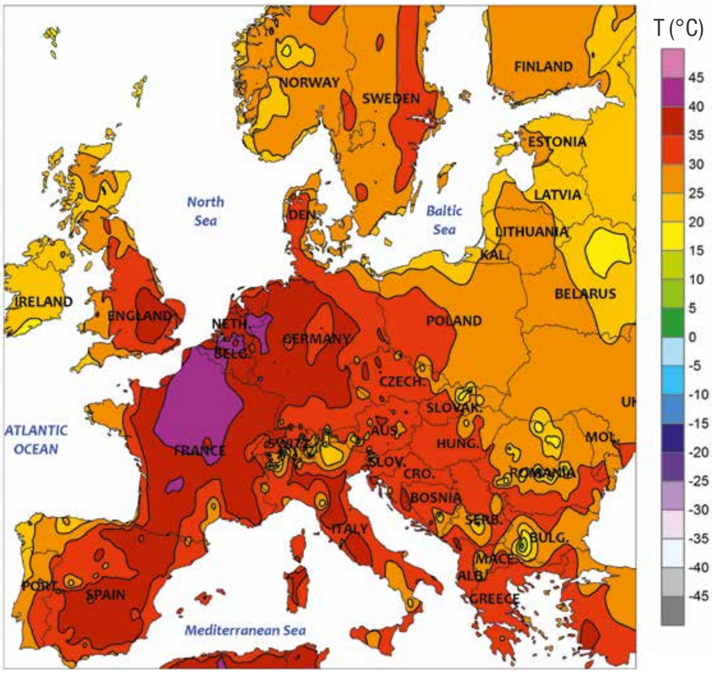
WORKSHEET C3.2

TRAINEE

Look at the documents below and answer the following questions:

- What kind of documents are they? When were they published?
- What are the sources of these documents? Are these sources reliable?
- Describe the map: What can you see? Where are the hottest regions in Eastern Europe?
- What type of extreme event is shown here?
- Did this event concern a small region or several countries?
- Have you or people you know ever experienced such an event? How did you feel? What did you do to protect yourself? You can share a story.

DOCUMENT 1: EXTREME MAXIMUM TEMPERATURES (°C) IN EUROPE, JULY 25, 2019



In July 2019, Europe experienced exceptionally hot weather, setting all-time high temperature records in Belgium, Germany, Luxembourg, the Netherlands, and the United Kingdom, with temperatures reaching up to 9°C above the average temperatures for this season.

Source: National Oceanic and Atmospheric Administration, cited in:
https://en.wikipedia.org/wiki/July_2019_European_heat_wave

DOCUMENT 2: THE LINK BETWEEN HEATWAVES AND CLIMATE CHANGE

"In June, new all-time records were set in multiple places across Western Europe. In July, records were broken again, albeit in different areas. Again, the role of climate change in producing such high-amplitude events was questioned. […]
Over France and the Netherlands, such temperatures would have had extremely little chance to occur without human influence on climate (return periods higher than ~1000 years). […]
It is noteworthy that every heatwave analysed so far in Europe in recent years (2003, 2010, 2015, 2017, 2018, June 2019, this study) was found to be made much more likely and more intense due to human-induced climate change."

02 August, 2019

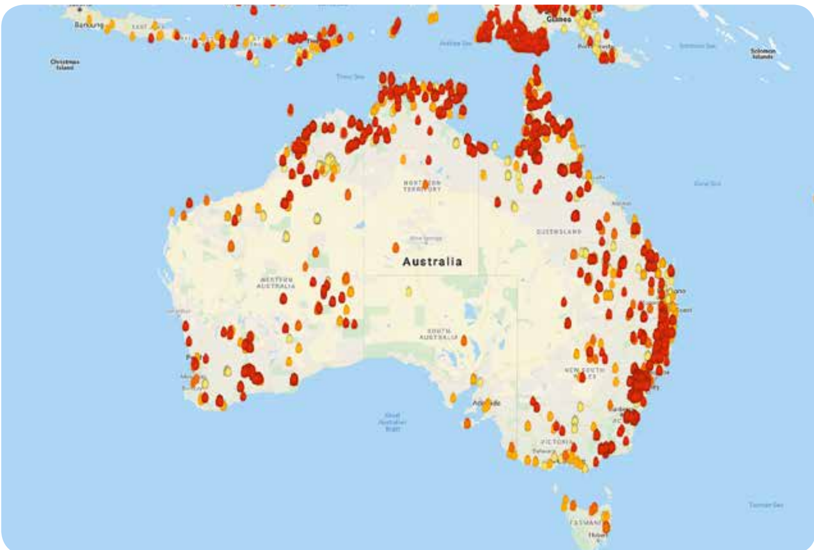
Source: Adapted from:
https://www.worldweatherattribution.org/human-contribution-to-the-record-breaking-july-2019-heat-wave-in-western-europe/

Look at the documents below and answer the following questions:

- What kind of documents are they? When were they published?
- What are the sources of these documents? Are these sources reliable?
- What type of extreme event is shown here? What happened in Australia in 2019?
- Describe the map (**DOCUMENT 1**): what do you observe?
- Read **DOCUMENT 2** and explain what the consequences of megafires for ecosystems and for human societies may be.
- Look at the maps of the other countries (**DOCUMENT 3**). What does the red circle represent? Imagine a whole region the size of the circle burning. Can you describe how this would affect you, the ecosystems, and the farms around your city / town / village?
- Considering temperatures are rising, how will this impact such an event?
- Have you or people you know ever experienced such an event? How did you feel? What did you do to protect yourself? You can share a story.

DOCUMENT 1: LOCATIONS OF BUSHFIRES IN AUSTRALIA, DECEMBER 2019

Each yellow, orange and red point represents a fire. During the megafire of 2019-2020, the different bushfires in Australia burnt around 100,000 km^2.



Source: Screenshot taken from https://myfirewatch.landgate.wa.gov.au/ – December 2019.

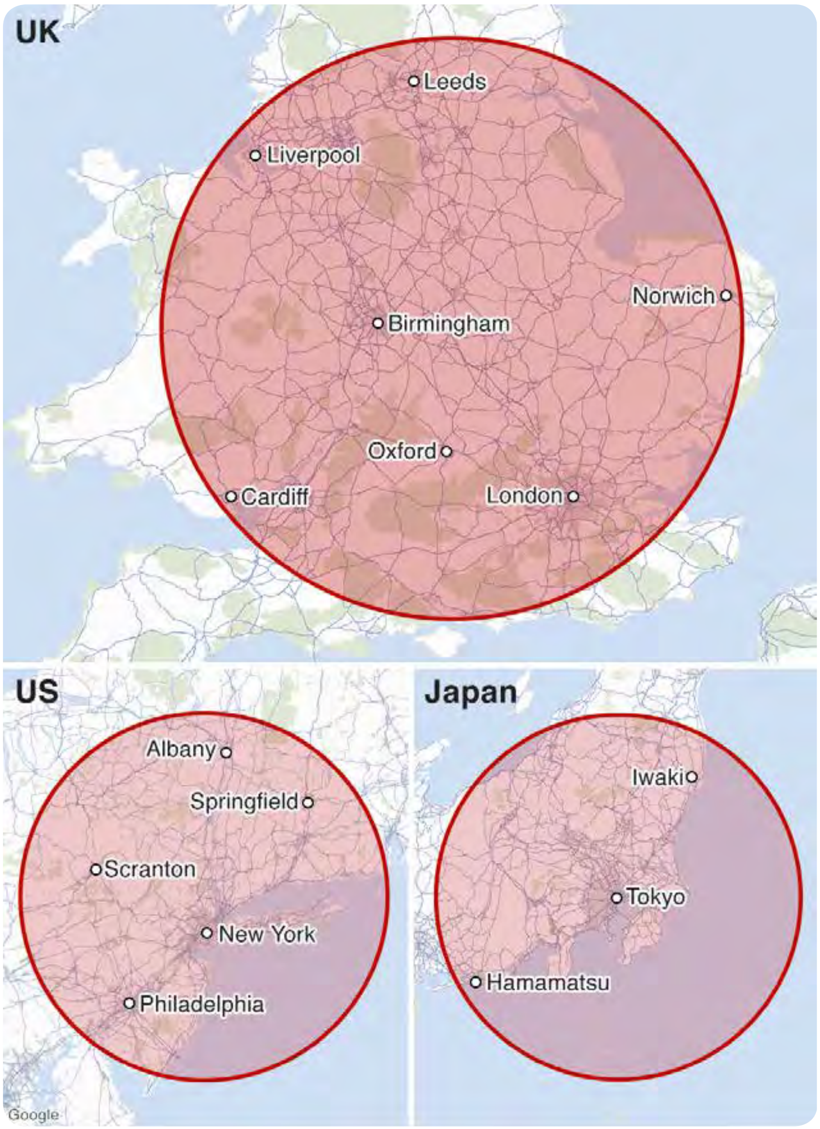
DOCUMENT 2: AUSTRALIA'S FIRES "KILLED OR HARMED THREE BILLION ANIMALS" (ARTICLE FROM THE BBC)

"Nearly three billion animals were killed or displaced during Australia's devastating bushfires of the past year, scientists say.
The findings meant it was one of "worst wildlife disasters in modern history", said the World Wide Fund for Nature (WWF), which commissioned the report. Mega blazes swept across every Australian state last summer, scorching bush and killing at least 33 people. Mammals, reptiles, birds and frogs died in the flames or from loss of habitat. During the peak of the crisis in January, scientists had estimated that 1.25 billion animals had been killed in New South Wales and Victoria alone. But the new estimate takes in a larger area. About 11.46 million hectares – an area comparable to England – was scorched from September to February."

Source: https://www.bbc.com/news/world-australia-53549936

DOCUMENT 3: MAP SHOWING THE SIZE OF THE AUSTRALIAN REGIONS AFFECTED BY WILDFIRES IN 2019

How big are Australian fires? An estimated 10 million hectares (100,000 sq km) across Australia since 1 July.



Source: BBC – “Australia fires: A visual guide to the bushfire crisis”.
https://www.bbc.com/news/world-australia-50951043

Optional: if you have internet access, go to this website: https://www.mapdevelopers.com/draw-circle-tool.php
Mark the city/town/village where you live on the map and then draw a circle with a radius of 178km (because that represents a surface of 100,000km^2).

Look at the documents below and answer the following questions:

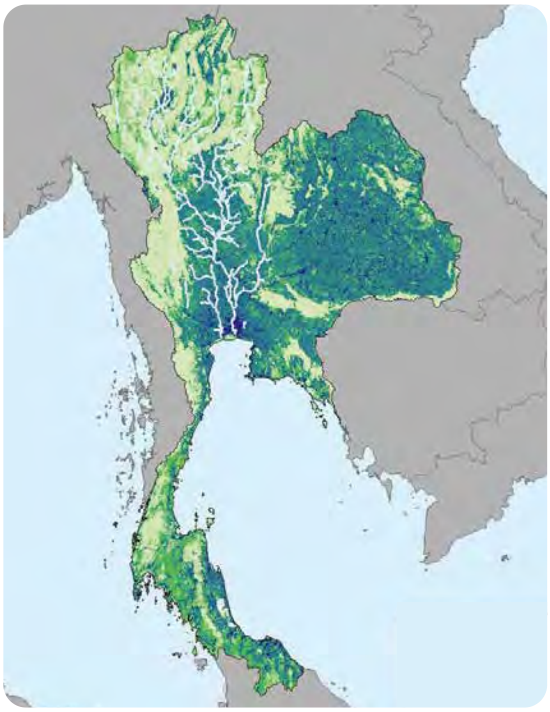
- What kind of documents are they? When were they published?
- What are the sources of these documents? Are these sources reliable?
- What type of extreme event is shown here?
- Look at the maps (**DOCUMENT 1**) where the floods happened: How dense is the population? Is it a problem for cities and people?
- Describe the **DOCUMENT 2**: what information is on the x and y (horizontal and vertical) axes? What are the units in the graph? What patterns do you see? Describe how the number of flooding events has changed since 1950. Is this pattern similar everywhere in the world? Which regions are the most severely affected by flooding?
- From the **DOCUMENT 3**, can you explain why there is an increase in floods throughout the world? What would you predict concerning the rate of future flooding events?
- Have you or people you know ever experienced such an event? How did you feel? What did you do to protect yourself? You can share a story.

DOCUMENT 1: FLOODING AND POPULATION DENSITY IN THAILAND

Number of provinces in Thailand affected by flooding on September 6, 2019

National Capital Flood affected province Other country

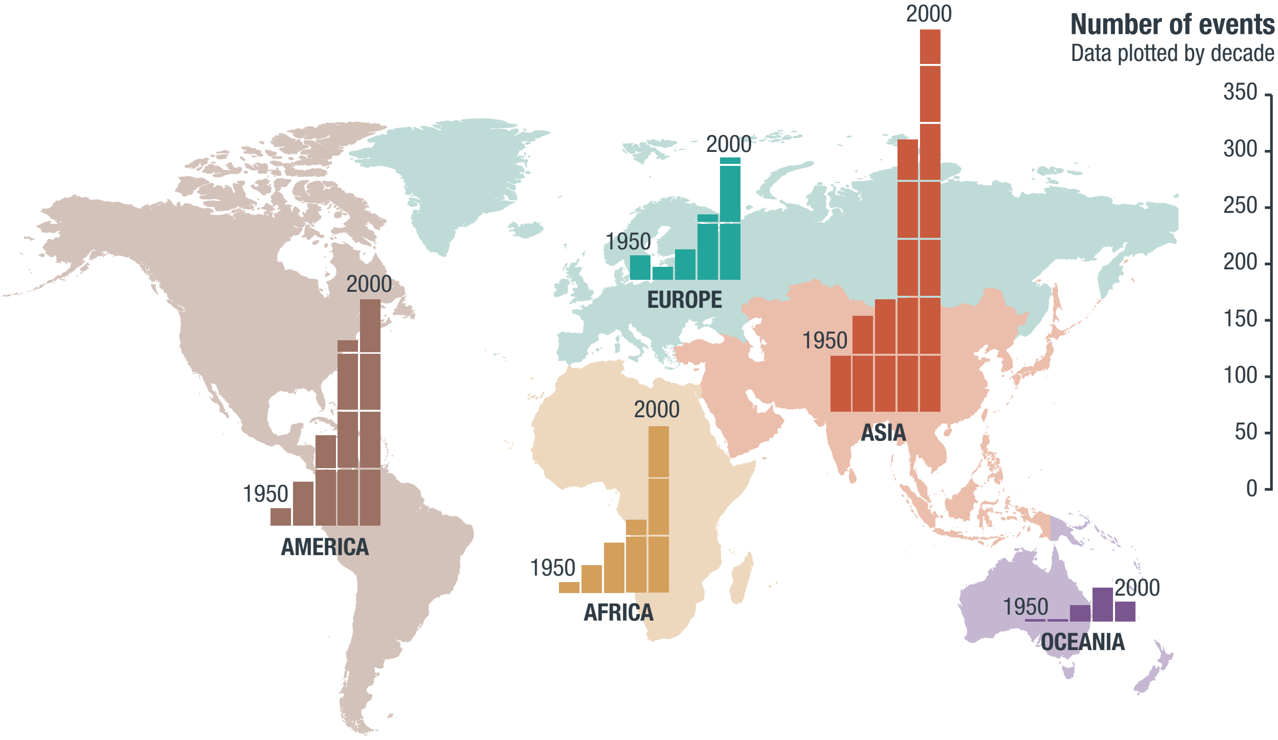
Population density in Thailand December 2016



Population density : High Low

Source:
– Left: Red Cross and Red Crescent Societies. https://reliefweb.int/map/thailand/thailand-floods-information-bulletin-6-september-2019
– Right: AIR website. https://www.air-worldwide.com/Blog/Floods-in-Thailand-Are-Regular-Natural-Disasters/

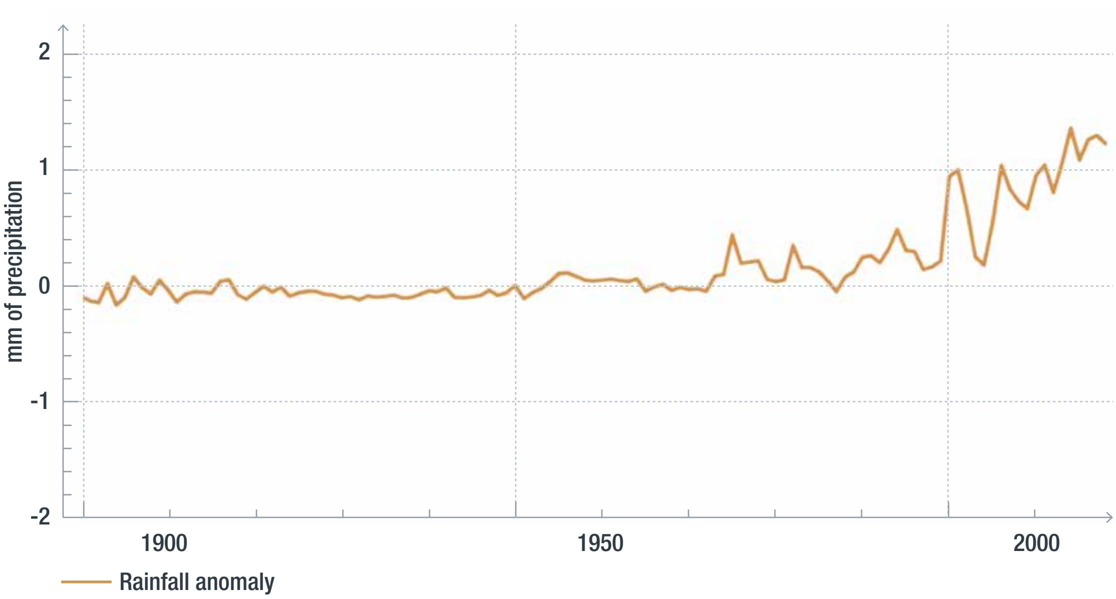
DOCUMENT 2: NUMBER OF FLOOD EVENTS OVER FIVE DECADES, 1950–2000



Source: Adapted from Millenium Ecosystem Assessment, 2007. https://www.grida.no/resources/6062

DOCUMENT 3: CHANGE IN THE GLOBAL ANNUAL AVERAGE DAILY RAINFALL COMPARED TO A 30 YEAR "NORMAL" VALUE FROM 1961-1990 (I.E. RAINFALL ANOMALY)

Floods are related to precipitation (number of rain days or intensity of rain).



Source: Adapted from clivebest.com, data from NCDC Daily. http://clivebest.com/blog/?p=8502

Look at the documents below and answer the following questions:

- Describe the documents below. When were they published?
- What are the sources of these documents? Are these sources reliable?
- What type of extreme event is shown here?
- According to the picture (**DOCUMENT 1**), how is drought affecting the population?
- Look at the map (**DOCUMENT 2**). The droughts have greatly impacted the Sahel region, especially in 2012. Can you explain why this region in particular has frequent droughts?
- Study **DOCUMENT 3**: what information is on the x and y (horizontal and vertical) axes? What are the units on the graph? What patterns do you see?
- How does the pattern of rainfall change over the years in Sahel? Compare the rainfall in Sahel with the precipitation above Jakarta or Berlin. Can you explain how this is related to the increase in drought events in Sahel?
- How do you think these types of events can change over time, especially with reference to climate change?
- Have you or people you know ever experienced such an event? How did you feel? What did you do to protect yourself? You can share a story.
- **DOCUMENT 4** describes the project, the Great Green Wall of trees. What do you think this project is about? How do you think this will help the region?

DOCUMENT 1: THE CONSEQUENCES OF DROUGHT

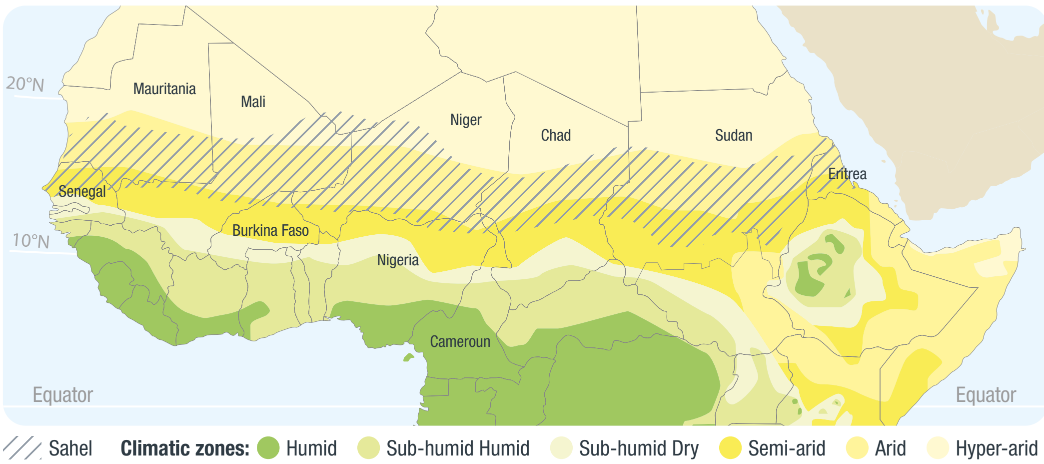
"This drought is slowly killing everything," says Mahmoud. *"First it 'swept away' the land and the pastures; then it 'swept away' the animals, which first became weaker and weaker and eventually died. Soon, it is going to 'sweep away' people. People are sick with flu, diarrhoea, and measles. If they don't get food, clean water, and medicines, they will die like their animals."* Mahmoud Geedi Ciroobay.

Source: Oxfam.
https://www.oxfam.org/en/drought-east-africa-if-rains-do-not-come-none-us-will-survive

DOCUMENT 2: CLIMATE IN THE REGION OF SAHEL

This map shows the different climates in the Sahel region:
- → An "arid" climate means that it only rains 50 to 150 mm per year. These rains fall seasonally.
- → A "semiarid" climate is also seasonal, with up to 500 mm of rain per year.

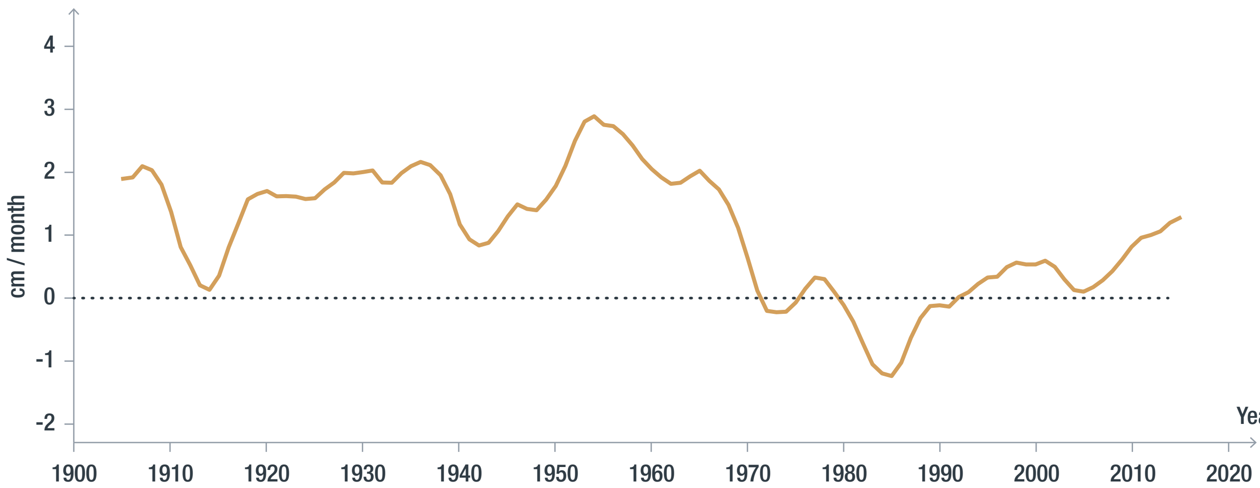
To get an idea, it may rain about 50 to 300 mm per month in Jakarta, and 650 mm per month in Berlin, so Sahel is a particularly dry region!



Source: Adapted from Climate and climate change, Regional Atlas on West Africa, chapter 14, SWAC/OECD, West African Studies, January 2008.
https://www.oecd.org/swac/publications/40121025.pdf

DOCUMENT 3: SAHEL RAINFALL INDEX (JUNE-OCTOBER)

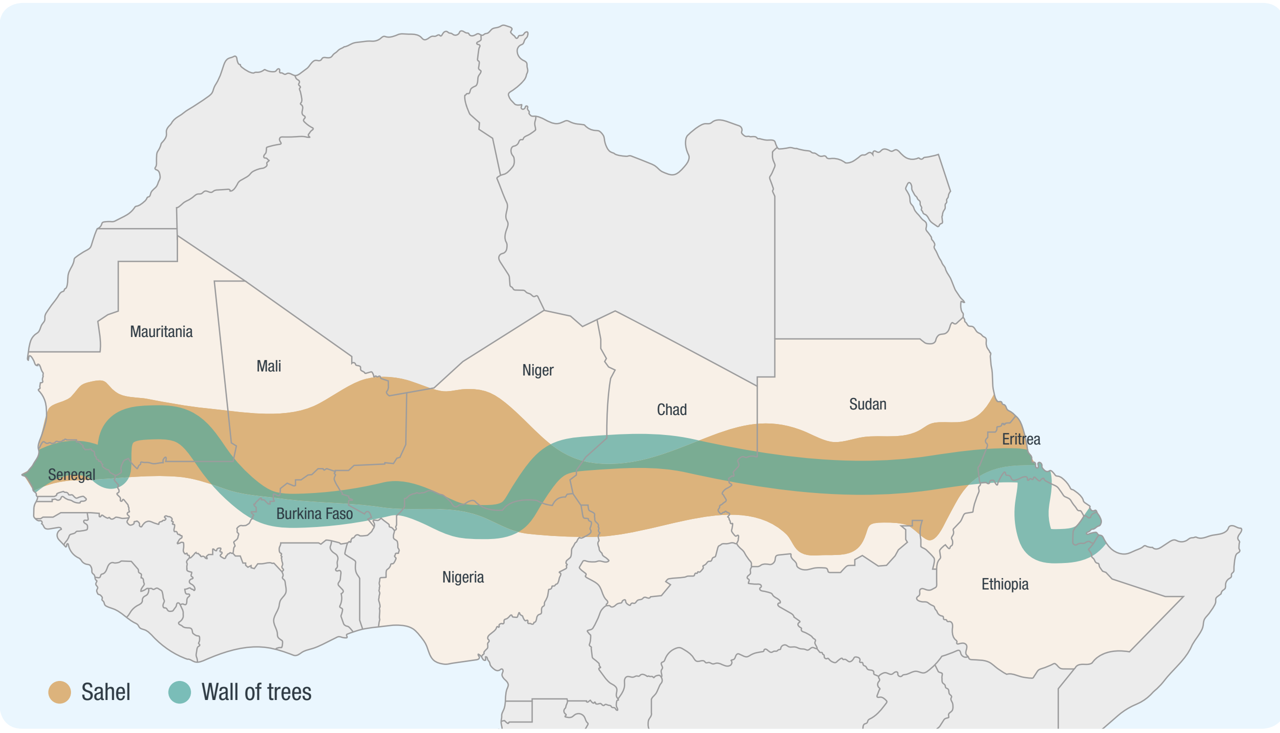
The rainfall index quantifies the rainfall, in cm / month. If the quantity of rain falls below 0, it means that soil is losing more humidity than it gains with rain.



