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Handout of

Environment and Sustainable Development

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Summary

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Syllabus

Semestre 3 : Environment and sustainable development

Crédit 6

Coefficient 3

Sustainable Development is currently one of the responses emerging throughout the world to address the current conjunction of the world's major ecological, economic and societal challenges.

The objectives of the teaching

It is about making students aware that it is possible to act for the preservation of the environment, through their training, as well as on their scale, on their consumption, their daily activities and their society.

- The student will have the opportunity to learn and experiment his knowledge on sustainable development.

Syllabus

1. Definitions: Environment, components of an environment, Sustainable development.

2. Meaning of development

II.1. The main dimensions of the environmental crisis: human demography, Global warming, Fossil fuels (non-renewable), Depletion of natural resources, Drinking water, Biodiversity and Agriculture

II.2. Sustainable development, why?

II.3. The Concept of Sustainable Development

II.4. The fields of sustainable development

II.5. The principles of Soustainable development and their origins: precaution, prevention, responsibility, solidarity, equity, polluter pays

II.6. Sustainable Development stakeholders

II.7. Key dates in Sustainable Development

II.8. Some indicators of sustainable development: ecological footprint and biocapacity, impact on the environment, environmental performance index, human development index, GDP: gross negligible product (economic) and School enrollment rate boys/girls (societal), accessibility to care (societal).

II.9. Environmental education, Awareness and nature animation, environmental communication,

Chapter I

Generalities on the environment

Chapter I: Generalities on the environment

I.1. The Environment (What do we mean by the environment)

The term "environment" already existed in old French before passing into the English language around 1825. It designates all the things that surround the living being. Today this word means everything that is around Man, therefore the surrounding environment and includes, for example: material objects, living beings, the climate **(Delort, 2001)**. The concept of environment is perceived as an entity, in a given space and time, where certain factors (biological, chemical, physical and social) can have direct or indirect, instantaneous or slow effects on the human species, as well as on fauna and flora **(Dictionnaire de l'environement, 1992).**

Now the historical approach also seeks to question the dynamics of co-evolution between societies and the environment. In other terms, it is the environment that conditions the way of life of society and which encompasses the natural, social and cultural values that exist in a place at a given time **(Devienne, 2020)**.

- **In the broad sense**, the environment is associated with the problems of the global ecological crisis marked by a degradation of the ecosphere as a result of the action of technological civilization on all natural environments.
- **In its specific sense**, the environment designates the abiotic component, that is to say the physical environment (Biotope) and the biotic component (living beings or biocenosis). The biotope and the biocoenosis form the ecosystem.

I.2. Components of environment

The environment comprises of abiotic (non-living) and biotic (living)

Components. An interaction is created between these two components: the physical or abiotic elements allow the survival of the biotic elements, which in turn maintain the environment. These connections between these elements promote the circulation of energy and the recycling of matter **[1]**.

1.3. The concept of ecosystem

The ecological unit that groups together the animal and plant community is called an ecosystem.

According to A.G. Tansley (1935), "An ecosystem is a self-regulating ecological unit consisting of biotic factors (living) and abiotic factors (non-living) in a specific area exchanging energy and matter".

I.3.1.Abiotic component : Includes climatic or physical factors then chemical component ; all these factors play an important role in ecosystem functioning **[2]**.

(A) Climatic and *Physical components* includes :

1- Sunlight and solar intensity : for photosynthesis and therefore primary production in terrestrial and aquatic environments ; depending on the light intensity, a distinction is made between heliophile plants (Rosemary) and sciaphilous plants (Ferns and mosses) s)

2- Photoperiod : During the nycthemeral cycle, a period of lighting (day) : **Photophase** alternates with a night period : **Scotophase** The photoperiod varies according to the seasons and latitude.

- **Action of the photoperiod on plants** - Control of germination - Entry into dormancy - autumn fall - Flowering…
- **Action of the photoperiod on vertebrates** - feeding - night rest - Testicular development, - nuptial plumage that are conditioned by a hypothalamic-pituitary reflex initiated by the lengthening of the day in winter.
- In some arthropods, the photoperiod induces the obligatory Diapause during the bad season

3- Temperature: It is a limiting factor because it controls biological phenomena and the distribution of species in the biosphere. Four types of organisms can be distinguished

- **Poikilothermous** animals or « Cold-blooded » is a creature whose internal temperature changes greatly with changes in the external environment for example, amphibians, and reptiles, as well as many invertebrate animals **[3]**
- **Homeothermous :** Homeothermic or endothermic organisms. A relatively stable internal temperature. Homeotherms are those organisms, that maintains the internal body temperature under the influence of variable environmental conditions through their metabolic activities like shivering, sweating. Some examples like all mammals and birds and in some reptiles, fish, insects, and plants **[4].**
- **Stenothermal Organisms** ; Are organisms can survive only under a narrow range of temperatures. They tolerate only small temperature variations around average values. Examples : Crustaceans, insects, salmon, penguins **[5]**
- **Eurythermous** or eurythermal organismss : Are organisms that can tolerate a variable wide range of temperatures. Like Humans, cows, deer, monkeys, camels **[5]**

Resistance to extreme temperatures: Cold does not have a harmful effect on plants: Dormancy. This minimizes metabolic activity and therefore helps an organism to conserve energy. Dormancy tends to be closely associated with environmental conditions (freezing or drought).

Plants that resist high temperatures are those of the desert (65°). In animals, it is stronger in eurythermouss than in stenothermous.

Morphological adaptations to climatic factors – The Plumage - Fur and a strong layer of fat **[6]**

4- Rainfall: Constitutes an important ecological factor for the distribution of terrestrial ecosystems. It presents strong variations in its distribution on the surface of the continents: Maximum in the equatorial, subequatorial and mountainous zones

Biomes: Macroecosystem, biotic area, ecozone or ecoregion: is a set of ecosystems characteristic of a biogeographic area and named from the vegetation and animal species that predominate there.

- A vast biogeographic region extending under the same climate, such as tundra, temperate forest, tropical and equatorial forest, boreal forest, savanna, mangrove, temperate grassland, desert, riverine water, brackish water, coastal, coral reef, sea grass, deep-sea **[7]**

Biomes	**Annual rainfall**
Tropical rainforests	> 1300 mm
Temperate forests	> 700 mm
Dry forests	> 500 mm
Grassy formations (Steppes, savannas Deserts	> 250 mm
	< 250 mm

Table 1: Biomes according to the rainfall

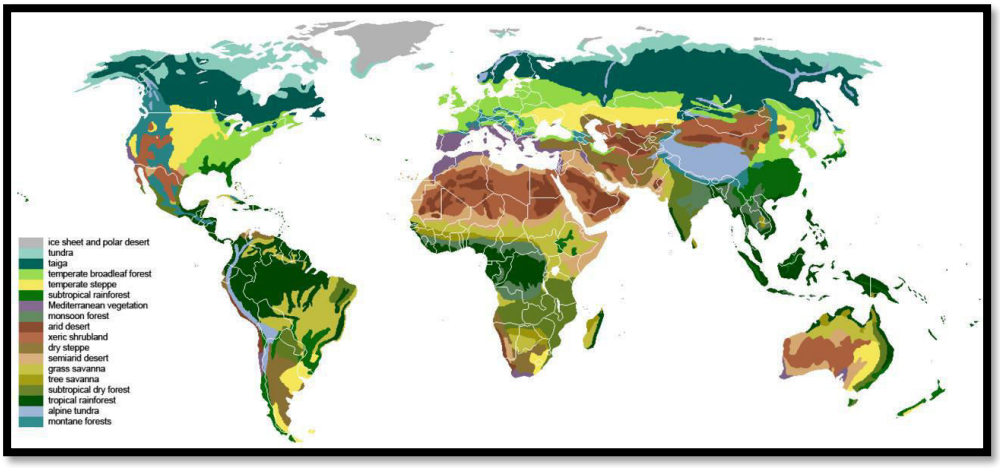


Figure 1: Distribution of the main biomes across the Earth

5- The Moisture / (humidity): It is the amount of water vapor contained in the air; it is expressed in g/m3 or in pourcentage (%) of saturation. The interference between temperature and evapotranspiration has led to the measurement of rainfall indices, which measure the degree of climatic aridity. It shows that the whole Mediterranean basin can be subdivided into five bioclimatic stages:

- Arid (P between 100 and 400 mm)
- Semi-arid (P between 400 and 600 mm)
- Sub-humid (P between 600 and 800 mm)
- Humid (P between 800 and 1200 mm)
- Per-humid (P > 1200 mm) (QUEZEL, 2000).

The Emberger rainfall quotient (Q), specific to the Mediterranean climate, allows situating a study area in a bioclimatic stage.

Q = 3.43x P/M-m

- Q: The Emberger rainfall quotient; P: Average annual rainfall in mm - M: Maximum average of the hottest month - m: Minimum average of the coldest month **[8]**

6- The wind: It helps in the dispersal of seeds, spores and pollen

- Increases evapotranspiration
- Destruct forests

7- The snow: Plays an important role in polar, subpolar and mountainous regions due to its insulating properties: because it contains a lot of air, which slows down heat loss. it protects vegetation and rodents from the cold.

Air temperature -50°C in the air, -20°C on the ground surface. However, it has an unfavorable mechanical effect on plants (plant breakage) **[9]**.

8- Currents: Ocean currents regulate the heat of different continents as well as the humidity of the air. The sun does not reach the Earth equally, the currents redistribute solar energy from hot areas to cold areas. This is the case of the Gulf Stream which transports

heat from the tropics to Europe. In addition, it allows good circulation of nutrients and minerals, essential for the development of marine species. Finally, the upwelling of cold water in hot areas promotes the proliferation of plankton which is the prey of fish and cetaceans.

Abstract :

- Adjust marine temperatures
- Promote the circulation of mineral nutrients
- Control the life cycle of fish : transport in coastal environments (Cod larva to reach the adult stage)
- Development of marine species : Cnidarians, sponges, Bryozoans

9- Soil texture

Soils are formed by rock under the influence of climate and living beings. It crumbles into small pieces that dissolve under the effect of precipitation [11]. Soil is composed of organic and inorganic particles matter. It provides structural support for plants and is a source of water and nutrients. Soils vary in chemical and physical properties **[12].**

A) **Types of soil** : Soil is classified into four types : Sandy soil, Silt Soil, Clay Soil, loamy Soil.

- **Sandy soil** : he first type of soil is sand. It consists of small particles of weathered rock. Sandy soils are one of the poorest types of soil for growing plants because it has very low nutrients and poor water holding capacity, which makes it hard for the plant's roots to absorb water. This type of soil is very good for the drainage system. Sandy soil is usually formed by the breakdown or fragmentation of rock like granite, limestone and quartz **[12]**. .
- **Silt Soil** : Silt, which is known to have much smaller particles compared to sandy soil and is made up of rock and other mineral particles, which are smaller than sand and larger than clay. It is the smooth and fine quality of the soil that holds water better than sand. Silt is easily transported by moving currents and it is mainly found

near the river, lakes and other water bodies. The silt soil is more fertile compared to the other three types of soil. Therefore, it is also used in agricultural practices to improve soil fertility **[12].** .

- **Clay Soil** : Clay is the smallest particle among the other two types of soil. The particles in this soil are tightly packed together with each other with very little or no airspace. This soil has very good water storage qualities and makes it hard for moisture and air to penetrate into it. It is very sticky to the touch when wet but smooth when dried. Clay is the densest and heaviest type of soil which does not drain well or provide space for plant roots to flourish **[12].**
- **Loamy Soil** : Loam is the fourth type of soil. It is a combination of sand, silt and clay such that the beneficial properties of each are included. For instance, it has the ability to retain moisture and nutrients; hence, it is more suitable for farming. This soil is also referred to as agricultural soil as it includes an equilibrium of all three types of soil materials, being sandy, clay, and silt, and it also happens to have humus. Apart from these, it also has higher calcium and pH levels because of its inorganic origins **[12].**

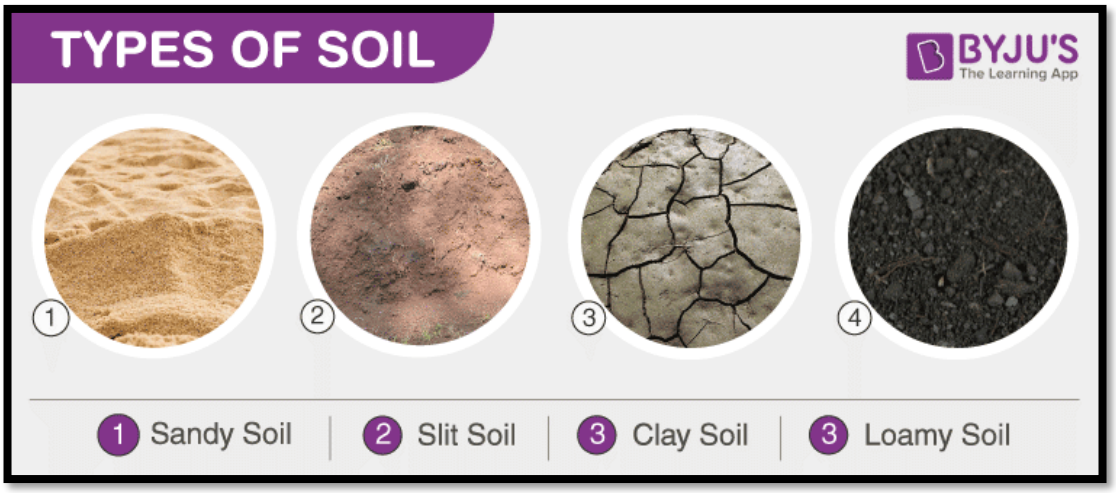


Figure 2: Types of soil [12]

B) Physical characteristics of soils

- **Texture of soils**: Soil texture (such as loam, sandy loam or clay) refers to **the proportion of sand, silt and clay sized particles that make up the mineral fraction of the soil**. For example, light soil refers to a soil high in sand relative to clay, while heavy soils are made up largely of clay **[13]**

Soil Texture Classes: The United States Department of Agriculture (USDA) has identified twelve (12) soil texture classes as follows: **sand, loamy sand, sandy loam, sandy clay loam, loam, silt loam, silt, silty clay loam, clay, clay loam, sandy clay and silty clay [14]**.

- **Soil structure**: The structure of the soil is described is defined by the degree of aggregation there exists There are four main degrees of aggregation from 0 to 3 0

0 : **Structureless** has no observable aggregation or no definite orderly arrangement such as pure sand

1- **Weak structure :** It is poorly formed from indistinct aggregates the soil material decomposes and is very little aggregated
2- **Moderate structure** : Moderate structure is well formed from distinct aggregates. When removed from the profile, the soil material breaks down into a mixture of many distinct entire aggregates, some broken aggregates and little unaggregated material ;
3- **Strong structur**e is well formed from distinct aggregates that are durable and quite evident in undisturbed soil. The soil material consists very largely of entire aggregates and includes few broken ones and little or no non-aggregated material. **[14]**

- Aggregate soils: Soil aggregates are **groups of soil particles that bind to each other more strongly than to adjacent particles**. Aggregate stability refers to the ability of

soil aggregates to resist disintegration when disruptive forces associated with tillage and water or wind erosion are applied **[15]**

Soil aggregates are consequently stabilized naturally by the accumulation of organic matter produced by microorganisms such as fungi, whose hyphae hold soil particles together and generate a glycoprotein (glomalin) cementing agent that helps bond primary soil particles **[16]**.

- Porosity: It is the total volume of the soil that is occupied by the pore space. This latter facilitate the movement of air or water in the soil **(Thangavel et al., 2019)**

- Soil hygrometry: This is the percentage of water contained in a soil in relation to the total volume of earth

The pH: Nitrogen, phosphorus, and potassium are the most important nutrients for plant life. They are found in soil at a pH ranging from 6 to 7.5 **[17]**

We distinguish between acidic soils, neutral soils and basic soils. The pH depends on

- CO2,
- The concentration of mineral salts,
- The organic molecules dissolved in this retention water.

NB/ The pH is lowered by the organic acids produced by the microbial and fungal biodegradation of animal and plant detritus

C) Chemical components include :

(1) Proteins

(2) Carbohydrates

(3) Fats

(4) Major essential nutrients like Carbon, nitrogen, phosphorus, potassium, sulfur and oxygen (C, N, P, K, H2, O2, S) etc.

Phosphorus: Enters into the composition of nucleic acids (phosphates and phosphoric acids). It represents a limiting factor given its low concentrations.

Nitrogen: essential for the development of autotrophs: decomposers transform organic nitrogen into mineral nitrogen Potassium: Cultivated plants are demanding in potassium
Calcium: Necessary in the construction of shells and skeletons of metazoans. Essential for the mineral nutrition of plants:

- Calcicolous plants: plants that establish themselves in calcareous soils
- Calcifuge plants: Avoid calcareous soils
- **Magnesium:** it is the most abundant metallic element in plants after calcium; it is associated with the tetrapyrrolic nucleus in the chlorophyll molecule
- **Sodium:** an important element for all living beings, but its concentration beyond a few per thousand blocks the normal development of most plant species

(5) Micronutrients like Iron (*Fe*), Molybdenum (*Mo*), *Zinc* (*Zn*), Copper (*Cu*), and other minerals. These trace elements are required at low concentrations, for the development of plants or animals: photosynthesis requires manganese, iron, and cobalt. In addition to these elements, animals need fluorine and iodine.
(6) Salts and toxic substances like pesticides.

I.3.2 Biotic component : Include various living organisms like plants, animals, microorganisms, and humans

1.3.2.1. Producers (Autotrophs): These are self-nourishing organisms, They produce food themselves; Green plants produce food through chlorophyll bearing by the photosynthesis processes in the presence of sunlight from raw materials like water and carbon dioxide. They are known as photoautotrophs (auto = self, photo = light, troph = food).

