SYSTEMIC 1: UNDERSTAND CURRENT ECOLOGICAL ISSUES AND PLANETARY LIMITS

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Introduction

In ecology, the term ecological crisis occurs when the living environment of a species evolves in a way unfavorable to its survival. The human species is now living through a major ecological crisis. This crisis is the consequence of the deregulation of many biotic and abiotic factors, the most notable of which are global warming and the erosion of biodiversity.

1. Introduction to ecology and planetary boundaries

Module objectives:

Adopt a systemic vision of the world and understand the issues related to planetary limits.

Courses related to the theme:

Climate changes

Biodiversity and preservation issues

Ocean acidification

Biogeochemical cycles

Global water use

Strastospheric ozone

Chemical pollution and atmospheric aerosols

Land use deforestation and agriculture

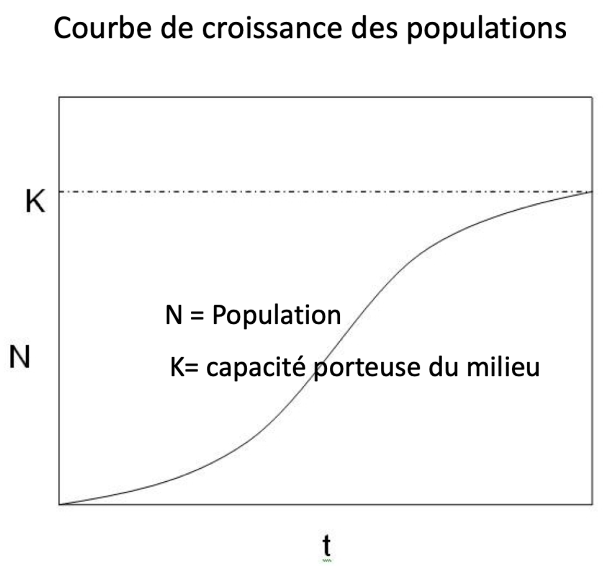
What is ecology?

We distinguish Scientific Ecology: Science of the relationships between living organisms among themselves and with their environment. (Haeckel, 1866).

And Political Ecology: Taking into account of ecological issues in political action and in social organization (1970).

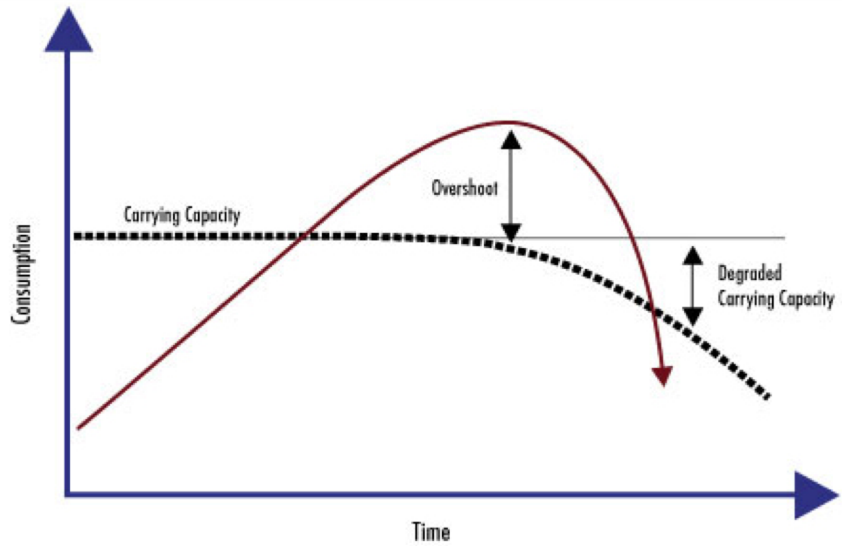
1.1. Scientific ecology and population growth

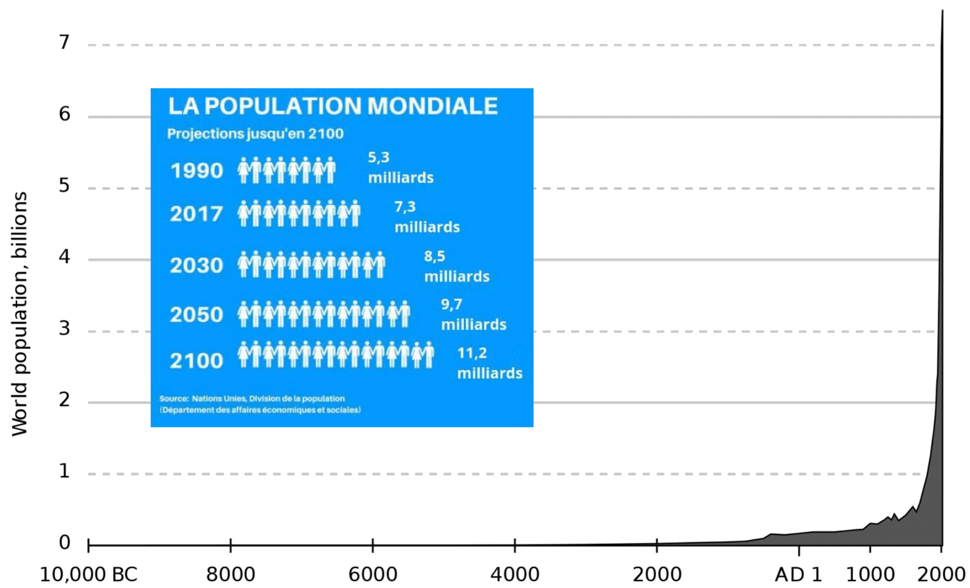
The object of study in ecology is the ecosystem. This term designates a whole formed by a community of living beings (biocenosis) within their environment (biotope). The richness of an ecosystem will therefore depend on the quality of the environment and the populations there. When an animal or plant population (denoted N) develops within an environment with favorable conditions (physicochemical properties favorable to its development, no predation ...) this population will follow an exponential growth until reaching a certain threshold called the carrying capacity of the environment (denoted by K). This carrying capacity K is the maximum size of the population of an organism that a given environment can support (in view of available resources, space, etc.).



When we exceed this carrying capacity, if the population grows too quickly for example, we observe an overshooting phenomenon leading to the degradation of the environment and therefore the decline of the population.

In the case of the human species, the environment considered is planet Earth. Our species is seeing its population evolve exponentially with a population explosion in the 1950s, going beyond the 5 billion people mark and nearly 8 soldiers today.



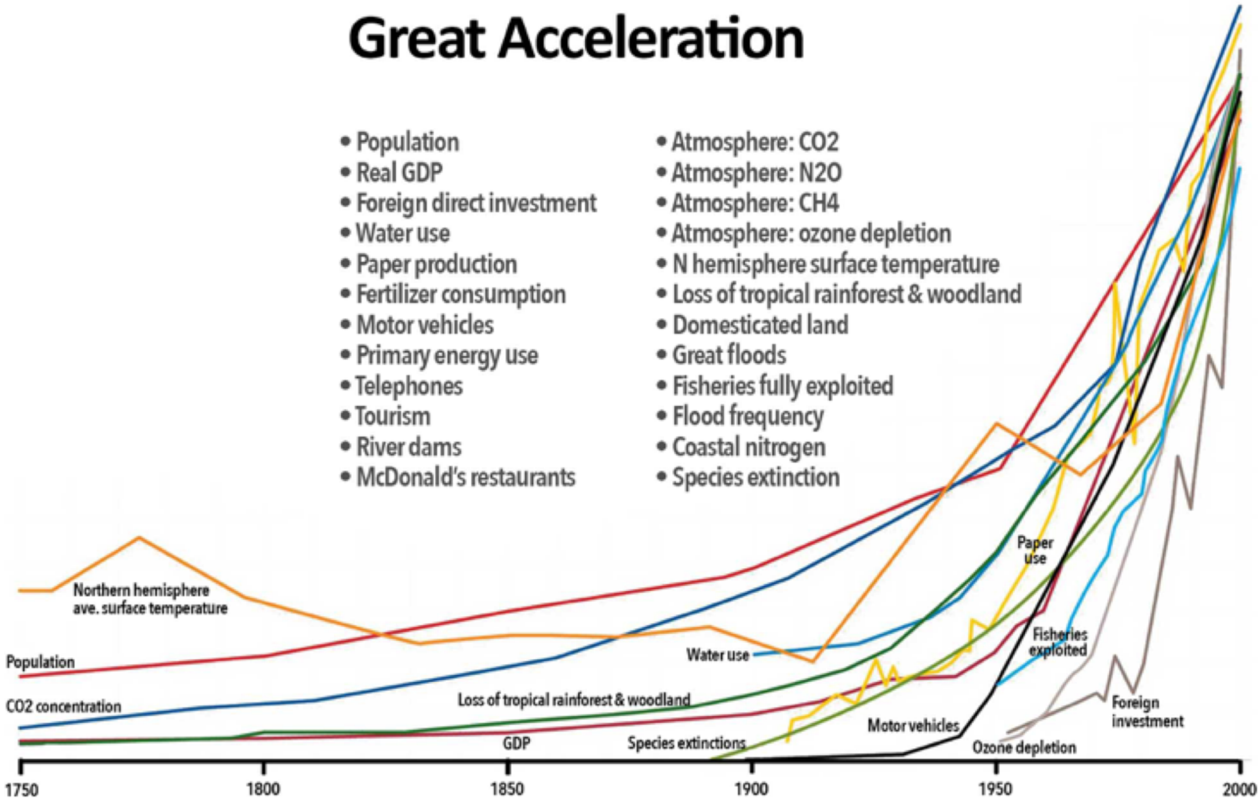


1.2. The great acceleration

This population increase is accompanied by an increase in a large number of parameters such as the average income per capita or the consumption of energy and resources. This phenomenon is thus called the great acceleration.

Steffen et al. (2015) The trajectory of the anthropocene: the great acceleration

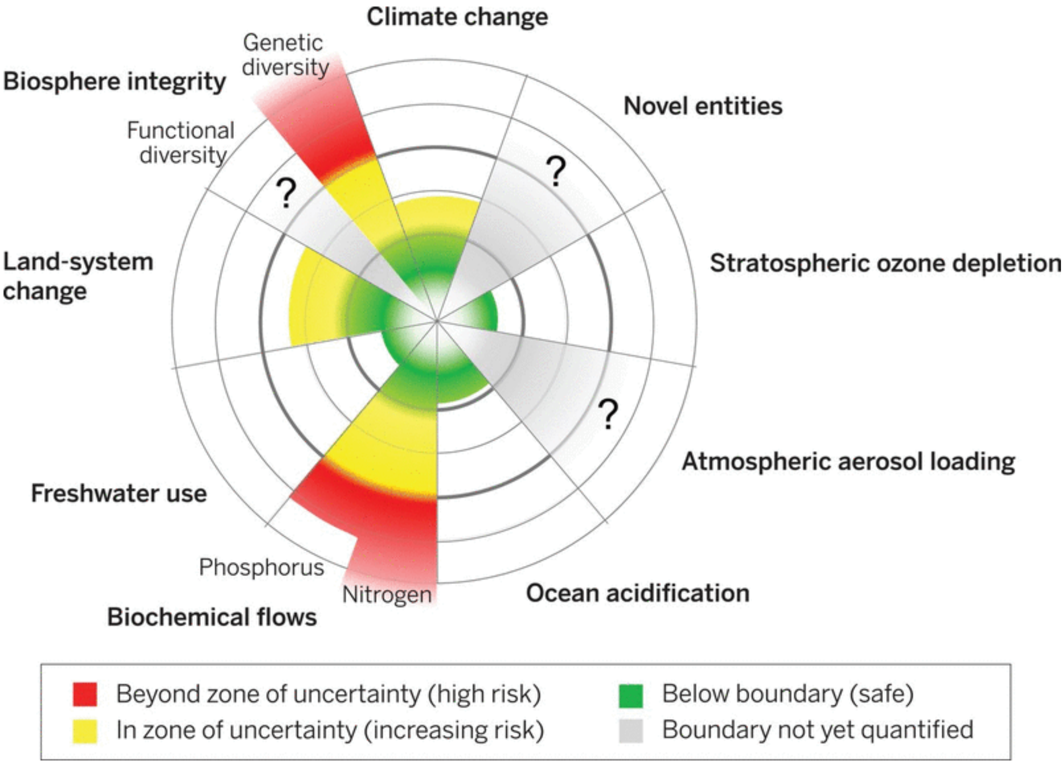
This exponential curve of human activities translated by the explosion of our economic activities and human demography exerts a massive effect on the Earth system, thus modifying the geological era of the planet. We thus switch from the Holocene, a geological period lasting 11,700 years, to the Anthropocene, a geological era which would have started the last 50 years. The Holocene separates us from the end of the previous Ice Age is characterized by a relative stability of conditions on Earth and creates conditions conducive to the flourishing of agriculture and great civilizations. The change of geological era therefore irreversibly leads to a modification of the terrestrial state that is most favorable to our activities and to the survival of our species.



1.3. Planetary boundaries

Since infinite growth in an environment with limited resources is not possible, it is therefore necessary to ask what is the real capacity that the Earth can support and what are the planetary limits not to be exceeded. These limits have been defined thanks to the work of Johan Rockström et al., 2009 and represent the thresholds that humanity must not exceed in order not to compromise the favorable conditions in which it has been able to develop and to be able to continue to live. sustainably. To date, of the 9 limits that have been defined, 4 of them have already been crossed.

The first two limits of climate change and the erosion of biodiversity are enough on their own to change the geological era.



Useful links :

Planetary boundaries: Guiding human development on a changing planet : http://science.sciencemag.org/content/347/6223/1259855

CRI sur « quelles pistes pour un monde soutenable? » : https://youtu.be/GTP25MoU870

2. Planetary boundary 1: Climate change - Introduction

Objectives of course :

- Understand the mechanisms involved in climate changes.
- Identify the anthropogenic factors leading to climate change.
- Explain the observed and projected changes and impacts of the climate.
- Analyze different climate change scenarios and think about adaptation strategies to adopt to cope these changes.

Introductory video

Introductory video to the concept of climate:

https://youtu.be/2KVT0_NqmiU

What are the four major components that make up the climate?

How do they intervene in climate regulation?