Source: Data from JISAO, 2018

DOCUMENT 4: THE “GREAT GREEN WALL” PROJECT

The Great Green Wall is an African-led movement with an epic ambition to grow an 8,000 km natural wall of trees. Since trees provide humans with humidity and oxygen, as well as absorbing carbon dioxide, it may be a solution to the threat of climate change.



Source: https://www.greatgreenwall.org

LESSON C4
CLIMATE CHANGE, HUMAN ACTIVITIES AND BIODIVERSITY

MAIN SUBJECTS
Natural sciences

DURATION
~ Preparation: 25 min
~ Activity: 55 min

AGE GROUP
9-12 years

LEARNING OUTCOMES
Through a roleplaying game or multimedia animation activities, students explore different terrestrial food webs.

They learn that:
~ In ecosystems, living organisms interact with and depend on others.
~ Living species are adapted to specific climates and landscapes.
~ Land biodiversity is affected by climate change and human activities in different ways (species may migrate or disappear, or sometimes evolve over long timeframes).

KEYWORDS
Ecosystems, food web, prey-predator relationship

TEACHING METHOD
Roleplaying game, multimedia activities

PREPARATION 25 MIN

EQUIPMENT
- **WORKSHEETS C4.1, C4.2, C4.3, C4.4, C4.5** and **C4.6**.
- Yarn (so that each species of the food webs on the worksheets can be hung around the neck of each student).
- String (yarn will do as well) to extend between groups of students (long enough to allow at least 2m for each piece, and more than one piece per student). We strongly recommend having several spools or balls.
- Multimedia resources: Land food webs multimedia activities.

LESSON PREPARATION
Option 1:
1. Choose one or several food webs to work on (depending on the level of your students), and print the corresponding worksheets:
   → **Trainees:** soil (**C4.2**), agrosystem (**C4.6**).
   → **Curious:** savannah (**C4.3**), Guyanese tropical forest (**C4.5**).
   → **Experts:** riparian ecosystem in Alaska (**C4.1**), temperate forest in England (**C4.4**).
2. Cut out the different species and make a necklace for each one in the food web (the image of the species, glued on cardboard, and a piece of yarn, for example). Each student will embody a species and hang the corresponding necklace around their neck, so that their hands are free to hold strings that will connect them to other species.
3. Think about the roles for each student in advance, as well as the organisation of classroom space to allow for the game. If it is possible for you to do this activity outside, it may be a good idea to have more space.
4. Tie a big knot (or several) at one extremity of the strings, representing the "predator" end.

TEACHER TIP
The knotted end represents the direction of the flow of matter, from prey to predator, as might be shown with an arrow on a document.

Option 2: Login to multimedia activities. If the Internet connection is too weak or non-existent, the activities can be downloaded ahead of time. Refer to the instructions on the OCE website.

TEACHER TIP
The goal of this lesson is to explore the consequences of climate change on food webs, but it does not focus on the study of the food webs themselves. A preliminary lesson about the different species can be introduced beforehand to describe the food webs.

INTRODUCTION 10 MIN

Go over the different consequences of climate change on land. Ask the students: *What consequences could the various climate change phenomena (like extreme events, drought, desertification, land degradation, global warming, etc.) have for animals and plants in different ecosystems?*
Write the students' suggestions on the whiteboard.

PROCEDURE 35 MIN

OPTION 1: ROLEPLAYING GAME 35 MIN

1. Tell the students they will now play "the ecosystem game". Give each of them a necklace depicting a species that is part of a food web (provided in the worksheets) and several pieces of string. Different ecosystems are available with different levels of complexity depending on the grade you are teaching. The food webs can be chosen according to the level of your students, their previous knowledge of ecosystems, and their geographical area. Assign each student one species depending on their level.

Example 1: Riparian ecosystem in Alaska food web

WORKSHEET C4.1 EXPERT

- 1 student for each of these species: brown bear, moose, grey wolf, river otter.
- 2 students for each of the following: salmon, organic matter, mineral matter, blue fly, krill.
- For the remaining students: 1/3 play diatoms, 1/3 play red elderberries, 1/3 play Sitka spruce.

> **TEACHER TIP**
> The riparian ecosystem is special as these two particularities need to be considered:
> Students who play organic matter will connect with salmon only when the latter have been connected with the bear, since salmon can only be turned into organic matter as leftover carcasses from the bear's meals.
> Students who play mineral matter will only connect with organic matter, and subsequently Sitka spruce, when organic matter has been connected to the blue fly, since blue flies contribute to organic matter decay, producing mineral matter.

Example 2: Soil food web

WORKSHEET C4.2 TRAINEE

- 1 student for each of these species: wolf spider, mole, ant.
- 2 students for each of the following: earthworm, bacteria, fungi, nematode.
- For the remaining students: 1/2 play fern, 1/2 play organic matter.

Example 3: Savannah food web

WORKSHEET C4.3 CURIOUS

- 1 student for each of these species: lion, leopard, spotted hyena.
- 2 students for each of the following: giraffe, Thomson's gazelle, African buffalo, zebra.
- For the remaining students: 1/2 play acacia, 1/2 play common finger gras.

Example 4: Temperate forest in England food web

WORKSHEET C4.4 EXPERT

- 1 student for each of these species: sparrowhawk, wild boar.
- 2 students for each of the following: blue tit, great spotted woodpecker, Capricorn beetle, spider, oak processionary caterpillar.
- For the remaining students: 1/3 play oak leaves, 1/3 play acorns, 1/3 play dead wood.

Example 5: Guyanese tropical forest food web

WORKSHEET C4.5 CURIOUS

- 1 student for each of these species: jaguar, harpy eagle, boa constrictor.
- 2 students for each of the following: howler monkey, tamarin, capuchin monkey, spider monkey, tapir, agouti.
- For the remaining students: 1/2 play balata trees, 1/2 play carapa trees.

Example 6: Agrosystem food web

WORKSHEET C4.6 TRAINEE

- 1 student for each of these species: human, European honey buzzard.
- 2 students play bumblebees.
- For the remaining students: 1/3 play cultivated wheat, 1/3 play apple trees, 1/3 play clover.

2. Make sure the students understand that diatoms, elderberries, trees, grass and plants are the most abundant organisms, at the base of every food web, because they can grow using only minerals, water, carbon dioxide and light. Top predators are always less abundant, but they need a lot of individuals of the species they feed on to have enough food.

3. Make sure the students take some time to read the text related to their species.

4. The students have to figure out on which species their own depends for survival (which species it can eat). Start at the beginning of the food web (diatoms, elderberries, trees, grass and plants), and continue up the food web to the predators. Ensure the predators keep hold of the knotted end of the strings. They will hold a string for every species they depend on, their prey holding the other end of the string. Ask the students in turn to explain their choice of connections.

5. Once the food web is completed (all species are connected and everyone agrees on all connections), you can suggest different configurations for these ecosystems. You can review the student suggestions you wrote on the whiteboard and add some of the below suggestions for the corresponding food web. If one species disappears due to an imbalance in its ecosystem, the student sits down on the floor, and any "predator" students connected to it would also sit down if this were their only source of food. In this way it is possible to visualise the impact of the disappearance of a species on the whole food web.

TEACHER TIP
This game is a really simplified version of what would actually happen in reality: if a species disappears, this would not necessarily completely destabilise the ecosystem. Nevertheless, representing it in this way to pupils makes it possible for them to visualise what might happen.

Examples of the impact of climate change and human activities you can use:

Example 1: Alaska food web

- Because of higher temperatures, there is a seasonal offset. In Alaska, this has led to a modification in elderberry bush development: their fruit appears sooner in the year (mid-July instead of mid-August), around the same time as salmon spawn in the rivers; in the past, there were only salmon available to eat at this time.
- Bears prefer eating elderberries to salmon, probably because they are easier to gather. Thus, less salmon carcasses are left on the soil and there is less associated organic-enriched waste on forest soils.
- Since soil is becoming less rich in organic matter, it is also growing poorer in mineral content.
- Because of this loss in the soil's nutrients, the spruce grows at a slower rate and produces smaller needles, which are less tasty for the moose.

Example 2: Soil food web

- Because of temperature rise and an increase in the frequency of droughts in already dry regions, soil will potentially become drier and hotter.
- This drier and hotter soil makes it more difficult for species to develop, leading to less organic matter.
- Since organic matter is at the beginning of the food web, climate change affects everything.

Example 3: Savannah food web

- The rise in temperature, regular droughts and the increase of CO_2 in the atmosphere has led to better growing conditions for some trees, like acacias.
- On the other hand, grasses are slowly withering away because they are more sensitive to fluctuations in rainfall.
- This situation will be riskier for grazing animals than for those who feed on leaves.

Example 4: Temperate forest in England food web

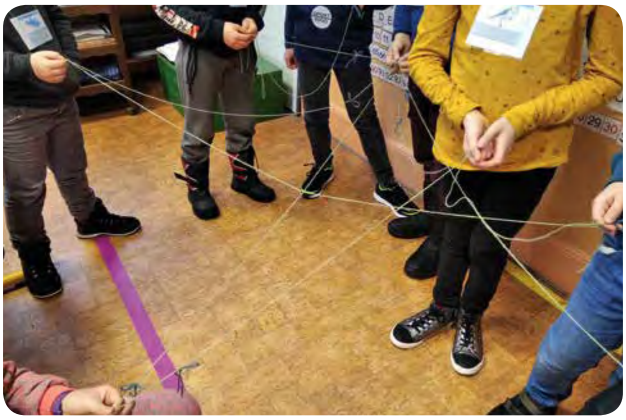
- Climate change has led to an increase in temperature in England.
- Because of the warmer weather at the end of winter, oak leaves are appearing earlier.
- Caterpillars are able to adapt to this change, but blue tits are not so fortunate. They can't find proper food for their nestlings and, as a result, their populations are slowly declining.

Example 5: Guyanese tropical forest food web

- In the Guyanese forest, human activities have several impacts: the logging industry has led to a decrease in some species of trees.
- Spider monkeys and jaguars are hunted to be eaten or for their fur.

Example 6: Agrosystem food web

- In order to produce more food for humans, monocultures are favoured at the expense of biodiversity: more wheat fields are being cultivated.
- The clover plant is disappearing, being replaced by wheat, and bumblebees can no longer find the floral resources necessary for their survival. With the disappearance of the bumblebee and its honey, the European honey buzzard also vanishes.
- Since the bumblebee is also a pollinator for apple trees, it is becoming more difficult for apple trees to spread.
- Humans are harvesting more wheat but less apples.



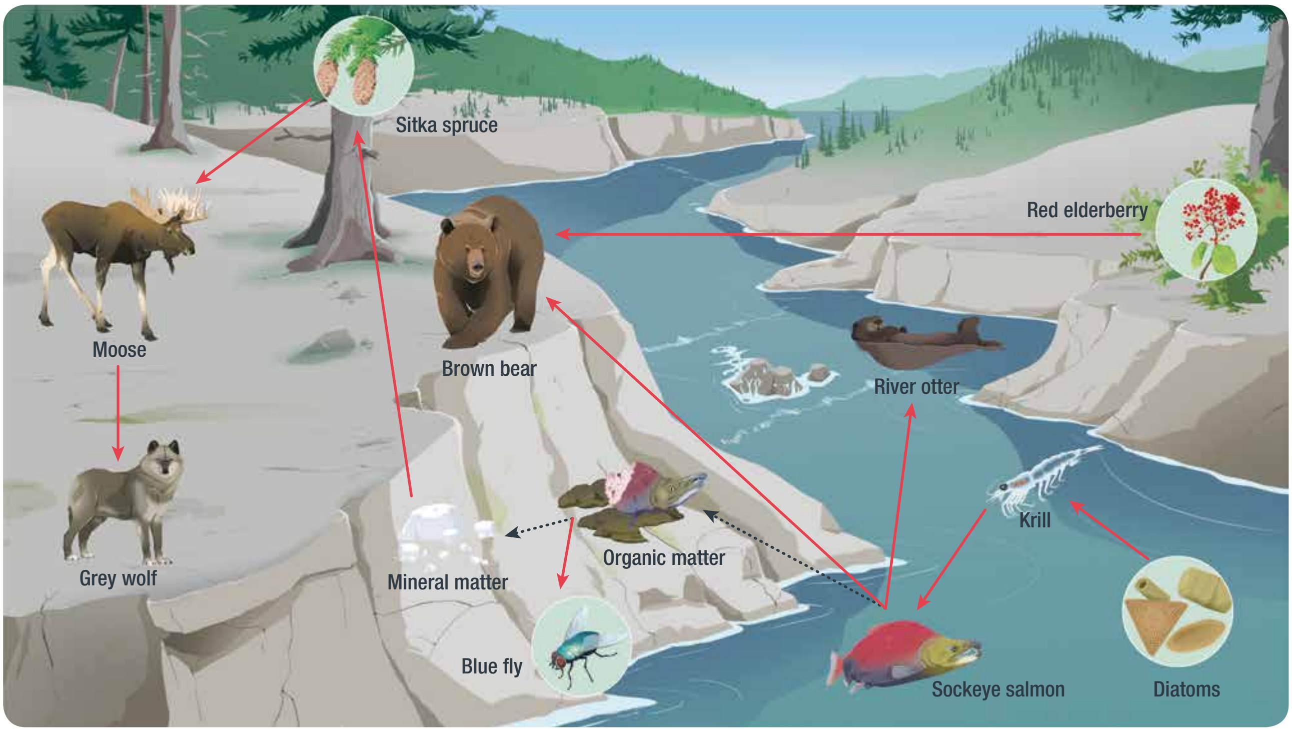
Students are connecting through the temperate forest food web.

6. You can play the same game with different food webs. The students should realise that all living beings are interconnected and that it is important to maintain a balanced ecosystem.

7. After the game has been played with different ecosystems and climate change consequences, place all the roleplaying cards on the whiteboard. Ask the students to draw all the links between species that were represented in the game, connecting them all with arrows, starting with those that are at the base of the food webs. Explain that the arrows mean “is eaten by”: the pointed end is always oriented towards a predator.