NB: There are some chemoautotrophs, which are a group of bacteria, producing their food from oxidation of certain chemicals, e.g. sulfur bacteria.

1.3.2.2. Consumer (Heterotrophs): Require organic matter for their trophic needs. They get their food by feeding on other organisms. They depend on the energy, produced by the producer. There are different types of producers:

(1) Herbivores- That feed on plants e.g. rabbit, insect.

(2) Carnivores—which feed on herbivores as secondary carnivores (e.g., frog, small fish) or tertiary carnivores (e.g., snake, big fish), which feed on other consumers.

(3) Omnivores—which feed on both plants and animals e.g., humans, rats, many birds.

(4) Detritivores—that feed on dead organisms e.g., earth worm, crab, and ants

1.3.2.3. Decomposers: by the processes of decomposition and disintegration, these microorganisms converting organic matters to simpler inorganic compounds. They play a very important role in changing the essential nutrients from unavailable organic form to free inorganic form and then recycle all the nutrients back that is available for use by plants producers again. Bacteria and fungi that secrete enzymes that dissolve dead organic matter, animal excreta and detritus and absorb the resulting lysates: They perform a mineralization of the organic waste that will be recycled and reused by the producers **[2].**

NB: There are interdependent relationships between these groups called: competition, symbiosis and parasitism etc…

❖ Detritus feeders and decomposers

A) Detritus feeders : These are organisms that feed on dead organic matter or 'necromass' left behind by other organisms.

- **In a terrestrial environment** :

- Saprophages : Consume **animal** or vegetal organic matter in the process of decomposition

- Necrophages : Consume animal corpses

- Coprophages : Consume excrement

- Geophagous : Ingest humus and feed on its organic matter

- **In aquatic environments**

- **Necrophages or -** Scavengers **: Such** as crustaceans that feed on dead fish.

- **Suspension feeders or filter feeders** : These are fixed or mobile animals that feed on suspended matter.

NB/ Filtration is indiscriminate or undifferentiated : mineral or organic particles, dead or alive.

- **Deposivores :** suck up organic particles once they have settled on the sediment.

Examples: Crabs, crustaceans, snails, sea cucumbers, eels and certain bottom-dwelling fish are deposit feeders.

- **Osmotrophs or Saprobies :** Absorb dissolved or colloidal organic particles.

Examples: Planktonic larvae, unicellular algae or protozoa.

B) Decomposers

- **On the soil:** Bacteria and fungi are present in the soil, depending on the environmental conditions.

NB/ - The activity of bacteria is stopped at a pH lower than 6

- In anaerobiosis, bacteria degrade organic molecules less than in an aerobic environment.

- At an acidic pH, in the absence of oxygen, fungi actively decompose organic matter.

- **In water:** There are practically no fungi in aquatic environments. Surface bacteria degrade and solubilize dead organic particles **(Ramade, 2004)**

Antagonism:

- There is an antagonism between bacteria and fungi. This latter emit antibiotics and bacteriostatics that stoppe the development of bacteria
- Bacteria emit toxins that prevent detritivores from intervening
- NB/ There are symbiotic relationships between microorganisms and detritivores or not or between plants

Bivalva ***Aequipecten opercularis***

Arenicola marina **(Deposivore) [2]**

Microscopic organisms of plankton [3]

Figure 3: Types of detritivores in aquatic environments

I.3.4. Concept of limiting factor: Any ecological factor is able to became a limiting factor depending on environmental conditions, its value decreases below a minimum value incapable of meeting the requirements of a species or a biocoenosis

- **Concept of tolerance or Shelford's tolerance law**: For each ecological factor, there is a tolerance interval or gradient that allows the growth of a species depending on this factor: - There is a lower limit below which death occurs by deficiency - An upper limit beyond which excess of this factor is fatal - Within the interval, there is an optimal preferendum value for which the metabolism of the species is carried out at a maximum speed (see figure below)

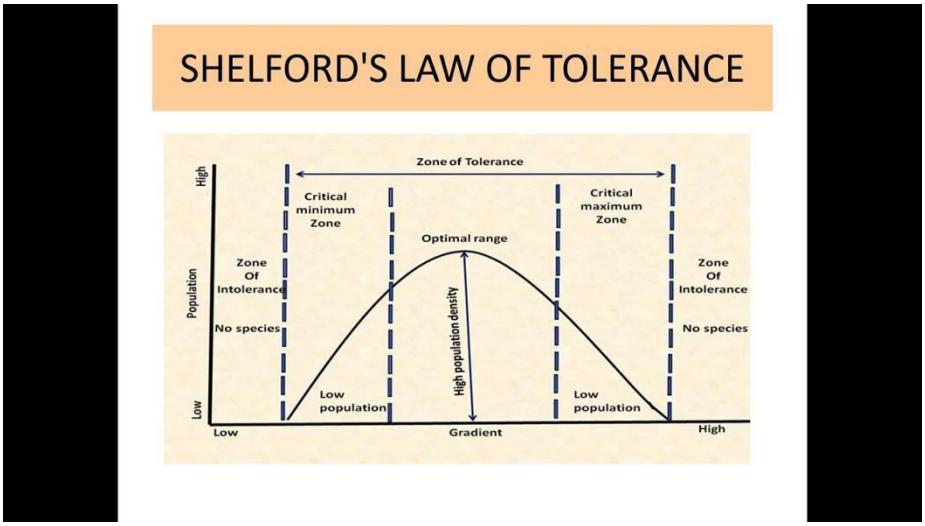


Figure 4 : Representation of Shelford's Law [18]

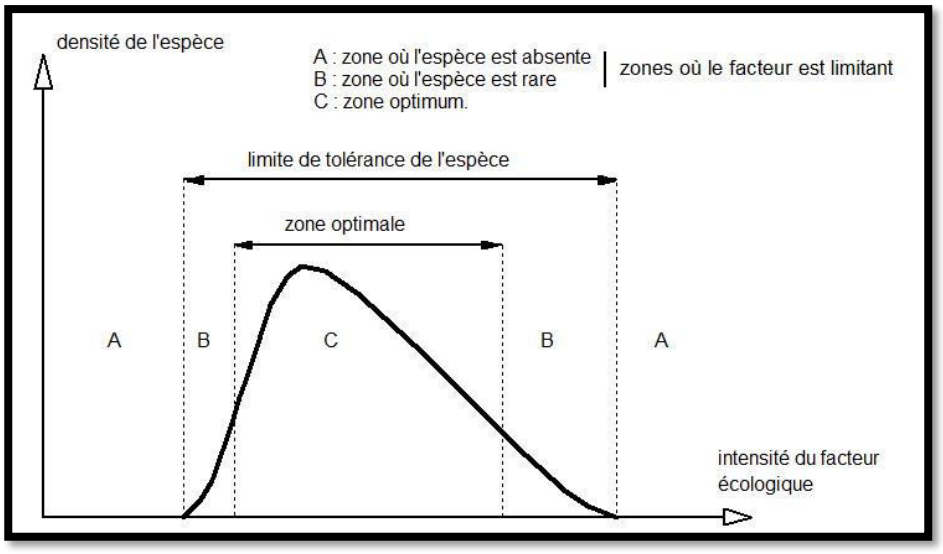


Figure 4 : Representation of the tolerance of a species as a function of the intensity of the ecological factor [18].

1.3.4. Ecosystem classification

Ecosystems are classified in reference to existing

- **Continental (terrestrial) ecosystems**:
  - **Forests:** Tropical, temperate, and boreal forests.
  - **Grasslands:** Temperate grasslands and savannas.
  - **Deserts:** Hot and cold deserts.
  - **Mountains:** Montane and alpine ecosystems.

  Wetlands: Marshes, peatlands, and coastal wetlands.

- **Aquatic ecosystems (continental waters)**:
  - Limnic ecosystems: (Ponds and lakes)
  - Lotic écosystems: (River, waterfalls.)

- **Coastal ecosystems** : (Lagoons, estuaries, mangroves)
- **Oceanic ecosystems**: (The sea and the oceans)

I.3.4.1. Functions of an Ecosystem

1- It has different food chains and food webs.

Example 1: Grass → Grasshopper → Frog → Snake → Hawk

Example 2: Phytoplanktons (water-algae) → water fleas → small fish → large fish (Tuna)

✓ Another type is detritus food chain, which starts with dead organic matter.

Example 3: Leaf litter in forest → Fungi → bacteria

The interconnection of different trophic chains is known as a food web.

2- It maintains a balance among the various trophic levels in the ecosystem

3- In an ecosystem, nutrients move in a cyclic manner. The cycling of nutrients takes place between the biotic and abiotic components.

4- Every ecosystem functions to produce and sustain some primary production (plant biomass) and secondary production (animal biomass) **([11], Ramade , 2003)**

A)

B)

C)

D)

E)

Figure 5: Different types of ecosystems A) Savanna B) Grasslands C) Rivers D) Oceans E) Desert [5]

I.3.4.2: The Dynamics of Ecological Disturbances

The dynamics of disturbances refer to how sudden or chronic events—such as wildfires, storms, epidemics, or human activities—affect the structure and function of ecosystems **(Turner, 2010).** These disturbances are not necessarily negative; they can play a crucial role in ecological renewal.

Recently, **Seidl et al. (2020**) showed that temperate forests are experiencing intensified disturbances due to climate change, which alters biogeochemical cycles and biodiversity. The frequency, duration, and combination of disturbances—referred to as compound disturbances—are key factors in transforming ecological landscapes **(Buma, 2015).**

Understanding disturbance dynamics helps anticipate critical thresholds and adapt ecosystem management strategies to avoid irreversible transitions, particularly in vulnerable areas **(Paine et al., 2021)**.

I.3.5. Ecosystem Resilience

Ecosystem resilience refers to the capacity of ecosystems to absorb disturbances, reorganize, and maintain their essential functions in the face of change **(Holling, 1973; Folke et al., 2010)**. Today, it is a central concept in ecology, particularly in the context of climate change and increasing anthropogenic pressures.

According to **Gunderson et al. (2022)**, resilience is based on three dimensions: resistance to change, recovery capacity, and adaptive potential. For example, boreal forests, although frequently exposed to wildfires, can recover through natural regeneration mechanisms. However, this resilience can be exceeded when disturbances become too frequent or intense **(Pimm et al., 2019)**. Integrating resilience into ecosystem management policies is now considered essential to ensure their long-term sustainability **(Biggs et al., 2015).**

1.3.6. Interactions between species within an ecosystem

1.3.6.1. Competition: There is competition when two individuals of the same species (intraspecific competition) or two populations of different species (interspecific competition) compete for the same resources (shelters, spawning grounds, food, etc.) which are in limited quantities; this is competition by exploitation **(Ricklefs &Miller).**

- **Intraspecific competition:** It depends on the population density when resources become scarce. In plants, competition can be for light or water, while in animals it is for females or nesting sites. It results in an increase in mortality and a decrease in birth rates.

NB/ increasing densities of a population can be favorable; this is the case of the group effect: The number of individuals within a population has consequences on the reproduction of individuals and on the survival of this population.

Examples: reindeer, the group must include at least 300 heads to survive and maintain the species. As for Bougainville cormorants, the colony must include 10,000 individuals.

• **In aquatic invertebrates**: Rotifers, case of the species *Notommata copeus* where the species can secrete substances that inhibit reproduction Density-Dependent Factor (DFm), which inhibits reproduction in others. This phenomenon is an example of chemical population regulation and is particularly interesting in the context of competition and survival strategies. When the population density of ***Notommata copeus*** increases, some individuals release a **chemical substance (DFm)** into the environment.This substance affects other members of the species by reducing or completely inhibiting their ability to reproduce.The secretion of DFm likely serves as a **self-regulation mechanism**, preventing overpopulation and resource depletion in a limited habitat, such as small bodies of water.

- **Interspecific competition:** In this case, a common resource is limited and is disputed by two different species. Hence Gause's principle of reciprocal exclusion: "Populations of two species with the same ecological requirements cannot coexist, one of them eliminating the other in the more or less short term" it is always the first species that excludes the second. (Ramade, 2003)

1.3.6.2. Predation: A predatory species attacks a prey species to feed on it; this relationship has several advantages:

- It is the initial factor of energy transfer in biocoenoses
- Prey species determine the growth rate of predatory species
- One of the most important selection pressures in evolution
- Regulates prey numbers

Prey avoidance strategies from predators:

- Escape (Gazelle)
- Hiding (Burrow, rodents)
- Mimicry (Chameleon)
- Camouflage (fish)
- Emission of toxic substances

The Reindeer: ***Rangifer tarandus*** **[6]**

The Bougainville Cormorant [7]

The Rotifer *Notommata copeus* [8]

Figure 6: Intraspecific competition in reindeer, cormorants and rotifers

1.3.6.3. Cannibalism: It is widespread among arthropods (insects, spiders), and vertebrates (fish, birds), it is a form of predation where individuals devour each other. The population may become extinct since predation is exerted on juveniles

1.3.6.4. Parasitism: It is also a form of predation where the host ends up dying. There are two types of parasites: Ectoparasites that are hematophagous live outside the host's body and endoparasites that can insert themselves into the circulatory system, viscera or digestive tract. It has a regulatory effect since it limits the numbers of pests **(Ramade, 2003).**

There are also phytoparasites (Plants) and zooparasites (Animals). Depending on the level of dependence, we can distinguish:

Obligate parasites: They are completely dependent on the host throughout their life cycle.

Optional parasites whose parasitism is not obligatory and can live differently.

Accidental parasites: Which are accidentally found inside an animal and manage to survive.

Eratic parasites: They are not found in their normal preferred site (e.g. *Fasciola hepatica* in the lung) **[20].**

In relation to the time spent in the host, we can find:

Temporal parasites (Superficial or external),

Periodic (Spends a period of its life cycle in the host to be able to live independently).

Permanent parasites, therefore for the whole life inside or outside the host. Among the advantages of parasitism: Energy saving, Shelter against predators, Access to resources.

NB/ A parasite can be found on several hosts it is namelly **euryxene or polyxene**; if it has only one host it is namelly **stenoxene**

Examples: Coccidiosis: Obligate parasitic single-celled organisms

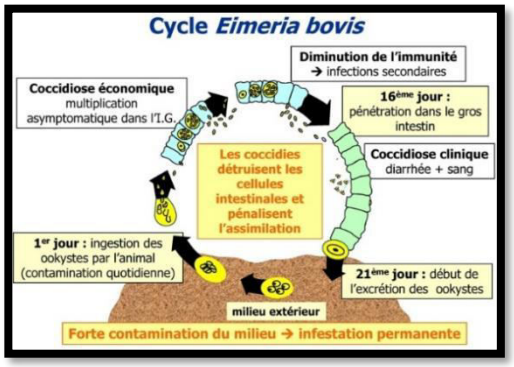


Figure 7: Cycle of *d'Emeria bovis* [9]

1.3.6.5. Allelopathy: This is a type of antagonistic relationship where higher plants emit toxic substances into the environment.

Example: Between vascular plants: The walnut tree of the genus Juglans secretes juglone, a chemical substance of phenolic nature that is emitted by the aerial parts and whose leaching introduces it into the soil. This substance inhibits the growth of herbaceous plants living approximately these trees.

Among these substances, we can cite molecules belonging to the class of terpenoids, alkaloids and polyphenols and in particular tannins. These substances can be toxic to insects and vertebrates that consume them or give them a bad taste or poor digestibility **(Delabays et al., 2009; Ramade, 2003)**

1.3.6.6. Antibiosis: This phenomenon results in the reduction of the inhibition of the growth of one organism by another, particularly bacteria and fungi. Examples include the species Bacillus subtilis, actinomycetes (Streptomyces sp.) and fungi (Aspergillus, Penicillium, Trichoderma, etc.) **(Ramade, 2003).**

1.3.6.7. Phoresy: A vagile or sessile species is carried by another species.It's a relationship in which an animal attaches to another without becoming a parasite, on the outer surface of another animal species, without the occurrence of a mutualistic (reciprocal) relationship between the carried and the carrier."

Ecological advantages of phoresy:

- ✓ The exploitation of new habitats or microhabitats more suitable for resources when these latter disappear or degrade, this is the case for carrion, excrement, and temporary accumulations of decomposing matters such as tree holes and beach debris.
- ✓ The transport of the phorant due to the lack of morphological adaptations to cross long distances alone
- ✓ Avoid predation during migration
- ✓ For the dispersal of eggs…

Examples: ***Histiogaster arborsignis***, which uses more than forty species of hosts

Carpoglyphus lactis that can be collected from nine different species of butterflies **(Houck & Oconnor, 1991)**

1.3.6.8. Commensalism: This is a positive interaction of species in a terrestrial and/or aquatic environment. The foreign species neither benefits nor harms the host **(Dajoz, 1971)**

- ✓ Commensalism with permanent contact: A crustacean Cirripede (A barnacle: marine crustacean, belonging to the infraclass of cirripedes) attached to the lower mandible of a whale
- ✓ Commensalism involving no contact: Diptera Syrphids of the genus Volucella that develop in the larval state in wasp nests

***Carpoglyphus lactis* [10]** **Phoretic mites Histyogaster arborsignis [11]**

Figure 8: Phoretic organisms

1.3.6.9. Cooperation: In this case, the organisms without obligatory association that mutually benefit from this association and develop independently **(Dajoz, 1971).**

Example: Phanerogams promote the activity of soil microflora, by releasing carbohydrates, phenols, amino acids, enzymes and vitamins into the environment. In return, rhizosphere bacteria degrade toxic substances in the soil in order to promote the growth of autotrophic plants **(Ramade, 2003)**

Balane larvae (Zooplancton, Crustacé) [12] Syrphides gender Volucella [13]

Figure 9: Types of commensalism

1.3.6.10. Mutualism : Beneficial association for both species

Example : The relationship between the sea anemone (*Heteractis magnifica*) and the clownfish (*Amphiprion nigripes*) A protective mucus on the fish's body allows it to tolerate the anemone's venom. The fish finds shelter within the anemone. In return, the clownfish can serve as a lure to attract prey to the anemone. It can also defend its anemone against attacks by a kind of fish that can graze on the anemone.

