Chapter III: Dynamics of biological diversity and consequences of human activities

The growth of the human population and the corresponding increase in the demand for natural resources on the one hand, and the development of industrial, agricultural, and commercial activities on the other, are transforming the surface of the globe, altering biogeochemical cycles as well as the composition of biodiversity in most terrestrial and aquatic ecosystems. These impacts are reasonably well known and quantified. However, they create feedback effects on the functioning of the biosphere, leading to climate change and the irreversible loss of biodiversity components (genes, species, ecosystems). This human influence on the biosphere manifests itself through different processes summarized in Figure 7.

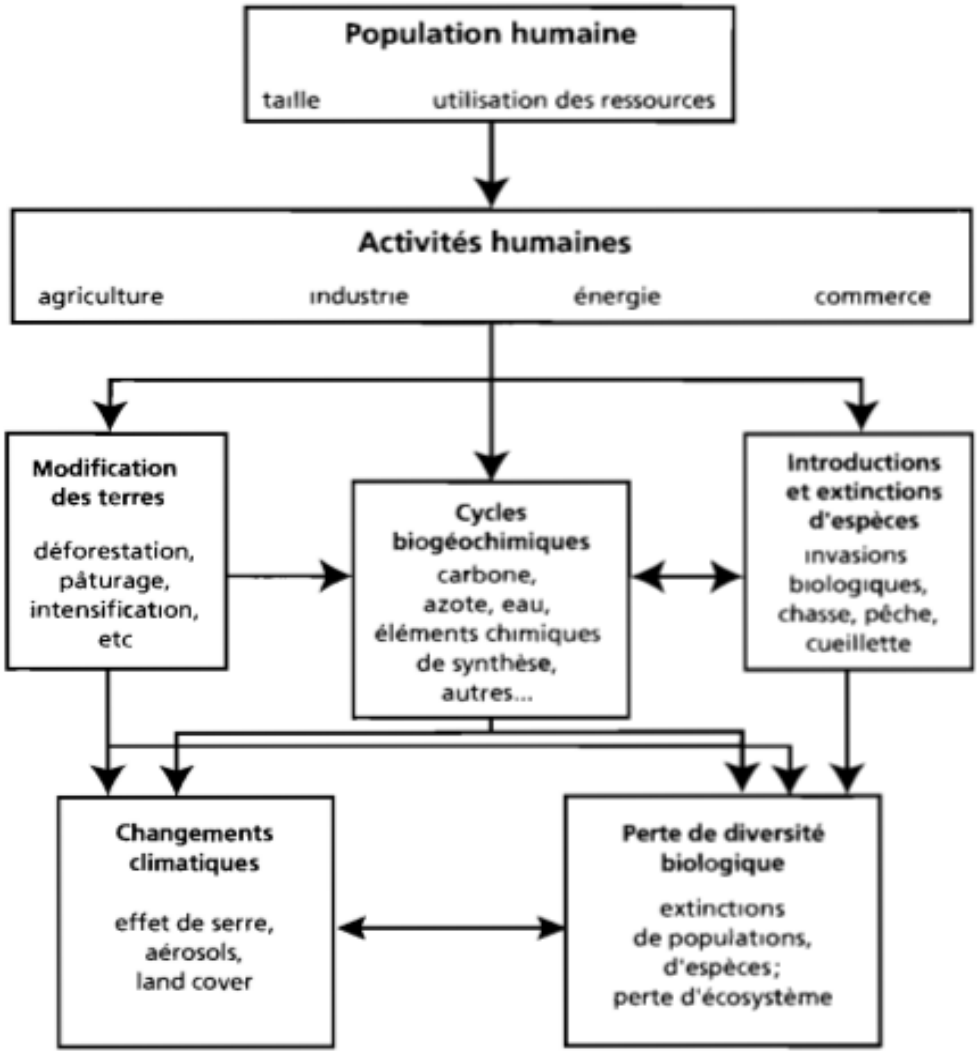

Figure 7: Conceptual model illustrating direct and indirect effects on the biosphere, adapted from Lubchenko et *al. (1991).*

The term *"global changes"* is often used to describe all these phenomena, which can be grouped into four major categories:

- changes in land use and vegetation cover;
- changes in atmospheric composition;
- climate change;
- alterations in the composition of natural communities and biodiversity loss.