3. The climate system

Objectives

- Explain the difference between weather and climate
- Know how the climate system works
- Understand the greenhouse effect and learn the main greenhouse gases
- Understand the albedo effect

3.1. Introduction: What is the difference between weather and climate?

Quotes

The notions of “weather” and “climate” are sometimes confused when discussing the subject of global warming. Read the quotes below and think about the differences between the two concepts:

"The climate is what we expect, the weather is what we get."

"The weather is to a football match what the climate is to the whole history of the League"

"The climate tells you what clothes to buy, the weather tells you what clothes to wear."

"What is the most worrying? + 10 ° C between two days or + 1 ° C throughout the year? "

Définition

Weather: Atmospheric situation in a certain place on a certain date.

Climate: Set of meteorological phenomena that characterize the average state of the atmosphere in a given location. In other words, it is the “average weather” over a period ranging from a few months to millions of years.

Exceptional weather episodes (occurrence of a harsh winter or a rainy summer) only illustrate the variability of the climate in the short term (at the scale of a season, or a year). This does not change the long term warming trend.

3.2. How is the climate regulated?

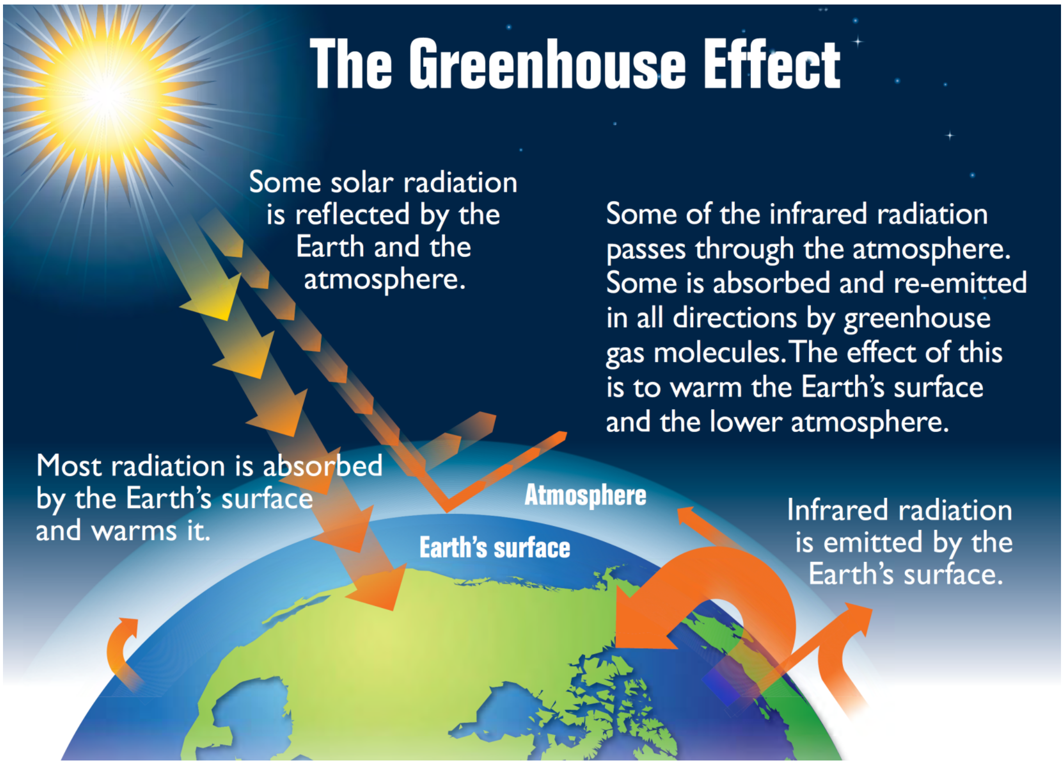
The sun is the greatest source of energy on Earth. Part of solar radiation is absorbed by the earth's surface (50%). The other part of the radiation is absorbed by the atmosphere (20%) or reflected in space (30%) thanks to the clouds and the clear surfaces of the Earth (glaciers, snow, deserts ...). The absorbed rays heat the earth's surface.

The more the surface heats up, the more it emits significant infrared thermal radiation. This radiation carries heat, part of which is returned out of the atmosphere.

The other part of the radiation is trapped by clouds and certain gases and gets stuck on the surface, this is called the greenhouse effect.

The temperature of the Earth adjusts to find a balance between the energy of the sun absorbed and that re-emitted in the form of infrared radiation, thus allowing an average temperature of 15 ° C. Without greenhouse gases, the global average temperature would be -18 ° C.

The greenhouse effect allowed the appearance of life on Earth. However, the increase in greenhouse gases as a result of human activities has greatly increased the proportion of infra red radiation retained, resulting in an increase in the global temperature of more than one degree.



3.2.1. Greenhouse gases

Definition

Greenhouse effect: Thermal phenomenon by which the atmosphere, made "impermeable" by the presence of gas, reflects infrared radiation towards the earth's surface, thus causing global warming.

a) Carbon dioxide (CO2):

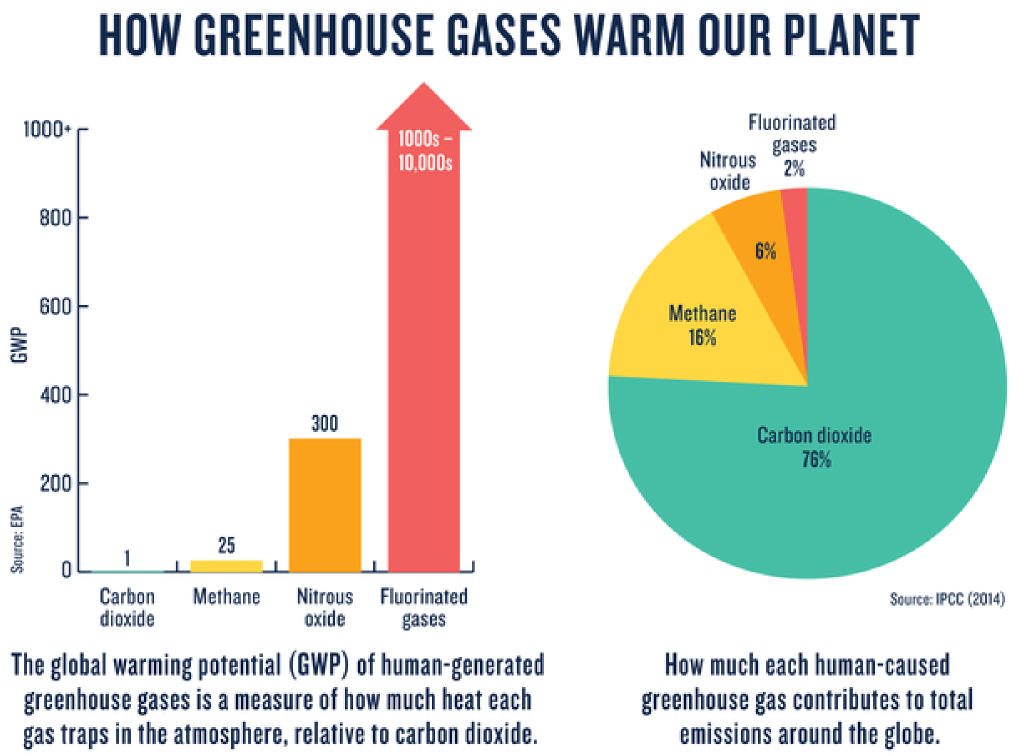
The accumulation of CO2 in the atmosphere contributes 2/3 of the increase in the greenhouse effect caused by human activities (combustion of gas, oil, deforestation, cement factories, etc.). This is why we measure the effect of other greenhouse gases in CO2 equivalent (CO2 eq).

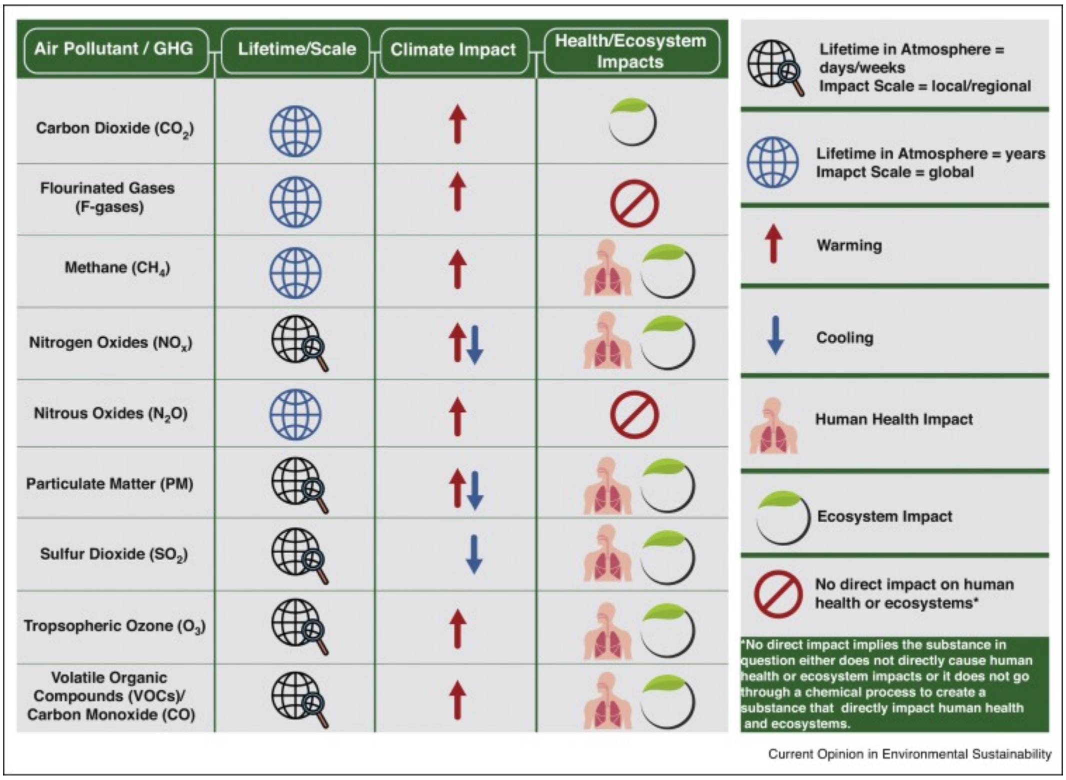
b) Methane (CH4):

Ruminant farms, flooded rice fields, landfills, and oil and gas operations are the main sources of human-induced methane. The lifespan of methane in the atmosphere is of the order of 12 years.

Other greenhouse gases

Nitrous oxide (N2O) comes from nitrogen fertilizers and certain chemical processes. It has a lifespan of around 120 years. Sulfur hexafluoride (SF6): It has a lifespan of 50,000 years in the atmosphere





Air Pollutant / GHG	Lifetime/Scale	Climate Impact	Health/Ecosystem Impacts
Carbon Dioxide (CO_2)	Lifetime in Atmosphere = years, Impact Scale = global	Warming	Ecosystem Impact
Flourinated Gases (F-gases)	Lifetime in Atmosphere = years, Impact Scale = global	Warming	No direct impact on human health or ecosystems*
Methane (CH_4)	Lifetime in Atmosphere = years, Impact Scale = global	Warming	Human Health Impact, Ecosystem Impact
Nitrogen Oxides (NO_x)	Lifetime in Atmosphere = days/weeks, Impact Scale = local/regional	Warming, Cooling	Human Health Impact, Ecosystem Impact
Nitrous Oxides (N_2O)	Lifetime in Atmosphere = years, Impact Scale = global	Warming	No direct impact on human health or ecosystems*
Particulate Matter (PM)	Lifetime in Atmosphere = days/weeks, Impact Scale = local/regional	Warming, Cooling	Human Health Impact, Ecosystem Impact
Sulfur Dioxide (SO_2)	Lifetime in Atmosphere = days/weeks, Impact Scale = local/regional	Cooling	Human Health Impact, Ecosystem Impact
Tropsopheric Ozone (O_3)	Lifetime in Atmosphere = days/weeks, Impact Scale = local/regional	Warming	Human Health Impact, Ecosystem Impact
Volatile Organic Compounds (VOCs)/ Carbon Monoxide (CO)	Lifetime in Atmosphere = days/weeks, Impact Scale = local/regional	Warming	Human Health Impact, Ecosystem Impact

Lifetime in Atmosphere = days/weeks
Impact Scale = local/regional

Lifetime in Atmosphere = years
Imapct Scale = global

Warming

Cooling

Human Health Impact

Ecosystem Impact

No direct impact on human health or ecosystems*

*No direct impact implies the substance in question either does not directly cause human health or ecosystem impacts or it does not go through a chemical process to create a substance that directly impact human health and ecosystems.

Current Opinion in Environmental Sustainability

c) Water steam

Water vapor is the third most abundant gas in the atmosphere and the leading greenhouse gas. Water steam is not the engine of global warming, but it contributes to it through an amplifying effect. Indeed, the increase in the concentrations of gases such as CO2 and CH4 leads to an amplification of the greenhouse effect, and therefore to a rise in temperatures. However, in a warmer atmosphere there may be more water vapor. The rise in temperatures therefore leads to an increase in atmospheric water vapor concentrations. Since water vapor absorbs infrared radiation, there is a strengthening of the greenhouse effect, which leads to a further increase in temperatures.

3.2.2. Albedo effect

Definition

Albedo is a dimensionless quantity, representing the fraction of the global solar energy reflected by a surface. It is expressed as a percentage or by a number between 0 (all light is absorbed) and 1 (all light is reflected). If the Earth were for example covered with water (low albedo of about 0.08), its average temperature would be around 32 ° C! Moreover, if it was completely covered with ice (albedo 0.6), this temperature reaches -52 ° C.

