Chapter 3 : Natural Resources

Introduction

Since the dawn of time, natural resources have been the basis of life for living beings. They are one of the main causes of wars and invasions of poor countries by those rich in natural resources. Natural resources play a vital role in the well-being of populations, and countries' economies depend primarily on their exploitation. Unfortunately, however, the future of humanity and the planet is threatened by economic development policies based on the overexploitation of natural resources, which cause considerable damage to the environment. As a result, environmental regulations are being introduced, including the rational use of natural resources in accordance with environmental standards, which is one of the major objectives of sustainable development.

1. Definition of natural resources

Natural resources are all goods that come from nature without human intervention. They are vital to the social and economic development of humanity.

2. Different types of natural resources

There are two types of natural resources: renewable and non-renewable.

2.1. Renewable natural resources

These are natural assets that regenerate or grow back and whose reserves can be replenished naturally.

2.1.1. Water

Water is essential for life on Earth. It accounts for 63% of the human body's weight and is one of the renewable natural resources that is regenerated by the hydrological cycle. However, this resource can become non-renewable due to human activities such as the pollution of water supplies (e.g. groundwater pollution), etc. The Earth, also known as the ‘blue planet’, is mostly made up of water, as oceans cover approximately 71% of its surface area, covering around 361 million km² of the globe's 510 million km² surface area, representing 97.5% of the total amount of water. Of all the water on Earth, only 2.5% is fresh water, and of this amount, approximately 2% is locked up in ice caps and glaciers, 0.5% exists in the soil, and only 0.014% is accessible and can be found in lakes, rivers, streams, etc. To this end, the oceans play a

key role in the constant movement of water across the globe: in the atmosphere, on the surface and underground, which is called the water cycle or hydrogeological cycle.

2.1.1.1. The water cycle

The water cycle is the path followed by water on Earth as it passes through several states (liquid, solid and gaseous) and follows a four-step process: - Evaporation: water evaporates, transforming from liquid water into water vapour; Evaporation is a very important phenomenon because it allows clouds to form in the atmosphere.

- **Condensation:** this allows water to change from a vapour to a liquid or solid state in the clouds in the atmosphere when it encounters cold air currents, causing precipitation in the form of rain, snow or hail, depending on weather conditions.

- **Precipitation**: runoff water on the Earth's surface flows into rivers, which all flow into the oceans. While feeding watercourses, another part of this water seeps into the ground and flows through the Earth's rocks. This rehydrates the soil, which stores water, particularly in surface rocks, and feeds groundwater and underground rivers.

- **Storage:** Precipitation water can also be stored for a short period before evaporating back into the oceans, lakes, polar ice caps, subsoil, etc. Figure 1 below shows a diagram of the different stages of the water cycle.

