EDUCATIONAL MATERIALS

NUBIP OF UKRAINE

Vita Strokal

LECTURES

of the course:

«PRINCIPLES OF INTEGRATED ENVIRONMENTAL SCIENCES»

for Ukrainian BSc students with a specialization in Ecology

2023

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Three lectures are developed for a BSc course of "Introduction to the Specialization". This educational document presents the lectures of the course. These lectures are clustered into six topics including (1) the concept of the course with professional fields and competencies, (2) the history of the ecological and environmental sciences, (3) the challenges of Climate Change impacts on the environment, (4) biomes and ecological factors, (5) environmental issues, (6) interactions between human activities and footprint. The document also presents control tests to check the learned materials and interactive exercises.

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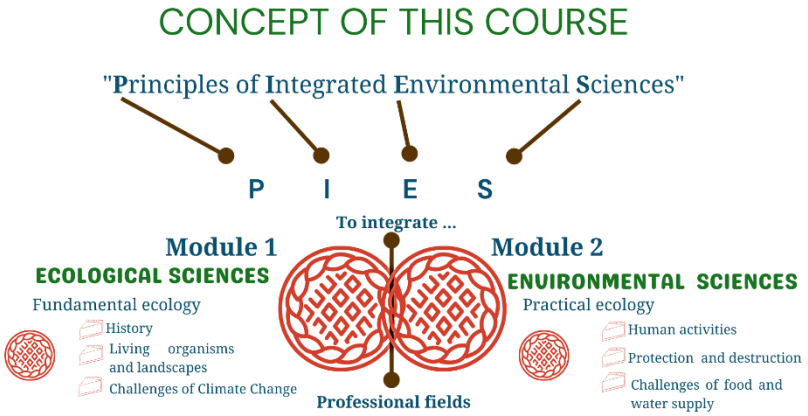


Vocabulary	
Environmental science	is an interdisciplinary academic field that integrates physics, biology, and geography (including ecology, chemistry, plant science, zoology, mineralogy, oceanography, limnology, soil science, geology and physical geography, and atmospheric science) to the study of the environment, and the solution of environmental problems
Ecological Science	is the scientific analysis and study of interactions among organisms and their environment. It is an interdisciplinary field that includes biology, geography, and Earth science. Ecology includes the study of interactions organisms have with each other, other organisms, and with abiotic components of their environment
Environmental studies	is a multidisciplinary academic field that systematically studies human interaction with the environment. Environmental studies connect principles from the physical sciences, commerce/economics, the humanities, and social sciences to address complex contemporary environmental issues. It is a broad field of study that includes the natural environment, the built environment, and the relationship between them
Environmentalism or environmental rights	is a broad philosophy, ideology, and social movement about supporting life, habitats, and surroundings. While environmentalism focuses more on the environmental and nature-related aspects of green ideology and politics, ecologism combines the ideology of social ecology and environmentalism
An environmentalist	is a person who advocates or works to protect the air, water, animals, plants, and other natural resources from pollution or its effects, and an expert on environmental problems. Environmentalists are skilled professionals who complete different tasks to help maintain and protect the environment
An ecologist	is a scientist who studies how animals and plants interact with their environment. Ecologists study nature, including fauna, flora and other organisms, with a focus on how these organisms interact with one another and the environment, to preserve and protect species and ecosystems and solve environmental issues
Principles of Environmental Sciences	provides a comprehensive picture of the principles, concepts and methods that are applicable to problems originating from the interaction between the living and non-living environment and human activities

1.1. Concept of this course

The course "*Principles of Integrated Environmental Sciences – PIES*" includes two modules highlighting foundational ecological and practical environmental sciences.

The primary reasons for conducting fundamental research are satisfying curiosity, acquiring knowledge, and achieving understanding. Here we develop why we believe it is essential to promote basic ecological research, despite increased impetus for ecologists to conduct and present their research in the light of potential applications. This includes understanding our environment, for intellectual, economic, social, and political reasons, and as a major source of innovation. We contend that we should focus less on short-term, objective-driven research and more on creativity and exploratory analyses, quantitatively estimate the benefits of fundamental research for society, and better explain the nature and importance of fundamental ecology to students, politicians, decision-makers, and the general public. Our perspective and underlying arguments should also apply to evolutionary biology and to many of the other biological and physical sciences.

What is fundamental ecology?

Fundamental ecology, or basic ecology, is the study of organismal diversity and of the interactions between organisms and their abiotic and biotic environments. Its main goal is to advance knowledge and understanding, and its results, even if sometimes predictable, are not known with certainty in advance. By contrast, applied ecology is usually motivated by particular, well-defined objectives, typically to solve environmental problems, including the management of natural resources such as land, energy, food, or biodiversity. Because applied ecology often involves the development of interventions to alter events (e.g., exotic species invasions, endemic species decline), this research is essentially an attempt to achieve a defined objective.

Different types of research

We define fundamental research as theoretical or experimental work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts without any particular application in view. Fundamental ecology is therefore often exploratory and curiosity-driven. By contrast, applied research focuses on finding solutions and improving them and is thus goal-driven. The distinction in objectives is important. Conducting research with a specific goal in mind makes achieving it more likely but also reduces the chances of obtaining unexpected results, a major source of scientific discovery. Curiosity-driven research often challenges accepted thinking and may generate new fields of investigation. Applied research feeds to some extent on the outcomes of fundamental research (see *Figure 1*). However, basic and applied research are not entirely discrete alternatives but rather can be viewed as a continuum. *This is especially pertinent to ecological research, where fields such as conservation biology, fisheries science, or global-change biology often integrate both fundamental and applied perspectives*.

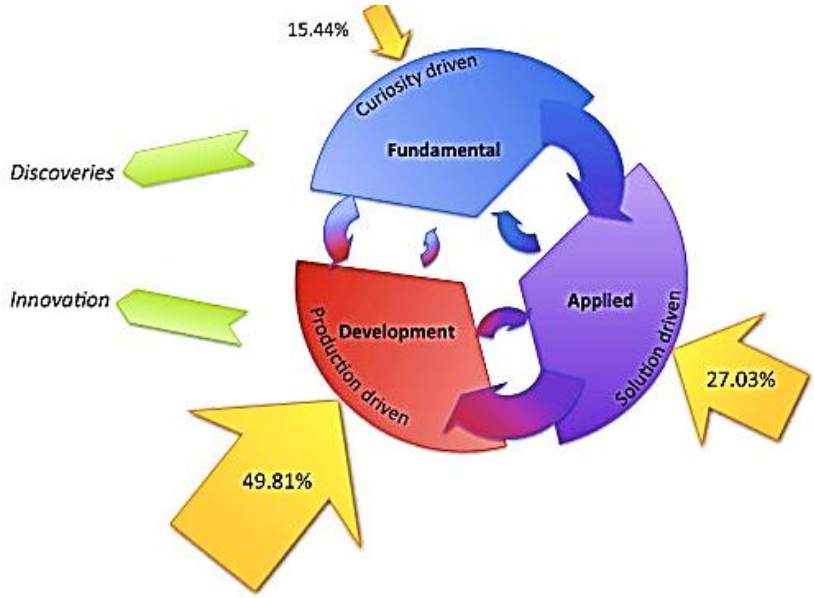


Figure 1. A conceptual model showing the links between different types of scientific research (Source: Fundamental ecology is fundamental - ScienceDirect)

There are other, less discussed but nevertheless important research approaches. Development research aims to make products from newly discovered technologies. Strategic research is primarily directed towards understanding the fundamental basis of an applied, ultimate goal [Dos Remedios, C. (2000) The value of fundamental research. International Union for Pure and Applied Biophysics (http://iupab.org/publications/value-of-fundamental-research/)]. Finally, translational research seeks to rapidly transfer findings from fundamental research into practical applications of direct relevance to human needs. In contrast to applied research, which usually represents incremental improvements to current understanding, translational research strives to deliver breakthroughs, notably through the creative and multidisciplinary exploration of results from fundamental research. Most translational research is aimed at innovative, basic biological science to improve medicine, bypassing the typically long time separating basic research and concrete clinical application. Ecology provides fertile grounds for translational research; for example, in conservation science. Unfortunately, translational research often competes for funding and attention with both fundamental and applied research, although its success obviously relies to a great extent on progress in the latter. In principle, the boundaries between all of these different types of research should be more porous, since they have the potential to interact and instruct in achieving their respective aims.

Environmental science is an interdisciplinary academic field that draws on agroecology, ecotoxicology, urban-ecology, and radiobiology to study environmental problems and human impacts on the environment. Environmental issues are quantitative pollutions and destructions with both applied and theoretical aspects and have been influential in informing the policies of governments around the world. Environmental science is considered separate from environmental studies, which emphasizes the human relationship with the environment and the social and political dimensions thereof. For example, whereas *a researcher in environmental studies*

might focus on the economic and political dimensions of international climate-change protocols, an environmental scientist would seek to understand climate change by quantifying its effects with models and evaluating means of mitigation.

Principles of Environmental Sciences[1] *provides* a comprehensive picture of the principles, concepts and methods that are applicable to problems originating from the interaction between the *living* and *non-living* environment and human activities. Both the analysis of such problems and the way solutions to environmental problems may work in specific societal contexts are addressed. Disciplinary approaches are discussed but there is a focus on *multi- and interdisciplinary methods*.

In Figure 2, we can see the concept of this course which is divided into two modules. Module 1 emphasizes ecological sciences principles and related issues such as the history of ecology, relationships between living organisms, challenges of Climate Change, and their effects on biodiversity. Module 2 relates to environmental issues that explore human activities, show the protection and destruction processes, and describe the challenges of food and water supply, addresses a wide range of environmental issues.

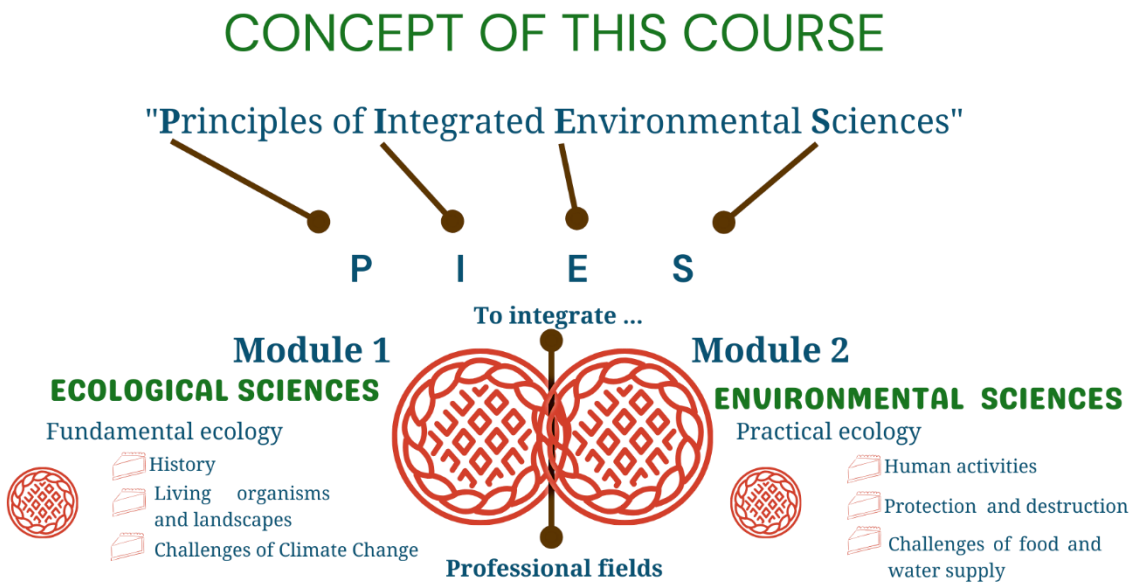


Figure 2. Concept of this course "PIES"

Environmental Science is an interdisciplinary field that studies the interactions between the natural environment and human society. It encompasses the study of the Earth's air, water, soil, and biotic systems, as well as the impacts of human activities on these systems. Environmental science provides a framework for understanding the complex relationships between natural resources, pollution, climate change, and other environmental issues, and helps to develop solutions to mitigate and adapt to these challenges.

One of the key principles of environmental science is the understanding that the environment is a complex and dynamic system that is affected by many different

[1] Principles of Environmental Sciences: book. URL: https://www.researchgate.net/publication/295980998_Principles_of_Environmental_Sciences

factors. *Environmental scientists* use a range of tools and techniques, such as GIS, remote sensing, and statistical analysis, to study the environment and to understand how it is changing over time.

Another important principle of environmental science is the idea of sustainability. This means the use of natural resources in a way that meets the needs of the present without compromising the ability of future generations to meet their own needs. Environmental scientists work to develop sustainable resource management strategies that balance economic development with the protection of natural resources.

The scope of environmental science is broad and encompasses many different disciplines and subfields, including ecology, geology, atmospheric science, hydrology, and oceanography. Environmental scientists work on a wide range of issues, from air and water pollution to climate change to conservation biology. They also work in a variety of settings, including government agencies, non-profit organizations, private industry, and research institutions.

*One of the key areas of focus within environmental science is the study of how human activities impact the natural environme*nt. This includes issues such as air and water pollution, climate change, deforestation, and loss of biodiversity. Environmental scientists study the sources and effects of these impacts, and work to develop solutions to mitigate and adapt to them.

Another key area of focus is the study of natural resource management. Environmental scientists study the sustainable use and management of resources such as water, forests, and minerals. They also work to develop policies and management plans that balance economic development with the protection of natural resources.

A third area of focus is the study of environmental policy and regulation. Environmental scientists work to understand the legal and policy frameworks that govern environmental management, including international and national laws and regulations. They also work to evaluate the effectiveness of different policy options and make recommendations for changes that can improve environmental outcomes.

In summary, *Environmental Science* is an interdisciplinary field that studies the interactions between the natural environment and human society. It encompasses the study of the Earth's air, water, soil, and biotic systems, as well as the impacts of human activities on these systems. Environmental science provides a framework for understanding the complex relationships between natural resources, pollution, climate change, and other environmental issues, and helps to develop solutions to mitigate and adapt to these challenges. Principles of environmental science include understanding the complexity of the environment and the importance of sustainability. The scope of environmental science is broad, encompasses various disciplines and subfields, and addresses a wide range of environmental issues[2].

[2] Definition, Principles and Scope of Environmental Science? URL: https://www.environmentalsciences.in/2023/03/definition-principles-and-scope-of.html

1.2. Why do we need to study this course?

A bachelor's degree in ecology or environmental science is the typical education requirement for landing an ecologist job. A master's degree may support career advancement, and a Ph.D. is required for university teaching and research positions. Aspiring ecologists enroll in subjects such as biology, chemistry, ecology, zoology, genetics, environmental policy and hydrology.

Why do we need to study this course? The first we need to understand the specific fields of professional skills. Second – understand the main ecological and environmental problems in the World and Ukraine. And also, have to be able to find out the correct solutions to avoid the consequences of the destruction of natural resources and to make solutions for improving our surrounding area.

This course reveals the main ecological and environmental issues, figures out how the natural world works, explores the causes of Climate Change, and how we can protect our future from increasing temperatures. Within this course, students will understand which professional skills are important for the future profession.

Highlighting ***three main goals***:

- *Learn how the natural world works*
- *Understand how we as humans **interact** with the environment*
- *Determine how we **affect** the environment*

The ***main objectives*** of this course are:

- *Appreciate the interrelationship between living and non-living components of our environment;*
- *Understand the impact of human activities on the local environment;*
- *Understand biodiversity and interdependence of plants and animals and their relationship with the environment;*
- *Understand pollution and its harmful effect on the environment and devise strategies for reducing pollution;*
- *Realize the importance of energy and the relevance of energy audit for the conservation of energy;*
- *Learn about assessing the quality of air, water and soil.*
- *Become aware of environmental deterioration due to human activities.*
- *Be able to think of strategies for reducing or reversing the adverse impacts.*

Picture 3 shows us the main objectives that students obtain in this course.

3.a: ecological issues	3.b: environmental issues	3.c: human activities

Figure 3. The main related issues to ecology, environment, and activities

Nowadays, it is important to understand the main consequences of anthropogenic activities such as habitat destruction, invasive species, overexploitation, deforestation, mining, agriculture urbanization, air and water pollution, and soil contamination. That is why, future environmental specialists are able to solve these environmental problems, and ecological specialists – protect our natural resources and biodiversity (population, species). Specialists have to understand tha main complex relationships between the environment and humans. The following are the environmental principles that relate to environmental and ecological specialists who have abilities in this professional area.

The framework incorporates five key environmental principles and concepts (EP&Cs) designed to help students understand the complex relationship between humans and the natural world (see Fig. 4).

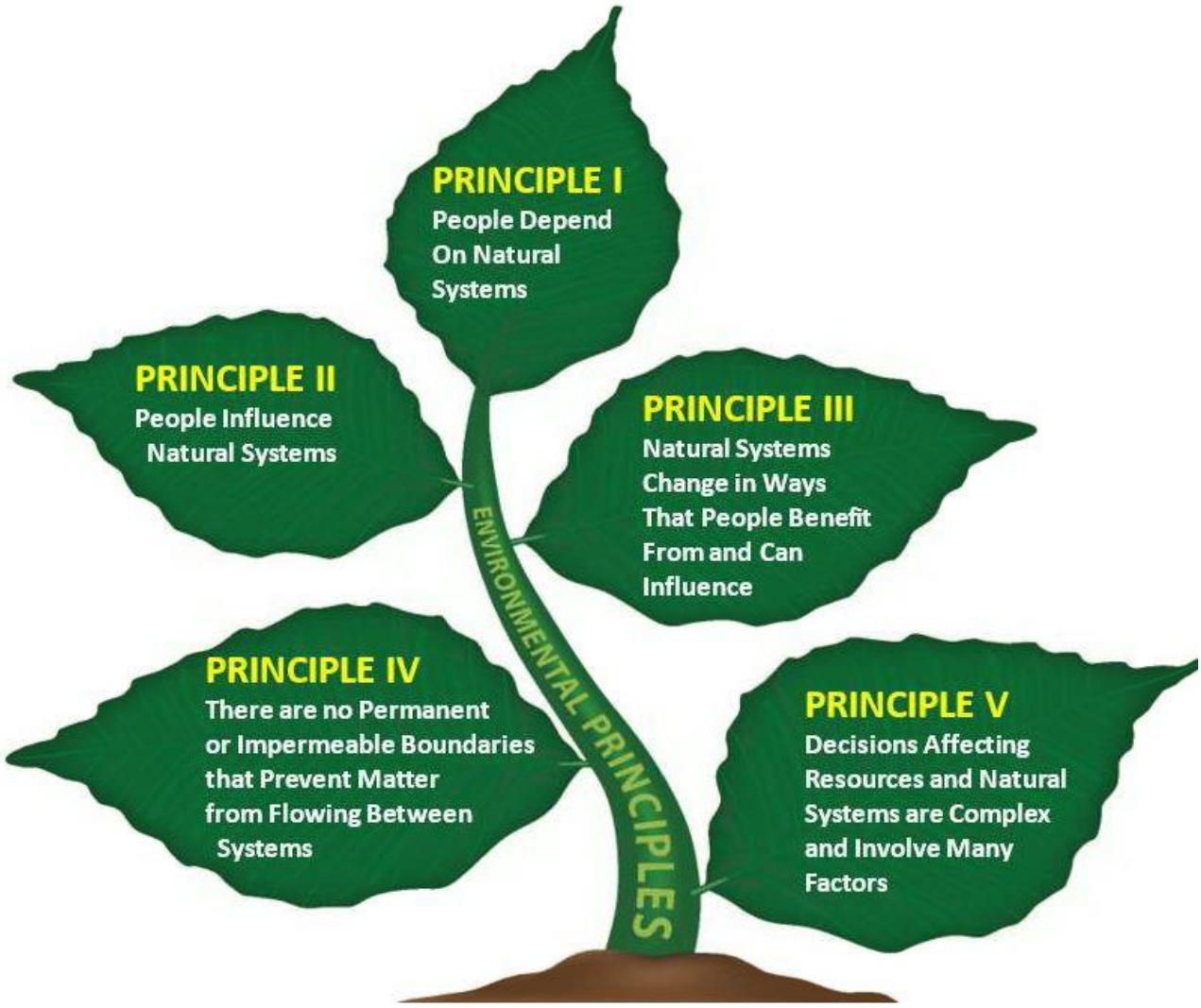


Figure 4. Environmental Literacy Framework[3]

[3] Environmental Literacy Gets Boost from Newly Approved Science Framework. URL: https://californiaeei.blogspot.com/2016/12/environmental-literacy-gets-boost-from.html

1.3. Who are you? Ecologist or Environmentalist?

An ecologist is a scientist who explores an ecosystem in which living organisms interact with each other and with their environment. A pond is a good example of an aquatic ecosystem. The study of pond ecosystems is a very simple means to understand how various organisms are related to each other and their interdependence.

An environmentalist (Environmental scientist) is a scientist who explores the impact of human activities on food, water, and soil quality (other natural resources), analyzes sources (point and diffuse) of pollution (multiple pollutants), and researches the main solution for preventing environmental problems.

Environmental scientists also develop plans to restore polluted areas and consult with government officials, businesses and the public on environmental hazards or health risks. Like all scientists, they also have to write technical reports to present their findings and explain their research.

Environmental scientists, sometimes called ecologists, study the physical, chemical and biological conditions of the environment and how these conditions impact organisms. Knowing the difference between environmental science and environmentalism can help clarify options when exploring careers.

Environmentalist Goals

An environmentalist believes in and works toward the preservation and restoration of the natural environment. In general, environmentalists believe that humans should live in a harmonious balance with natural ecological systems. Control of man-made pollution is a primary concern of environmentalists; that is, how to minimize pollution, mitigate its impact and repair the damage already done to various ecosystems.

Environmental science specialists are passionate about preserving and improving the world's land, water and air quality. *A degree in environmental science can open up many job opportunities in research, education, law and more*. Oftentimes, environmental science specialists end up working for universities, the government or private research institutes. While some of the jobs on this list can be achieved with solely a bachelor's degree, many of them require further, more specialized education or training. Below is a list of 12 possible jobs for environmental science specialists in general (see Fig. 5)[4]:

1.4. Jobs for Environmental Science

1.4.1. Most Common Jobs for Environmental Science

1. Environmental Scientist

In a nutshell, environmental scientists are tasked with studying, analyzing and potentially providing sustainable solutions to environmental problems, including pollution, biodiversity loss and climate change. Oftentimes, they are employed by the government, universities or research institutes. While some environmental science jobs can be earned with only a bachelor's degree, a master's degree will open up

[4] 12 possible jobs for environmental science specialists. URL: https://www.tun.com/blog/12-jobs-for-environmental-science-majors/

many more prestigious employment opportunities. Common entry-level degree: Master's degree and PhD degree.

2. College and University "professor/docent"

As with many students in the sciences, many environmental specialists go on to become professors (doctor in) or docent (candidates in) of their discipline. Patience, communication, organization and enthusiasm are some of the most important characteristics of a good college professor/docent. To earn a job teaching at the post-secondary level, a master's degree (and sometimes a doctorate degree), is required. In addition to teaching, some college professors also conduct research and write scholarly articles. Common entry-level degree: Master's degree and PhD degree.

3. High School Science Teacher

Being a high school science teacher is a common path for environmental science specialists. As a teacher, you can communicate and hopefully pass down your love for science to the next generation. To become a secondary school teacher, you will need to graduate with a master's degree. You'll then need to complete a teaching internship in your subject, take and pass your state's teaching licensure tests, and get your teaching license. Common entry-level degree: Master's degree.

1.4.2. Specialized/Unique Jobs for Environmental Science

4. Environmental Engineer / Environmentalist in industries

Environmental engineers might work on a wide range of projects relating to environmental health and sustainability. This could include developing new recycling programs, strategies and methods. It could also include developing renewable energy technologies and systems like dams or large-scale water filtration systems. A bachelor's degree is necessary for entry into the field, and some employers may seek out candidates with master's degrees. Leadership and management positions require a Professional Engineering (PE) license, which can be attained after 4 years of working in the field. Common entry-level degree: Master's degree.

5. Environmental Consultant

Environmental consultants work on projects with organizations offering their expertise on environmental regulations or environmental impact. Typically, they will be employed by an environmental consultancy firm, which takes on contracts with commercial or government organizations. Environmental consultants may specialize in subfields like air or water pollution, waste management, natural disaster risk, or renewable energy. In order to become an environmental consultant, you will need at least a bachelor's degree. Common entry-level degree: Bachelor's degree.

6. Forester

A career in forestry is ideal for anyone who strives to be outdoors and sighs at the thought of working at a desk all day. Foresters are primarily tasked with maintaining and preserving wilderness areas and forest habitats. They may have to engage in pest control, fire prevention, soil sampling, and more. Generally, foresters are employed by government agencies, such as national and state parks and wildlife refuges. Common entry-level degree: Bachelor's degree.

1.4.3. Non-Traditional Jobs for Environmental Science

7. Environmental Reporter

If you are interested in the environment but would like to write for a living, an environmental science major can prepare you well for a career as an environmental reporter. Technically, there is no required degree to become a reporter, but you will have a hard time finding a job without one. Skilled reporters are master storytellers with strong writing and grammar skills. To learn the essential skills, most aspiring reporters study journalism in college. However, the knowledge gained through an environmental science degree will give you an advantage in reporting on the environment and sustainability efforts. Common entry-level degree: Bachelor's degree.

8. Environmental Lawyer

At large, environmental lawyers strive to uphold and lobby for laws that protect the quality of the air, water and land. They also can represent individuals and communities who may have been injured or developed an illness due to environmental conditions in a town, workplace, building or more. However, to become an environmental lawyer, completing a bachelor's degree program is just the first step. Aspiring lawyers will also have to pass the Master's degree in low. Common entry-level degree: Master's degree.

9. Toxicologist

Toxicologists are experts in chemicals and toxic materials, who use their expertise to research and evaluate the safety of chemical products and drugs, and identify the safety of chemical products. Toxicologists are often employed by water, pharmaceutical and chemical companies to test the safety of their own products. They may also be employed by government regulatory agencies like the Food and Drug Administration (FDA) or the Environmental Protection Agency (EPA). Most aspiring toxicologists are specialists in environmental toxicology in universities and scientific institutes. However, for environmental science specialists who were late to realize they want to become toxicologists, there is still hope. Some universities allow students to add a toxicology specialization or focus to their degree. Additionally, a master's degree in toxicology would help students refine their skill set and qualify for more jobs. Common entry-level degree: Master's degree.

Other Potential Jobs for Environmental Science

10. Marine Biologist

Primarily, marine biologists are tasked with analyzing ocean life and identifying possible threats or diseases. Typical assignments could include assessing the changes in a specific fish population over time or determining the cause of an obscure algal bloom. Although most aspiring marine biologists pursue a major that is specific to animals, such as biology, zoology or ecology, an environmental science degree can serve as the base for a career in marine biology. However, to earn a job in the field, a more advanced degree may be needed. Common entry-level degree: Bachelor's/Master's degree.

11. Climatologist

At large, climatologists study trends in climate and how it impacts people and the environment. They observe how climate has changed over time, so they can predict trends for the future and avoid potential long-lasting damage. A degree in environmental science could serve as the backbone to a climatology career; however, to earn a research position at a university or institute, further education that is specific to climatology, meteorology or atmospheric science is likely necessary. Common entry-level degree: Master's degree.

12. Fish and Game Warden

Fish and game wardens work in protected outdoor conservation areas, such as state and national parks and forest preserves, to protect wildlife and enforce fishing, hunting and boating laws, among others. In addition to an environmental science education, aspiring fish and game wardens should be versed in criminal justice. To earn a job as a fish and game warden, internships or apprenticeships are almost always necessary. Common entry-level degree: Bachelor's degree.

Figure 5. Environmental Science Major/specialist[5]

Control questions for students

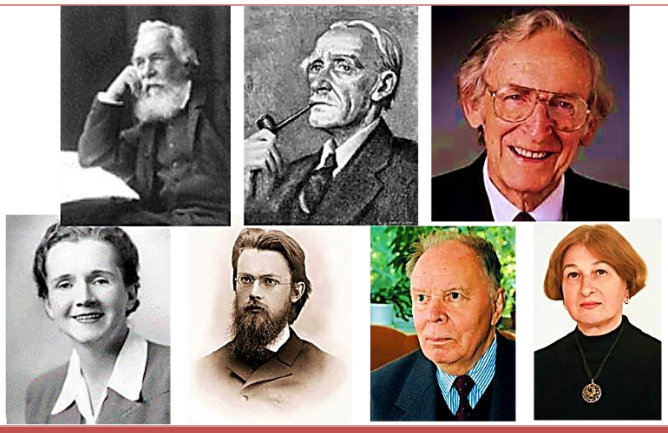
1. What are the main differences between the skills of an ecologist and environmentalist?
2. What are the main differences between ecological and environmental issues?
3. To describe the main related issues to ecology, environment, and activities and their interactions.
4. To describe the Environmental principles.
5. What are the main goals and objectives students study in this course?

[5] 12 possible jobs for environmental science specialists. URL: https://www.tun.com/blog/12-jobs-for-environmental-science-majors/

2. History of ecological and environmental sciences

2.1. History

2.2. Contribution of scientists to the development of ecology and environmental studies



Vocabulary	
Ecology (Ernst Haeckel, 1834–1919)	the original definition is from Ernst Haeckel, who defined ecology as the study of the relationship of organisms with their environment
Ecology (Charles S. Elton, 1900-1991)	in the pioneering book Animal Ecology (1927) defined ecology as scientific natural history
Ecology (Eugene Odum, 1913-2002)	ecology as the study of the structure and function of nature
Ecology (Charles Joseph Krebs, 1936)	ecology as the scientific study of the interactions that determine the distribution and abundance of organisms
The Biosphere	is the shell of life – the area of existence of living matter
An ecosystem	(or ecological system) consists of all the organisms and the physical environment with which they interact
Book "Silent Spring"	was written by Rachel Louise Carson and published by Houghton Mifflin on September 27, 196; the book documented the environmental harm caused by the indiscriminate use of pesticides

2.1. History

18th and 19th century ~ Ecological murmurs
The botanical geography and Alexander von Humboldt

Throughout the 18th and the beginning of the 19th century, the great maritime powers such as Britain, Spain, and Portugal launched many world exploratory expeditions to develop maritime commerce with other countries, and to discover new natural resources, as well as to catalog them. At the beginning of the 18th century, about twenty thousand plant species were known, versus forty thousand at the beginning of the 19th century, and almost 400,000 today.