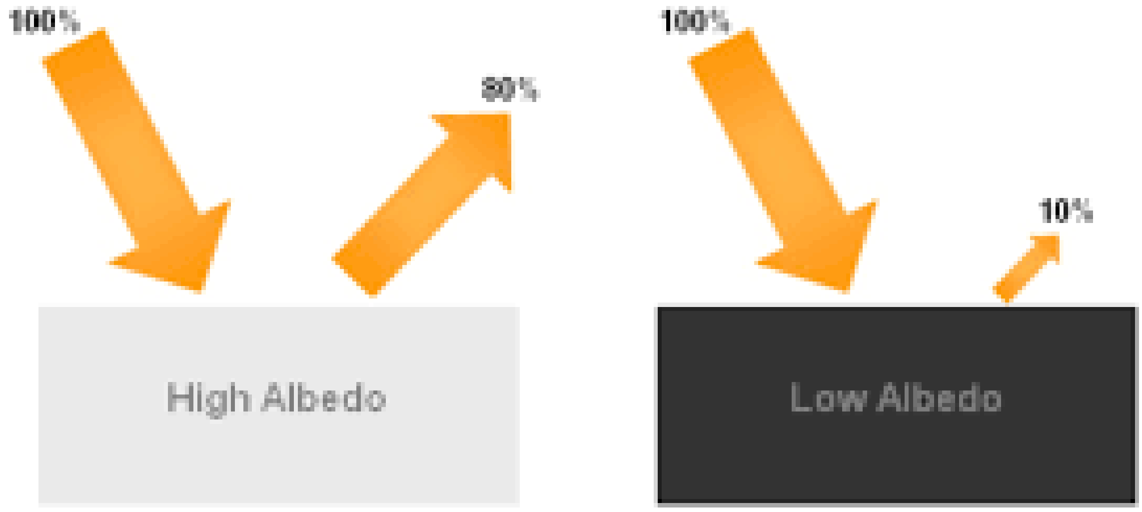
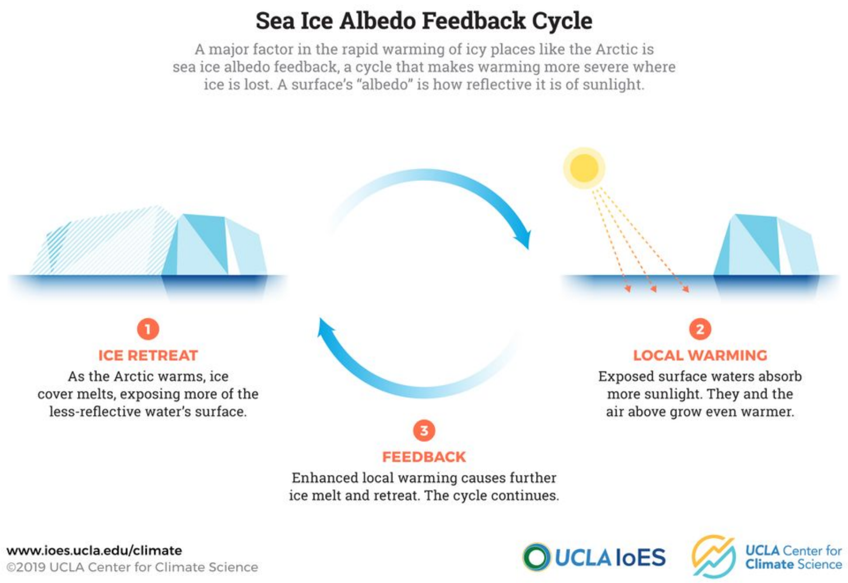


Figure A. A high albedo surface reflects 80% of incoming radiation. The low albedo surface reflects only 10% of incoming radiation.

a) Albedo et climate change

With the increase in temperature at the surface of the globe, the problem of the increase in albedo arises. In fact, the melting of the ice floes causes a decrease in the ice-covered and snow-covered surface of the planet and increase surfaces corresponding to bare soils or oceans, which have a lower albedo.

Therefore the Earth returns a smaller part of the solar energy received, which contributes to the increase in temperature in a feedback cycle:



b) To go further :

Exercise on the greenhouse effect and the albedo effect:

https://climacol.scenari-community.org/collesClimat_web/co/200527_Effet_Serre_Base.html

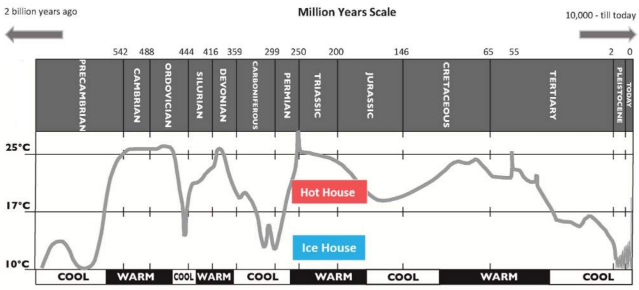
4. Climate on Earth and the anthropocene

Objectives

- Know how to describe the evolution of the climate on Earth
- Understanding the influence of humans on the climate

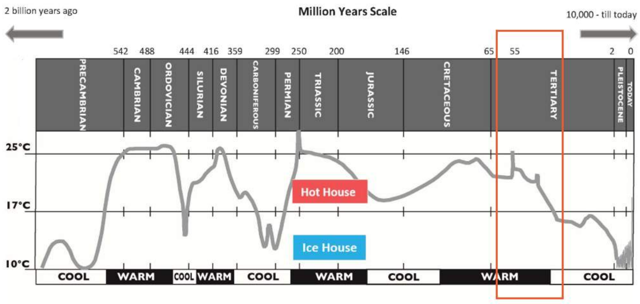
4.1. -2 billion years

Over the past 2 billion years, Earth's climate has alternated between "hot" periods and ice ages during which ice could cover the entire planet.



-55 million years

The last transition between these phases occurred around 55 million years ago when the temperature reached a thermal maximum followed by a long period of cooling, which we are now experiencing.



-500,000 to -100,000 years

500,000 to 100,000 years ago, a period of fluctuation between hot and cold temperatures occurred. Arctic ice samples show that over a period of several hundred thousand years, the large ice caps that covered parts of North America and Europe melted in a series of surges of temperature, each occurring approximately every 100,000 years.

-10,000 to today

The last 10,000 years are known as the Holocene. Sea level stabilized at its current level about 7,000 years ago. This period of stable temperatures allowed human civilization to develop.

Cause of climate change

The Earth's climate does not change without reason. Many factors can influence it over long periods of time. These factors are known as “climate forcings”. The 3 main climate forcing factors are: 1) solar variability, 2) volcanic activity and 3) changes in the carbon cycle

4.1.1. Human influence on the climate

Definition

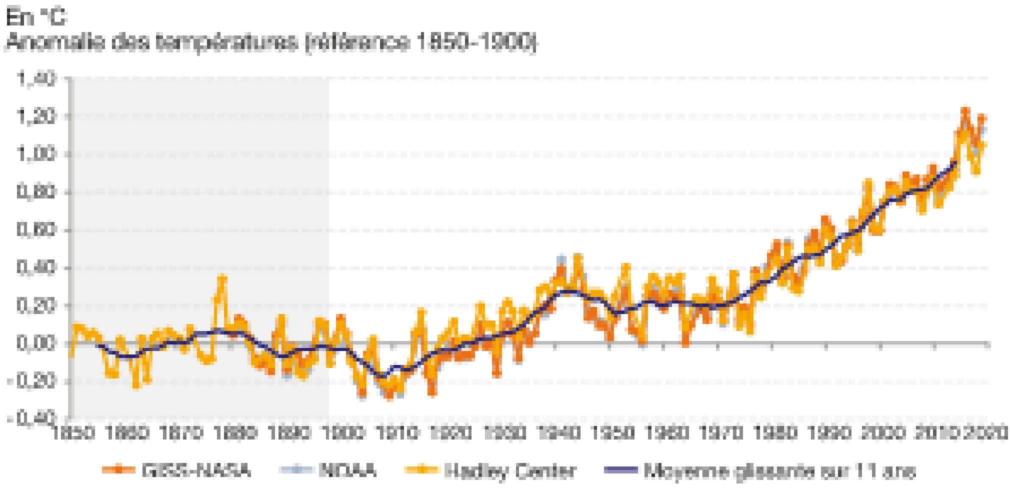
Anthropocene (“Human Age”): Geological period following the Holocene and characterizing all the geological events that have occurred since human activities have a significant global impact on the Earth's ecosystem.

Popularized at the end of the twentieth century Paul Josef Crutzen and Eugene Stoermer, it would have started according to them at the end of the eighteenth century with the industrial revolution.

Impact of human activities and carbon sinks

Almost all human activities emit GHGs. Whether it is for the production of heat, electricity or other energies, agriculture and animal husbandry, industry, buildings and transport, every major sector of the world economy contributes to CO2 emissions. Current CO2 emissions will have an impact on the temperature of the globe for more than a century. On the other hand, certain activities reduce the capacity of ecosystems to absorb these gases. Indeed, certain natural environments (forests, peat bogs, ocean) are called “carbon sinks” because of their ability to filter CO2 from the atmosphere and transform it into organic carbon. Their degradation (deforestation, urbanization, pollution, agriculture, etc.) thus considerably reduces the capacity of these environments to absorb CO2.

Evolution of the annual average temperature



WORLDWIDE ANNUAL AVERAGE TEMPERATURE EVOLUTION FROM 1850 TO 2019

Since the early 1980s, the global average temperature of land surface air and ocean surface water has warmed markedly.

The decade 2010-2019 (with a temperature 0.66 ° C above the 1961-1990 average) was 0.19 ° C warmer than the decade 2000-2009 (0.47 ° C above the 1961-1990 average). The last five years are the five warmest since 1850. The year 2016, with a temperature 0.86 ° C higher than the 1961-1990 average, ranks first among the warmest years since 1850, the year 2019 ranking second. Since the end of the 19th century, the global average temperature has increased by almost 1 ° C (2010-2019 ten-year average of 0.97 ° C).

source: NASA; NOAA; Hadley Center

https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/chiffres-cles-du-climat/1-observations-du-changement-climatique

5. Climate change indicators

Objectives

- Know the main indicators of climate change
- Follow a forward-looking approach on climate change
- Understand the consequences of climate change and mitigation and adaptation strategies

Introductory video on climate change indicators:

https://youtu.be/gcoTOCOrzCo

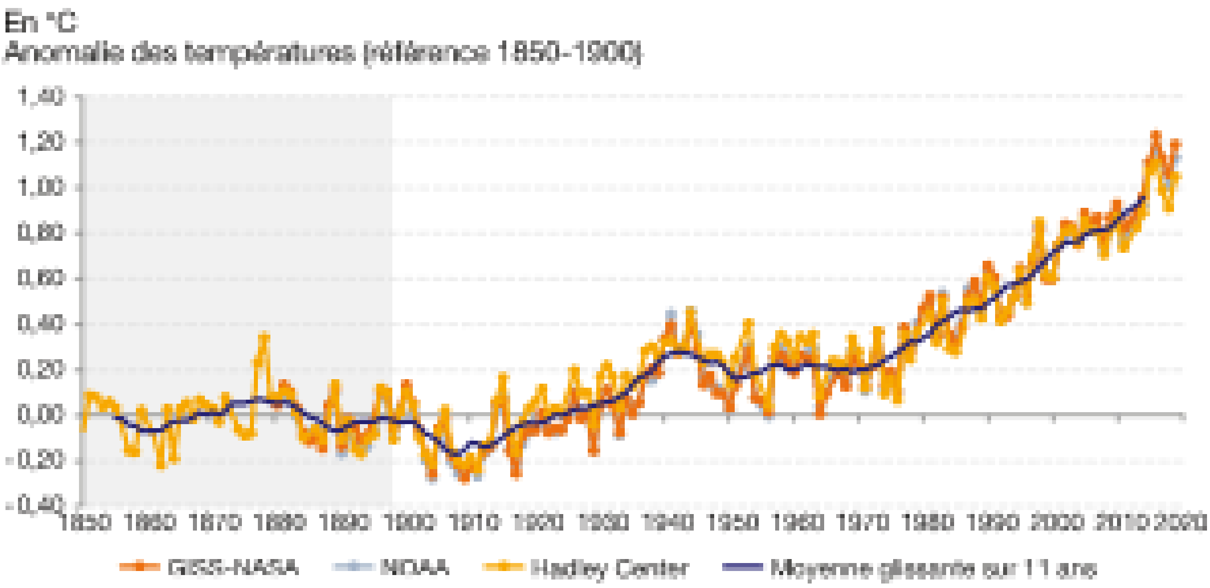
What are the main indicators of climate change?

What information they give us?

5.1. 1) First indicator: Earth temperature

Evolution of the annual average temperature

The warming since the mid-18th century is estimated to be around 1.1 degrees Celsius. The surface temperature has increased by 0.1 degrees Celsius every 5 to 6 years since the 1970s. 2015, 2016, 2017 and 2018 are the four hottest years on record.



Paris Agreement

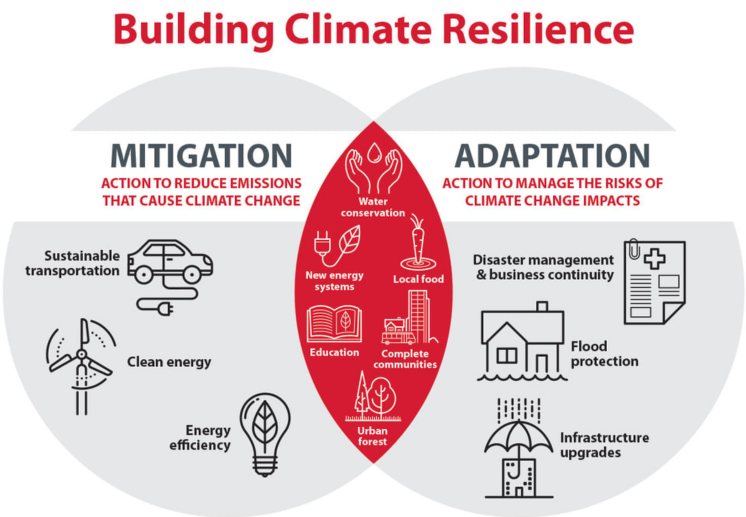
To limit the effects of climate change, the signatory countries of the United Nations Framework Convention on Climate Change (UNFCCC) have set themselves the objective in the 2015 Paris Agreement to "Contain the rise in the average temperature of the planet below 2 ° C compared to pre-industrial levels ".

Mitigation and adaptation:

In order to limit the temperature rise, a mitigation strategy has been adopted. It consists of slowing down the causes of climate change by limiting net greenhouse gas (GHG) emissions.