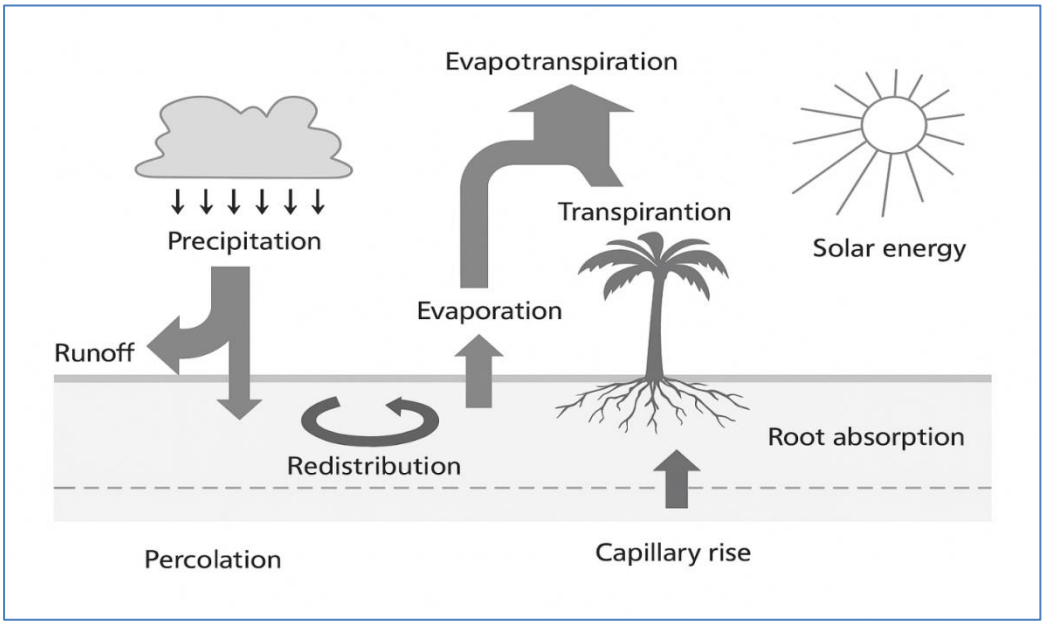

Fig.1 Water cycle.

2.1.1.2. Human influence on the water cycle While the uneven distribution of water around the world is becoming increasingly rare, human influence on the water cycle persists through poor management and various human activities related to land use (deforestation, urban and industrial expansion) and industrial pollution, which have a significant impact on all stages of the natural water cycle, particularly on the quantity and quality of rainfall caused by atmospheric pollution (acid rain).

2.1.2. Air or the atmosphere

Aerosols are present in the lower layers of the atmosphere, including dust from volcanoes, grains of sand and salt, pollen, polluting gases released by industry, etc.

2.1.2.1. The different layers of the Earth's atmosphere

The atmosphere consists of five superimposed layers with different properties in terms of thickness, temperature and pressure, and has a total thickness of approximately 10,000 km. These layers are the troposphere, stratosphere, mesosphere, thermosphere and exosphere, as shown in Figure 2.

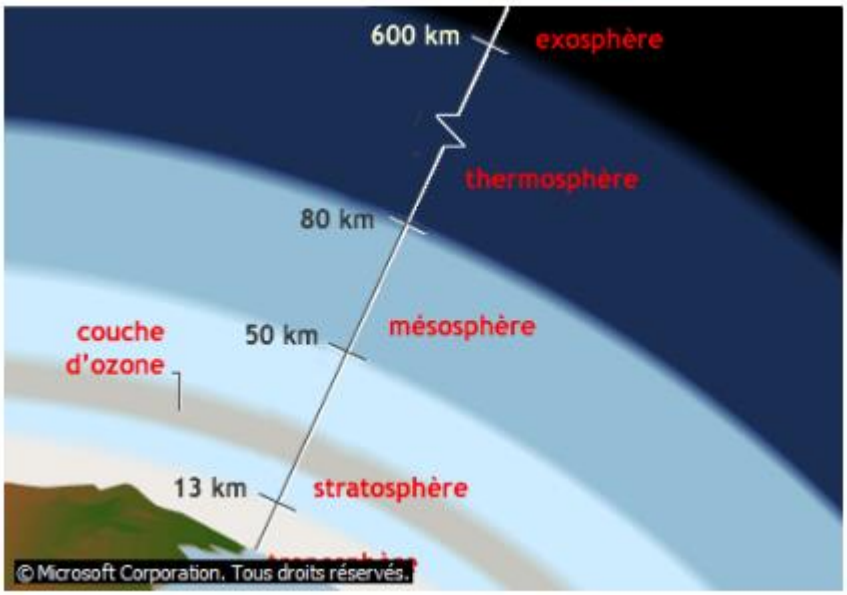

Figure 2. The layers of the Earth's atmosphere.

Unfortunately, air quality has been steadily deteriorating for 18 centuries and continues to do so today. This has harmful effects on human health and well-being, and is therefore considered one of the greatest nuisances that must be combated.

2.1.3. Land

By definition, the earth refers to all terrestrial elements above mean sea level, including the soil with its various reliefs, fauna and flora. It is one of the essential resources for the survival of populations in biological and environmental terms (ecological balance) and in economic terms through the exploitation of land and the establishment of various industrial and agricultural activities and mineral and fossil fuel deposits.

2.1.4. Forests

Forests are the most abundant and varied natural resources. They play a very important role in human existence, providing us with shelter, wood, oxygen, medicinal plants, building materials and fuel. Forests can combat desertification and erosion, and they play an important role in maintaining environmental balance by regulating the climate and in the socio-economic development of industrialised countries. Deforestation, industrial activities, forest fires and acid rain destroy thousands of hectares of forest every year around the world, posing a real threat to biodiversity, forest ecosystems and environmental balance.