1.3.6.11. Symbiosis : Is a special case of mutualism. The links are so close that the first species cannot survive without the second.

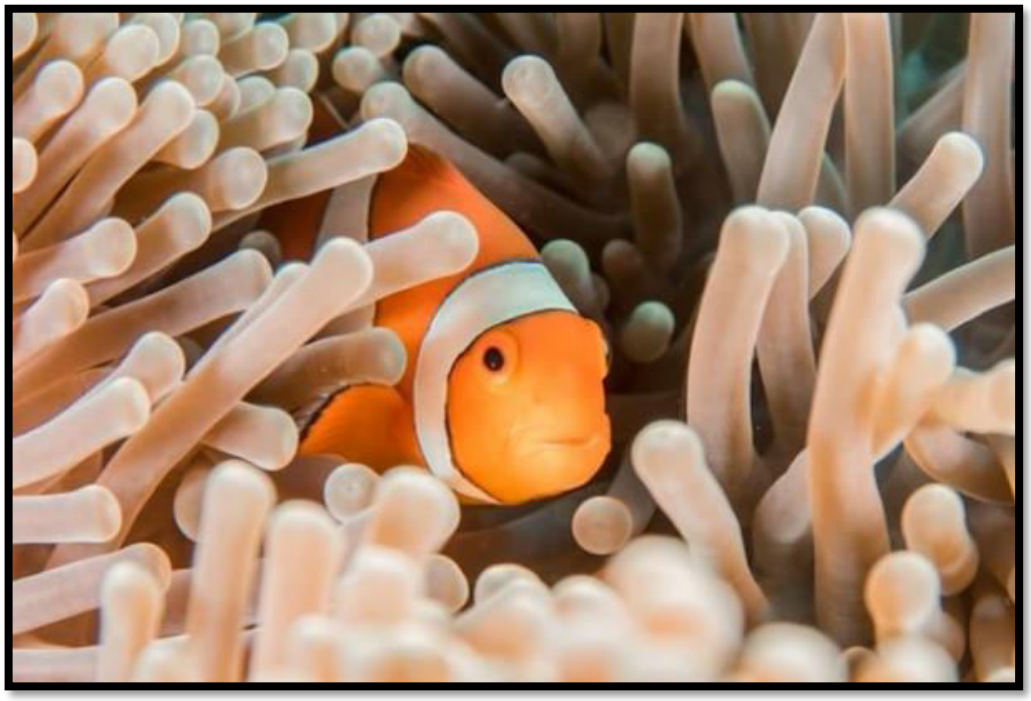
Example : This is the case of legumes which have root nodules in their roots that contain nitrogen-fixing microorganisms (Rhizobium sp).

Symbiosis or obligatory mutualism: Lichens: Symbiosis between a fungus and a photosynthetic algae (Cyanobacteria) which are protected by the hyphae of the fungus against drought and solar radiation and the latter receives from the algae the products of photosynthesis namely organic matter **(Mackenzie et *al*., 2000).**

1.3.6.11. Amensalism: It is a biological interaction between several partners (of the same species or different species) which is negative for one of the partners while it is

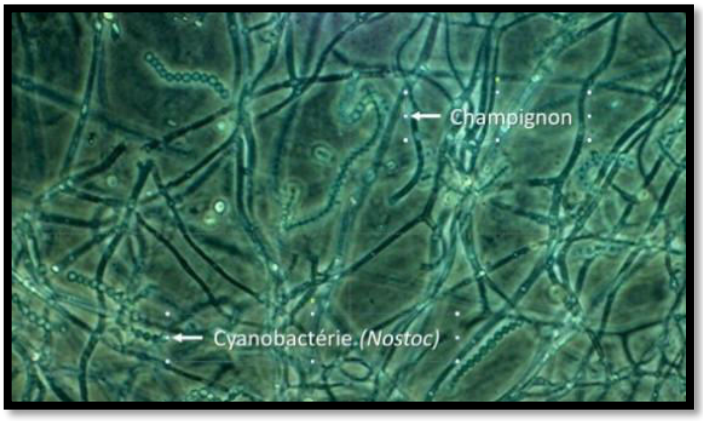
neutral for the other one, that is to say it does not involve any cost or benefit. Thus, one species inhibits the development of the other, while the latter has no implication on the former. This interaction is most often observed in plant species

1.3.6.12. Neutralism: Two species coexist in the same territory but there is no effect of one on the other.

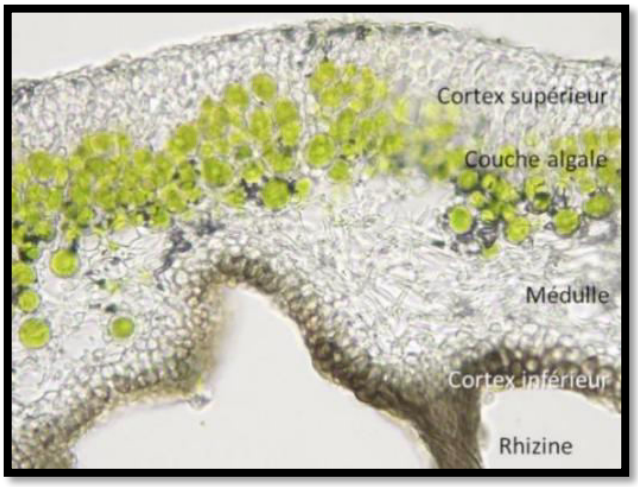


Mutualisme chez le poisson clown

et l'anémone de mer [14]



The homomeric structure of *Enchylium tenax* with thallus**[15]**



The heteromeric structure of *Phaeophyscia orbicularis* **[15]**

Figure 10: Symbiosis and mutualism

Chapter II

Sustainable development.

Chapter II : Sustainable development.

II. 1. Meaning of development:

The term development refers to the improvement of the conditions and quality of life of a population, through the economic development of agriculture, industry, services and trade activities.

Development has transformed the planet since the Industrial Revolution of the 19th century and has created development inequalities on a global scale : Northen countries (Western Europe, North America, Japan, Australia) and Southern contries.

Actually, A division into three large groups is proposed : favored, emerging, and precarious states **(Bouron et *al*, 2022)**.

Brief reminder of the industrial revolution of the 19th century context and origins

The Industrial Revolution of the 19th century, often referred to as the Second Industrial Revolution. The first revolution was agricultural ; it was the agricultural revolution of the Neolithic (prehistory) that contributed to the transition from a nomadic society of hunter-gatherers to a sedentary society of agricultural producers **[21]**. Industrial revolution took place primarily in Europe and North America. This period was characterized by the acceleration of technological advances and the transformation of agrarian societies into industrial economies. Factors such as political stability, access to natural resources, and technological innovations have encouraged this societal transformation **(Crouzet, 2008).**

The main inventions and innovations

Steel : The Bessemer and Siemens-Martin processes revolutionized the production of steel, which was essential for the construction of machines, railroads, and infrastructure.

• **Electricity** : The invention of dynamos and electric motors led to significant advances in industrial and domestic production.

• **Transportation** : Henry Ford's improvement of the internal combustion engine and the popularization of automobiles transformed the way people got around.

• **Telecommunications** : The inventions of the telegraph and the telephone have considerably improved communications **(Bairoch, 1997 ; Rioux, 2014).**

Environmental Impacts

The Industrial Revolution had significant effects on the environment :

• Pollution : The massive use of coal and other fossil fuels has considerably increased air and water pollution.

• Deforestation : The increased demand for wood for construction and industry led to significant deforestation.

• Land degradation : The expansion of agricultural and industrial land contributed to soil degradation.

• Climate change : Greenhouse gas emissions from industry began to impact the global climate.

Economic impact

The Industrial Revolution transformed economic structures in a deep and lasting way :

• **Industrial growth :** The rise of manufacturing industries has increased the production of goods on an unprecedented scale.

• **Market expansion :** New communication and transportation technologies expanded national and international markets.

• **Industrial capitalism :** The concentration of capital and the emergence of large companies marked this era. This also led to rapid urbanization and the creation of new industrial centers **(Fernand Braudel, 1985).**

• **Financial innovations :** The rise of banks and financial institutions facilitated industrial investment.

Social Impacts

The Industrial Revolution had social and often contradictory impacts :

• **Urbanisation :** The influx of rural populations to industrial cities led to rapid urbanization. Living conditions in these new cities were often unsanitary, with overcrowded neighborhoods.

• **Working conditions :** Workers worked long hours in often unsafe and poorly paid conditions. This situation led to the emergence of unions and workers' movements demanding better working conditions.

- **Social inequalities :** Economic disparities have widened, with increasing wealth for industrialists and increased exploitation of workers.

• **Lifestyle changes :** The shift to an industrial economy has altered family structures and lifestyles, with greater reliance on wage employment.

II.1.1. Sustainable development.

"Sustainability" is the capacity to endure.
Development is "sustainable" if it is designed in such a way as to ensure the continued benefit for future generations.

The practical goal of SD is to interact with the natural world indefinitely without depleting the resources on which it depends: This is called sustainability

II.2. The main dimensions of the environmental crisis:

II.2.1. Human demography: Demographic Transition: From Continuous Growth to Stability The demographic transition describes the passage from a rapidly growing population to a stable population, passing through several distinct phases. This process is fundamental to understanding population dynamics and their impact on the environment.

❖ **The phases of the demographic transition**

• **First Phase :** Characterized by high birth and death rates, leading to slow population growth due to wars, epidemics and famines. a natural rate of change on average close to zero (is the difference between the number of live births and the number of deaths in a territory during a period. It can be either positive, negative or zero).

• **Second Phase :** Death rates decrease due to improvements in medicine, hygiene and nutrition, while birth rates remain high, leading to rapid population growth. The rate of natural increase of the population becomes increasingly high.

• **Third Phase :** Birth rates begin to decline due to family planning, urbanization and improved education, especially for women. Population growth slows down due

to a change in mentalities that takes place. The birth rate decreases. The maximum rate of natural increase is reached at the beginning of this second phase. Then the birth rate drops more sharply, which implies a deceleration in the rate of population growth (Population growth or demographic increase or total population change is the difference between the size of a population at the end and the beginning of a given period) .

• **Fourth Phase :** Birth and death rates are low, stabilizing the population **(Diggs, (2008; [22]).**

❖ **The phases of the demographic transition in numbers**

- **Fertility Rate :** In 1960, the global fertility rate was 5 children per woman. In 2020, this rate fell to about 2.4 children per woman ;

• **Infant Mortality Rate :** In 1960, the infant mortality rate was 120 per 1,000 births, while in 2020, it fell to 29 per 1,000 births ;

• **Elderly Population :** In 2020, about 9% of the world's population was aged 65 or older. This proportion is expected to reach 16% by 2050 ;

• **Natural Increase :** Global natural increase has slowed from 2.5% in 1960 to about 1.1% in 2020 **[23]**.

❖ **Consequences of galloping population :**

• **Pressure on Resources :** A rapidly growing population puts increased pressure on natural resources, leading to their overexploitation. A stable population can reduce this pressure.

• **Green House Gas Emissions :** A stable or declining population can contribute to the reduction of greenhouse gas emissions, as demand for energy and resources decreases (**UNEP, 1990)**

• **Urbanization and Infrastructure :** Rapid population growth requires rapid urban expansion, often to the detriment of the environment. A transition to a stable population allows for better urban planning and sustainable infrastructure management [23]

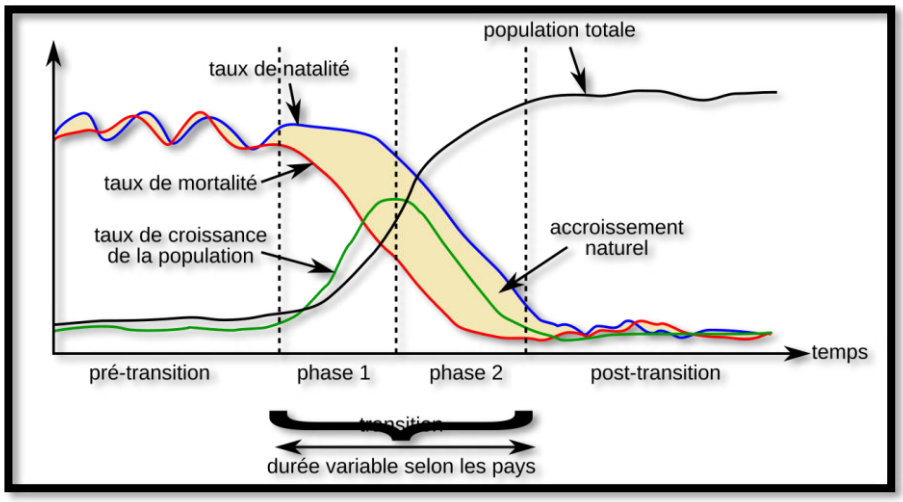


Figure 11 : Demographic transition [22]

II. 2.2. Global warming

Global warming is a complex phenomenon that began to take shape over the centuries, but it has been prticularly exacerbated by human activities in the last two centuries. Its origins are natural: variations in solar activity, for example, solar cycles, which last about 11 years, can slightly affect global temperatures. Additionally, massive volcanic eruptions, such as that of Mount Tambora in 1815, released large quantities of ash and gases into the atmosphere, causing a temporary global cooling, known as the "year without a summer."

Furthermore, the Industrial Revolution, which began in the late 18th century, marked a turning point with the drastic increase in greenhouse gas emissions. In 1750, carbon dioxide (CO2) levels in the atmosphere were around 280 ppm (parts per million). In addition, the burning of coal, oil, and natural gas for energy and industry has released billions of tons of CO2 and other greenhouse gases into the atmosphere. These gases trap heat, increasing the Earth's average temperature. Today, CO2 levels exceed 420 ppm, a 50% increase (Fig. 15A &15 B). Recent warming appears atypical, with atmospheric CO2 concentration measurements showing a rapid increase, and the Intergovernmental Panel on Climate Change (IPCC) attributes this increase to anthropogenic causes that will worsen, and projects an increase in average annual temperatures of between 2.2°C and 5.1°C for the period 2080-2099. The estimate of a warming between 3 and 4°C is about 50% (Atlas of sustainable and responsible development, 2011)

What is the Greenhouse effect: What is the Greenhouse effect: The greenhouse effect is a natural thermal phenomenon that maintains the average temperature of the Earth at a habitable level, which is on average 15°C on Earth. Without this natural process, the Earth's temperature would reach -18°C... However, this process is amplified by human activities such as the burning of fossil fuels, deforestation, cattle breeding, etc. certain gases called (GHGs) present in the Earth's atmosphere trap part of the infrared radiation emitted by the Earth's surface, thus preventing heat from escaping into space and causing climate change **[24; 25].**

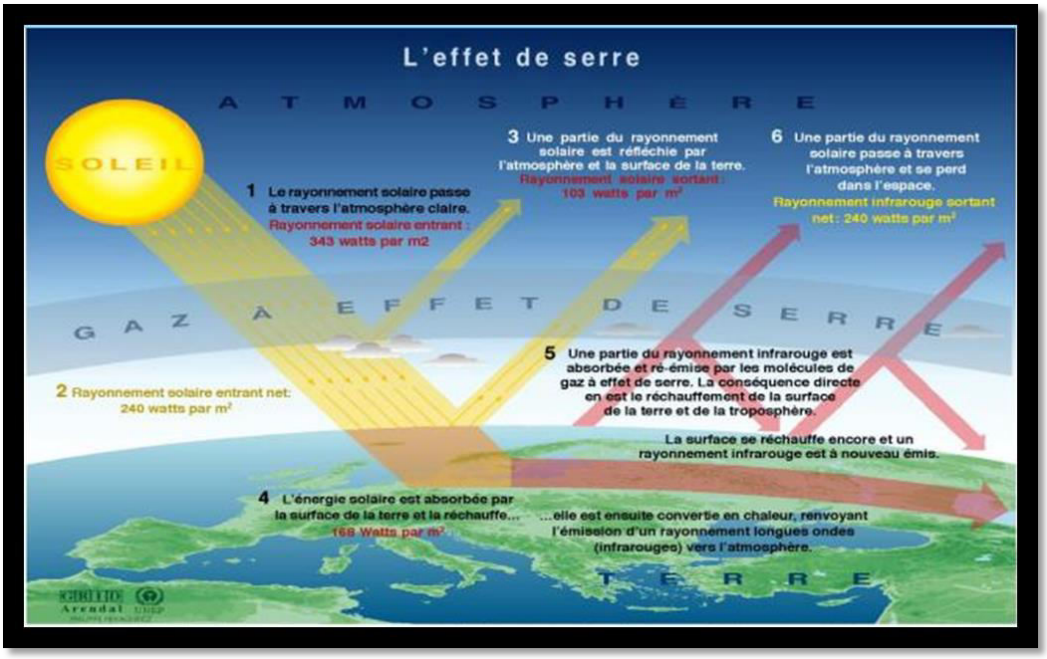


Figure 12. The greenhouse effect in focus Source - © 2005 UNEP / GRID-Arendal

Mechanism of the Greenhouse Effect : Absorption and Re-emission of radiation : The solar rays are absorbed by the Earth's surface, which heats up. These rays are re-emitted in the form of infrared rays. The latter are trapped by greenhouse gases in the atmosphere which re-emit them on Earth, which induces the increase in the Earth temperature.

Greenhouse Gases: The main greenhouse gases are carbon dioxide (CO2), methane (CH4), water vapor (H2O), nitrous oxide (N2O), and ozone (O3).