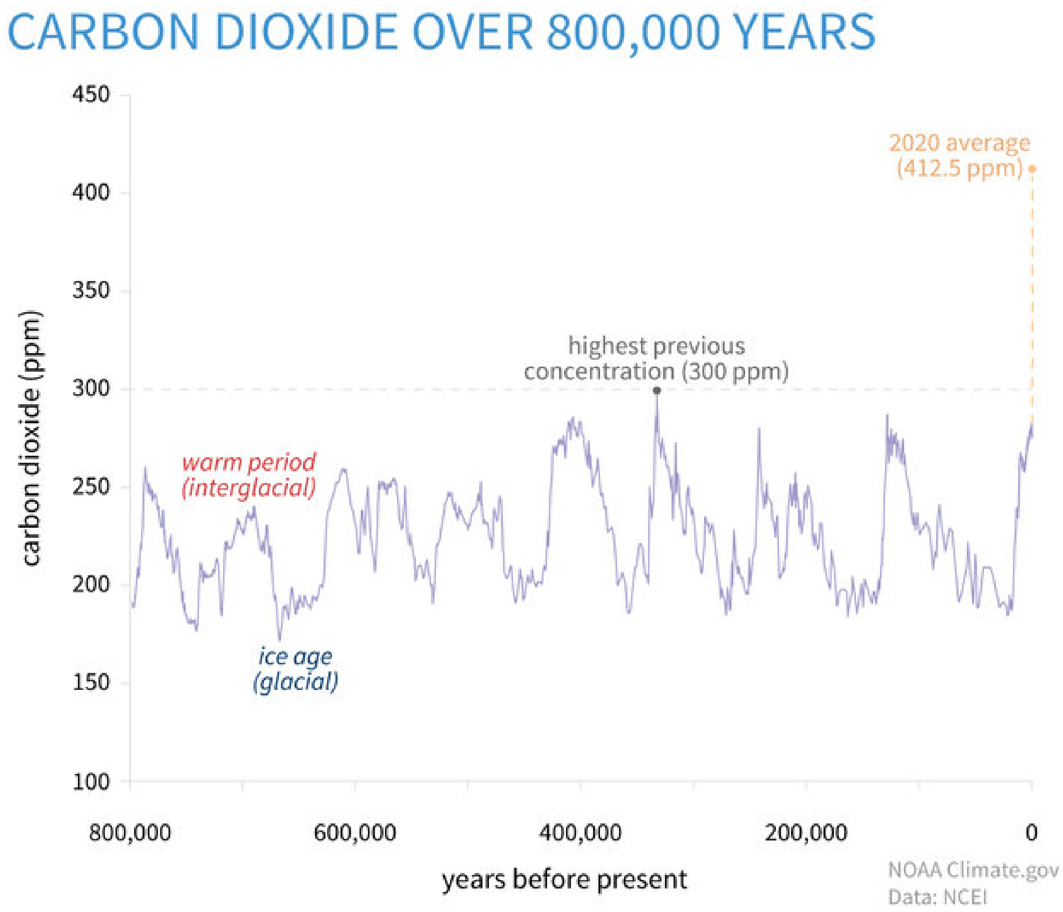
However, given the long lifespan of greenhouse gases accumulated in the atmosphere, the increase in temperatures by the end of the century is inevitable and all regions of the world are concerned. A climate change adaptation strategy is therefore necessary to limit its consequences on our environment.

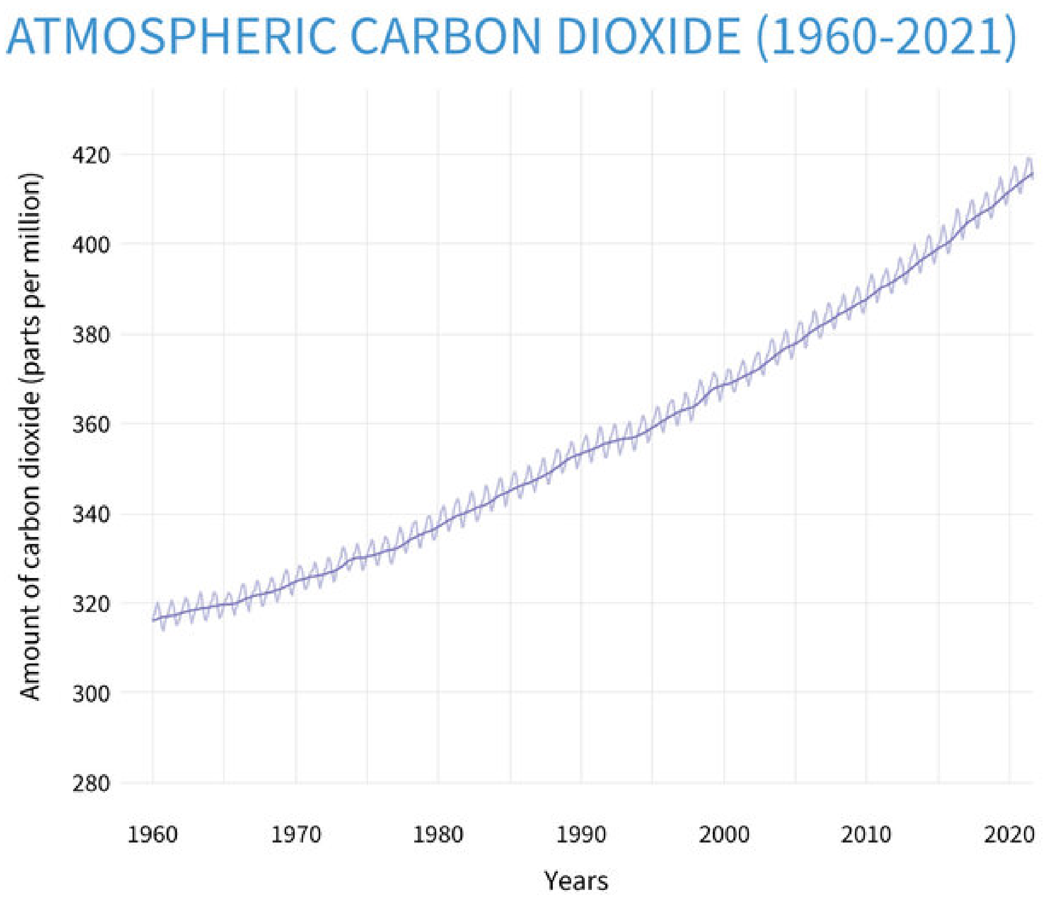
The objectives of adaptation are to anticipate the impacts of climate change and limit their possible damage by intervening on the factors that control their magnitude (for example, the urbanization of risk areas).



5.2. 2) Second indicator: CO_2 level in the atmosphere

Graph of the evolution of CO2 in the atmosphere





The concentration of CO2 in the atmosphere is a good indicator of climate change. It is evaluated in ppm CO2 (parts per million) which is the fraction equal to 10–6, ie one millionth. 1ppm of CO2 is equivalent to saying that there is 1 molecule of CO2 for 1 million molecules of other gases (= 1mg of CO2 / 1 kg of gas).

On the first graph, we see the evolution of the CO2 concentration over the last 800,000 years. From the beginning of human civilization (-3500) until 200 years, our atmosphere oscillated between 180 and 280ppm of CO2. This level allowed the maintenance of living conditions conducive to the development of our species. In order to contain the rise in temperatures to less than + 2 ° C, it is estimated that the safety level would be 350ppm of CO2 in the atmosphere.

The second graph shows the evolution of the CO2 concentration between 1960 and 2020. We then notice a very clear increase in the concentration in recent years with a rate of 320 ppm in 1960 which exceeds the threshold of 405 ppm in 2017.

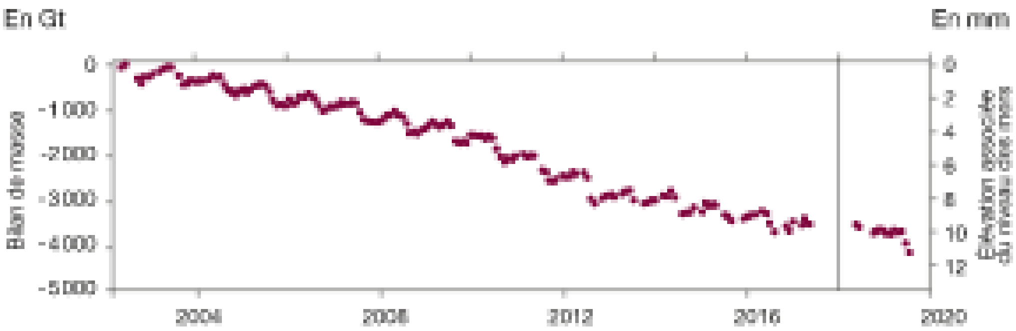
Global CO2 emissions per year now exceed 40 GtCO2 per year (41.5 GtCO2 in 2018).

5.3. 3) Other indicators of climate change

Ocean warming, melting ice and sea level

The oceans absorb 94% of the heat linked to the increase in CO2, causing the Arctic and Antarctic ice to melt and the sea level to rise.

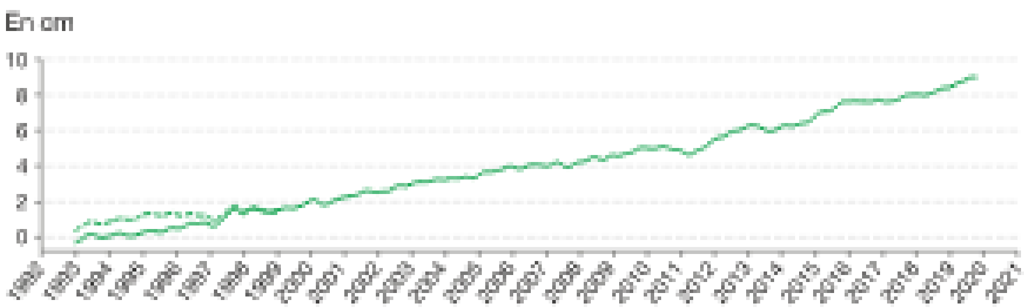
According to the IPCC, the rate of sea level rise has accelerated in recent decades to reach nearly 3.2mm per year over the period 1993-2010. This rise in the level of the oceans results in the retreat of the coastline and the disappearance of low-altitude island territories.



GREENLAND ICE MASS BALANCE FROM 2002 TO 2019

The polar regions are losing ice and this loss accelerated in the 2000s. Between 2002 and 2019, the mass of the Greenland ice sheet shrank by an average of 268 ± 11 gigatons per year (Gt / year) . During the unusually warm arctic summer of 2019, Greenland lost 600Gt of ice, equivalent to a sea level rise of 2.2mm.

source: GRACE, GRACE-FO. Processing: Danish Meteorological Institute, GEUS, DTU Space



EVOLUTION OF THE AVERAGE LEVEL OF THE GLOBE SEAS SINCE 1993:

The average sea level rose by 1.7 ± 0.3 mm / year over the period 1901-2010. The rate of sea level rise has accelerated in recent decades to reach 3.3 ± 0.4 mm / year over the period 1993-2019 (satellite measurements). About 30% of sea level rise is due to expansion caused by increasing water temperature.

Source: E.U. Copernicus Marine Service Information

Ocean acidity

The increased concentration of CO2 in the atmosphere also results in a higher concentration of CO2 in the ocean. As a result, seawater becomes acidic because on contact with water, CO2 turns into carbonic acid. From 1751 to 2004, the pH (potential hydrogen) of the surface waters of the oceans decreased from 8.25 to 8.14. This acidification represents a major risk for coral reefs and certain types of plankton threatening the balance of many ecosystems.

Create your own prospective scenario:

Interactive climate calculator developed for educational purposes by a team from Climate Interactive, MIT, Ventana Systems, UML Climate Change Initiative and Todd Fincannon:

https://www.climateinteractive.org/tools/c-roads/[1]

5.4. Other impacts of climate change

The IPCC also assesses how climate change will translate in the medium and long term. He plans :

Aggravated climatic phenomena: changes in the climate are modifying the frequency, intensity, geographical distribution and duration of extreme weather events (storms, floods, droughts).

A disruption of many ecosystems: with the extinction of 20 to 30% of animal and plant species and significant consequences for human settlements.

Crises linked to food resources: in many parts of the world (Asia, Africa, tropical and subtropical zones), agricultural production could fall, causing serious food crises, sources of conflict and migration.

Health dangers: climate change will likely have direct impacts on the functioning of ecosystems and on the transmission of animal diseases, which may present pathogenic elements that are potentially dangerous for humans.

Population displacements: the increase in sea level (26 to 98 cm by 2100, depending on the scenarios) should cause the flooding of certain coastal areas (in particular the deltas in Africa and Asia), or even disappearance entire island countries (Maldives, Tuvalu), causing significant migrations.

Source: https://www.ecologie.gouv.fr/comprendre-giec

5.5. Conclusion

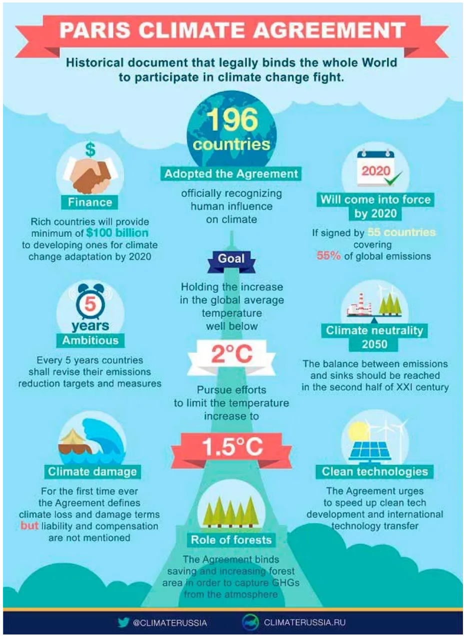
[1] https://croadsworldclimate.climateinteractive.org/

Since the 19th century, humans have dramatically increased the amount of greenhouse gases in the atmosphere. As a result, the natural climate balance is altered and the climate is readjusted by a warming of the earth's surface. We can already see the effects of climate change. This is why we must mobilize and act. Everyone is concerned: elected officials, economic players, citizens, to reduce our greenhouse gas emissions, but also to adapt to the changes already underway.