2.1.5. Soils

By definition, soil is a dynamic, living natural environment that is highly complex due to the diversity of its constituents. According to educational nomenclature, soil is subdivided into three layers: an upper layer called ‘horizon A’ or “humus”, which is close to the surface and rich in organic matter; a lower layer called ‘horizon B’, which corresponds to the accumulation of minerals leached from the surface; A surface layer that covers the unaltered bedrock called ‘horizon C’. Soil is mainly composed of organic matter, mineral matter, living organisms, air and water, which can be divided into gravitational water, retention water and groundwater.

It is essential to understand that, of all environmental issues, soil and groundwater pollution is unique in several respects, notably: The difficulty of identifying sources and, consequently, of assessing their impacts and risks.

2.1.6. Food resources

These are all the energy-providing nutrients (animal, plant, mineral) consumed by living beings. Unfortunately, poor management of human food resources can have a harmful impact on biodiversity (e.g. overfishing and deforestation).

2.2. Non-renewable natural resources

These are all exhaustible natural resources that do not renew themselves, such as fossil fuels, minerals, etc.

2.2.1. Minerals

Minerals are inorganic products (metals or materials) extracted from the earth's rocks. The extraction of minerals is very profitable, despite the cost and price of mining techniques. The only problem is the inevitable impact of these deposits on the environment and the ecosystem. Table 1 shows the global reserves of some minerals.

Table 1: Global reserves of some mineral resources

Mineral	**Number of years of production at this rate**
Salt	Huge production, not estimated
Kaolin	170
Iron	Over 100
Platinum	200
Copper	35
Zinc, lead, silver	20
Diamond	10

There are five main types of mineral resources:

2.2.1.1 Minerals used to produce building materials

These are quarried minerals used in construction and public works, such as in the manufacture of cement and asphalt. Some can be used directly, such as stone, gravel, sand and slate. Others are fired and processed, such as clay (for making tiles and bricks), limestone (for cement and lime) and gypsum (used to make plaster).

These ores are often available in large quantities, but their extraction and transport are costly. It is therefore advantageous to extract them from the location closest to where they will be used.

2.2.1.2 Industrial minerals

These are minerals used for their physical and chemical properties such as hardness, colour, density, electrical properties or flexibility. Generally, these substances are not rare, but the difficulty lies in the accessibility of their deposits and their purity. The problem of their depletion is less of an issue than the cost of their extraction.

There are more than 80 different minerals of this type in the world. The most commonly used are:

- **salt:** used in the food and chemical industries,

- **kaolin**: used to produce paper, ceramics and earthenware,

- **talc:** used in pharmacology and cosmetics,

- **quartz:** used in glass, fibreglass,

- **calcite:** for paper, plastic, rubber,

- **diamond:** used in jewellery and to manufacture cutting tools.

- **calcite :** pour le papier, le plastique, le caoutchouc,

- **diamant :** utilisé en joaillerie et pour fabriquer les outils de coupe.

2.2.1.3 Minerals used in agriculture

These minerals are used for farming. Farming is necessary given the growth in the world's population and the reduction in land dedicated to agriculture. This type of mineral is quite common. They are mainly:

- **phosphorus:** for the manufacture of fertilisers. It is in high demand, but its extraction costs can become high over time;

- **nitrogen:** for fertilisers. However, the manufacture of these nitrogen fertilisers requires a large amount of energy. As a result, their prices are constantly rising worldwide.

- potassium: also used in the manufacture of fertilisers. It is found in seawater and in deposits in the form of potash salt. The best deposits are located near areas of consumption.

2.2.1.4 Metals (common)

Metals are simple substances that are good conductors of heat and electricity. Metals exist at all depths within the Earth. The difficulty of exploiting their deposits is compounded by geopolitical issues. Metals have the great advantage of being recyclable. They can be reused, which is a significant ecological advantage. Thanks to their properties, they are used in a wide range of industrial fields, from everyday objects to the automotive and aeronautical industries, medical equipment, machinery, and more.

Deposits are exploited by extracting the metal, followed by processing to transform it into ingots, plates, or bars. Mining is generally costly.