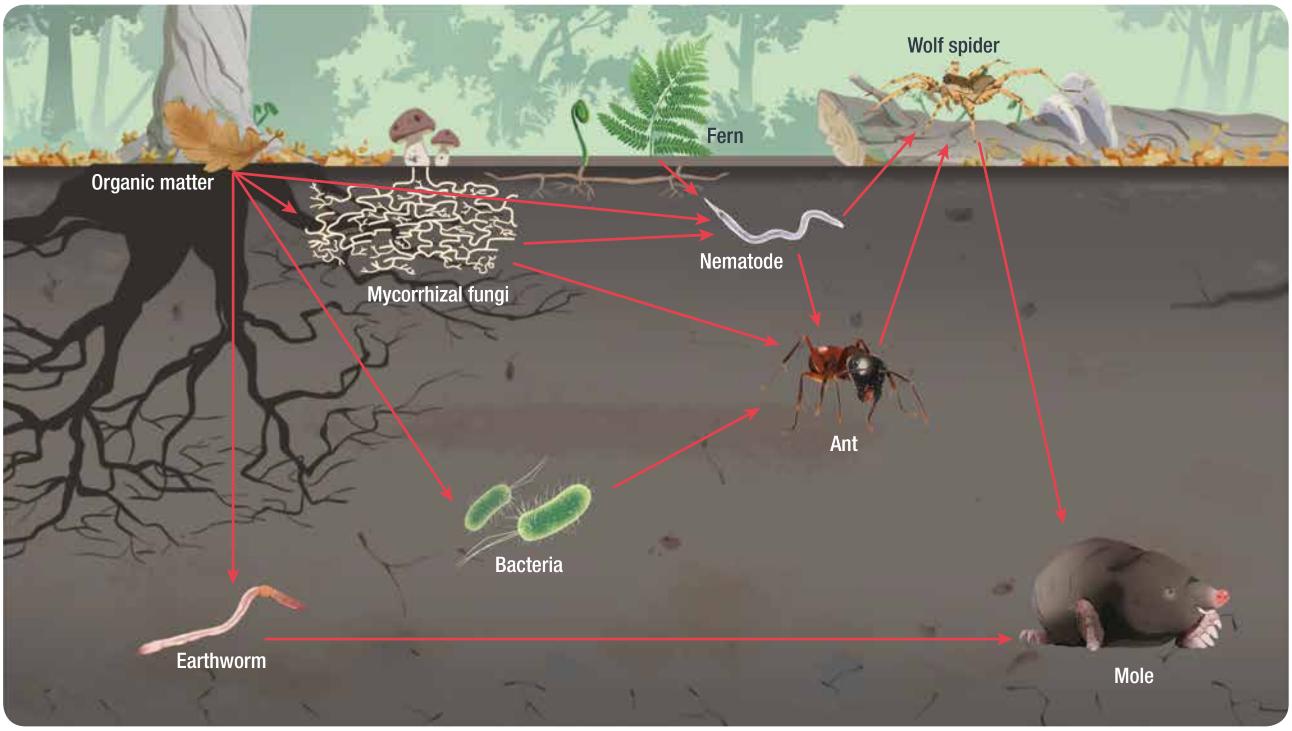
SOLUTION FOR WORKSHEET C4.1

Example 1 – Riparian ecosystem in Alaska food web



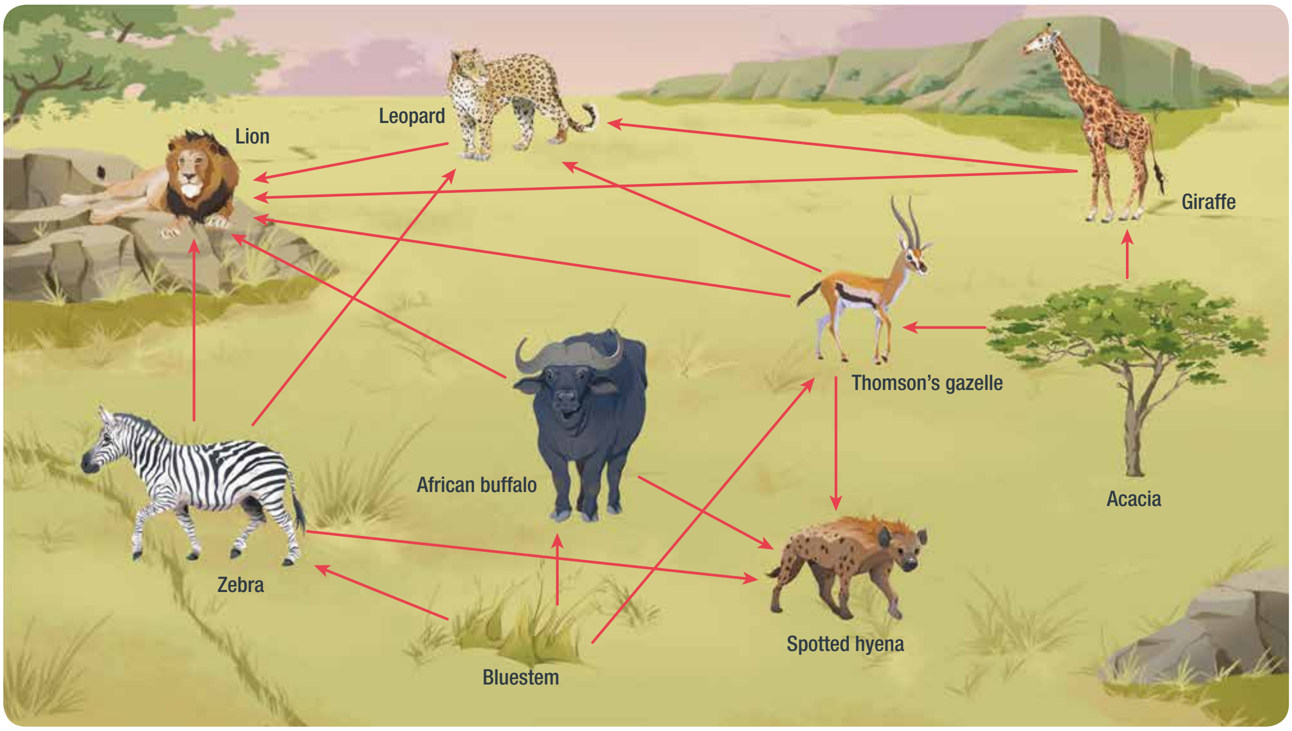
SOLUTION FOR WORKSHEET C4.2

Example 2 – Soil food web



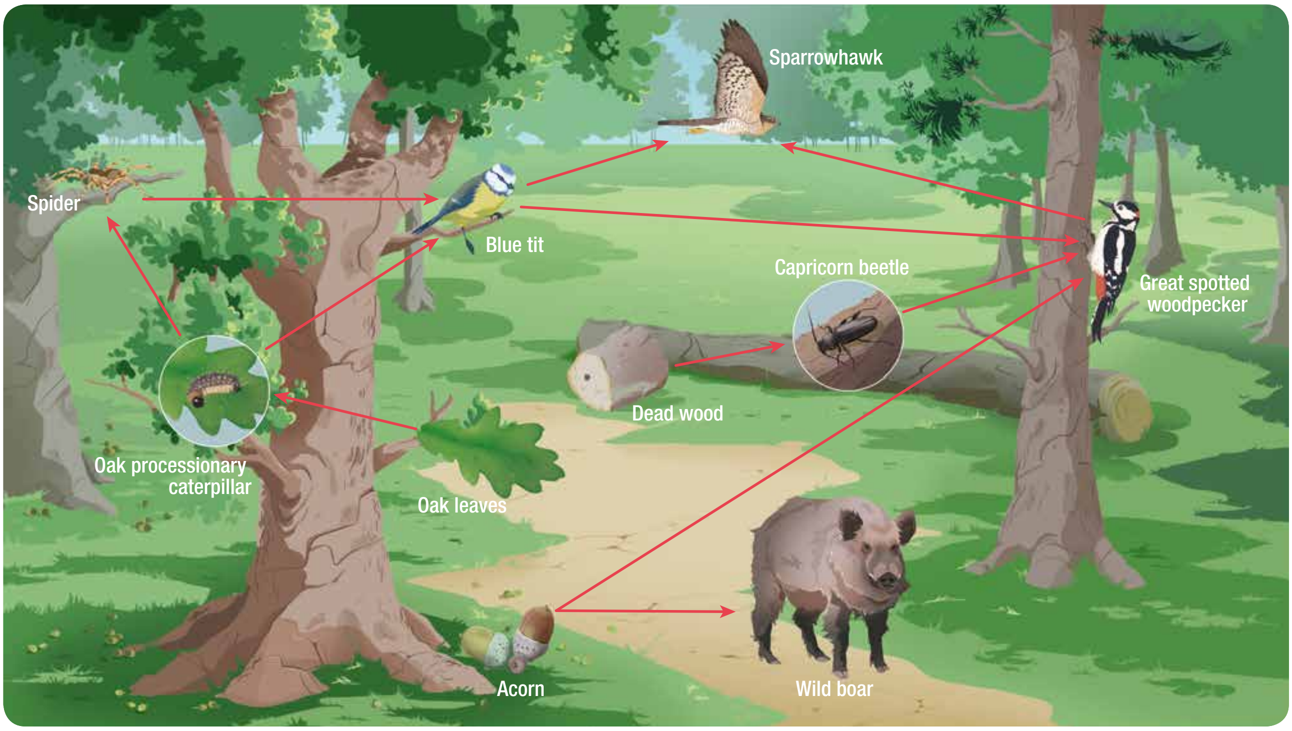
SOLUTION FOR WORKSHEET C4.3

Example 3 – Savannah food web



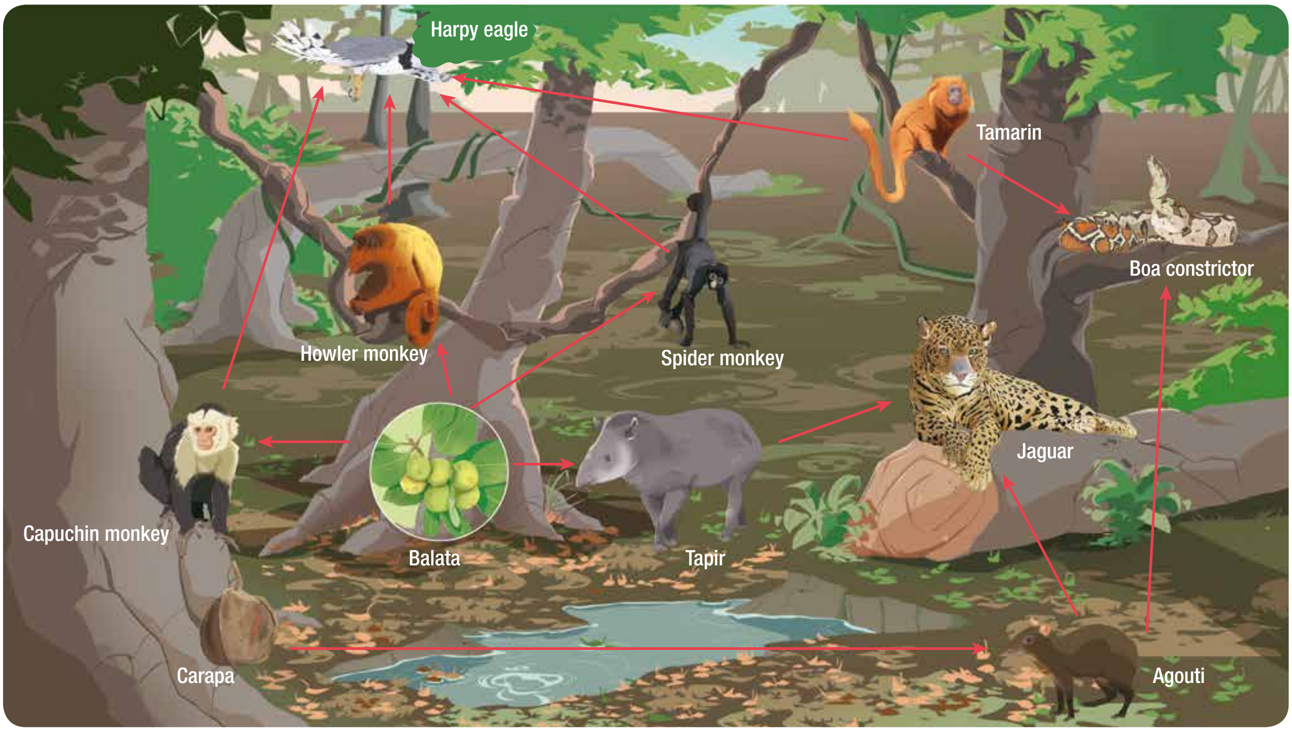
SOLUTION FOR WORKSHEET C4.4

Example 4 – Temperate forest food web



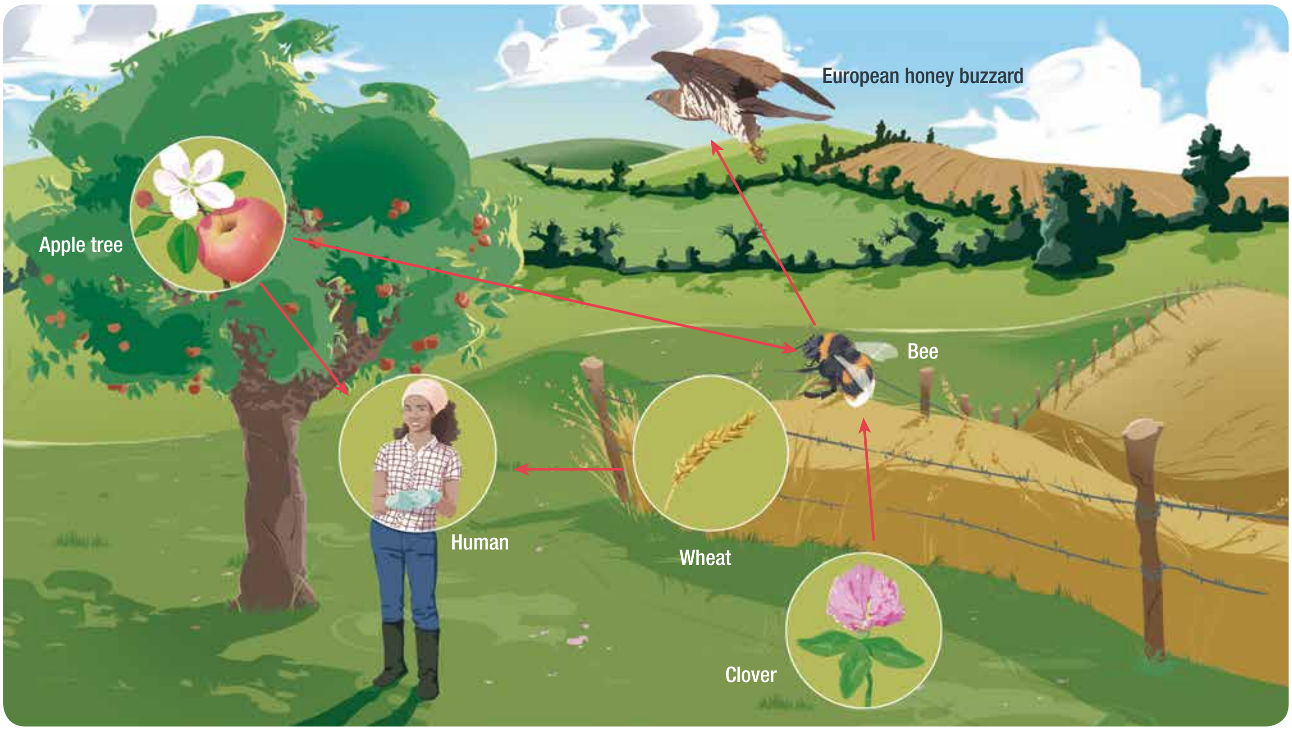
SOLUTION FOR WORKSHEET C4.5

Example 5 – Guyanese tropical forest food web



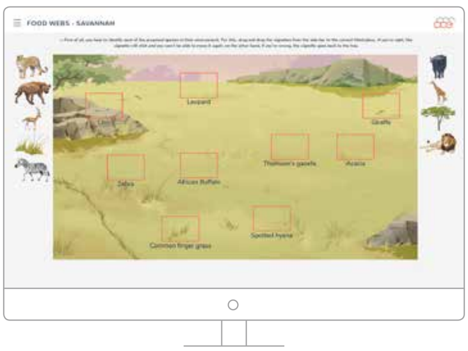
SOLUTION FOR WORKSHEET C4.6

Example 6 – Agrosystem food web



OPTION 2: MULTIMEDIA ACTIVITIES 35 MIN

Instead of doing the roleplaying game, you can use the multimedia activities provided (Land food webs).



WRAP-UP 10 MIN

Discuss the alimentary interdependence of all organisms in the ecosystems, how ecosystems have a fragile balance that must be maintained, and the consequences for humans if this balance is not preserved.

OPTIONAL EXTENSION: ECOSYSTEM FOOD WEB MURAL

Each student draws a species from the chosen food web, along with its predators and prey, on a landscape A4 sheet of paper. Predator/prey ratios should be respected within the class.
With the help of your students' drawings, you can create a large mural depicting an ecosystem and its species.

BACKGROUND FOR TEACHERS

ECOSYSTEM

All living things from a given environment form a functional whole, within which the different elements, both living things (a **biocenosis** is a community of living organisms) and non-living things **(abiotic factors)**, such as climate-related factors, soil type and chemical elements **(biotope)**, interact. The term **"ecosystem"** describes this whole. There are a multitude of terrestrial ecosystems since there is a large variety of landscapes, each one depending on local climate and characterised by a number of abiotic factors and living beings. One type of terrestrial ecosystem created solely due to human activities, the agrosystem, is used to produce food.

While ecosystems evolve over time to reach a state of equilibrium, known as **"climax"**, this equilibrium may be easily broken if the functioning of the ecosystem is disrupted, by human activities or climate change, for example.

FOOD WEBS

Each ecosystem is structured by trophic relations, in which every organism is either **prey** or **predator** to each other. These relations can be viewed as chains, symbolising "who is eaten by whom". However, the reality is more complex because **food chains** are actually **food webs**, meaning that an organism may eat several species and a species may be eaten by multiple organisms.
Photosynthetic organisms **(autotrophs)** are the basis of every food web: they can produce their own food using light, water, carbon dioxide or other chemical compounds and so are called **"primary producers"**. Autotrophs are then eaten by **primary, secondary or tertiary consumers.** When drawing a food web, the arrows conventionally symbolise "is eaten by".

As all species in an ecosystem are interconnected, even the slightest disruption in a species population, or the loss of a single species, can affect all others depending on it.

RIPARIAN ECOSYSTEM IN ALASKA FOOD WEB

DIATOMS

Diatoms are really tiny organisms floating in the sun-lit upper layer of the water or lying on the bottom. Like plants, diatoms use sunlight, water, CO_2 and dissolved minerals for photosynthesis to produce sugar, which they feed on. Diatoms are a primary producer, at the base of the food web.

RED ELDERBERRIES

Elderberries are the fruit of the sambucus tree. The berries are juicy and, in the past, they used to ripen in late August. They are a primary producer, at the base of the food web. Elderberries are particularly appreciated by bears.

SITKA SPRUCE

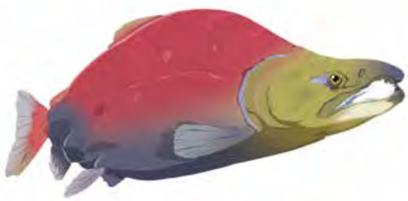
Sitka spruce is a species from the west coast of North America. Since it is a tree, it uses sunlight, water, CO_2 and minerals for photosynthesis and growth. Enriched mineral matter soil, associated with salmon decomposition, allows the tree to develop more tasty needles for moose.

KRILL

Krill is part of the zooplankton family. They can be a few centimetres long and weigh up to 2g. Krill feed by filtering diatoms out of the water. They are eaten by sockeye salmon.

BLUE FLY

The blue fly is a big fly (almost 1.5cm long) that feeds on matter from other organisms, such as salmon carcasses and dead bodies. The blue fly lays its eggs on the carcass and its larvae's development enhances decomposition.



SOCKEYE SALMON

Sockeye salmon, also known as red salmon, live in lakes. They feed on krill and are able to filter them through gill rakers. They are eaten by brown bears and their decaying carcasses enrich the soil with nutrients.

RIPARIAN ECOSYSTEM IN ALASKA FOOD WEB

RIVER OTTER

The river otter typically weighs between 8 and 11 kg. They can remain underwater for nearly 4 minutes and swim at speeds approaching 11 km/h. They may even cooperate with each other when they fish. They prey mostly on salmon.

BROWN BEAR

Brown bears can weight up to 350 kg and live to be 25 years of age. They are omnivorous and quite good hunters, able to catch salmon directly in the flowing river! They feed on salmon, but would prefer to eat elderberries, if available.

MOOSE

Moose are the largest members of the deer family, standing as tall as 2.3 m high. As herbivores, they have a fantastic sense of smell, allowing them to find the best needles of the spruce tree to eat.

GREY WOLF

Grey wolves live in groups called packs, which include 7 or 8 wolves. They work together to hunt, raise their young and protect their territory. Wolves are carnivorous and they mostly feed on big herbivores, like moose.

ORGANIC MATTER – SALMON CARCASSES

When bears hunt and eat salmon, they leave the carcasses on the banks of the river. Blue flies then eat and lay their eggs on the decaying bodily remains.

MINERAL MATTER – SOIL NUTRIENTS

Mineral matter is produced when blue flies feed on organic matter, such as salmon carcasses, enhancing the decomposition process. This leads to an enrichment of the soil, which is useful for the growth of the Sitka spruce.

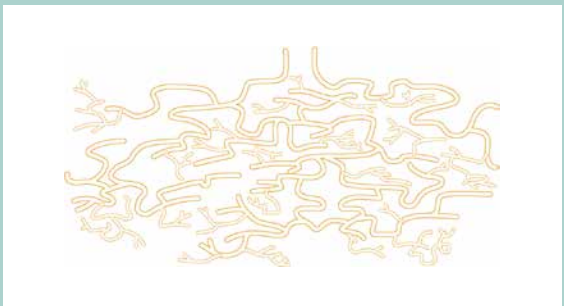
SOIL FOOD WEB

ORGANIC MATTER

Organic matter in temperate forests is mostly found under trees and plants, in the soil layer called litter. We use the term 'organic matter' for everything that comes from dead animals or plants, mostly from dead leaves, for example.

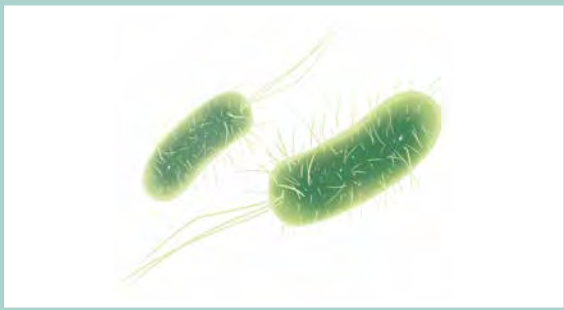
FERN

Ferns are flowerless green plants which reproduce by spores rather than by seeds. Many fern species grow on the trunks and branches of trees. They can have a close relationship with mycorrhizal fungi and their roots are eaten by some nematodes.



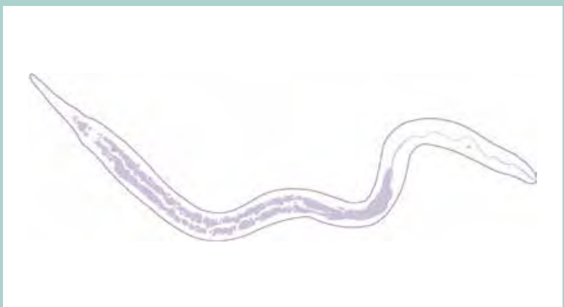
MYCORRHIZAL FUNGI

Some fungi in the forest can develop an important 'root' web, called mycorrhizae. This deep soil web can associate with trees or fern roots, exchanging nutrients. They are eaten by some nematodes.



BACTERIA

Bacteria are microscopic (invisible to the eye) living things that only consist of one cell. Bacteria play an important role in organic matter decay and they feed on nematodes and ants.



NEMATODE

Nematodes are also called round worms because of the shape of their body. There are more roundworms in the world than any other multicellular creature! They feed on plant roots, bacteria and fungi and are eaten by spiders or insects, like ants.

ANT

Ants are social insects living in colonies, which consist of the queen, the female workers and the males. The queen is the only one that can lay eggs. Female workers are in charge of providing the colony with food, like fungi, nematodes or bacteria.

SOIL FOOD WEB

WOLF SPIDER

Wolf spiders get their name from the way they hunt, which is similar to the way wolves hunt: they generally wait for their prey to wander close by, and then rush out to kill it. Wolf spiders live on the soil's surface and catch insects, like ants, as well as nematodes.

MOLE

Moles are small, dark mammals. Their poor eyesight is balanced by their acute senses of smell and touch. They have powerful claws allowing them to dig through the ground to find their prey: earthworms.

EARTHWORM

Earthworms live in damp, loose soils or in loose leaf litter. They play a key role in forest ecosystems as they aerate and enrich the soil with their mineral droppings. Their typical diet is decaying organic matter.

SAVANNAH FOOD WEB

ACACIA

Acacias are trees; hence they use sunlight, water, CO_2 and minerals for photosynthesis and growth. They have developed many different defensive tactics against herbivore predators (like giraffes and gazelles), including thorns, chemical production and ant recruitment.

BLUESTEM

Bluestems are the most abundant species of grass on the African savanna. They use sunlight, water, CO_2 and minerals for photosynthesis and growth. They are a primary producer, at the base of the food web. They are consumed by herbivorous grazers, like zebras or buffaloes.

THOMSON'S GAZELLE

The Thomson's gazelle is the most common gazelle in East Africa. This small antelope can run extremely fast, 80 to 96 km/h, to escape from its predators, mostly lions and leopards. They feed on acacias and grass.

GIRAFFE

Giraffes are the world's tallest living land animals and an adult male can grow up to 5.5 m high! They use their long necks to feed on the acacia leaves and are eaten by leopards.

AFRICAN BUFFALO

The African buffalo is a very robust species; one buffalo can weigh up to 1,000 kg. Thus, there are only a few predators (such as lions and hyenas) who can eat them as they are able to defend themselves well. The buffalo is one of the most successful grazers in Africa.

ZEBRA

Zebras look like horses, but their black-and-white striped coat is quite unique, considering every zebra has a different pattern! They are herbivores and eat grass. Despite their fierce fighting skills, they have several predators, including hyenas, lions and leopards.

SAVANNAH FOOD WEB

LEOPARD

The leopard belongs to the feline group and can run up to 58 km/h and leap 6 m forward into the air! They are solitary predators that climb trees to eat their prey, including giraffes, zebras and gazelles, and keep it safe from hyenas and lions.

LION

Lions are the only felines that live and sleep in close-knit groups. Only the females are involved in hunting, chasing animals such as giraffes, gazelles, zebras and buffalos.

SPOTTED HYENA

Spotted hyenas are also known as laughing hyenas because of their particular call. They live in groups of 5 to 90 members, in dens. Spotted hyenas are mostly scavengers and feed on the carcasses of zebras and buffalos.

TEMPERATE FOREST IN ENGLAND FOOD WEB

OAK LEAF

A mature oak tree stands about 30 m tall and produces leaves that fall during the autumn. Oaks use sunlight, water, CO_2 and minerals for photosynthesis and growth, thanks to their leaves. Thus, they are at the beginning of the food web.

ACORN

Oak trees may start producing acorns when they are about 20 years old and a mature tree can produce 90,000 acorns a year. Acorns are nuts, each containing a single seed. The great spotted woodpecker and the boar have made acorns an important part of their diets.

OAK PROCESSIONARY CATERPILLAR

Oak processionary caterpillars are parasitic pests that thrive almost exclusively on oak trees. They hatch in spring and feed on oak leaves, stripping the tree of its leaves. They are part of the blue tit's diet

CAPRICORN BEETLE

Capricorn beetles are insects belonging to the family of the longhorn beetle. They mostly feed on dead wood and even their larvae develop on the wood under the bark. They are eaten by great spotted woodpeckers.

SPIDER

Spiders do not belong to the insect group as they have 4 pairs of legs. They are quite good hunters and can spin webs in order to catch their prey. In temperate forests, they feed on oak processionary caterpillars.

BLUE TIT

Blue tits are common singing birds resident in temperate Europe and Asia. They are very useful as they destroy pests. When caterpillars hatch during the spring, blue tits use them to feed their nestlings.

TEMPERATE FOREST IN ENGLAND FOOD WEB

GREAT SPOTTED WOODPECKER

Great spotted woodpeckers have black and white plumage with a red patch on their lower belly. They use their long tongue to pick out insects or even the chicks of other birds, such as blue tits, once they have pecked open the tree trunk. Great spotted woodpeckers also eat acorns.

SPARROWHAWK

Sparrowhawks are small birds of prey. They mostly eat small birds which live in woodland areas, as well as in towns and city gardens. Sparrowhawks hunt blue tits and great spotted woodpeckers.

WILD BOAR

As a nocturnal animal, the wild boar is active during the night. As an omnivore, they can consume food of both plant and animal origin, but they particularly like acorns.

DEAD WOOD

Dead wood is what remains when trees die. It plays a major role in forests since it is home and food to many insects, including the capricorn beetle.

GUYANESE JUNGLE FOOD WEB

BALATA

The balata, also called the bully tree, produces a milky juice that can be turned into rubber. Like other trees, they need sunlight, water, CO_2 and minerals for photosynthesis and growth. Their fruits are eaten by many species, including tapirs, capuchin monkeys, spider monkeys and howler monkeys.

CARAPA

The carapa is a tree mostly found in South America and Guyana, where the oil in its fruit is used as insect repellent or for traditional medicine. As a tree, it needs sunlight, water, CO_2 and minerals for photosynthesis and growth. It is part of the diet of the agouti.

AGOUTI

The agouti is a rodent from Central and South American rain forests that looks like a large guinea pig. They have teeth designed like sharp incisors; carapa nuts are an important part of their diet.

TAPIR

Tapirs are nocturnal animals that like to spend a lot of time in water and they can even use their snout as a snorkel! They are herbivorous and mostly feed on the leaves and nuts of balata trees.

HOWLER MONKEY

Howler monkeys are one of the largest New World monkeys and they are definitely the loudest! The function of their howling may relate to intergroup spacing and territory protection. They move slowly and eat the leaves, fruits and nuts of the balata tree. They are prey for the harpy eagle.

TAMARIN

Tamarins are small monkeys which particularly enjoy climbing up trees. They can even jump 18 m from tree to ground without injury! They eat both plants and insects, and their biggest predator is the harpy eagle.

GUYANESE JUNGLE FOOD WEB

CAPUCHIN MONKEY

Capuchin monkeys are active during the day: they live and travel through the trees. Since they use tools, capuchin monkeys are considered to be the smartest New World monkeys. They are omnivorous and their diet includes balata fruit. They can be eaten by the harpy eagle.

SPIDER MONKEY

Spider monkeys use their long arms with hooklike hands and their prehensile tail to grab and climb up trees. The fruit of the balata tree is one of their favourite foods. Harpy eagles hunt spider monkeys.

BOA CONSTRICTOR

Boa constrictors are stealthy hunters and powerful snakes: they ambush prey and then swallow them whole. They particularly like agoutis and tamarins.

HARPY EAGLE

Harpy eagles are the heaviest birds in existence: their legs can be as thick as a small child's wrist! They use their powerful claws to catch prey, like capuchin monkeys, spider monkeys, tamarins and howler monkeys.

JAGUAR

Jaguars are the third largest cats in the world, are quite good swimmers and can also climb trees. In the Guyanese forest they hunt agoutis and tapirs.

AGROSYSTEM FOOD WEB

CULTIVATED WHEAT

Wheat is a cultivated species belonging to the Gramineae group. Like plants, wheat uses sunlight, water, CO_2 and minerals for photosynthesis and growth. Wheat is used as a basic human food in many countries.

APPLE TREE

Apple trees are cultivated in order to provide humans with food. To produce fruit, the flowers of the apple tree need to be pollinated by bumblebees, who, in turn, use them as a source of nectar for their food.

CLOVER

Clover belongs to the same family as the pea. The small herbaceous plants have three sections to each leaf. The flowers serve as food resources for bumblebees, and the bees, in turn, pollinate them.

BUMBLEBEE

Bumblebees are social insects that live in colonies: the queen bee, drones and worker bees all have specific tasks. Worker bees are in charge of gathering pollen from clover flowers or apple blossoms, for example, which is then transformed into nectar for food.

EUROPEAN HONEY BUZZARD

The European honey buzzard is a bird of prey and a long-distance migrant. It is a specialist feeder, living mainly on the larvae and nests of bumblebees.

HUMAN

Humans belong to the animal group. Hence, they need to feed on living things, such as plants and animals. Humans have domesticated numerous species and can eat cultivated wheat and apples.

SEQUENCE D
WHAT CAN WE DO?

Once the consequences of climate change on land are understood, and the true value of what is at stake grasped, there is just one more aspect needed before taking action: **accepting responsibility for what is happening.** This is the objective of our last sequence: students will explore their share of responsibility for climate change, as well as that of their family and country. **They will then spend some time expressing their feelings on this subject.** Afterwards, they will learn about the **social inequalities** associated with climate change, and about **climate justice.** Finally, they will discover that there are already many people in many places around the world taking action to mitigate and adapt to climate change. At this point, **they will decide what they can do themselves to help the situation.**

This sequence is strongly rooted in the social sciences and is aimed at pushing students to think beyond the exclusively environmental and self-preservation aspects of climate change.

LESSON LIST

◉ Core lesson ○ Optional lesson

◉	D1	Ages 9-15	**Our carbon footprint** Social sciences / Natural sciences / Computer sciences Students use a carbon footprint calculator to assess their carbon footprint and discuss what they can do to reduce it.	page 201
◉	D2	Ages 9-15	**How do you feel about climate change? Working on emotions** Social sciences / Philosophy / Visual arts / Written expression This lesson gives students the opportunity to explore their emotions, those intrinsically linked to the whole subject of climate change, as well as the idea of a totally different world in the future.	page 204
○	D3	Ages 9-12	**Climate justice: A roleplaying game** Social sciences / Geography Through roleplaying games, students discover the wealth inequities that exist between different countries and their link to climate change responsibility and vulnerability.	page 212
○	D4	Ages 9-12	**Adaptation and mitigation measures worldwide** Social sciences / Geography Through documentary analysis, students realise that many solutions currently exist to cope with climate change, either through adaptation or mitigation, and that a large number of actors are already acting.	page 221

LESSON D1
OUR CARBON FOOTPRINT

MAIN SUBJECTS
Social sciences / Natural sciences / Computer sciences

DURATION
- Preparation: 5 min
- Activity: 1h

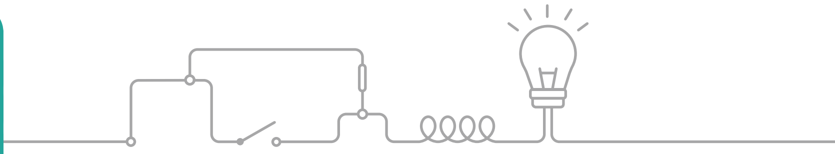
AGE GROUP
9-15 years

LEARNING OUTCOMES
Students use a carbon footprint calculator to assess their carbon footprint and discuss what they can do to reduce it.

Students learn that:
- We all have a carbon footprint, but we can help mitigate climate change if we reduce our individual emissions of greenhouse gases.
- Each country and each person has a different carbon footprint.
- There are individual responsibilities as well as collective responsibilities regarding our carbon footprint.

KEYWORDS
Carbon footprint, greenhouse gas emissions

TEACHING METHOD
Data collection



TEACHER TIP
This session is compulsory if the class chooses a mitigation-oriented project (see Part 2 of this lesson plan) but can also be studied in the case of an adaptation-oriented project.

PREPARATION 10 MIN

EQUIPMENT
- **WORKSHEET D1.1** and/or interactive online questionnaire.
- Computers (at least one for each pair of students).
- Multimedia resource:
  Carbon footprint calculator.

LESSON PREPARATION
1. Print out **WORKSHEET D1.1** (one per student).
2. The interactive calculator can be used both online and offline (you may download it before the class). If no computers are available in the school, this session can also be done as an "unplugged" activity (with a printed spreadsheet) or at home (if the students have an internet connection at home).

INTRODUCTION 10 MIN

Explain that in order to efficiently reduce our greenhouse gas emissions, we must know which behaviours in our daily lives are emitting the most greenhouse gases. This is why we should calculate our "carbon footprint".