- **Hydrofluorocarbons (HFCs)** are synthetic chemical compounds composed of carbon, fluorine, and hydrogen atoms. They are often used as refrigerants in refrigeration and air conditioning systems, as well as in foam insulation and aerosol propellants

Characteristics of HFCs: No chlorine, unlike chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), HFCs do not contain chlorine, which means they do not deplete the ozone layer

Global Warming Potential (GWP): HFCs have a significant GWP, up to 14,800 times that of CO2 over a 100-year period.

Common Use: They are widely used in stationary and mobile refrigeration systems, automotive air conditioning, and as blowing agents in foam insulation

Environmental Impact: Although HFCs do not deplete the ozone layer, their contribution to global warming is a major concern. Due to their high GWP, there is a global effort to reduce their use and replace them with less climate-damaging **alternatives International accords:** The Kigali Amendment to the Montreal Protocol signed in 2016 by representatives of 197 States, industrialized countries committed to reducing the use of H-FCs by 45% by 2024 and 85% by 2036, taking the period 2011-2013 as a reference **[25]**

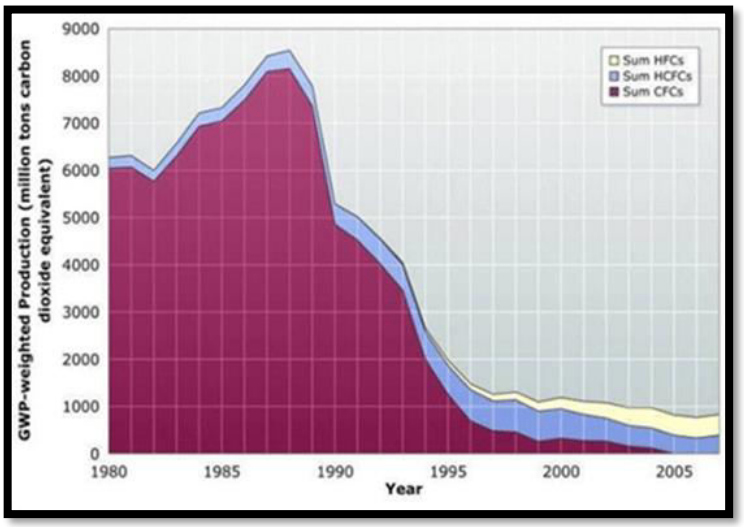


Figure 13 : Global warming Potential GWP-Weighted Fluorocarbon Production (1980-2007) [26]

- **PFCs or** Perfluorocarbons: These are chemical compounds containing only carbon and fluorine. They are used in various industrial applications, as heat transfer fluids in refrigeration and industrial air conditioning systems in the production of some

types of technical plastics. Finally, as blowing agents in the production of insulating foams.

Characteristics of PFCs: Chemical stability: PFCs are extremely stable and do not decompose easily in the atmosphere. They have a High atmospheric lifetime: They can persist in the atmosphere for thousands of years. They have a high (GWP)

Regulation and alternatives: Due to their environmental impact, the use of PFCs is regulated in many countries. More environmentally friendly alternatives, such as hydrofluoroethers (HFOs), are being developed to replace PFCs in many applications **[26]**.

- **Sulfur hexafluoride (SF6):** is an exceptionally potent greenhouse gas, with a global warming potential that is 23,500 times greater than that of CO_2 over a 100-year period. Its prolonged presence in the atmosphere and high warming potential make it a major contributor to climate change. It is important to note that this gas is non-toxic; it can reduce oxygen levels in confined spaces, potentially causing asphyxiation. Therefore, ensuring proper ventilation and following strict handling procedures is crucial when working with this gas **[26].**

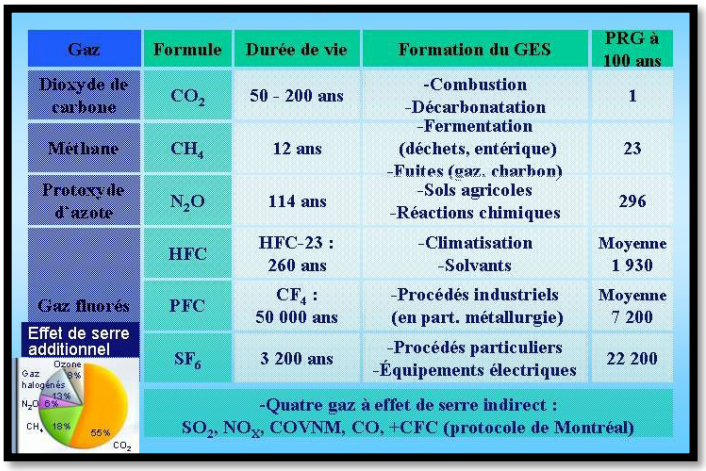


Figure 14. The principal Greenhouse Gas Source - © 2005 ADEME

Consequences

- **Temperature increase:** Since the beginning of the 20th century, the global average temperature has increased by about 1.1°C. In 2023 (Fig.11). This increase was 1.17°C above the 1951-1980 average.

  • **Melting of Glaciers and Polar Ice Caps:** The loss of ice contributes to the rise in sea level, which increased by 20 cm during the 20th century, and continues to rise at a rate of 3.2 mm per year. Meteorological studies estimate that by the end of the century, there would be an average increase of 35 cm. This increase will have the following consequences:

  - Submersion of coastlines, maritime marshes, deltaic areas and low-lying coasts

  - Disappearance of habitats and erosion of biodiversity (5% to 10% by the end of the century

  Extreme Weather Events: Heatwaves, floods, droughts and storms have become more frequent and intense. For example, the European heatwave of 2022 was directly linked to global warming, with record temperatures exceeding 40°C in several countries.

  • **Agricultural yields threatened by a decrease in water resources:** Cereal yields would decrease by 10% in Morocco and by 5.7% in Algeria, vegetable yields could also decrease by up to 30% in Algeria and 40% in Morocco. A reduction in pasture productivity is also threatening due to droughts

  Tourism affected: The increase in temperatures in the Mediterranean regions could affect the choice of tourist destinations

  • **Health impacts:** The increase in temperatures should induce high summer mortality due to heat stroke, acute dehydration, cardiovascular, cerebrovascular, respiratory and metabolic diseases, and the development of parasitic diseases such as Aedes albopictus, vector of dengue fever, the West Nile virus which has colonized southern Italy since 1999 **(Atlas of sustainable and responsible development, 2011)**

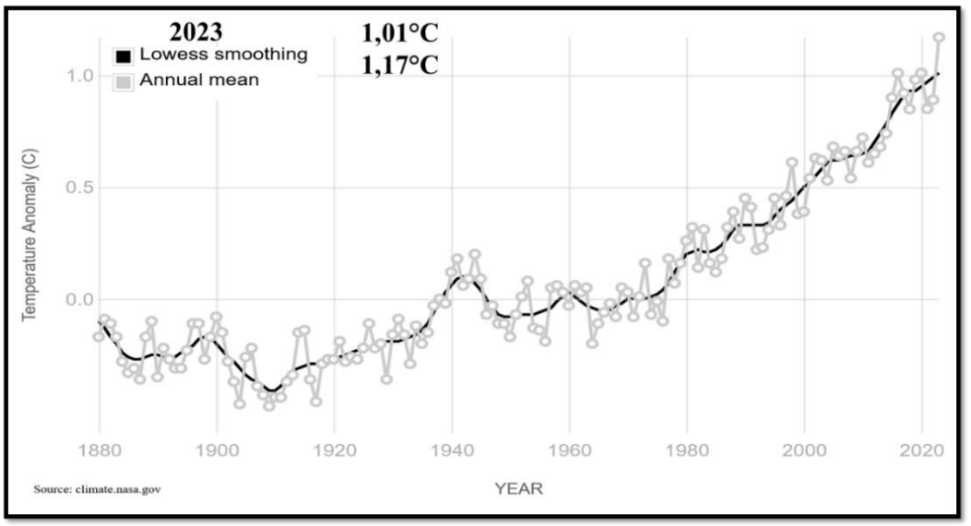


Figure 15: Average global temperature [27]

This graph shows the change in global surface temperature compared to the long-term average from 1951 to 1980. Earth's average surface temperature in 2023 was the warmest on record since recordkeeping began in 1880 (source: NASA/GISS). NASA's analysis generally matches independent analyses prepared by theNational Oceanic and Atmospheric Administration (NOAA) and other research groups. Overall, Earth was about 2.45 degrees Fahrenheit (or about 1.36 degrees Celsius) warmer in 2023 than in the late 19th-century (1850-1900) preindustrial average. The 10 most recent years are the warmest on record

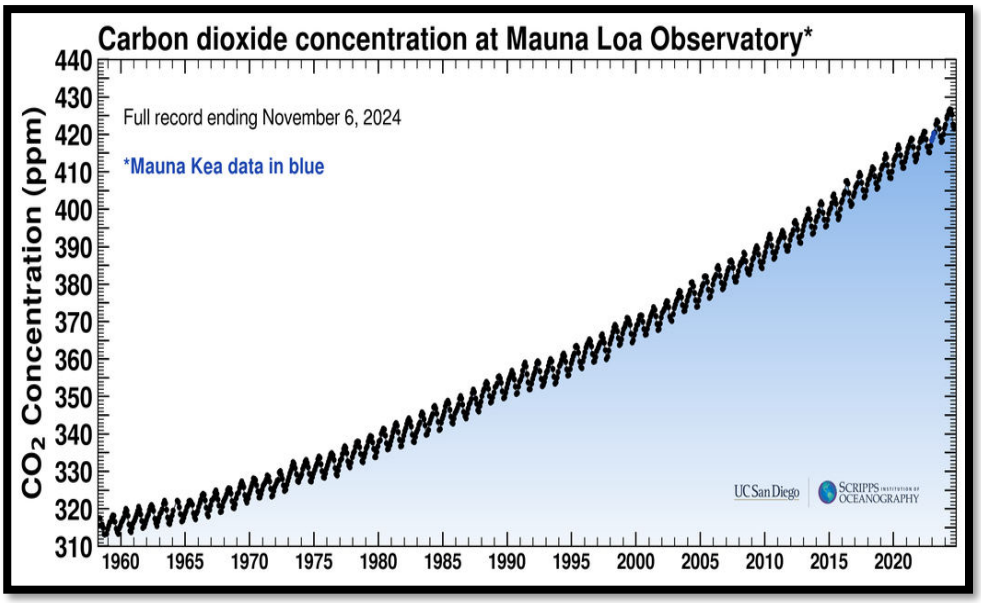


Figure 16 A : Carbon dioxide concentration at Mauna Loa Observatory[28]

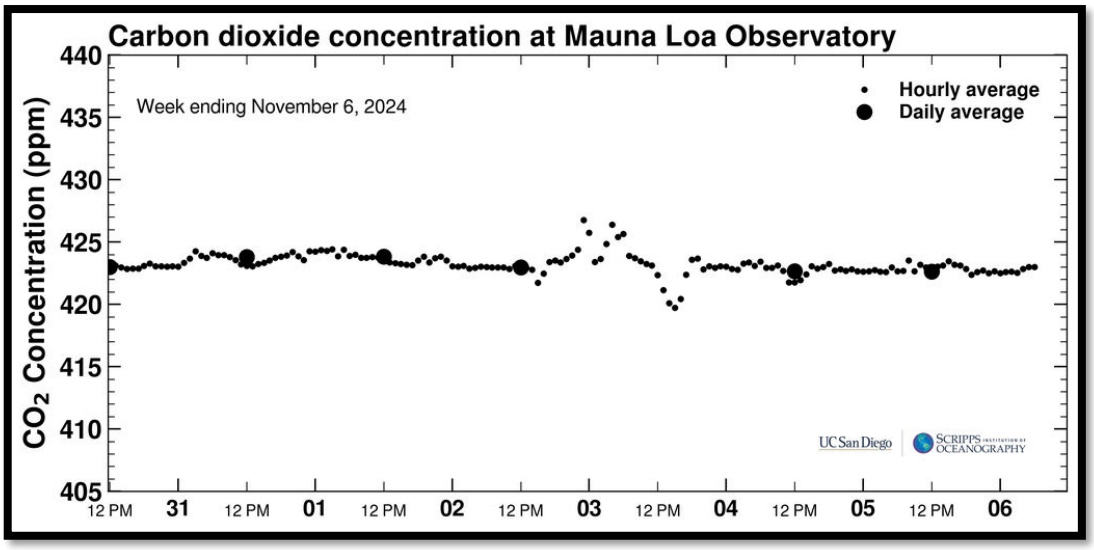


Figure 16 B: Carbon dioxide concentration at Mauna Loa Observatory Latest CO2 reading in the week ending (6/11/2024) 422, 90 ppm[29]

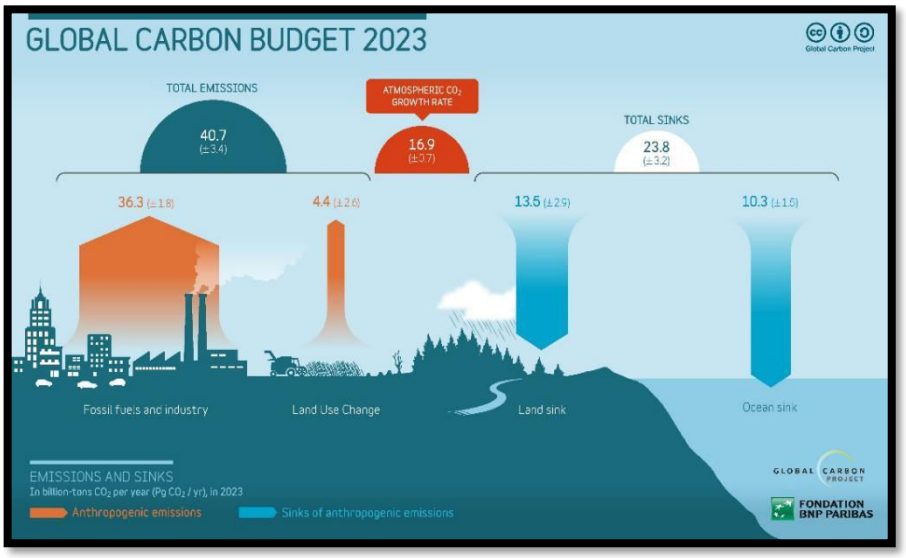


Figure 17 A : GLOBAL CARBON BUDGET 2023 [17]

Figure 17 B: CO2 emissions in the world [17]

Organisation for Economic Co-operation and Development (OCDE) or (OECD) countries Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, Italy, Japan, Finland, Australia, New Zealand, Mexico, Czech Republic, Korea, Hungary, Poland, Slovak Republic, Chile, Estonia, Israel, Slovenia, Latvia, Lithuania, Colombia, Costa Rica, United Kingdom (https://ocde.delegfrance.org/Membres-article)

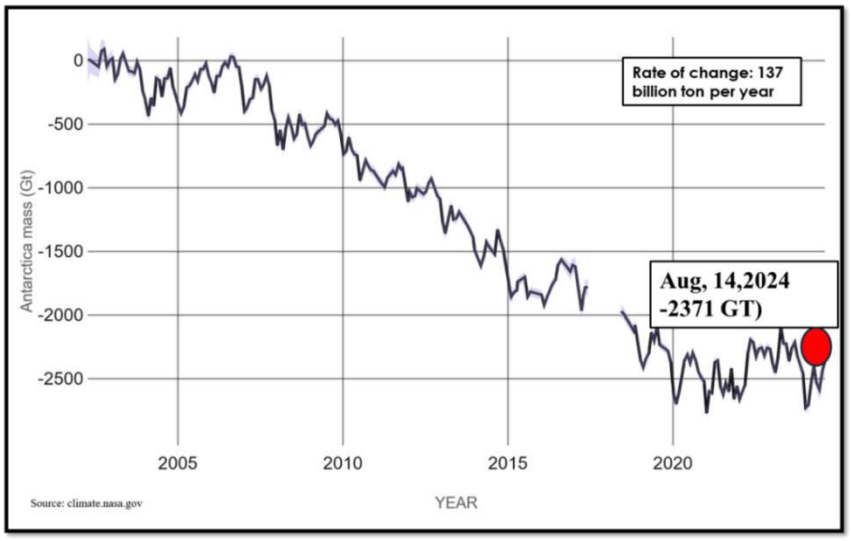


Figure 18: Antarctica mass variation since 2002.Data source: Ice mass measurement by NASA's GRACE satellites. Gap represents time between missions. Credit: NASA [27]

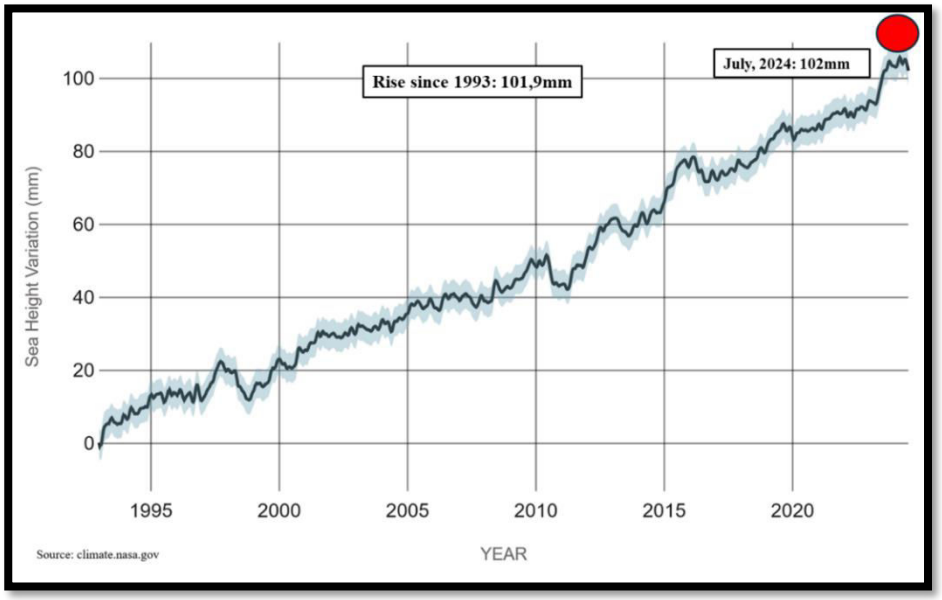


Figure 19 : Sea height variation since1995 to 2024

Global sea levels are rising as a result of human-caused global warming, with recent rates being unprecedented over the past 2,500-plus years. Sea level rise is caused primarily by two factors related to global warming: the added water from melting ice sheets and glaciers,

and the expansion of seawater as it warms. The first graph tracks the change in global sea level since 1993, as observed by satellites **[27]**.