The most commonly used metals are as follows:

- Iron: 900 million tonnes of iron are extracted from the earth each year in the form of iron oxides. The mines are very large and the iron is then transformed into cast iron, steel or other highly used subsequently in a multitude of fields. Iron and its alloys are consumed on a massive scale, particularly in developing countries, in construction and large urban projects, and in factories.

- Aluminium: it is found in the form of bauxite in deposits. It is then extracted and processed. Widely used in the aerospace industry, 25 million tonnes are extracted each year.

- Copper: Copper has very good electrical conductivity properties. 15 million tonnes of this metal are extracted each year. Chile produces 30%, followed by the United States (12%) and Indonesia (10%).

- Other metals: such as zinc, lead, tin, etc.

2.2.1.5 Rare metals

These include rare earths and platinum group metals such as gold. They are widely used in high technology, such as electronics, IT and aerospace. They are crucial to the development of these technologies, given the advances in communications and electronics.

Deposits of these metals are rare. Access is sometimes difficult due to geopolitical conditions and the high cost of extraction. Production of rare earths rose from less than 30,000 tonnes in 1980 to more than 120,000

tonnes in 2010. Production is currently concentrated in China. This country accounts for more than 97% of global production and consumes more than 60%.

These metals are also in high demand in green technologies, such as the manufacture of wind turbines, hybrid engines and superconductors.

Chapter 3: Natural Resources Part 2

2.2.2. Fossil fuels (fossil energy)

These are excellent fuels. Fossil fuels are any combustible materials that originate from the degradation of organic matter, including coal, oil and natural gas.

Conventional energy sources remain the primary source of energy worldwide. Most of these energies are produced from fossil sources. Fossil sources produce energy through combustion, which makes them highly polluting. This energy is converted in boilers, furnaces, internal combustion engines or turbines.

Table 2 shows global reserves of unconventional energy sources and the estimated number of years of production remaining.

Table 2: Global reserves of non-renewable energy by source in 2011.

Resource	**World reserve %**	**Number of years of production at this rate**
Petroleum	23%	43
Natural Gas	18%	44
Coal	56%	132
Uranium	3%	35

2.2.2.1. Coal

Coal is a black rock rich in carbon. It accounts for 80% of available fossil fuels and is formed by the decomposition of plant debris that has been sedimented over many years. It is used as a raw material in steelmaking, where it is mixed with iron ore to produce steel or iron. Coal consists of volatile matter, namely carbon dioxide and compounds containing sulphur and nitrogen. It may also contain varying amounts of moisture, depending on its source. The fixed carbon content represents the mass of the residues of a sample

after removing volatile matter and water. It mainly contains carbon, as well as hydrogen, nitrogen and sulphur in smaller quantities.

The different types of coal are listed in Table 3 with their carbon contents.

Table 3:Types of coal and their carbon content

Nomenclature	% de carbone C
Tourbe	55
Lignite	70-75
Houille	85
Anthracite	92- 95

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2.2.2.2. Crude oil and petroleum products

Oil is currently one of the world's primary sources of energy. It is used in the manufacture of a large number of products. Oil comes from the accumulation of bacteria and algae that remained deep underground for more than 15 million years, transforming into hydrocarbon molecules. After refining, oil is used to manufacture dozens of products:

- petrol for spark ignition engines,

- diesel fuel for diesel engines,

- fuel for military and civil aircraft,

- kerosene,

- petrochemical products, such as plastic,

- naphtha,

- lubricants, used to reduce friction between machine parts, but also in drilling. There are several types depending on their viscosity, and they can be produced directly after refining or using petroleum residues,

- waxes, which are solid or semi-solid materials produced from refining or petroleum residues,

- asphalt, bitumen and tar, used to build roads,

- LPG (Liquefied Petroleum Gas), which is a less polluting fuel than conventional fuels, used in the automotive sector,

- some light gases used as fuels in the oil refining process. Oil production is measured in barrels or Brent. One barrel contains 158.98 litres. OPEC (Organisation of Petroleum Exporting Countries) sets global oil prices. Table 4 shows the ranking of the world's top 15 oil reserves.