These expeditions were joined by many scientists, including botanists, such as the German explorer Alexander von Humboldt. Humboldt is often considered a father of ecology. He was the first to take on the study of the relationship between organisms and their environment. He exposed the existing relationships between observed plant species and climate, and described vegetation zones using latitude and altitude, a discipline now known as geobotany.

In 1804, for example, he reported an impressive number of species, particularly plants, for which he sought to explain their geographic distribution with respect to geological data. One of Humboldt's famous works was "Idea for a Plant Geography" (1805).

Warming and the foundation of ecology as discipline

Charles Darvin**.** While Darwin focused exclusively on competition as a selective force, Eugen Warming devised a new discipline that took abiotic factors, that is drought, fire, salt, cold etc., as seriously as biotic factors in the assembly of biotic communities. Biogeography before Warming was largely of descriptive nature - faunistic or floristic. Warming's aim was, through the study of organism (plant) morphology and anatomy, i.e. adaptation, to explain why a species occurred under a certain set of environmental conditions. Moreover, the goal of the new discipline was to explain why species occupying similar habitats, experiencing similar hazards, would solve problems in similar ways, despite often being of widely different phylogenetic descent.

Darwinism and the science of ecology

It is often held that the roots of scientific ecology may be traced back to Darwin. This contention may look convincing at first glance inasmuch as On the Origin of Species is full of observations and proposed mechanisms that clearly fit within the boundaries of modern ecology (e.g. the cat-to-clover chain – an ecological cascade) and because the term ecology was coined in 1866 by a strong proponent of Darwinism, Ernst Haeckel. However, Darwin never used the word in his writings after this year, not even in his most "ecological" writings such as the foreword to the English edition of Hermann Müller's The Fertilization of Flowers (1883) or in his own treatise of earthworms and mull formation in forest soils (The formation of vegetable mould through the action of worms, 1881).

Early 20th century ~ Expansion of ecological thought

The biosphere - Eduard Suess, Henry Chandler Cowles, and Vladimir Vernadsky

By the 19th century, ecology blossomed due to new discoveries in chemistry by Lavoisier and de Saussure, notably the nitrogen cycle. After observing the fact that life developed only within strict limits of each compartment that makes up the atmosphere, hydrosphere, and lithosphere, the Austrian geologist Eduard Suess proposed the term biosphere in 1875. Suess proposed the name biosphere for the conditions promoting life, such as those found on Earth, which includes flora, fauna, minerals, matter cycles, et cetera.

In the 1920s Vladimir I. Vernadsky, a Russian geologist who had defected to France, detailed the idea of the biosphere in his work "The biosphere" (1926), and described the fundamental principles of the biogeochemical cycles. He thus redefined the biosphere as the sum of all ecosystems.

First ecological damages were reported in the 18th century, as the multiplication of colonies caused deforestation. Since the 19th century, with the industrial revolution, more and more pressing concerns have grown about the impact of human activity on the environment. The term ecologist has been in use since the end of the 19th century.

The ecosystem: Arthur Tansley

Over the 19th century, botanical geography and zoogeography combined to form the basis of biogeography. This science, which deals with habitats of species,

seeks to explain the reasons for the presence of certain species in a given location.

It was in 1935 that Arthur Tansley, the British ecologist, coined the term ecosystem, the interactive system established between the biocoenosis (the group of living creatures), and their biotope, the environment in which they live. Ecology thus became the science of ecosystems.

Tansley's concept of the ecosystem was adopted by the energetic and influential biology educator Eugene Odum. Along with his brother, Howard Odum, Eugene P. Odum wrote a textbook which (starting in 1953) educated more than one generation of biologists and ecologists in North America.

Ecological Succession - Henry Chandler Cowles

At the turn of the 20th century, Henry Chandler Cowles was one of the founders of the emerging study of "dynamic ecology", through his study of ecological succession at the Indiana Dunes, sand dunes at the southern end of Lake Michigan. Here Cowles found evidence of ecological succession in the vegetation and the soil with relation to age. Cowles was very much aware of the roots of the concept and of his (primordial) predecessors. Thus, he attributes the first use of the word to the French naturalist Adolphe Dureau de la Malle, who had described the vegetation development after forest clear-felling, and the first comprehensive study of successional processes to the Finnish botanist Ragnar Hult (1885).

Environmental History[6]

Environmental history emerged as a new field of study as environmental problems began to rise up the global political agenda in the 1960s and 1970s. Its primary goal is to show how environmental change and human actions are interconnected. And the natural world, instead of being merely the backdrop against which the affairs of humans are played out, is recognized as playing an active role in historical processes. Undertaking research in this area can be challenging since environmental history, influenced from the outset by the holism of ecology, is an interdisciplinary endeavor that requires some familiarity with methods and approaches from both the humanities and environmental sciences. As well as trained historians, environmental history attracts contributors from a wide range of other disciplines, from social anthropology through to historical geography and the natural sciences (including botany, climatology, ecology, hydrology, pedology and zoology). Environmental historians, whatever their backgrounds may be, are breaking down disciplinary borders to examine the complexities of human-environment relationships over the long term. By exploring the interactions between social systems and ecological processes in the past, environmental history aims to promote better informed planning and policymaking for the future. In this essay, the emphasis will be on major themes and issues in environmental history—such as biological exchanges, cities, deforestation, pollution problems, soil erosion, rivers, seas and oceans—to demonstrate the dynamic growth and development of the field.

Environmental history can be written on any scale, from the macro to the micro, and often takes a very longue durée perspective. But as environmental problems tend to transcend national boundaries (climate change illustrates this point

[6] Environmental History. URL: https://www.oxfordbibliographies.com/display/document/obo-9780199363445/obo-9780199363445-0026.xml

well), global-scale overviews are the best starting point for research in environmental history. Building on regional and national studies, Turner, et al. 1990 provided an ambitious and influential account of the human transformation of the earth that sparked interest in writing world environmental histories. Recently, the literature has been increasing with both broad surveys (Hughes 2009; Simmons 2008; Radkau 2008; Penna 2009; and Mosley 2010) and studies covering shorter spans of time appearing in print (McNeill 2000 and Richards 2003). However, the number of truly global studies remains relatively small in an otherwise fast-growing field.

Human ecology

Human ecology began in the 1920s, through the study of changes in vegetation succession in the city of Chicago. It became a distinct field of study in the 1970s. This marked the first recognition that humans, who had colonized all of the Earth's continents, were a major ecological factor. Humans greatly modify the environment through the development of the habitat (in particular urban planning), by intensive exploitation activities such as logging and fishing, and as side effects of agriculture, mining, and industry. Besides ecology and biology, this discipline involved many other natural and social sciences, such as anthropology and ethnology, economics, demography, architecture and urban planning, medicine and psychology, and many more. The development of human ecology led to the increasing role of ecological science in the design and management of cities.

In recent years human ecology has been a topic that has interested organizational researchers. Hannan and Freeman (Population Ecology of Organizations (1977), American Journal of Sociology) argue that organizations do not only adapt to an environment. Instead it is also the environment that selects or rejects populations of organizations. In any given environment (in equilibrium) there will only be one form of organization (isomorphism). Organizational ecology has been a prominent theory in accounting for diversities of organizations and their changing composition over time.

James Lovelock and the Gaia hypothesis

Main article: Gaia hypothesis

The Gaia theory, proposed by James Lovelock, in his work Gaia: A New Look at Life on Earth, advanced the view that the Earth should be regarded as a single living macro-organism. In particular, it argued that the ensemble of living organisms has jointly evolved an ability to control the global environment — by influencing major physical parameters as the composition of the atmosphere, the evaporation rate, the chemistry of soils and oceans — so as to maintain conditions favorable to life.

This vision was largely a sign of the times, in particular the growing perception after the Second World War that human activities such as nuclear energy, industrialization, pollution, and overexploitation of natural resources, fueled by exponential population growth, were threatening to create catastrophes on a planetary scale. Thus Lovelock's Gaia hypothesis, while controversial among scientists, was embraced by many environmental movements as an inspiring view: their Earth-mother, Gaia, was "becoming sick from humans and their activities".

Conservation and environmental movements

Environmentalists and other conservationists have used ecology and other sciences (e.g., climatology) to support their advocacy positions. Environmentalist views are often controversial for political or economic reasons. As a result, some scientific work in ecology directly influences policy and political debate; these in turn often direct ecological research.

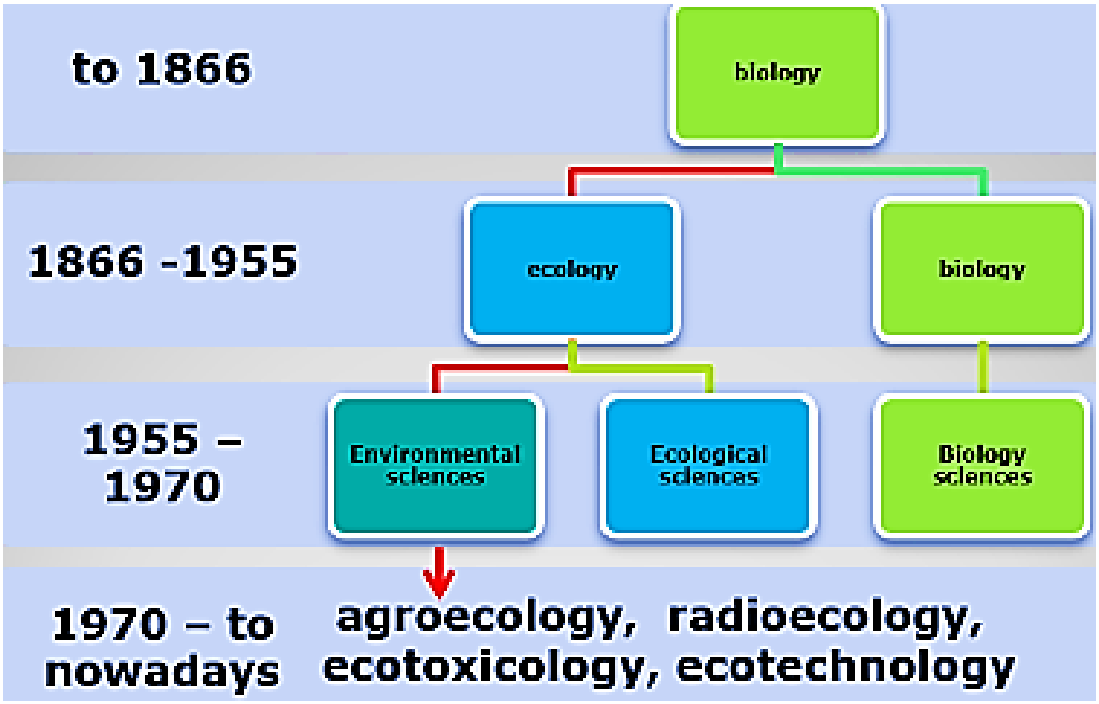


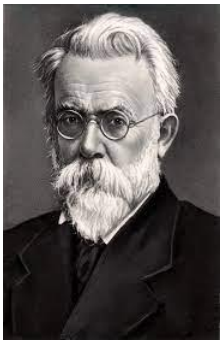
Figure 6. Evolution of ecology like science – Structure

Video about environmental history students can watch on YouTube: Environmental History

2.2. Contribution of scientists to the development of ecology and environmental studies

Bellowing describes the well-known scientists who contributed to the history of ecology and environmental sciences (see Table 1).

Vernadsky and Biospheral Ecology[7]. An early point to clarify is the plurality of different meanings that have been associated with the term biosphere in scientific literature. For us, *The Biosphere* is the'...integrated living and life-supporting system comprising the peripheral envelope of Planet Earth together with its surrounding atmosphere so far down, and up, as any form of life exists naturally. This concept, stemming from Vernadsky, was already recalled by G. Evelyn Hutchinson (1970) in his authoritative paper introducing the special issue of Scientific American devoted to 'The Biosphere', by the celebrated Soviet soil scientist Victor



[7] Vernadsky and Biospheral Ecology. URL: https://www.jstor.org/stable/44521108

Abrahamovich Kovda (1970) in the first chapter (entitled 'Contemporary scientific concepts relating to the biosphere') of the proceedings of the UNESCO so-called 'Biosphere Conference', and by one of us in the first International Conference on Environmental Future, held in Finland in 1971 (Polunin, 1972).

Although neglected by many historians of ecology and of science in general, Biosfera (The Biosphere), published by Vernadsky in 1926 in Russia, in 1929 in France (Vernadsky, 1929; cf. Grinevald, 1986), and in 1930 in Germany, is, we believe, a major landmark in our intellectual history and global understanding. In it Vernadsky adopted a new scope of perception, viewing The Earth as a 'living planet' in the solar system, and presenting the concept of The Biosphere as a 'scientific revolution'.

The fact that Vernadsky was the first natural scientist, in the 1920s, to define The Biosphere within a very modern thermodynamic and biogeochemical perspective, despite some mistakes due to the state of science at the time, merits our respectful gratitude, and should be widely acknowledged. In the manner of at least one other vital concept which we are not at present at liberty to divulge, the basic theme was too simple to have attracted attention until Vernadsky advanced it, and even then it was very slow in taking root at all widely.

The concept of The Biosphere as the integrated living and life-supporting system comprising the peripheral envelope of planet Earth together with its surrounding atmosphere so far down, and up, as any form of life exists naturally, stems from the writings of V.I. Vernadsky in the 1920s but has only emerged and become widely accepted in the latest decades. Yet it is quite one of the largest and most important entities with which humans have to deal, being, moreover, the only natural habitat and life-support of Mankind and Nature and, as such, needful of safeguarding and healthful maintenance.

Tansley A.G.: The use and abuse of vegetational concepts and terms "Ecology"[8]. Sir Arthur George Tansley, British plant ecologist (1871–1955), was born in London. In 1890 he went to Cambridge University and on graduation was Oliver's assistant before returning to Cambridge. In 1902 Tansley founded The New Phytologist, and in 1913 he founded and *was the first president of the British Ecological Society*, later founding and editing the Journal of Ecology. These activities, and his ecology courses at Cambridge, played a large part in establishing the science of ecology. Tansley's 1935 paper challenged the use of ecological terms then in use, including Clementsian ideas of succession and climax and the basic concept of vegetation as an 'organism', derived from late nineteenth-century German romantic organistic philosophers. *He was the first to use the term "ecosystem".*

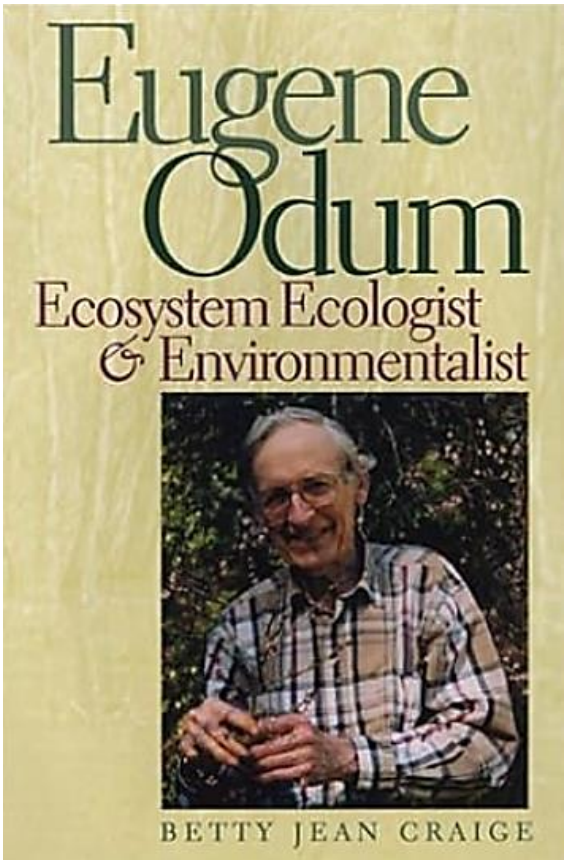
On ecosystems, Tansley's insights into psychoanalysis, together with Freud's thinking on consciousness and unconsciousness, led him to observe that the mind was

[8] Tansley, A.G. 1935: The use and abuse of vegetational concepts and terms. Ecology 16, 284 307. URL: https://www.researchgate.net/publication/249823757_Tansley_AG_1935_The_use_and_abuse_of_vegetational_concepts_and_terms_Ecology_16_284_307

an “inter-woven plexus of moving material – a more or less ordered system or rather a system of systems acting and reacting” (Cameron and Forrester, 2000b). There are clear elements of this in Tansley’s writings on the ecosystem: *An ecosystem … consists of components that are themselves more or less unstable – climate, soil and organisms. Relatively to the more stable systems the ecosystems are extremely vulnerable, both on account of their own unstable components and because they are very liable to invasion by the components of other systems.*

In Practical Plant Ecology (1923) Tansley wrote: “It is not the ecologist’s role to concern himself with hindering human activity – destructive or otherwise. If human activity destroys a large number of plant communities and plant habitats, and modifies, to a greater or lesser extent, many more, it also produces fresh habitats and fresh plant communities, and thus provides fresh opportunities for study on every hand”. Now there is an interesting set of thoughts.

Tansley (1935) defined an “ecosystem” as a biological assemblage interacting with its associated physical environment and located in a specific place.



Eugene Odum: The father of modern ecology[9]. Eugene Odum is lionized throughout science as *the father of modern ecology* and recognized by the University of Georgia as the founder of what became the Eugene P. Odum School of Ecology — the world's first stand-alone college of ecology. Before lead was banned from gasoline, before Rachel Carson published Silent Spring about the dangers of pesticides and before the U.S. created Earth Day, Odum’s research and advocacy inspired the modern -environmental movement. He was also instrumental in developing the University of Georgia Marine Institute, where he began a long-term analysis of salt marsh ecology and coastal food webs that inspired generations of wetland scientists. Today, the Marine Institute provides researchers with ready access to coastal habitats and long-term data on the state’s estuaries and barrier islands.

“*Fundamentals of Ecology*,” a book which Odum published in 1953 with his younger brother and fellow ecologist Howard, was the discipline’s only textbook for more than a decade. This book was the first to suggest that scientists approach nature “top-down.” Fundamentals of Ecology is still an international bestseller.

While Odum was a careful and thoughtful researcher, his work often blurred the lines between science and advocacy. Ecology, he would tell people, simply comes from the Greek word “oikos,” meaning house. The various ecosystems, or houses,

[9] Eugene Odum: The father of modern ecology. URL: https://news.uga.edu/the-father-of-modern-ecology/

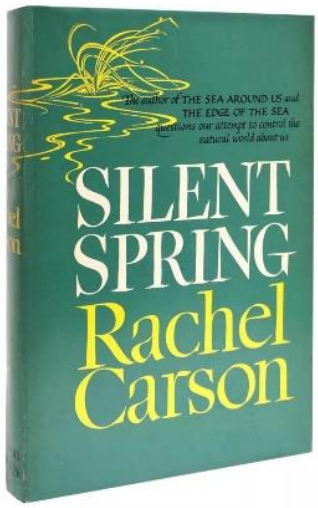
could be as small as a lonely woodland pond or as large as an entire planet, and humans had a responsibility to treat our "big house" with utmost care.

Eugene Odum: Ecosystem Ecologist & Environmentalist"[10] a book that was written by Betty Jean Graige. She decided to write a biography about Odum. The picture of Odum that results is very impressive and illustrates the relationship between science and society, and between academic and government policy. However, further information must be given concerning the general picture of ecology and of holism that emerges in this book. First, where the author is looking for a historical context concerning the emergence of ecology, she neglects the non-Anglo-Saxon European sources of this discipline (Acot 1998). Second, some clarifications are necessary concerning the holistic philosophical background of the Odum's position. Fundamentals of Ecology (Odum 1971) has recently been called the book that has made the greatest impact on the careers of biologists and ecologists (Barrett & Mabry 2002). This evaluation cannot be necessarily shared by all the scientists in biological sciences, particularly those that work in evolutionary biology, but it is certain that Odum's book is paradigmatic. The holistic perspective presented has influenced generations of scientists[11].

While Odum did wish to influence the knowledge base and thinking of fellow biologists and of college and university students, his historical role was not as a promoter of public *environmentalism* as we now know it. However, his dedication in his 1963 book, Ecology, expressed that his father had inspired him to "seek more harmonious relationships *between man and nature*".

By 1970, when the first Earth Day was organized, Odum's conception of the living Earth as a global set of interlaced ecosystems became one of the key insights of the environmental movement that has since spread through the world. He was, however, an independent thinker who was at times, gently critical of the slogans and fashionable concepts of the environmentalist movement.

Eugene Odum wrote the groundbreaking, now-classic textbook Fundamentals of Ecology; brought ecosystem into the popular lexicon; and stirred up great controversy with his holistic view of nature.



The Story of Silent Spring (Rachel Carson): how a courageous woman took on the chemical industry and raised important questions about humankind's impact on nature! *Silent Spring is an environmental science book by Rachel Carson*. Published on September 27, 1962, the book documented the ***environmental harm caused by the indiscriminate use of pesticides***. Carson accused the chemical industry of spreading disinformation, and public officials of accepting the industry's marketing claims unquestioningly. In the late 1950s, Carson began to work on environmental conservation, especially

[10] Eugene Odum: Ecosystem Ecologist & Environmentalist: book review. URL: https://philarchive.org/archive/BEREOE

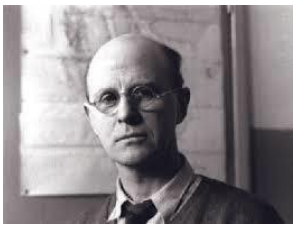
[11] Eugene Odum: Ecosystem Ecologist and Environmentalist. Betty Jean Craige. The University of Georgia Press, Athens, 2001, pp. 226. $34.95. ISBN 0-8203-2281-4. URL: https://muse.jhu.edu/article/11205/pdf

environmental problems that she believed were caused by synthetic pesticides. The result of her research was Silent Spring, which brought environmental concerns to the American public. The book was met with fierce opposition by chemical companies, but it swayed public opinion and led to a reversal in U.S. pesticide policy, a nationwide ban on DDT for agricultural uses, and an environmental movement that led to the creation of the U.S. Environmental Protection Agency[12].

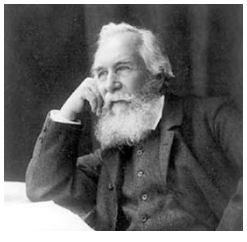
Carson, a renowned nature author and a former marine biologist with the U.S. Fish and Wildlife Service, or FWS, was uniquely equipped to create so startling and inflammatory a book. A native of rural Pennsylvania, she had grown up with an enthusiasm for nature matched only by her love of writing and poetry.

Silent Spring took Carson four years to complete. It meticulously described how DDT entered the food chain and accumulated in the fatty tissues of animals, including human beings, and caused cancer and genetic damage. A single application on a crop, she wrote, killed insects for weeks and months - not only the targeted insects but countless more - and remained toxic in the environment even after it was diluted by rainwater. Carson concluded that DDT and other pesticides had irrevocably harmed animals and had contaminated the world's food supply[13].

In 2006, Silent Spring was named one of the 25 greatest science books of all time by the editors of Discover magazine.



Animal Ecology – Charles Elton. 20th-century English zoologist and ecologist, Charles Elton, is commonly credited as "*the father of animal ecology"*. Elton influenced by Victor Shelford's Animal Communities in Temperate America began his research on animal ecology as an assistant to his colleague, Julian Huxley, on an ecological survey of the fauna in Spitsbergen in 1921[14]. Elton's most famous studies were conducted during his time as a biological consultant to the Hudson Bay Company to help understand the fluctuations in the company's fur harvests. Elton studied the population fluctuations and dynamics of snowshoe hare, Canadian lynx, and other mammals of the region. Elton is also considered the first to coin the terms, food chain and food cycle in his famous book Animal Ecology. Elton is also attributed with contributing to disciplines of: invasion ecology, community ecology, and wildlife disease ecology[15].



Ernst Haeckel (1834-1919) was a German-born biologist, naturalist, evolutionist, artist, philosopher, and doctor who spent his life researching flora and fauna from the highest mountaintops to the deepest ocean. *A vociferous supporter and developer of Darwin's theories of evolution*, he gained a doctorate in zoology, and coined scientific terms which have passed into common usage, including ecology, phylum, and stem cell**[16]**.

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[12] Paull, John (2013) "The Rachel Carson Letters and the Making of Silent Spring". URL: https://web.archive.org/web/20131103230258/http://orgprints.org/22934/7/22934.pdf
[13] The Story of Silent Spring: URL: https://www.nrdc.org/stories/story-silent-spring
[14] Southwood, R.; Clarke, J. R. (1999). "Charles Sutherland Elton. 29 March 1900 - 1 May: Elected F.R.S. 1953"
[15] Elton, C.S. 1968 reprint. Animal ecology. Great Britain: William Clowes and Sons Ltd
[16] Rainer Willmann, Julia Voss (2020). THE ART AND SCIENCE OF ERNST HAECKEL. 40TH ANNIVERSARY EDITION. *TASCHEN*. 512 p.

At the heart of Haeckel's colossal legacy was the motivation not only to discover but also to explain. To do this, he created hundreds of detailed drawings, watercolors, and sketches of his findings which he published in successive volumes, including several marine organism collections and the majestic Kunstformen der Natur (Art Forms in Nature), which could serve as the cornerstone of Haeckel's entire life project. Like a meticulous visual encyclopedia of living things, Haeckel's work was as remarkable for it's graphic precision and meticulous shading as for it's understanding of organic evolution. From bats to the box jellyfish, lizards to lichen, and spider legs to sea anemones, Haeckel emphasized the essential symmetries and order of nature, and found biological beauty in even the most unlikely of creatures.

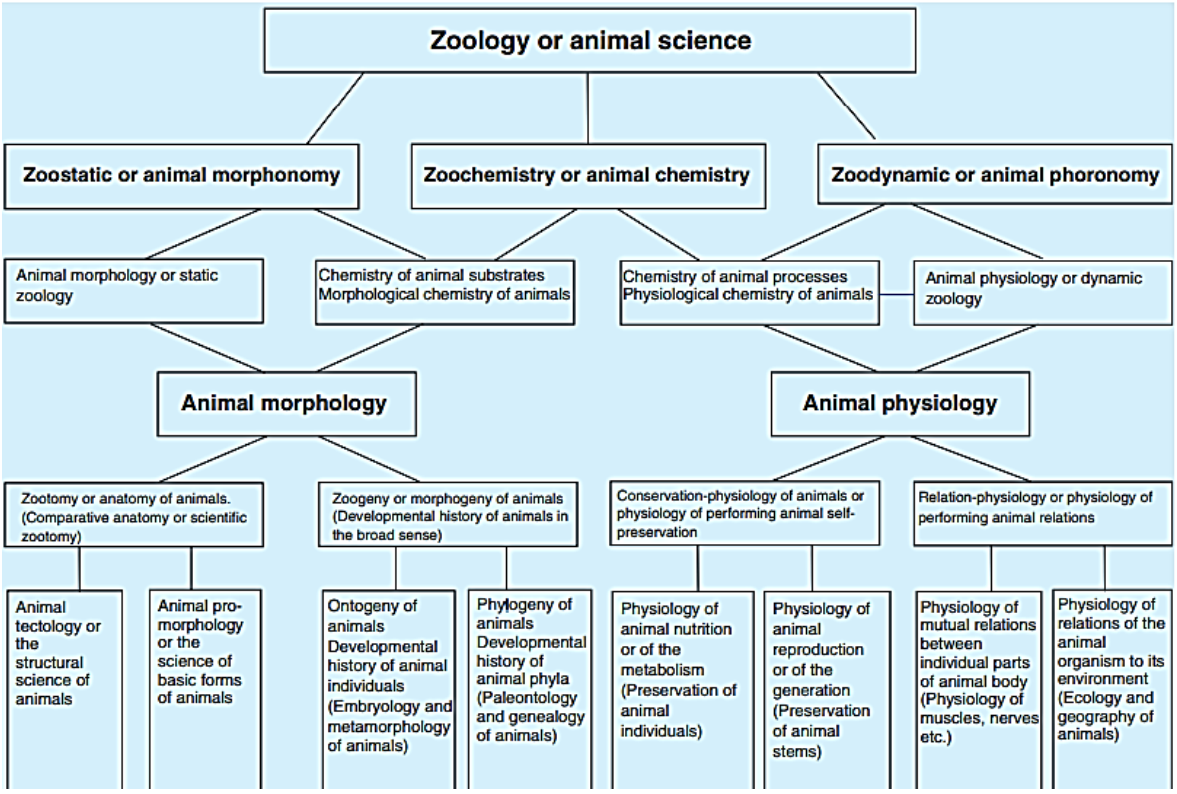


Figure 7. Haeckel's "Animal Science"[17].

Haeckel's overview of zoology, where he introduced his famous concepts of ontogeny, phylogeny and ecology. The scheme incorporates both the 'static', and 'dynamic' aspects of animal life, where 'static' is used to describe structures and forms (morphology), and 'dynamic' deals with astate of change.

Makarenko Nataliya Anatoliivna (1959-2022), was born in Glukhiv city, Sumy Oblast. She was a Doctor of Agricultural Sciences, a professor, a Ukrainian ecotoxicologist, and an environmentalist. She was a vice-director of the Institute of Agroecology and Nature Management NAAS in scientific fields (2003-2011); and worked at the National University of Life and Environmental Sciences of Ukraine (2003-2022). Her scientific

[17] Levit, G. S., & Hossfeld, U. (2019). Ernst Haeckel in the history of biology. Current Biology, 29(24), R1276-R1284. URL: https://www.cell.com/current-biology/pdf/S0960-9822(19)31436-8.pdf

research connected with the ecotoxicological assessment of agrochemicals, pesticides, nanopreparations, and heavy metals; implementation of organic crop production in Ukraine; environmental monitoring of rural areas where solid waste landfills are located. Awards and honors: Certificate of Honor of the Verkhovna Rada of Ukraine (2009), Honorary award of the Ukrainian Academy of Agrarian Sciences (2009), Certificate of Honor of the Presidium of the Ukrainian Academy of Agrarian Sciences (2007), Certificate of Honor of the Ministry of Environmental Protection (2006), Acknowledgment of the Ministry of Education and Science of Ukraine (2020)[18].