II.2.3. Depletion of natural resources:

Non-renewable resources are being depleted because they are used faster than they can naturally replenish, eventually leading to their exhaustion. This is due to several factors : a growing global population that drives increased consumption of natural resources—some of which, like certain plastics, aren't renewable—as well as high energy use in transportation. Deforestation, and the expansion of urban areas, agriculture, livestock farming, and industry, all of which take a toll on forests.

Examples of overexploitation of natural resources

• Overexploitation of soils.

• Large-scale mining.

• Deforestation.

• Overfishing and its consequences on biodiversity

• Illegal hunting

• Extraction of fossil fuels such as oil, natural gas and coal.

• Water is increasingly overexploited

• Animals and plants are increasingly exploited in various fields (Cosmetics, medicine, etc.),

Consequences of the depletion of natural resources

• Fragmentation and destabilization of ecosystems.
• Extinction of animal and plant species.
• Contamination of terrestrial and aquatic ecosystems.
• The depletion of resources, such as drinking water

How to avoid the depletion of natural resources

- **Explore Clean Energy Alternatives :** Identify and adopt energy sources that minimize environmental impact.
- **Enhance Waste Management :** Develop and implement systems to manage waste efficiently, preventing the overuse of raw materials.
- **Embrace Ecodesign :** Create products using renewable resources that are designed with sustainability in mind.
- **Prioritize Sustainable Technologies :** Invest in and promote technologies that reduce environmental harm.
- **Support Circular Economy Transition :** Facilitate a social shift, particularly in European countries, toward a circular economy focused on reducing waste, reusing materials, and recycling resources.
- **Promote Sustainable Consumption Education :** Educate the public on responsible consumption practices to foster a more sustainable future [30].

There are renewable and non-renewable resources

Non-renewable resources: They consist of mineral raw materials (sand, clay, stone, slate, gravel, etc.), metal raw materials (aluminum, iron, silver, platinum, gold, etc.) and fossil fuels, which come from deposits formed during the geological history of the Earth and correspond to an exhaustible stock **(Fig. 17)**

II.2.4. Fossil fuels : Fossil fuels are energy sources that have been fundamental to the industrial and economic development of many societies. They are formed from the decomposition of organic material—mostly plants and animals—over millions of years. When subjected to heat and pressure deep beneath the Earth's surface, these remains transform into carbon-rich fuels like coal, oil, and natural gas.

II.2.4.1. Oil : Oil originates from the decomposition of ancient marine organisms, such as plankton and algae, that accumulate on the ocean floor. Over time, these organic materials are buried under layers of sediment, and the resulting heat and pressure convert them into liquid hydrocarbons. Today, crude oil is refined to produce a range of fuels—including gasoline, diesel, and kerosene—and also serves as a crucial raw material in the manufacture of chemicals, plastics, asphalt, and many other products.

Evolution of global oil demand

• **1950-1970 :** Oil demand grew rapidly with global economic growth and industrial expansion

• **1970-1980 :** The oil crisis of 1973-1974 led to higher prices and a revaluation of oil consumption

• **1980-2000** : Demand continued to grow, but at a more moderate pace, with fluctuations due to economic crises and technological change

• **2000-2020 :** Global demand peaked in 2019, before declining slightly due to the energy transition and efforts to reduce carbon emissions

2020-2024 : Demand began to grow again, but at a slower pace, due to the post-COVID-19 economic recovery and investments in renewable energy

Oil-importing countries : The major oil importers are the United States, China, India and the European Union

Oil Exporting Countries : The major oil exporters are Saudi Arabia, the United States, Russia and Canada **(Tables 2A & B)**

Oil Demand Scenarios for 2030

• **Optimistic Scenario** : Demand might reach its peak around 2030 and then decline as electric vehicles and renewable energy become more widely adopted.

• **Pessimistic Scenario** : If attempts to reduce carbon emissions fall short, growing demand could further strain oil supplies and drive prices higher **[30] [31].**

II.2.4.2. Coal

• **Formation** : Over time, coal is formed from dead plant remains that accumulate in marshy environments. These organic materials are covered by sediments and are transformed under pressure and heat into different types of coal:

• **Lignite** : The youngest coal, with a relatively low carbon content.

• **Bituminous coal** : Intermediate quality coal with a higher carbon content.

• **Anthracite** : The highest quality coal, rich in carbon and energy.

• **Use**: Coal is mainly used to generate electricity in thermal power plants and to fuel blast furnaces in the steel industry.

Major Coal-Consuming Countries :

1. China : China is by far the world's largest coal consumer, using about 50.5% of the world's coal consumption

2. India : India ranks second with about 11.3% of global consumption

3. United States : The United States consumes about 8.5% of the world's coal

4. Germany : Germany's coal consumption accounts for about 3% of the world's total

5. Russia : Russia uses about 2.7% of the world's coal consumption

These countries use coal primarily for power generation and industrial energy **[33]**

II.2.4.3. Natural Gas

• **Formation** : Natural gas is formed in a similar way to oil, often in the same deposits, from the decomposition of marine organisms under conditions of high pressure and high temperature. It is used for electricity generation, residential and commercial heating, and as a feedstock for chemicals and fertilizers. It is also used as a fuel for vehicles. The extraction, transportation, and combustion of fossil fuels have significant impacts on the environment :

• **CO2 Emissions** : The combustion of fossil fuels is the largest source of carbon dioxide (CO2) emissions, a greenhouse gas that contributes to global warming.

• **Air Pollution** : In addition to CO2, the combustion of coal, oil, and natural gas releases sulfur oxides (SOx), nitrogen oxides (NOx), and fine particles, which are harmful to human health and the environment.

• **Ecosystem Degradation** : Fossil fuel extraction can lead to deforestation, soil and water pollution, biodiversity loss, and disruption of local communities.

Energetic transition

To mitigate these impacts, many countries are embarking on an energy transition towards renewable energy sources:

Renewable energy resources

There are mainly five types of renewable energy

- **Solar energy**: It is important to distinguish between photovoltaic solar energy and solar thermal energy. The former refers to the electricity generated by photovoltaic systems, whereas the latter pertains to the heat produced by thermal collectors. Algeria has one of the largest solar potentials in the Mediterranean basin, with an estimated annual solar energy intake of 169,400 TWh, equivalent to 5,000 times the country's yearly electricity consumption.

- **Wind energy**: Over the past two decades, wind energy has grown significantly, benefiting from especially favorable weather conditions. As an inherently intermittent source, it captures the wind's kinetic energy through turbines installed either onshore or offshore, with offshore installations generally yielding higher energy production efficiency. The wind's kinetic energy is converted into mechanical energy.

- **Hydraulic energy**: Hydroelectric energy is generated by harnessing the power of water, whether through ocean currents or dams. The movement of water drives turbines that produce electricity. The greater the water pressure, the higher the energy output. Thus, this form of energy is closely tied to rainfall and river flow. The energy of water drives a turbine, which spins an alternator and generates electricity
- **Biomass**: Biomass energy is erived either from wood combustion or from the anaerobic digestion of organic matter. It can be used to produce electricity, heat, or

fuel. The heat produced by combustion warms a water reservoir, generating high-pressure steam. This steam powers a turbine connected to an alternator, which then transforms mechanical energy into electricity.

- **Geothermal energy**: Geothermal energy involves extracting the heat stored in the ground. Depending on the depth at which this heat is harnessed, it can be converted into either thermal energy or electricity. It is also important to note that energy sources derived from biomass and geothermal processes are not intermittent. To harness this underground energy, cold water is injected into the subsurface, where it naturally heats up. Once warmed, it is pumped back to the surface and used either in a power plant to generate electricity or directly as hot water for domestic needs. **[34] (Azizi, 2019)**

Année	USA	Chine	Inde	Japon	Corée du Sud	Allemagne	Italie	Espagne	Royaume uni	France	Pays -Bas	Singapour	Thailande	Taiwan	Belgique
1950	2	1	0,5	0,3	0,2	0.1	0.1	0.1	0,05	0,05	0,05	0,03	0.02	0.02	0,01
1970	6	3	1,5	1	0,8	0,5	0,4	0,3	0,2	0,02	0,15	0.1	0,08	0.07	O,05
1980	8	5	2,5	1,5	1,2	0,7	0,6	0,5	0,3	0,3	0,2	0,15	0.12	0.1	0,08
1990	10	7	3,5	2	1,5	1	0,8	0,6	0,4	0,4	0,3	0,2	0,15	0.12	0.1
2000	12	8	4	2,5	1,8	1,2	1	0,7	0,5	0,5	0,35	0.25	0,2	0.15	0.12
2010	15	10	5	3	2,2	1,5	1,2	0,9	0,6	0,6	0,45	0,3	0,25	0.2	0.15
2020	18	12	6	3,5	2,5	1,8	1,4	1,1	0,7	0,7	0,55	0,35	0,3	0.25	0.2
2024	20	14	7	4	2,8	2	1,6	1,3	0,8	0,8	0,6	0,4	0,35	0.3	0.25

Tableau 2 A: Oil imports in millions of barrels per day (mb/j) [30] [31].

Figure 2 B: Oil exports in millions of barrels per day (mb/j) [30] [31].

Année	Arabie Saoudite	Russie	USA	Canada	Iran	Émirats Arabes Unis	Koweit	Nigeria	Venesuela	Brésil	Angola	Norvège	Australie		Algérie
1950	5	3	2	1	1	0,5	0,4	0,3	0,2	0,1	0,1	0,05	0,03	0,02	0,01
1970	10	6	4	2	2	1	0,8	0,6	0,4	0,2	0,2	0,1	0,05	0,03	0,02
1980	15	9	6	3	3	1,5	1,2	0,9	0,6	0,3	0,3	0,15	0,08	0.05	0,03
1990	20	12	8	4	4	2	1,6	2,2	0,8	0,4	0,4	0,2	0,1	0.06	0.04
2000	25	15	10	5	5	2,5	2	1,5	1	0,5	0,5	0,25	0,15	0.1	0.06
2010	30	18	12	6	6	3	2,4	1,8	1,2	0,6	0,6	0,3	0,2	0.12	0.08
2020	35	20	14	7	7	3,5	2,8	2,1	1,4	0,7	0,7	0,35	0,25	0.15	0.1
2024	40	22	16	8	8	4	3,2	2,4	1,6	0,8	0,8	0,4	0,3	0.18	0,12

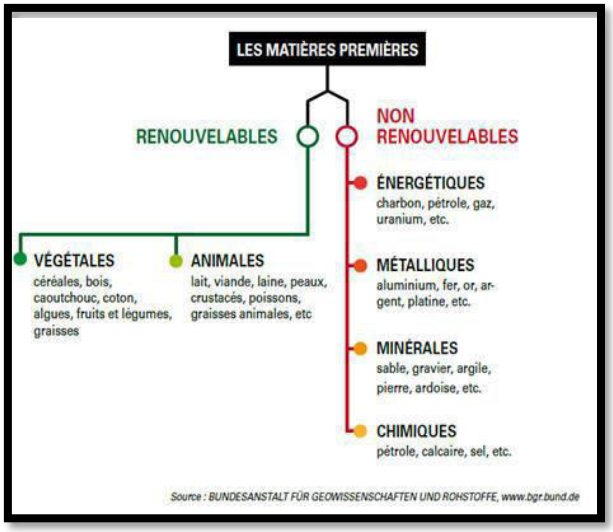


Figure 20: Different types of raw materials

a)

b)

c)

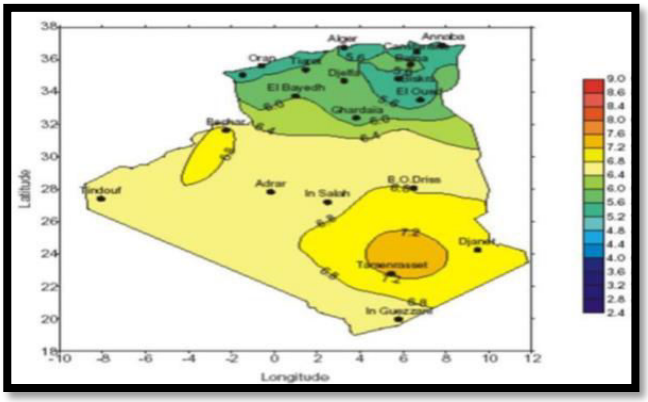


Figure 21 : Types of energy a) wind, b) solar c) illumination map in Algeria

II.2.5. Drinking water

Access to clean drinking water is a fundamental human right, yet many people around the world still face challenges in obtaining it

Global Drinking Water Statistics

- **Safe Drinking Water** : In 2022, about 73% of the global population (6 billion people) used safely managed drinking water services. These services are defined as water located on premises, available when needed, and free from contamination
- **Unsafe Water** : Despite progress, 1.7 billion people still use drinking water sources contaminated with feces, posing significant health risks
- **Water Stress**: Over 2 billion people live in water-stressed countries, a situation expected to worsen due to climate change and population growth
- **Geographic Disparities** : Access to safe drinking water varies widely, with less than half of the population in 35 countries using safely managed services. Sub-Saharan Africa is particularly affected, with over half of the 703 million people without basic drinking water living in this region

Impact on Health : Unsafe water sources are responsible for over 505,000 diarrheal deaths each year Contaminated water can transmit diseases such as cholera, dysentery, typhoid, and polio

Efforts and Challenges : Efforts to improve access to clean water include infrastructure development, better water resource management, and policies promoting hygiene practices

Safely managed : Drinking water from an improved source that is accessible on premises, available when needed and free from faecal and priority chemical contamination

Basic : Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing

Limiting : Drinking water from an improved source, for which collection time exceeds 30 minutes for a round trip, including queuing

Unimproved : Drinking water from an unprotected dug well or unprotected spring

Surface water : Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal **(WHO, 2023), [35].**

Figure 22 : Water stress in Africa (WHO, 2023), [35].

II.2.5.1. Drinking water in Algeria: Algeria is facing water stress as demand continues to rise. Meanwhile, the volume of available water is decreasing due to various natural and human factors affecting water collection sites. These issues include the silting of dams, the evaporation of reservoir lakes, leaks through rock formations and dam foundations, water eutrophication, and seawater intrusion into coastal aquifers **(Remini, 2006).** Added to this are the physical constraints inherent to the country's topography and morphology. Indeed, the Tell region, which accounts for only 4% of the territory, is subject to a Mediterranean climate. The High Plateaus region, covering 9% of the total area, is predominantly characterized by a semi-arid climate. Finally, the Sahara, which extends over 87% of the national territory, is marked by an arid climate, where precipitation is exceedingly rare.

Currently, In the context of sustainable development, the country's new water policy to address shortages is built around two strategic pillars :

1. Expanding hydraulic infrastructure, including dams, water transfer systems, seawater desalination plants, and wastewater treatment facilities.
2. Implementing institutional reforms in the water sector to enhance resource management through the establishment of multiple specialized agencies (ABH, ANRH, ONA, ANBT, ADE, DHW, ONID)

II.2.6. Biodiversity: Biodiversity is defined as the full range of living organisms, regardless of their origin, along with the terrestrial, marine, and aquatic ecosystems to which they belong. It encompasses species variability, ecosystem diversity, and the ecological interactions that connect them **(Based on Article 2 of the Convention on Biological Diversity, 1992 – Falque and Lamotte, 2012).**

Importance of Biodiversity

Genetic Resources: According to the Convention on Biological Diversity, genetic resources refer to any genetic material of animal, plant, or microbial origin that contains functional units of heredity and holds actual or potential value. For animals, this includes wild populations, standardized breeds, as well as selected lines and strains. In the case of plants, genetic resources encompass both ancient and modern cultivated varieties, local cultivars, and related wild forms. As for microorganisms, they include strains, isolates, populations, and microbial communities.

- **Food Use of Living Resources :** The harvesting of living resources for food has been practiced for centuries through activities such as foraging and fishing. Wild and semi-wild plants—including leaves, roots, tubers, fruits, and mushrooms—play a crucial role in food security and public health, particularly for rural populations dependent on subsistence farming. In certain tropical societies, people commonly consume invertebrates such as caterpillars, mollusks, and grasshoppers, while several vertebrate species, including mammals, reptiles, and birds, are hunted for their meat. Fishing, whether in marine or freshwater environments, remains the world's primary source of protein.

- **Extractivism Products :** Extractivism refers to the commercial exploitation of non-timber forest products such as fruits, gums, resins, oils, and fibers. Materials like cotton, flax, wool, silk, and rubber (extracted from Hevea trees, certain vines, and euphorbias) also originate from plants and animals. Despite competition from synthetic alternatives, these natural products remain widely used. The overexploitation of this resource has led to the degradation of forest ecosystems.

Industrial Prospects of Biotechnology : The industry is interested in various elements of biodiversity, particularly microorganisms, genes, and molecules. Industrial microbiology utilizes the enzymatic and metabolic capacities of microorganisms for two types of transformation : **Fermentation**, used in fields such as brewing and cheesemaking. The production or modification of molecules, including antibiotics, hormones, and flavor compound. Since the 1970s, bacteria have been genetically modified to synthesize substances such as insulin and erythropoietin, a hormone that stimulates red blood cell production.