In reality, this term encompasses both the impacts of economic development and global population growth on the major compartments of the Earth system namely the atmosphere, soils, and aquatic systems as well as the processes involved in the exchange of matter and energy between these compartments.

III.1. Demographic pressure

Among all the factors responsible for the erosion of biological diversity, demographic pressure combined with increasingly powerful technological means constitutes the ultimate cause. Larger areas are needed to house and feed a world population that has grown significantly: 2 billion individuals in 1930, 4 billion in 1975, and 8 billion or more projected around 2020. This population growth affects the entire planet, but especially tropical countries, where biological diversity is greater than in temperate regions.

III.2. Land use and landscape transformation

To produce goods and services, humans modify the structure and functioning of ecosystems. The first significant human impacts on the environment were fires used to flush out game or clear land. Fire favored resistant plant species as well as the development of savannas and grasslands. Later, the emergence of agriculture initiated a process of environmental transformation in which domesticated species dominate, along with opportunistic species—crop weeds and ruderal vegetation around human settlements. Hedgerows made it possible to combine livestock enclosure with the preservation of useful tree species or cultivated zones.

Some systems have been completely modified by humans: globally, 10–15% of land is used for agriculture and 6–8% has been converted into pastures.

Other ecosystems the majority are used only for hunting, gathering, or the quasi-industrial extraction of biological resources (wood, fisheries). It is estimated that 40–50% of terrestrial areas are transformed or degraded by humans. These transformations are the main cause of biodiversity erosion.

At the global scale, forests are losing ground. The situation is especially concerning for tropical forests, and is becoming serious for boreal and temperate forests. In contrast, in metropolitan France, the trend is reversed: over 40 years, forested areas increased from 11.3 to 15 million hectares, so that forests now cover more than a quarter of the territory. This is partly the result of strong political action, including the creation in 1966 of the National Forestry Office (ONF), which manages more than one-quarter of the national forest territory. But these overall figures mask deeper changes:

- The expansion of wooded areas occurs at the expense of agriculture and landscapes due to agricultural abandonment (a slow process of land desertion).
- *Linear forests*—sparse trees forming hedgerows (acacias, ashes), small woods, orchards (apple, pear, mulberry, olive trees), riparian forests (poplars, alders)—have sharply declined due to land consolidation, urbanization, and agricultural abandonment. Around 100 million trees and 500,000 km of hedgerows have disappeared over the past thirty years. Since the beginning of the century, 3 million hectares have been transformed, and only 1.6 million hectares of linear forests remain.
- Coniferous trees, which once represented only one-quarter of forested land, have expanded and now represent more than one-third. Pines, firs, and spruces grow more quickly than broad-leaved trees and are more profitable in the short term. However, conifers increase soil acidity and weaken forests due to their greater sensitivity to diseases and pollution.

A poorly understood but significant phenomenon concerns the decline of soil biological diversity, despite its essential role in primary production and organic matter recycling.

Around the world, soil structure, functioning, and properties are altered by human activities: agricultural practices, pollution, and urbanization. This results in:

- increased erosion, partly due to deforestation, overgrazing, and crop intensification. Annual global soil loss is estimated at 5–7 million hectares per year;
- salinization as a consequence of irrigation, particularly in arid and semi-arid regions;
- soil compaction caused by heavy or unsuitable farming equipment, excessive trampling by livestock, or poorly managed irrigation;
- chemical treatments (fungicides, insecticides, etc.) that pollute soils with toxic organic compounds or heavy metals (Cu, As, etc.).

The impoverishment of soil biodiversity and biological activity, as well as the decline in organic matter, affects nearly all cultivated soils. This is a major component of **desertification**, which refers to the degradation of land in arid and semi-arid areas due to climatic variations and human activities. It is manifested by reduced vegetation cover and a decline or loss of the land's biological potential and its capacity to support human populations.

A general phenomenon linked to land use is habitat loss and/or fragmentation, which can strongly affect the structure of biological communities.

III.3. Species introduction and biological invasions

Human migrations linked or not to the colonization of new environments have, for tens of thousands of years, triggered the transfer of species within continents, between continents and nearby islands, and between continents themselves. Neolithic humans did not only transport domesticated species; they also introduced wild animal and plant species. Mediterranean islands, for example, were populated before human arrival 5,000–6,000 years ago by endemic fauna inherited from the Tertiary period.

In just a few thousand years, this entire fauna disappeared, replaced entirely by modern fauna. Whether these species were intentionally introduced or not remains uncertain.