To begin the lesson, you can use **WORKSHEET D1.1** to discuss with your students their ideas on the amount of greenhouse gases emitted by different everyday activities. Since they are possibly not familiar with this exercise, you can start by telling them that a car emits 180g of CO_2-eq per km and per passenger.

PROCEDURE 30 MIN

1. Explain the purpose of the activity and the importance of truthfully answering all questions (it is not a "who has the smallest emissions" challenge but a tool that is useful to understand what each person can do).

2. Distribute **WORKSHEET D1.1** to each student and let them complete the interactive online questionnaire in order to fill in the worksheet and discuss it with their group.

3. Compare the results and discuss the actions that could be undertaken to reduce the carbon footprint of individuals, schools, families, etc.

BACKGROUND FOR TEACHERS

A **carbon footprint** is usually defined as the total amount of CO_2 and other greenhouse gases emitted by an entity, such as a person, country, activity or product, and is expressed as kilograms of CO_2 equivalent (CO_2-eq) for a specific action and / or period of time.

CO_2-eq is a measure based on the Global Warming Potential of each greenhouse gas that is used to express the warming effect of emissions from different greenhouse gases. The warming effect of each greenhouse gas is thus measured in terms of the amount of CO_2 that would generate the same amount of warming.

For instance, in the case of a product, such as a piece of clothing, the CO_2-eq is a measure of the effect of the different greenhouse gases emitted during the entire life cycle of that product, such as production, transport, use and disposal / recycling.

Calculating the footprint will help you identify which of your activities produce the most CO_2-eq, and therefore which are the most critical to target. Rather than trying to get a precise estimate of each contribution to the footprint, the key is to get a rough estimate of their relative size, so you can identify which are the largest and thus most important to mitigate.

TEACHER TIP

Keep in mind that the greenhouse gas emission values provided in this lesson are indicative, since they depend on multiple factors, such as the country considered, the individual, the year, etc. You may try to find more precise values for your own country / region if you wish.

WRAP-UP 20 MIN

Compare the average carbon footprint of the class with the average footprint of different countries. Discuss the importance of reducing carbon emissions on a global scale and the necessity of implementing this reduction in countries where carbon emissions per capita are higher; other countries may focus on adaptation. At this point, stress that even if there are aspects that are based on the level of individual, family or community behaviour, other aspects are simply not reachable on such small scales, but can only be tackled by cities or governments.
You can ask the students to discuss what laws they would enact if they were part of their country's government.

TEACHER TIP

Carbon footprints only measure one aspect, namely, our greenhouse gas emissions, of the myriad of ways in which we impact the environment. Students should be aware that there are other environmental impacts associated with the goods and services we consume – things they might want to consider at the same time as they act to reduce their carbon footprint. For instance, when considering buying food ask yourself: were any trees cut down or pollutants released to produce this product? Did the farmers receive a fair price?

WORKSHEET D1.1

Once you have finished the test, write your results in the box below:

Your carbon footprint: ....

The sector where your footprint is the largest: ....

The sector where you have the lowest footprint: ....

The amount of CO_2 that would be released into the atmosphere if all the inhabitants of the planet had the same habits as you:

....

Ideas to reduce your footprint: ....

....

SMARTPHONE [1]

- One text message via a telephone network (SMS) produces 0.002g of CO_2.
- One text message via the Internet (social media) produces 4g of CO_2.
- One year's use of a smartphone at one hour per day produces 1.4 tons[2] of CO_2.
- Smartphone production – some examples below[3]:

IPHONE MODEL	CARBON EMISSIONS (KG OF CO_2)
iPhone 11	72
iPhone X	79
iPhone 8	57
iPhone 7	56
iPhone 6	95
iPhone 5s	65

TRANSPORTATION [4]

- A car emits 180g of CO_2 per km and per passenger.
- An airplane emits 255g of CO_2 per km and per passenger.
- A bus emits about 100g of CO_2 per km and per passenger.
- A train emits from 6 to 40g of CO_2 per km and per passenger.

Transportation modes with the largest footprint are therefore the airplane and the car (with only one passenger). The advantage of one over the other depends on the distance travelled: for a trip of less than 1,000km, the car is preferable. The plane has a smaller footprint thereafter.

FOOD [5]

- 1kg of beef = 20kg of CO_2 emitted = 100km of travel by car.
- 1kg of chicken = 6.2kg of CO_2 emitted = 30km of travel by car.
- 1kg of Brazilian beef consumed in Europe = 335kg of CO_2 emitted = 1,675 km of travel by car.
- 1kg of potatoes = 0.08kg of CO_2 emitted = 0.4km of travel by car.

ONE TONNE OF CO_2 EQUALS [6]

- One round-trip flight for one person between Beijng (China) and Moscow (Russia).
- 5,000km car journey.
- The average energy consumption of a person living in France to heat their home for one year.
- A tree will sequester 1 tonne of CO_2 during its lifetime.

Note: for simplicity reasons, carbon emissions are expressed in kg of CO_2. Scientists measure carbon emissions in CO_2-eq units, which consider the warming effect of the CO_2, but also of other greenhouse gases.

1 How Bad are Bananas? The Carbon Footprint of Everything, by Mike Berners-Lee, 2010.
2 https://www.viessmann.co.uk/company/blog/the-carbon-footprint-of-nearly-everything
3 https://www.apple.com/uk/environment/
4 https://ourworldindata.org/travel-carbon-footprint
5 Journal of Life Cycle Assessment, ADEME.
6 Adapted from the Direction Générale de l'Aviation Civile.

LESSON D2
HOW DO YOU FEEL ABOUT CLIMATE CHANGE? WORKING ON EMOTIONS

MAIN SUBJECTS
Social sciences / Philosophy / Visual arts / Written expression

DURATION
- Preparation: 10 min
- Activity: 55 min to 1h50

AGE GROUP
9-15 years

LEARNING OUTCOMES
This lesson gives students the opportunity to explore emotions intrinsically linked to the subject of climate change, as well as the idea of a totally different world in the future.

Students:
- Learn that climate change can generate different feelings and emotions; some may leave us feeling helpless or hopeless – this is called "eco-anxiety".
- Work through different subjects, like the arts, philosophy and written expression, to express these feelings.
- Take a step back from science and go deeper into their emotions, personal projections and personal current stories.
- Learn to manage these emotions and take part in action.

KEYWORDS
Emotions, eco-anxiety

TEACHING METHOD
Debate, self-expression

PREPARATION 10 MIN

EQUIPMENT
- **WORKSHEET D2.1** (one for two students)
- Post-its (one for each student)
- **WORKSHEET D2.2**
- One big sheet of paper in order to take notes during the debate.

LESSON PREPARATION
This lesson is designed to be carried out in two separate parts: the first part focuses on the vocabulary of the emotions, and the second one on how pictures related to climate change can trigger emotional responses. **If your students are familiar enough with the vocabulary of emotions, you then need to only work on the second part of this lesson.**

1. **The previous day:** Ask your students to bring to class the following day an article, picture, movie, piece of art, etc. that reminds them of climate change and that had a particular impact on them. They have to be able to present the piece and describe the source.
2. You can also select pictures and / or videos about climate change communication – you can pick some from **WORKSHEET D2.2** or choose something else. The idea is to gather together about ten different pieces.
3. Print out enough copies of **WORKSHEET D2.1**.

Some examples of documents brought by the students.

PART ONE: EMOTIONS 1H

INTRODUCTION 10 MIN
This first part is perfect to help your students become familiar with the vocabulary of emotions, and to ensure that the whole class will use the same words. At the beginning of the lesson, explain that we all respond to information, events and challenging situations differently. Introduce key messages: everyone has feelings (emotions) and all feelings are important and okay.

In this lesson, they will have to try to focus on emotions brought up by climate change and to express these feelings.

PROCEDURE 30 MIN

1. Write down the following questions on the whiteboard:

- *What does "climate crisis" mean to you?* (write down their answers).
- *How do these words make you feel?*

2. Using **WORKSHEET D2.1**, ask them to individually pick 3–5 cards representing their current feelings and to write these feelings on their post-it.

3. Then, ask one of your students to read one word from their list. Does anybody else feel the same? If so, they can stick their post-it onto the board, and so on. At the end of the lesson, you will be able to show that some occur frequently and to link different emotions.

Key questions to guide the discussion:

- *What can you say about these words?*
- *Which ones appear the most?*
- *Is it possible to group some emotions?*

4. If you would like a more visual way to figure out which ones appear the most often, you may use a word cloud with your students, for example using https://worditout.com/word-cloud/create.

WRAP-UP 20 MIN

Using the words that are stuck on the whiteboard or in the word cloud, discuss with your students the fact that climate change may trigger various feelings (both positive and negative) and emphasise that these emotions are perfectly normal.

Students are looking at the documents before expressing their feelings.

PART TWO: CIRCLE TIME AND PHILOSOPHICAL DEBATE 55 MIN

TEACHER TIP

This lesson is presented as a "philosophical workshop". If you are not familiar with this kind of activity, we suggest that you practice one beforehand, on a "lighter" topic.
During this lesson, it is recommended that you only ask questions – or even better, that you let your students ask each other questions – and then intervene as little as possible. In order to do so, you might consider giving various roles to some students for the first half of the debate, and then to others for the second half; those with "special roles" will not be able to participate directly in the discussion:

→ **President:** the person who gives the floor to the participants, taking note of who raises their hand to talk.
→ **Reformulator:** the one who is in charge of reformulating the proposition, if necessary, in order to clarify the debate. It may be useful to involve several students in this role.
→ **Summariser:** the person who takes notes / draws a mind map to summarise what has been said during the discussion so it can be shared with the whole class at the end.

The idea is not to reach a specific conclusion or determine what is true or false, but to have the students express their feelings and then reflect on various dilemmas about what they would / could do. Here, the science (and the facts) provide food for thought and cannot be denied, but the emotions and the motivation to take action, associated with climate change, are personal.
This is an opportunity to allow your students to talk about their feelings. Keep in mind that the key factor here is to provide a safe space for the students to discuss "tricky" issues. All the documents and activities provided in this lesson are only suggestions, and other resources / images can be used.

INTRODUCTION 5 MIN

Using the previous word cloud or post-its, remind your students that the bigger the words in the cloud (or more the post-its), the more times they have been chosen, whereas the smaller they are (or the fewer), they have only been chosen fewer times. Then ask: *What does this word cloud show regarding your class? Does your individual feeling appear on it?* The idea here is to be sure that each one of your students feels represented.

Place all the classroom chairs in a circle with no tables. Pupils can also sit on the ground.

PROCEDURE 40 MIN

1. The students sit in a circle. You can choose to remain outside the circle with the president, the reformulator and the summariser, if you would prefer not to take part in the discussion, or you can be a part of the circle.

2. Explain to the students the rules of the discussion:

- Outline the roles of the president, summariser and reformulator to the class. Ask if there are any volunteers and if so, ask them to repeat their role to you.
- Everyone can express whatever feelings/emotions they are experiencing, in response to the document or discussion, as long as the student raises their hand and waits to be allowed to speak by the president.
- There are no right or wrong answers.
- No one is allowed to speak while another person is speaking.
- No one is allowed to judge or make fun of the person talking. Everyone must listen and respect the others' ideas.
- No one is obliged to speak; they can simply be observers.

TEACHER TIP

The initial setup is very important as students must feel they are in a safe space, which will encourage them to talk, reflect and share their emotions. Therefore, having them sit in a circle allowing them to see everyone else in the class, on an equal footing, is important. The teacher can sit in the circle too, but only as a participant.

Students are sitting in a circle during the philosophical debate.

BACKGROUND FOR TEACHERS

It is a well-known and well-studied fact that climate change can generate difficult feelings and emotions. This phenomenon is called **"eco-anxiety"**. In the previous lessons, even when only focusing on the science of climate change, you may have noticed some reactions from your students, such as fear, rejection, anxiety, etc. Even you may have felt this way. The most common feelings associated with climate change content are helplessness, hopelessness, anger, fear and dissociation, sometimes leading to inaction.

Simply exposing the facts about climate change is not enough, considering that it is such a highly emotionally charged topic. Working with these emotions allows people to more comprehensively deal with disturbing information. Such feelings are perfectly normal and acknowledging them makes "people aware that they are not 'odd', which also helps them face climate change, rather than running away from it"[1]. Sometimes our defense mechanisms, like denial, can kick into action in order to protect us from the harsh reality of climate change.

Thus, the strategy to cope with emotions associated with climate change is, first of all, to acknowledge our feelings[2]. Another important point is to stay connected with others and avoid being alone. Civic engagement may also represent a way to step into action and, by doing so, be part of the solution, at our own level, and find reasons for hope.

One final important thing to mention is the fact that **we are not all equal regarding emotional expression,** especially because of our gender: thus, women are able to express a much higher level of concern than men when it comes to local environmental issues[3], leading to a higher level of engagement amongst women. This can be explained by upbringing, as women are more frequently raised with "care" values, encouraging them to be aware of their close environment and to take care of it. In the same way, men are frequently "emotionally repressed", making them less comfortable with expressing their feelings.

1 https://www.yaleclimateconnections.org/2019/04/scientists-dont-ignore-peoples-emotions/
2 https://www.yaleclimateconnections.org/2019/09/im-having-a-hard-time-coping-with-scary-climate-news-what-should-i-do/
3 https://keep.lib.asu.edu/items/155254

3. Conduct a class discussion either on some photographs or images from **WORKSHEET D2.2** or on a document brought in by your students. We suggest the use of a projector so the whole class will be able to clearly see the document(s) at the same time. Explain that you will show some images, and they will have to describe them first and then tell how they feel about it.

Key questions to guide the discussion:

- *How does this document make you feel? Why?*
- *Which document do you think could lead to action? Why?*
- If it is a picture one of your students brought, you may ask: *Why did you choose it? How do you feel about it?*

> **TEACHER TIP**
> It is possible that some of your students may experience difficulties in sharing their emotions, especially boys[1]. Do not force anyone to express their feelings if they do not wish to do so. Simply reiterate the fact that their feelings are totally normal. Expressing your own concerns about climate change issues may help them to feel safer about sharing theirs.

4. At the end of the class discussion, ask the summariser to carry out a quick recap of the debate and let everyone give a last comment/impression if they would like to do so.

WRAP-UP 10 MIN

After this session, encourage your students to make a drawing, illustration, painting or cartoon, write a letter[2], or express in whatever way they choose their feelings at the end of the discussion: *How do you feel now? Are your feelings different from the ones you had at the beginning?* Have them express what they learned during this session, about themselves and about the others. Emphasise the importance of connecting, with ourselves and with others, regarding such an emotional topic. End by asking them if their point of view about taking action to tackle climate change has changed, and if so, why. At this point you can propose that now is the time to act! Follow up by discussing potential projects you can implement in your community.

Some sources of inspiration:

- "Many Strong Voices" project: http://www.manystrongvoices.org/portraits/
- Time #ForNature, A Collective Poem: https://youtu.be/MlSW3u-1AbI
- 350.org – Climate Change Is About Power: https://youtu.be/m95K7LClIC4

Give me my sea ice back!

> **TEACHER TIP**
> At the end of this activity it is important that you are a reassuring figure for your students. You should now take back the status of teacher and leader in order to express a determination to take action, and to respond to any potential anxiety that might have arisen from such an activity. This will lead directly to the second part of this lesson plan – "We Act".

1 For more details on this topic, we suggest you read the chapters "Gender and emotion" and "Emotional geographies and climate change" (pp. 26–32) from the study "Cross-Cultural Approaches to Understanding the Emotional Geographies of Climate Change" by Margaret V. du Bray (2017). https://keep.lib.asu.edu/items/155254

2 You can find some examples of letters written by scientists and students about climate change on this website: https://www.isthishowyoufeel.com/

EMOTION CARDS

DEMOTIVATED

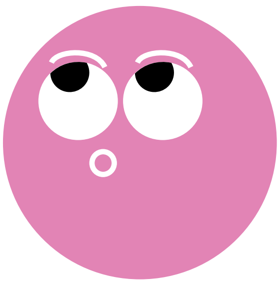
SATISFIED

TOUCHED

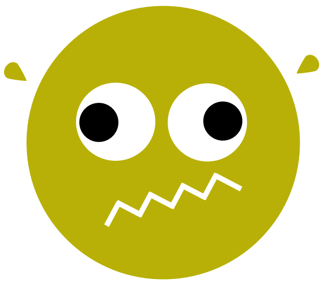
DEPRESSED

SERENE

OPTIMISTIC



UNINTERESTED



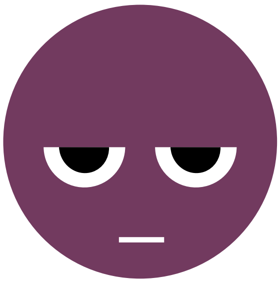
TORN

TENSE

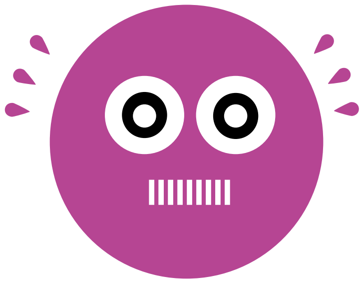
Note: These cards have been designed to allow students to express their emotions. They can be modified to better suit their level.

Source:
- Design inspired from the «Feelin' cartes», edited by SVJ.
- «Inspired» card: Designed by Alvaro_cabrera / Freepik

EMOTION CARDS



CONCERNED



STRESSED

CONFIDENT

MOTIVATED

FRUSTRATED

ENTHUSIASTIC

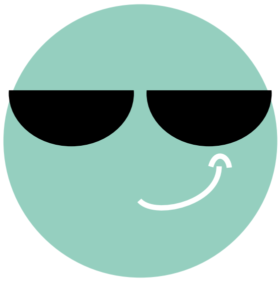
ANGRY

SAD

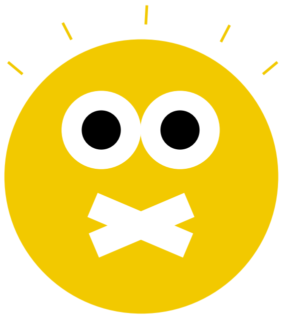
UPBEAT

EMOTION CARDS

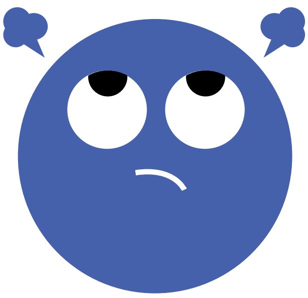
HAPPY



PROUD

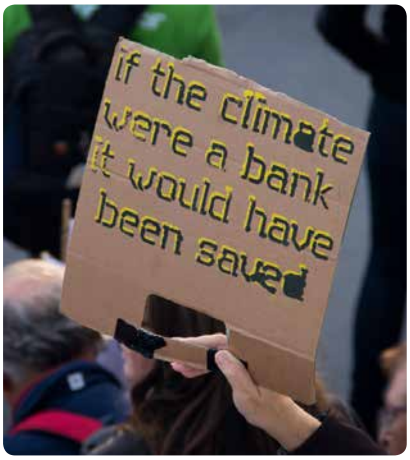


POWERLESS

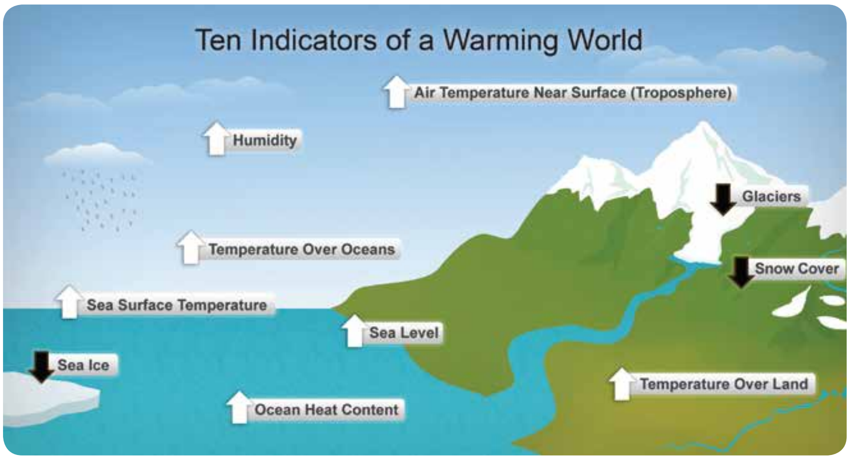


INFURIATED

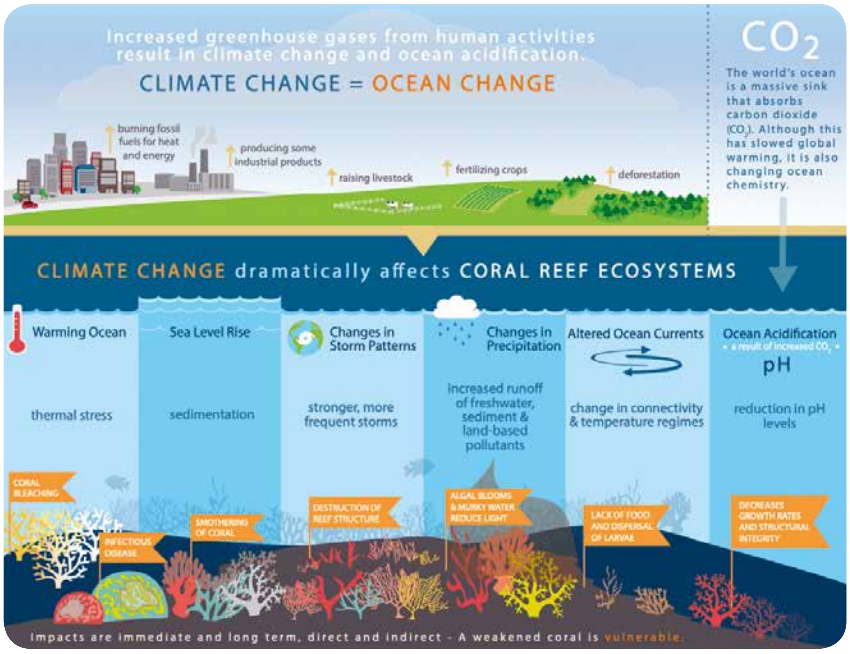
INSPIRED



if the climate
were a bank
it would have
been saved



Ten Indicators of a Warming World
Air Temperature Near Surface (Troposphere)
Humidity
Glaciers
Temperature Over Oceans
Snow Cover
Sea Surface Temperature
Sea Level
Sea Ice
Temperature Over Land
Ocean Heat Content



Increased greenhouse gases from human activities result in climate change and ocean acidification.
CLIMATE CHANGE = OCEAN CHANGE
burning fossil fuels for heat and energy
producing some industrial products
raising livestock
fertilizing crops
deforestation
CO_2
The world's ocean is a massive sink that absorbs carbon dioxide (CO_2). Although this has slowed global warming, it is also changing ocean chemistry.
CLIMATE CHANGE dramatically affects CORAL REEF ECOSYSTEMS
Warming Ocean
Sea Level Rise
Changes in Storm Patterns
Changes in Precipitation
Altered Ocean Currents
Ocean Acidification
pH
thermal stress
sedimentation
stronger, more frequent storms
increased runoff of freshwater, sediment & land-based pollutants
change in connectivity & temperature regimes
reduction in pH levels
CORAL BLEACHING
INFECTIOUS DISEASE
SMOTHERING OF CORAL
DESTRUCTION OF REEF STRUCTURE
ALGAL BLOOMS & MURKY WATER REDUCE LIGHT
LACK OF FOOD AND DISPERSAL OF LARVAE
DECREASES GROWTH RATES AND STRUCTURAL INTEGRITY
Impacts are immediate and long term, direct and indirect - A weakened coral is vulnerable.

THE MORE YOU
TALK
THE MORE WE
SINK

SKOLSTREJK
FÖR

CLIMATE CHANGE???...
FAKE NEWS!

You'll die of
OLD AGE
We'll die of
CLIMATE CHANGE

12
1
2
3
4
5
6
7
8
9
10
11

LESSON D3
CLIMATE JUSTICE[1]

MAIN SUBJECTS
Social sciences / Geography

DURATION
- Preparation: 15 min
- Activity: 2h

AGE GROUP
9-12 years

LEARNING OUTCOMES
Through a roleplaying game, students discover the inequalities that exist between countries with respect to wealth and greenhouse gas emissions. Another roleplaying game helps them realise that vulnerability to climate change is not the same for all countries – the most vulnerable not always being the most responsible.

Students learn that:
- Not all countries emit the same amount of greenhouse gases, nor are they equally vulnerable to the impact of climate change.
- The wealthiest countries emit the greatest amounts of greenhouse gases.
- Droughts, storms and floods exacerbated by climate change mainly affect people living in developing countries, who have contributed the least to climate change.
- The majority of the world's people live in rapidly developing countries; this will have an impact on future greenhouse gas emissions.
- There is growing awareness of the need for urgent and widespread action to limit climate change and protect the most vulnerable.
- Science can explain the origins and mechanisms of what is happening, but it is the citizens and legislation of a country that guide actions.

KEYWORDS
Climate change, greenhouse gases, responsibility, vulnerability, inequity, climate justice

TEACHING METHOD
Roleplaying games

PREPARATION 15 MIN

EQUIPMENT
- **WORKSHEETS D3.1**[2]**, D3.2** (or a set of toy cars), **D3.3, D3.4.**
- Sheets of paper or stickers.
- Optional: a world map + labels for each continent: North America, Latin America, Europe, Oceania, Africa, Asia (they can also be written on the floor).

LESSON PREPARATION
This lesson contains two independent activities. You can choose to do one or the other, or both.

Activity 1
- Make sure that the room contains one (and only one) chair per student.
- Print out **WORKSHEET D3.1** (one copy for you).
- Gather a set of small toy cars (one car per student) or, if not possible, print out **WORKSHEET D3.2** (one copy for the whole class).
- Place the continent labels at different locations in the room (either on the floor or on the wall).

Activity 2
Print out **WORKSHEETS D3.3, D3.4,** and **D3.5** (one for each group of 6 students).