Her scientific school includes 2 doctors of science and 9 candidates of science who prepared theses under her supervisionю The author of 7 monographs and textbooks, 100 scientific papers, 30 educational and methodological materials for the training of specialists of the educational degree Bachelor, Master, Doctor of Philosophy in the specialty Ecology.

She developed of methods in environmental soil sciences, such as (1) the method of determining the lands suitability of agricultural purposes to the requirements for special raw material zones (utility model patent No. 33772); (2) the method of environmental expertise to growing agricultural crops (Patent for utility model No42925); (3) the method of assessment soils from residual amounts of DDT (Patent for the invention Ukraine, (11)50678 (51)VO 9C1/08, C09K17/00 (46) 15.02.2005. Bull. No. 2); (4) the way for water sampler (Patent for the invention Ukraine. (19) UA (11) 6806. (13) U (51) 7G01N/10); (5) the method of environmental expertise for using mineral fertilizers (Patent for the invention Ukraine, (11)44191 (51)7 G01N33/24 (46) 15.07.2003. Bull. No. 7); (6) the method of soil assessment to remove hexachlorocyclohexane (Declaratory patent for the invention Ukraine, (11)53530 (51) VO 9C1/08, C09K17/00 (46) 15.01.2003. Bull. No. 1); (7) the method of determination of residual amounts of herbicide stomp in environmental objects and agricultural products (Patent for invention Ukraine, (19) UA, (11) 34515, (46) 15.03.2001. Bull. No. 2)[19].

Table 1. – A list of founders, innovators and their significant contributions to ecology, from Romanticism onward

Notable figure	Lifespan	Major contribution & citation
Antonie van Leeuwenhoek	1632–1723	First to develop the concept of food chains
Carl Linnaeus	1707–1778	Influential naturalist, inventor of science on the economy of nature
Alexander Humboldt	1769–1859	First to describe ecological gradient of latitudinal biodiversity increase toward the tropics in 1807
Charles Darwin	1809–1882	Founder of the hypothesis of evolution by means of natural selection, founder of ecological studies of soils
Elizabeth Catherine Thomas Carne	1817-1873	Geologist, mineralogist and philosopher who observed rural vs urban living, spatially and culturally, finding in country living the best attack on suffocating class divides, healthier living, and best access to natural education
Herbert Spencer	1820–1903	Early founder of social ecology, coined the phrase 'survival of the fittest
Karl Möbius	1825–1908	First to develop concept of ecological community, biocenosis, or living community

[18] Дем'янюк О. С. Макаренко Наталія Анатоліївна // Енциклопедія сучасної України / ред. кол.: І. М. Дзюба [та ін.] ; НАН України, НТШ. - К. : Інститут енциклопедичних досліджень НАН України, 2001-2023

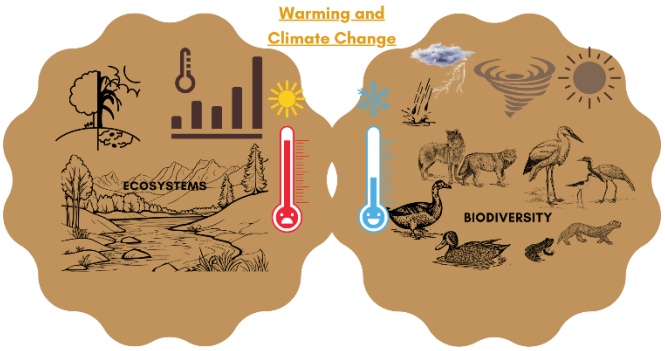
[19] Макаренко Наталія Анатоліївна: науково-педагогічна діяльністью URL: https://nubip.edu.ua/node/86141

Ernst Haeckel	1834–1919	Invented the term ecology, popularized research links between ecology and evolution
Victor Hensen	1835–1924	Invented term plankton, developed quantitative and statistical measures of productivity in the seas
Eugenius Warming	1841–1924	Early founder of Ecological Plant Geography
Ellen Swallow Richards	1842–1911	Pioneer and educator who linked urban ecology to human health
Stephen Forbes	1844–1930	Early founder of entomology and ecological concepts in 1887
Vito Volterra	1860–1940	Independently pioneered mathematical populations models around the same time as Alfred J. Lotka
Volodymyr Vernadsky	1869–1939	Founded the biosphere concept
Henry C. Cowles	1869–1939	Pioneering studies and conceptual development in studies of ecological succession
Jan Christiaan Smuts	1870–1950	Coined the term holism in a 1926 book Holism and Evolution
Arthur G. Tansley	1871–1955	First to coin the term ecosystem in 1936 and notable researcher
Charles Christopher Adams	1873–1955	Animal ecologist, biogeographer, author of first American book on animal ecology in 1913, founded ecological energetics
Friedrich Ratzel	1844–1904	German geographer who first coined the term biogeography in 1891
Frederic Clements	1874–1945	Authored the first influential American ecology book in 1905
Victor Ernest Shelford	1877–1968	Founded physiological ecology, pioneered food-web and biome concepts, founded The Nature Conservancy
Alfred J. Lotka	1880–1949	First to pioneer mathematical populations models explaining trophic (predator-prey) interactions using logistic equation
Henry Gleason	1882–1975	Early ecology pioneer, quantitative theorist, author, and founder of the individualistic concept of ecolog
Charles S. Elton	1900–1991	'Father' of animal ecology, pioneered food-web & niche concepts and authored influential Animal Ecology text
G. Evelyn Hutchinson	1903–1991	Limnologist and conceptually advanced the niche concept
Eugene P. Odum	1913–2002	Co-founder of ecosystem ecology and ecological thermodynamic concepts
Howard T. Odum	1924–2002	Co-founder of ecosystem ecology and ecological thermodynamic concepts
Robert MacArthur	1930–1972	Co-founder on Theory of Island Biogeography and innovator of ecological statistical methods

Control questions for students

1. In which the science of ecology began to develop?
2. In which the science of the environment began to develop?
3. In what years did the disciplines appear such as agroecology, radioecology, and ecotoxicology?
4. Which scientists did contribute to ecology as a science?
5. Which scientists did contribute to environmental science?

3. Challenges of Climate Change impacts on the ecological levels of the organizations



3.1. Warming and Climate Change

3.2. The difference between a population, community, and an ecosystem

3.3. Climate Change influences the biodiversity

3.4. The principles of rewilding

Vocabulary	
Climate Change	is the significant variation of average weather conditions becoming, for example, warmer, wetter, or drier-over several decades or longer. It is the longer-term trend that differentiates climate change from natural weather variability[20]
Climate	refers to the long-term regional or global average of temperature, humidity and rainfall patterns over seasons, years or decades
The greenhouse effect	is the process through which heat is trapped near Earth's surface by substances known as 'greenhouse gases.' Imagine these gases as a cozy blanket enveloping our planet, helping to maintain a warmer temperature than it would have otherwise[21]
Greenhouse gases	consist of carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, and water vapor
Organism	is defined as an entity with life; organism (biology definition): a living thing that has an organized structure, can react to stimuli, reproduce, grow, adapt, and maintain homeostasis
Population	*a group* of individuals that belong to *the same species* and live in the same area
A community	is basically an ecosystem of *many different species* of living things that interact with each other. A rainforest is an example of a biological community
Ecosystem	all the living and non-living components of an area
Biodiversity loss	a decrease in biodiversity within a species, an ecosystem, a given geographic area, or Earth as a whole. Biodiversity, or biological diversity, is a term that refers to the number of genes, species, and individual organisms within a given species, and biological communities within a defined geographic area, ranging from the smallest ecosystem to the global biosphere
Rewilding	is all about letting nature be spontaneous, dynamic, and unpredictable. Rather than trying to manage and control which plants, animals, and habitats thrive, it is about sitting back and letting nature decide[22]

[20] Climate Change Knowledge Portal. URL: https://climateknowledgeportal.worldbank.org/overview
[21] What is the greenhouse effect? URL: https://climate.nasa.gov/faq/19/what-is-the-greenhouse-effect/
[22] What is the rewilding? URL: https://rewildingsussex.org/seeking-a-wilder-future-for-the-benefit-of-people-and-nature/what-is-rewilding/

3.1. Warming and Climate Change

"Climate change" and "global warming" are often used interchangeably but have distinct meanings. Similarly, the terms "weather" and "climate" are sometimes confused, though they refer to events with broadly different spatial- and timescales.

Weather refers to atmospheric conditions that occur locally over short periods of time-from minutes to hours or days. Familiar examples include rain, snow, clouds, winds, floods, or thunderstorms.

Climate, on the other hand, refers to the long-term (usually at least 30 years) regional or even global average of temperature, humidity, and rainfall patterns over seasons, years, or decades.

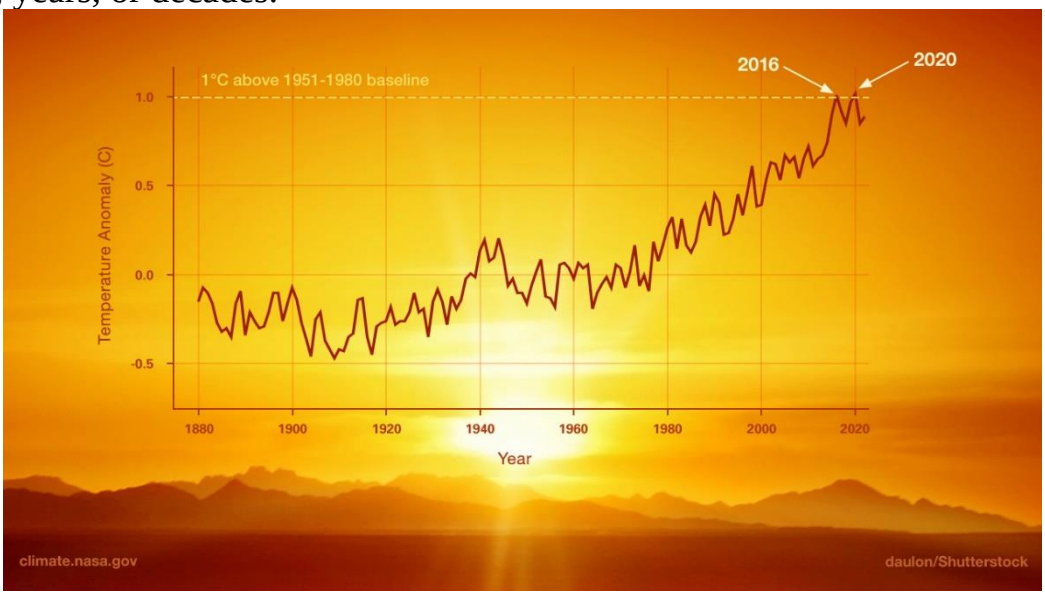


Figure 8. This graph illustrates the change in global surface temperature relative to 1951-1980 average temperatures, with the year 2020 statistically tying with 2016 for hottest on record (Source: NASA's Goddard Institute for Space Studies)

What Is Global Warming?

Global warming is the long-term heating of Earth's surface observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere. This term is not interchangeable with the term "climate change."

What Is Climate Change?

Climate change is a long-term change in the average weather patterns that have come to define Earth's local, regional and global climates. These changes have a broad range of observed effects that are synonymous with the term.

Changes observed in Earth's climate since the mid-20th century are driven by human activities, particularly fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere, raising Earth's average surface temperature. Natural processes, which have been overwhelmed by human activities, can also contribute to climate change, including internal variability.

3.1.1. Causes of Climate Change

Fossil fuels – coal, oil and gas – are by far the largest contributor to global climate change, accounting for over 75 per cent of global greenhouse gas emissions and nearly 90 per cent of all carbon dioxide emissions.

As greenhouse gas emissions blanket the Earth, they trap the sun's heat. This leads to global warming and climate change. The world is now warming faster than at any point in recorded history. Warmer temperatures over time are changing weather patterns and disrupting the usual balance of nature. This poses many risks to human beings and all other forms of life on Earth.

Causes of Climate Change: generating power, manufacturing goods, Cutting down forests, using transportation, producing food, powering buildings, consuming too much[23].

Generating power

Generating electricity and heat by burning fossil fuels causes a large chunk of global emissions. Most electricity is still generated by burning coal, oil, or gas, which produces carbon dioxide and nitrous oxide – powerful greenhouse gases that blanket the Earth and trap the sun's heat. Globally, a bit more than a quarter of electricity comes from wind, solar and other renewable sources which, as opposed to fossil fuels, emit little to no greenhouse gases or pollutants into the air.

Manufacturing goods

Manufacturing and industry produce emissions, mostly from burning fossil fuels to produce energy for making things like cement, iron, steel, electronics, plastics, clothes, and other goods. Mining and other industrial processes also release gases, as does the construction industry. Machines used in the manufacturing process often run on coal, oil, or gas; and some materials, like plastics, are made from chemicals sourced from fossil fuels. The manufacturing industry is one of the largest contributors to greenhouse gas emissions worldwide.

Cutting down forests

Cutting down forests to create farms or pastures, or for other reasons, causes emissions, since trees, when they are cut, release the carbon they have been storing. Each year approximately 12 million hectares of forest are destroyed. Since forests absorb carbon dioxide, destroying them also limits nature's ability to keep emissions out of the atmosphere. Deforestation, together with agriculture and other land use changes, is responsible for roughly a quarter of global greenhouse gas emissions.

Using transportation

Most cars, trucks, ships, and planes run on fossil fuels. That makes transportation a major contributor of greenhouse gases, especially carbon-dioxide emissions. Road vehicles account for the largest part, due to the combustion of petroleum-based products, like gasoline, in internal combustion engines. But emissions from ships and planes continue to grow. Transport accounts for nearly one quarter of global energy-related carbon-dioxide emissions. And trends point to a significant increase in energy use for transport over the coming years.

[23] Causes and Effects of Climate Change. United National. Climate Action. URL: https://www.un.org/en/climatechange/science/causes-effects-climate-change

Producing food

Producing food causes emissions of carbon dioxide, methane, and other greenhouse gases in various ways, including through deforestation and clearing of land for agriculture and grazing, digestion by cows and sheep, the production and use of fertilizers and manure for growing crops, and the use of energy to run farm equipment or fishing boats, usually with fossil fuels. All this makes food production a major contributor to climate change. And greenhouse gas emissions also come from packaging and distributing food.

Powering buildings

Globally, residential and commercial buildings consume over half of all electricity. As they continue to draw on coal, oil, and natural gas for heating and cooling, they emit significant quantities of greenhouse gas emissions. Growing energy demand for heating and cooling, with rising air-conditioner ownership, as well as increased electricity consumption for lighting, appliances, and connected devices, has contributed to a rise in energy-related carbon-dioxide emissions from buildings in recent years.

Consuming too much

Your home and use of power, how you move around, what you eat and how much you throw away all contribute to greenhouse gas emissions. So does the consumption of goods such as clothing, electronics, and plastics. A large chunk of global greenhouse gas emissions are linked to private households. Our lifestyles have a profound impact on our planet. The wealthiest bear the greatest responsibility: the richest 1 per cent of the global population combined account for more greenhouse gas emissions than the poorest 50 per cent.

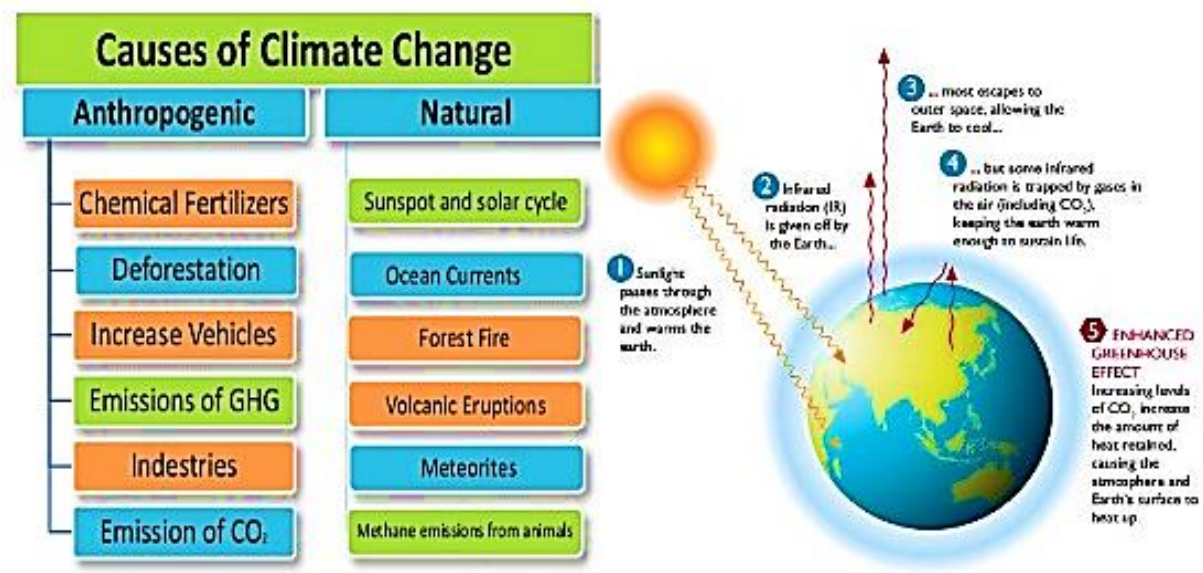


Figure 9. Factors that cause climate change[24]

[24] Factors that cause climate change. URL: https://www.insightsonindia.com/environment/climate-change-and-associated-issues/factors-that-cause-climate-change/

A) Natural Factors:

There are numerous natural factors that cause the Earth's climate to change. They affect the climate over a period of thousands to millions of years.

- **Continental Drift:** The present-day continents were not the same prior to 200 million years. They have formed millions of years ago when the landmass began to drift apart due to plate displacement. This movement had an impact on climate change due to the change on the landmass's physical features and position and the change in water bodies' position like the change in the follow of ocean currents and winds. The drifting of the landmass is continued today. The Himalayan range is rising approximately 1 millimetre every year as the Indian landmass is moving towards the Asian landmass.
- **Variation of the Earth's orbit:** The Earth's orbit has an impact on the sunlight's seasonal distribution that is reaching the Earth's surface. A slight change in the Earth's orbit can lead to variation in distribution across the world. There are very few changes to the average sunshine. However, it causes a high impact on the geographical and seasonal distribution. There are three types of orbital variations – variations in Earth's eccentricity, variations in the tilt angle of the Earth's axis of rotation and precession of Earth's axis.These together can cause Milankovitch cycles, which have a huge impact on climate and are well-known for their connection to the glacial and interglacial periods.The Intergovernmental Panel on Climate Change finding showed that the Milankovitch cycles had influenced the behaviour of ice formation
- **Plate tectonics:** Due to the change in the temperature in the core of the Earth, the mantle plumes and convection currents forced the Earth's Plates to adjust leading to the rearrangement of the Earth Plate. This can influence the global and local patterns of climate and atmosphere.The oceans' geometry is determined by the continents' position. Therefore, the position of the continents influences the pattern of the ocean. The location of the sea also plays a crucial role in controlling the transfer of heat and moisture across the globe and determines the global climate.The recent example of the tectonic control on ocean circulation is the formation of the Isthmus of Panama about 5 million years ago, leading to the prevention of the direct mixing of the Atlantic and Pacific oceans.
- **Volcanic Activity:** When a volcano erupts, it emits gases and dust particles, causing a partial block of the Sunrays. This can lead to the cooling of the weather. Though the volcanic activities last only for a few days, the gases and ashes released by it can last for a long period, leading to it influencing climate patterns. Sulphur oxide emitted by the volcanic activities can combine with water to form tiny droplets of sulphuric acid. These droplets are so small that many of them can stay in the air for several years.
- **Ocean Currents:** Ocean current is one of the major components of the climate system. It is driven by horizontal winds causing the movement of the water against the sea surface. The temperature differences of the water influence the climate of the region.

B) Anthropogenic Factors:

Scientists, since the beginning of the 20th century, have studied the impact of climate change caused by human activities. Global warming, the long-term rise in the average temperature of the Earth's climate system, is a major aspect of climate change. It is mainly a human-caused increase in global surface temperature. The anthropogenic factors causing climate change are as follows:

- **Greenhouse Gases:** The greenhouse gases absorb heat radiation from the sun. Following the initiation of the Industrial Revolution, the emission of greenhouse gases into the atmosphere has increased exponentially. This has led to more absorption and retaining the heat in the atmosphere. This resulted in an increase in Global Temperature. The greenhouse gases mostly do not absorb the solar radiation but absorb most of the infrared emitted by the Earth's surface.
  - The main greenhouse gases include
    - water vapour (the majority of the GHG in the atmosphere but the impact is less)
    - Carbon dioxide released due to natural and anthropogenic factors spends more time in the atmosphere, leading to an increase in its impact. There has been a 30% increase in the concentration of CO2 since the start of the industrial revolution. Apart from the industrial revolution, deforestation also contributes to the increase in the CO
    - Chlorofluorocarbons, used for industrial purposes, especially in refrigerants and air conditioning, is a man-made compound regulated under the Montreal Protocol due to their adverse effects on the Ozone layers.
    - Methane is released due to decomposition of organic matter. It is stronger than CO_2 because of its capacity to absorb more heat.
    - Nitrous oxide is produced by the agricultural sector, especially in the production and use of organic fertilizers and while burning fossil fuels.
- **Change in the land use pattern:** Half of the land-use change is said to have happened during the industrial era. Most of the forests were replaced by agricultural cropping and grazing of lands. The increased albedo (reflectivity of an object in space) in the snow-covered high-altitude regions due to deforestation led to the cooling of the planet's surface. The lower the albedo, the more of the Sun's radiation gets absorbed by the planet and the temperatures will rise. If the albedo is higher and the Earth is more reflective, the more of the radiation is returned to space, leading to the cooling of the planet. The tropical deforestation changes the evapotranspiration rates (the amount of water vapour put in the atmosphere through evaporation and transpiration from trees), causes desertification and affects soil moisture characteristics. From the satellite imagery, it is seen that the clearing of forest cover for agriculture and irrigated farming in arid and semi-arid lands can

increase solar energy absorption and the amount of moisture evaporated into the atmosphere.

- **Atmospheric aerosols: Atmospheric aerosol can:** Scatter and absorb the solar and infrared radiation, change microphysical and chemical properties of the clouds, Solar radiation, when scattered, cools the planet. On the other hand, when the aerosols absorb solar radiation, it causes an increase in the temperature of the air instead of allowing the sunlight to be absorbed by the Earth's surface. Aerosols can directly affect climate change by absorbing or reflecting solar radiation. They can also produce indirect effects by modifying the cloud's formation and properties. They can even be transported thousands of kilometres away from its source through wind and upper-level circulation in the atmosphere.
    - There are two types of aerosols – Natural aerosols and Anthropogenic aerosols.
        - The sources of natural aerosols include volcanic eruptions (produces sulphate aerosols) and biogenic sources like planktons (can produce dimethyl sulphide).
        - The anthropogenic aerosols include: The ammonia used for fertilizers or released by the burning of plants and other organic materials forms a major source for Nitrate aerosols. Burning of coal and oil produces sulphur dioxide that forms a major source of sulphate aerosols. Burning of biomass can release a combination of organic droplets and soot particles. Industrial activities cause the release of wide-ranging aerosols into the atmosphere. Vehicle emissions can produce numerous pollutants that are aerosol from the beginning or becomes one due to chemical reactions in the atmosphere. It is found that the concentration of aerosols is about three times higher in the Northern Hemisphere than in the Southern Hemisphere, leading to the Northern Hemisphere's radiation concentration being 50% higher than that of the Southern Hemisphere.

3.1.2. Effects of Climate Change

Climate change has already caused significant impacts on the environment and human societies. Some of the effects of climate change include:

Hotter temperatures

As greenhouse gas concentrations rise, so does the global surface temperature. The last decade, 2011-2020, is the warmest on record. Since the 1980s, each decade has been warmer than the previous one. Nearly all land areas are seeing more hot days and heat waves. Higher temperatures increase heat-related illnesses and make working outdoors more difficult. Wildfires start more easily and spread more rapidly when conditions are hotter. Temperatures in the Arctic have warmed at least twice as fast as the global average.

More severe storms

Destructive storms have become more intense and more frequent in many

regions. As temperatures rise, more moisture evaporates, which exacerbates extreme rainfall and flooding, causing more destructive storms. The frequency and extent of tropical storms is also affected by the warming ocean. Cyclones, hurricanes, and typhoons feed on warm waters at the ocean surface. Such storms often destroy homes and communities, causing deaths and huge economic losses.

Increased drought

Climate change is changing water availability, making it scarcer in more regions. Global warming exacerbates water shortages in already water-stressed regions and is leading to an increased risk of agricultural droughts affecting crops, and ecological droughts increasing the vulnerability of ecosystems. Droughts can also stir destructive sand and dust storms that can move billions of tons of sand across continents. Deserts are expanding, reducing land for growing food. Many people now face the threat of not having enough water on a regular basis.

A warming, rising ocean

The ocean soaks up most of the heat from global warming. The rate at which the ocean is warming strongly increased over the past two decades, across all depths of the ocean. As the ocean warms, its volume increases since water expands as it gets warmer. Melting ice sheets also cause sea levels to rise, threatening coastal and island communities. In addition, the ocean absorbs carbon dioxide, keeping it from the atmosphere. But more carbon dioxide makes the ocean more acidic, which endangers marine life and coral reefs.

Loss of species

Climate change poses risks to the survival of species on land and in the ocean. These risks increase as temperatures climb. Exacerbated by climate change, the world is losing species at a rate 1,000 times greater than at any other time in recorded human history. One million species are at risk of becoming extinct within the next few decades. Forest fires, extreme weather, and invasive pests and diseases are among many threats related to climate change. Some species will be able to relocate and survive, but others will not.

Not enough food

Changes in the climate and increases in extreme weather events are among the reasons behind a global rise in hunger and poor nutrition. Fisheries, crops, and livestock may be destroyed or become less productive. With the ocean becoming more acidic, marine resources that feed billions of people are at risk. Changes in snow and ice cover in many Arctic regions have disrupted food supplies from herding, hunting, and fishing. Heat stress can diminish water and grasslands for grazing, causing declining crop yields and affecting livestock.

More health risks

Climate change is the single biggest health threat facing humanity. Climate impacts are already harming health, through air pollution, disease, extreme weather events, forced displacement, pressures on mental health, and increased hunger and poor nutrition in places where people cannot grow or find sufficient food. Every year, environmental factors take the lives of around 13 million people. Changing weather patterns are expanding diseases, and extreme weather events increase deaths and

make it difficult for health care systems to keep up.

Poverty and displacement

Climate change increases the factors that put and keep people in poverty. Floods may sweep away urban slums, destroying homes and livelihoods. Heat can make it difficult to work in outdoor jobs. Water scarcity may affect crops. Over the past decade (2010–2019), weather-related events displaced an estimated 23.1 million people on average each year, leaving many more vulnerable to poverty. Most refugees come from countries that are most vulnerable and least ready to adapt to the impacts of climate change[25].

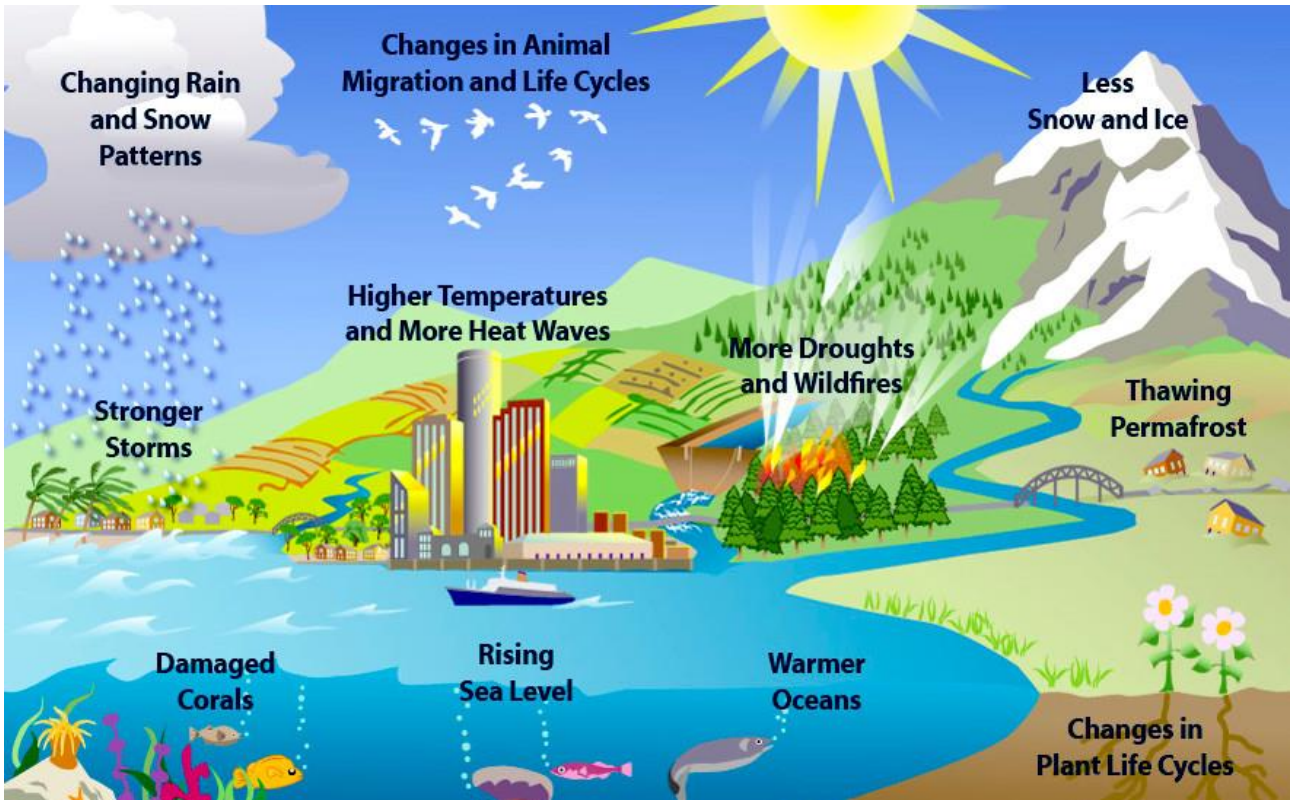


Figure 10. Effects of Global warming and Climate Change on our immediate environments[26]

In summary, Climate change refers to the long-term alterations in the Earth's climate patterns, including temperature, precipitation, and wind patterns, among others. It is primarily caused by human activities, and it has significant impacts on the natural world and human societies worldwide. Below, you can see the causes, effects, and solutions to climate change.