2.2.2.3. Natural gas

Natural gas plays a gradual role in energy production. Its use in various sectors, particularly in electricity generation and precision industries, is linked to the size of its reserves and its environmental advantages. Natural gas is composed mainly of methane (CH4) (up to 98%), ethane (C2H6), propane (C3H8), butane (C4H10) and pentane plus (C5+). It also contains nitrogen, carbon dioxide and hydrogen sulphide (H2S). In the case of natural gas, the various stages of production, processing and transport constitute a gas chain. Natural gas is transported in the form of liquefied natural gas (LNG) in pipes and methane tankers after being liquefied at very low temperatures.

2.2.2.4. Nuclear energy

Nuclear energy is one of the most important sources of energy in the world today. It is produced by the fission of naturally occurring radioactive elements such as uranium and thorium. Uranium can undergo fission as soon as it is extracted in its natural state, while thorium must first be converted in a nuclear reactor. All isotopes of these elements are radioactive. Raw uranium, which exists in the form of yellow uranium oxide (U3O8), is processed to recover pure uranium. One tonne of raw uranium yields 1 to 2 kg of pure uranium. The rest consists of radon and other products that must be treated as nuclear waste.

Table 6 shows the types of accidents that can occur.

Définition du niveau	Impact sur l'environnement du site	Impact sur le site	Exemples
7 : Accident majeur	Propagation majeure: Effets très importants sur la santé et l'environnement	Majeur	Tchernobyl, URSS, 1986 Fukushima 2011
6 : Accident sérieux	Propagation significative: Application complète des plans d'urgence	Majeur	
5 : Accident comportant des risques pour l'environnement du site	Propagation limitée: Application partielle du plan d'urgence	Sérieux endommagement du cœur du réacteur	Windscale, Royaume Uni, 1957 (militaire); Three Mile Island, Etats Unis, 1979
4 : Accident au sein de l'installation	Propagation mineure: Exposition des personnes de l'ordre de la limite du danger	Endommagement partiel du cœur du réacteur, conséquences sur la santé du personnel	Saint-Laurent, France, 1980 (panne de combustible) Tokai-Mura, Japon 1999 (critique)
3 : Sérieux incident	Très faible propagation: Exposition des personnes au-dessous des limites de sécurité	Contamination majeure, exposition au dessus de la limite du personnel	Vandellos, Espagne, 1989 (Incendie de turbine, pas de contamination radioactive)
2 : Incident 1 : Anomalie 0 : Minimum de l'échelle	Nul Nul Nul	Nul Nul Nul	

3. Renewable energies

The growth in renewable energy production capacity observed worldwide over the last decade has been particularly rapid, representing a profound and lasting change in the global energy balance. Renewable energies are inexhaustible, unlike fossil fuels, and are also known as clean energies or renewable sources. They are used to produce heat, electricity or fuel. The main sources of energy (wave energy) are dams or small power stations on rivers that convert the kinetic energy of moving water into electricity.

3.1 Solar energy

The sun represents a very large nuclear power source, generating radiation with a power of 3.8 x 1023 kW. A small portion of this power reaches the Earth's surface.

Solar energy is captured and used either by photovoltaic panels or by CSP mirrors. The latter is a recent technology and less expensive than the former. It is very easy to maintain. It uses parabolic mirrors, which concentrate the sun's rays and reflect them into tubes that pass through the focal point of the parabolas.

This energy is then used to produce heat and electricity.

3.2 Wind energy

Wind energy converts the kinetic energy of the wind into power that can be used to generate electricity, for example. This type of energy is very old and was one of the first forms of energy used by humans. This technique is very environmentally friendly, but its cost can sometimes be high. The kinetic energy of the wind generates power W, which is equal to: $W = 1/2\rho Sv^3$

where ρ is the density of the air, v is the wind speed and S is the exposed surface area. Wind speeds are sometimes low, which reduces the power of the wind turbine. The efficiency of a wind turbine depends heavily on its location. The sites most exposed to wind are those located on mountain tops, by the sea or in the middle of the ocean.

Wind turbines generate a lot of noise. Current research in this field is aimed at reducing the noise pollution caused by these machines.

Wind turbines are equipped with auxiliary systems that enable energy to be stored.

3.2. Hydropower

Hydropower is currently by far the leading source of electricity generation worldwide. Most of the time, electricity is generated from dam water.