INTRODUCTION 20 MIN

We have learned about the greenhouse effect and the consequences of climate change. We have seen that many of the resources we need may be affected. Initiate a debate with your students on whether they think that everyone in the world is equally responsible for climate change and will be equally affected.

1 This lesson was inspired by Lesson 4 of the "Creating Futures" resource, produced under the scope of the Education for a Just World initiative, by Trócaire and the Centre for Human Rights and Citizenship Education, DCU Institute of Education (Dublin, Ireland); it was also inspired by the education resource "Ma maison, ma planète et moi!" produced by *La main à la pâte* foundation. The OCE is grateful to the authors.

2 An Open Office version is available on the OCE's website if you need to adapt/update the lesson (data-chair-game-EN.ods)

PROCEDURE 1H40

ACTIVITY 1: WHO IS MOST RESPONSIBLE FOR CLIMATE CHANGE? 45 MIN

TEACHER TIP
You can also choose to do this activity with small figurines on a table instead of using chairs.

1. Ask the students to form a standing circle: they represent the (almost) 8 billion earthlings. You may choose gender to explain the concept of this activity. Discuss what proportion of the world is male and what proportion is female and ask the students to divide themselves accordingly. The 8 billion people in the world can roughly be divided into 4 billion females and 4 billion males. Half the class should stand on one side of the room and half the class on the other side (regardless of actual gender).

Students in a circle outdoors.

2. Then ask the students to reform a large circle. Ask them to consider the population of each of the continents labelled around the room and to divide themselves up accordingly — based on what they think to be true, as they don't have any numerical data yet.

3. Using the first table provided in **WORKSHEET D3.1,** tell the class the true distribution pattern of population for the continents and let the students reposition themselves as needed. Each student now represents a number of people on a particular continent. For example, there are so few people in Oceania, compared to the other continents, that it does not even have one "full" student. Each student will continue to represent their continent for the remainder of this activity. Discuss with the class their responses to the actual population breakdown.

4. Each student now retrieves a chair and sits around their assigned continent label in a small group. Tell the students that all of their chairs combined represent the wealth of the world. In their groups, the students discuss how they think the chairs (wealth) are divided amongst all the people of the world in each continent. Each group shares their thoughts with the rest of the class. The class decides together if some chairs should be moved to a different continent. The chairs are moved as the class thinks appropriate. Remember, the students do not move with the chair but stay with their continent.

Students representing the African population and its wealth.

Students representing the European population and its wealth.

5. Using the second table provided in **WORKSHEET D3.1,** inform the students about the true distribution of wealth. Move the chairs to different continents as needed. Ask the students to sit on a chair without leaving their continent group. In some continents, some students will be left without a seat (or will have to share a chair), while in other continents there will be a surplus of chairs.

6. Discuss with the class how this feels and what has just been demonstrated, including ideas related to conflict, migration, justice and inequality.

7. The students remain in their continents with their assigned number of chairs. They start by discussing in their groups if each person in the world emits the same amount of greenhouse gases. The students also discuss on which continents in the world people emit more greenhouse gases per capita, and on which continents they emit less.

8. The toy cars (or their equivalent in **WORKSHEET D3.2**) represent the average amount of greenhouse gases emitted in a year. Give each group the amount of cars that represents the corresponding average greenhouse gas emissions of each continent (see the third table in **WORKSHEET D3.1**). *How many cars per person are there in each continent?*

Discuss greenhouse gas emissions with regard to the population and wealth of their continent. Highlight that the greenhouse gas emissions per capita are not the same for all continents. *What will happen if more and more people around the world adopt the lifestyle of people in Europe and North America? Does every person on a given continent emit the same amount of greenhouse gases?* (Compare the number of chairs to the number of cars in the different groups.)

You can use a world map to summarise the activity and have the class mark on the map population, wealth and greenhouse gas emissions. This map is provided only as an example: it was made by a class some years ago, so the distributions are outdated and do not correspond to today's values.

ACTIVITY 2: WHO IS MOST VULNERABLE TO CLIMATE CHANGE? 35 MIN

9. Now that they have discussed who is most responsible for climate change, the class will find out who is most vulnerable to climate change. Divide the class into groups of up to 6 students and give each member of a group a different roleplay card from **WORKSHEETS D3.3**.

10. Ask the students to stand in a line across the middle of the room holding their roleplay card so that the others can see their role. Read the "Forwards and Backwards" statements of **WORKSHEET D3.4** and ask the students to:

- step forward for each of the first set of statements, if it applies to their role;
- step backwards for each of the second set of statements, if it applies to their role.

Forwards and backwards with climate change.

11. Discuss with the students who in the world is most vulnerable to climate change and why.

WRAP-UP 20 MIN

Conclude the lesson by asking the students: *Given what you have learned about who is responsible for and who is most vulnerable to climate change, do you think climate change is "fair"?* The issues of wealth, greenhouse gas emissions and differences in exposure and vulnerability to climate change should be discussed. (The wealthiest countries are the biggest greenhouse gas emitters per capita but are the least exposed to and affected by the impacts of climate change. This is, in most cases, due to their geographic locations and to the resources they have available to adapt to and cope with climate change consequences.)

BACKGROUND FOR TEACHERS

Current greenhouse gas emissions are unevenly distributed amongst countries. For example, China is the biggest emitter of greenhouse gases but due to its very large population size, it has lower per capita emissions than the United States. On the other hand, although the population of the United States is lesser by about a billion, the average American has higher emissions than an average Chinese person.

Looking at the past, developed countries have contributed heavily to the current CO_2 concentration: during the 100 years between 1880 and 1980, the United States and Europe each contributed 30% of the CO_2 emitted by fossil fuel burning. Even today, developed countries are the biggest greenhouse gas emitters. The increase in the Asian contribution (China and India) began around the year 2000, with a growth in their industrialisation process and population.

Not all countries contribute equally to global greenhouse gas emissions and not all countries are equally affected by climate change consequences; frequently, the most affected are not the most responsible. Ensuring there is **climate justice** in a given action thus requires the weighing up of different factors, including wealth, greenhouse gas emissions, energy needs, etc.

Science can and must give the facts and the evidence, improve future projections, estimate probability of events as best it can, and establish conclusions based on rationality and make them known and understood by everybody. However, **science alone cannot provide the necessary rules for the steps to be taken, nor say what is fair or prove that there is justice in global solidarity.** With such complex and global issues, **the ethical and moral values of both individuals and societies are ultimately the source of judgment and decisions.**

WORKSHEET D3.1

		NUMBER OF STUDENTS PER CONTINENT															
CONTINENT	POPULATION %	Class with **15** students	Class with **16** students	Class with **17** students	Class with **18** students	Class with **19** students	Class with **20** students	Class with **21** students	Class with **22** students	Class with **23** students	Class with **24** students	Class with **25** students	Class with **26** students	Class with **27** students	Class with **28** students	Class with **29** students	Class with **30** students
Africa	**17%**	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5
Asia	**59%**	9	9	10	11	11	12	12	13	14	14	15	16	16	17	18	18
Europe	**10%**	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3
Latin America	**8%**	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2
North America	**5%**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Oceania	**1%**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	100%	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Source: https://www.worldometers.info/world-population/#region

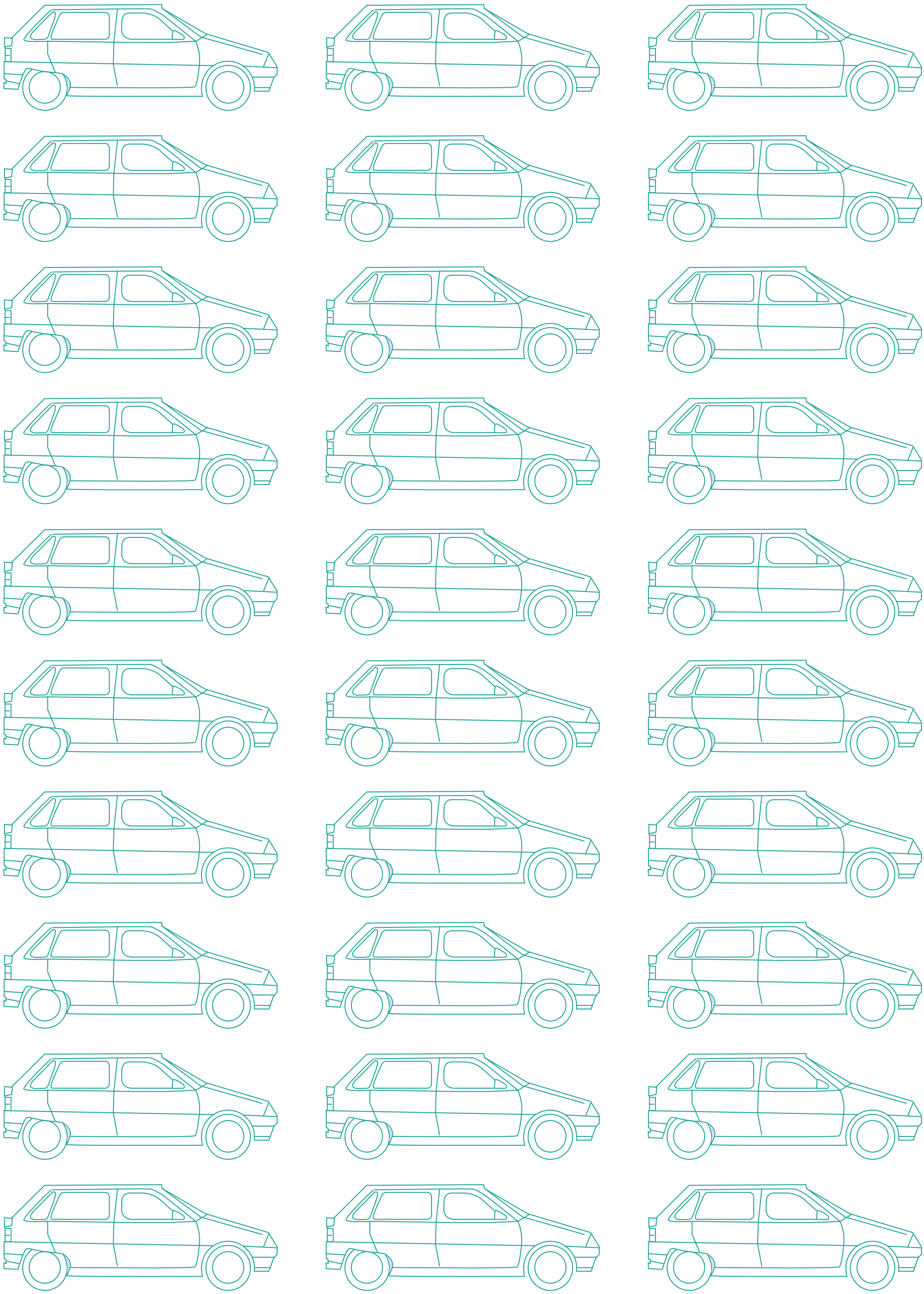
		NUMBER OF "CHAIRS" PER CONTINENT															
CONTINENT	WEALTH %	Class with **15** students	Class with **16** students	Class with **17** students	Class with **18** students	Class with **19** students	Class with **20** students	Class with **21** students	Class with **22** students	Class with **23** students	Class with **24** students	Class with **25** students	Class with **26** students	Class with **27** students	Class with **28** students	Class with **29** students	Class with **30** students
Africa	**5%**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
Asia	**49%**	7	8	8	9	10	10	10	11	11	12	12	13	13	14	14	15
Europe	**21%**	3	3	4	4	4	4	4	4	5	5	5	5	6	6	6	6
Latin America	**7%**	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
North America	**17%**	3	3	3	3	3	3	4	4	4	4	5	5	5	5	5	5
Oceania	**1%**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	100%	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Source: https://www.dsw.org/landerdatenbank/

		NUMBER OF "CARS" PER CONTINENT															
CONTINENT	GHG EMISSIONS %	Class with **15** students	Class with **16** students	Class with **17** students	Class with **18** students	Class with **19** students	Class with **20** students	Class with **21** students	Class with **22** students	Class with **23** students	Class with **24** students	Class with **25** students	Class with **26** students	Class with **27** students	Class with **28** students	Class with **29** students	Class with **30** students
Africa	**4%**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Asia	**49%**	7	8	8	9	9	10	10	11	11	12	12	13	14	14	15	15
Europe	**16%**	2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5
Latin America	**12%**	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4
North America	**18%**	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5
Oceania	**1%**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	100%	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Source: Our world in Data, based on UN “global carbon project” and World Bank. https://ourworldindata.org/co2-by-income-region

WORKSHEET D3.2



JIAO-LONG FROM CHINA

My name is Jiao-Long and I am ten years old. I live with my mum in a small apartment at the top of a forty-floor building, in the city of Shanghai. My mother says it is the second biggest city in the world in terms of inhabitants.

I love seeing all the lights from the buildings, the cars and the advertising screens in the great avenues of the city at night. I also love eating noodles with chicken! I wish I had a brother to play all my videogames with me. We could go together to the technology fair and it would be so much fun.

My mum has taken me to school every morning, since I was little. We take the Shanghai metro. I like riding the metro, but sometimes there are too many people and I feel squished. There are always lots of people everywhere in my city. Sometimes I wish there were less people, like in my grandpa's village, where I can run everywhere. My mum says there are more people every year in our city, because life is getting harder and harder in the countryside and people seek a better life in the city.

MAHLET FROM ETHIOPIA

My name is Mahlet. I'm thirteen years old and I live with my family in a small village in Northern Ethiopia. My sister's name is Shewit and my brother's name is Samuel. I enjoy school. My favourite subject is biology. I want to be a doctor when I grow up.

My family grows vegetables on our land. We grow maize, sorghum, potatoes and tomatoes. We eat these vegetables and then sell some at the market to earn money. We use this money to buy more seeds, books for school and things for our house.

When my father was a young boy, there was enough rain for the vegetables to grow. Now, there is not always enough rain for the crops to grow. My family and our neighbours are ready to sow, but the land is too dry. Together we are building an irrigation system. This is a long pipe that will bring water from a place far away. This will help the crops to grow.

ARIANNE FROM PHILIPPINES

My name is Arianne. I live in a house with my mother, father and younger brother. When I was little, we lived in a nice house just in front of the beach. I liked playing with the seashells and watching the baby turtles coming out of their eggs and walking towards the sea. I liked seeing from the window of our house my father arriving in his fishing boat after a long day at sea.

One day, at high tide, the water came further up the beach than usual and our house was flooded. I remember it was a very windy day. In the following months, this happened more and more regularly. We decided to move, and now we live in a new house a bit further away from the beach. It is built on stilts, so that it can avoid being flooded in the future. We feel much safer here.

I really like living near the beach and I hope we will not have to move even further inland in the future.

RORY FROM IRELAND

My name is Rory and I am eight years old. I live with my mummy, daddy and my brother Eoin in a small village. We drive to school in another small village near Downpatrick.

I like school and I really enjoy sports and music. I play Gaelic football for my local team. Because it rains a lot in Ireland, we often have to cancel training as it's too wet to play! Last spring the lane to our house got flooded as the river overflowed so we couldn't get in or out.

Most years we get some days off school because of heavy snow. Our country roads don't get gritted which means they are often too dangerous to drive on in the snow. I don't mind though as I get off school and we can go sledding down the hill beside our house. It's great fun.

We always build a snowman in the garden too. Last summer we went to Spain on our holidays as it was sunny and hot there. Sometimes I wish we had nicer weather here, but Mummy says Ireland wouldn't be known as the Emerald Isle then.

RENATA FROM CHILE

My name is Renata. I am nine years old and I live in Valparaíso with my mother, my brother, my sister and my dog, Gasparín. I don't see my father every day, because he works in the mines in the north of Chile. When he comes home a few weekends per year, he always brings candies for me and my siblings.

During summer holidays, we drive a long way in our car with our uncles and cousins to a really nice wood house in the countryside, near the mountains. Gasparín is also very happy because he can run a lot. My brother likes fishing with my uncle. My older sister doesn't come all the time, because she prefers staying in the city and going out with her friends or watching videos on the internet.

The old people that live in the mountains say that the mountain tops used to have snow that didn't melt in summer. Now I don't see that much snow.

WESTON FROM USA

My name is Weston and I am eleven years old. I live in Boston with my mom and dad and my twin sisters, Anna and Melissa. We live in a house in a nice neighbourhood where I have a lot of friends. My parents drive us to school every day.

I like playing baseball on the local team with my friends. We love going out to eat Mexican food at the big mall after our Saturday match. When we don't have a match, we stay home playing video games.

Every year I fly to California with my family for summer vacation. I love going to the beach there. We even tried surfing once with my sisters and then we had huge burgers at the beach restaurant! Last summer we visited Silicon Valley. It was so impressive! I wish I could work for one of those tech companies when I grow up.

I heard on the news last week that huge fires are ravaging Californian forests. It makes me sad to know this, I really like going to California on holidays!

"FORWARDS AND BACKWARDS" WITH CLIMATE CHANGE

Some people contribute more to climate change than others.
Some people are more vulnerable to climate change than others.
Think about your role (from **WORKSHEET D3.3**).

FIRST SET OF STATEMENTS

Take a step forward if your person's family:
- → travels in a car
- → flies abroad for a holiday
- → has money to buy enough food for all the family
- → eats meat as often as they want
- → has adapted because of climate change
- → has a government that could help them adapt to climate change
- → uses technology in their everyday life

SECOND SET OF STATEMENTS

Take a step backwards if your person's family:
- → relies on the food they grow to survive
- → is affected by flooding as sea levels rise
- → is affected by drought as temperatures rises
- → might go hungry if there is a drought
- → one day may not have enough freshwater to drink if glacier melting continues

LESSON D4
ADAPTATION AND MITIGATION MEASURES WORLDWIDE

MAIN SUBJECTS
Social sciences / Geography

DURATION
~ Preparation: 10 min
~ Activity: 1h

AGE GROUP
9-12 years

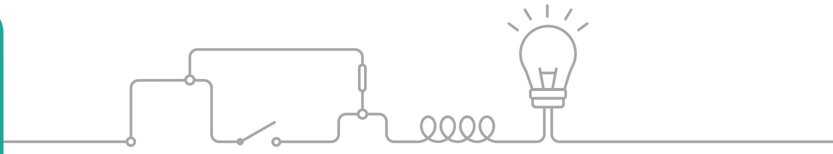
LEARNING OUTCOMES
Students realise that there are many solutions to deal with climate change, either through adaptation or mitigation, and that many people and organisations are already taking action. Students choose a climate adaptation / mitigation project to work on.

Students learn that:
~ We must adapt to the impacts of climate change and we must do our best to reduce greenhouse gas emissions.
~ There are many people, communities and organisations around the world implementing adaptation and mitigation solutions. We can all do many things to help.
~ Adaptation will benefit us in the short term, while mitigation will be fundamental in the long term. Both must be considered together.
~ Adaptation measures help reduce vulnerability and / or exposure to climate change, reducing the risk of negative impacts.
~ We can implement measures of adaptation to climate change effects.
~ We all have a carbon footprint, but we can help reduce climate change if we decrease our emissions of greenhouse gases.

KEYWORDS
Adaptation, mitigation, solutions, vulnerability, exposure

TEACHING METHOD
Documentary analysis

TEACHER TIP
This lesson is a good way to introduce Part 2 of the lesson plan – "We Act". Therefore, it is important for you to already have had a look at Part 2 and keep in mind examples of projects you could introduce in your school or community.



PREPARATION 10 MIN

EQUIPMENT
- Video projector, computer and an Internet connection.
- Multimedia resource: How can we act?
- If the class cannot use the online activity, **WORKSHEET D4.1** (one of each for the whole class) can be used.

LESSON PREPARATION
Feel free to use other material to illustrate adaptation or mitigation solutions. It is a particularly good idea to discuss solutions that have been implemented in the student's "vicinity" (their region or country).

INTRODUCTION 10 MIN

After a short reminder of the different impacts of climate change on land, and their consequences for ecosystems and human societies, ask the students to think about what kind of action could be taken to deal with these problems.

PROCEDURE 40 MIN

1. Let the students present their solutions to the whole class and write them on the whiteboard, without commenting on them. These should be actions that can be taken by the students themselves, as individuals, or by their families or small communities (school, village, etc.). This avoids a discussion on what other larger entities (i.e., governments, industry, etc.) could / should do.

2. Once a few actions have been identified, ask the students to propose a way of sorting them (by defining appropriate criteria). Different kinds of sorting can emerge:
- Mitigation / adaptation (some actions will reduce greenhouse gas emissions and thus the magnitude of global warming, whereas others will reduce the impact of global warming on our societies).
- Individual / collective.
- At home, at school, at the store, transportation, etc.

BACKGROUND FOR TEACHERS

In order to reduce the impacts of climate change on human societies and the Earth's ecosystems, two lines of action exist: **mitigation and adaptation.** Pages 16-19 of the Scientific Overview offer a detailed outline of both.

These two complementary strategies are to be considered at different levels: individuals, local groups (e.g., schools), cities, national or regional entities, and international or global actors (United Nations, international treaties). All levels have a role to play, even if their relative impacts vary. Both strategies involve knowledge, engineering and societal changes. Even in a simple case (school action), the timescales and the multiple possible consequences of a given action have to be considered.

3. During this activity, let the students discuss the relevance of each action (and the reasons behind the action). Some difficulties may appear during the classification process as sometimes the same action can be relevant from an adaptation point of view but not from a mitigation one (for example, using air conditioning is good from an adaptation point of view, because you can cool down rooms that are too hot, but it is harmful from a mitigation viewpoint due to energy consumption).

4. After all the actions have been discussed and categorised, the students may want to use the multimedia resource or analyse the **WORKSHEET D4.1** to discover different kinds of initiatives already underway.

5. Explain that they should try to do something tangible, and help them choose an action they wish to implement (with their class, their entire school, or even their community).

WRAP-UP 10 MIN

In conclusion, define the project in which the class will be involved (some examples of projects are proposed below).

TEACHER TIP

This lesson provides an introduction to Part 2 of the lesson plan; hence, the 1 hour duration is merely indicative, as it can take you and the class longer to choose which project to carry out.

AGRICULTURE AND FOOD

Permaculture (Guatemala)

On the shores of Lake Atitlan, the Mesoamerican Permaculture Institute aims to raise awareness and educate local populations about permaculture, following the footsteps of their Mayan ancestors. Permaculture is a technique that combines different crops on the same plot of land, capitalising on the biological interactions between the various plant species. It is particularly effective, does not require polluting chemical fertilisers, and contributes to the conservation of biodiversity.

ENERGY

Cycling (Netherlands)

Amsterdam is probably the most welcoming capital in Europe if you enjoy cycling. The facilities include cycle paths, free bicycle parking and two-way lanes. Car use, on the other hand, is strongly discouraged. As a result, in this city of one million inhabitants, more than 60% of journeys are made by bicycle.

Cycling is cheap, does not emit greenhouse gases, does not contribute to urban air pollution, and allows moderate physical effort that is very beneficial to health. It is also one of the fastest means of transport in the city.

ENERGY

Football (Spain)

Teenagers who play football on Spanish streets probably do not realise that they are saving energy (and this is probably not their goal!). Yet, reading a book, playing sports and meeting friends are much better activities for the environment (but also for health and social interactions) than just sitting in front of the screen of a computer or smartphone.

Storing and sending data from computers and smartphones requires a lot of energy: about as much as global air traffic. Why not unplug from time to time?

ENERGY

Repair Café (France)

Throw it away? No way!

At a time of disposability and programmed obsolescence, some people are opting for more sustainable consumption. “Repair Cafés”, invented in the Netherlands, are being created all over the world. There are more than 1,500 of them, found on all continents. They are located in schools, bars, cafés, municipal halls, etc.

For example, in Quimper, France, on one Friday each month the resourceful residents organise Do It Yourself workshops where people bring an everyday object to repair (bicycle, coffee machine, computer or toy, for example). While meeting other people, the local residents can find help and learn simple methods to give a second life to their belongings. This approach is also used for holiday internships for young people, who dismantle the equipment, understand how it works and then see how it can be diverted and reused.

This saves energy, raw materials... and also money!

HABITAT

Bioclimatic “low tech” constructions (Burkina Faso)

Unlike other schools in Burkina Faso, this primary school in Gando is not built of cement but of raw earth. It is a locally available material, very cheap, and doesn’t require transport or processing. The raw earth offers great thermal comfort, saves a lot of energy in comparison to cement, and is 100% recyclable.

Adobe, pisé, cob... these raw clay construction techniques have been around for thousands of years and are back in fashion. Homes, schools, stations... there are almost no limits!

Bioclimatic architecture takes into account the local environment to provide occupants with a comfortable, functional, water – and energy – efficient building. Some buildings are very sophisticated, but others (such as this school) use ancestral, inexpensive materials and techniques.

HABITAT

Solar cookers (Sudan)

Collecting firewood as fuel for cooking is dangerous, time-consuming and a major cause of deforestation.

This can be avoided by using solar cookers. In a solar cooker, sunlight is reflected by mirrors and concentrated into the cooking pot or pan. In very sunny and warm regions, the heat produced is sufficient to cook food. Their use makes it possible to cook with free solar energy and without emitting greenhouse gases or other pollutants. Drinking water can also be boiled in a solar cooker. Thus, both air and water are cleaner. Additionally, not having to collect firewood saves time.

Some NGOs have helped increase the use of solar cookers, thereby contributing to forest conservation and hence to climate protection, as well as improving human health.

URBAN RESILIENCE

Revegetation (Australia)

While cities have replaced trees and grass with buildings and concrete, residents are increasingly seeking to reconnect with nature and a greener environment. In Brisbane (Australia), local authorities have encouraged the planting of trees and grass in the city centre. Beyond its aesthetic appeal, revegetation makes it possible to develop biodiversity (the population of urban birds has significantly increased), improve air quality, contribute to the cooling of the city by limiting the "urban heat island" effect, and adapt to the consequences of climate change.

Many cities now allow their inhabitants to initiate reforestation projects. Sometimes, it is the schools that are in charge of such projects.

ECOSYSTEMS

Planting of corals (Malaysia)

While they cover less than 0.1% of the ocean bed, coral reefs are home to 30% of the world's biodiversity and play a key role in carbon sequestration and oxygen production. In addition, coral reefs are of great importance to local populations, providing food security and protection against coastal erosion.