[25] Causes and Effects of Climate Change. United National. Climate Action. URL: https://www.un.org/en/climatechange/science/causes-effects-climate-change

[26] Effects of Global warming and Climate Change on our immediate environments. URL: https://www.linkedin.com/pulse/effects-global-warming-climate-change-our-immediate-lawrence-comb

Figure 11. The causes, effects, and solutions to climate change [27]

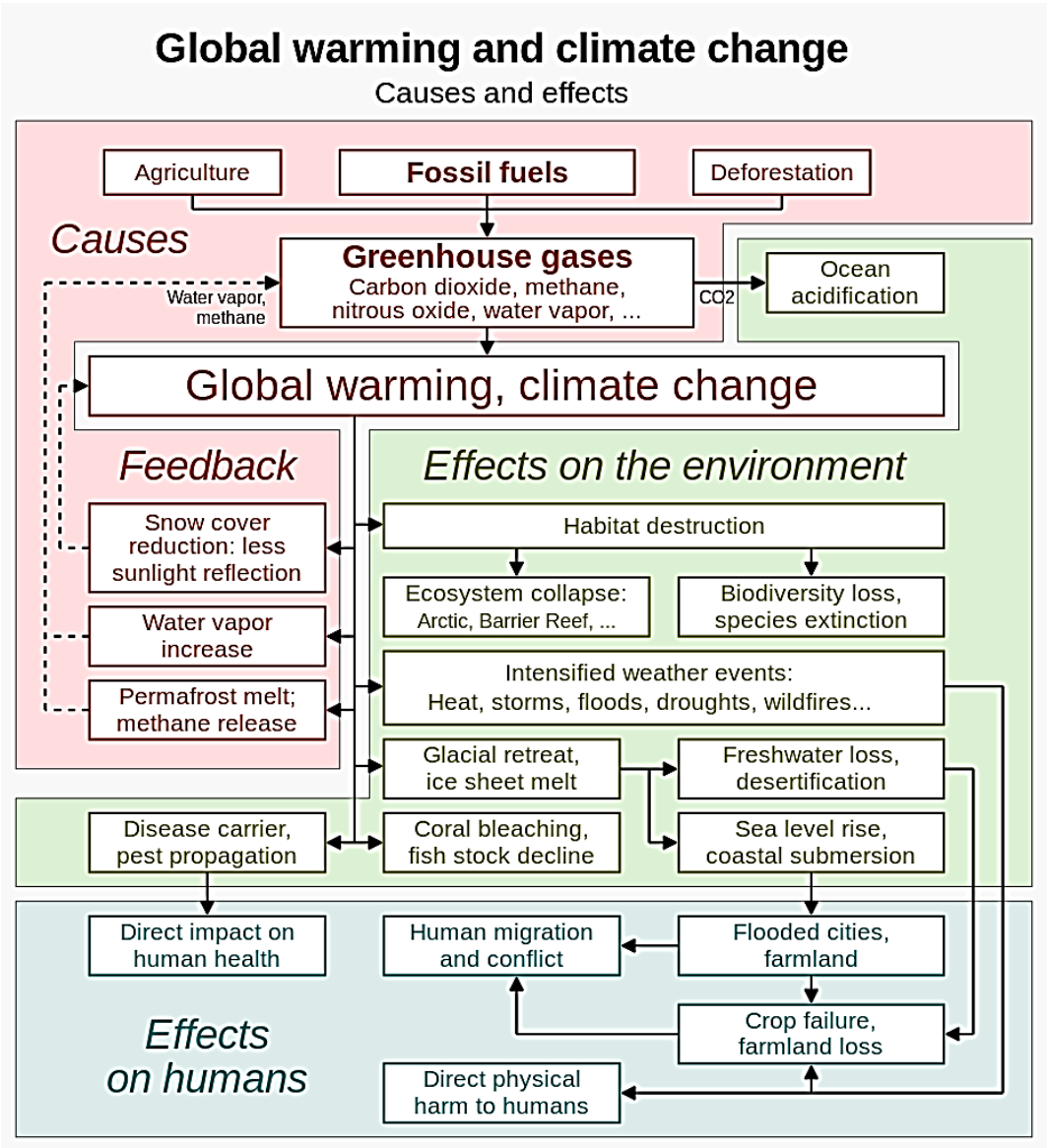
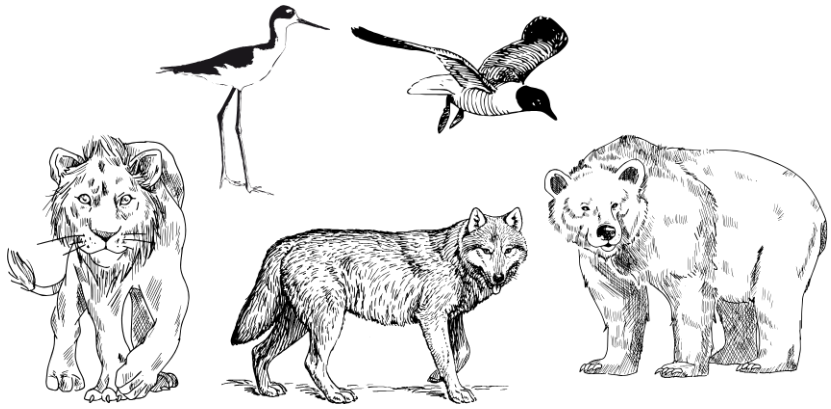


Figure 12. Global warming and climate change - vertical block diagram - causes effects[28]

[27] Understanding Climate Change: Causes, Effects, and Solutions. URL: https://vocal.media/earth/understanding-climate-change-causes-effects-and-solutions

[28] Global warming and climate change - vertical block diagram - causes effects. URL: https://sv.m.wikipedia.org/wiki/Fil:20200118_Global_warming_and_climate_change_-_vertical_block_diagram_-_causes_effects_feedback.svg

3.2. The difference between a population, community, and an ecosystem

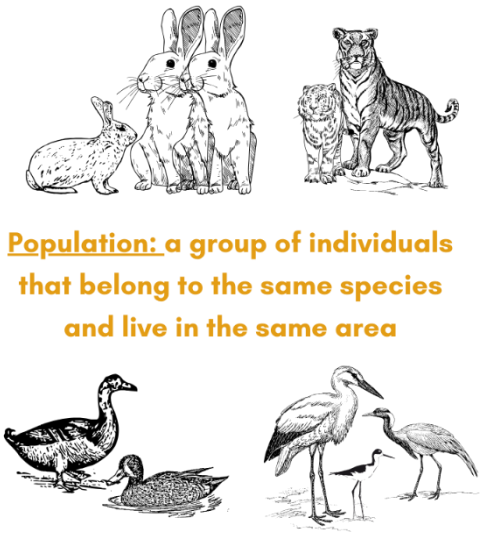


The main difference between population and community is that a population is a group of individuals of a particular species living in a particular ecosystem at a particular time whereas a community is a collection of populations living in a particular ecosystem at a particular time. Furthermore, a population consists of a single species while a community consists of several species living together.

Population and community are two levels of classification in ecology. Both describe the groups of individuals living in a particular ecosystem.

- Populations and communities are groups of organisms.
- A **population** is a group of the *same* species living in the same area.
- A **community** is a group of *different* species living in the same area.
- An **ecosystem** is all of the organisms in an area plus the nonliving parts of their environment.
- Organisms interact with both living and nonliving parts of their ecosystem. Organisms depend on these interactions in order to survive and have offspring.

3.2.1. What is a Population?

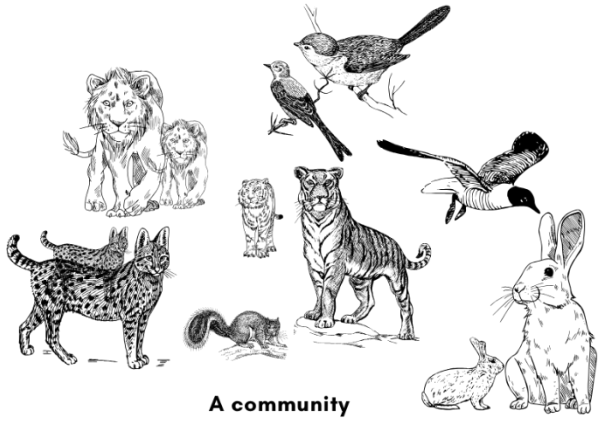


A population is ***a group of individuals of a particular species***, living and interbreeding in a defined geographical area at a defined time period. The number of individuals in the population defines the size of the population. Therefore, the size of the population varies over time due to birth, death, immigration, and emigration. Moreover, it increases under favourable environmental conditions and plentiful resources. Here, the ability of a population to increase its size to the maximum amount is called the biotic potential of the population.

Also, the other common terms involving population are population density, population distribution, exponential and logistic growth, and population dynamics. Here, the number of individuals per unit geographical area of a particular population is the population density. On the other hand, population distribution is the location of individuals within a specific area. The two observable types of population growths

are exponential growth and logistic growth. The study of the changes in the size, structure, birth rate, growth rate, death rate, and migration rate of a population is known as the population dynamics. Intra-specific competition occurs when the individuals of the population have to compete with each other for the limited resources in the ecosystem.

3.2.2. What is a Community?


A community

A community in ecology refers to ***all of the populations in a specific are***a at a certain time. Communities have many types of interactions among species. Some of these interactions among species can lead to situation where individuals have a life or death struggle. Ecologists believe that a community with a high level of diversity is more complex and stable than a community that has a low diversity.

A community is a group of two or more populations in a particular ecosystem living in a particular time. Though the individuals that belong to the different species interbreed, a number of ecological relationships occur between them within the community called interspecific interactions. This process is known as biocoenosis, the interacting organisms living together in a particular habitat.

Several types of interspecific interactions may occur including interspecific competition, predation, mutualism, commensalism, parasitism, etc. Community structure refers to the organization of the biological community with respect to ecological interactions.

3.2.3. Similarities between Population and Community

Population and community are two levels of ecology, consisting of groups of organisms living in a particular ecosystem at a particular time period.

Also, both population and community are important while describing the ecological relationships between individuals in a particular ecosystem.

Difference Between Population and Community

A population refers to a group of interbreeding individuals of the same species, isolated from other groups, while a community refers to a group or association of populations of two or more different species occupying the same geographical area and in a particular time. Hence, this is the main difference between population and community.

A group of populations make up a community in a particular ecosystem while a community and the abiotic factors make up an ecosystem.

Furthermore, a population is a small group in an ecosystem while a community is a large group when compared to a population.

3.2.4. What is an ecosystem?

An ecosystem is a system consisting of *biotic* and *abiotic components* that function together as a unit. The biotic components include all the *living things* whereas the abiotic components are the *non-living things*. Thus, an ecosystem science definition entails an ecological community consisting of different populations of organisms that live together in a particular habitat. Natural sciences like ecology and geography define an ecosystem as a geographic area where organisms, weather, and landscape, work together to form a "bubble of life".

An ecosystem is a community plus the environment. Ecology, which is the scientific study of the interactions between populations or between organisms and the environment, can be viewed at the level of an individual, a population, a community, or an ecosystem.

The structure of an ecosystem consists of *two major components*[29]:

(1) **biotic components** – producers, consumers, decomposers

(2) **abiotic components** – air, soil, sunlight, water.

The biotic components include all the living things. Basically, there are two major types of living things. They are the eukaryotes and the prokaryotes. Eukaryotes are characterized by having membrane-bound organelles (such as a nucleus) inside their cells. The prokaryotes, in turn, are those lacking membrane-bound organelles. For further differences between these two groups, read this). Examples of eukaryotes are plants, animals, fungi, and protists. Bacteria and archaea represent the prokaryotes. Now, each of them has a "job" to do in the ecosystem.

Plants, for instance, have chloroplasts that enable them to harvest light energy. Then, they take carbon dioxide and water from their environment to convert them into sugar, a biomolecule that can be used to synthesize chemical energy (such as ATP). Because they are capable of producing their own food through photosynthesis, they are referred to as the producers. Next to the producers are the primary consumers. They feed on the producers while they serve as a food source to the higher levels of consumers (e.g. secondary and tertiary).

[29] Esosystem. URL: https://www.biologyonline.com/dictionary/ecosystem

The animals are examples of consumers. The animals that feed on plants are called herbivores whereas those that feed on other animals are carnivores. Then, there are those that feed on both plants and animals. They are called omnivores.

The abiotic components include all the non-living things, such as rocks, soil, minerals, water sources, and the local atmosphere. Similar to biotic components, the abiotic components also have their ecological role. For example, elements and compounds serve as sources of nutrients. They are essential to the growth and metabolism of an organism. Apart from providing nutrients, they also provide organisms a place to live and thrive – a habitat.

Four types of ecosystems are terrestrial, freshwater, marine, and artificial. The first three occur naturally in various biomes. The last one is man-made. Ecosystems vary in size – from the micro-ecosystems (e.g. tree ecosystems) to the largest ecosystems such as ocean ecosystems[30]. This topic is described in the next lectures.

3.3. Climate Change influences the biodiversity

Biodiversity is the web of life that distinguishes planet Earth from the other lifeless spheres in our solar system, if not the universe. Biodiversity is short for biological diversity. It describes the variety of living organisms of all kinds - animals, plants, fungi, and microorganisms - that inhabit a particular area.

Most commonly, biodiversity is measured by the number of species present in an ecosystem, but genetic diversity within those species and the diversity of different ecosystems across the landscape are also important. The diversity of subdivisions of species, such as subspecies and populations, is important as well, since it is the raw material for the evolution of new species in the future.

The link between climate change and biodiversity has long been established. Although throughout Earth's history the climate has always changed with ecosystems and species coming and going, rapid climate change affects ecosystems and species ability to adapt and so biodiversity loss increases.

Climate change is happening due to natural factors and human activities. It expressively alters biodiversity, agricultural production, and food security. Mainly, narrowly adapted and endemic species are under extinction. Accordingly, concerns over species extinction are warranted as it provides food for all life forms and primary health care for more than 60–80% of humans globally. Nevertheless, the impact of climate change on biodiversity and food security has been recognized, little is explored compared to the magnitude of the problem globally. Therefore, the objectives of this review are to identify, appraise, and synthesize the link between climate change, biodiversity, and food security. Data, climatic models, emission, migration, and extinction scenarios, and outputs from previous publications were used. Due to climate change, distributions of species have shifted to higher elevations at a median rate of 11.0 m and 16.9 km per decade to higher latitudes. Accordingly, extinction rates of 1103 species under migration scenarios, provide 21–23% with unlimited migration and 38–52% with no migration. When an environmental

[30] What is an ecosystem? URL: https://www.khanacademy.org/science/biology/ecology/intro-to-ecosystems/a/what-is-an-ecosystem

variation occurs on a timescale shorter than the life of the plant any response could be in terms of a plastic phenotype. However, phenotypic plasticity could buffer species against the long-term effects of climate change. Furthermore, climate change affects food security, particularly in communities and locations that depend on rain-fed agriculture.

Summarizing, from a human perspective, the rapid climate change and accelerating biodiversity loss risks human security (e.g. a major change in the food chain upon which we depend, water sources may change, recede or disappear, medicines and other resources we rely on may be harder to obtain as the plants and fauna they are derived from may reduce or disappear, etc.).

Video about Biodiversity and Climate Change you can see on YouTube: https://vimeo.com/7965089

3.3.1. Causes of biodiversity loss

The impact of man on biodiversity includes species exploitation, land degradation, nitrogen deposition, pollution, the introduction of invasive or alien species, water diversion, landscape fragmentation, urbanization, and industrialization[31].

Biodiverse ecosystems and biodiversity are critical for the survival of the world's food items and provide food for humans, animals, and all life forms. It is the foundation of all food industries and related services. Human food forms derived from biodiversity resources include vegetables, fruits, nuts, meat, and adjuncts to food in the form of food colorants, flavoring, and preservatives[32].

Biodiversity loss is caused by five primary drivers: habitat loss, invasive species, overexploitation (extreme hunting and fishing pressure), pollution, climate change associated with global warming. In each case, human beings and their activities play direct roles.

Biodiversity loss is caused by habitat loss.

Habitat loss is the thinning, fragmenting, or outright destruction of an ecosystem's plant, soil, hydrologic, and nutrient resources.

Biodiversity loss is caused by invasive species.

An invasive species is any non-native species that significantly modifies or disrupts the ecosystems it colonizes. Invasive species can disrupt ecosystems because they are better competitors than native species; they may consume food resources

[31] Wood, A., Stedman-Edwards, P., & Mang, J. (2013). The root causes of biodiversity loss: book. Routledge. URL: file:///C:/DOCUMENTS/My%20documents/ARTICLES/%D0%94%D0%A0%D0%A3%D0%9A/%D0%A1%D1%82%D1%80%D0%BE%D0%BA%D0%B0%D0%BB%D1%8C%20%D0%92.%D0%9F/%D0%92%D1%81%D1%82%D1%83%D0%BF%20%D0%B4%D0%BE%20%D1%84%D0%B0%D1%85%D1%83_%D0%B0%D0%BD%D0%B3%D0%BB/Book_biodervirsity%20loss.pdf

[32] Primary Drivers of Biodiversity Loss. URL: https://www.britannica.com/study/learn-about-the-causes-of-biodiversity-loss

more rapidly or more efficiently or take over habitats faster than native species can adapt to the new changes. Some invasive species prey on native species, and if the native species have no natural defenses against the invaders, they may be eliminated rapidly.

Biodiversity loss is caused by overexploitation.

Overexploitation (overhunting and overfishing) is the process of harvesting too many aquatic or terrestrial animals, which depletes the stocks of some species while driving others to extinction.

Biodiversity loss is caused by pollution.

Pollution is the addition of unneeded or harmful nutrients or substances to an ecosystem. In a polluted area the quality of food, water, or other habitat resources declines, sometimes to the point where some species must move away or perish if the pressure is too great. For example, a 2014 study that followed the 2010 Deepwater Horizon oil spill in the Gulf of Mexico projected that perhaps 12 percent of the brown pelicans and more than 30 percent of the laughing gulls in the area hit by the spill had been wiped out. According to another 2014 study, up to 800,000 birds were thought to have died. Consequently, with such deep population losses, one could understand how genetic diversity of a species in an area could be lost. As casualties mount in the aftermath of a large single pollution event or over the combined pressure of several pollution events in an area, whole species may be lost.

Biodiversity loss is caused by climate change associated with global warming.

Global warming is the long-term increase in Earth's average air temperature (which has occurred largely from human activities) over the past one to two centuries. It can refer specifically to such warming that is due to the influence of rising concentrations of carbon dioxide, methane, and other greenhouse gases in the atmosphere. As the concentration of these gases increases, the ability of Earth's atmosphere to retain energy from incoming sunlight (most of which is released as heat energy back to space at night) also increases. With more heat available, once reliable temperature and rainfall patterns change, upsetting the natural order of breeding and resource availability. Also, ecosystems that rely on the presence of ice shrink as melting breaks them down. Global warming itself does not necessarily produce biodiversity loss, but climatic changes (some of which are sudden and drastic) can modify ecosystems and the expectations of the species within them significantly.

Ecologists emphasize that habitat loss (typically from the conversion of forests, wetlands, grasslands, and other natural areas to urban and agricultural uses) and invasive species are the largest causes of biodiversity loss, but they acknowledge that climate change could rival them as the 21st century progresses.

The uninterrupted biodiversity loss could lead to less nutrition, decreased wild foods, impoverished pollination, and subordinate and less irrepressible agriculture systems. This can further result in more vulnerability to Agrichemicals, decreased traditional medicines access, less chance for development of drugs, further leading to surpassing disease strains. The numerous factors are ***responsible for the loss of***

Biodiversity such as pollution, habitat loss, hunting, introduction of invasive species, overexploitation of preferred species, climate change, and natural disasters[33].

However, biodiversity is extremely important, both to agriculture and to humans in general (see Fig.13).

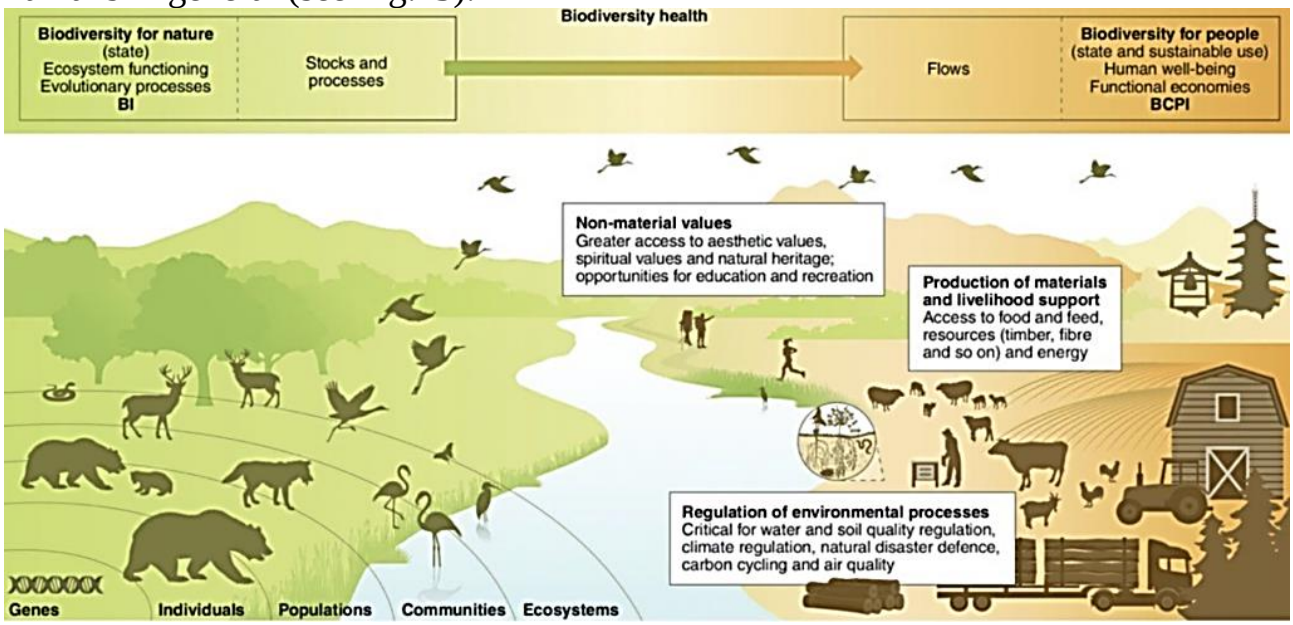


Figure 13. Biodiversity Loss, Agriculture and Climate Change (Source: *Soto-Navarro et al., 2021*)[34]

The loss of biodiversity is considered as big of *a threat to human survival* as climate change due to the many services biodiversity provides to humanity, including:

Provisioning Services: Also defined as material outputs or energy, for much of human history, communities have and still rely on the natural world as a source of food, fuel, medicine, building materials and drinking water.

Regulating Services: Ecosystems are essential for providing a temperate and livable environment for humans through regulatory services. Biodiversity is responsible for cleaning the air, sequestering carbon and regulating water flow to reduce the chances of flooding.

Support Services: Biodiversity provides a habitat for beneficial plants and animals and supports them while they provide other services to the ecosystem such as in the case of pollinators. It also is the home to genetic diversity, which provides humans with a gene pool to draw livestock, crops and medicine from.

Cultural Services: Beyond its basic utility, the natural world provides us with a sense of place and belonging. It is beneficial to our mental, emotional, physical and spiritual well-being. It provides recreational opportunities and creative inspiration in the arts and in the sciences alike.

[33] Singh, V., Shukla, S., & Singh, A. (2021). The principal factors responsible for biodiversity loss. Open Journal of Plant Science, 6(1), 011-014. URL: https://www.researchgate.net/profile/Vijeta-Singh-2/publication/348875795_The_principal_factors_responsible_for_biodiversity_loss/links/601b1a6f92851c4ed549056a/The-principal-factors-responsible-for-biodiversity-loss.pdf

[34] Biodiversity Loss, Agriculture and Climate Change. URL: https://organiccouncil.ca/biodiversity-loss-agriculture-and-climate-change/

3.3.2. How to support climate action and biodiversity?

Measures that benefit biodiversity have the potential to support climate action and some aspects of climate action can support biodiversity.

How to develop a coordinated effort to combat both climate change and biodiversity decline?

Policy measures to encourage[35]

Building a sustainable food system

One third of crops are fed to livestock rather than humans, and a third of food globally is lost or wasted. Animal agriculture is a major contributor to global biodiversity loss.

A reduction in meat and dairy consumption and a significant reduction in food loss and waste would not only significantly reduce Greenhouse Gasses (GHG) emissions, which itself benefits biodiversity through limiting climate change, it would also reduce pressure for deforestation with associated biodiversity loss and free land and resources for biodiversity recovery and the wider use of Nature-based Solutions (NbS).

As such, dietary shifts for people who can choose what they eat and reduction in food loss and waste create the enabling conditions that make other actions outlined below more feasible.

A revolutionary change in farming is essential to meeting the goals of the Paris Agreement and reducing biodiversity decline. To achieve that aim, further research on agriculture, which is underfunded compared to other key human activities, should be a priority. Moreover, farmers should be offered financial and other incentives to support climate and biodiversity friendly activities, such as agro-ecological practices.

Sustainable and responsible food trade, and equitable food distribution

Since the price of food and other products does not incorporate environmental externalities, too often, many countries benefit from cheap products that are grown unsustainably in other countries, with the latter having to bear the burden of environmental degradation without benefiting from the food. Avoiding importing food that has been produced unsustainably elsewhere, and instead supporting sustainable production modes and distributing available food fairly amongst those who need it is a critical part of a sustainable and responsible food system.

Reducing rates of natural habitat loss and degradation, particularly of forests.

Deforestation, currently mainly in the tropics and subtropics, is the major contemporary cause of terrestrial biodiversity loss and local climate change, and has contributed 5.7 GtCO2 annual emissions over the last decade, 14% of global CO2 emissions. Reducing deforestation and degradation rates can be achieved through both supporting in situ conservation, resourcing alternative development pathways and reducing international demand for products of deforestation. Reducing deforestation would have the health co-benefit of lowering the risk of disease outbreaks caused by pathogens present in these areas passing from wildlife to humans.

[35] Climate change and biodiversity. URL: https://www.interacademies.org/publication/climate-change-and-biodiversity

Natural ecosystem restoration and expansion

Expansion of native ecosystems, through restoration and rehabilitation, in a network that facilitates connectivity and species migration, will enhance biodiversity and carbon storage in ecosystems. Natural forests have been calculated to be 40 times better than plantations at storing carbon48. A global forest restoration effort could absorb 2 GtCO2/year. Ecologically appropriate restoration of non-forest ecosystems, such as savannas and grasslands, can increase carbon stocks in soils and maintain biodiversity.

Peatland preservation and restoration

Peatlands have been estimated to store more than 600 Gt or 20% of the global world's forests49, on only 3% of its land. Peatland preservation and restoration has multiple benefits for amenity, water resources, flood protection, biodiversity and the climate. For example, restored peatlands show renewed growth of Sphagnum moss species and attract invertebrates and birds. Existing drained peatlands globally are expected to cumulatively release the equivalent of nearly 2 GtCO2 that could be saved by restoration.

Extension and enforcement of Marine Protected Areas (MPAs)

As well as restoring and protecting biodiversity, and helping it to be resilient to climate change, many MPAs support climate resilience, either by protecting the coastline from severe weather events, for example through coral reefs or mangroves, or by absorbing carbon dioxide in seagrasses, salt water reedbeds and muddy habitats. To be effective, MPAs should be extended with new investment in their management and enforcement of protection rules.

Biodiversity friendly renewables

Upscaling of renewable energy production should avoid negative impacts on biodiversity where possible. For example, engineers can design offshore wind farms to be biodiversity friendly and attract species under water. Techniques include structures on which new reefs can grow along with fish habitats and sea grass settlements.

Overall, marine sites where renewable energy technologies are being deployed should be managed to optimise potentially positive effects, by adopting exclusion zones from other destructive activities such as bottom trawling and dredging and support the colocation of other industries such as mariculture that support wider benefits from nature. On land, solar farms should avoid fragmenting habitats or becoming barriers to the movement of animals56. It is also important to source raw materials for renewables in a way that ensures minimal damage to biodiversity.

Increased landscape connectivity

Creating corridors (for example restoring river corridors planting and connecting conservation efforts) and increased coverage of semi-natural ecosystems in intensively used landscapes will assist species migration and support ecosystem resilience in a changing climate. Increasing green spaces in cities is vital for adaptation as they have a cooling effect and support biodiversity and its connectivity. They contribute to climate change mitigation through carbon storage, and enable many biodiversity-associated mental and cultural welfare benefits to urban people.

Policy measures to discourage

Tree planting in inappropriate ecosystems.

Expanding tree cover in ecosystems that do not naturally support expansive tree cover (e.g. grasslands, grassland savannas, temperate peatlands) has negative consequences for biodiversity and ecosystem functioning. In the case of peatlands, planting trees can also have negative climate consequences by resulting in drainage and consequent release of soil carbon reserves.

Monocultures

Planting trees, either for bioenergy or as long-term carbon sinks, should focus on restoring and expanding native woodlands, as well as avoid creating large monoculture plantations that do not support high levels of biodiversity. Simple targets such as 'numbers of trees planted' ignore biodiversity considerations, such as long-term survival of trees or stewardship, and can be misleading, potentially contributing to policy failure and misuse of carbon offsets.

Unsustainable energy crops

The modelled benefits of Bioenergy with Carbon Capture and Storage (for example, the use of crops to generate power and fuel while capturing CO2) to mitigate climate change are significant.

However, the scale of some modelled deployments would either take up large amounts of land now used for food production or have negative effects on the amount of land available for preservation or restoration of natural ecosystems. Policy should also limit use of fuelwood pellets and other feedstocks for bioenergy where it might intensify pressure on semi-natural ecosystems.

Disempowerment of indigenous and local communities

Biodiversity and climate change actions should recognise, respect and safeguard the rights and livelihoods of local and traditional users of ecosystems.