• Deliberate introductions

Many deliberate introductions were motivated by efforts to increase the availability of species useful to humans. In most world regions, food needs are supplied by plant and animal species originating from other continents.

The “discovery” of the Americas revealed an ancient and sophisticated agricultural system based mainly on three plants: maize, cassava, and potato. Indigenous American agriculture was diverse, and Europeans rapidly transferred around twenty South American crops around the world: maize, cassava, potato, tomato, pumpkin, tobacco, strawberries, chili peppers, beans, etc. Europe later benefited from North American species such as Jerusalem artichoke and sunflower.

Turkey (Meleagris gallopavo) and Muscovy duck also contributed to European livestock. These transfers were at the origin of the greatest food revolution in human history. Maize and potato played a key role in the development of European agriculture and the “new agriculture” at the beginning of the 19th century. Intercontinental transfers also contributed to the industrial revolution (cotton, rubber) and enriched medicinal resources (quinine).

Although Europe is often considered the main beneficiary of American biodiversity, South American species were also transferred to Africa and Asia: rubber tree, cotton, sisal, cocoa, and staple crops such as maize, cassava, sweet potato, peanut, etc., which reduced risks of famine.

Conversely, the Americas benefited from introduced horses, cattle, pigs, poultry, and wheat from Europe. From Africa came coffee and yam; from Asia, rice, sugarcane, soybean, banana, citrus, coconut palm, etc. Thus, the New World was not a disadvantaged participant in these exchanges.

Intercontinental transfer of plants and animals for food production has existed for centuries and is clearly still ongoing—for example, the introduction of kiwi fruit only a few decades ago.

The world has gradually become a vast supermarket of biodiversity. If a species seems to have any potential value, humans attempt to acclimatize it. **But this creates a problem:** The biological characteristics sought in these species (rapid growth, adaptability, high reproduction) are the same traits that make them excellent candidates for biological invasions.

• Escaped species

Aquaculture-based introductions occur worldwide. Many captive introductions eventually result in the escape of species into natural environments. Dozens of aquatic species have thus been introduced “accidentally” almost everywhere.

• Accidental or fortuitous introductions (the “ecological roulette”)

Introduced species can profoundly alter the ecological balance and functioning of recipient ecosystems. If environmental conditions are unfavorable, the introduced species appears only briefly. But when conditions are favorable, these species may proliferate and eliminate native species.

III.4. Overexploitation

Overexploitation of hunted or fished species has been a major cause of extinctions. Overhunting to satisfy luxury food demands, the fur industry (panthers, wolves, foxes), collectors (shells, insects, orchids), increased demand for traditional medicine, fishing pressure on marine ecosystems, and the transformation of trophic chains all contribute to heavy exploitation of biological resources.

Despite bans on exploiting the most threatened species, regulated by international conventions, many species remain threatened by poaching, such as West African elephants and rhinoceroses. Their rarity may further motivate collectors. Current overexploitation primarily targets **top predators**. Beyond the risk of extinction, it heavily affects trophic network organization.

III.5. Modification of Biogeochemical Cycles (Climate Change)

Climate change may have major functional consequences. Ocean acidification associated with increased dissolved carbon dioxide could affect their carbon storage capacity. Combined with rising temperatures, temperate regions are experiencing an increase in the length of the vegetation growing season by 3 to 4 days per decade.

Global warming is expected to cause shifts in species distribution ranges and changes in phenology, disrupting ecosystem functioning.

Modifications in biogeochemical cycles affect the diversity and functioning of ecosystems through habitat eutrophication, climate change, and increased aridity. The consequences of climate change can be summarized as follows:

- Global temperature could rise by 2–4°C by the end of the century.
- Changes in the intensity and spatial distribution of precipitation.
- Increased CO_2 directly stimulates photosynthesis by 20–30% and lengthens the growing season.
- Average water temperature increases.
- Distribution ranges of many species shift toward higher latitudes (e.g., African dragonflies appearing in southern Europe).
- Reduced distribution ranges for many species, leading to risks of extinction.

III.6. Chain extinction

Species are linked through feeding interactions. When one species disappears, other species within the same trophic network may also become threatened. The risk is greater for species at higher trophic levels.

The disappearance of top-level species, such as super-predators, triggers **trophic cascades**, as these species regulate populations at lower trophic levels.