❖ **Biofuels :** Which aim to partially replace petroleum-derived fuels due to the rapid depletion of fossil reserves, are produced from oilseed plants like rapeseed and sunflower or through the fermentation of sugars from beets. In Brazil, two-thirds of cars run on alcohol, though they require a modified engine **(Dajoz, 2006).**

❖ **Ornamental Animals and Plants :**

Today, the number of cultivated plant species for ornamental use exceeds those for agriculture. Continuous hybridization leads to new species being commercialized. Meanwhile, the trade of animals for zoos, aquariums, and research is significant. Products like ivory, tortoise shells, snake and crocodile skins, fur, and bird feathers serve decorative, symbolic, cultural, and clothing purposes. However, this trade endangers many species. Annual extractions reach 100 million tons, nearing sustainability limits.

Ecotourism : Ecotourism has become a major industry, with biodiversity-based tourism generating income for countries investing in national parks and trekking. While beneficial for local communities (guides, porters, hotel staff), it also causes environmental damage such as soil erosion and wildfires.

❖ **Research, Education, and Monitoring :** More research is needed to optimize biological resource use, maintain genetic diversity, and restore ecosystems. Natural areas serve as valuable living laboratories for ecological studies.

Biodiversity's Role in Environmental Integrity :

- **Nitrogen Fixation :** Essential for plant growth, nitrogen is introduced into ecosystems by prokaryotes like *Rhizobium* (associated with legumes) and *Frankia* (associated with trees like *Alnus* and *Casuarina*).
- **Organic Matter Decomposition :** Prokaryotes play a key role in biogeochemical cycles by breaking down organic material and recycling nutrients.
- **CO_2/O_2 Balance :** Biodiversity helps regulate atmospheric carbon dioxide and oxygen levels.
- **Pollutant Absorption and Waste Decomposition :** Through food chains and energy flow, ecosystems process pollutants and organic waste.

Unfortunately, biodiversity is rapidly declining due to several factors :

- **Habitat Loss** : Deforestation, urbanization, and intensive agriculture destroy natural habitats.
- **Pollution** : Chemicals, plastics, and other forms of pollution affect species and their ecosystems.
- **Climate Change** : Changes in temperature and precipitation patterns disrupt ecosystems.

- **Overexploitation** : Hunting, overfishing, and the illegal wildlife trade threaten many animal and plant populations.
- **Invasive Species** : Non-native species can outcompete local species and disrupt ecosystems.

Biodiversity Conservation : To combat biodiversity loss, various initiatives and strategies are being implemented :

- **Protected Areas** : The creation of national parks, nature reserves, and other protected zones.
- **Ecosystem Restoration** : Projects aimed at restoring degraded habitats and reintroducing locally extinct species.
- **Policies and Regulations** : Laws and international agreements to protect endangered species and regulate wildlife trade.
- **Education and Awareness** : Campaigns to raise public awareness of the importance of biodiversity and promote sustainable behaviors.

II.1.7. Agriculture

Agriculture plays a crucial role in ensuring food security by providing essential food sources such as grains, fruits, vegetables, dairy, and meat to sustain the world's population. Beyond its role in feeding people, agriculture is also a key contributor to the global economy, creating jobs and generating income for millions of individuals. Additionally, sustainable agricultural practices help preserve ecosystems, protect biodiversity, and maintain healthy soils, ensuring long-term environmental sustainability.

Types of Agricultural Practices

Traditional Agriculture: Based on ancestral methods, often manual, and adapted to local conditions.
Industrial Agriculture: Uses advanced technologies and machines to produce in large quantities, often criticized for its environmental impact.
Organic Agriculture: Favors natural methods and sustainable practices, without the use of synthetic chemicals.
Agroecology: Integrates ecological principles into agricultural practices to promote biodiversity and sustainability.

Current Challenges in Agriculture

Climate change affects agriculture by reducing crop yields and water availability, while soil degradation, through erosion and loss of fertility, further threatens production. Additionally,

biodiversity loss, driven by monoculture practices and excessive pesticide use, diminishes the variety of agricultural species. Moreover, smallholder farmers often struggle to access modern technologies and markets, limiting their ability to adapt and thrive in an increasingly challenging environment.

Solutions and Innovations: Precision Technologies leverage drones, sensors, and GPS data to optimize agricultural yields while minimizing environmental impact. Meanwhile, the development of resilient crops ensures resistance to diseases, pests, and extreme weather, securing food production against climate challenges. Urban agriculture plays a crucial role in enhancing local food security by integrating farming into city landscapes. Additionally, education and training equip farmers with sustainable practices and advanced technologies, fostering a more efficient and eco-friendly agricultural sector.

II.3. Why sustainable developpment

The scale of human activities far exceeds the Earth's capacity to eliminate the waste produced. In recent years, this has resulted in serious environmental problems such as acid rain, the thinning of the ozone layer and climate change. This is why it was necessary to consider a long-term action plan sustainable development.

Awareness of States and citizens

- An alarming future:
- Population pressure
- Overexploitation of natural resources
- Increasing waste
- Intensive agriculture
- Natural disasters
- Industrial disasters
- A significant North/South imbalance

Introduction :

- The report "Our Common Future" is the result of the deliberations of a group set up by the World Commission on Environment and Development (WCED) world commission on environment and development chaired by the Then Norwegian Prime Minister Gro Harlem it is the first time that the word sustainable development has been announce
- Brundtlandt Commission defined sustainable development as the development that involves "…meeting the need of present generation without compromising the ability of

future generations to meet their own needs”

II.3. The Concept of Sustainable Development

It is a concept of development that is part of a long-term perspective and integrates environmental and social constraints into the economy. It is based on 3 pillars: **Social equity, economic efficiency and environmental quality.**

II.3.1. Social Pillar (People)

This pillar concerns the well-being of individuals and communities. It aims to:

- **Reduce inequalities:** Promote equity and social inclusion.
- **Access to education and health services:** Ensure that all individuals have access to quality education and health care.
- **Decent working conditions:** Improve working conditions and ensure fair wages.
- **Community participation:** Encourage the active participation of citizens in decision-making processes.

II.3.2. Environmental Pillar (Planet)

This pillar focuses on environmental protection and sustainable management of natural resources. It includes:

- **Ecosystem protection:** Preserve biodiversity and natural habitats.
- **Natural resource management:** Use resources responsibly to avoid their depletion.
- **Pollution reduction:** Minimize greenhouse gas emissions and air, water and soil pollution.
- **Promotion of renewable energy:** Encourage the use of clean and renewable energy sources **["Sustainable Development Goals" (2015) by the United Nations]**

II.3.3 Economic efficiency: (Profit or Prosperity)

This pillar focuses on sustainable economic growth and wealth creation. Its objectives include:

- **Economic Growth** : Fostering economic growth that is inclusive and benefits all segments of society.
- **Sustainable Jobs** : Creating jobs that are environmentally friendly and economically viable.
- **Innovation and Technology** : Promoting technological innovation to improve efficiency and reduce environmental impacts.
- **Balance between Growth and the Environnent** : Ensuring that economic growth does not come at the expense of the environment and social well-being **(O'Riordan & Voisey, 1997).**

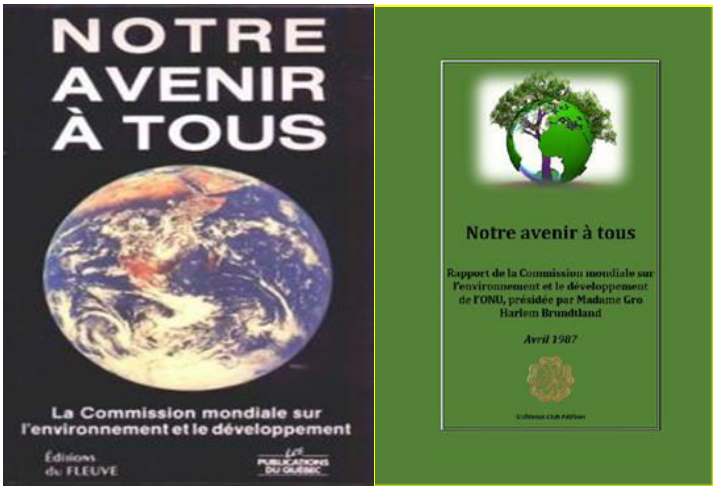


Figure 23: The report "Our Common Future" [18] [19]

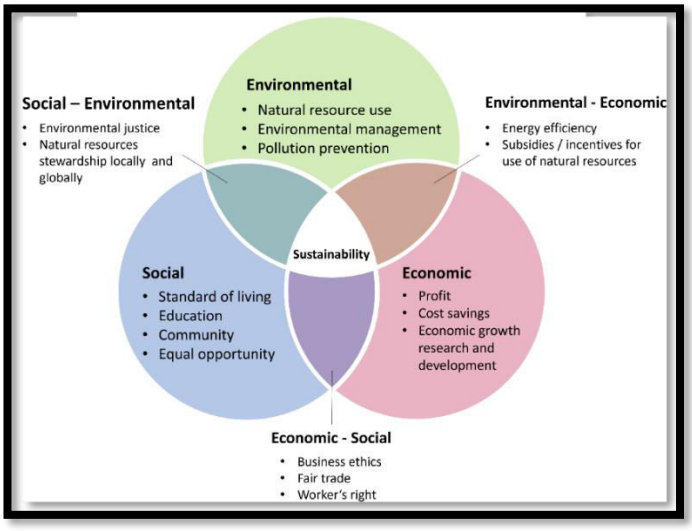


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Figure 24 : The three pillars of sustainable development [16]

II.4. The fields of sustainable development

II.4.1. Priority Areas for Achieving Sustainable Development

1. Slow Down Population Growth : This is essential for addressing all the other priority areas.

2. **Reduce Poverty, Inequality and Third World Debt** : Improving health, longevity and literacy, increasing employment etc. This is important for curbing the loss of species, the extent of land degradation and water

Pollution.

3. Make Agriculture Sustainable : This includes reducing soil erosion and decreasing the use of harmful agricultural practices. This is important for curbing the loss of biodiversity, land degradation and pollution.

4. Protect Forests and other Habitats : This includes reforestation and afforestation of wastelands, protection of other living resources, control greenhouse gases and ozone layer depletion. This is important for reducing air pollution, land degradation, depletion of energy and minerals

5. **Make Water and Energy Use Sustainable** : This includes improved energy efficiency, conserving energy and developing renewable energy resources. This is important for reducing air pollution, land degradation, depletion of energy and minerals.

6. Make Water Use Sustainable : This includes improving the efficiency of water use and protecting water quality. This is important for curbing water pollution and depletion and land degradation.

7. Reduce Waste Generation : This includes improving production processes, waste treatment and recycling processes. This is important for reducing air and water pollution and energy, mineral and water depletion.

II. 4. 1.1. Sustainable Architecture

In an era marked by environmental challenges, architecture has become a key driver of sustainable transformation. The construction sector accounts for nearly 40% of global CO_2 emissions (IEA, 2022), which makes it essential to rethink how we design and build. Sustainable architecture emerges as a vital response—integrating low-impact materials, innovative construction techniques, and thoughtful design to align the built environment with ecological and social responsibility. Modern sustainable architecture is grounded in several core principles: reducing environmental impact, conserving resources, improving energy efficiency, and ensuring that buildings are well integrated into their natural context. A major part of this approach involves choosing construction materials that are environmentally friendly throughout their life cycle—from production to use and eventual disposal or reuse.

Among the most effective **nature-friendly materials**, several stand out:

> **Sustainably sourced wood**, which acts as a carbon sink and requires relatively low energy to process, while offering excellent insulation and structural properties (Churkina et al., 2020).
>
> **Straw bales**, used for natural insulation, are locally available, renewable, and offer great thermal performance with minimal processing (King, 2006).

Raw earth, such as adobe or rammed earth, is increasingly used for its low embodied energy, thermal inertia, and recyclability (Minke, 2009).

Hempcrete, a mix of hemp and lime, is valued for its insulating qualities and ability to regulate indoor humidity while being fully biodegradable.

Reclaimed and recycled materials, including reused bricks, salvaged timber, or insulation from recycled fabrics, support a circular economy and help reduce construction waste (Aksamija, 2021).

In addition to materials, sustainable architecture relies heavily on **bioclimatic design strategies**—orienting buildings to capture sunlight, maximize natural ventilation, and reduce reliance on mechanical systems. These passive approaches help lower energy consumption while enhancing occupant comfort and health.Sustainable architecture is not only about energy efficiency or technical choices; it reflects a broader ethical commitment to build spaces that respect the environment and serve communities. It combines **ecological intelligence**, **cultural awareness**, and **social equity**, paving the way for buildings that regenerate rather than degrade ecosystems (UNEP, 2023).In this way, architecture becomes a powerful tool for building a sustainable future—where innovation, nature, and human well-being are not in conflict but work in harmony.

II.4.2. Sustainable Development Goals

1. No Poverty and **eradication of extreme poverty by 2030 is a major goal of sustainable development.** After decades of progress, the COVID-19 pandemic reversed this trend, pushing nearly 90 million more people into extreme poverty, bringing the total to 670 million by the end of 2022. If no action is taken, 575 million people will still be affected in 2030, mainly in sub-Saharan Africa. Poverty is driven by unemployment, social exclusion, and vulnerability to crises. **Social protection is essential**, yet 55% of the global population lacks access to it. Although 105 countries have implemented measures which most of them are temporary.

2- Zero Hunger : This goal is crucial to be achieved by 2030. Since 2015, the situation has continued to worsen due to the combined effects of the pandemic, conflicts, climate change, and growing inequalities. In 2022, about 735 million people suffered from chronic hunger, while 2.4 billion faced food insecurity. Malnutrition has severe consequences on health and human development, reducing productivity and slowing economic growth. By 2030, more than 600 million people could still be affected by hunger, worsened by rising food prices and global crises. Investing in agriculture and

social protection systems is essential to strengthen food security and promote sustainable development. Eradicating hunger remains a key challenge in achieving the other Sustainable Development Goals **[37]**.

3. Good Health and Wellbeing : Progress has been made in improving people's health.146 out of 200 countries have met the SDG target on under-five mortality. Effective HIV treatment has reduced AIDS-related deaths globally by 52% since 2010, and at least one tropical disease has been eliminated in 47 countries. However, inequalities in access to health care persist. The COVID-19 pandemic and other ongoing crises have hampered progress towards Goal 3. Childhood immunizations have declined by the largest amount in three decades, and deaths from tuberculosis and malaria have increased compared to pre-pandemic levels. The SDG Goals promise to end the epidemics of AIDS, tuberculosis, malaria and other communicable diseases by 2030. The aim is to achieve universal health coverage and 'access to affordable medicines and vaccines for all **[38].**

4. Quality Education : By 2030, approximately 84 million children and young people will remain out of school, while nearly 300 million students will lack fundamental skills in reading and mathematics, essential for their success. To address this issue, it is crucial to invest in education by making it free and compulsory, increasing the number of teachers, improving school infrastructure, and promoting digital transformation. Indeed, education plays a key role in reducing inequalities and contributes to achieving gender equality **[39]**.

5. Gender Equality : Gender equality is a fundamental right. However, the world is still far from achieving this goal by 2030. Women and girls make up half of the global population and, therefore, represent a vital resource for development. Yet, progress toward social justice remains limited. On average, women earn 23% less than men worldwide and take on three times more unpaid domestic and caregiving work. Sexual violence and exploitation, the unequal division of household labor, and the underrepresentation of women in public life continue to be major obstacles to gender equality **[40].**

6. CleanWater and Sanitation : Access to safe drinking water, sanitation, and hygiene is a fundamental human necessity. However, water demand is rising due to population growth, urbanization, and the increasing needs of the agricultural, industrial, and energy sectors. Climate change is exacerbating this pressure by worsening water scarcity through rising global temperatures. To ensure universal access to safe and affordable drinking water by 2030, it is essential to invest in infrastructure and sanitation systems, protect and restore water-related ecosystems, and promote hygiene education **[41]**.

7. Affordable and Clean Energy : Between 2015 and 2021, the share of the global population with access to electricity increased from 87% to 91%. However, if the current trend continues, 660 million people will still be without electricity by 2030, while nearly 2 billion will continue relying on polluting fuels and technologies for household tasks. It is therefore crucial to invest in clean energy sources such as solar, wind, geothermal, and thermal energy **[42]**.

8. DecentWork and Economic Growth : It remains essential to strengthen employment, particularly for young people, reduce informal work and labor market inequalities, and ensure safe working environments. In 2022, the global unemployment rate significantly declined, dropping from 6.6% in 2020 to 5.4%, reaching a level even lower than before the pandemic.Decent work is defined by fair wages, a safe working environment, social protection for families, and opportunities for professional growth and social integration **[42]**.

9. Industry, Innovation and Infrastructure : To promote economic growth, job creation, and improved living conditions, especially in developing regions, strong infrastructure is essential. Sustainable industrialization, in turn, ensures that industries operate efficiently while minimizing their environmental impact. Moreover, innovation plays a crucial role in technological advancements, increased productivity, and the development of solutions to global challenges such as climate change and resource scarcity. Thus, this goal is based on three key pillars : the development of resilient infrastructure, the promotion of inclusive and sustainable industrialization, and the encouragement of innovation **[43].**

10. Reduced Inequalities : Inequalities threaten social and economic development, hinder poverty reduction, and harm individual well-being. Reducing inequalities requires a fair distribution of resources, investments in education, social protections, as well as efforts to combat discrimination and support marginalized groups. There are various forms of inequality—economic, social, ethnic, and gender-based—affecting vulnerable groups such as women, people with disabilities, migrants, and refugees. These inequalities have serious consequences, including crime, illness, and poverty. to address this, discriminatory practices must be eliminated across various sectors, including education, healthcare, and access to decent employment **[44]**.