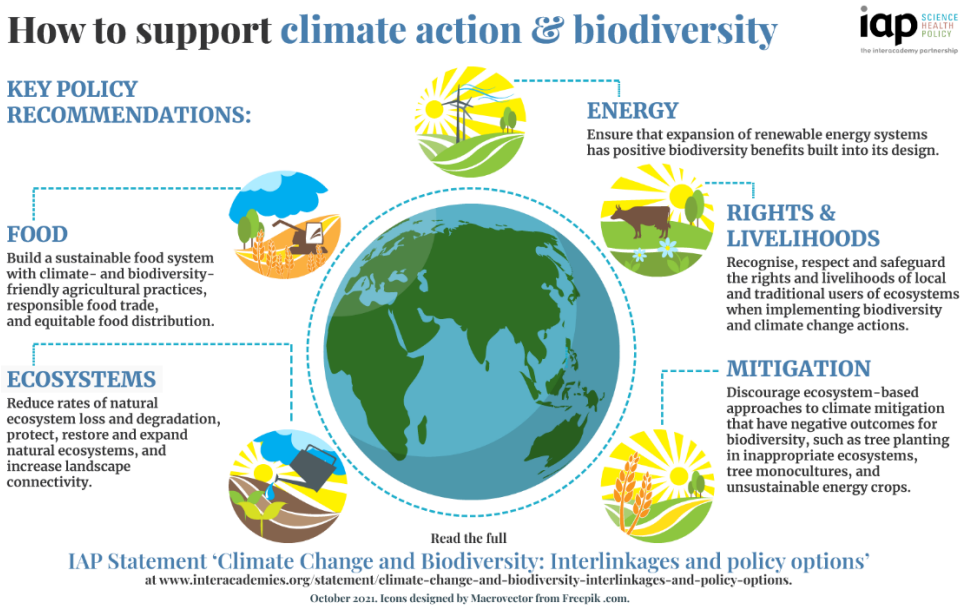
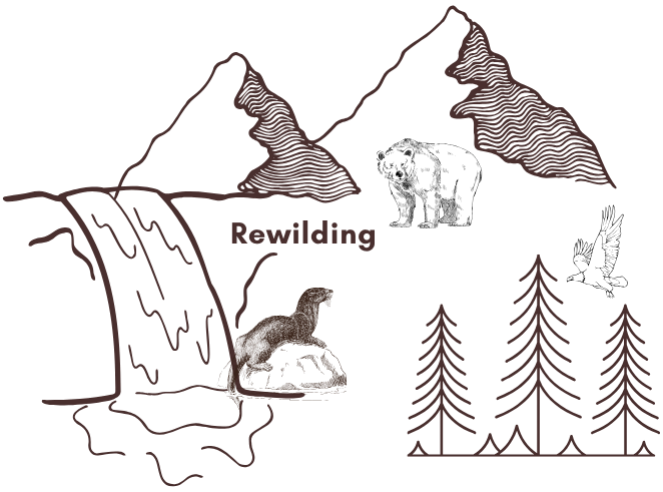


Figure 14. How to support "climate action and biodiversity" includes the key policy recommendations (Source: https://www.interacademies.org/publication/climate-change-and-biodiversity)

3.4. The principles of rewilding



We define **rewilding** as ***the large-scale restoration of ecosystems to the point where nature is allowed to take care of itself***. Rewilding seeks to reinstate natural processes and, where appropriate, missing species – allowing them to shape the landscape and the habitats within. It's focused firmly on the future although we can learn from the past.

Rewilding encourages a balance between people and the rest of nature so that we thrive together. It can provide opportunities for communities to diversify and create nature-based economies; for living systems to provide the ecological functions on which we all depend; and for people to reconnect with wild nature.

Conservation has worked hard for decades, with passion and dedication, to save wildlife. But it's time to move beyond saving certain species and patches of nature. Rewilding takes a big picture approach, aiming to restore the wider natural processes that support life (for example, grazing, flooding, natural woodland regeneration). It complements existing conservation work and those sectors seeking a better way forward for nature including regenerative farming, marine protection, low impact silviculture, nature tourism and so on.

Rewilding is about[36]:

1. Nature's own ways. Nature knows best when it comes to survival and self-governance. We can give it a helping hand by creating the right conditions – by removing dykes and dams to free up rivers, by reducing active management of wildlife populations, by allowing natural forest regeneration, and by reintroducing species that have disappeared as a result of man's actions.

2. Bringing back wildlife. European wildlife species have strongly declined, even in our wildest areas. Some of them have even gone extinct, while they play a critically important ecological role. Rewilding works to restore lost species guilds by giving them space to thrive, by population enhancement, and by reintroducing key native species.

3. Ensuring wellbeing. When nature is healthy, we are healthier too. We rely on the natural world for water, food and air. There is a growing realisation that connecting with wild nature makes us feel good and keeps us mentally and physically well.

Rewilding is about reconnecting a modern society – both rural and urban – with wilder nature. We invite people to experience and live in these new, rewilded landscapes.

4. Delivering for the future. There is no defined end point for rewilding. The aim is to support nature-driven processes, which in turn will bring about wilder

[36] What is rewilding? URL: https://rewildingeurope.com/what-is-rewilding/

nature. This takes time and space. Rewilding is about moving up a scale of wildness, where every step moving up this scale is seen as progress. If we create and protect areas where rewilding can take place, both people and wildlife will benefit in the long term.

Five principles of rewilding[37]:

1. Support people and nature together

Rewilding is about all of us finding ways to work and live within healthy, flourishing ecosystems. Rewilding can enrich lives and help us to reconnect with wild nature while providing a sustainable future for local and wider communities.

2. Let nature lead

From the free movement of rivers to natural grazing, habitat succession and predation, rewilding seeks to reinstate natural processes. This includes reintroducing missing species where appropriate, particularly keystone species. It is not geared to reach any human-defined optimal point or end state. It goes where nature takes it.

3. Create resilient local economies

Rewilding creates opportunities for resilient new nature-based economies. It's about finding opportunities for livelihoods that thrive alongside and enrich, nature.

4. Work at nature's scale

Rewilding is restoring ecosystems with enough space to allow nature to drive the changes and shape the living systems on which we all depend. Scale may come from single landholdings or through joining up nature so it can thrive from mountain top to doorstep, from source to sea.

5. Secure benefits for the long-term

Rewilding leaves a positive legacy for future generations. Securing the continued, long-term benefits of rewilding areas is key to a healthy, prosperous future.

Rewilding in Ukraine[38]

Nature has long been a silent casualty of war. From pollution and habitat destruction to the collapse of entire management systems, the environmental impact of armed conflict can be devastating, wide-reaching, and hugely difficult to reverse.

In Ukraine, where fierce fighting has now raged for over four months following the Russian invasion, the full environmental impact of war remains unclear. Yet with one-third of the country's protected areas and sites – including two biosphere reserves – currently located in zones of active hostility, occupation, and humanitarian crisis, it's clear that Ukrainian nature is suffering on a daily basis.

Rewilding Europe's cross-border Danube Delta rewilding landscape, which is located partly in southwest Ukraine, is located well away from the main areas of fighting. Supported by funding from the Endangered Landscapes Programme, the Rewilding Ukraine team and partners are continuing their work to restore 40,000 hectares of wetland and terrestrial steppe habitat, with a focus on key natural processes such as flooding and natural grazing.

Yet even in this untouched corner of the country, war is affecting rewilding

[37] Defining rewilding. URL: https://www.rewildingbritain.org.uk/why-rewild/what-is-rewilding/an-introduction-to-rewilding/defining-rewilding
[38] Rewilding in Ukraine: uplifting progress in the face of adversity. URL: https://rewildingeurope.com/blog/rewilding-in-ukraine-uplifting-progress-in-the-face-of-adversity/

efforts. Rewilding Ukraine Executive Director Mykhailo Nesterenko and communications officer Katya Kurakina fled Ukraine when their home city of Odessa was attacked, and are now based in Rewilding Europe's head office in the Dutch city of Nijmegen. The remaining Rewilding Ukraine team members, all of whom are safe, are divided between Romania and Ukraine. Some make frequent visits to the delta.

"There are many things we cannot do now, but we focus on the things we and our partners can do," explains Nesterenko. "In parts of the Danube Delta Biosphere Reserve we are able to remove dams and dykes, and we are trying to relocate red and fallow deer to the Danube Delta. However, wildlife breeders are less willing to sell animals these days, because of the fear of famine. We also have to take into account the sharp hike in fuel prices in our budgeting."

Despite their many operational difficulties, the Rewilding Ukraine team have been greatly cheered by a number of exciting new arrivals. Following the release of a herd of kulan (Asiatic wild ass) onto the Tarutino Steppe in late 2021, a foal was born in the early spring almost certainly the first fully wild kulan born in Ukraine over 200 years.

Oblivious to events taking place elsewhere in the country, the steppe marmots released by the Rewilding Ukraine team in 2021 have also been finding the Tarutino Steppe to their liking. At least six pups were born in the spring, with the team hoping to make another release later this year.

Video: https://www.youtube.com/watch?v=TVM6WeiwRW0

Looking to the future

There is still no sign of the brutal and unjustified Russian invasion of Ukraine coming to an end. Yet despite the challenges arising from the conflict, the rewilding agenda in the Danube Delta is moving forwards, to the huge credit of the local rewilding team.

In other areas of Ukraine, the impact of the war on nature and animals has been far more severe. Valuable natural areas are being destroyed and degraded, with large numbers of animals dying in reserves, zoos, and abandoned houses. Rewilding Ukraine is taking parting in a fundraising campaign with 1+1 (a Ukrainian media group) to support Ukrainian protected areas, shelters, and sanctuaries (donations welcome).

There are also concerns about how Ukraine will rebuild itself after the war is over, and whether environmental regulations will be respected. Nevertheless, Mykhailo Nesterenko remains positive about Ukrainian nature and its recovery.

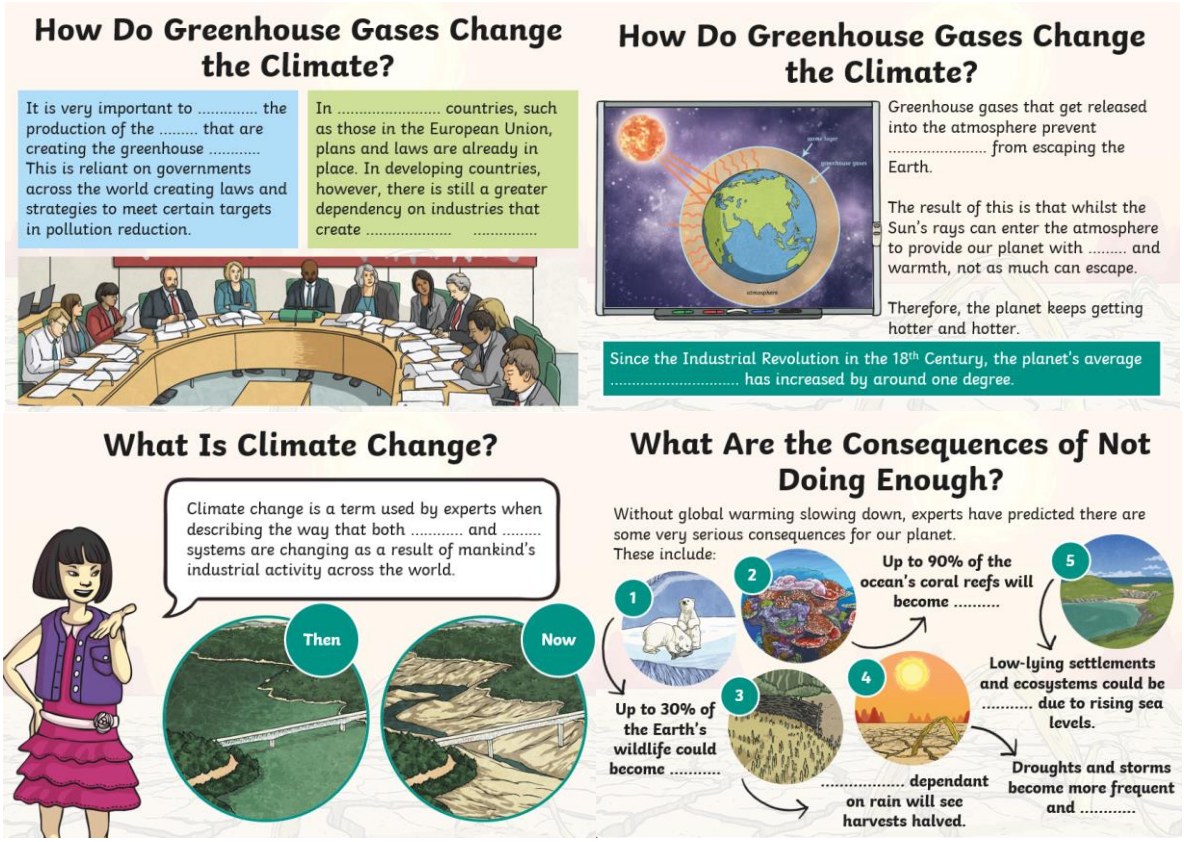
"Ukraine is dealing with a very difficult humanitarian situation, but nature is fundamental to people: you cannot separate us from nature," he says. "It directly affects us when water is polluted, or when villages are flooded because of destroyed dykes.

"As our own rewilding efforts in the delta have shown, Ukrainian nature is as resilient as the people of Ukraine, and they both depend on each other. Once the war is over, they will both recover."

Control questions for students

1. What are the main causes of Climate Change
2. What are the main consequences of Warming?
3. What are the main causes of biodiversity loss?
4. What are the main solutions to solve the climate change?
5. What is the main concept of Rewilding?

Interactive task: fill in the nessecery information

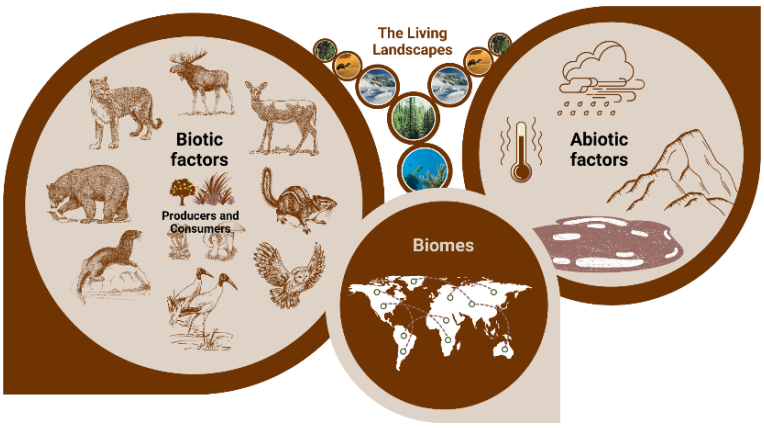


4. Biomes and ecological factors

4.1. Definitions of ecological factors

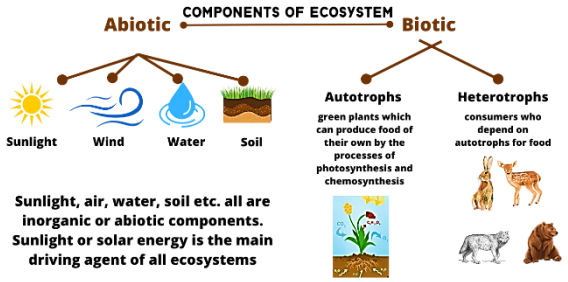
4.2. Biomes in the World (Classification, Distribution, Destruction)

4.3. Biomes in Ukraine (Classification, Distribution, Destruction)



Vocabulary	
Landscape	a large area of land, especially in relation to its appearance: a rural/barren landscape; demolition firms and builders are busy changing urban landscapes; the landscape is dotted with the tents of campers and hikers.
An abiotic factor	is a non-living part of an ecosystem that shapes its environment; it includes all the physical and chemical aspects of an ecosystem (Water, Sunlight, Temperature, Soil, Atmosphere, pH, Air Humidity, Wind, Elevation); these factors may be present in the atmosphere, hydrosphere, and lithosphere; it contributes to the continuity of life on earth by supporting the survival and reproduction process.
Biotic factors	include living things like plants, animals, bacteria, etc; it is divided into three main groups (producers, consumers, decomposers)
Biome	the largest geographic biotic unit, a major community of plants and animals with similar life forms and environmental conditions. It includes various communities and is named for the dominant type of vegetation, such as grassland or coniferous forest
Niche	in ecology, all of the interactions of a species with the other members of its community, including competition, predation, parasitism, and mutualism. A variety of abiotic factors, such as soil type and climate, also define a species' niche. Each of the various species that constitute a community occupies its own ecological niche
Trophic pyramid	the basic structure of interaction in all biological communities characterized by the manner in which food energy is passed from one trophic level to the next along the food chain. *The base of the pyramid* is composed of species called ***autotrophs***, *the primary producers* of the *ecosystem*. All other organisms in the ecosystem are consumers called ***heterotrophs***, which either directly or indirectly depend on the primary producers for food energy.
Food chain	the sequence of transfers of matter and energy in the form of food from organism to organism.
Trophic level	step in a nutritive series, or food chain, of an ecosystem. The first and lowest level contains the *producers, green plants*. The plants or their products are consumed by the second-level organisms – *the herbivores, or plant eaters*. At the third level, *primary carnivores, or meat eaters.*
Herbivores	***plant-eating heterotrophic organisms*** occupy the second tier of food chains; they feed on organic matter like living plants such as sedges, trees, grasses, flowering plants, and bushes.
Carnivores and Omnivores	carnivores eat meat, meaning they eat other heterotrophs; omnivores eat both plants and meat, and ***both types of heterotrophs*** occupy the third level of food chains.
Detritivores	like herbivores, detritivores occupy *the second level of food chains* because they feed on decaying organic material such as dead plants and animal matter, and animal feces.

4.1. Definitions of ecological factors



There are *two main components of an ecosystem* which are in constant communication with each other. They are the biotic components and the abiotic components.

Biotic Components of Ecosystem[39]

The living components of an ecosystem are called the biotic components. Some of these factors include plants, animals, as well as fungi and bacteria. These biotic components can be further classified, based on the energy requirement source. Producers, consumers, and decomposers are the three broad categories of biotic components.

Producers are the plants in the ecosystem, which can generate their own energy requirement through photosynthesis, in the presence of sunlight and chlorophyll. All other living beings are dependent on plants for their energy requirement of food as well as oxygen.

Consumers include *herbivores, carnivores, and omnivores*. The herbivores are the living organisms that feed on plants. Carnivores eat other living organisms. Omnivores are animals that can eat both plant and animal tissue (see Fig.15).

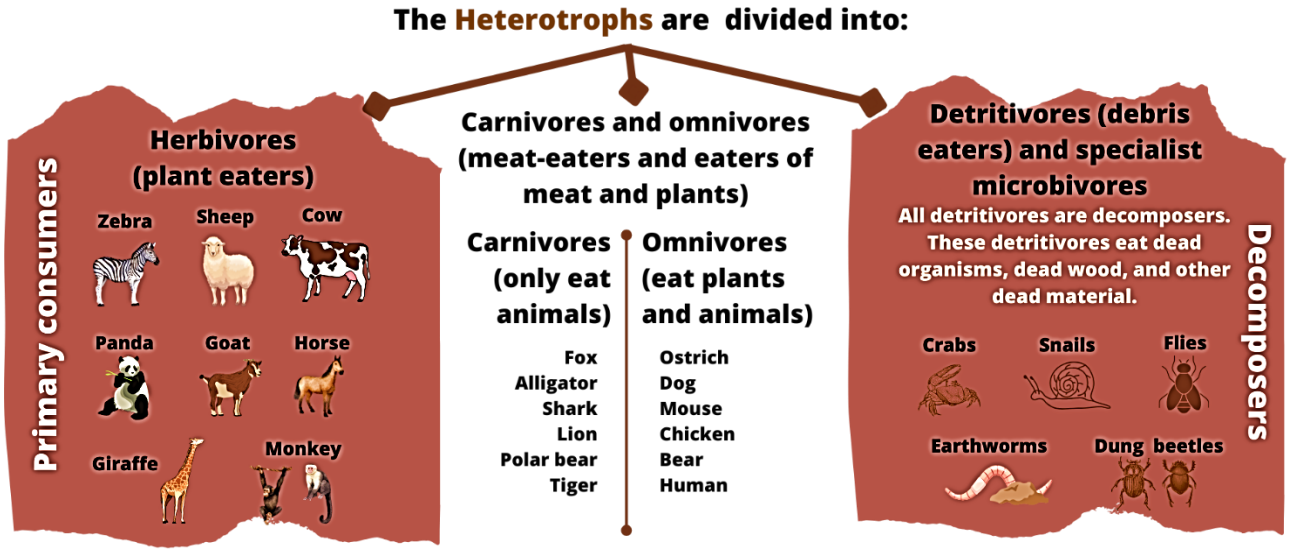


Figure 15. Heterotrophs – Consumers

Decomposers are the fungi and bacteria, which are the saprophytes. They feed on the decaying organic matter and convert this matter into nitrogen and carbon dioxide. The saprophytes play a vital role in recycling the nutrients so that the producers i.e. plants can use them once again.

Abiotic Components of Ecosystem[40]

Abiotic components are the physical and/or the chemical factors that act on the living organisms at any part of their life. These are also called as the ecological

[39] What are Biotic Factors? URL: https://microbenotes.com/biotic-factors/
[40] What are the Abiotic Factors? URL: https://microbenotes.com/abiotic-factors/

factors. The physical and chemical factors are characteristic of the environment. Light, air, soil, and nutrients, etc. form the abiotic components of an ecosystem.

The abiotic factors vary from ecosystem to ecosystem. In an aquatic ecosystem, the abiotic factors may include water pH, sunlight, turbidity, water depth, salinity, available nutrients and dissolved oxygen. Similarly, abiotic factors in terrestrial ecosystems can include soil, soil types, temperature, rain, altitude, wind, nutrients, sunlight etc.

Here, the sun is the energy source. Producers/plants use this energy to synthesize food in the presence of carbon dioxide and chlorophyll. The energy from the sun, through several chemical reactions, turns into chemical energy.

The herbivores are dependent on plants for the energy requirements. The carnivores, in turn, feed on the herbivores and other carnivores. At any level, microbes then decompose any dead and decaying organic matter. These decomposers, after various chemical reactions, release molecules back to the environment in the form of chemicals. The chemicals are again used by the producers, and the cycle starts again.

In conclusion, ecosystems have a complex set of interactions that happen between the biotic and abiotic components. The components of an ecosystem are linked to each other through the energy flows and nutrient cycles. Even though ecosystems do not have clear boundaries, these interactions get affected, even if one factor is changed or removed. This ultimately has the capacity to affect the entire ecosystem.

To sum up, the main different components of ecosystem

The structural component of an ecosystem may be classified under two main types:

1. Biotic components
2. Abiotic components

Biotic components comprise the living organisms present in an ecosystem. These include plants, animals and micro-organisms (bacteria and fungi). The biotic component of an ecosystem has been classified into three groups:

1. Producers (green plants)
2. Macro consumers (usually animals)
3. Micro consumers or decomposers (organisms like bacteria and fungi).

Abiotic components consist of the non-living components like light, temperature, water, oxygen,carbon, nitrogen and minerals. Various important abiotic factors have been classified as follows:

1. Climatic factors: These include light, temperature, precipitation, atmospheric humidity and wind.
2. Topographic factors: These include altitude, surface slope and exposure, etc.
3. Edaphic factors: These include soil and substratum.

What is the difference between a biome and an ecosystem? The biome is a large natural ecosystem where all vegetation and wildlife communities are studied

together. Most people would say that they are essentially the same thing, but that's not the case. A biome is an area classified according to the species that live in that location. Temperature range, soil type, and the amount of light and water are unique to a particular place and form the niches for specific species allowing scientists to define the biome. However, scientists disagree on how many biomes exist. Some count six (forest, grassland, freshwater, marine, desert, and tundra), others eight (separating two types of forests and adding tropical savannah), and still others are more specific and count as many as 11 biomes[41].

There are some key differences between these two ecological communities that you need to know about if you want to truly understand how our world works (see Fig.16). Biomes are large, geographically defined regions with similar climate and vegetation, encompassing multiple ecosystems. Ecosystems, on the other hand, are localized communities of living organisms and their interactions within a specific area, often found within biomes[42].

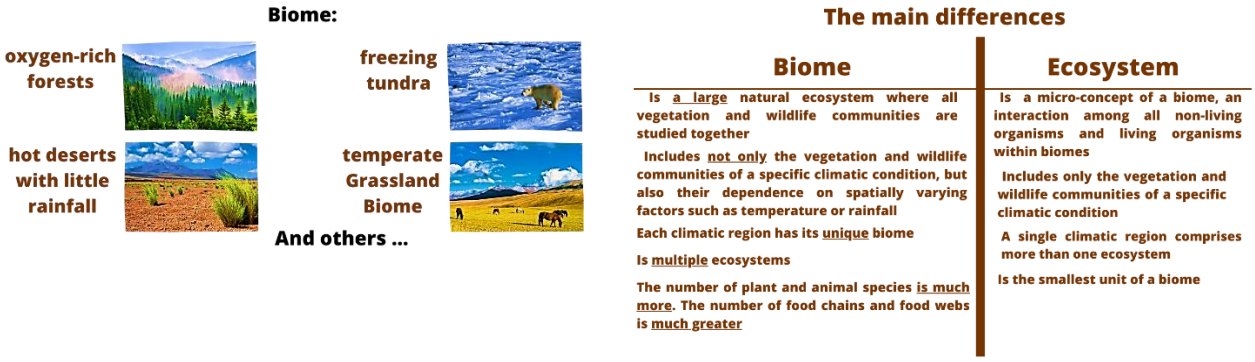
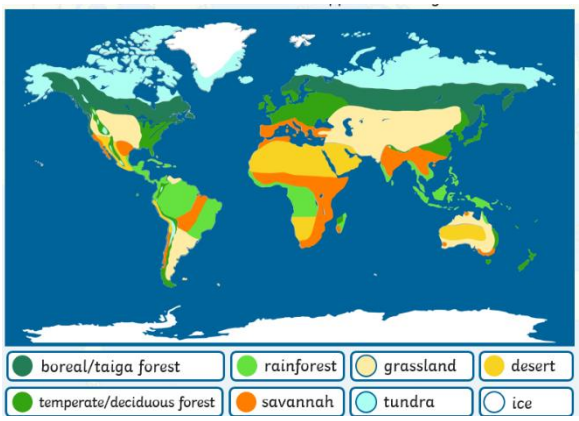


Figure 16. The maine differences between Biome and Ecosystem

4.2. Biomes in the World (Classification, Distribution, Destruction)



What is a biome? The word "biome" has been used to describe the diverse range of habitats that make up Earth's ecosystems. There are oxygen-rich forests, hot deserts with little rainfall, and even freezing tundra wildernesses where few people can survive for long periods without modern technology! They're called biomes because each one contains both organic (life) components as well nonliving elements like rocks or water ice.

*According to I. G. Simmons (*1982), "*the biomes of the world are major world-scale regions which integrate several factors into an intuitively recognizable whole – deserts, forests, savannas, oceans, etc*.

[41] BIOMES. National Geographics. URL: https://education.nationalgeographic.org/resource/resource-library-biomes/
[42] Difference Between Biome and Ecosystem: Key Distinctions: URL: https://testbook.com/key-differences/difference-between-biome-and-ecosystem

In other words, the biome is a large natural ecosystem where all vegetation and wildlife communities are studied together.

While a biome can cover large areas, a microbiome is a mix of organisms that coexist in a defined space on a much smaller scale. For example, the human microbiome is the collection of bacteria, viruses, and other microorganisms that are present on or in a human body.

A biota is the total collection of organisms of a geographic region or a time period, from local geographic scales and instantaneous temporal scales all the way up to whole-planet and whole-timescale spatiotemporal scales. The biotas of the Earth make up the biosphere.

4.2.1. Classification of biomes

The biome includes not only the vegetation and wildlife communities of a specific climatic condition but also their dependence on spatially varying factors such as temperature or rainfall. This means that different parts of our world have corresponding biomes–though it's important to note how these vary from region to region!

The biomes of the world are fascinating and diverse. They vary from tropical rainforests, which can be found only on Earth's surface (although there is some controversy about this), to cooler high-altitude mountain regions like those in Asia or North America where we find alpine meadows at higher elevations above sea level due to both their altitude as well as farther away from oceans who provide the moisture necessary for plant life through evaporation.

The basic classification of biomes of the world based on the nature of habitat are:

A. Terrestrial Biomes

B. Aquatic Biomes

A. Terrestrial Biomes:

The terrestrial biomes are **a group of habitats** that can be found on land. These include everything from rainforests to deserts and all other types in between, with their unique features identifying them as such!

This biome is further classified as:

1. Tundra Biome

2. Temperate Biome: There are four Temperate Biomes in the world. Those are:

- Taiga Biome
- Temperate Deciduous Forest Biome
- Mediterranean Biome
- Temperate Grassland Biome

3. Tropical Biome: The tropical biome has three different types:

- 1. Tropical Forest Biome

✓ Evergreen Rainforest Biome

✓ Tropical Deciduous Forest Biome

- ✓ Montane Forest Biome
- 2. Savanna Biome
- 3. Desert Biome

B. Aquatic Biomes:

All over this planet, you'll find lakes or rivers that fit into one of five groups – cold high mountain streams; warm deep ocean current channels (like along coastlines); seasonally-influenced waterfall drops onto rocks below Paradise Falls – whatever temperature suits their surroundings best at any given time.

This biome is further classified as-

a. Marine Biomes

b. Freshwater Biomes

a. Marine Biomes:

About two-thirds of the total biome areas of the world are marine biomes. Marine biomes provide varied habitats. Marine biomes are further classified as follows –

- Continental Shelf Biome
- Tropical Coral Biome
- Kelp Forest Biome
- Benthic Biome
- Pelagic Biome

b. Fresh Water Biomes:

About only one-third of the total biome areas of the world are freshwater biomes. Freshwater biomes provide varied habitats. Freshwater biomes are further classified as follows:

- Pond Biome
- Riverine Biome
- Lacustrine Biome
- Polar Freshwater Biome
- Littoral Forest Biome

Classification biome that is based on Climate Zone

There are **seven major terrestrial biomes on Earth**: tundra, taiga, temperate deciduous forest, tropical rainforest, temperate grassland, desert, and boreal forest. Each biome is characterized by its unique climate and vegetation.