The water falls from a significant height and the kinetic energy it generates is used to operate turbines and generators that convert this energy into electrical energy. The turbine turns the generator's rotor, which produces a magnetic field inside the stator, which is essentially a giant coil that generates electricity. Mechanical energy is thus converted into electrical energy. This system of generating electricity from water is the most widespread in the world. Table 7 shows the size and capacity of hydroelectric power stations.

There is another technique that is less widespread but is used in countries bordering the oceans. This involves generating electricity from wave energy. As in hydroelectric power stations, the potential energy of the water is converted into electrical energy. Waves are sinusoidal with peaks and troughs. The amplitude of the waves depends on the weather: it is greater when there is wind or a storm. The movement of the waves is converted into mechanical energy which turns an electric generator. Wave energy is captured by floats or blades which transmit it to the rotors of the electric generators. Energy can also come from the tides.

Hydropower is inexpensive. Only the energy conversion devices require investment. Furthermore, it is a clean energy source that does not produce polluting emissions.

3.4. Geothermal energy

Geothermal energy is the use of the Earth's heat to produce energy. This energy is used to generate electricity, but also for district heating, greenhouse heating and fish farming. The Earth's heat comes from the decay of radioactive elements present in the rocks that make up the Earth's crust, and from the dissipation of primordial heat.

A geothermal deposit consists of three elements:

- a heat source,

- a reservoir, which is a rock formation in which the fluid circulates,

- a fluid: in the form of liquid, steam or a mixture of both. It is most often water heated by contact with rocks.

Geothermal deposits can be geologically stable or active. These deposits are distributed as follows: 35% are in Asia, 29% in America, 26% in Europe and 5% in Africa. One third of these

geothermal deposits produce electricity and two-thirds of the heat for heating. When installed in strict compliance with regulations, geothermal power plants have undeniable environmental advantages over conventional energy sources. They do not produce greenhouse gases. However, replacing fossil fuels with geothermal energy remains impossible overall.

3.5. Biomass energy

Energy production from biomass encompasses a range of techniques that use plants and organic matter to produce energy. These materials are used either directly as fuel or to generate electricity. Biomass has several sources. It can take the form of wood produced from forests, agricultural waste, wastewater waste or industrial waste. The advantages of using biomass are as follows:

- this energy source has the great advantage of being virtually pollution-free,

- it also has the advantage of being economical, as it uses recycled materials and is inexpensive,

- it offers a wide choice of sources,

- it allows waste to be disposed of in an environmentally friendly way instead of being stored.

Biomass in its raw state can be very clean, but it can also be contaminated with iron, animal residues or waste such as plastic. Table 8 shows the composition and properties of certain biomass fuels.

Table 5: Properties of four types of biomass

Propriétés	Copeaux de pin	Déchets d'herbes	Enveloppes de riz	Paille de riz
% de cendre	1,43	10,10	18,34	15,90
Carbone	48,54	47,79	40,96	41,78
Hydrogène	5,85	5,76	4,30	4,63
Azote	0,47	1,17	0,40	0,70
Soufre	0,01	0,10	0,02	0,08
Oxygène	43,69	35,07	35,86	36,57
Pouvoir calorifique (GJ/t)	19,38	17,99	16,14	16,28

4. Cogeneration or combined heat and power generation

By far the most common use of biomass is to use it directly as fuel, to recover heat to run boilers. This technique requires lengthy preparation, cleaning and also dehydration of the biomass fuel.

Another technique involves fermenting biomass in digesters by adding bacteria to facilitate the process. This produces biogas, a gas consisting of methane, carbon dioxide and other volatile components. In general, its calorific value is low and its composition depends on the raw material from which it is derived

Cogeneration is a system that produces two types of energy: heat and electricity. It allows excess heat to be recovered for heating, for example, instead of being wasted. To do this, a primary fuel is burned, which can be fossil-based, such as coal or natural gas, but also biomass, which significantly reduces pollutant emissions.

The objectives of cogeneration are as follows:

- reduction of pollutant emissions,

- energy independence,

- economic gain,

- recovery of free heat,

- waste recovery.

However, the initial cost of this technology is high.

Cogeneration is used to power engines and turbines. Growing interest in this environmentally friendly technology is currently enabling its implementation in small and medium-sized operations.