11. Sustainable Cities and Communities : In 2022, the global population reached 8 billion, with more than half living in urban areas—a figure expected to rise by 2050. Currently, 1.1 billion people live in slums, a number that could double in the next 30 years. Achieving sustainable development requires a fundamental transformation in how urban spaces are built and managed. Adopting a

sustainable approach would help reduce traffic congestion, greenhouse gas emissions, and urban sprawl, ensuring decent and stable living conditions for all **[45].**

12. Responsible Consumption and Production : Our planet is depleting its resources. By 2050, the global population will reach 9.8 billion, and even three planets would not be enough to meet its needs. We must reduce our consumption levels. Food waste, in particular, must be eliminatedevery year, 931 million tons of food are wasted, while a significant portion of the world's population suffers from hunger. It is essential to rethink our consumption habits and move toward a circular economy **[46].**

13 Climate Action : Climate change constitutes a global threat that will inevitably affect every individual on Earth. Driven by human activities, it leads to extreme weather events, rising sea levels, as well as droughts and floods, jeopardizing societal stability and heightening the risks of conflicts and large-scale migrations. In the absence of decisive action, global temperatures could exceed 3°C, endangering ecosystems and exacerbating food and water insecurity. To limit warming to 1.5°C, a 50% reduction in emissions by 2030 is imperative, yet current efforts remain inadequate. Transitioning to a sustainable economy requires a profound transformation of the energy, transportation, industrial, and agricultural sectors, alongside substantial investment in renewable energy sources **[47].**

14. Life BelowWater : Goal 14 aims to protect and sustainably use the oceans, which are essential to the balance of our planet. Covering 75% of the Earth and containing 97% of its water, they absorb 23% of CO_2 emissions, playing a key role in climate regulation. As vital sources of food, medicine, and jobs, they are now severely threatened by pollution, acidification, and warming. Every year, millions of tons of plastic flood the seas, endangering biodiversity and coastal economies. To safeguard this fragile ecosystem, it is urgent to strengthen research, enhance international cooperation, and reduce plastic consumption **[48].**

15. Life on Land : Ecosystems are vital to human life, yet they are facing a severe crisis due to climate change, pollution, and deforestation—primarily driven by agriculture. Land degradation impacts 1.3 billion people, and one million species are at risk of extinction. The destruction of forests worsens climate change and threatens biodiversity.To take action, we must recycle, adopt responsible consumption habits, and support local initiatives that protect nature **[49].**

16. Peace, Justice and Strong Institution : Goal 16 aims to establish peaceful and inclusive societies, ensure equitable access to justice, and strengthen transparent and accountable institutions. However, the resurgence of conflicts, notably the war in Ukraine, threatens these advancements, as

evidenced by the alarming increase in civilian deaths in 2022. Instability hinders development and exposes populations to violence and exploitation. It is imperative to reinforce the rule of law, combat the proliferation of illicit arms, and fight corruption. Without concrete action, injustice and exclusion risk exacerbating tensions. It is everyone's responsibility to defend their rights, promote inclusion, and demand accountability from leaders **[50].**

17. Partnership for the Goals : Goal 17 aims to strengthen global partnerships for inclusive sustainable development. Developing countries face rising debt, and public aid remains insufficiently directed toward their needs. It is crucial to mobilize more resources, enhance cooperation, and monitor progress on a global scale. Everyone can contribute by supporting local initiatives and encouraging public-private partnerships **[51].**

To achieve these goals, societies have to make certain transitions which are essential. There is a broad consensus on the following transition to make future societies :

- ✓ **A demographic transition** : from a continually growing population to one that is stable.
- ✓ **A resource transition** to an economy that is not solely obsessed with growth, rather relies more on nature's income and protects ecosystem capital from depletion.
- ✓ **technological transition** from pollution-intensive economic production to environment friendly processes.
- ✓ **Apolitical/sociological transition**
- ✓ **Acommunity transition [1]**

Figure 25 : Sustainable-development-goals [20]

Beyond 2030 : structures for achieving sustainable development (Tom Cernev and Richard Fenner, 2024) in Frontiers in Climate
16 Octobre 2024 **doi: 10.3389/fclim.2024.1453366**

This paper highlights the urgent need for a renewed framework for sustainable development beyond the **2030 Sustainable Development Goals (SDGs) deadline**. Drawing lessons from both the **Millennium Development Goals (MDGs)** and SDGs, the authors emphasize their limitations, particularly the **lack of legally binding commitments and robust monitoring mechanisms**. In light of escalating global challenges—including **climate change, socio-economic inequalities, catastrophic risks, and the transgression of planetary boundaries**—they propose a new, structured framework centered around **seven key objectives** grouped into **four overarching categories**: **environmental preservation and sustainable economic growth**, **universal access to essential infrastructure and services**, **reducing inequalities while strengthening education and healthcare**, and **enhancing global governance and international cooperation**. To ensure meaningful progress, the authors advocate for a **rigorous oversight system featuring five-year review cycles, legally enforceable commitments for governments and corporations, and a combination of incentives and penalties**. They call for a **science-driven, approach** to prevent a looming global crisis and pave the way for a more sustainable and equitable future.

II.5.The principles of Soustainable development and their origins:

II.5.1. precautionary principle: Situations that present a potential risk of serious or irreversible damage, in the absence of scientific knowledge on the subject.It is the responsibility of the public authorities.This principle is defined for the environment but can be applied to several areas (health, food) and the precautionary measures can be temporary (research) or definitive prohibition.

The fifteenth principle of the RIO declaration explains this notion :

"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (CNUED), 1992.

II.5.2. Principle of prevention: A situation with known risk and foreseeable damage.

The Law No. 76-663 of July 19, 1976, on classified installations for environmental protection (ICPE) laid the foundation for the principle of responsibility in environmental matters in France. It is based on several fundamental principles, including the responsibility of operators of installations that may present dangers to the environment.

Link with the principle of responsibility :

- **Operator responsibility :** Any person operating a classified installation is responsible for the nuisances it may cause and must take all necessary measures to prevent environmental damage.
- **Polluter-pays principle:** This law contributed to the application of the principle that those who cause pollution or environmental damage must bear the costs.
- **Sanctions and reparations :** In case of non-compliance with regulations, administrative and criminal sanctions are provided, requiring the operator to remedy the pollution or risks caused.
- **Administrative control :** The State has the authority to monitor and authorize ICPEs to prevent environmental and health risks.

Aims to prevent pollution and subjects to a prior authorization regime factories, depots, workshops, construction sites and, in general, all industrial or craft installations which may present nuisances or dangers to the environment and health.

NB: prevention concerns proven risk situations involving predictable damage, precaution concerns situations of serious and irreversible risk for which we do not have scientific evidence.

II.5.3. Responsibility/ Polluter pays: Responsibility, in the common sense, is the fact that each person is required to answer legally or morally for his actions and decisions and to assume the consequences.Everyone must become aware of their actions and take responsibility**.**

This is the polluter pays principle

The seventh and thirteenth principles of the Rio Declaration (Earth Summit-1992) introduced the concept of environmental responsibility of developed countries: "Developed countries recognize their responsibility in the international effort towards sustainable development, taking into account the pressures that their societies exert on the global environment and the technologies and financial resources at their disposal." "States must develop national legislation concerning liability for pollution and other environmental damage and compensation for their victims."

II.5.4. Equity: It assumes two types of equity

1- Intergenerational: the present generation has the duty to preserve the planet's natural resources for future generations

2- Intragenerational: « solidarity between the richest and the poorest."

The third principle of the RIO declaration**:**

"The right to development must be realized in a manner that equitably meets the developmental and environmental needs of present and future generations."

II.5.5. Right to information and the principle of participation: A person must be informed of the facts or decisions that concern him, so that he can act accordingly in his own interest or in the collective interest. (Democracy) Citizen participation in the decision-making process is one of the conditions for building sustainable development.

Origine : The tenth principle of the Rio Declaration:

"Environmental issues are best addressed through the participation of all concerned citizens, at the appropriate level. At the national level, everyone should have appropriate access to environmental information held by public authorities, including information on hazardous substances and activities in their communities, and the opportunity to participate in decision-making processes. States should facilitate and encourage public awareness and participation by making information available to the public."

II.5.6. Principle of subsidiarity: Aims to privilege the lower level of decision-making power as long as the higher level cannot act more effectively.

The **principle of subsidiarity** states that decisions should be made at the most local level possible, as long as that level is capable of handling the matter effectively. A higher authority (such as a national government or an international organization) should intervene only when the lower level (regional, local, or individual) cannot act independently.

Key Principles :

1. **Decentralization of Power :** Decisions should be made by the authority closest to the people affected.
2. **Efficiency and Complementarity :** Higher-level intervention is justified only if it improves the management of an issue that lower levels cannot resolve on their own.
3. **Autonomy and Responsibility:** The principle encourages local initiatives and ensures that decisions are adapted to specific circumstances.

4. **Balance Between Local and Central Authority:** Higher levels are not excluded but should play a supporting role rather than taking control.

Origines of principle : All principles of sustainable development originate from the Rio de Janeiro Declaration, Brazil June 3-14, 1992. They are cited below as published in the EARTH Summit in 1992

Principle 1

Human beings are at the center of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.

Principle 2

In accordance with the Charter of the United Nations and the principles of international law, States have the sovereign right to exploit their own resources pursuant to their environmental and developmental policies, and they have the duty to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or areas beyond national jurisdiction.

Principle 3

The right to development must be fulfilled so as to equitably meet the developmental and environmental needs of present and future generations.

Principle 4

In order to achieve sustainable development, environmental protection must be an integral part of the development process and cannot be considered in isolation from it.

Principle 5

All States and all people must cooperate in the essential task of eradicating poverty as an indispensable requirement for sustainable development, in order to reduce disparities in living standards and better meet the needs of the majority of people in the world.

Principle 6

The special situation and needs of developing countries, particularly the least developed and those most environmentally vulnerable, must be given special priority. International actions in the field of environment and development should also take into account the interests and needs of all countries.

Principle 7

States shall cooperate in a spirit of global partnership to conserve, protect, and restore the health and integrity of the Earth's ecosystem. In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. Developed countries acknowledge the responsibility they bear in the international pursuit of sustainable development, considering the pressures their societies place on the global environment and the technologies and financial resources they command.

Principle 8

To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.

Principle 9

States should cooperate to strengthen endogenous capacities for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge and by facilitating the development, adaptation, dissemination, and transfer of technologies, including innovative and advanced technologies.

Principle 10

Environmental issues are best handled with the participation of all concerned citizens at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.

Principle 11

States shall enact effective environmental legislation. Environmental standards, management objectives, and priorities should reflect the environmental and developmental context to which they apply. Standards applied by some countries may be inappropriate and cause unwarranted economic and social costs for other countries, particularly developing countries.

Principle 12

States should cooperate to promote a supportive and open international economic system that would

lead to economic growth and sustainable development in all countries to better address environmental degradation. Trade policy measures for environmental purposes should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade. Unilateral actions to deal with environmental challenges outside the jurisdiction of the importing country should be avoided. Environmental measures addressing transboundary or global issues should, as far as possible, be based on international consensus.

Principle 13

States shall develop national law regarding liability and compensation for the victims of pollution and other environmental damage. States shall also cooperate expeditiously and more determinedly to develop further international law regarding liability and compensation for adverse environmental effects caused by activities within their jurisdiction or control to areas beyond their jurisdiction.

Principle 14

States should effectively cooperate to discourage or prevent the relocation and transfer to other States of any activities and substances that cause severe environmental degradation or are found to be harmful to human health.

Principle 15

In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Principle 16

National authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments, taking into account the principle that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment.

Principle 17

Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority.

Principle 18

States shall immediately notify other States of any natural disasters or other emergencies that are likely to produce sudden harmful effects on the environment of those States. The international community should make every effort to help States afflicted by such disasters.

Principle 19

States shall provide prior and timely notification and relevant information to potentially affected States on activities that may have a significant transboundary harmful effect on the environment and shall consult with those States at an early stage and in good faith.

Principle 20

Women play a vital role in environmental management and development. Their full participation is essential to achieving sustainable development.

Principle 21

The creativity, ideals, and courage of the youth of the world should be mobilized to forge a global partnership in order to achieve sustainable development and ensure a better future for all.

Principle 22

Indigenous people and their communities, as well as other local communities, have a vital role in environmental management and development because of their knowledge and traditional practices. States should recognize and duly support their identity, culture, and interests and enable their effective participation in achieving sustainable development.

Principle 23

The environment and natural resources of people under oppression, domination, and occupation shall be protected.

Principle 24

Warfare is inherently destructive of sustainable development. States shall therefore respect international law providing protection for the environment in times of armed conflict and cooperate in its further development as necessary.

Principle 25

Peace, development, and environmental protection are interdependent and indivisible.

Principle 26

States shall resolve all their environmental disputes peacefully and by appropriate means in accordance with the Charter of the United Nations.

Principle 27

States and people shall cooperate in good faith and in a spirit of partnership in the fulfillment of the principles embodied in this Declaration and in the further development of international law in the field of sustainable development **(PLANET EARTH SUMMIT, 1992)**

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II.6.Sustainable development stakeholders: These are all those who are involved in the implementation of the principles of Sustainable Development in all areas. Each of them contributes to the realization of this project at different scales (economic, environmental and social).

1- Non-governmental organizations (NGOs) : They advocate addressing the global mechanisms that obstruct sustainable development, such as the impact of unsustainable production, consumption, and marketing methods in industrialized countries and the predation on natural resources **[52]** for more explanation:http://www.un.org/esa/coordination/ngo/

2- Trade unions and workers : There are 2.5 billion workers worldwide, 40% of whom are women. Around 20% are unionized, and 500 million earn less than $1 per day. Trade unions are at the forefront of advocating for human rights, changes in production methods, and corporate social responsibility. At the 2002 World Summit on Sustainable Development, they called for better access to public goods **[53] http://www.adequations.org/spip.php?rubrique63.**

3- Local authorities : Chapter 28 of Rio's Agenda 21 highlights the crucial role of local governments in implementing sustainable development at the territorial level. They are responsible for developing, managing, and maintaining key economic, social, and environmental infrastructure. Additionally, they oversee planning processes, establish local environmental policies and regulations, and support the enforcement of national and regional environmental strategies. Being the administrative entities closest to citizens, they play a vital role in educating, engaging, and incorporating public perspectives to promote sustainable development **[54]**. http://www.adequations.org/spip.php?article458.

4- **Businesses and industries** : Small and medium-sized enterprises (SMEs) and very small enterprises (VSEs) have an important role to play. Multi-partner initiatives have been developed in the areas of water management, energy and health **[55]**.

http://www.adequations.org/spip.php?rubrique201#outil_sommaire_1.

5- Scientific and technical communities : Technological progress and research play a crucial role in developing innovative solutions for renewable energy, sustainable agriculture, waste management, and combating climate change. Scientists provide data and recommendations to guide policies and actions taken by various stakeholders **[56] ; (*La Recherche au servie du DD*, Ministère de l'Ecologie, Documentation française, 2005).**

6- Governments : It plays a key role by enacting laws, regulations, and incentive policies to promote sustainable development. They can establish environmental standards, support the circular economy, and invest in sustainable infrastructure. Additionally, international organizations such as the UN, the European Union, and the World Bank contribute to these efforts through financial support and agreements **[57]**.

7- Citizens and consumers : Individuals' consumption choices and lifestyles have a direct impact on sustainable development. By opting for environmentally friendly products, reducing their energy consumption, and adopting responsible behaviors such as waste sorting or using sustainable transportation, they actively contribute to the ecological transition **[58].**

8- The Media : The media play a crucial role in sharing information about sustainable development challenges. They educate the public, emphasize the urgency of climate crises, and showcase positive initiatives **[59].**

II.7. Key dates in sustainable development

- **UCN 1951** : Published the first global report on the state of the environment, emphasizing the need to balance economic development with ecological preservation.
- **Stockholm 1972** : United Nations Conference on the Environment highlighted the incompatibility between unlimited economic growth and the finite availability of non-renewable resources. **Outcome**: Creation of the United Nations Environment Programme (UNEP).
- **Meadows Report et al. 1972** : Warned about the risks of ecosystem overexploitation, pollution, unchecked economic growth, and rapid population expansion.
- **The Club of Rome 1972** : Gained global recognition with its report **"The Limits to Growth"**. This think tank, comprising scientists, economists, government officials, and

industry leaders from 53 countries, advocated for limiting growth and embracing sustainable development principles.

- **Brundtland Report 1987 « Our Common Future »** Chaired by Gro Harlem Brundtland, this report introduced the term **"sustainable development"**, defined as **« development that meets the needs of the present without compromising the ability of future generations to meet their own needs »**.
- **Rio Earth Summit 1992** : Since 1972, the UN has hosted these decennial conferences. Following Nairobi in 1982, the 1992 summit in Rio brought together 178 countries to address major environmental challenges (global warming, deforestation, desertification). It reinforced the collective commitment to protecting, preserving, and restoring the environment for a sustainable future.

❖ **The Conference of the Parties:** Following the Rio Summit in 1992, which brought together 178 countries, a climate convention was adopted to reduce greenhouse gas emissions. Each year, the signatory states (the "parties") meet at the Conference of the Parties (COP) to coordinate global efforts to combat climate change, with the involvement of non-governmental actors.

COP 1: Berlin, Germany (1995): First meeting of the parties to discuss initial commitments to reduce emissions. The Berlin Agreement lays the foundations for a future binding protocol for industrialized countries, paving the way for the adoption of the Kyoto Protocol in 1997.

COP 2: Geneva, Switzerland. 8-19 July 1996: Adoption of the "Geneva Declaration", recognizing the need for stronger action against climate change. Bringing together the signatory countries of the United Nations Framework Convention on Climate Change (UNFCCC).

COP 3: Kyoto, Japan, 1-11 December 1997: Adoption of the Kyoto Protocol, establishing binding emission reduction targets for developed countries.

COP 4: Buenos Aires, Argentina. 2 - 13 November 1998

Development of the "Buenos Aires Action Plan" for the implementation of the Kyoto Protocol.