6. How to limit your carbon footprint?

Paris climate plan

To achieve carbon neutrality in 2050, an objective set by the Paris climate plan, every citizen has a duty to reduce their individual carbon footprint to 2 tonnes of CO2 equivalent per year. For an average French person, this amounts to dividing his energy consumption by 5. It is therefore difficult to know where to start. However, by knowing the main emitting stations and the effective actions to be implemented, reducing your carbon footprint is achievable!



6.1. Carbon footprint

What is the carbon footprint?

L'empreinte carbone correspond à l'ensemble des émissions de gaz à effet de serre induites par nos activités. Elle est calculée en tonnes équivalent CO_2 (tCO_2eq) par an. Cela englobe la production des biens que nous consommons et des aliments que nous mangeons ainsi que notre consommation d'énergie à la maison et celle utilisée lors de nos transport. L'empreinte carbone de Paris est de 22,7 millions de tCO_2eq par an, soit 10,3 tonnes par individu. Ce calcul comprend les émissions locales, produites directement sur le territoire (bâtiment, transport et industrie intra-muros…), et les émissions indirectes, générées à l'extérieur (transport hors Paris, importation de biens et services et d'aliments…).

How to calculate our carbon footprint?

The carbon footprint varies according to the lifestyle of each individual, as well as according to other parameters such as socio-professional category, family and geographic situation.

Some jobs will be the main ones for some, but negligible for others (transport for example). The levers to be activated will therefore not be the same for everyone.

Simulating your own carbon footprint is a good way to know where to start. The beta.gouv.fr team, funded by the Ecological Transition Agency (ADEME) and the Bilan Carbone Association (ABC), has developed the “Nos Gestes Climat” simulator, which allows you to calculate your carbon footprint and proposes actions to reduce it by quantifying their potential:

Calculate your carbon footprint:

https://nosgestesclimat.fr/

Transports

Transport is the main source of greenhouse gas emissions with 31% of emissions, ahead of housing, agriculture and industry. Among transport, the car represents more than half of emissions.

Indeed, the personal car is the main mode of transport for 72% of French people. However, a large part of those who use it consider that the journeys they make on a daily basis (less than 5km) could be made by bicycle. And 5 km by car is already more than 1 kg of CO2 emitted. Repeated twice a day and 5 times a week, this equates to more than a ton and a half of CO2 in a year.

The first thing to do in order to reduce your carbon footprint is therefore to favor soft mobility on a daily basis (walking, cycling, public transport). To a lesser extent, it is also preferable to adopt carpooling (80% of vehicles carry only one person). Adopting eco-driving also cuts fuel consumption by 15%.

Regarding the longest distances, the impact of the plane on the climate is 200 times greater than the TGV, if we take the example of a trip to France or a European destination. A Paris-New York return trip emits around 1.8 tonnes of CO2 equivalent, the annual individual quota to achieve the carbon neutrality. These trips must therefore remain rare, even if it means making them last longer, which invites you to think about your holidays differently.

ADEME's ECOLAB tool allows you to calculate the CO2 impact for each of your journeys:

https://monimpacttransport.fr/

6.1.1. Alimentation

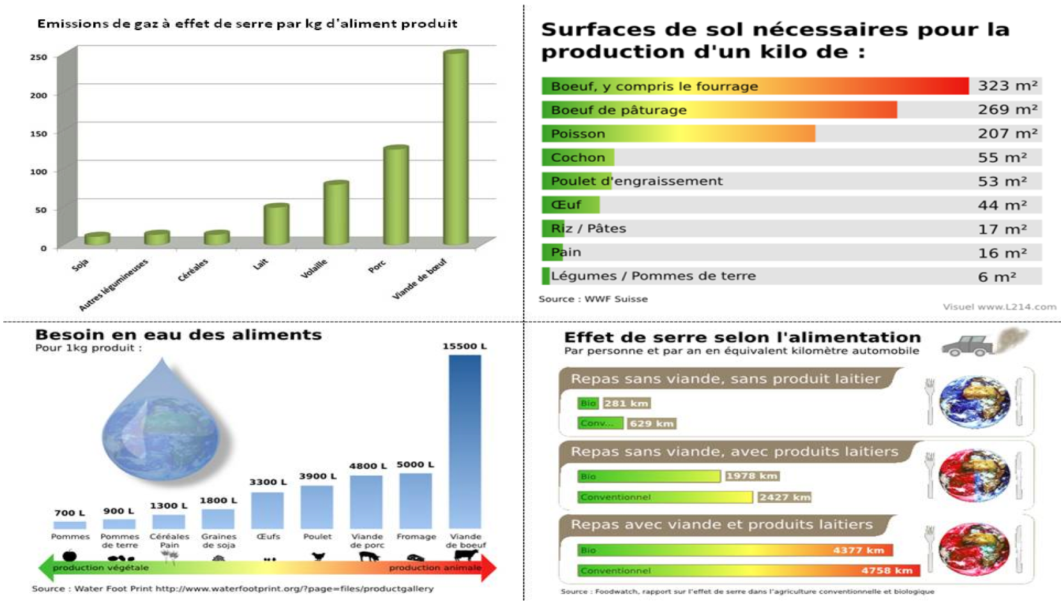
Red meat

Food is the second largest carbon footprint (17%). It is possible to reduce it considerably by changing your eating habits.

To adopt a low carbon diet, it is first necessary to limit your consumption of red meat.

Indeed, ruminants (such as beef and lamb) release methane, responsible for 45% of CO2 equivalent emissions from livestock in France. The carbon footprint of one kilo of beef is 6 times that of one kilo of chicken.

On the other hand, it takes on average 300m2 of fodder and cereals to produce 1kg of beef, this production consumes a lot of water and land, and contributes to deforestation and therefore to the decline of biodiversity.



Local products and waste

The second stage of the low carbon regime involves the consumption of local and seasonal products in order to avoid emissions linked to transport or grown in greenhouses. (The energy used for heating greenhouses is even higher than that of an imported seasonal product.)

To find out if your fruits and vegetables are in season, you can refer to the ADEME website:

https://mesfruitsetlegumesdesaison.fr/

Finally, it is necessary to reduce food waste (46 kg of food waste per year, including 13 kg of food still packaged).

6.1.2. Housing

Residential housing is responsible for 1.9 MtCO2eq per year and 35% of overall energy consumption.

Starting to reduce the carbon footprint of your home is possible thanks to eco-gestures. Heating is the main item to target because it represents on average 70% of the energy consumption of the home, far ahead of lighting. Lowering the heating temperature has a significant effect: 1 ° C less = 7% energy savings. Other actions can reduce the need for heating: install door strips, replace old convectors, equip windows with curtains ...

In summer, it's the same with air conditioning, which is very energy-intensive and heats up the urban heat island by exhausting the hot air outside. On the other hand, refrigerants are greenhouse gases which have a warming potential 4000 times greater than that of CO2. Mobile room air conditioners, which require an open window to pass a pipe through, are particularly harmful and should therefore be avoided.

Beyond temperature management, other energy savings can be made by saving domestic hot water (11% of energy consumption in the home), in particular by taking shorter showers.

For household appliances, preference should be given to second-hand or refurbished devices and pay attention to their lifespan.

Finally, energy savings can be achieved by opting for more sober electronic devices and not leaving unnecessary watches.

6.1.3. Consumer goods

Responsible consumption is based on the logic of the three "Rs":

- Reduce purchases: Buy only what is necessary and limit packaging by buying in bulk or making your own products and pay attention to the way goods are produced.
- Reuse : Give your belongings a second life by repairing them, using second-hand sales and purchases.
- Recycle or recover: The French throw on average nearly 500 kg of waste per year (PLPDMA de Paris, 2017) and 70% of this waste could be reduced, repaired, diverted to reuse or be recovered.

6.1.4. To go further :

Test your knowledge of the energy consumption of different electrical devices thanks to the game La Révolt: http://la-revolt.org

7. Planetary boundary 2: Biodiversity and conservation issues

Objectives

Understand the issues linked to the erosion of biodiversity and what are the means implemented to preserve it.

7.1. Introduction

What is biodiversity ?

Biodiversity is the contraction of the words “diversity” and “biological”.

It therefore designates both all living beings as well as the diversity of the natural environments in which they live (= ecosystems).

The animal and plant biodiversity of an ecosystem therefore corresponds to the diversity of species present in this environment.

The biodiversity of ecosystems is the diversity of natural environments (forest, meadows, deserts, etc.).

7.1.1. Why preserve biodiversity?

3 fundamental reasons

- For its intrinsic value (it participates in the evolutionary history created more than 2 billion years ago)
- For its evolutionary potential, it has the ability to adapt to current global changes.
- For functionalities linked to ecosystems essential to human societies, also called ecosystem services. Indeed, the proper functioning of ecosystems depends on maintaining biodiversity.

7.1.2. What part of the biodiversity do we want to preserve?

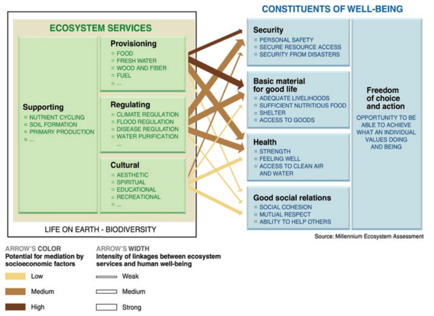
- Threatened Species: Conservation ecology and restoration (eg creation of protected areas) are used to protect rare or endangered species.
- Ordinary biodiversity: the one that surrounds us (present in 80% of ecosystems)
- The genetic diversity of domesticated species

7.1.3. Biodiversity and ecosystem services

Ecosystem service: Service that ecosystems (and biodiversity) provide to humans.

Biodiversity and the ecosystems in which it is expressed provide many of the goods and services that support human life: food, fuel and building materials; purification of air and water; stabilization and moderation of the planet's climate; moderation of floods, droughts, temperature extremes and wind forces; the generation and renewal of soil fertility; the maintenance of genetic resources that contribute to crop variety and the selection of animals, medicines, and other products; and cultural, recreational and aesthetic benefits.

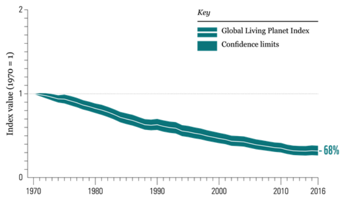
The Millennium Ecosystem Assessment carried out in 2005 standardized this notion of ecosystem service and defined 24 main social and environmental issues.

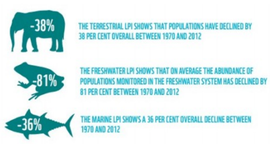


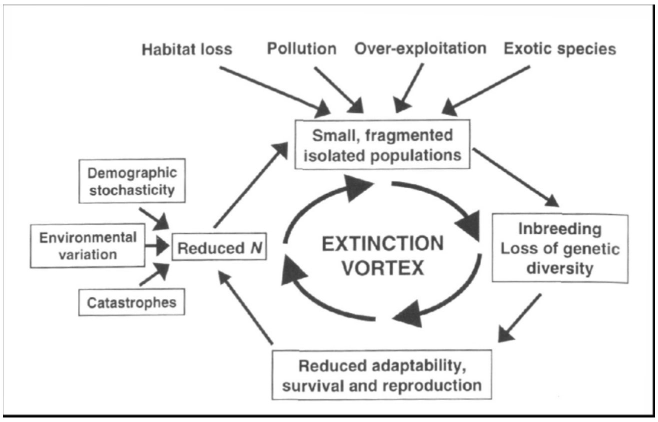
7.2. Biodiversity preservation issues

General finding

- Biodiversity is deteriorating around the world, in fact 75% of terrestrial environments and 40% of marine ecosystems are severely degraded: this is the alarming observation shared by international experts. One million species are threatened with extinction around the world. The rate of disappearance is 100 to 1000 times greater than the natural rate of extinction: we are talking about a sixth mass extinction of species. This degradation of biodiversity is largely the consequence of our human activities, which exert major pressures on nature.
- WWF and the London Zoologic Society have produced a Living Planet Index. This index is based on the study of 10,000 populations of 3,000 vertebrate species distributed around the world. This index shows that the average abundance of these populations has declined by 68% since 1970. This leads to the so-called extinction vortex (see figure 3).
- Natural environments are also weakened: more than 35% of coastal and continental wetlands have disappeared since 1970 in the world and tropical forests could disappear within 50 to 70 years at the current rate of deforestation.







7.2.1. The causes of the biodiversity erosion

Certain natural causes may explain the disappearance of species or natural environments, but the current rate of erosion is largely attributable to human activities:

- The transformation of habitats: Some natural habitats rich in biodiversity are artificialized. For example the transformation of forests into agricultural ecosystems. The destruction and fragmentation of the related natural environments is due in particular to urbanization and the development of transport infrastructure;
- Overexploitation of wild species: overfishing, deforestation, poaching, etc. ;
- Eco-toxicity: pollution of water, soil and air by pesticides or other toxic products for the environment;
- Biological invasion: This is the introduction of invasive alien species supplanting native species.
- Climate change which can add to and worsen other causes. It helps to modify the living conditions of species, forcing them to migrate or to adapt their way of life;

Measures taken against these threats:

- Measures against habitat transformation: Ecological Compensation. Each time a human infrastructure is put in place, it will be necessary to either avoid the destruction of natural environments or to compensate for the impact by restoring other ecosystems.
- Solve the problem of open access: There is no restriction on access to common resources, so the solution would be to regulate access to common resources.
- Evaluate the toxicity of products using participatory science: observers will assess the state of biodiversity in all areas in order to understand the impact of a given product on a given environment by comparing it to other environments in which it is product is not present.
- Nature-based solutions: Managing ecosystems through biodiversity, for example by reintroducing species that regulate the environment.
- Payments for services rendered to nature: remunerate farmers to maintain the functionality of ecosystems (by limiting the use of pesticides and intensive agriculture in favor of more sustainable and environmentally friendly methods).

7.3. Link between climate and biodiversity

Biodiversity plays a fundamental role in regulating the climate. Indeed, forests, wetlands and oceans have the ability to store atmospheric carbon, and thus help to mitigate global warming. On the other hand, it also helps to mitigate the effects of global changes, for example by protecting the coastline from erosion or by reducing the intensity of floods and floods.