◆ Tundra:

Tundra is a word meaning "barren land" in Finnish. It can refer to either the freezing tundras of Polar regions or more generally any area with little vegetation and often extensive ice caps such as Canada's Northwest Territories.

Cryophytes like mosses, willows, and campions are common plant species found within this biome which extends into warmer areas too-they grow best when there's minimal light available but since it gets plenty cold enough for their needs these clients thrive here! Muskoxen caribou wolves lemmings Ptarmigan (a kind bird) all play important roles within Tunder habitat offerings.

◆ Taiga:

Taiga biome includes sub-arctic regions of North America (from Alaska across Canada to the Hudson Bay), Scandinavian Peninsula, Russian Siberia, Germany, Switzerland, and other parts of Europe, etc. Taiga biome is a mix of higher altitude Tundra and lower altitude Temperate Forest biome.

In these temperate rainforests, you will find a variety of plants including pines, firs, and spruce trees with larch trees thrive at a higher altitude while shrubs like birches grow at lower elevations.

Herbivores such as caribou can be found here alongside carnivorous animals like wolves or even smaller creatures who live on their prey's leftovers -such insects Andrew Blackflies when it comes to wildlife Taigas offers plenty for every type!

◆ Savanna:

The savanna is a typical tropical vegetation type with the dominance of grasses. This biome can be found in Columbia, Venezuela South-central Brazil Paraguay northern Australia parts of India, etc.

The main plant species are African elephant grass, panicum, andropogon, shrubs, small woody plants, baobab, palm, and eucalyptus. Animals and birds include elk, giraffe, zebra, hippopotamus, gazelle, antelope, ostrich, emu, bustards, cassowaries, condor, vultures, quail, etc.

◆ Grassland:

The temperate grasslands are the important grassland biomes of the world. Prairie in North America, Pampas in South America, Velds in Africa, and Downs in Australia, etc are some major grassland biomes of the world.

Important plant species are grasses like poa tussock, kangaroo grass, Danthonia, Festuca; aristida, mulga (one kind of shrub), eucalyptus, etc. The main animal species are buffalo, antelope, wild horse, kangaroo, guanaco, gazelle, mole rat, wolves, eagle, hawk, etc.

◆ Desert:

Desert biomes are very hot and dry regions of the world. The atmosphere and the soil lack moisture. Sahara, Atacama, Sonoran, Patagonia, West Australian desert, etc are some major desert biomes of the world.

The Sahara and Atacama Deserts in Chile and Argentina are among the most narrow deserts on Earth. These regions have extremely hot summers with little rain in all seasons- it's difficult to even for succulents to grow here!

However, some plant species manage though like cacti or Joshua tree which only exist because they can tolerate such harsh conditions (in addition these areas also host an abundance of lizards). Other animals that live alongside these plants include snakes, Scorpions, and various kinds of insects.

◆ Temperate Forests:

Temperate forests are found all over the world. They contain a variety of plants and animals that live in warm summers, and cold winters with softwood trees dominant at higher latitudes while coniferous ones grow closer to colder regions such as those Nearctic mountains where they can escape harsh conditions during summer months when temperatures soar above 40 degrees Celsius (104 Fahrenheit).

Some examples include bear species who hibernate throughout winter; deer-, and elk-or coyote varieties depending on what prey is available also live here but not just because it's easier than elsewhere–this place has been sustaining life since time immemorial!

◆ Tropical Evergreen Forest:

The Tropical Rainforests is a lush, green haven for all sorts of wildlife. The rainforests are often considered one step away from being called "the ultimate destination" because they have everything you could want in your vacation: pristine waterfalls; beautiful flowers and colorful birds filling up their schedules with life!

Tropical rainforests are a haven for plants and animals living in the hot, humid equatorial region with high annual rainfall. The soil is always moist making these forests incredibly diverse–home to many types of trees including epiphytes (a type that grows on other plants), herbs or shrubs as well gorgeous flowers such as bright-colored birds like parrots which can be found everywhere here!

The Amazon rainforest is a unique and incredible place. Not only does it contain some of the most diverse plant life on Earth, but also has an amazing variety in animal population as well! From small animals such as toucans or bees up to large carnivores such condors which can measure over 10 feet tall when they're not flying around looking for food – there aren't many other places where you'll find something like this kind of harmony between human interference (agriculture) with natural ecosystems.

The tropical moist forests thrive under high average annual rainfall conditions because soil always stays moist due to persistent rains throughout each year.

Weather changes daily and it is the temperature and conditions for the day. Often we describe the weather as hot, rainy, sunny, humid, overcast, freezing or snowy. Climate is the average weather condition of a place over a long period of time. The climate of a location is often linked to its location in the world. Places near the equator will have a hotter climate than places near the North and South Poles which will have a colder climate.

To sumorize, types of Biomes:

Alpine – colder climates found at high altitudes in mountain ranges. Populated with coniferous trees such as firs and pines.

Chaparral – hot and dry like a desert, but has more rain and therefore more plants and animals, including yucca, trees and cacti, coyotes, deer, lizards and jack rabbits.

Deciduous forest – warm, wet and mild areas and dominated by deciduous

trees (trees that lose their leaves in the autumn).

Desert – deserts are dry; less than 25cm rain per year. They can be hot and sandy or cold and icy. Both hot and cold deserts can support life as long as it is well adapted, such as cacti and silver ants in hot deserts, and penguins in cold deserts.

Desert scrub – very dry areas of hot deserts populated with grasses, herbs and shrubs adapted to live in very arid areas.

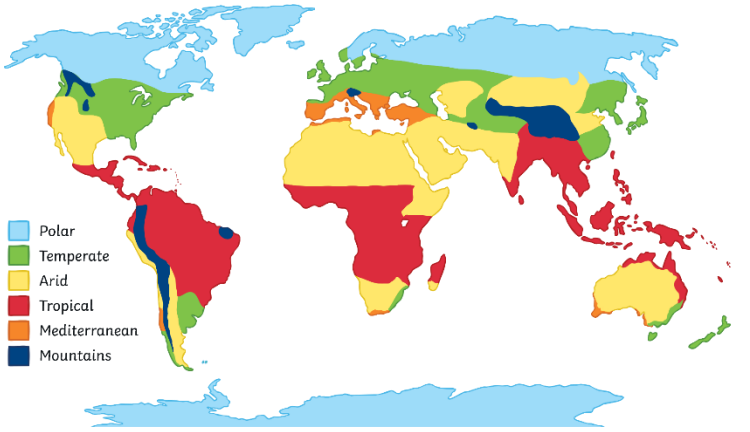
Grasslands – areas where a variety of grasses grow. There are few other trees or plants apart from near to water sources. The grasslands are very hot places in summer. Some become extremely cold in the winter.

Rainforest – warm, wet and humid, rainforests are home to half of the world's species and are populated with dense vegetation and trees. Rainforest animals include sloths, howler monkeys and jaguars.

Savanna – this is a mixture of grasslands and woodland. There are some trees but they are spread out enough to allow the sunlight to reach the ground and grasses in between. Animals that live here include zebras, giraffes and lions.

Taiga – very wet and cold, receiving plenty of snow during the winter. Coniferous trees are evergreen and remain green all year round. The soil is not very nutritious and therefore, the variety of vegetation is limited.

Tundra – cold, harsh and difficult for much vegetation to survive. Found at the top of mountains and the Poles. These areas are snow-covered and all life here is very hardy, including mosses, birds and mountain goats.



Biome	Description	Example
Polar	Very cold and dry all year round	Antarctica
Temperate	Cold winters and mild summers	UK
Arid	Dry and hot all year round	Sahara Desert
Tropical	Hot and wet all year round	Brazil
Mediterranean	Dry, hot summers and mild winters	Spain
Mountain	Very cold, sometimes wet, all year	Himalayas

Figure 17. Classification biome that is based on Climate Zone

4.2.2. Destruction and Conservation of biomes

The loss of biomes is depriving us of vital resources and damaging our environment in ways we're only beginning to understand. We need to act now to save the world's biomes - and ourselves (see Fig.18).

- Large-scale deforestation causes loss of habitat of the species
- Over-exploitation of natural resources disturbs the equilibrium of nature
- Environmental degradation is a result of faulty agricultural practices of man
- Incorrect landuse system creates a negative impact on biomes of the world

- Logging, building, construction work, etc also misbalance the functioning of the biomes
- Shifting agriculture, timber exploitation, formation of grazing land, cattle ranching, etc also harm the very important world biomes, like- Tropical Rainforest, Temperate Softwood Forest, etc.
- The construction of shipping lines, ports, construction of marine oil fields pollute the marine biome
- Water pollution harms all sorts of aquatic biomes
- The biomes that thrived in the Transitional Zones are the most vulnerable biomes of the world and are most threatened by human activities
- Overfishing is a major reason for the destruction of marine and freshwater biomes
- Global warming is another major reason for biome destruction in past few years
- The climatic change also affects the biomes of the world severely, especially in the polar regions

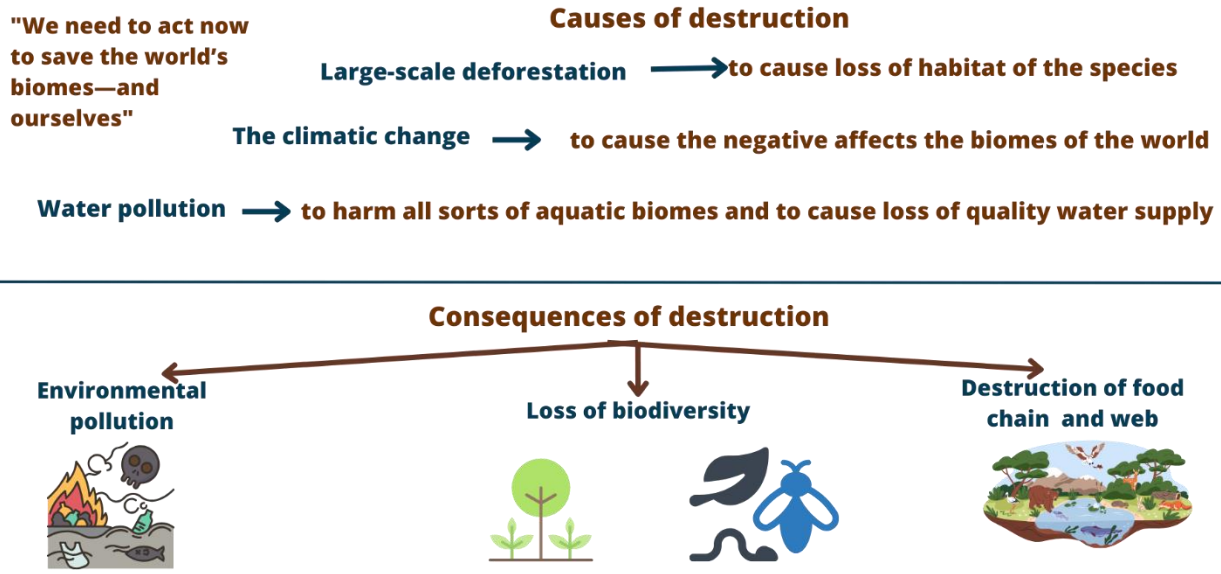


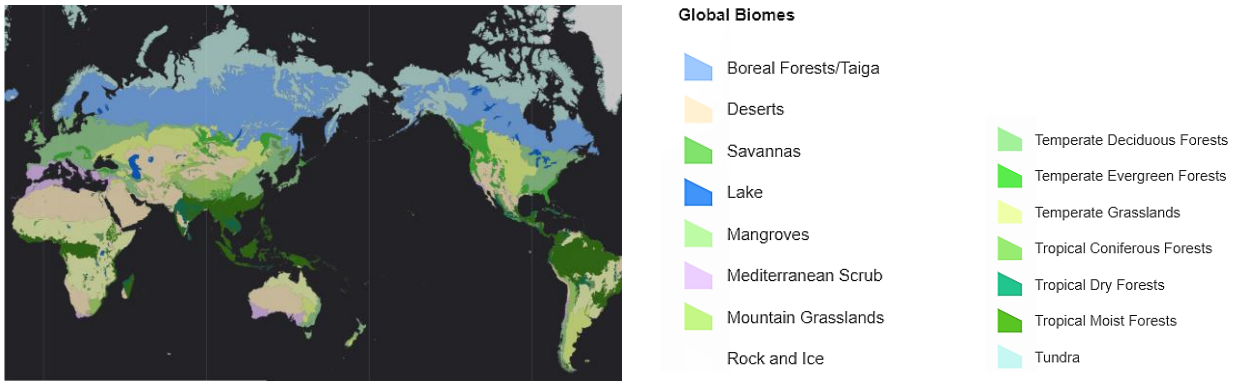
Figure 18. Biomes in the World – Destruction

We need to act now to save the world's biomes — and ourselves. The loss of biomes is depriving us of vital resources and damaging our environment:

1. Excessive exploitation of nature results in environmental pollution
2. Habitat loss may cause the collapse of the micro or macro ecosystem
3. Habitat loss may result in loss of biodiversity
4. Destruction of a single ecosystem may destroy a biome
5. Species loss hampers the food chain and food web relationships among different trophic levels
6. Destruction of biomes makes species vulnerable, endangered, or even extinct

These conservation methods may be as follows:

- Conservation of natural resources is the first and foremost step to conserving the world's biomes
- The practice of both In-situ and Ex-situ conservation is very much effective in this regard
- Pollution control is another method to prevent the loss of biomes
- The environmental Awareness Programme is also an important step in this context
- Wiser and sustainable use of natural resources lengthens their existence and conserves the biomes
- Implementation of strict laws helps in protecting and preserving the biomes
- Public awareness about the consequences of human actions can help them to understand the need for the conservation of biomes of the world
- Area-specific conservation methods are more effective to conserve the more fragile world biomes, like the Tundra Biome, Taiga Biome, Tropical Rainforest, etc
- Ban on illegal fishing and fishing techniques, prevention of malpractice of landuse, check on overgrazing, check the use of chemical fertilizers, pesticides, etc also help to reduce pollution, and habitat loss; thus, conservation of the world biomes.



Figere 18. Global Biomes[43]

4.3. Biomes in Ukraine (Classification, Distribution, Destruction)

The geography of Ukraine varies greatly from one region of the country to another, with the majority of the country lying within the East European Plain. Ukraine is the second-largest European country, after Russia. Its various regions have diverse geographic features ranging from highlands to lowlands, as well as climatic range and a wide variety in hydrography.

[43]ArgGis-map. URL: https://www.arcgis.com/apps/View/index.html?appid=144b1d74a5964d728b25aeb0542de485

4.3.1. Classification of biomes in Ukraine

The landscape of Ukraine consists mostly of fertile steppes and plateaus, crossed by rivers such as the Dnieper, Siverskyi Donets, Dniester and the Southern Bug as they flow south into the Black Sea and the smaller Sea of Azov. To the southwest, the delta of the Danube forms the border with Romania. The country's only mountains are the Carpathian Mountains in the west, of which the highest is Hoverla at 2,061 metres (6,762 ft), and the Crimean Mountains, in the extreme south along the coast.

Ukraine also has a number of highland regions such as the Volyn-Podillia Upland (in the west) and the Near-Dnipro Upland (on the right bank of the Dnieper). To the east, there are the south-western spurs of the Central Russian Upland, over which runs the border with Russia. The Donets Ridge and the Near Azov Upland can be found near the Sea of Azov. The snow melt from the mountains feeds the rivers and their waterfalls.

The northern part of Ukraine is a forest zone (Polissia), predominated by pine and oak trees. Forest-steppe zone, which is just south of the forest one and is more capable of sustaining agriculture. The Steppe zone is situated in southern and eastern Ukraine (see Fig.19). This zone is the most suitable for intensive agriculture. It is obvious that land use intensity and principles are unique for each zone. View Ukraine native zones map (new tab). There are different borders shown on maps within different sources. However, these potential uncertainties are insignificant on country scale.

		
Polissia zone map in Google Earth format	Forest-Steppe zone map in Google Earth	Steppe zone map in Google Earth

Figure 19. Nature-Agricultural zoning of Ukraine[44]

The main characteristics[45]:

The Polissya (marshy woodlands) zone in the North and Northwest covers about 11 mln ha of lowlands. The soils are characterized by low humus content, high acidity, low natural fertility and a relatively short growing season. Water holding capacity is low due to sandiness, resulting in inefficient use of both rainfall and plant nutrients.

[44] Nature-Agricultural zoning of Ukraine. URL: https://www.google.com/maps/d/u/0/viewer?ie=UTF8&hl=ru&oe=UTF8&start=0&num=200&msa=0&ll=48.312428000000004%2C31.684570000000015&spn=13.376872%2C33.815918&t=h&z=6&mid=1MEGcqrK1pfatf6IrfkTo1lXaDEs

[45] Michiel A., Keyzer Max D., Merbis Rudolf Witt (2012). Farming and rural development in Ukraine: making dualisation work. *JRC scientific and policy reports*. URL: file:///C:/DOCUMENTS/My%20documents/ARTICLES/%D0%94%D0%A0%D0%A3%D0%9A/%D0%A1%D1%82%D1%80%D0%BE%D0%BA%D0%B0%D0%BB%D1%8C%20%D0%92.%D0%9F/%D0%92%D1%81%D1%82%D1%83%D0%BF%20%D0%B4%D0%BE%20%D1%84%D0%B0%D1%85%D1%83_%D0%B0%D0%BD%D0%B3%D0%BB/jrc%2080164.pdf

The Forest-steppes zone is located in the central part of Ukraine and covers about 20 mln ha of mostly flat land with insignificant area of woodlands. Here the famous black soils can be found, which are fine grained and easy to cultivate. The northern belt consists of typical deep chernozem soils. It is the most fertile part, rich in humus and more than a meter thick. Yet, because of the continental climate with warmer

summers, colder winters and lower precipitation in this region, there is a risk of frost and snow mold ("winterkill") causing crop failure.

The Steppes zone extends further towards the South and the East, where the humus layers are not as thick. This area covers about 24 mln ha and is ideally suited for crop cultivation, mostly of winter wheat, other grains, sugar beet and sunflower, and also hosts some animal husbandry. The southern regions are warmest overall, and well suited for growing fruits, vegetables and wines, but have a risk of drought.

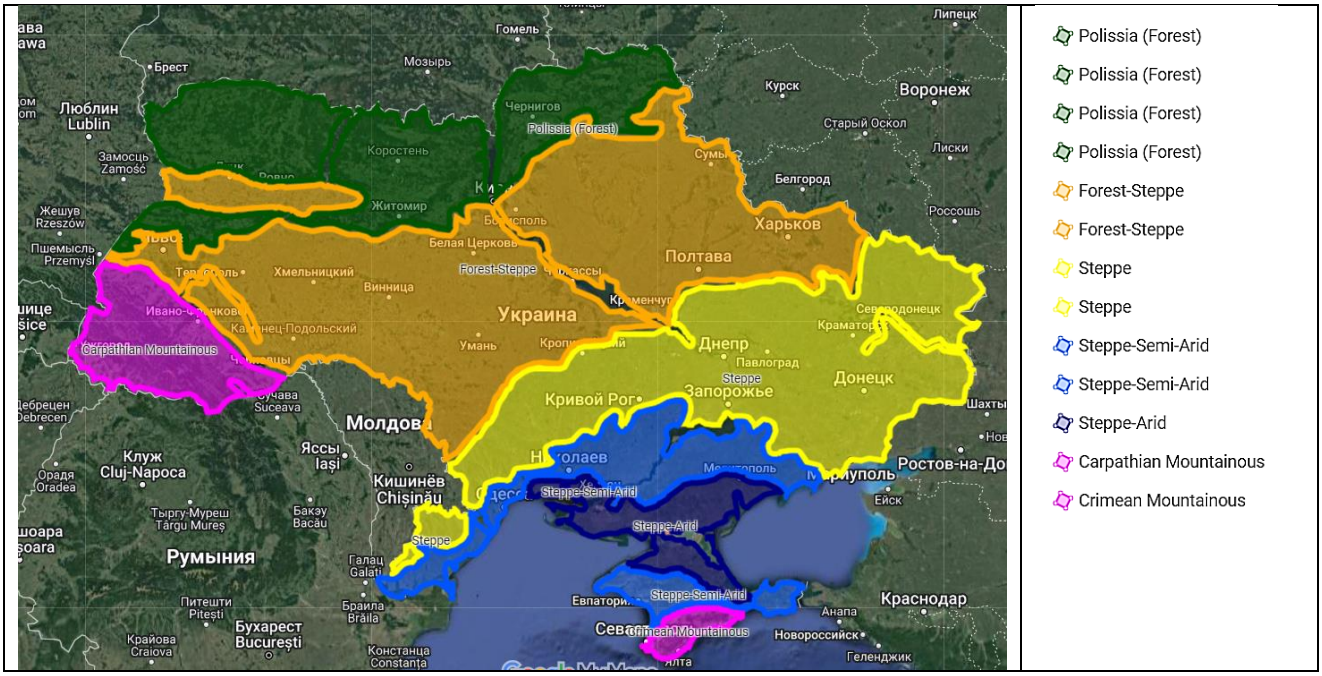


Figure 20. Nature-Agricultural zoning of Ukraine[46]

4.3.2. Destruction of biomes in Ukraine

Ukraine impacts by more than its export potential alone. Its trade policies and product composition play an important role as well, particularly since price volatility in world food markets has risen significantly in the past decade. This change is attributable to several primary and secondary drivers. Ukraine has a distinct role in both. The primary drivers are weather shocks and consequent output variations. Ukraine is under a strong impact here, because of its frost and drought-sensitive conditions, and its limitations in managing irrigation, storage, and plant protection.

Soil degradation[47]

[46] Nature-Agricultural zoning of Ukraine. URL: https://www.google.com/maps/d/u/0/viewer?ie=UTF8&hl=ru&oe=UTF8&start=0&num=200&msa=0&ll=48.312428000000004%2C31.684570000000015&spn=13.376872%2C33.815918&t=h&z=6&mid=1MEGcqrK1pfatf6IrfkTo1lXaDEs

[47] Ukraine: Soil degradation. URL: https://www.agroberichtenbuitenland.nl/documenten/publicaties/2021/06/17/ukraine-soil-degradation

According to the ministry, in Ukraine, 13 million hectares of agricultural land are exposed to the harmful effects of water erosion, more than 6 million hectares - of wind, up to 20 million hectares are covered by dust storms.

The ministry clarified that the development of degradation processes is largely influenced by the high level of plowing of the land (54% of 33 million hectares of the total arable land).

The ministry noted that for Ukraine, combating desertification and land degradation is one of the priority areas of environmental policy. For this, an action plan to combat this phenomenon until 2025 was approved and a coordination council was created to combat land degradation and desertification (see Fig.21).

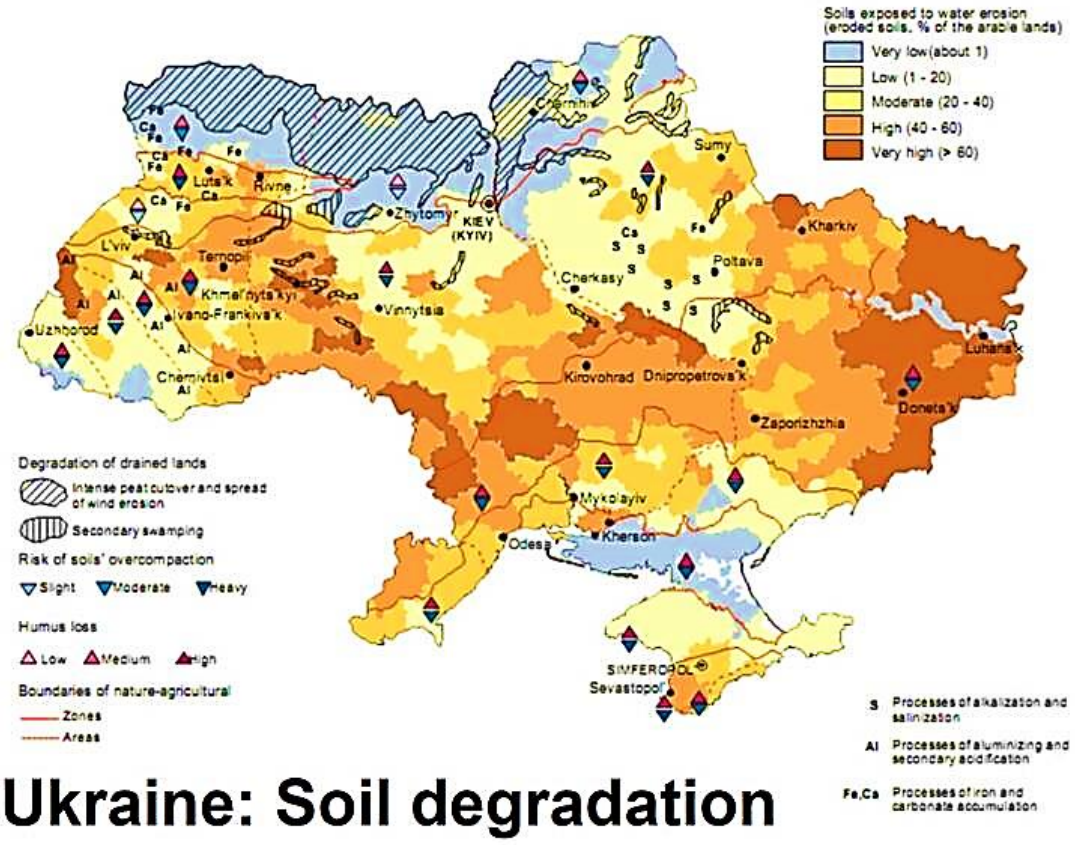


Figure 21. Soil degradation[48]

The most large-scale degradation processes include soil erosion caused by water and wind (nearly 57% of the country's territory), waterlogging of land (about 12%), acidification (almost 18%), salinization and alkalinization of soil (over 6%). According to various criteria, approximately 20% of Ukrainian lands are polluted. Almost 23 thousand cases of landslides are registered yearly. Abrasion is the cause of destruction of 60% of Azov and Black Sea coastlines and 41% of the Dnipro River reservoirs coastlines. Over 150 thousand hectares of land are disturbed by mining and other activities. The number of underground and surface karst phenomena amounts to 27 thousand cases.

[48] Ukraine: Soil degradation. URL: https://www.agroberichtenbuitenland.nl/documenten/publicaties/2021/06/17/ukraine-soil-degradation

The impacts of war on Zones of Ukraine

No war has ever taken into account the need to preserve nature. Meanwhile, the war brings millions of silent victims in each of the military conflicts. The Russian invasion of Ukraine is not an exception.

Being in temporary occupation, the administrations of protected areas lost opportunities to sustain protected areas; the workers themselves are at risk of dying from the shelling and are experiencing a humanitarian crisis. Animals kept in rehabilitation centers, zoos and nurseries die without food.

he Ukrainian Nature Conservation Group has launched the initiative “Let’s save nature in the days of war together”, which can be joined by concerned people from all over the world.

Nature that has been under special state protection for decades, including nature in the occupied territories, has no guarantee of preservation.

In addition, in the occupied territories, there are numerous unique undisturbed places that do not have protected status. These are old swampy forests in the north of the country, steppes in the east and south, the Cretaceous mountains of Slobozhanshchina, all coastal ecosystems. We should not forget about the previously occupied Crimea and Donbas, which is also a treasure trove of unique natural ecosystems.

Given the barbaric actions of the Russian invaders, the resources available to the enemy will be taken away or destroyed. Knowing the experience of Crimea, there is no doubt that during the occupation, barbaric development or direct destruction of natural resources may begin.

It is even worse with forests: in the occupied territories nobody puts out fires that break out en masse in places of jet artillery. Thousands of hectares of forests in Polissya and Slobozhanshchyna have already been lost.

According to the assessment of the Ukrainian Nature Conservation Group, the total area of forests in the war zone, under the temporary control of Russian invaders or which is inaccessible to Ukraine, is more than 3 million hectares. This is about 22% of all forest areas in Ukraine (see Fig.22).

In the zone of hostilities and under the occupying forces are 1,654,736 hectares of virgin steppes, which is approximately 59% of the steppes in Ukraine, and 4,514 hectares of shrubs – more than 10% of such areas of Ukraine. The nature reserve fund of the highest rank of protection (national parks, natural and biosphere reserves, national nature parks) covers 1,236,366 hectares. 44% of them are in the war zone, under the temporary control of Russian invaders or are inaccessible to Ukraine[49].

The natural resources of Ukraine are under risks of the Russian-Ukrainian war. This is associated largely with environmental and ecological implications covering not only the natural resources, but also human activities. The main impacts of Russion-Ukrainian war on resourses:[50].

1. Approximately 35% of the Ukrainian territories have been experiencing the

[49] 44% of the most valuable natural areas of Ukraine are covered by war: join the initiative “Save nature in the days of war together”! URL: https://uncg.org.ua/en/most-valuable-natural-areas-of-ukraine-covered-by-war/

[50] Вплив російської агресії на стан природних ресурсів України : монографія / В. П. Строкаль [та ін.]. - К. : Видавничий центр НУБіП України, 2023. - 222 с. URL: https://dglib.nubip.edu.ua/handle/123456789/10632

soil destruction processes due to the war implications. For example, 130 thousand km2 of the land is mined or damaged based on the information of January 2023. As a result, part of the agricultural land for growing crops are not suitable especially in regions (oblasts) such as Kharkiv, Mykolaiv, Kherson, Zaporizhzhia, Kyiv and Chernihiv. The mined area consists of 8 billion ha (according to the information of May 2023).