COP 5: Bonn, Germany. 25 October - 5 November 1999

Technical discussions on the mechanisms for implementing the Kyoto Protocol.

COP 6: The Hague, Netherlands. 13 - 25 November 2000.

Negotiations fail to reach agreement on flexibility mechanisms and financing.

COP 6-bis: Bonn, Germany. 16 - 27 July 2001

Agreement on the "Bonn Accords", defining the mechanisms for implementing the Kyoto Protocol.

COP 7: Marrakech, Morocco. 29 October - 10 November 2001

Adoption of the "Marrakech Accords", detailing the rules of the Kyoto Protocol.

COP 8: New Delhi, India. October 23 - November 1, 2002

Highlighting sustainable development and adaptation to the impacts of climate change.

COP 9: Milan, Italy. December 1 - 12, 2003

Discussions on financial mechanisms to support developing countries.

COP 10: Buenos Aires, Argentina. December 6 - 17, 2004

Focus on adaptation and measures to assist vulnerable coun countries in their climate actions

COP11/CMP1: Montreal, Canada. 28 November - 9 December 2005

First Meeting of the Parties to the Kyoto Protocol (CMP1) and discussions on post-2012 commitments.

NB/ CMP (Meeting of the Parties to the Kyoto Protocol): Convenes only countries that have ratified the Kyoto Protocol (adopted in 1997 and entered into force in 2005).

COP12/CMP2: Nairobi, Kenya. 6 - 17 November 2006

Establishment of the Adaptation Fund to finance projects in developing countries.

COP13/CMP3: Bali, Indonesia. 3 - 14 December 2007

Adoption of the "Bali Action Plan", a roadmap for a new global climate agreement.

COP14/CMP4: Poznan, Poland. 12 December 2008

Discussions on climate finance and technology transfer mechanisms.

COP15/CMP5: Copenhagen, Denmark. 7-18 December 2009

Intense negotiations culminate in the “Copenhagen Accord,” recognizing the need to limit global warming to 2°C.

COP16/CMP6: Cancun, Mexico. 29 November-10 December 2010

Adoption of the “Cancun Accords,” establishing the Green Climate Fund and recognizing the need to limit global warming to 2°C.

COP17/CMP7: Durban, South Africa. 28 November-11 December 2011

Launch of the “Durban Platform,” aimed at developing a new global climate agreement by 2015.

COP18/CMP8: Doha, Qatar. November 26 - December 8, 2012

Adoption of the "Doha Amendment", extending the Kyoto Protocol until 2020.

COP19/CMP9: Warsaw, Poland. November 11 - 23, 2013

Establishment of the "Warsaw International Mechanism" to address loss and damage associated with the impacts of climate change.

COP20/CMP10: Lima, Peru. December 1 - 12, 2014

Adoption of the "Lima Action Plan", setting the basis for the Paris climate agreement in 2015.

COP21/CMP11: Paris, France. November 30 - December 12, 2015

Adoption of the "Paris Agreement" committing countries to limit global warming to well below 2°C, with efforts to limit it to 1.5°C.

COP22/CMP12/CMA1: Marrakech, Morocco. 7 - 18 November 2016

Implementation of the Paris Agreement and launch of the " Marrakech Partnership for Global Climate Action".

COP23/CMP13/CMA1-2: Bonn, Germany. 6 - 17 November 2017

Chaired by Fiji, this conference advanced discussions on the implementation guidelines for the Paris Agreement.

COP24/CMP14/CMA1-3: Katowice, Poland. 2 - 14 December 2018

Adoption of the "Katowice Package", detailing the rules for implementing the Paris Agreement.

COP25/CMP15/CMA2: Madrid, Spain. 2 - 13 December 2019

Originally scheduled for Santiago, Chile, the conference was moved to Madrid. Discussions focused on market mechanisms and climate finance.

COP26/CMP16/CMA3: Glasgow, United Kingdom. 31 October - 12 November 2021

Postponed by one year due to the COVID-19 pandemic, the conference produced the"Glasgow Climate Pact", calling for more ambitious emissions cuts and a coal phase-out.

COP27/CMP17/CMA4: Sharm el-Sheikh, Egypt. 6 - 18 November 2022

Establishment of a loss and damage fund to support vulnerable countries affected by the impacts of climate change.

COP28/CMP18/CMA5: Dubai, United Arab Emirates. 30 November - 12 December 2023

Discussions focused on accelerating the energy transition and implementing climate finance commitments.

COP29/CMP19/CMA6: Baku, Azerbaijan. 11-22 November 2024

The negotiations resulted in an agreement on the phase-down of fossil fuel use and strengthened commitments on climate adaptation.

COP30/CMP20/CMA7: Belém, Brazil. 10-21 November 2025

This conference, scheduled to take place in the Amazon, will focus on the protection of tropical forests and the role of ecosystems in regulating the climate.

These conferences illustrate the ongoing efforts of the international community to combat climate change and strengthen commitments to a sustainable future.

II.8. Some indicators of sustainable development: They cover different dimensions environmental, économic and social dimensions of sustainable development.

- **Environmental Index**

II.8.1.The Ecological Footprint: The ecological footprint measures how much natural resources a population (individual, city, country, etc.) consumes and compares it to the Earth's ability to regenerate those resources. It quantifies this consumption in terms of the biologically productive land and sea area needed to provide the resources used and absorb the waste generated.Its main goal is to assess the sustainability of our lifestyles and highlight ecological overshoot—when resource demand exceeds the planet's capacity to replenish them.

Components of the Ecological Footprint : The ecological footprint is made up of several key elements, representing different types of resource consumption :

- **Cropland** : Land used for growing food and fiber.
- **Grazing land** : Areas needed for livestock.
- **Forests** : Land required for timber production and carbon dioxide (CO2) absorption.
- **Built-up land** : Space occupied by human infrastructure such as cities and roads.
- **Fishing grounds** : Ocean and freshwater areas needed to sustain fish and seafood harvests.
- **Carbon absorption land** : Forested areas required to offset CO2 emissions from fossil fuel use.

Calculation and Units : The ecological footprint is measured in **global hectares (gha)**, a standardized unit that accounts for variations in biological productivity across different land types. Its calculation is complex and considers multiple factors, including energy consumption, dietary habits, transportation choices, and waste production.

Why the Ecological Footprint Matters : It provides how our lifestyles impact the planet and underscores the urgency of reducing resource consumption.It serves as a valuable tool for evaluating the sustainability of government policies and business strategies.It encourages responsible behaviors such as reducing energy use, opting for sustainable transportation, and choosing locally sourced, seasonal products **60].** .

To calculate our ecological footprint, we do this exercise live with the students using the websites **« www.wwf.fr and www.footprintnetwork.org »**

Biocapacity and impact on the environment: It refers to the ability of an ecosystem to regenerate the resources consumed by humans and to absorb the waste they produce. It is usually expressed in **global hectares (gha)** per person and depends on factors such as land productivity, resource availability, and ecological management. Its main aspects are **:**

1. **Renewable Resource Generation** : Encompasses forests, croplands, fisheries, and grazing areas that supply food, timber, and raw materials.
2. **Waste Processing** : The ecosystem's capability to absorb and neutralize waste, especially carbon emissions.
3. **Sustainable Carrying Capacity** : The extent to which an area can support human activity without depleting its natural assets.

- **Biocapacity vs. Ecological Footprint :** When biocapacity exceeds the ecological footprint, a region is ecologically sustainable, meaning resources regenerate faster than they are consumed but When biocapacity is lower than the ecological footprint, a region faces an ecological deficit, where resource consumption outpaces regeneration, leading to environmental degradation.

II.8.2. Environmental performance index : is an index created to evaluate, compare and improve the effectiveness of environmental policies. It assesses environmental performance. The 16 criteria of the index are: Access to drinking water, Sanitation, Infant mortality, Indoor pollution, Particulate matter in urban air, Ozone in air, Nitrates in water, Water consumption, Protection of wild areas, Protection of ecoregions, Logging,Overfishing, Agricultural subsidies, Energy efficiency, Renewable energy,CO2 emissions. They can grouped in 6 fields : Environmental health, Air pollution, Water resources
Biodiversity, Natural resources, Climate change.
In 2022 this index is based on 40 indicators divided into 11 categories, which are grouped into three main areas :

1. **Environmental health** (20%) : Measures the impact of the environment on human health, considering air quality, access to drinking water, and waste management.

2. **Ecosystem vitality** (42%) : Evaluates biodiversity conservation and natural resource management, including sustainable agriculture and habitat preservation.
3. **Climate change mitigation** (38%) : Analyzes countries' efforts to reduce greenhouse gas emissions and promote renewable energy

Each country receives a score between 0 and 100 for each indicator, with 100 representing the best possible performance. These scores are then weighted and combined to establish an overall ranking. In 2022, the top five ranked countries were Denmark, the United Kingdom, Finland, Malta, and Sweden. France ranked 12th, performing particularly well in environmental health (score of 83.9) and ecosystem preservation (score of 64). This index remains a key reference in the analysis of global environmental policies and serves as a tool encouraging governments to adopt more effective ecological strategies **[61].**

- **Social index**

II.8.3. Human development index: The HDI iscalculated by the (UNDP). United Nations Development Programme. It ranges between 0 and 1. The closer the HDI is to 1, the higher the country's level of development. It allows for the establishment of an annual ranking of countries and integrates three areas :

1- Health/longevity (measured by life expectancy at birth), which measures the satisfaction of basic material needs such as access to healthy food, clean water, adequate housing, good health and medical care.

2- Educational attainment. Measured by the average years of schooling for adults over 25 and the expected years of schooling for school-age children. The ability to participate in decision-making in the workplace or in society.

3- Standard of living mobility or access to culture.

The (UNDP) published its 2016 Human Development Index on March 21 in Stockholm. In the world ranking, Algeria comes in 83rd position out of 188 countries analyzed. Globally, Norway tops the rankings, followed by Australia, Switzerland, Germany and Denmark. The bottom of the ranking is occupied by five African countries: Burundi (184th), Burkina Faso (185th), Chad (186th), Niger (187th) and the Central African Republic (188th) **[62] & [63].**

The most recent Human Development Index (HDI) rankings are from the United Nations Development Programme's (UNDP) Human Development Report 2023/2024, published on March 2024. Switzerland ranks first with an HDI value of 0.967, followed by Norway at 0.966, and Iceland at 0.959. Algeria is positioned at 93rd with an HDI value of 0.745, reflecting a slight increase of 0.005 from the previous assessment. These statistics highlights growing inequalities in HDI values between

countries at the top and bottom of the index, emphasizing the need for renewed global cooperation to address shared challenges **[64].**

II.8.4. School enrollment rate boys/girls: The **Gender Parity Index (GPI)** measures equal access to education for boys and girls. It is calculated by comparing their enrollment rates at the same level of education. A value of 1 indicates perfect parity, while any deviation highlights inequality.Recognized by UNESCO and the World Bank, this indicator helps assess educational progress and guide policies to promote gender equality **[65].** Access to education remains unequal across regions, influenced by cultural, economic, and social factors. Enrollment rates vary from country to country, highlighting disparities between boys and girls. In 2015, in Afghanistan and South Sudan, there were 80 girls for every 100 boys in primary education. In Eritrea, Djibouti, the Central African Republic, and Niger, the average schooling duration for girls was less than six years. In South Asia, in 2008, only 61% of girls were enrolled in secondary education, compared to 74% of boys. Globally, in 2021, 118.5 million girls were out of school, underscoring the scale of the educational challenge. The 2021 UNESCO report emphasizes the importance of education as a public and common good, advocating for global solidarity and international cooperation to build a future based on human rights, social justice, respect for life, human dignity, and cultural diversity **(Carney, 2022) ; [66] ; [67]**.

II.8.5. Accessibility to care: Nearly 1.2 billion people living in developing countries face extreme poverty, depriving them of adequate access to healthcare and exposing them to numerous, sometimes severe, illnesses. According to a report by the International Labour Organization (ILO), more than half of rural populations, or 56%, do not have access to essential health services. Furthermore, 800 million individuals allocate at least 10% of their income to medical expenses, while 100 million of them fall into extreme poverty. The causes of this situation are. Firstly, the lack of healthcare infrastructure in rural areas constitutes a major barrier to medical access. Secondly, the particularly high cost of medical services, combined with inadequate social protection, exacerbates the vulnerability of these populations. Moreover, the shortage of qualified healthcare personnel significantly limits the efficiency of health systems. Finally, recurrent economic crises, along with ongoing political conflicts, further weaken healthcare structures, thereby deepening health inequalities **[68].**

Economic index :

II.8.6. GDP gross negligible product: The Gross Domestic Product (GDP) is an economic indicator used to assess the wealth generated by a country over a year as well as its level of

economic growth. However, this index has significant shortcomings, notably as it does not take into account environmental externalities, such as pollution or the depletion of natural resources, nor social disparities. In order to address these deficiencies, the Genuine Progress Indicator (GPI) offers a more comprehensive approach by adjusting GDP based on the social and ecological costs generated by economic activity **[69].**

II.9. Environmental education, Awareness and nature animation, environmental communication,

❖ **Environmental education :** Environmental education (EE) is a process that aims to raise awareness among individuals and communities about environmental issues, to develop the knowledge, attitudes and skills necessary to adopt responsible behavior towards the environment, in order to promote sustainable actions for the preservation of nature.

Programs to implement environmental education in the field integrating environmental education into school curricula, raising awareness among students about environmental issues through conferences and seminars, creating ecological clubs to involve them in concrete actions such as reforestation and recycling. Carrying out concrete actions in the field such as reforestation, cleaning up public spaces (waste collection campaigns on the beach, in the forests). At the university, for example, creating mobile applications to raise awareness and encourage environmental preservation **(Gillett, 1977; (Reid et al, 2021)**. Several programs have been implemented:

- **Eco-Schools Program (Foundation for Environmental Education- FEE)**: Intended for schools that adopt ecological practices (waste management, energy saving and protection of biodiversity - Project WILD & Project Learning Tree (PLT): These are American programs intended for teachers where educational activities on ecosystems and biodiversity are offered
- **Project WILD & Project Learning Tree (PLT) :** These are American programs intended for teachers where educational activities on ecosystems and biodiversity.

❖ Environmental awareness campaigns and Nature animation

- **Earth Hour** : This is a global event where the lights are turned off for an hour to raise awareness around the world to reduce energy consumption **[71]**
- **The "Plastic Free July** movement Reducing plastic and refusing to use it for a month **[72]**
- **Animated films and educational series**

What we can do to reduce our own own single-use plastics.
https://www.nationalgeographic.com/environment/planetorplastic

❖ **Environmental communication in communities :** Citizen science projects

• **iNaturalist :** A platform where users can document biodiversity and contribute to scientific research [73] https://www.inaturalist.org.

• **The Great Backyard Bird Count** : A global event involving amateur birdwatchers and data collectors [74] https://www.birdcount.org.

In conclusion, environmental education, awareness, and ecological communication play a crucial role in fostering sustainable lifestyles and encouraging collective engagement. Through school programs, media campaigns, digital platforms, and community initiatives, these efforts educate, inspire, and motivate action [75].

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Glossary

Biodiversity: The variety and variability of life on Earth, including species and ecosystems diversity

Biodegradable: Capable of being decomposed by bacteria or other living organisms, reducing pollution.

Carbon Footprint: The total amount of greenhouse gases emitted directly or indirectly by an individual, organization, event, or product.

Carbon Neutrality: Achieving net-zero carbon emissions by balancing emitted and offset carbon.

Carbon Offset: A reduction in emissions of carbon dioxide or other greenhouse gases made to compensate for emissions made elsewhere.

Carrying Capacity: The maximum number of individuals or activities an environment can sustain without degradation.

Circular Economy: An economic system aimed at eliminating waste and promoting the continual use of resources.

Climate Change Mitigation: Efforts to reduce or prevent the emission of greenhouse gases.

Climate Resilience: The ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate.

Corporate Social Responsibility (CSR): A company's commitment to manage its social, environmental, and economic effects responsibly and in line with public expectations.

Decarbonization: The reduction of carbon dioxide emissions through the use of low-carbon power sources and clean technology.

Ecological Footprint: A measure of how much nature a person, population, or activity requires to produce the resources it consumes and absorb the waste it generates.

Energy Efficiency: Using less energy to perform the same task or produce the same result.

Environmental Impact Assessment (EIA): A process to evaluate the environmental consequences of proposed actions before decisions are made.

Environmental Justice: The fair treatment and involvement of all people in environmental laws, regulations, and policies.

Green Economy: An economy that aims at reducing environmental risks and ecological scarcities.

Green Technology: Technology that is considered environmentally friendly based on its production process or supply chain.

Greenwashing: Misleading marketing that gives the impression a company or product is environmentally friendly when it's not.

Greenhouse Gases (GHG): Gases in Earth's atmosphere that trap heat, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Life Cycle Assessment (LCA): A method to assess environmental impacts associated with all the stages of a product's life.

Net Zero: Balancing the amount of emitted greenhouse gases with an equivalent amount of removal or offsetting.

Non-Renewable Resources
Resources that cannot be replenished on a human timescale, such as fossil fuels and minerals.

Renewable Energy: Energy derived from natural sources that are replenished constantly, such as solar, wind, or hydro power.

Resource Efficiency: Using the Earth's limited resources in a sustainable manner while minimizing environmental impact.

Stakeholder Engagement: The process by which an organization involves people who may be affected by the decisions it makes.

Sustainable Consumption: The use of products and services that have minimal impact on the environment and allow future generations to meet their needs.

Sustainable Development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable Development Goals (SDGs): 17 global goals adopted by the Uinted Nations to address global challenges such as poverty, inequality, and climate change by 2030.

Sustainability Reporting: Disclosing a company's environmental, social, and governance (ESG) performance.

Triple Bottom Line: A sustainability framework that includes social, environmental, and economic dimensions.