Conversely, current climate change is modifying the interactions between species and their living environments in ecosystems. For a global warming of 2 to 3 ° C, experts predict an increase in the risk of disappearance for 20 to 30% of animal and plant species.

7.3.1. Examples of climate impacts on biodiversity

The rise in temperatures reduces climatic harshness, lengthens the vegetation periods and modifies the behavior of migrants populations. For example, the flowering and harvest dates for fruit trees and vines are advanced which can disrupt the synchronizations between the reproductive period of species and the seasonal development of the plants on which they feed.

Rising water temperatures are changing the distribution of fish populations.

Ocean acidification, linked to the absorption of atmospheric carbon, is damaging to the construction and survival of coral reefs, as well as to all marine organisms with calcareous shells.

7.4. Conservation of biodiversity in France

Issues related to agriculture

Ecosystems provide two types of services related to agriculture:

- Provisioning services: production of food and other goods.
- Regulation services: Pollination is a central mechanism in the regulation of crops, in fact 90% of plant species are pollinated. The disappearance of pollinating insects thus leads to the disappearance of a large number of plant species and presents a major stake for agriculture. Another example is biological control: birds, bats (bats) and parasitic insects are carnivorous species which allow the regulation of pest species in crops.

In recent decades, the improvement of supply services (intensive production) has led to a degradation of regulatory services (disappearance of key species). However, if the degradation of regulatory services in turn leads to the degradation of supply services. One solution would therefore be to moderate agricultural production in order to ensure the proper functioning of ecosystem services in the long term.

7.4.1. Biodiversity plan

Announced in 2018, the Biodiversity Plan is oriented around five main issues to preserve environments, protect ecosystems and endangered species, allow the transition of production and consumption models, take into account the link between health and the environment and preserve the sea. and the coastline.

Find out more: ecologie.gouv.fr/plan-biodiversite[1]

[1] https://www.ecologie.gouv.fr/plan-biodiversite

a) National strategy for protected areas

Adopted in January 2021, this national strategy for protected areas 2030 aims to protect, from 2022, 30% of the national territory and maritime areas, of which a third under strong protection.

Find out more : ecologie.gouv.fr/aires-protegees-en-france[1]

i) SNDI

Launched in 2018, the National Strategy to Combat Imported Deforestation (SNDI) aims to put an end by 2030 to deforestation caused by French imports of unsustainable forest or agricultural products such as soybeans, palm oil, beef, cocoa, rubber and wood.

[1] https://www.ecologie.gouv.fr/aires-protegees-en-france

8. Species preservation strategy and indicators

8.1. Preservation of threatened populations

Population evolution monitoring

In order to improve the viability of an animal population, it is first necessary to have a good understanding of the ecology (the life cycle) of the specie. To do this, these populations are monitored and the demographic analysis of the populations is realized. This monitoring then makes it possible to model the evolution of the population as well as its probability of extinction.

State of conservation assessment

The second step is the assessment of the conservation status of the population and the development of diagnostics on the cause of its decline. It is thus possible to prescribe management measures and define indicators of success for the preservation of the species.

IUCN

The International Union for the Conservation of Nature (IUCN) monitors the state of the world's biodiversity, with the Global Red List of Threatened Species. In 2021, out of the 134,425 species studied in this list, 37,480 are classified as threatened, including 41% of amphibians, 14% of birds and 26% of mammals, or 34% of conifers.

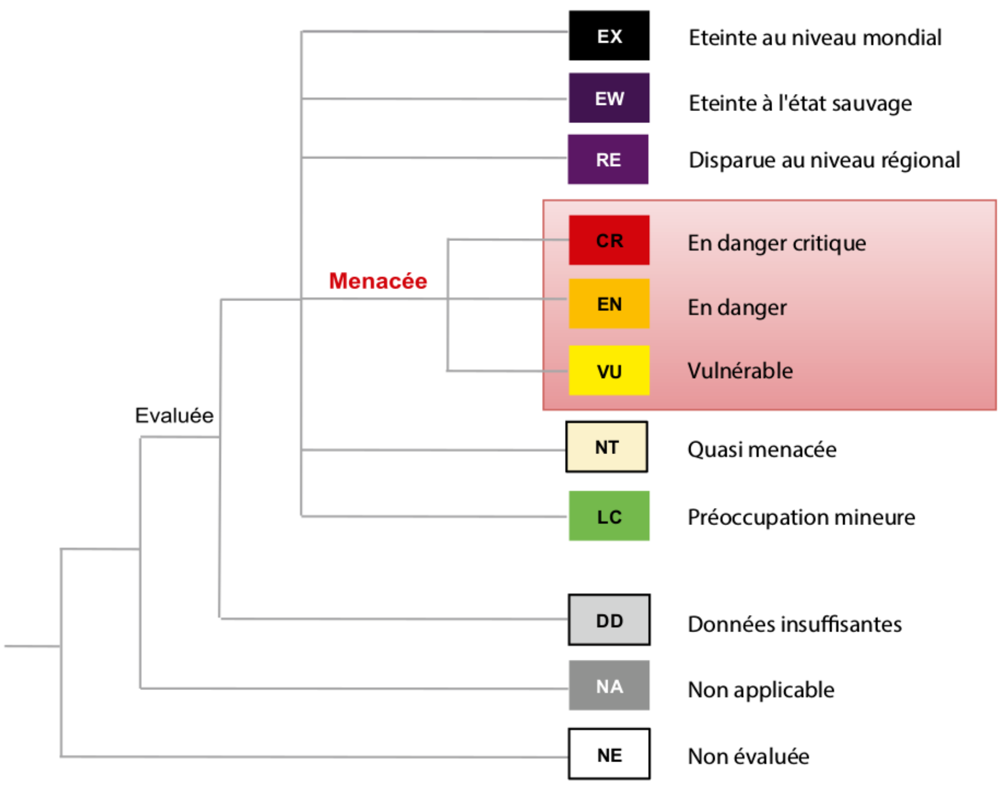


Figure 1. *Présentation des catégories de l'UICN utilisées à une échelle régionale (d'après le Guide 2012 et le Guide régional 2012 de l'UICN)*

With the IUCN Red List system, each species or subspecies can be classified into one of nine categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), Not Assessed (NE).

The classification of a species or a subspecies in one of the three categories of endangered species (CR, EN or VU) is carried out through a series of five quantitative criteria.

These criteria are based on various biological factors associated with the risk of extinction: population size, rate of decline, geographic range, degree of settlement and distribution fragmentation.

8.2. Preservation strategies

- Protection of species thanks to terrestrial and marine protected areas (represent 13% of emerged lands). However, the creation of these spaces sometimes generates conflicts with the development of certain human activities.
- Regulation of the exploitation of certain species thanks to international conventions such as: The Washington CITES convention which regulates the trade of a large number of animal and plant species. The International Whaling Commission. The Bern Convention which defines the list of protected species. These laws also clash with cultural, social and economic interests (poaching, illegal trade, etc.).
- “Ex situ” conservation of the most endangered species by placing them outside their natural habitat in zoological parks or botanical gardens. However, this approach includes several constraints such as the loss of genetic diversity linked to the small numbers or the habituation of species to captivity posing a problem for the long-term maintenance of these populations.
- Restoration of the population thanks to the recesses of existing populations or the reintroduction of extinct species into an environment. The main constraint of these actions is the length of time required for them to be carried out.

8.3. Preservation of ordinary biodiversity:

Définition

Ordinary species: Species neither threatened, nor domesticated, nor exploited representing 80% of the species in the world.

Report

- Concerning birds: Thanks to the temporal monitoring of common birds (STOC) carried out by ornithologists, we have been able to describe the dynamics of the 125 most common bird species in France for 25 years. We note that the populations of birds located in agricultural areas are in decline compared to all species.
- Concerning insects: 40% to 50% of insect species are in decline
- Food chains (or trophic networks) are disturbed both in terrestrial and aquatic environments, secondary consumers (carnivores) are the most affected

- We observe a shift from oligotrophic aquatic environments (rich in oxygen, with clear water) with ordinary high biodiversity (fish, crustaceans, etc.) towards eutrophic environments (poor in oxygen) colonized by algae and sometimes phytotoxic microorganisms.
- Change in species phenology: modification of the period of reproduction, migration and behavior of species due to climate change.

Why preserve ordinary biodiversity?

- Intrinsic Value of Ordinary Biodiversity: Although these animal and plant populations are not threatened with extinction, they have significant ecological value.
- These species constitute the habitat of threatened species: the gradual decrease in ordinary biodiversity modifies food webs and thus accelerates that of threatened species.
- These species constitute the living environment of humans, our environment is therefore deteriorating with the disappearance of ordinary biodiversity.
- For their evolutionary potential.
- These species are essential for the functioning of ecosystems.

8.4. Biomonitoring of natural environments

Définition

Biomonitoring (or biomonitoring): The use of organisms reactive to a pollutant (also called bio-indicators) to monitor the quality of an environment.

Les bio-indicateurs peuvent être de différente nature (insectes, plantes, humains...) et sont donc utilisés pour surveiller l'évolution (modifications, altérations) ou la stabilité de la qualité d'un milieu.

Example of bio-indicators

- Lichens: they react very strongly to pollution (well before plants and animals and before the stones of monuments are degraded. Each species of lichen resists a specific rate of pollution. Their observation thus makes it possible to follow the evolution of some pollution over time.
- Bees: it is a good witness of the overall environmental quality. They make it possible, for example, to characterize the level of contamination of the environment by xenobiotics or heavy metals.
- Clovers: it quantifies the ozone content in the air.

9. Planetary boundary 3: Disruption of biogeochemical cycles

Objectives

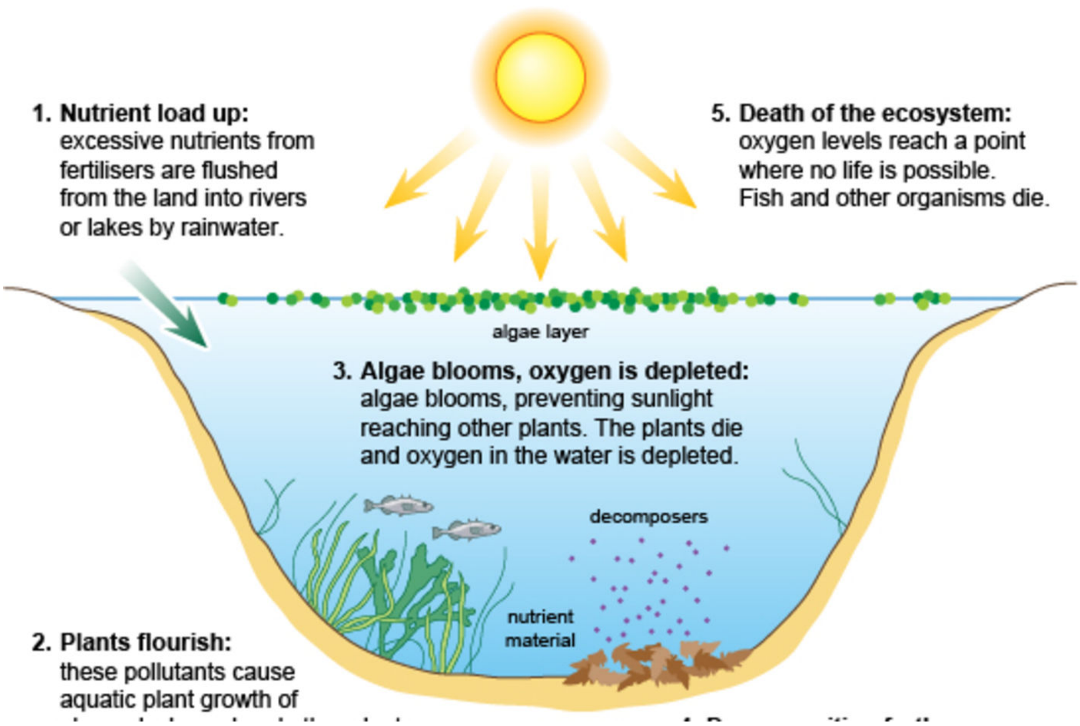
Understand the functioning of nitrogen and phosphorus cycles and the impacts associated with their disruption.

Introduction

Nitrogen and phosphorus are essential elements for life. As a result of human activities, their biogeochemical cycle is disrupted, which can cause heavy damage to the environment (anoxia of the oceans, eutrophication of continental freshwater, proliferation of green algae, etc.). The damage caused by nitrogen and phosphorus are generally seen as regional rather than global problems. However, as part of the work on the nine planetary boundaries, an overall threshold was defined for each of the two biogeochemical cycles of nitrogen and phosphorus.

Définition Eutrofication

Eutrophication: Process by which nutrients accumulate in an environment and alter its quality.



9.1. About nitrogen cycle

Nitrogen is an essential nutrient for plant growth. Reactive nitrogen, emitted in abundance in the environment, can however constitute a surplus compared to the needs of the plants. It then contributes to the pollution of water by nitrates. Associated with other nutrients such as phosphate, and depending on particular physicochemical conditions, it is responsible for the phenomenon of eutrophication. The main sources of nitrogen emissions into the environment are nitrogen fertilizers and the combustion of fossil resources and industrial processes. Nitrogen from polluting emissions of nitrogen oxides (NOx) to the atmosphere from transport and industry is not included in the global limit.

The challenge is to prevent an excessive release of reactive nitrogen into water and natural aquatic environments in order to prevent their eutrophication. The threshold not to be exceeded has been set between 62 and 82 million tonnes (Mt) per year, i.e. 41 to 55 kg of excess nitrogen (surplus) per hectare per year (kg / ha / year) on average at the global scale. In 2015, nitrogen losses to the environment are estimated at 150 Mt.

9.2. About phosphorus cycle

Like nitrogen, phosphorus is also an essential nutrient for plant growth. The modification of its biogeochemical cycle, caused by agriculture (fertilizers, livestock manure) and urban wastewater (excrement and detergents), affects the ability of the biosphere to sequester it and leads to eutrophication of fresh water.

The challenge initially envisaged was to prevent a major ocean anoxic event from occurring (an episode of strong reduction of oxygen in the oceans) with impacts on marine ecosystems. During the revision of the conceptual model in 2015, a two-level geographic approach is proposed.