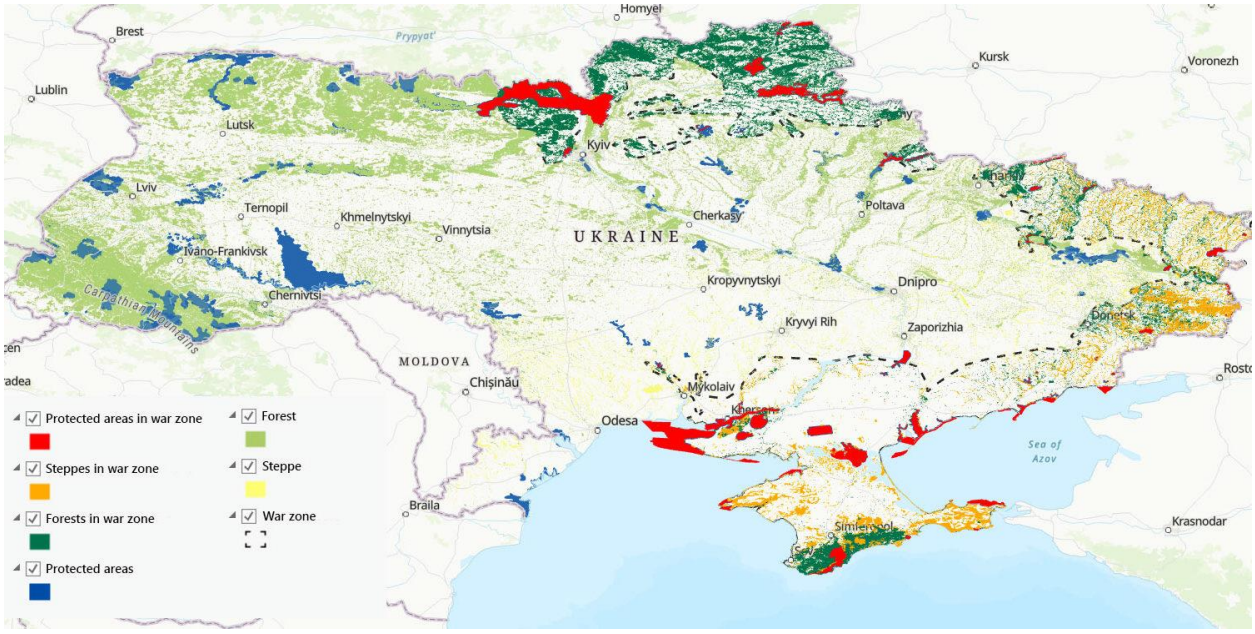


Figure 22. Protected areas of Ukraine of the highest priority in war (Source: https://uncg.org.ua/en/most-valuable-natural-areas-of-ukraine-covered-by-war/)

2. The disruption of the Kakhovka Hydropower Dam has resulted in the flooded areas. Water from the dammed reservoir was flushed and flooded the surrounded areas and households. As a result, a lot of pollution was released into water from untreated humna waste, products of animals etc. Around 31 water supply and drainage facilities were affected, 13 villages left without centralized water supply and 4 landfills of solid household waste became flooded. Furthermore, there is an assumption that 150 tons of machinery oil were released into the Dnipro River that can export further this pollution to the Black Sea. All these factors contribute to water pollution in the Dnipro Basin and the coastal waters of the Black Sea in Ukraine.

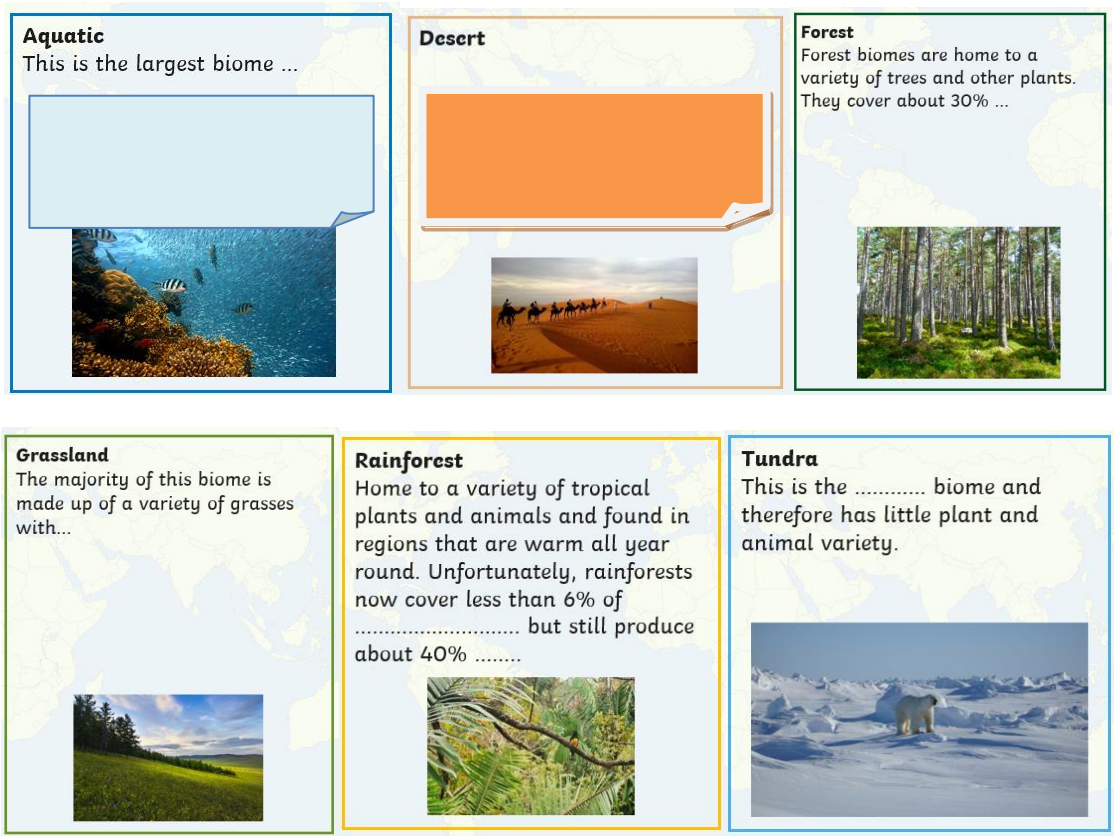
3. According to the status of July 2023, 72 278 animals were damaged or destroyed (economic losses of around 50 million dollars), 149 rare Danube newts were killed by the blowing up of the Kakhovkadam, 333 species of plants and animals have threatened extinction due to blowing up of the Kakhovka dam, 25 parks and nature reserves are or have been under occupation or in the war zone, 900 dolphins died in the Black and Azov Seas because warships use sonars, 183.2 thou. ha area of burned forests and other plantations[51].

[51] Вплив російської агресії на стан природних ресурсів України : монографія / В. П. Строкаль [та ін.]. - К. : Видавничий центр НУБіП України, 2023. - 222 с. URL: https://dglib.nubip.edu.ua/handle/123456789/10632

Control questions for students

1. What are the main types of the biome based on climate and vegetation?
2. What is the difference between biome and ecosystem?
3. What are the main implications of war?
4. Which levels of a food chain do heterotrophs occupy?
5. Discribe the Nature-Agricultural zoning of Ukraine

Interactive task: fill in the nessecery information

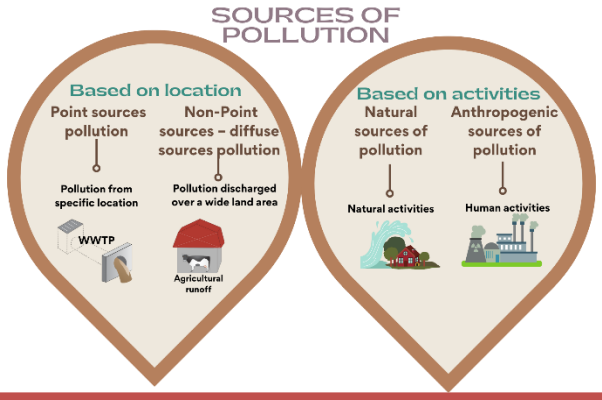


5. Environmental issues: sources and responsibilities

5.1. Environmental pollution

5.2. Environmental impacts

5.3. Environmental justice



Vocabulary	
Pollution	is the introduction of harmful materials into the environment.
Environmental pollution	is one of the biggest threats to life as we know it. Pollution affects the air we breathe, the water we drink, and the ecosystems we depend on. If pollution severity continues to increase; human, animal, and plant populations will break down as they will not be able to cope with a drastically changing environment.
Pollutant	a substance that pollutes or a harmful substance that causes pollution.
Environmental impact	the effect that the activities of people and businesses have on the environment: environmental *impact of sth* (many stores are committed to reducing the environmental impact of plastic shopping bags), environmental *impact on sth* (the environmental impact on the city of the flood).
Environmental effect	an environmental effect is the result of environmental impacts on human health and welfare. The term is also used synonymously with environmental impact.
Environmental justice	is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies; is a social movement to address environmental injustice, which occurs when poor or marginalized communities are harmed by hazardous waste, resource extraction, and other land uses from which they do not benefit.
Point source pollution	is a single identifiable source of air, water, thermal, noise or light pollution, pollution from specific location (water discharging from an industrial plant of some kind or a *wastewater treatment plant*)
Non-Point sources – diffuse sources pollution	is the other type of pollution in which the source of the effluent cannot be traced to a single point, pollution discharged over a wide land area (farming fertilizers, road, urban, agricultural runoff).
Urbanization	is an important source of many water pollutants, including emerging chemicals such as plastics and antibiotics.
Food production	is a source of various pollutants in water systems. For example, nutrients are lost from fertilized fields and pathogens from livestock production.
Agricultural pollution	relates to the derivatives from farming practices caused by living and nonliving organisms that lead to polluting of the environment and ecosystems around which causes damage to humans and their gainful interests

5.1. Environmental pollution

Pollution can be described as a nutrient or substance that is out of place. More specifically, however, it is the addition of any substance (solid, liquid, or gas) or any form of energy (such as heat, sound, or radioactivity) to the environment at a rate faster than it can be dispersed, diluted, decomposed, recycled, or stored in some harmless form. This infographic defines seven major types of pollution and summarizes the issues connected to them.

Pollution is the introduction of contaminants into the natural environment that cause adverse change.

Pollution can take the form of any substance (solid, liquid, or gas) or energy (such as radioactivity, heat, sound, or light).

Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants.

Environmental pollution is one of the most serious problems facing humanity and other life forms on our planet today.

Environmental pollution[52] is defined as "the contamination of the physical and biological components of the earth/atmosphere system to such an extent that normal environmental processes are adversely affected"

5.1.1. Types of pollution

The three major types of environmental pollution are air, water, and soil. Besides these three main types are noise, light, thermal, radioactive, and nutritional pollution.

5.1.1.1. Based on environment

Air Pollution

The air in our atmosphere has a roughly stable chemical composition consisting of nitrogen, oxygen, argon, carbon dioxide, and trace amounts of other gases. Any change in the air composition due to the addition of unwanted gases such as sulphur dioxide, carbon monoxide, and nitrogen oxides, chemicals, particulate matter, and biological molecules is called air pollution.

Among all other types of pollution, air pollution is found to have the most diverse impact on Earth.

Sources/Causes:

Air pollution can happen from both human-made (anthropogenic) and natural sources. Some of the significant sources of air pollution are given below:

- Burning of fossil fuels such as coal, oil, and natural gas
- Exhaust from automobiles and industries
- Indiscriminate cutting of trees (deforestation)
- Wildfires resulting from burning stubble and farm residues
- Release of methane from microbial decay

[52] Environmental and Pollution Science book. URL: https://books.google.com.ua/books?hl=uk&lr=&id=6ZrBZCllgeIC&oi=fnd&pg=PP1&dq=Environmental+and+Pollution+Science&ots=0srI1P2TJB&sig=2N4xaHJoG96FZKJBAHT-HKVoudE&redir_esc=y#v=onepage&q=Environmental%20and%20Pollution%20Science&f=false

- Excessive discharge of greenhouse gases like carbon dioxide and nitrous oxide
- Chlorofluorocarbons (CFCs) released from aerosols sprays, refrigerants, and air conditioners
- Release volcanic ash and gases

Effects:

- Respiratory disorders in humans such as asthma, lung cancer, chronic bronchitis, and other lung problems
- Formation of smog that reduces visibility
- Formation of acid rain
- Depletion of the ozone layer
- Global warming
- Hazards to Wildlife

Prevention:

- Planting of trees (afforestation) purifies the air
- Use of renewable energy such as sunlight and wind energy and reducing dependence on non-renewable sources such as coal, petroleum, and natural gas
- Increasing efficiency in energy usage
- Use of eco-friendly vehicles
- Cleaning of industry emissions before their release into the atmosphere
- Reducing dependence on vehicle

Water Pollution

Water pollution occurs when toxic pollutants and particulate matter are introduced into water bodies such as oceans, rivers, lakes, ponds, and aquifers, making them impure and toxic. These contaminants are primarily generated by human activities and sometimes by natural disasters. Water pollution has become a global problem now a day's ongoing evaluation of water resource policy is needed to counter this problem. Deaths and diseases are caused worldwide due to water pollution and approximately 14000 people die every day due to water pollution[53].

Among all other types of pollution, water pollution is found to have the maximum adverse consequences on the ecosystem.

Sources/Causes[54]:

- Industrial and domestic sewage discharge
- Oil spills and natural gas leakage into water bodies from underground sites called petroleum seeps
- Social practices such as washing, bathing, and littering in water bodies and religious practices
- Acid rain
- Agricultural runoff containing pesticides, fertilizers, herbicides, slurry, debris, and manures

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[53] Chaudhry, F. N., & Malik, M. F. (2017). Factors affecting water pollution: a review. J. Ecosyst. Ecography, 7(1), 225-231. URL: https://www.researchgate.net/profile/Fahad-Nazir/publication/326930223_Factors_Effecting_Water_Pollution/links/5b6d29dd92851ca65053f1ca/Factors-Effecting-Water-Pollution.pdf

[54] Goel, P. K. (2006). Water pollution: causes, effects and control. New age international. URL: https://books.google.com.ua/books?hl=uk&lr=&id=4R9CYYoiFCcC&oi=fnd&pg=PA2&dq=water+pollution&ots=fLbzB-XS8x&sig=eqasMDJQcLCDF7eOL-WtEibdIAo&redir_esc=y#v=onepage&q=water%20pollution&f=false

- Mining and drilling sometimes make underground water contaminated
- Floods and storms carrying dust and debris to the water bodies

Effects:

- Algal bloom (eutrophication) caused due to an increase in nutrients of the water bodies
- Reducing dissolved oxygen in the water bodies thus disrupting aquatic life
- Disturbing the pH and salinity of the water bodies leading to loss of aquatic life
- Increasing the risk of water-borne diseases such as hepatitis, cholera, diarrhea, and typhoid in humans
- Increasing the level of toxins and pollutants at each successive level of the food chain (biomagnification)

Prevention:

- Proper disposing of domestic, agricultural, and industrial wastes before releasing them into water bodies
- Using sewage treatment methods such as precipitation, ion exchange, reverse osmosis, and coagulation
- Reducing the reusing, and recycling of water
- Using plants such as water hyacinth that absorb heavy metals in areas contaminated with radioactive pollutants

Effects of Pollution of Water:

1. Diseases: In humans, drinking or consuming polluted water in any way has many disastrous effects on our health. It causes typhoid, cholera, hepatitis and various other diseases.
2. Destruction of Ecosystems: Ecosystems are extremely dynamic and respond to even small changes in the environment. Water pollution can cause an entire ecosystem to collapse if left unchecked.
3. Eutrophication: Chemicals in a water body, encourage the growth of algae. These algae form a layer on top of the pond or lake. Bacteria feed on this algae and this decreases the amount of oxygen in the water body, severely affecting the aquatic life there.
4. Effects the food chain: Disruption in food chains happens when toxins and pollutants in the water are consumed by aquatic animals (fish, shellfish etc) which are then consumed by humans.

Prevention[55]

The best way to prevent large-scale water pollution is to try and reduce its harmful effects. There are various small changes we can make to protect ourselves from a scary future where water is scarce.

1. Save Water: Conserving water is our first aim. Water wastage is a major problem globally and we are only now waking up to the issue. Simply small changes you can make domestically will make a huge difference.

[55] How to stop water pollution. URL: https://www.stopglobaldestruction.org/how-to-stop-water-pollution/?gad_source=1&gclid=CjwKCAiA7t6sBhAiEiwAsaieYuOwBZz0nffh-BrPwVO4ZkNcDzFwQztCtJ9RBgkpQ7K_k2taHmoWCRoCH1EQAvD_BwE

2. Better treatment of sewage: So treating waste products before disposing of it in a water body helps reduce water pollution on a large scale. Agriculture or other industries can reuse this wastewater by reducing its toxic contents.

3. Use environmentally friendly products: By using soluble products that do not go on to become pollutants, we can reduce the amount of water pollution caused by a household.

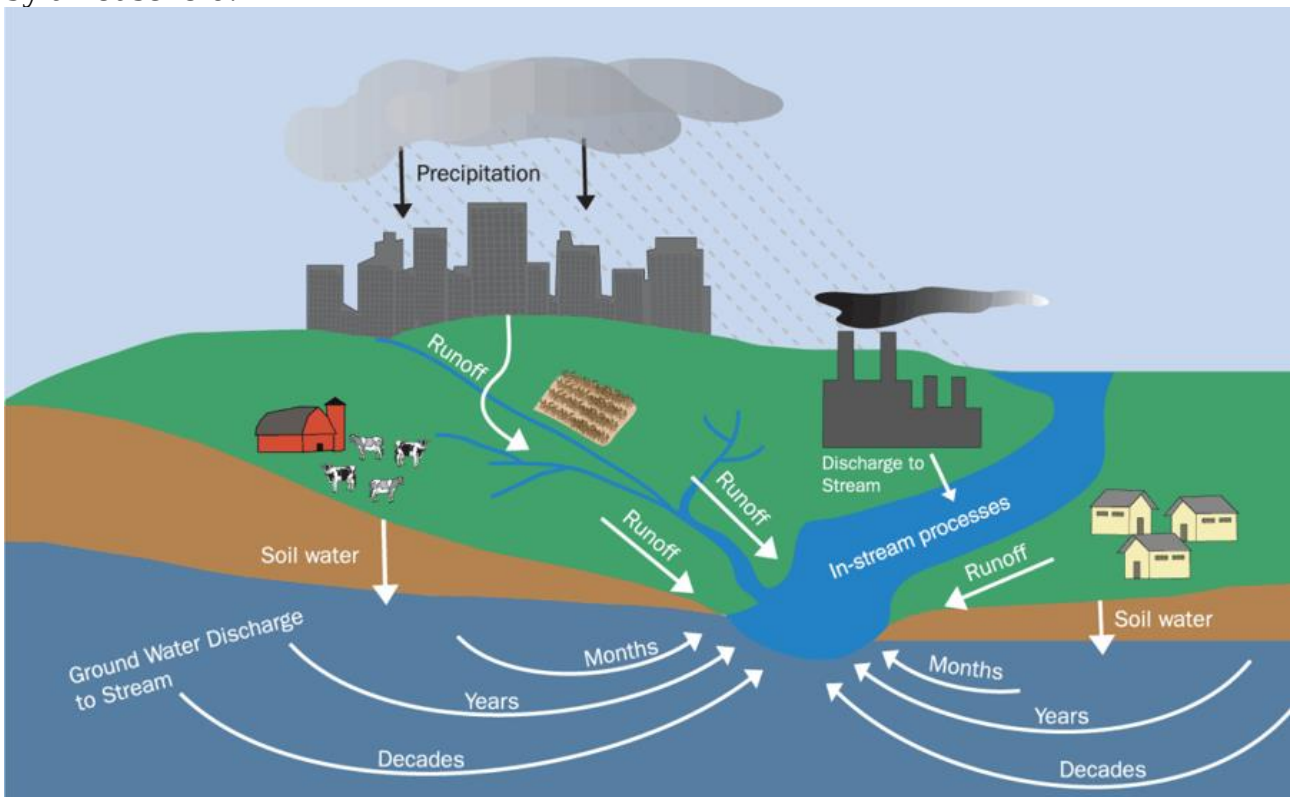
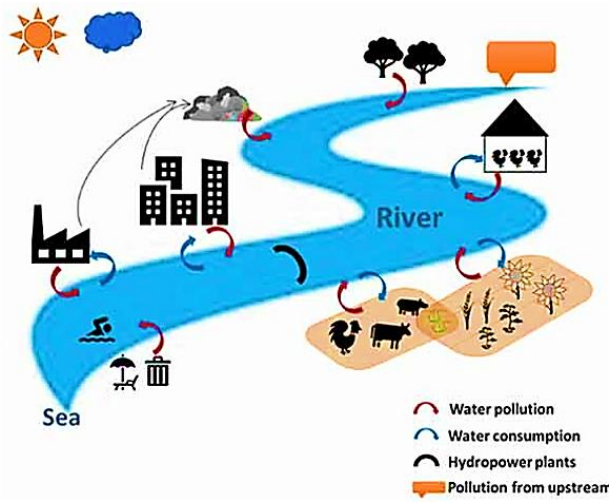


Figure 23. Water pollution[56]



In Ukraine[57] the main causes of river pollution are agriculture, cities, landfills, industries and tour. In Ukraine various crop types are produced because of the fertile soils and favourable climate conditions, contributing considerably to the global food security. Ukrainian cities are growing fast in size and number, which is in line with global trends. In 2010, more than half of the Ukrainian population nationally was urban. In 2014, the percentage of the urban population ranged from 37% (Zakarpats'ka oblast) to 91% (Donetsk oblast) among 24 oblasts and most of the urban population was connected to centralized sewage systems whereas the rural population was not. Wastewater treatment is often inefficient compared to the European countries.

[56] How to control water pollution? URL: http://businessadvice.over-blog.com/2016/09/how-to-control-water-pollution.html
[57] Strokal, V. (2021). Transboundary rivers of Ukraine: perspectives for sustainable development and clean water. Journal of Integrative Environmental Sciences, 18(1), 67-87. URL: https://www.tandfonline.com/doi/full/10.1080/1943815X.2021.1930058

Treatment efficiencies for removing pollutants in sewage waste are low in many cities, which can cause water pollution in the two main ways. Firstly, sewage effluents often release multiple pollutants such as nutrients, chemicals, and pathogens to rivers because of poor treatment. Secondly, flooding from cities can contaminate waters because of poor infrastructures. For example, due to old sewage infrastructures, flooding occurred several times in recent years in the capital city, Kyiv, that can potentially bring pollutants to nearby water systems. Human activities contribute different pollutants to rivers in Ukraine. In general, diffuse and point sources of river pollution are distinguished. Agriculture is often a diffuse source of nutrients and pesticides in the rivers of the country because synthetic fertilizers (contain nutrients) and animal manure (contains nutrients and pathogens) are often used to fertilize soils to grow crops, and pesticides are used to protect crops. In comparison, agriculture is often a diffuse source of river pollution in other countries except for China where direct discharges of manure are point sources of pollutants in rivers. Ukrainian cities and their sewage systems are point sources of many pollutants in rivers such as microplastics, nutrients, pathogens and triclosan (an antibacterial agent). In rural areas of Ukraine human waste often stays on land and can become a diffuse source of nutrients and pathogens in rivers. Landfills are often not managed properly in the country. As a result, heavy metals can enter rivers through surface and subsurface runoff (diffuse source). Industries are often point sources of river pollution with heavy metals.

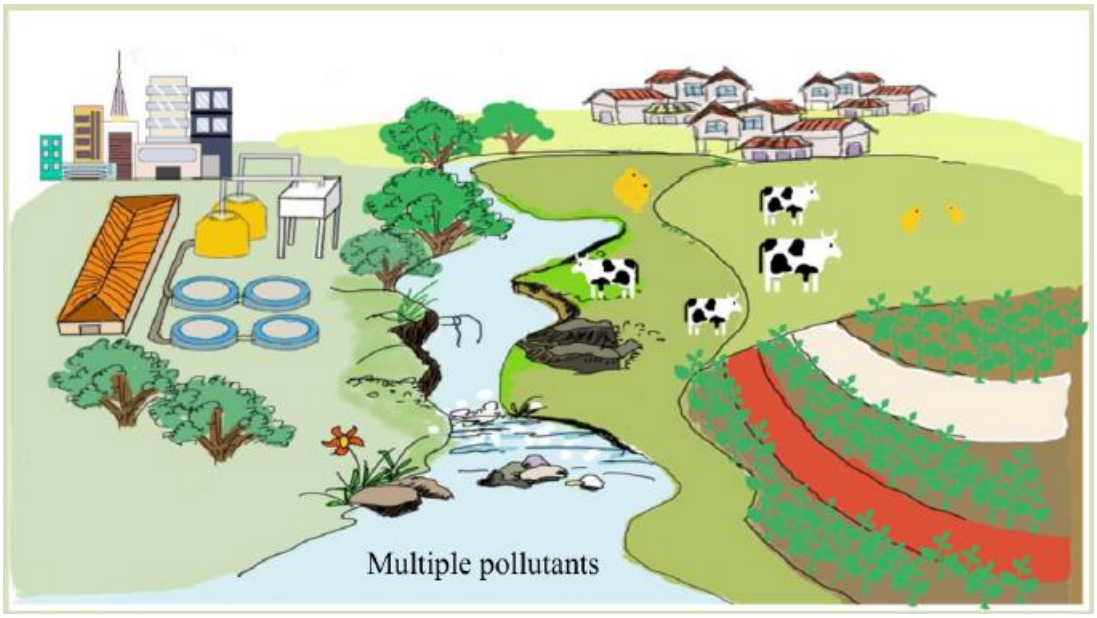


Figure 24. Multiple pollution of river[58]

Ukrainian rivers experience multi-pollutant problems with varied impacts on society and nature. Examples of the impact on nature are eutrophication problems, caused by increased concentrations of nitrogen and phosphorus in water systems. Examples of the impact on society are increased concentrations of nitrogen in rivers

[58] Mengru WANG and others (2023). Water pollution and agriculture: multi-pollutant perspectives. URL: https://journal.hep.com.cn/fase/EN/10.15302/J-FASE-2023527

that can cause “Blue Baby Syndrome”. Another example is diarrhoea in children that can happen when children have contact with contaminated water during swimming or drink untreated water from contaminated rivers. In addition, emerging pollutants such as pharmaceuticals and plastics can pose a risk for the health of society and nature because of their toxicity. Many interactions between pollutants in river systems are still not known yet making it difficult to analyse the combined impacts of multi-pollutant problems on society and nature[59].

Agriculture is an important cause of multiple pollutants in water. With population growth and increasing food demand, more nutrients, plastics, pesticides, pathogens and antibiotics are expected to enter water systems in the 21st century. As a result, water science has been shifting from singlepollutant to multi-pollutant perspectives for large-scale water quality assessments[60].

Soil Pollution

Sometimes called land pollution, it refers to the degradation of land quality due to unwanted chemicals and other factors in the soil. Such chemicals change the soil’s chemical and biological properties, thus affecting plant growth. Green plants, being the primary producer, absorb those pollutants, which are then passed through the food chain, affecting the whole ecosystem.

Soil pollution can seep into groundwater or run off to the nearest streams and lakes, creating a vicious pollution cycle.

Sources/Causes:

- Intensive farming leading to the overuse of agrochemicals such as pesticides, fertilizers, herbicides, slurry, debris, and manures
- Improper disposal of wastes from paper mills, sugar factories, petroleum, and chemical industries
- Dust particles such as silica dust
- Urban wastes consisting of garbage and rubbish materials, dried sludge, and sewage from households and commercial bodies
- Accidental oil spills from oil refineries
- Radioactive pollutants such as radium, thorium, and uranium from power plants
- Acid rain, increasing the acidity of the soil
- Deforestation that increases soil erosion causing low soil fertility

Effects:

- Loss of soil fertility making it unfit for agriculture
- Adverse effect on the growth of flora and fauna in the soil
- Groundwater pollution
- Increasing the salinity of the soil, making it unfit for agriculture
- Causing respiratory problems, neuromuscular blockage, and various forms of cancer, especially lung cancer
- Causing nausea, headache, eye irritation, skin rash, and depression

Prevention:

[59] Strokal, V. (2021). Transboundary rivers of Ukraine: perspectives for sustainable development and clean water. Journal of Integrative Environmental Sciences, 18(1), 67-87. URL: https://www.tandfonline.com/doi/full/10.1080/1943815X.2021.1930058

[60] Mengru WANG and others (2023). Water pollution and agriculture: multi-pollutant perspectives. URL: https://journal.hep.com.cn/fase/EN/10.15302/J-FASE-2023527

- Use of organic matures instead of artificial fertilizers in agriculture
- Planting of trees (Afforestation)
- Treating solid wastes such as garbage, domestic refuse, and industrial materials before dumping them in landfills
- Recovering and recycling of materials such as plastics, cloth, and glass before dumping.

5.1.1.2. Based on substances of pollution

Light Pollution

Light pollution refers to the excessive amount of light in the night sky. It occurs due to excessive, misdirected, and inefficient lighting systems by humans. It is also called photo pollution that disrupts the ecosystem by reducing the distinction between night and day.

Although light pollution seems to have a lesser impact than any other form, it is expected to have consequences similar to air or water pollution.

Sources/Causes:

- Increased energy consumption through over-illumination from artificial light sources such as street lighting, domestic lighting, and garage
- Poor planning by engineers while placing street lights and signage
- Overpopulation increases electricity consumption, which increases glare
- Smog and fog due to air pollution reflect light emitted by cities, making the surrounding look much brighter

Effects:

- Produce behavioral changes in animals. Nocturnal animals, who are active at night, venture out during the daytime. In contrast, diurnal animals, which are active during the day, remain active at night
- Affecting migration pattern in seasonal birds
- Difficulty for astronomers to see the stars properly
- Affecting newly hatched turtles that rely on starlight to guide them from the beach to the ocean. They often head in the wrong direction.
- Causing flowering and developmental patterns in plants
- Inducing smog by destroying nitrate radicals, helping in the dispersion of smog, and causing air pollution
- Inducing a delay in melatonin secretion in humans, which delays sleep at night

Prevention:

- Reducing the use of decorative lightings that produces more light and consumes more energy
- Use of covered bulbs or light that face downwards
- Switching to an LED light that reduces luminance without compromising visibility
- Proper planning during installation of street lights and signage
- Switching off street lights during daytime
- Using glare-free lighting in the outdoors

- Stopping light-trespass

Noise Pollution

It refers to the excessive amount of sound in the surroundings disrupting the natural balance. The acceptable amount of sound is about 60 to 65 decibels, which is the same as our everyday conversation.

Sound levels above 85 decibels are harmful depending on the duration of exposure. Noise above 140 decibels can cause permanent hearing loss. Also, the duration of exposure to the sound is found to have negative health impacts.