Between 1980 and 2019, about 30% of global coral reefs disappeared (IUCN Red List Index). To address this, many NGOs, companies and scientists are working with local populations to restore coral reefs (for example, on Tioman Island in Malaysia). Some of these projects are funded through voluntary carbon offset programmes (think about it next time you fly!).

AWARENESS

Felix and his "Plant for the Planet" organisation (Germany)

In 2007, Felix Finkbeiner, a nine-year-old boy from Bavaria, Germany, made a presentation to his class on climate change. He planted his first tree with his classmates, and decided to create the "Plant-for-the-Planet" project. At the age of ten, Felix addressed the members of the European Parliament, and at thirteen he made a speech to the United Nations General Assembly.

Ten years later, Felix is still involved, on a voluntary basis, in the development of "Plant-for-the-Planet", which now has 130 employees and 70,000 members in 67 countries. By 2019, nearly 14 billion trees have been planted under this project. On average, each tree absorbs 10kg of CO_2 per year, and a tree planted in the tropics absorbs many times this amount.

ECOSYSTEMS

Sandwatch program (Trinidad and Tobago)

Mayaro Primary School has joined the Sandwatch program, along with many other schools around the world. By "adopting", monitoring and protecting the beach near the participating school, carrying out regular clean-up operations, and studying beach transitions, biodiversity, currents and tides, the project has completely changed the way students, parents, and the whole community view the coastal ecosystem.

Many students of Mayaro Primary School later became involved in environmental studies and activities. The project taught parents, students and teachers that education goes beyond the four walls of the classroom.

AWARENESS

Amazonian school (Brazil)

Brazil hosts the world's largest biological diversity, but its forests are among the most threatened. The president of an ecological foundation and two biologists created Escola da Amazónia in 2002, to raise awareness amongst Brazilian youth.

"A day in the forest" aims to provide young people aged 11 to 14 years direct contact with the Amazonian forest and encourage them to observe the fauna and flora. Older teens (15 to 19 year-olds) participate in workshops on eco-tourism, sustainable livestock and socio-economic development.

A twinning programme links urban schools to schools located at the edge of the forest.

AGRICULTURE AND FOOD

Eco-school (Mauritius)

Loreton College in Mauritius is part of the "Eco-Schools" network, made up of more than 50,000 schools around the world. The students have built a small-scale aquaponic farm, which combines salad farming with fish farming, in symbiosis. Fish droppings provide nutrients to plants, which in turn filter the water in the aquarium. It is an effective and sustainable way to produce food, especially in urban areas.

A school is awarded the Eco-School label by the Foundation for Environmental Education (FEE) if it engages students in ecological and sustainable projects within the school or the community. Eco-school themes are biodiversity and nature, climate change, energy, global citizenship, health and wellbeing, litter, marine and coast, school grounds, transport, waste and water.

Discover stories of other successful projects led by students from all over the world: https://www.ecoschools.global/stories-news

WE UNDERSTAND
REVIEW SESSION

MAIN SUBJECTS
Natural sciences / Geography / Physics

DURATION
- Preparation: 25 min
- Activity: 1h30

AGE GROUP
9-15 years

LEARNING OUTCOMES
The students create a conceptual framework showing the scientific basis of climate change and its impacts on land and services provided, and figuring out the causes and consequences of the different phenomena.

They learn to:
- Develop a systemic view of this topic.
- Draw links between the Earth's four systems, called the spheres: hydrosphere (water), atmosphere (air), geosphere (land) and biosphere (living organisms).
- Bring together all their knowledge on the subject of climate change.

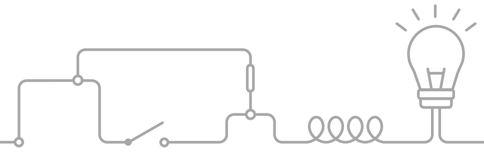
KEYWORDS
Climate change, ecosystem services, complex system, human activity, land

TEACHING METHOD
Conceptual framework

PREPARATION 25 MIN

EQUIPMENT
- **WORKSHEETS 1** and **2**
- A large sheet of paper for each group of students (for their stickers)
- Glue
- Post-its

LESSON PREPARATION
1. Print **WORKSHEETS 1** and **2**, one copy for each group of 3 to 4 students.
2. Cut out the different boxes and collect them together according to their colour.



TEACHER TIP
This lesson has two main objectives:
→ to review the links between climate change and land, studied in the previous lessons;
→ to understand how these links will have consequences on terrestrial ecosystems and human livelihoods.
Depending on the level of your students and the lessons in this handbook you have carried out with your class, choose which boxes to distribute to your students.

INTRODUCTION 20 MIN

Start by asking the students to think about the different effects of climate change on land, discussed in the previous lessons, and note each concept on the whiteboard.
Continue the discussion with your students: *Why do we care about these changes to the land? What may be the consequences for humans and other living beings?* Note the answers on the whiteboard, again, in the form of concepts. Some of the ideas suggested by the students will certainly match the stickers provided in **WORKSHEETS 1** and **2**.

TEACHER TIP
"Concept" refers to a simple statement that corresponds to an idea you want the students to take away (validated by the scientific community, and not an initial representation). One concept equals one sentence. It is not a keyword, a question or even a "notion" (which tends to involve intuitive knowledge). Example: "The concentration of CO_2 in the atmosphere is increasing."

PROCEDURE 40 MIN

1. Divide the class into groups and give each group the list of concepts needed to build the first part of the conceptual framework ("climate physics" stickers, **WORKSHEET 1**). If some of the concepts suggested by the students are pertinent but not mentioned in the list provided, allow the students to add a new sticker (post-it) for each concept suggested and validated by the class.

2. Ask the students to place the stickers in a logical order, indicating the connections between them with arrows. For example, an arrow could mean leads to or is due to.

3. Once they have managed to put all the "Climate physics" stickers into a logical order, give them the "water" stickers on **WORKSHEET 1**, and then do the same with every set of stickers on the two worksheets.

> **TEACHER TIP**
> Depending on the level of your students, you could give them the stickers set by set or all at the same time.

4. Explain to the students that when they receive a new set of stickers, they must connect them with the others.

5. A representative from each group presents the conceptual framework.

WRAP-UP 30 MIN

Compare and discuss the different conceptual frameworks (one example is given on the next page), and how climate change affects many spheres of our lives, as well as many species. You can also take advantage of the discussion to go further into the social consequences of climate change. Some communities can adapt, others cannot: *What does the ability to adapt depend on? Resources? Education? Other factors?* Some people will have to migrate, becoming climate refugees.

Finally, depending on the time you have, you can finish up the discussion by asking them to find solutions to reduce the impacts of climate change. For instance, if we change the way we consume food, we can reduce the impact of agriculture on deforestation. *How does this positively affect the climate and what would be the impact on human activities?*

> **TEACHER TIP**
> This lesson also helps evaluate what the students have learned during the previous lessons. Mistakes or missing parts may lead to a deeper discussion to recall the logical sequence that may have been poorly retained or not completely understood. For this activity, there is no single right answer, and the conceptual frameworks prepared by the different student groups may all be different. What is important is the thought process involved in their organisation and linkage of the concepts. The main objective of the activity is that students, in groups, discuss with each other and explain to each other what they understood about the topic. It is important to place them in an atmosphere where they can discuss freely with no fear of making mistakes.

POSSIBLE EXTENSION

Work with a visual arts teacher to produce a mural painting about the impacts of climate change on land (considering humans and other living beings as well).

Presentation in front of the whole class.

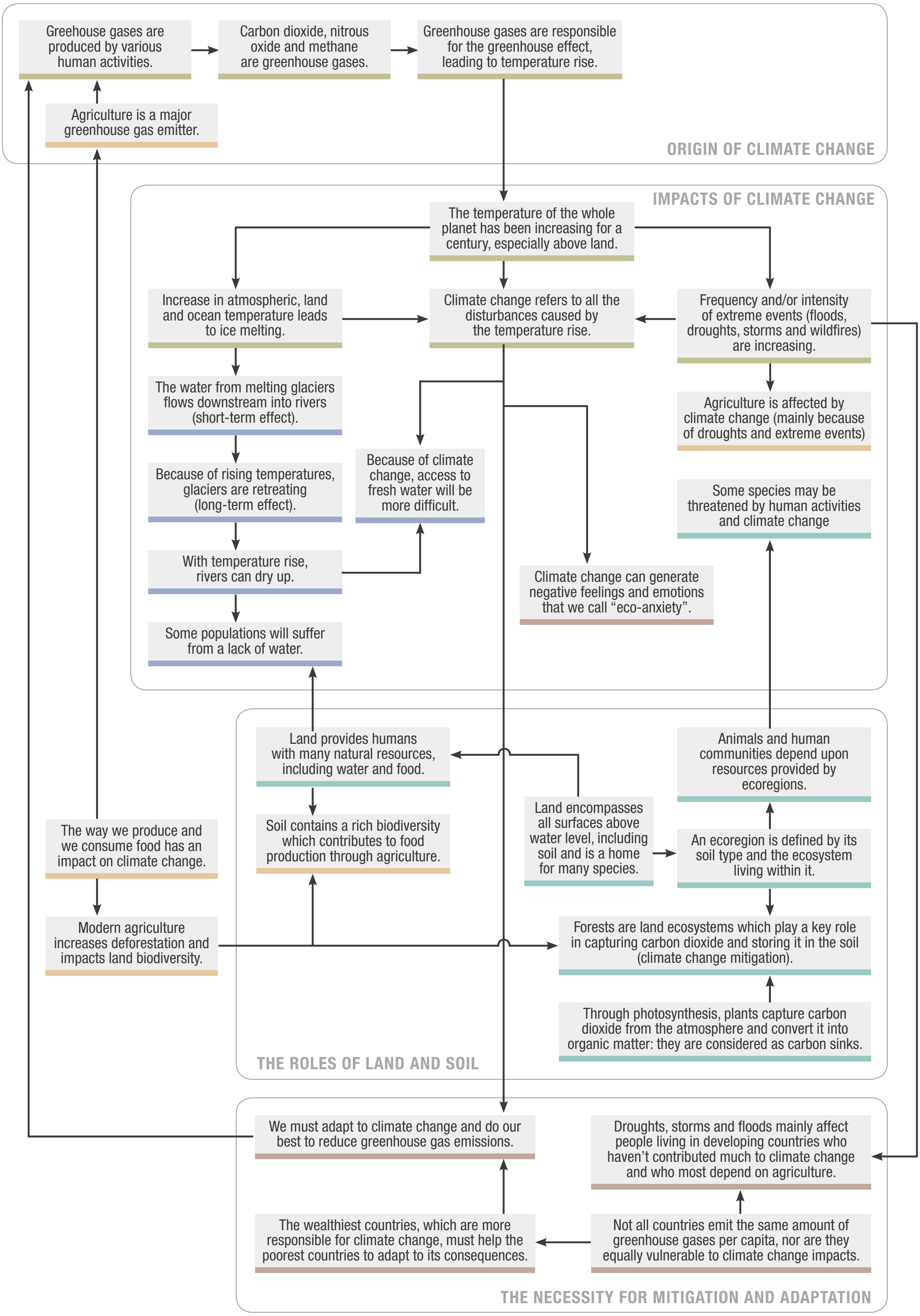
BACKGROUND FOR TEACHERS

This lesson is based on constructing a conceptual framework, consisting of fundamental concepts on the topic of climate change, formulated using simple and clear sentences (one box refers to one concept). Your students will have to connect the concepts using logical links ("this happens because of that"). By doing this, the students will get an overview of the whole subject "Climate Change and Land", and it will help them review some of the knowledge covered during the previous lessons.

Here are some principles around conceptual frameworks:

- It is a list of scientific concepts organised using logical links.
- Concepts are written as short, simple sentences, using a phrasing level expected from a student.
- It may be used to build a mind map that can be kept to conclude this part of the handbook.

ONE OF THE MANY POSSIBLE FRAMEWORK SOLUTIONS



Topics:

Climate change and humans | Agriculture | Climate physics | Land and biodiversity | Water

WORKSHEET 1

CLIMATE PHYSICS

Carbon dioxide, nitrous oxide and methane are greenhouse gases.

Frequency and/or intensity of extreme events (floods, droughts, storms and wildfires) are increasing.

Greenhouse gases are produced by various human activities.

Climate change refers to all the disturbances caused by the rise in temperature.

Increase in atmospheric, land and ocean temperature leads to ice melting.

The temperature of the whole planet has been increasing for a century, especially above land.

Greenhouse gases are responsible for the greenhouse effect, leading to temperature rise.

WATER

The water from melting glaciers flows downstream into rivers (short-term effect).

With temperature rise, rivers can dry up.

Some populations will suffer from a lack of water.

Because of climate change, access to fresh water will be more difficult.

Because of rising temperatures, glaciers are retreating (long-term effect).

CLIMATE CHANGE AND HUMANS

Climate change can generate negative feelings and emotions that we call “eco-anxiety”.

We must adapt to climate change and do our best to reduce greenhouse gas emissions.

The wealthiest countries, which are more responsible for climate change, must help the poorest countries to adapt to its consequences.

Not all countries emit the same amount of greenhouse gases per capita, nor are they equally vulnerable to climate change impacts.

Droughts, storms and floods mainly affect people living in developing countries who have contributed least to climate change and who most depend on agriculture.

WORKSHEET 2

LAND AND BIODIVERSITY

Some species may be threatened by human activities and climate change.

An ecoregion is defined by its soil type and the ecosystem living within it.

Land encompasses all surfaces above water level, including soil, and is a home for many species.

Land provides humans with many natural resources, including water and food.

Animals and human communities depend upon resources provided by ecoregions.

Forests are land ecosystems which play a key role in capturing carbon dioxide and storing it in the soil (climate change mitigation).

Through photosynthesis, plants capture carbon dioxide from the atmosphere and convert it into organic matter: they are considered as carbon sinks.

AGRICULTURE

Modern agriculture increases deforestation and impacts land biodiversity.

Soil contains a rich biodiversity which contributes to food production through agriculture.

The way we produce and consume food has an impact on climate change.

Agriculture is affected by climate change (mainly because of droughts and extreme events).

Agriculture is a major greenhouse gas emitter.

WE ACT

LESSON PLAN – PART II

WE ACT #PROJECTS

This part of the guidebook is project-based and focuses on solutions. It promotes the implementation of projects aimed at giving students the opportunity to participate in solutions or measures designed to mitigate climate change impacts, as well as taking part in climate research and developing awareness on the subject. Depending on the local context, time or resource constraints, various types of projects can be considered.

Here we present some examples of projects that have already taken place in different schools, involving students, teachers, experts, families, artists and so on. These projects may not necessarily be the most relevant for your context but are intended to give you an idea of the kinds of projects you can carry out with your students. Lesson D4, page 221 (Part 1) also provides examples of multiple solutions already being implemented worldwide that may serve as an inspiration for creating your own project.

First, we introduce a programme ("climathon") that will help students to choose their own project; as such, it is a complete methodology explaining how you can encourage your students to design their own project, with some guidance. Students can work on many different types of projects, ranging from mitigation and adaptation to awareness.

The other examples demonstrate various projects, including ones on adaptation (Oasis, gardens), mitigation (biodigesters, aquaponics), citizen sciences (oak bodyguard) and awareness (Orbis). A given project can cover one or more of these four aspects.

Many projects aimed at mitigating climate change often double as adaptation projects as well (*e.g.* improving building insulation can help cope with heatwaves – adaptation – and simultaneously reduce greenhouse gas emissions from air conditioning devices – mitigation).

CREATE YOUR OWN PROJECT!

Each project will generally follow similar steps – only their length may vary, depending on the topic you choose:

Data studies and information gathering
↓
Problem definition
↓
Brainstorm and reflect on solutions
↓
Budgeting
↓
Looking for stakeholders
↓
Definition of deliverables
↓
Project setup
↓
Presentation and evaluation

When you and / or your class decide to organise a project, you must draw a roadmap in order to have a clear overview of the objectives, the different stakeholders, the key steps and the duration. Your roadmap may answer some of the below questions, define the end, and clarify what will be the outcome for you as a teacher, for the students and for the school:

Is it a project that can run for several years (such as projects #3 and #6)?
Is it a project that requires collaboration with other structures (such as research institutes, as in project #6, or municipalities, as in project #2), and therefore some degree of follow-up reporting?
Is the project presented to a jury (project #7)?
Is it a project that involves families and communities (projects #4 and #5)?

These questions all lead to varied ways of ending a project and communicating about it with various stakeholders.

The sustainability project action plan presented below can be used as a guideline for designing your own project:

CREATE A SUSTAINABILITY PROJECT ACTION PLAN [1]

VISION	CURRENT STATE	COMPONENTS OF CHANGE
What is the desired outcome for your school?	What is your school like right now?	What will you need to change to achieve your vision?

BARRIERS & CHALLENGES	STAKEHOLDERS	CHANGE AGENTS & OPINION LEADERS	TOOLS
What is standing in your way?	Who will be involved and affected?	Who can help you change things?	What processes can you use?

SHORT-TERM	MID-TERM	LONG-TERM
What will you do in the next few weeks?	What will you do in the next few months?	What will you do in the next few years?

EVALUATION

An important aspect is defining a way to evaluate your project, before you initiate it. This may include an assessment of the students, or also an evaluation of the project by the students, often through presentations of their work.

A good way to evaluate their feelings, skills and motivations, is to ask your students to present their intentions before they start the project (such as at the end of the first day of the climathon, project #1). Ask them to keep a written record or a recording of this day. Then, at the end of their project, ask the students to give a presentation, describing their actions and the results. The best way to do this is to have a formal day dedicated to this event, with families and stakeholders who have been invited. You can then ask students to refer back to their list of intentions, and to comment on where they succeeded, where they struggled, and how they overcame difficulties.

Another way to encourage students to reflect on their project is to ask them to talk about it, through interviews, photographs and/or video recordings, press releases, and so on. This process of reporting will push them to reflect on their knowledge about their topic, as well as their own experience and skills, which may have changed over time, thanks to the project.

You can also assess the impact of the project on the school or on the community, using a poll (consider making a poll before launching the project and another one, after it has ended) which will help you evaluate, for example, if some entrenched habits have changed.

1 Inspired by Redman (2013), Opportunities and challenges for integrating sustainability education into K-12 schools: case study phoenix, *Journal of Teacher Education for Sustainability,* vol. 15 (2): pp. 5–24.

PROJECT LIST

#1 **METHODOLOGY PROJECT**
CLIMATHON

MAIN SUBJECTS
Any climate change related local challenge

AGE GROUP
8 - 18 years

STAKEHOLDERS
Teachers, communities, local experts

A “climathon” (climate + hackathon) is an initiative that has been brought to life by the Climate-KIC organisation (https://www.climate-kic.org/). Using a project-based pedagogy over several months, students go through two major steps: **one “climathon” day,** which is used to **think about solutions to a local climate change related challenge,** and **one day dedicated to general feedback.**

In the city of Strasbourg, France, three climathons were setup in 2021 – and one across the border, in the town of Fribourg, Germany – thanks to the collaboration between a local science structure, the MPLS Alsace, the OCE, and some really motivated teachers. Each school chose to focus on a particular topic and involved around thirty students:

- **Mobility:** how to develop alternative ways to go to school in order to reduce the carbon footprint associated with existing methods of transport.
- **Urban heat island effect:** how to reduce the urban heat island effect in the school’s neighbourhood.
- **Climate change awareness:** how to make school students care about climate change.
- **Collective catering:** how to reduce the ecological footprint of the school canteen.

During the climathon day, students were able to approach experts from different areas of expertise (climate science, urban planning, mobility, etc.) in order to familiarize themselves with their specific challenge.

The second part of the day was focused on team work, and thinking about various solutions and their implementation (*who will be involved? how much will it cost? what steps might follow?*).

At the end of the climathon day, some schools asked a jury to vote for the most relevant solution: for example, to tackle the urban heat island effect, the award went to a balcony greening contest, encouraging residents to put plants on their balconies.

The next step is for both students and teachers to ensure that the project actually happens, with or without the involvement of external stakeholders, and the results can be presented on the feedback day at the end of the school year.

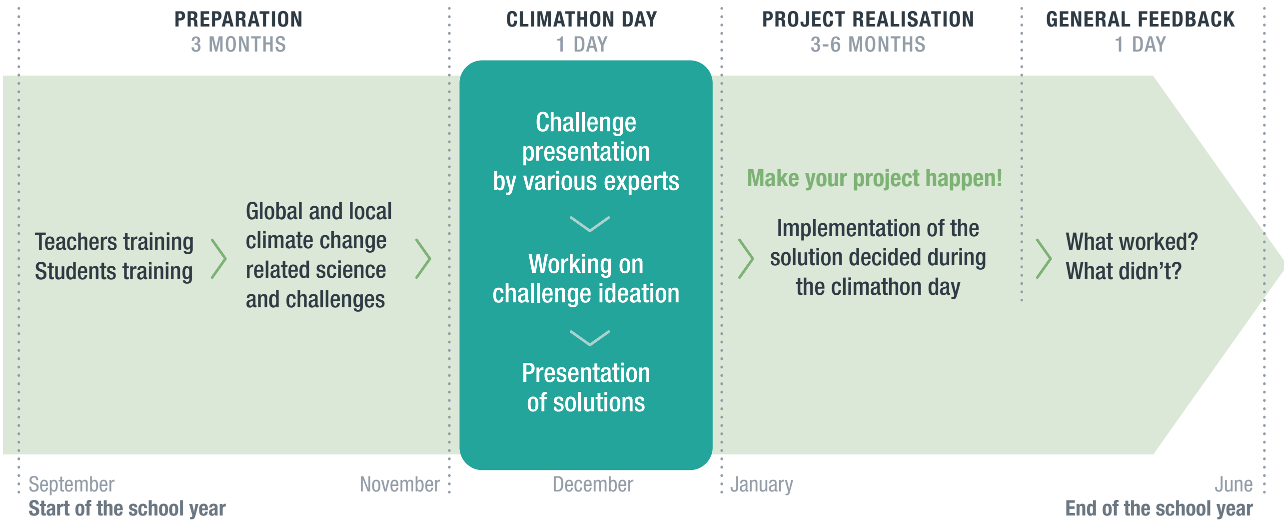
TESTIMONY
PAUL KOPP, BIOLOGY TEACHER
We are used to initiating a number of actions within the framework of sustainable development and have also received a French label for schools involved in sustainable development. In this context, we have already invited one or two partners for a particular activity several times, but never so many partners at the same time on the same day [as at the climathon].

A group of students working on an experiment demonstrating greenhouse effect.

TESTIMONY
OLIVIER DORVAUX, PHYSICIST

We held a rather interactive question-and-answer session with the students; they really played the game well and it was very pleasant. In the afternoon, I worked with them on the theme of carbon balance: Are there ways to reduce CO_2 *and ways of sequestration? If we manage to trap all the greenhouse gases emitted by energy production, does that solve the problem? The answer is yes; now we need to know how to trap them, how it works and see if it is effective. It's an idealistic answer, but nevertheless there are different ways to capture* CO_2*. In any case, I felt I was being useful as a scientist!*

TIMELINE



#2 ADAPTATION PROJECT
OASIS

MAIN SUBJECTS
Playgrounds, nature in the city, urban heat islands, extreme events

AGE GROUP
6 - 12 years

STAKEHOLDERS
Teachers, municipalities, families, architects, urban planners

One of the consequences of climate change is that heatwaves are becoming more frequent, longer and more intense. In many large cities this can be further aggravated by the density of buildings and concrete surfaces at the expense of green spaces. School grounds in large cities, such as Paris, Lyon, Brussels and Barcelona in Europe, are traditionally laid out as large concrete areas with little vegetation apart from a few trees. For some years now, projects have been flourishing in these large cities, on the initiative of town halls or associations, to **redesign school grounds, to remove the concrete and introduce more greenery.**

This is also the case with **the "Oasis" project** in Paris. A group of urban planners and architects got together with teachers from different schools and proposed to work with the students to **design a new school courtyard.** Many workshops were carried out in class so that pupils could **understand the issues of space planning, the notions of climate change, and the need to change outdoor school spaces.** The pupils were able to make their own proposals, which were then taken up and worked on by the architects until the final design of the school grounds emerged.
These schemes enabled the implementation of classroom projects, which required the involvement of students throughout the process.

With **the "Chaud Devant" project,** schools in the Lyon area were able to contact researchers in climatology and urban planning to facilitate **experimenting with various courtyard arrangements to find the best way to regulate the temperature.** This project, therefore, enabled pupils to carry out research through experimentation, and based on their results to put into practice a project to help adapt to climate disturbances.

In addition to the benefits of adapting to heatwaves, these schoolyard projects also allowed for the **development of initiatives related to food production** (vegetable gardens, orchards), the **discovery and restoration of degraded soil,** and, moreover, an opportunity to **fight against gender inequality** by offering similar activities to all the students.

Finally, these projects are often openly available to use by the local inhabitants and the pupils' families, who can enjoy the naturalised areas outside the school year.

Court yard is covered with mulch on an open soil.

Hidden spots helps students to be in contact with nature.