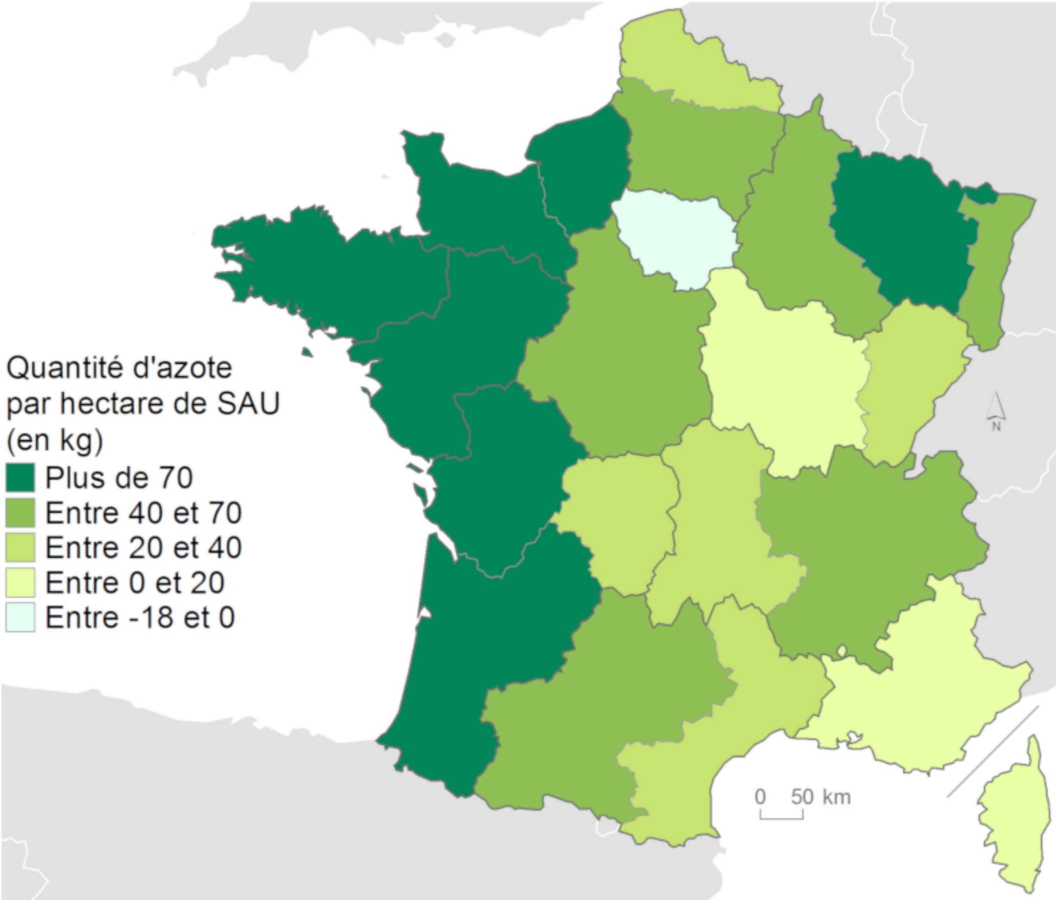
Globally (asphyxiation of the oceans), the threshold is estimated at 11 Mt per year of phosphorus released into water (agricultural surplus and insufficiently purified wastewater). In 2015, it was exceeded with 22 Mt of phosphorus actually released into the water.

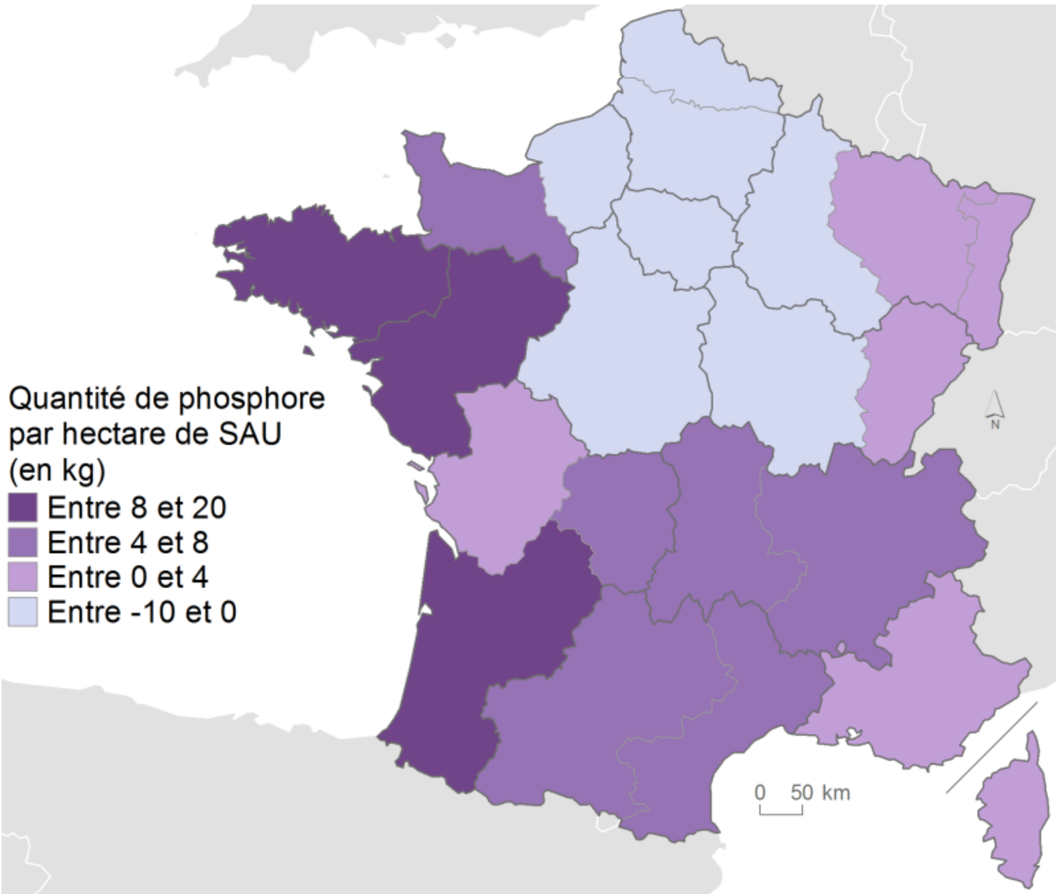
At a more localized level, an additional threshold is defined to address eutrophication of inland freshwater. This threshold relates to the phosphorus surplus resulting from excessive inputs during the fertilization of agricultural soils. These phosphorus surpluses must not exceed, each year, a range of between 6.2 and 11.2 Mt (i.e. 4.1 to 7.5 kg / ha / year) to avoid Eutrophication of water systems. pure water. In 2015, the limit was crossed with around 14 Mt.

9.3. Situation in France

In France, the excessive supply of nitrogen and phosphorus, mainly from agricultural activity for the first, and from urban wastewater for the second, corresponds to the surplus in the environment, to discharges at sea and in fresh water, which can lead locally to eutrophication phenomena and the proliferation of green algae. Surpluses are calculated on a regional scale without taking into account treatments and exports to other regions, if any, particularly in the breeding regions. The nitrogen and phosphorus surplus tends to decrease in metropolitan France between 2000 and 2015

Quantity of nitrogen and phosphorus per usable agricultural area in France

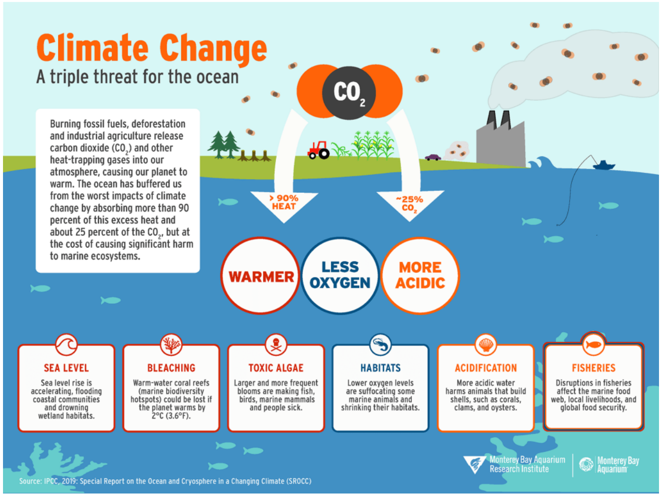




10. Planetary boundary 4: Ocean Acidification

Introduction

A large part of the carbon dioxide (CO2) emissions released by human activities is absorbed by the oceans, just like other natural carbon reservoirs such as forests, which are referred to as “carbon sinks”. ". This CO2 retention capacity plays a fundamental role in climate regulation. The very significant increase in CO2 of anthropogenic origin results in the acidification of the oceans and is at the origin of a very significant loss of marine biodiversity due to the degradation of coral reefs.



10.1. Issues related to ocean acidification

A quarter of CO2 is absorbed by the ocean through dissolution or photosynthesis. The dissolved CO2 is transformed into carbonic acid and releases H + ions responsible for the acidification of the oceans. The drop in pH affects the ability of phytoplankton to grow and renew itself. Phytoplankton is the primary producer of oxygen on Earth. It is at the base of the food chain for all living things in the oceans. Its disappearance therefore leads to a great loss of marine biodiversity.

Like plankton, coral has difficulty developing in an acidic environment. Their degradation also leads to the decline of a very rich biodiversity.

The reefs also guarantee coastal human communities many services (protection of the coast against storms, underwater tourism and recreation, food supply, water purification, etc.) and contribute to local development. Conversely, other environmental impacts resulting from human activities on the coast (overfishing, land pollution, urban development along the coasts, etc.) combine with the acidification of the oceans and the rise in sea level. sea to weaken coral reefs.

The disappearance of coral reefs in favor of more banal ecosystems dominated by algae is a marker of the vitality of the oceans and their ability to continue to function as carbon sinks.

https://ree.developpement-durable.gouv.fr/

10.1.1. Stakes for 2100

The future state of the oceans will depend on how much CO2 is emitted into the atmosphere in the coming decades. According to the IPCC, 4 scenarios are possible depending on the evolution profile of greenhouse gas (GHG) emissions.

The most optimistic RCP2.6 trajectory predicts a sharp reduction in GHG emissions with a peak before 2050 (this trajectory is compatible with a maximum warming of 2 ° C by 2100). The most pessimistic RCP8.5 scenario predicts an increase in emissions at the current rate leading to a probable warming of 4 ° C in 2100.

In the case of RCP2.6, the surface water temperature and pH could increase by 0.71 ° and 0.07 pH units, respectively. In the case of RCP8.5, they would increase by 2.73 ° and 0.33 pH units (an increase in acidity of 170% compared to 1850).

https://ree.developpement-durable.gouv.fr/themes/defis-environnementaux/limites-planetaires/les-9-limites-ecologiques-de-la-planete/article/acidification-des-oceans

a) Situation in France

The issue of ocean acidification is important for France because the country has more than 11 million km2 of exclusive maritime economic zones and represents about 20% of the atolls and 10% of all the reefs on the planet over a linear distance of more than 5000 km.

In the Mediterranean, over the period 2007-2015, the temperature of surface water increased by 0.7 ° C. The pH decreased by 0.003 units per year, an increase in acidity of almost 7%, which corresponds to one of the highest acidification rates recorded to date (Kapsenberg et al., 2017)

10.1.2. Impacts of ocean acidification on biodiversity

The decrease in pH has a strong impact on marine biodiversity. The health and ecology of species (birth rate, reproduction, species behavior, etc.) depend on the quality of the water. According to the ANR Gigassat project, the decrease in pH would alter the ability of oysters to resist disease and the reproductive cycle of fish.

Acidification is also one of the causes of the disappearance of coral reefs (29% decrease in the living coral cover of the stations monitored in the French overseas territories).

11. Planetary boundary 5: Land use change

Introduction

The intensification of agricultural areas and urban sprawl lead to the deforestation of forest areas. Over the past fifty years, the transformation of natural and semi-natural environments (forests, meadows and other ecosystems) into agricultural land has increased by an average of 0.8% per year (Rockström et al., 2009). This has the following consequences: loss of biodiversity and ecosystem services, soil erosion, risk of flooding and mudflows, increased greenhouse gas emissions, carbon de-stocking ...

11.1. Issues of land use change

The "land use change" limit is understood in terms of the percentage of the total land area converted to agricultural land. The threshold not to be exceeded is set at 15% of agricultural land. In 2009, around 12% of the world's land surface was cultivated.

Two indicators are defined within the framework of this planetary limit:

The first concerns, at the global level, the area forested in relation to the area covered by forest before human intervention, ensuring that at least 75% of the land once forest remains forested. In 2015, only 62% of previously forested land was forested, so the limit was exceeded. This reduces the Earth's ability to serve as a carbon sink.

The second concerns the area of the three main forest biomes (tropical, temperate and boreal forests) with regard to the potential forest cover. Among forest biomes, tropical forests converted to non-forest systems, have significant effects on climate (evapotranspiration), while boreal forests affect soil albedo (reflective power of a surface) and therefore the exchange of regional energy. The limit, at the biome level for these two forest types, was set at 85% of the potential forest cover. It was set at 50% for temperate forests, as changes would have a lower impact.

11.2. Situation in France

Contrary to the global situation, agricultural land is declining there, in particular under the effect of the artificialization of soils. However, given its high level of consumption, associated with population growth, and the insufficiency of raw materials on the national territory, France imports significant quantities of agricultural and forestry raw materials from the deforestation of tropical forests. It thus indirectly uses land located in other regions of the world, and contributes to exerting strong pressure on foreign land resources: consumption of resources, disappearance of natural habitats.

According to WWF, France imports and consumes large quantities of agricultural and forestry raw materials from tropical forest deforestation: soybeans (4.8 million tonnes), palm oil (970 kilotons), cocoa (460 kilotons) . France's ecological footprint linked to these imports represents 14.8 million hectares, or more than a quarter of the metropolitan area and half of the French agricultural area. About 5.1 Mha are in countries with a high risk of deforestation (Argentina, Brazil, China, Ivory Coast, Indonesia, etc.).

11.3. Impact of land use change

Forests are home to a great diversity of species and help mitigate climate change by storing large amounts of carbon. Their role is central in adapting to climate change, protecting soil and providing fresh water. Thus, deforestation has a strong influence on the environment: disappearance of natural habitats, loss of biodiversity and ecosystem services, increase in the intensity and frequency of weather extremes amplifying climate disasters, decrease in water resources, increase in greenhouse gas emissions responsible for global warming.