TIMELINE

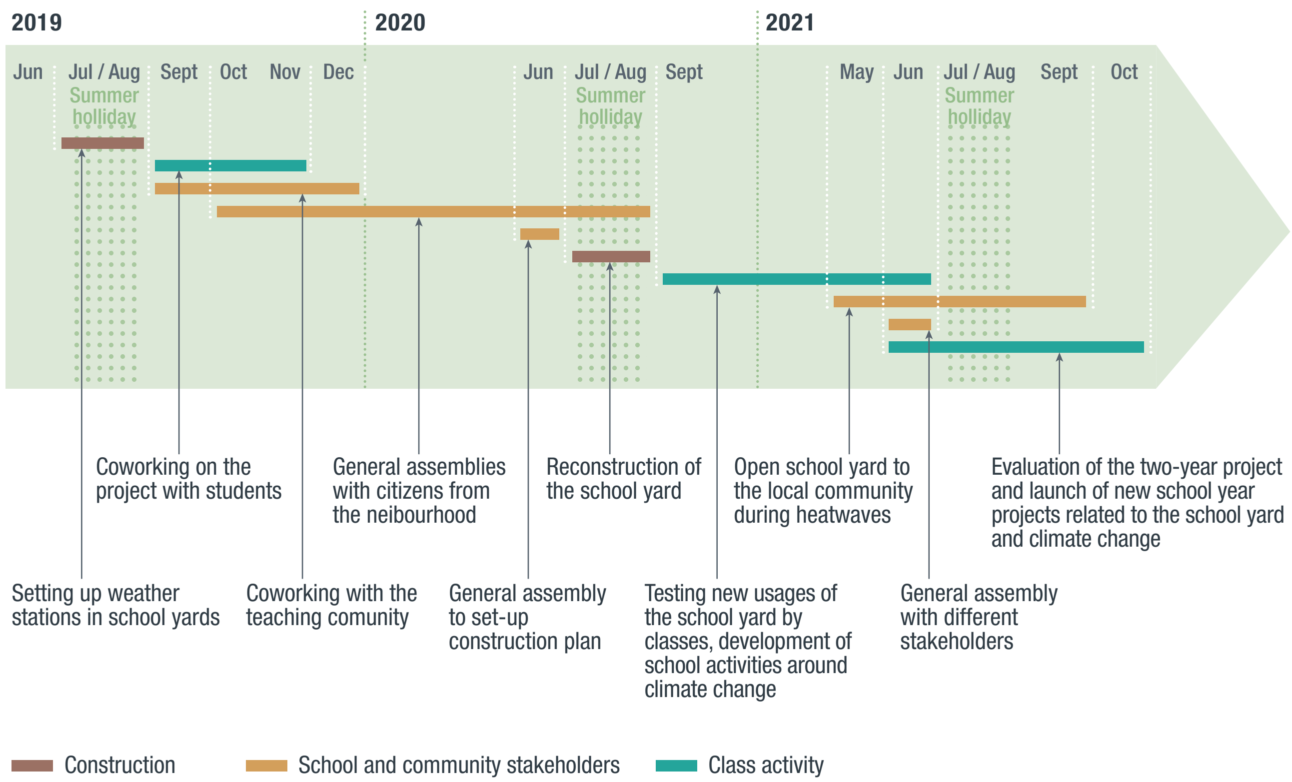
The "Oasis" project took place over three years, and included the three phases of preparation, consultation and implementation. i. The preparation stage was at the beginning of the first term of the year, with co-design by students and the educational community. ii. There was a long consultation phase with the local community (families and citizens of the neighbourhood) during the rest of the school year. iii. The implementation was carried out during the students' school holidays.

Throughout the following school year, many educational activities took place in the new courtyard, and during the summer holidays, the space was opened up to local inhabitants during the heatwaves. Finally, at the beginning of the third year, an assessment was made of the project.

TESTIMONY

RAPHAËLLE THIOLLIER IN CHARGE OF THE OASIS PROJECT, PARIS

The Oasis courtyards offer more natural space and vegetation, better management of rainwater and water points, and more play facilities adapted to the needs of pupils, all with a view to urban cooling, restoration of the water cycle, and improvement of the wellbeing of the users of this space. Designed as real islands of coolness in the heart of neighbourhoods, these courtyards can be used by a wider public outside school time, and become "refuges" for vulnerable people during heatwaves. Finally, this project is an opportunity for educational communities and children to become aware of and participate in a concrete project to fight climate change.



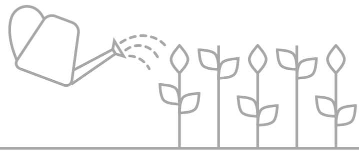
#3 MITIGATION AND ADAPTATION PROJECT

AQUAPONICS

MAIN SUBJECTS
Energy, agriculture, water cycle

AGE GROUP
8 - 18 years

STAKEHOLDERS
Teachers, researchers, engineers, hobbyists, students, etc.



Aquaponics systems are structures that combine the production of fish and herbs or vegetables. The water is filtered by the plants, which feed on the nutrients from the fish's excrement through the activity of bacteria, and the fish benefit from water that has been purified of elements that are toxic to them. In schools, small structures can be built to experiment with this real ecosystem.

Several schools have used aquaponics as a way to teach science and technology subjects, to work on project-based teaching, and to develop student autonomy. In France and Quebec, several schools, from primary to high school, have set up projects of varying sizes around aquaponics. These range from a small tank combining fry (young fish) or goldfish and aromatic plants, to tanks containing several hundred litres of water.

For example, at the **Albert Camus secondary school** in Clermont Ferrand, France, a multi-disciplinary project involving several classes developed **a 600-litre aquaponics tank for farming several kilos of trout.** On the **French islands of Saint-Pierre and Miquelon,** several schools (both primary and secondary) have successfully installed **tanks for growing lettuce and tomatoes.** On these islands, where agriculture is very complicated due to weather conditions, aquaponic farming seems to be a technically feasible solution.

© Guillaume Rech

TESTIMONY
SÉBASTIEN BARON, TEACHER

This project gives meaning to learning, by contextualising the knowledge and skills gained from the sciences and humanities. Students learn to work collaboratively, with a common objective, and to provide a collective response, necessarily condensed, to adaptation to climate change.

Indeed, because it saves space, needs very low water input and yields high protein output, aquaponics is an agricultural system that can meet many of the challenges posed by the impacts of climate change. It **reduces the pressure on land agriculture and promotes agricultural production** even in regions of low productivity, and **lowers greenhouse gas emissions** by limiting transportation.

Projects are often initiated through a partnership with scientists and / or associations and professionals working in aquaponics; but **the implementation of a simple system is possible for educational teams.** The costs are relatively low, although there is a need for a material investment (about €2,000 for a large efficient system; see the explanatory diagram on next page for the materials needed).

The aim of the project is to **put the pupils at the heart of the development, the running, and the monitoring of the system.**

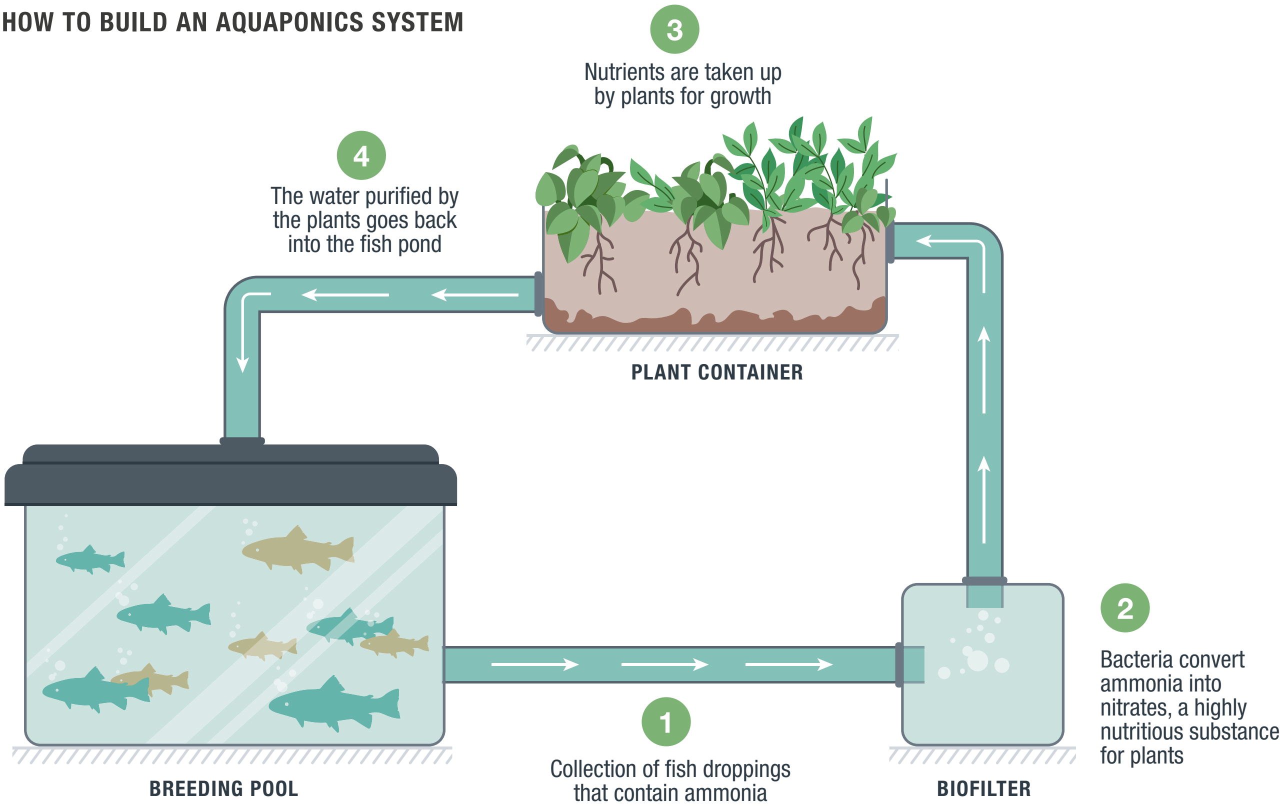
The advantage of this project is that it encourages students to collaborate and to use the knowledge gained from science and social studies.

Pupils from the Julienne Farenc secondary school (Dombasle-Sur-Meurthe) working on water quality and pH as part of an aquaponics project in Saint-Pierre and Miquelon, assisted by a scientist (Fabrice Teletchea, in the photo) and a biology teacher (Maxime Aubert).
Source: https://la1ere.francetvinfo.fr/autonomie-alimentaire-aquaponie-atout-outre-mer-689736.html

TESTIMONY
FABRICE TELETCHEA, RESEARCHER

Aquaponics is an innovative system that allows for the year-round production of fish, plants and vegetables above ground. This system is therefore particularly suitable for urban areas (e.g., empty premises, basements) and in regions where open field farming is difficult (unfavourable climate, poor soil). Moreover, it is a great educational tool for tackling different notions of plant and fish biology, ecosystems and, more broadly, local development and the circular economy.

HOW TO BUILD AN AQUAPONICS SYSTEM



Source: Poliway (adaptation).
http://www.polyway.fr/content/l%E2%80%99essor-de-l%E2%80%99aquaculture-%C3%A9coresponsable-dans-l%E2%80%99hexagone

#4 MITIGATION PROJECT
BIODIGESTER

MAIN SUBJECTS
Deforestation, sustainable energy, recycling, health

AGE GROUP
12 - 18 years

STAKEHOLDERS
Teachers, communities, local experts

The students of **the middle school Emilio Sanchez Piedras** implemented this project as a solution to various technical and health issues in the community of San Francisco Tetlanohcan, located in the State of Tlaxcala, Mexico. Some families still use traditional open wood fires to cook, which release smoke inside their homes, causing health problems and chronic respiratory diseases such as pneumonia in young children and pulmonary emphysema in the elderly, as well as eye diseases such as retinal detachment and cancer. Moreover, the need for wood to cook encourages deforestation. Finally, burning wood releases CO_2 into the atmosphere. The last two reasons explain the important impact this practice has on climate change. This way of cooking is still common because the price of gas is quite high compared to the average living wage.

The students, as leaders of this initiative, involved the community through workshops, providing information and advice on **wood-saving stoves and biodigesters, built with local, recycled material, and adapted to the needs of each family.**

A biodigester is a system that produces inflammable gas (methane CH_4) through the process of bacterial fermentation arising from the decomposition of organic matter in an anaerobic environment (a sealed tank with no oxygen). The project focuses on the holistic management of cattle dung used for the biodigesters, thus **optimising clean energy and avoiding the emission of greenhouse gases, reducing the impact of climate change, and improving the health of families.**

The project began in 2017 and was still running in 2021. It addresses at least four of the 17 Sustainable Development Goals (SDGs) defined by the United Nation General Assembly in 2015: **health and well-being, affordable and clean energy, sustainable cities and communities, and climate action.**

The pedagogical approach used in this project was problem-based learning and followed eight steps:

1. **Identification and delimitation of the subject or problem**
   Women had respiratory diseases due to inhaling the smoke generated by cooking on open fires, which is a tradition but also a consequence of the high price of gas, and causing deforestation.
2. **Collection, search and analysis of the information**
   Students carried out different surveys to discover how many families buy or still make their own tortillas; how many use firewood, gas or both for making them; what is the frequency of gas consumption by families; and what is the increase in the price of gas in relation to the state's minimum wage.
3. **Definition of the objective**
4. **Search and selection of alternatives**
   Two different models of stoves were identified and compared in order to choose the best type adapted to the situation.
5. **Planning**
   The students defined the costs involved, the materials needed, the timeline, etc.
6. **Execution of the selected method**
7. **Evaluation**
   After making sure that the stoves and biodigesters were working properly, the students conducted a new survey to find out how often families were buying gas cylinders while using their wood-saving stove, and the results showed that there was indeed a significant reduction in gas consumption.
8. **Communication**
   Once the stove had been evaluated, it was promoted and other classes and parents were invited to a presentation about the project, where students gave a talk and demonstration on the planning, execution and use of the wood-saving stove. A medium-term objective was fixed: to provide advice and support to mothers on how to make their own stoves and biodigesters.

TESTIMONY
ISIS FLORES, TEACHER

I must admit that at the beginning the students saw it simply as a school activity, as homework or, in this case, participation in a demonstration. However, once they lived the experience of showing the results of their research and publishing them, the perspective changed for them, and for me as well, as at that time I had been a teacher scarcely two years. We discovered that a project like this should not simply stay in the classroom simply to receive a qualification, but for students to find real meaning it must go beyond the walls of the school, into the community, and this was what happened. When we began to "make a noise" the community wanted us to go to their homes, and the school has become the hotbed of many projects beneficial to all.

Students building the base of the biodigester stove (bricks and cement).


Students building a biodigester.

EQUIPMENT

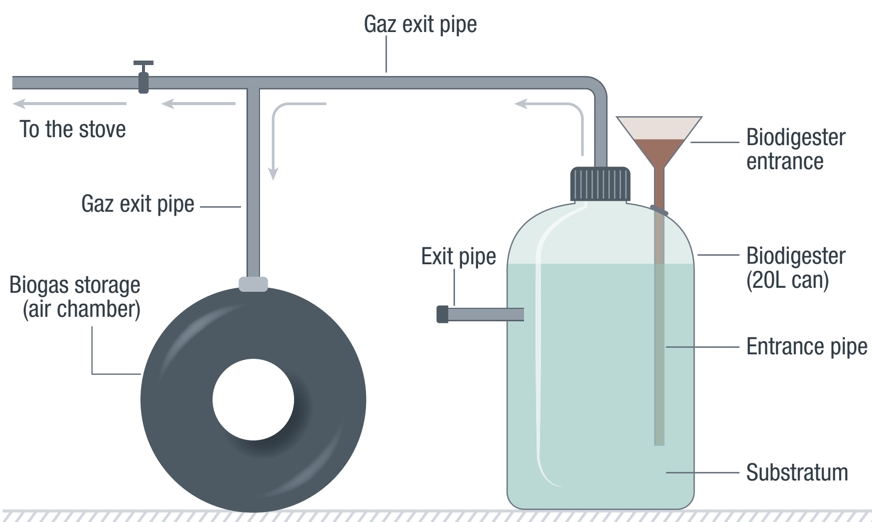
The model of energy-saving woodstove selected allows the use of different materials in order to retain heat inside the stove, which means that less wood is used and when biogas takes its place, heat is also conserved inside the stove for longer periods of time.

The materials for the **construction of the stove** are the following: bricks, sand, cement, and mud. The materials used to fill the stove to retain heat are gravel, sand, glass, salt, ash, red tezontle and chalk.

For the **biodigester,** you will need a large container, copper pipes, gas hoses, manure, water and tape.


Example of the traditional dish cooked with the stove.

HOW TO BUILD A BIODIGESTER




Example of a biodigester built by the students during the project

#5 MITIGATION AND ADAPTATION PROJECT
HOME GARDEN

MAIN SUBJECTS
Agriculture

AGE GROUP
12 - 18 years

STAKEHOLDERS
Teachers, communities, local authorities

During the COVID-19 pandemic, many schools were closed, and students remained at home with their families. Throughout the world, innovative pedagogical tools were introduced, thanks to teachers' creativity and goodwill.

In the **Huerto Challenge project,** during lockdown teachers asked students to establish **gardens based on their family's dietary pattern and what they traditionally consumed,** especially vegetables, such as lettuce, squash and coriander, and some grains and beans. Initially, the project was undertaken by seventy families in Tetlanohcan, Tlaxcala, Mexico, equivalent to the number of students aged between 13 and 14-years old. After a few months this number increased to **ninety families** and the municipality decided to scale up and to offer more families the opportunity to grow community gardens.

The seeds were obtained mainly from the food. Later the teacher provided students with seedlings that were purchased with the money generated from the sale of the school garden produce. **The students learned to prepare their own compost and design irrigation systems** allowing an efficient use of resources.

The plants grow from local seeds harvested by the students.

This project is a good way of involving families and to build a strong link between topics covered during class activities and their practical application, such as reducing the negative impact of diet on the climate. It is also a very efficient way to develop student autonomy and initiative. By working with a family's food habits and their local context, the project is **a wonderful way to involve the whole community and have students and their families do certain activities together.**

This project has the direct result of **reducing the impact of diet on greenhouse gas emissions through a reduction in transportation and the use of fertilisers in plant production.** It is also a good way to improve traditional and local knowledge about food production and food consumption, favouring the transmission of sustainable food habits.

TESTIMONY
ISIS FLORES, TEACHER

I have always said that garden activity is an excellent pedagogical tool because it is non-judgmental, besides being an excellent occupational therapy. Working in their family gardens allows students to make responsible decisions, carry out research and develop creativity because they all have different needs and spaces, and they face different problems that each student has to solve with their family. In addition, this project facilitates science activities, the rigorous application of mathematics, research, and reporting everything that takes place in a garden.

TESTIMONY
PAOLA PLUMA, STUDENT

The project took advantage of the pandemic lockdown, giving us time at home to plant different vegetables. I planted cabbage, radish, chard, broccoli, tomato, lettuce and purple lettuce. This project also allowed us to de-stress, not to be anxious, and to exercise a little bit since we were spending so much time at home.

Example of diverse home gardens built by students and their family.

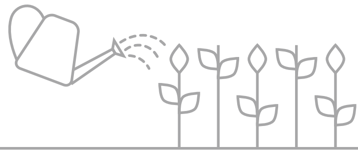
#6 CITIZEN SCIENCE PROJECT

TREE BODYGUARDS

MAIN SUBJECTS
Biodiversity, citizen science, research protocols

AGE GROUP
8 - 18 years

STAKEHOLDERS
Researchers, teachers



Climate science is always changing as new discoveries are made every year on the causes, impacts and mechanisms of the climate systems. Some scientific studies need large sample sizes of observations in order to have a good comprehension of the phenomenon. This is the case when exploring the impact of climate change on biodiversity. With species that we can find in cities and around schools, why not ask school students to be scientists and to collect data? Thus, citizen science projects conducted in schools are a good way to collect new data to study the impact of climate change on biodiversity and, at the same time, work on science protocols, teach about climate and employ project-based education.

The Tree bodyguards project evaluates how our current climate is influencing interactions between trees, herbivores (caterpillars), and their enemies in order to try and anticipate what might be **the consequences of climate change on a tree's ability to defend itself and be defended against herbivores.** This particular citizen science project invites teachers to collaborate with scientists. Since the project started in 2018, it has led to the collaboration of about 53 scientists and 96 teachers in 17 countries. In total, we have reached more than 90 classes.

Both professional scientists and school children apply the very same protocol (see next page) that was developed to **assess predator ability to reduce the amount of damage herbivores can cause to trees.** The study is carried out on a single tree species, the pedunculate oak Quercus robur, which is widespread from Spain to Finland, and the UK to Russia.

Training material is available to help teachers become familiar with observations made in the field, and we are currently working with education scientists to provide teachers with hands-on pedagogical material to help them incorporate the project into the curriculum.

TESTIMONY
ANJA NEUDÖRFLER, TEACHER

It is very important for students to realize that one can be part of something big, one can make a change in the world. That's one of the skills this project teaches the kids – noticing that everyone can be part of shaping our future. It gives my students the opportunity to be part of scientific research, at quite a young age.

The project has currently been running for a few years and there has been good feedback from both teachers and pupils (through their teachers). The project is seen as "authentic", as both teachers and their pupils appreciate carrying out real research. Even so, this may be an uncomfortable area because there is no definitive right or wrong answer to the research question that is asked. With good reason, because the only answer we have is: ***"we don't know as yet, but we are working on it!".*** **This is part of the excitement of doing the research.**

Scientists must also communicate about how they know what's going on out there, and how they can use current knowledge and uncertainty to make predictions. We need people to be able to trust science. Otherwise, any action taken against mitigating the effects of climate change may be misunderstood, or worse, questioned. Research takes time, energy, and has a cost. There is no immediate and easy answer to hugely complex ecological problems. **Giving schoolchildren a first-hand taste of what research is like will help them understand what science is,** and why trusting science is a good strategy in their everyday life.

In the tree bodyguards project, teachers are essential mediators between schoolchildren and scientists: to help collect data efficiently, and to provide relevant feedback on learning outcomes.

PROTOCOL

In the spring, we make fake caterpillars with green modelling clay that we attach to low-hanging oak branches. Predators are fooled: they attack these fake caterpillars as if they were real food, and by doing so they leave beak, tooth and mandible marks on the clay surface. We simply count the number of fake caterpillars with predation marks: this tells us how efficiently predators can protect oaks against real herbivores. We then collect oak leaves and estimate the surface that has been removed or impacted by the caterpillars.

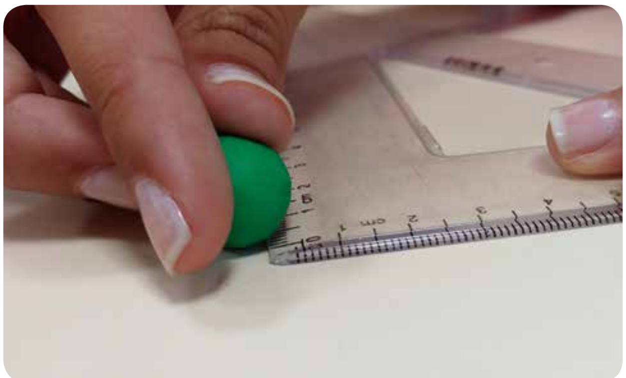
Data collection is carried out between May and early July. During the summer, while schoolchildren and teachers are on well-deserved holidays, scientists work on the data to correlate herbivore damage with predator activity and map this relationship on a European scale.

TESTIMONY
BASTIEN CASTAGNEYROL, RESEACHER

I am often upset that people only see ecology as a kind of philosophy or commercial argument. This is not wrong, but this is only part of the story. I wanted to show schoolchildren – and their teachers – that ecology is also a science, and that you do not require massive and hugely expensive machines to do good science: a piece of modelling clay and a network of motivated collaborators is sometimes enough.

TO GO FURTHER

See the Oakbodygards website.



Building a fake caterpillar

This fake caterpillar has been attacked by predators

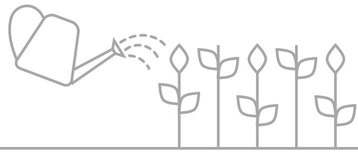
Student and researcher setting up fake caterpillars on trees.

#7 AWARNESS PROJECT
ORBIS

MAIN SUBJECTS
Dance, art, expression, awareness

AGE GROUP
8-18 years

STAKEHOLDERS
Teachers, communities (families)



Citizen mobilisation, individually and collectively, is a central element in the fight against global warming. Therefore, raising awareness of environmental issues is a very important type of engagement that students can make in different ways. Projects to raise awareness amongst the general public (other students, the school community, families or the wider community) can easily be implemented in school over a longer or shorter period of time. These projects, which can be very different, are often **multidisciplinary**, since they call for **scientific knowledge** on the subject as well as **writing, artistic or technical skills.**

This project was developed within the context of **the competition "Les Fairiades" (Festival des Vocations),** in France. Secondary school students and apprentices worked throughout the year on the theme "SOS Planet in danger: mobilise your talents to save it!"
The jury, chaired by Etienne Klein (philosopher of science and physicist), included education professionals, scientists and journalists. The educational objectives of the competition were based on the following:

- Encouraging **interdisciplinary approaches.**
- Teaching pupils to **work together** in a spirit of citizenship.
- **Inventing other ways** to help them choose their pathways.
- **Bringing pupils together** by bringing professions together.
- **Encouraging student commitment** by carrying out projects useful to society and humanity.

First prize was awarded to a group of 1st-year general class (specializing in cinema) in Camille Vernet high school in Valence, Drôme, **for their short film, *Orbis*:** Pauline Dubouloz, Sarah Casserini, Noah Buisson and Julia Maignan, high school students, and Sophie Fueyo, their teacher.

Orbis is a short film, of three and a half minutes. It is a choreographed story in which the issue of abused women is paralleled with the environmental damage caused by human activities, in particular, climate change. **The film was made as part of a collaboration between different disciplines, from the sciences to the visual arts.** The film was made by **a group of students, supervised by their different teachers,** in collaboration with recording studios and professional dancers for the shooting. All audio-visual equipment was provided by the school.

This project was initiated by a collective discussion within the class and debated amongst the pupils alongside other projects that were later not chosen. The pupils divided out the tasks and organised the filming part of the project in conjunction with the educational team and the professionals with whom they were in contact. This involved storyboard writing, rehearsals, filming and editing; the project was carried out **over a school year** and involved different disciplines.

The project taught the students to **work in groups,** especially through the exchange of ideas, to ensure that the film would be seen by as many people as possible. The students had to **learn to make concessions in order to make the project work.** *Orbis* allowed them to **be autonomous throughout the creative process,** so they could discover the realities of writing, shooting and editing. Although the primary purpose of such a project is artistic, **the students had to take ownership of the subject, and to convey a poetic and accessible version using emotions.** It is by emotionally touching the audience that this film will be able to make them rethink, to make things happen.

In winning the competition, the students were able to raise €1,000, which will allow them to buy equipment to be used in the film class.

TESTIMONY
LYDIE LESCARMONTIER,
PART OF THE FESTIVAL JURY

Orbis immediately stood out from the other project submissions thanks to its strong artistic component. The jury was unanimous when it came to choosing a winner. The format of the film was an asset in terms of visibility, as well as the personal expression of the students in the face of the climate challenge.

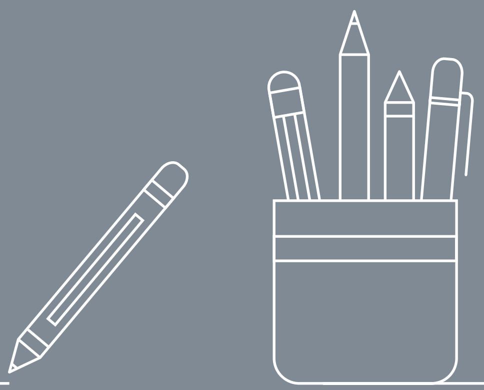
TESTIMONY
SOPHIE FUEYO, TEACHER

It all started with the desire to make a project in its entirety, from the script to the editing. Moreover, as the theme of the competition was ecology, the students felt concerned, especially as they were already involved in ecological events, such as the Fridays For Future movement, and they were really motivated by this theme.

Filming sessions with the students and the artists.

TO GO FURTHER

See the Orbis video clip.



AROUND THIS BOOK

ADDITIONAL MULTIMEDIA RESOURCES

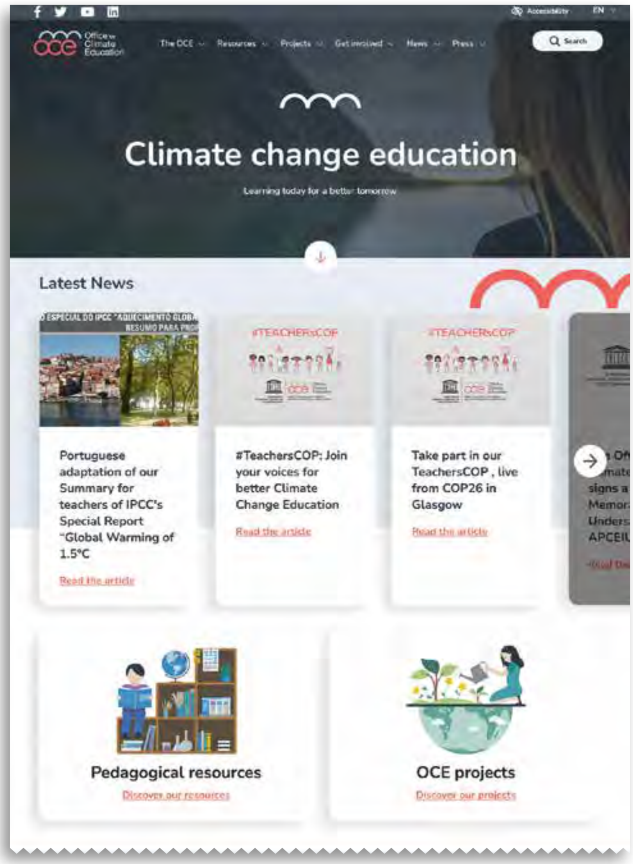
WEBSITE

The Office for Climate Education website offers many educational resources on climate change:

- Summaries of IPCC (Intergovernmental Panel on Climate Change) reports for teachers;
- Class activities;
- Multimedia activities and videos for class use;
- Resources for professional development.

All resources are published under the CC-BY-NC-SA license (free non-commercial use and adaptation).

https://www.oce.global



VIDEOS

Some of our videos and multimedia activities have been explicitly designed to accompany the teaching guide "The Climate in our Hands – Climate Change and Land", and are presented below. In each of the following videos, an expert speaks about a specific issue related to land, agriculture or food, in the context of climate change. These videos can be used either to initiate or conclude a discussion with students on a specific topic.

FOOD SYSTEM AND CLIMATE CHANGE

Prajal Pradhan, researcher on climate change and sustainable food,
Potsdam Institute for Climate Impact Research, Germany

Around one third of anthropogenic greenhouse gas emissions come from our food systems and the resulting climate change also impacts our food systems and food security. At the same time, there is a need to decrease emissions coming from food systems to mitigate climate change. Many response options are available which can help prevent climate change and provide health benefits.

LAND AND CLIMATE

Claire Fyson, policy analyst, Climate Analytics, Germany

Land can store a lot of carbon in vegetation and soil, thus mitigating climate change. It provides us with food, fibre and ecosystem services and, as such, it's important to maintain healthy, resilient land and ecosystems. But climate change and human land use damage land-based ecosystems.

SOILS AND BIOGAS

Frank Hofmann, international consultant, German Biogas Association, Germany

Methane is a very strong greenhouse gas, and livestock is responsible for a significant portion of such emissions. One way to avoid its large impact on climate is to take advantage of the organic matter produced by this kind of farming (excrement), trap it inside airtight containers and use the generated biogas as a source of energy.

FOREST AND CLIMATE CHANGE

Jens Schroeder, researcher in forest ecology,
University for Sustainable Development, Germany

All around the world, forests are experiencing increasing stress. They have to cope with more and more forest fires, heat, drought and floods. However, they can be mighty allies in mitigating and combating climate change by limiting its disastrous results.

SOILS AND PERMACULTURE

Mette Fraurud, gardener in Berlin, Germany

Permaculture is a new way of practicing agriculture based on observing Nature and trying to mimic its systems. It is increasingly adopted to answer some of the problems caused by conventional agriculture, such as ploughing. Protecting the land and soil is one way to mitigate climate change.

SOIL AS A SUSTAINABLE BUILDING MATERIAL

Henri Van Damme, emeritus researcher,
École supérieure de physique et chimie industrielle, France

Soil is not only the support for growing food; it also provides the most widely used building material in the world, in the form of bricks, dried sludge, mixed with straw, etc. An ecological use of an element that is available everywhere, under our feet.

CLIMATE MIGRATION PROCESS

François Gemenne, researcher in environmental geopolitics,
Sciences Politiques, France

Today, climate change has become one of the main causes of migration and population displacement in the world, whether it is due to rising sea levels, land degradation or natural disasters. Great progress has been made in recent years in the organisation of these migrations and the protection of these people.

INDIGENOUS POPULATIONS AND CLIMATE CHANGE

Sabah Rahmani, journalist and anthropologist, France

There are about 370 million indigenous people worldwide who have maintained a very strong connection to nature. But their territory, on which they depend for their survival, is being threatened by the exploitation of states and large companies, as well as by climate change. However, they are increasingly being listened to by scientists who draw on their knowledge.

PERMAFROST AND CLIMATE CHANGE

Antoine Séjourné, researcher in geosciences, Paris Saclay University, France

Permafrost is the ground that is permanently frozen over several centimetres and even up to one kilometre. It contains large amounts of carbon, in the form of organic matter, that can be degraded and potentially released into the atmosphere in the context of climate change.

CLIMATE CHANGE AND AGRICULTURE

Vincent Chaplot, researcher in agronomy, Sorbonne University, France

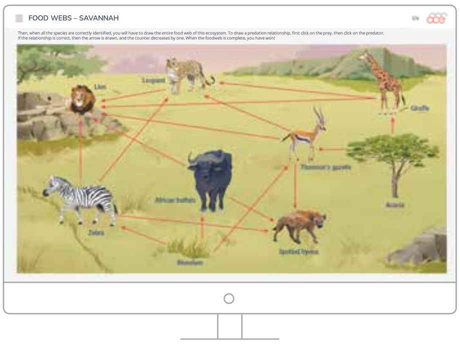
The agricultural sector is responsible for a large share of greenhouse gas emissions and current trends are towards intensification of these agricultural practices. However, many solutions currently exist to adapt to societal changes while limiting our impact.

MULTIMEDIA ACTIVITIES

The following multimedia activities offer students the possibility of working interactively on different topics related to climate change.

CARBON CYCLE

This multimedia animation focuses on the carbon cycle, including both natural and human activities. The students can build on these activities and see their impact on the environment. It is also possible to visualise the evolution of the atmospheric concentration of carbon dioxide.

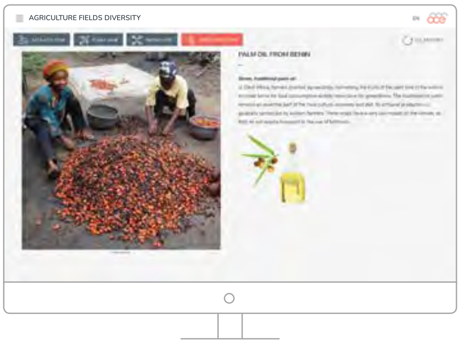


LAND FOOD WEBS

Through this activity, students learn the names and predatory relationships of multiple animal and plant species belonging to six different land food webs and living in distinct world regions: riparian ecosytems in Alaska, temperate forests, Guyanese tropical forests, savannah, soil and one example of an agrosystem. Students can also visualise the impact of climate change and human activities on these food webs.

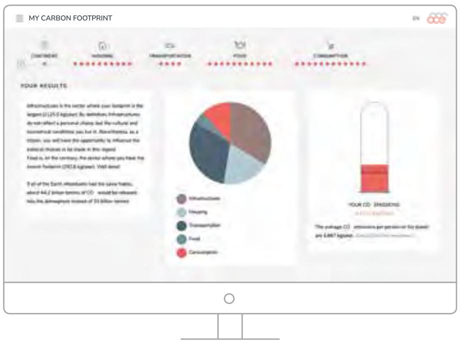
THE IMPACT OF OUR FOOD

This multimedia animation is a card game in which students have to rank foods according to three criteria: carbon footprint (greenhouse gas emissions), water use and land use. In the game, students are able to compare the environmental footprint of different common foods.



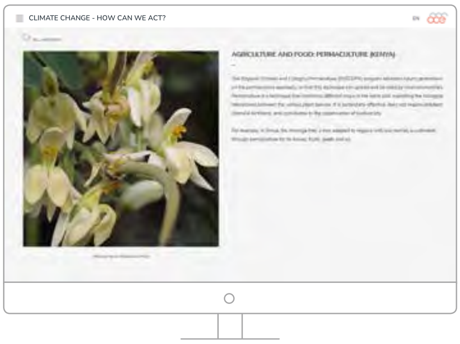
AGRICULTURE FIELDS DIVERSITY

This activity allows students to discover the diversity of agricultural practices around the world, by looking at aerial views of fields and farms from the sky. They can compare different ways of producing beef, maize, palm oil and tomatoes. They also learn how different types of agriculture have impacted the climate.



CARBON FOOTPRINT

In this activity, students are able to calculate their own carbon footprint. This helps them realise how much our daily actions or habits contribute to greenhouse gas emissions and, thus, how we can reduce them.



HOW CAN WE ACT?

This multimedia activity describes around thirty tangible actions that have been carried out around the world to address climate change issues. These adaptation or mitigation “solutions” include agriculture and food, energy, housing, urban resilience, ecosystems, research and public awareness.

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IPCC Special Report on Climate Change and Land
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Food and Agriculture Organisation of the United Nations (FAO) – The State of Food and Agriculture (2016)
https://www.uncclearn.org/wp-content/uploads/library/a-i6030e.pdf

Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) – Assessment Report on Land Degradation and Restoration
https://ipbes.net/assessment-reports/ldr

IPBES – Global Assessment Report on Biodiversity and Ecosystem Services
https://ipbes.net/global-assessment

Global Land Outlook of the UN Convention to Combat Desertification (UNCCD)
https://www.unccd.int/sites/default/files/documents/2017-09/GLO_Full_Report_low_res.pdf

NASA – Global Climate Change: Graphics and Multimedia
https://climate.nasa.gov/resources/graphics-and-multimedia/

Yale Climate Connections
https://yaleclimateconnections.org/

Achieving Food System Resilience: A case study on France
https://localscale.org/research/en/index.jsp

Global Soil Biodiversity Atlas
https://esdac.jrc.ec.europa.eu/content/global-soil-biodiversity-atlas

OCE EDUCATION RESOURCES

Climate science resources for teachers
https://www.oce.global/en/ressources/enseignants?field_resource_theme=All&f%5B0%5D=type%3A14

The Climate in our Hands – Ocean and Cryosphere
https://www.oce.global/en/resources/class-activities/climate-our-hands-ocean-and-cryosphere

Teachers' professional development resources
- The greenhouse effect: https://www.oce.global/en/resources/teacher-professional-development/greenhouse-effect
- Ocean and climate change: https://www.oce.global/en/resources/teacher-professional-development/ocean-and-climate-change

Video Billes de Science: Simon Klein – Food, Agriculture and Climate Change (French with English subtitles)
https://www.oce.global/en/resources/videos/food-agriculture-and-climate-change

OTHER EDUCATION RESOURCES

Agritopia – A roleplaying game to make students think about the impacts of agricultural choices on the climate
https://www.climateinteractive.org/programs/climate-smart-agriculture/agritopia/

California Academy of Sciences – Natural Resources Bingo
https://www.calacademy.org/educators/lesson-plans/natural-resources-bingo

Creating Futures – Resources: produced by Education for a Just World, an initiative of Trócaire and the Centre for Human Rights and Citizenship Education, Dublin City University, Institute of Education, Ireland
https://www.trocaire.org/getinvolved/education/creating-futures

Eco-Schools – Stories and news about sustainability projects conducted in schools
https://www.ecoschools.global/stories-news

FAO Discovering Forests: Teaching Guide
http://www.fao.org/3/i6208e/i6208e.pdf

NASA Climate Kids
https://climatekids.nasa.gov

The Sandwatch Foundation – A network of children, young people and adults working together to enhance their beach environment and build resilience to climate change
https://www.sandwatchfoundation.org

TROPICSU Climate Change Education Accross the Curricula, Across the Globe – Resources for high school teachers
https://tropicsu.org/un-resources/

INTERACTIVE SIMULATIONS

En-ROADS – Simulation used to understand how we can achieve our climate goals (high school)
https://www.climateinteractive.org/tools/en-roads/

University of Manchester – Build your own Earth (high school)
http://www.buildyourownearth.com

New Shores – A game for democracy
https://newshores.crs.org.pl/

GLOSSARY

ADAPTATION
The process of adjusting to current or expected climate change impacts. In human systems, the aim of adaptation is to reduce risks, increase resilience or seize beneficial opportunities. In natural systems, human intervention may facilitate adjustments to expected climate change impacts.

AFFORESTATION
The establishment of a forest through tree planting or seeding on land that has lacked forest cover for a very long time or has never been forested.

AGROECOLOGY
A type of sustainable farming that applies ecological concepts and principals in agriculture.

AGROFORESTRY
A method of using agricultural land combining trees and crops or animal husbandry.

ALBEDO
Meaning "whiteness", albedo is the reflective power of an object or surface. For instance, ice and fresh snow have a high albedo, ranging from 40-80%. This means that they reflect 40-80% of the incoming sunlight. The ocean is darker, so it has an albedo of less than 10%.

ANTHROPOGENIC EMISSIONS
Greenhouse gases emitted by human activities.

BIODIVERSITY
Biodiversity first refers to the variety of species (flora and fauna) that live on Earth or in a particular ecosystem. More precisely, we distinguish between three levels of biodiversity: intraspecific biodiversity (differences between members of the same species), interspecific biodiversity (differences between species) and ecosystem diversity (the environment and species that live in it).

BIOMASS
Organic matter used as a fuel, especially in a power station for the generation of electricity.

BIOME
The ensemble of flora and fauna in a specific region.

BROWNING
Browning is a systematic decrease in vegetation growth or the death of vegetation that results in a loss of productivity over a period of time.

CARBON CYCLE
Carbon is a chemical element which can be found in many molecules, in living beings as well as in non-living materials. Carbon is stored in huge amounts in what are called "reservoirs" on Earth – the most important being the ocean and the soil. But the carbon in these reservoirs does not stay there forever; it moves between reservoirs: these movements are called "flows". The natural flows are perfectly balanced, leading to a carbon cycle.

CARBON DIOXIDE (CO_2)
A gas produced by the combustion of carbon (for example: fossil fuels). It is also produced by living organisms while breathing. CO_2 contributes to the greenhouse effect.

CARBON FERTILISATION
Carbon fertilisation is also known as carbon dioxide fertilisation. It is the phenomenon by which the increase of carbon dioxide in the atmosphere increases the rate of photosynthesis in plants.

CARBON FOOTPRINT
A carbon footprint (in CO_2-eq) is defined as the total amount of greenhouse gases produced directly or indirectly by human activities. It can be calculated for an individual, a particular event or an organisation.

CARBON SINK
This is a natural reservoir that stores carbon-containing chemical compounds accumulated over time. Carbon sinks help reduce the amount of atmospheric CO_2. Natural sinks are soil – the largest carbon store – and part of the biosphere via photosynthesis by terrestrial plants and marine phytoplankton and algae, a process that incorporates atmospheric CO_2 into sugars, using solar energy.

CLIMATE
An average pattern of weather conditions – such as temperature, precipitation, humidity, wind, air pressure – for a particular region over a long period of time (months, years, decades, centuries or more).

CLIMATE CHANGE
Climate change refers to several global phenomena, for example: changes in temperature, precipitation, extreme events, sea level rise and ocean acidification. The term is most used to describe the current human-induced climate change that started around 1850 due to an increase in the global average temperature. The term "global warming" is also used.

CLIMATE JUSTICE
This term is used to acknowledge the social and political dimensions of the challenges associated with climate change, rather than considering only their environmental dimension. It relates the differences observed between those more responsible for climate change and those more affected by its consequences, to the notion of justice (in particular, social and environmental justice).

CLIMATE ZONES
Areas with distinct climates that can be classified using different parameters, such as temperature, precipitation, etc.

CO_2 UPTAKE
All the processes that contribute to the removal of CO_2 from the atmosphere. CO_2 can be removed by biological processes, such as ocean or land photosynthesis, or by more physical processes, such as carbon absorption in water.

COMPLEX SYSTEM
A system (such as the climate system) regulated by many factors that interact with and influence each other: atmosphere, ocean, land and biosphere, for example.

CONTINENTAL ICE
All the ice on land. Continental ice is formed by the accumulation and compaction of snow over a long period of time.

DEFORESTATION
Destruction of a forest, often with the aim of turning it into agricultural land.

DESERTIFICATION
Land degradation in arid or semi-arid areas by human or climatic actions.

DROUGHT
A drought is an event of prolonged shortages in the water supply. A drought can last for months or years, or may be declared after as few as fifteen days.

DRYLAND
Drylands are ecosystems characterised by a lack of water. They include cultivated lands, scrublands, shrublands, grasslands, savannas, semi-deserts and true deserts.

DUST STORMS
Masses of sand and dust raised by the wind in very dry areas such as deserts.

ECO-ANXIETY
Climate change can generate different feelings and emotions; some may leave us feeling helpless or hopeless. This is called “eco-anxiety”.

ECOREGION
See Biome.

ECOSYSTEM
The totality of living beings in a given environment, plus the environment itself. In an ecosystem, everything is interconnected and interdependent.

ECOSYSTEM SERVICES
Humans can directly or indirectly benefit from ecosystems, which provide them with services. They are grouped into four categories: provisioning, regulating, supporting and cultural. For example, ecosystems produce oxygen (through photosynthesis) and food, and they provide us with raw materials. Ecosystems also preserve soil fertility, fertilise plants and protect coasts.

EQUITY
Justice, fairness: when the same opportunities are given to all – education, health, rights, etc.

EVAPOTRANSPIRATION
The process by which water is transferred from the land to the atmosphere by evaporation, either from the soil and other surfaces, or by transpiration from plants.

EXPOSURE
How much a population is exposed to a certain climate hazard due, for example, to its geographic location. Example: low-lying lands are more exposed to sea level rise than mountain regions.

EXTREME EVENTS
Unusual events that have a high negative impact on humans and ecosystems. Examples: tornadoes, storms, landslides, droughts, wild fires and heatwaves.

FEEDBACK LOOP
A feedback loop is a cycle in which some outputs of a process can exacerbate or attenuate one or more of its own causes.

FERMENTATION
Fermentation is a chemical reaction that happens naturally in some plants and animal substances. It needs the presence of very small living organisms, such as bacteria, fungi or yeast, to occur. This phenomenon is also used for human activities and can produce methane, lactic acid (in yogurts) and alcohol (in wine or beer).

FOOD SYSTEM
The food system includes every step that our food goes through, from farm to fork: food production, processing, storage, distribution, consumption and recycling.

FOOD WEB
A food web is a representation of the “prey–predator” relationship in an ecosystem. It is a web rather than a chain, meaning that an organism may eat several species and a species may be eaten by multiple organisms.

GLACIER
A large mass of ice on land that slowly moves downhill.

GLOBAL WARMING
See Climate Change.

GLOBAL WARMING POTENTIAL (GWP)
The term Global Warming Potential is used to compare the “power” of a gas to warm the atmosphere and the duration of its effect. By definition, CO_2 has a global warming potential of 1 regardless of the time period used. CO_2 remains in the atmosphere for a century. CH_4 is estimated to have a GWP of 28-36 over 100 years, meaning it absorbs much more energy than CO_2. Nevertheless, it “only” remains in the atmosphere about a decade on average. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. N_2O has a GWP 265-298 times that of CO_2 for a 100-year timescale.

GREENHOUSE EFFECT
Solar radiation crosses the atmosphere, is absorbed by the Earth’s surface and warms it. The absorbed solar radiation is transformed into infrared radiation (heat). Some of this infrared radiation is ‘trapped’ on its escape towards space by greenhouse gases in the atmosphere and is sent back towards the Earth’s surface – heating it up even more. This is called the greenhouse effect.

GREENHOUSE GAS (GHG)
Greenhouse gases cause the greenhouse effect. Greenhouse gases are mainly water vapour, carbon dioxide, methane, nitrous oxide and ozone.

GREENING
Greening is an observed increase in vegetation productivity over a certain period of time. Trees, shrubs, herbaceous plants and ground cover vegetation are taken into account.

HEAT ISLAND EFFECT
An urban area has a higher average temperature than its rural surroundings owing to the greater absorption, retention and generation of heat by its buildings, pavements and human activities.

HEATWAVE
A period of abnormally and uncomfortably hot weather with high day temperatures and little or no cooling down at night. A heatwave can last up to several weeks.

ICE SHEET
A very large and thick layer of ice on a continent.

INDIGENOUS LOCAL KNOWLEDGE
Indigenous communities often live a lifestyle based on a complex and important relationship with their direct environment, with low impact on it and on the climate. Their local knowledge of nature management and agriculture is important to adapt and mitigate climate change.

INDUSTRIAL REVOLUTION
The historical period between 1760 and the 1840s. It has marked the transition from agricultural to industrial societies. The Industrial Revolution started in Europe and the United States and led to a rapid development of productivity, technologies and science, and therefore to population growth.

INFRARED RADIATION
Infrared radiation is the invisible part of light that we can feel as heat. It plays a key role in the greenhouse effect.

LAND DEGRADATION
Temporary or permanent decline in quality of soil, vegetation, water resources or wildlife – or the deterioration of the economic productivity of the land, such as the ability to farm the land.

LANDSLIDE
A mass of rock and earth moving suddenly and quickly down a steep slope.

MITIGATION
Human intervention to reduce global warming by reducing GHG emissions or by enhancing GHG sinks.

NATURAL VARIABILITY
Variations in the climate system that are not related to human activities (for example, alternation of glacial and interglacial eras).

PERMAFROST
Soil, rock or sediment that is permanently frozen (for at least two consecutive years).

PERMACULTURE
Development of an agricultural ecosystem intended to be sustainable and self-sufficient.

PHOTOSYNTHESIS
When they are exposed to light, plants are able to use this light, in addition to carbon dioxide, water and minerals, to produce their own organic matter and to grow. This process is called photosynthesis.

PRIMARY PRODUCTION
Primary production is the process by which a primary producer (a cell or an organism) produces its own organic matter using mineral materials. For example, photosynthetic living beings only use water, CO_2 and light to grow.

REFORESTATION
The planting of forests on lands that have previously contained forests but have since been converted for some other use.

SEA LEVEL RISE
Because of climate change, the global mean sea level has increased by about 15 cm from 1900 to 2018. The current rate of increase is between 3 and 4 mm / yr. The sea level is projected to rise by a further 20 cm to over one metre by the end of this century, depending on how much greenhouse gases we emit.

SOIL DEGRADATION
Soil degradation means the loss of arable land, and can be a consequence of water erosion, coastal erosion, wind erosion, salinity, loss of organic matter, fertility decline, soil acidity, etc.

SUSTAINABLE DEVELOPMENT
Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

VULNERABILITY
Sensitivity of a population when exposed to climate change hazards and its consequences. Example: a low-lying region with coastal protection infrastructures and resources is less vulnerable to sea level rise than a low-lying region with no coastal protection infrastructures and few economical resources.

WEATHER
The state of the atmosphere at a particular time and place. To define it, many variables such as temperature, precipitation, cloudiness or wind are taken into account.

WILDFIRE
A fire that is burning strongly and out of control on an area of grass in the countryside.

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The climate in our hands is a collection of educational resources for primary and secondary schools created by the Office for Climate Education and its partners.

This second volume, ***Climate Change and Land***, offers a ready-to-use lesson plan for students to understand climate change and land in both their scientific and societal dimensions, at local and global levels, to develop their reasoning abilities and to guide them to take action (mitigation and/or adaptation) in their schools or communities.

As the Intergovernmental Panel on Climate Change has stated:
→ **Land is where we live.**
→ **Land is under growing human pressure.**
→ **Land is a part of the solution.**
→ **But land can't do it all.**

This resource:
→ targets students from the upper end of primary school to the lower end of secondary school (9–15 years old);
→ includes scientific and pedagogical overviews, lesson plans, activities, worksheets and links to external resources (videos and multimedia activities);
→ is interdisciplinary with lessons covering the natural sciences, the social sciences, the arts and philosophy;
→ promotes active pedagogies: inquiry, roleplay, debate and project-based learning.

Office for Climate Education

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