12. Planetary boundary 6: Global Water Use

Introduction

Fresh water is a natural resource essential for human activities. The current freshwater use planetary boundary has been set at 4,000 km^3/year blue water consumption, the lower limit of a 4,000–6,000 km^3/year range that is considered a danger zone. Each year, about 3,800 km3 of fresh water are consumed per year in the world. This water is very unevenly distributed on the planet. The volume of renewable fresh water available annually per inhabitant ranges from less than 100 m3 in the Arabian Peninsula, to more than 30,000 m3 in Northern Europe. During the 20th century, water withdrawals have increased twice as fast as the size of the population. This strong increase concerns in particular agriculture which still takes 70% of the total volume (FAO, 2016). Despite a slowdown since the 1990s, water withdrawals should continue to grow by 1% per year by 2050, driven in particular by the increase in industrial uses and the cooling needs of power plants (UN, 2015) .

12.1. Issues related to the consumption of water

Human activities disrupt the hydrological cycle and alter the available freshwater resource. For example, withdrawing more water than its natural renewal allows risks drying up or salinizing groundwater tables (Dalin et al., 2017), rivers or the disappearance of lakes and wetlands. Human activities are the source of polluting emissions, which are even more concentrated during the event of water resources reduction. Finally, climate change should lead to a decrease in the volumes of fresh water renewed annually in certain regions of the world, in particular the Mediterranean rim, southern Africa, part of North America and Central America (Milly, 2005).

The challenge is therefore to have enough good quality water for all uses, leaving some for the proper functioning of natural ecosystems, on which human activities also depend. Limit values for the use of fresh water not to be exceeded have been defined on a planetary scale and on the scale of the watersheds. They represent the part of the renewable water resource that human activities can use without compromising ecosystems in the long term. Globally, this share is estimated at 4000 km3 of fresh water consumed per year (Rockström et al., 2009).

12.2. Water resource exploitation index (WEI +)

The water resource exploitation index (WEI +) is defined by the AEE as the share of water consumed in relation to the renewable water resource, over a period and a given geographical area (ETC / ICM, 2016). It varies according to the year, the season and the level of water demand linked to human activities. In watersheds modified by humans, the renewable water resource is renaturalized by adding the volume of water consumed to the volume flowing into the rivers. The flows considered in this document take into account the inflow of water reservoirs into the rivers. The volumes transferred artificially from another sub-basin are not identified.

12.3. Water footprint

The water footprint is a measure of humanity's appropriation of fresh water in volumes of water consumed and/or polluted. There are 3 different kind of water footprint:

- **Green water footprint** is water from precipitation that is stored in the root zone of the soil and evaporated, transpired or incorporated by plants. It is particularly relevant for agricultural, horticultural and forestry products.
- **Blue water footprint** is water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product or taken from one body of water and returned to another, or returned at a different time. Irrigated agriculture, industry and domestic water use can each have a blue water footprint.
- **Grey water footprint** is the amount of fresh water required to assimilate pollutants to meet specific water quality standards. The grey water footprint considers point-source pollution discharged to a freshwater resource directly through a pipe or indirectly through runoff or leaching from the soil, impervious surfaces, or other diffuse sources.

To go further:

About water footprint: https://youtu.be/b1f-G6v3voA

13. Planetary boundary 7: Stratospheric ozone depletion

Introduction

Stratospheric ozone refers to the layer of the atmosphere between 20 and 50 km altitude. By filtering out a large part of the solar ultraviolet (UV) radiation, mainly UVC and UVB rays, this layer protects living beings, overexposure to UV rays that can have harmful effects on human health (cataracts, skin cancer, weakening of the immune system) and on plants (inhibition of the photosynthetic activity of plants). Guaranteeing the integrity of the ozone layer is therefore a major issue, its excessive thinning, or even its disappearance in certain areas, which can have serious consequences for humans and ecosystems.

13.1. Issues related to stratospheric ozone depletion

Since the 1980s, observations have shown significant seasonal decreases in the stratospheric ozone layer over the Arctic and the Antarctic continent. These declines can reach 50% in late winter and early spring, and are also reflected, to a lesser extent, in mid-latitudes. The thinning of the ozone layer affects the polar regions during the spring.

The depletion of the ozone layer, one of the nine planetary limits (Rockström et al., 2009), is understood by measuring the concentration of stratospheric ozone evaluated in Dobson units (DU). Knowing that the average value of the ozone column is 300 DU, the limit is set at 275 DU, i.e. 95% of its pre-industrial level (290 DU). While this limit was broken in the 1980s, the trends have since reversed, and the average thickness of the ozone layer is gradually increasing. In 2009, the concentration amounted to DU 283. In the 1980s, during the end of the southern winter (September-October), when the sun appeared, the thickness of the ozone layer could approach 100 DU.

13.2. Compounds affecting the ozone layer

Research on the subject has shown that the depletion of the ozone layer follows complex chemical reactions occurring in the stratosphere and mobilizing brominated or chlorinated compounds requiring very low temperatures, reached during polar winters, then significant solar radiation, from the following spring. These compounds are emitted by human activities. The most famous are :

- chlorofluorocarbons (CFCs) used in refrigeration systems, air conditioning, aerosol cans, solvents, etc. ;
- hydrochlorofluorocarbons (HCFCs) developed to replace CFCs due to their shorter lifetime in the atmosphere;
- halons used for extinguishers and fire protection systems;
- carbon tetrachloride used in particular as an industrial cleaning solvent;
- methyl bromide used for the treatment of plants, premises and agricultural soils by fumigation.

13.3. Actions implemented

To preserve the ozone layer and in particular to help restore it, the international community has been committed since 1987 to the Montreal Protocol on Substances that Deplete the Ozone Layer. This international agreement aims to gradually stop the production and consumption of the substances in question. 197 countries have signed this protocol. Since its entry into force, global emissions of these products have fallen by more than 80% and almost all chemicals controlled by the Protocol have been phased out.

14. Planetary boundary 8: Increase in aerosols in the atmosphere

Introduction

Aerosols are a collection of fine particles from chemicals suspended in the air. Emitted by human or natural activities (volcanoes, fires), aerosols intervene on a planetary scale in the atmosphere as well as locally in the phenomena of air pollution and allergies.

14.1. Issues related to the use of aerosols

Since the pre-industrial era, human activities have doubled the global atmospheric concentration of most aerosols (Rockström et al., 2009). Moreover, as the IPCC shows in its successive reports, aerosols have a strong influence on the climate system by disturbing the Earth's radiation balance. Indeed, the increased concentration of aerosols in the atmosphere leads to an increase in the level of opacity of the atmosphere and can cause a decrease of 10% to 15% of solar radiation on the surface of the Earth. The impact of aerosols on cloud formation and life is one example of this.

Because of their potentially harmful effects on climate and health, the increase in aerosols in the atmosphere is one of the nine global critical processes. The planetary limit is understood in terms of the overall concentration of particles in the atmosphere, on a regional basis. However, the complexity of aerosols and the spatio-temporal variability of particles, sources and impacts, did not make it possible to define an overall threshold.

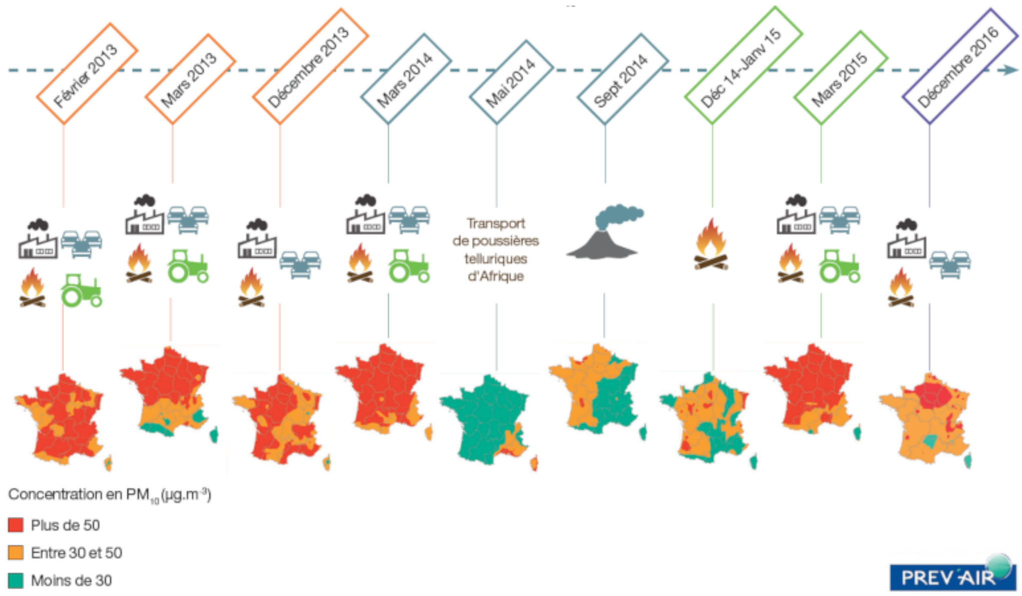
14.2. Activities causing fine particle emissions

In France, four main sectors of activity share PM10 particle emissions (fine particles with a diameter of less than 10 µm): the residential and tertiary sector (mainly due to the combustion of wood), industry, agricultural activities (spreading, storage of effluents, resuspension during plowing, burning) and transport. Their emissions have decreased, in total, by 41% over the period 2000-2017 following the progress made in all sectors of activity (improvement of dust removal techniques in industry, improvement of the performance of wood heating installations...)

14.3. Exposure of populations to fine particles

In Europe, outdoor air pollution due to fine particles is the cause of more than 400,000 premature deaths each year, including nearly 40,000 in France (European Environment Agency, 2018). Since October 2013, ambient air particles have been classified as carcinogenic to humans by the International Agency for Research on Cancer on the basis of a sufficient level of evidence of an association between exposure and increased risk of lung cancer.

France is thus regularly confronted with episodes of national pollution. Over the 2013-2016 period, these episodes are mainly due to particles with a diameter of less than 10 µm (PM10). At the start of winter, episodes are marked by a large amount of organic matter linked to combustion phenomena such as wood heating or the burning of green waste. In spring, the episodes observed are distinguished by the influence of emissions linked to agricultural activities (fertilizer spreading) which are added to and interact with the pollutants emitted by industry and transport.



15. Planetary boundary 9: Chemical pollution

Introduction

The introduction of new entities into the biosphere is the ninth of the nine planetary boundaries. In 2009, defined as "chemical pollution" (Rockström et al.), It referred to radioactive elements, heavy metals and many organic compounds of human origin present in the environment.

15.1. Issues related to chemical pollution

Two main factors have led to consider chemical pollution as a planetary limit: on the one hand, because of its harmful effects on human physiological development and on the functioning of ecosystems; on the other hand, because it acts as a slow variable that affects other planetary boundaries. Indeed, chemical pollution can have an impact on the limit "erosion of biodiversity" by reducing the abundance of species and potentially increasing the vulnerability of organisms to other threats (climate change). It also interacts with the "climate change" limit by the releases of mercury into the environment (via the combustion of coal) and by the emissions of CO2 due to industrial chemicals.

15.2. Main chemical pollants

Three types of pollutants are treated here: plastic waste at sea, nuclear waste, varieties tolerant to herbicides.

15.2.1. Plastic waste

Plastic, used since the 1950s, represents a major environmental issue, linked both to the consumption of resources necessary for its manufacture and to the production of waste it generates.

Between 1950 and 2017, world production of plastics continued to increase, from 1.5 million tonnes in 1950 to 350 million tonnes in 2017, i.e. 0.6 kg / inhabitant and 46 kg / inhabitant, respectively. .

Each year, between 5 and 13 million tonnes of plastic waste is thrown into the sea. 80% comes from the land and 20% from maritime activities. There are many sources of land-based waste: urban waste, tourism, illegal dumping, cosmetics, polyester and acrylic fibers. Half of the waste found on European beaches is single-use plastics: bottles, capsules, lids, cigarette butts, cotton swabs, sachets of chips, candy wrappers, sanitary items, plastic bags, cutlery, straws , etc.

Plastic waste is dumped into the oceans most often through sewers or rivers. They can also be linked to natural phenomena (storm, tsunami, flood, etc.). They come in the form of macroplastics. Microplastics are tiny particles of plastic that are less than 5 millimeters in size.

Marine pollution from plastic waste has multiple consequences for the environment, economy and health. A "plastic soup" forms in the oceans, causing in particular the strangulation of marine mammals and birds in the nets, but also the alteration of the balance of ecosystems due to the transport of invasive species over long distances. , etc.

Microplastics, ingested by many marine organisms (cetaceans, molluscs, plankton or fish), are found in the food chain. In addition, plastic contains chemical additives which can be endocrine disruptors. According to IUCN, globally, an average of 700 marine species are affected, of which 17% are threatened or critically endangered.

Faced with these global environmental, economic and health challenges, the international MARPOL convention (MARine POLlution) for the prevention of pollution from ships has banned the dumping of plastic materials into the sea since 1988.

15.2.2. Nuclear waste

Another national environmental issue, 77% of electricity in France is produced from nuclear power plants. France has 13% of the world's nuclear reactors in operation and produces 18% of nuclear power.

In 2013, a little less than 1.5 million m3 of radioactive waste was present in the territory, which represents a fifth of global nuclear waste (or 19%). This volume increased by 58% between 2002 and 2016.

15.2.3. Herbicides

In France, weeding of crops is a determining factor in agricultural yields. France is the leading user of herbicides in Europe (nearly 30,000 tonnes sold in 2017). However, to put an end to the chemical weed control that had been practiced until then and which was harmful to the environment, a new approach was introduced in 1996: the selection of plant varieties tolerant to herbicides (HTV).

Studies (Collective Expertise of INRA) and experiences in the United States show that an unreasonable use could lead to the acquisition of resistance by weeds ("weeds") and thus, a loss of the benefit of mutation with consequences of an increasingly important application of herbicides and impacts on the environment. The recommendations to limit these risks concern in particular the rotation of crops and treatments. It is necessary to remain vigilant on the use of these cultures.