Sources/Causes:

- Noise from heavy machines in factories, mills, and industries
- Traffic noise from vehicles (trains and buses) and airplanes
- Construction noises from boring and drilling machines
- Noise from firecrackers and loudspeakers in social events
- Household noises from television, mixer grinders, and music systems

Effects:

- Loss of hearing and behavioral disorders
- Loss of focus on work leading to low work output
- Stress and Hypertension (high blood pressure)
- Lack of sleep and fatigue
- Difficulty in speech and impairment
- Hearing disorders like tinnitus
- Songbirds, such as robins, fail to communicate and find food
- Disrupting sonar, used by marine animals to communicate and locate food

Prevention:

- Honking in public places like hospitals, academic institutions such as schools and colleges should be banned
- Installing adequate soundproof systems in commercial buildings and hospitals
- Afforestation as trees can absorb sound
- Restricting the use of firecrackers during festivities and doing open public rallies

Apart from the types of pollution discussed, there are other forms of pollution called thermal or heat pollution and radioactive pollution.

Thermal pollution is caused due to excessive heat in the environment released from industrial power plants, deforestation, urban sprawl, and air pollution. It increases the Earth's atmosphere causing drastic climate change and extinction of wildlife (https://prepp.in/news/e-492-sources-of-thermal-pollution-environment-notes).

In contrast, **radioactive pollution** results from accidental leakage from nuclear power plants and improper disposal of nuclear wastes. It can cause massive, long-lasting impacts such as cancer, infertility, blindness, and congenital disabilities.

Video “Hazards From Radioactive Material | Radioactivity | Physics”: https://www.youtube.com/watch?v=tfsanfG_yGo

Nuclear power stations produce electricity, which of course is extremely useful. However, they also make radioactive waste.

When items have no further use and have radioactivity above certain levels, they are known as radioactive waste.

Radioactive waste can come from a range of activities, including generating electricity from nuclear power stations, treating medical illnesses and conducting research.

Did you know that radioactive waste can be harmful to us?

Either by irradiation or contamination[61].

We’re going to look at these two in this video.

Irradiation is when a person or object is exposed to radiation without coming into direct contact with the radioactive source.

The person doesn’t make direct contact with the radioactive barrel, but since irradiation can happen at a distance, the person is still at risk.

The damage to the person only happens whilst the person is in the area of the radioactive waste. Therefore the person is only exposed to radiation for a short time, and so receives a low dose of radiation.

Irradiation can sometimes be useful, particularly during cancer treatment.

People are irradiated in an attempt to remove cancerous cells from their body.

Irradiation is also used to sterilise surgical equipment, or to remove bacteria from fruit in supermarkets. The objects don’t become radioactive themselves, and so are safe for use or consumption.

Contamination is when a person actually comes into contact with radioactive wastes.

The person takes the radioactive source away with them, and so are exposed for a longer period of time and consequently have a higher dose which can lead to more damage.

Contamination can happen in a variety of ways: from picking up a source, to breathing it, to ingesting it.

Contamination is used in medicine, by injecting radioactive tracers into the body to see possible blockages. Radioactive tracers are also used to find leaks in water pipes.

Radioactive waste can remain hazardous for a very short or a very long period of time, depending upon the different half lives.

‘Half lives’ mean the level of hazard of the radioactive waste reduces with time.

If we start off with a kilogram of radioactive waste that has a half life of 100 years, after 100 years we will have 500g of radioactive waste.

After another 100 years there will be 250g of it and so on.

Eventually the amount of radiation will decrease until it reaches the same level

[61] Radiation pollution sources, radioactive wastes and how to protect yourself from radiation pollution. URL: https://www.online-sciences.com/the-environment/radiation-pollution-sources-radioactive-wastes-how-to-protect-yourself-from-radiation-pollution/

as background radiation.

For medical contamination that involves injecting radioactive sources, isotopes that have very short half-lives are selected. The half life is long enough that they stay active for detection to be done. But short enough that they reduce to low-risk levels as quickly as possible.

Background radiation comes from artificial and natural sources around us, that we experience daily.

It is low in magnitude so it isn't harmful. However, for some radioactive wastes to reach this low background level it may take several thousand years.

So just how harmful is radioactive waste? The answer depends on the half life of the waste and whether a person is irradiated or contaminated. It's like asking, how long is a piece of string?

We've now learned about the differences between irradiation and contamination.

Plastic Pollution[62]

Plastic pollution is the addition of plastic waste to the landscape and waterways. It is caused by manufactured plastics that are not properly disposed of. It is a problem because plastic does not break down easily, the chemical additives in plastic may become endocrine disrupters, plastic waste flows downstream into rivers and oceans (sea life can ingest, choke on, or become trapped in plastic waste), and plastic is a source of polychlorinated biphenyls (PCBs), which are suspected carcinogens.

Every year, over 300 million tonnes of plastic are produced, with half of that going into single-use products like shopping bags, cups, and straws. Plastic is a petroleum-based synthetic organic polymer having properties that make it appropriate for a wide range of uses, including packaging, construction, home, sporting goods, cars, electronics, and agriculture. Construction and illegal dumping are the main sources of plastic detected. Other sources include single-use plastics arising from food wrappers and containers, bottles, container caps, and more. Plastic pollution in the ocean is mostly caused by the fishing industry, naval operations, and aquaculture.

Nutrient pollution

According to NOAA, ***nutrient pollution*** occurs when too many nutrients, mainly nitrogen (N) and phosphorus (P), flow into water bodies and act like fertilizers, causing algae to grow excessively. This phenomenon is also known as eutrophication.

Many harmful algal blooms (HABs), or cyanobacterial HABs, are a result of increasing nutrient pollution. The dramatic surge in nutrient flow from industrial, urban, and agricultural activities accelerates the eutrophication of lakes, streams, and coastal waters.

Harmful algal species are quickly adapting to the growing nutrient loads. The timing, amount, and proportions of nutrients are the critical factors contributing to the

[62] Sources of Plastic Pollution - Environment Notes. URL: https://prepp.in/news/e-492-sources-of-plastic-pollution-environment-notes

proliferation of HABs. The disbalance in nutrients accelerates the toxicity of diatoms and cyanobacterial HABs. Climate change with environmental and abiotic conditions due to human activities, also fuels the growth and spread of algae.

The main nutrients affecting the health of aquatic ecosystems are nitrogen and phosphorus. The natural biogeochemical cycles of nitrogen and phosphorous could be disrupted by increased effects brought on by climate change.

Algae and aquatic plants rely on these nutrients to grow. However, excessive amounts of N and P trigger extreme HABs.

What causes eutrophication?

The global production of P has increased 18 times since the 1940s. Meanwhile, the production of N grew over sixfold. It's estimated that the annual flow of P into aquatic systems has tripled, while N has doubled.

Nutrient pollution can occur due to land development, agriculture, aquaculture, and atmospheric nutrient deposition. These increase the amount, alter the proportions and chemical forms of nutrients promoting HABs.

The growing human population intensifies food production and wastewater discharge. These are the main contributors to global nutrient pollution. Anthropogenic activities and climate change further accelerate the prevalence and impact of HABs.

Major sources of nutrient pollution include:

Agriculture

Crop production involves chemical fertilizers or animal manure containing N and P. Fertilized soils and livestock operations release many nutrients into the air and waterways.

Wastewater

Municipal sewer and septic systems often fail to remove the N and P from urban waste. Discharges of untreated or inadequately treated waste in the waterways increase nitrate and phosphorus pollution. Some detergents used for cleaning and laundry contain nitrogen and phosphorus. Garden fertilizers and inadequately disposed biowaste also encourage nutrient pollution.

Fossil fuels

Widely used for manufacturing, transportation, electricity generation, and agriculture. Release unprecedented amounts of nitrogen oxide emissions into the air. A big part of it pollutes our water bodies. Additionally, industrial operations, airplanes, ships, road vehicles, and coal power plants are significant sources of nitrogen pollution.

Stormwater

Rain and snow runoff from roofs, roads, and pavements also carries nitrogen and phosphorus into local waters.

Nitrogen is also the most abundant element in the air composition. Human activities produce a significant surplus of nitrogen either as nitrogen oxides or ammonia. It ends up deposited back onto land and washed into nearby water bodies.

Extensive atmospheric N deposition leads to N-saturation of watersheds and exporting nitrate further to streams, lakes, and estuaries. This elevated water nutrient

pollution stimulates the spread of HABs. Too much ammonia and low pH creates oxygen-deprived water zones suffocating and intoxicating the aquatic organisms.

What are the effects of nutrient pollution?

The human-caused enrichment of water with nutrients contributes to the process of eutrophication. It accelerates the growth of algae and other aquatic life. This disturbs the natural balance of aquatic ecosystems and deteriorates the water quality.

Excessive nutrients dramatically alter the food webs in lakes, rivers, and coastal ecosystems. As a result, these systems become dominated by phytoplankton. The benthic microalgal and macrophyte production decreases and can be critical for fish survival.

In lakes, eutrophication creates hypoxia and biodiversity loss due to a lack of dissolved oxygen. Also, it promotes the proliferation of HABs. Lake eutrophication further increases emissions of greenhouse gases, methane, and nitrous oxide, contributing to global climate change.

What are the solutions for nutrient pollution?

Combating eutrophication requires a combination of comprehensive control and preventative measures. Governments, businesses, and individuals must take urgent actions to reduce nutrient pollution. Key strategies involve controlling nutrient pollutant sources and restoring damaged ecosystems.

5.1.2. Sourses of pollution

5.1.2.1. Based on location

Point sources of pollution

Point source pollution is a pollution which occurs through a single identifiable source. Therefore, the effect of this type of pollution is local to the point of discharge. The size of the pollution can vary from a small pollution to a large. As an example, the discharge of an electric battery to a water source is a small-scale point source pollution while the emission of smoke from a factory is a large-scale point source pollution.

Since point source pollution is a localized type of pollution, the pollutants enter in the environment in a high concentration and then, are slowly diluted into the ecosystem. Hence, a severe damage to the ecosystem can be observed at the point of discharge. On the other hand, it is easy to prevent and control point source pollution by stopping the source or installing a treatment plant.

Pollution point sources are identical to other physics, engineering, optics, and chemistry point sources and include:

- *Air pollution* from an industrial source (rather than an airport or a road, considered a line source, or a forest fire, which is considered an area source, or volume source)

- *Water pollution* from factories, power plants, municipal sewage treatment plants and some farms (see concentrated animal feeding operation).
- *Noise pollution* from a jet engine
- *Disruptive seismic* vibration from a localized seismic study
- *Light pollution* from an intrusive street light
- *Radio emissions* from an interference-producing electrical device.

Non- point sources of pollution

Non-point are more diffuse sources (NPS) that don't come from one single pipe or outlet.

Non-point sources include run-off from agricultural lands that may wash fertilizer or other chemicals into lakes or rivers - this may occur over thousands of square kilometres.

Nonpoint source pollution is the other type of pollution in which the source of the effluent cannot be traced to a single point. This means it is a more diffused type of pollution. Effects of this type of pollution can be identified in the atmosphere, water bodies or on the land. As an example, the high carbon dioxide concentration in the atmosphere is a result of the emission of carbon dioxide from various factories worldwide, vehicles, and so on. The emitting carbon dioxide moves across the globe through diffusion.

Types of NPS pollutants include:

1. Nutrients - fertilizer and pesticides from lawns or farms
2. Organic wastes - from manure and sewage
3. Pathogens - bacteria and viruses
4. Salt - from irrigation and acid-mine drainage
5. Sediment - from erosion of bare soils
6. Toxins - airborne chemicals, oils, and metals

Difference Between Point Source and Nonpoint Source Pollution[63]

The main difference between point source and nonpoint source pollution is that the point source pollution occurs through a specific, identifiable source whereas the nonpoint source pollution occurs through a combination of pollutants from a large area.

Point source and nonpoint source pollution are two mechanisms of pollution. Discharge pipes from factories, sewage treatment plants, and various organizations are responsible for point source pollution while the runoff of the contaminants of gardens and construction sites through water bodies is responsible for nonpoint source pollution.

Similarities Between Point Source and Nonpoint Source Pollution

Point source and nonpoint source pollution are two types of mechanisms of pollution. Pollution can be water pollution, air pollution, land pollution, noise

[63] Point and Nonpoint Pollution Sources: URL: https://www.youtube.com/watch?v=t7ZdmWuGy4M

pollution, etc.

Difference Between Point Source and Nonpoint Source Pollution[64]

Definition

Point source pollution refers to the pollution that occurs from a single identifiable source while nonpoint source pollution refers to the pollution that occurs via many diffuse sources.

Source

The discharge of effluents occurs at one point in point source pollution while the discharge of effluents over a wide area leads nonpoint source pollution. This is the main difference between point source and nonpoint source pollution.

Effect

The effect of point source pollution is high while the effect of nonpoint source pollution is less.

Treatment Plant

A treatment plant can be installed in the area of discharge in point source pollution while a treatment plant is less effective for nonpoint source pollution because of the source of pollution. This ia another important difference between point source and nonpoint source pollution.

Examples

Some examples of point source pollution include faulty treatment plants, oil tank spills, combined sewer outfalls, etc. while some examples of nonpoint source pollution are farming fertilizers, road salt runoff, etc.

Conclusion

Point source pollution is a type of pollution that occurs via an identifiable source while nonpoint source pollution is a type of more diffusible pollution. The effect of point source pollution is high in the affected area while the effect of nonpoint source pollution is more global. The main difference between point source and nonpoint source pollution is their source.

5.1.2.2. Based on activities

Natural sources pollution

Natural sources of sulphur dioxide include release from volcanoes, biological decay and forest fires. Actual amounts released from natural sources in the world are difficult to quantify. In 1983 the United Nations Environment Programme estimated a figure of between 80 million and 288 million tonnes of sulphur oxides per year (compared to around 69 million tonnes from human sources world-wide).

Natural sources of nitrogen oxides include volcanoes, oceans, biological decay and lightning strikes. Estimates range between 20 million and 90 million tonnes per year nitrogen oxides released from natural sources (compared to around 24 million tonnes from human sources worldwide).

Ozone is a secondary photochemical pollutant formed near ground level as a

[64] Difference Between Point Source and Nonpoint Source Pollution. URL: https://pediaa.com/difference-between-point-source-and-nonpoint-source-pollution/

result of chemical reactions taking place in sunlight. About 10 to 15% of low level ozone, however, is transported from the upper atmosphere (called the stratosphere), where it is formed by the action of ultraviolet (UV) radiation on oxygen (the ozone layer).

Natural sources of particulate matter are less important than man-made sources. These include volcanoes and dust storms. However, such sources do account for intense high particulate pollution episodes, occurring over relatively short times scales.

Volatile organic compounds (VOCs) are naturally produced by plants and trees. Isoprene is a common VOC emitted by vegetation, and some believe it to be a more significant trigger for asthma an other allergic reactions than man-made irritants. Plant, grass and trees are also a source of pollen, which can act as triggers in some asthmatics. Pollen is in the air year-round, but the concentration is highest during the growing season, from March to the first frosts in autumn.

Natural pollutants found indoors include the dustmite, mould spores and radon gas.

Dust storms are defined as events in which visibility is reduced to 1 km or less as a result of blowing dust.

Intense **wildfires** can cause chemical reactions that release metals, nutrients and other toxicants into the soil.

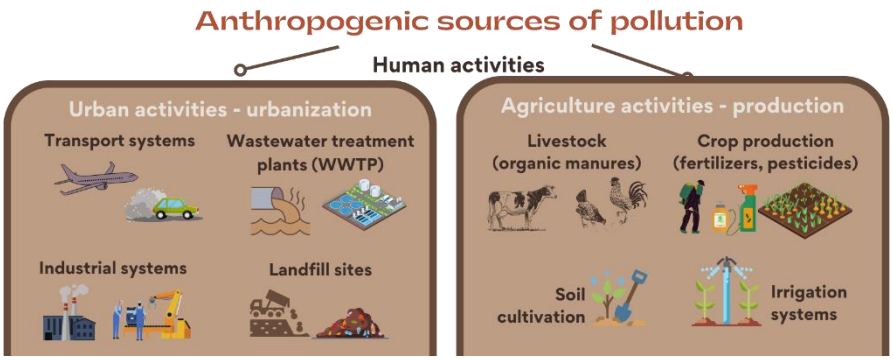
Volcanic gases can reach the stratosphere, where they form sulfuric acid aerosols that can reflect solar radiation and lower surface temperatures significantly

Floods can also be a huge destructive power. When water flows, it has the ability to demolish all kinds of buildings and objects, such as bridges, structures, houses, trees, cars... For example, in Bangladesh in 2007, a flood was responsible for the destruction of more than one million houses. And yearly in the United States, floods cause over $7 billion in damage. The primary effects of flooding include loss of life and damage to buildings and other structures, including bridges, sewerage systems, roadways, and canals. Floods also frequently damage power transmission and sometimes power generation, which then has knock-on effects caused by the loss of power. This includes loss of drinking water treatment and water supply, which may result in loss of drinking water or severe water contamination. It may also cause the loss of sewage disposal facilities. Lack of clean water combined with human sewage in the flood waters raises the risk of waterborne diseases, which can include typhoid, giardia, cryptosporidium, cholera and many other diseases depending upon the location of the flood.

Damage to roads and transport infrastructure may make it difficult to mobilize aid to those affected or to provide emergency health treatment.

Flood waters typically inundate farm land, making the land unworkable and preventing crops from being planted or harvested, which can lead to shortages of food both for humans and farm animals. Entire harvests for a country can be lost in extreme flood circumstances. Some tree species may not survive prolonged flooding of their root systems.

Anthropogenic sources pollution



Pollution is an emerging actual issue that our oceans have been experiencing. Plastic, light, sound and chemical pollution originate from different sources, mostly anthropogenic, which means they arise from human activities. Chemical pollution has been extensively assessed in the past decades, especially due to high industrial development in coastal areas and pesticides used in agriculture. One might wonder how can pesticides, for example, affect marine ecosystems if they're used inland. Well, the big problem here is that these products are transported beyond their intended area of action, ending, occasionally, in aquatic systems. As a consequence, some of these chemicals have been banned for their associated effects on marine organisms, for example, dichlorodiphenyltrichloroethane, commonly known as DDT. Even so, every year new compounds are being synthesized to meet the societies' demands but their effects on aquatic systems and, especially, organisms are mostly unknown.

Urban and peri-urban agriculture is growing rapidly due to the increase in urban population and food demands. According to FAO, some 800 million people worldwide produce food in urban gardens (FAO, 2019a), which has a major beneficial impact on household incomes, food security and nutrition while providing urban green space and its resilience to climate change. However where the soil is polluted, special attention must be paid to the potential transfer of contaminants from urban soils to crops and the risk posed to human health. Pesticides are also widely used to control weeds and pests that affect vegetation in urban green areas or to control disease vectors[65].

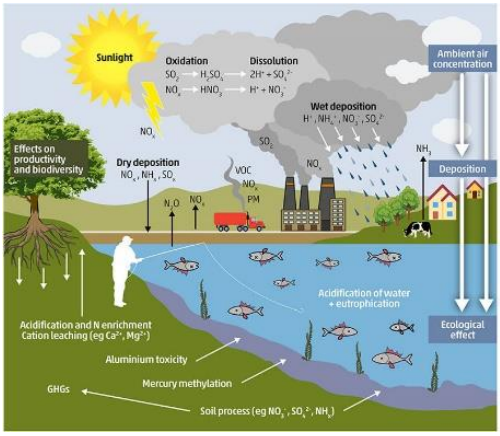


Figure 25. Atmospheric fluxes of contaminants that are subsequently deposited in soils (Source: https://www.fao.org/3/cb4894en/online/src/html/chapter-03-4.html)

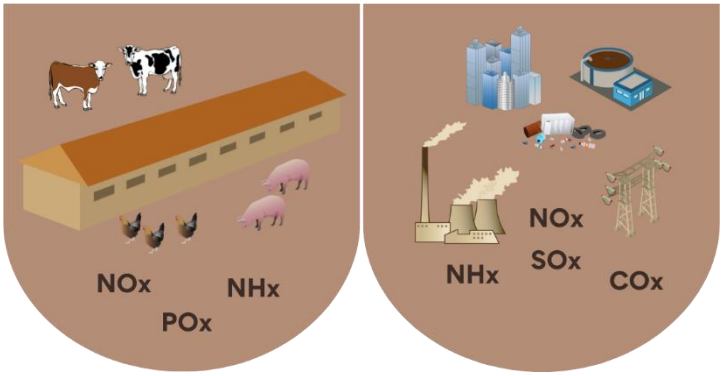
[65] Sources of soil pollution and major contaminants in urban areas. URL: https://www.fao.org/3/cb4894en/online/src/html/chapter-03-4.html

Figure 26. Most of the pollution sources are anthropogenic. Domestic sewage, industrial activity, mining, use of pesticides in agriculture and urban waste, among others, are sources of pollution than eventually enter the aquatic systems[66]

Plastic, light, sound and chemical pollution originate from different sources, mostly anthropogenic, which means they arise from human activities. Chemical pollution has been extensively assessed in the past decades, especially due to high industrial development in coastal areas and pesticides used in agriculture. One might wonder how can pesticides, for example, affect marine ecosystems if they're used inland. Well, the big problem here is that these products are transported beyond their intended area of action, ending, occasionally, in aquatic systems. As a consequence, some of these chemicals have been banned for their associated effects on marine organisms, for example, dichlorodiphenyltrichloroethane, commonly known as DDT. Even so, every year new compounds are being synthesized to meet the societies' demands but their effects on aquatic systems and, especially, organisms are mostly unknown.

[66] The hidden effects of pollution. URL: https://saveourseas.com/update/the-hidden-effects-of-pollution/

5.1.3. Substances of pollution



Substances that may cause pollution:

- **Nutrients**
  - The main potentially-polluting nutrients in relation to water are nitrogen, ammonia (a gas containing nitrogen and hydrogen), phosphorus and sulphur.
    - They arise from the natural breakdown of crop residues and soil organic matter, rainfall, fertilisers, urine and manure, silage, landfill sites, wastewater and industrial effluents, power generation and other fuel-burning activities.
    - For example, nutrients are the principal cause of eutrophication which is the enrichment of lakes, rivers and the marine environment leading to increased plant growth and the occurrence of algae.
- **Pesticides**
  - These include herbicides, insecticides and fungicides that are used in gardens, in agriculture, in roadside and trackside (railway) maintenance, and in parkland and golf courses.
- **Heavy metals**
  - These are widely-used ingredients for chemical compounds used in industry
  - Industrial contaminated land can be a source of heavy metals leaching into the environment
  - They also exist naturally in soils at low concentrations. They can be found in fuel, chemicals, waste materials and batteries.
  - In high concentrations they are toxic to humans, animals, fish and plants.
- **Suspended solids**
  - Suspended solids are mineral and organic particles that remain suspended in water. They sink only very slowly or are easily resuspended by water turbulence.
  - Suspended solids might be eroded soil or decayed leaves. Wastewater from sewage works and industry might also carry suspended solids into water bodies
- **Pathogens**
  - These are present in faeces from human and animal sources, including wildlife.
  - They can enter water through poor wastewater management or poor handling of manures, slurry and other farm wastes.

        - They may also be carried directly off fields by heavy rainfall or enter water bodies where stock and wildlife have direct access for drinking purposes
    - **Hydrocarbons**
        - These include vegetable and mineral oils (including petrol, diesel, white spirit, heating and lubricating oil), and chlorinated solvents such as dry cleaning fluids
    - **Persistent organic pollutants (POPs)**
        - These are chemicals that are capable of long-range transport, accumulate in human and animal tissue, and have a significant impact on human health and the environment, even at low concentrations.
        - They include substances such as dioxin and polychlorinated biphenyls (PCBs).

5.2. Environmental impacts

There are direct and indirect impacts of a given hazard. They include:

- Personnel
- Facilities
- Financial stability—note that financial impacts include credit and insurance ratings
- Surrounding community
- Long-term harm to reputation

Direct impact refers to changes immediately as a result of the hazard, such as destruction of a building as a result of the force of high winds or flooding.

Indirect impact refers to subsequent changes given the direct impact, such as loss of housing if the building was inhabitable.

Also, we can say that Impacts to the environment can be one of two types: Direct Impacts: Impacts caused by the action. Indirect Impacts: Impacts caused by the action, but that are later in time or farther removed in distance but are still reasonably foreseeable.

5.2.1. Direct impacts

Primary impact:

- Physical damage to agricultural land
- Physical damage to raw materials
- Physical damage to production equipment
- Physical damage to water infrastructure
- Discharge of any industry or effluent from the Effluent Treatment Plant or WWTP

Secondary impact:

- Cost for recovery and reconstruction

- Cost for remediation
- Rise of water and land toxins

5.2.2. Indirect impacts

Primary impact:

- The decline in water quality due to rise in temperature of water bodies receiving cooling water discharge from the nearby industry
- Loss of production due to infrastructure disruption (lack of water supply to agriculture, humans, etc.)
- Loss of production due to supply-chain disruption

Secondary impact:

- Damage to the company's image
- Increase poverty
- Reduction in fishing harvests

5.2.3. Examples of direct and indirect impacts

The availability of quality water especially for agriculture is significant to avoid problems with hunger at national and global levels. According to this, water quality is important to support livestock and crop production, and water supply to people. However, water quality is impacted by the war, reducing the supply of clean water for societal needs (e.g., domestic, and agriculture) and nature. These impacts are divided into direct and indirect (see Fig.27). It depends on the impact caused by the military action.

Direct impacts of the Russian-Ukrainian war: mining and bombing agricultural lands (physical damage to agricultural land, to raw materials); damage and destroy the agricultural farms (physical damage to production equipment); damage and destroy water infrastructures (physical damage to water infrastructure (dams, canals, bridges), discharge of any industry, or effluent from the Effluent Treatment Plant or WWTP).

Indirect impacts of the Russian-Ukrainian war: loss of production due to infrastructure disruption (lack of water supply to agriculture (livestock and crop production, irrigation systems), humans, etc.) – can cause a risk to water security; loss of production due to supply-chain disruption – can cause a risk to food security.

Also, water infrastructures in Ukraine were damaged especially in occupied and de-occupied territories (direct impacts). It caused deterioration of water quality in those territories and promoted land and water pollution (indirect impacts). In Ukraine, many bridges were destroyed due to war. For example, during the occupation of settlements in the Chernihiv region, 35 bridges were destroyed, the destruction of which was caused by minor flooding and physical pollution of the territories[67].

[67] Strokal V.P., Kurovska A.V. (2023). Direct and indirect impacts of war on water quality. Актуальні питання сьогодення та післявоєнного відновлення сільського господарства й екології: експертно-аналітичні складові формування продовольчої стратегії України: збірник матеріалів за підсумками науково-практичної конференції з нагоди 20-річчя УЛЯБП АПК НУБіП України (смт Чабани, 2 жовтня 2023 р.). К.: НУБіП України. 2023. 13-14 pp. URL: https://nubip.edu.ua/sites/default/files/u381/zbirnik.mat_.konf_ulyabp_2023.pdf#page=13

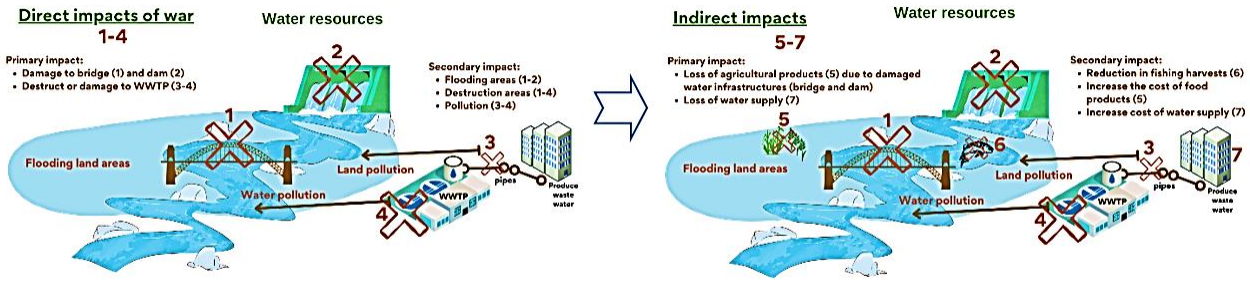


Figure 27. Explored implications of the war on water quality in Ukraine[68]

5.3. Environmental justice

Environmental justice is the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no population bears a disproportionate share of negative environmental consequences resulting from industrial, municipal, and commercial operations or from the execution of federal, state, and local laws; regulations; and policies. Meaningful involvement requires effective access to decision makers for all, and the ability in all communities to make informed decisions and take positive actions to produce environmental justice for themselves[69].

Environmental justice is typically defined as *distributive justice*, which is the equitable distribution of environmental risks and benefits. Some definitions address procedural justice, which is the fair and meaningful participation in decision-making. Other scholars emphasise recognition justice, which is the recognition of oppression and difference in environmental justice communities. People's capacity to convert social goods into a flourishing community is a further criteria for a just society However, initiatives have been taken to expand the notion of environmental justice beyond the three pillars of distribution, participation, and recognition to also include the dimensions of self-governing authority, relational ontologies, and epistemic justice (see Fig.28).

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[68] Strokal V.P., Kurovska A.V. (2023). Direct and indirect impacts of war on water quality. Актуальні питання сьогодення та післявоєнного відновлення сільського господарства й екології: експертно-аналітичні складові формування продовольчої стратегії України: збірник матеріалів за підсумками науково-практичної конференції з нагоди 20-річчя УЛЯБП АПК НУБіП України (смт Чабани, 2 жовтня 2023 р.). К.: НУБіП України. 2023. 13-14 pp. URL: https://nubip.edu.ua/sites/default/files/u381/zbirnik.mat_.konf_ulyabp_2023.pdf#page=13

[69] What Is Environmental Justice? URL: https://www.energy.gov/lm/what-environmental-justice

Figure 28. The five interrelated dimensions of environmental justice[70]

Climate change and climate justice have also been a component when discussing environmental justice and the greater impact it has on environmental justice communities. Air pollution and water pollution are two contributors of climate change that can have detrimental effects such as extreme temperatures, increase in precipitation, and a rise in sea leve. Because of this, communities are more vulnerable to events including floods and droughts potentially resulting in food scarcity and an increased exposure to infectious, food-related, and water-related diseases. Currently, without sufficient treatment, more than 80% of all wastewater generated globally is released into the environment.

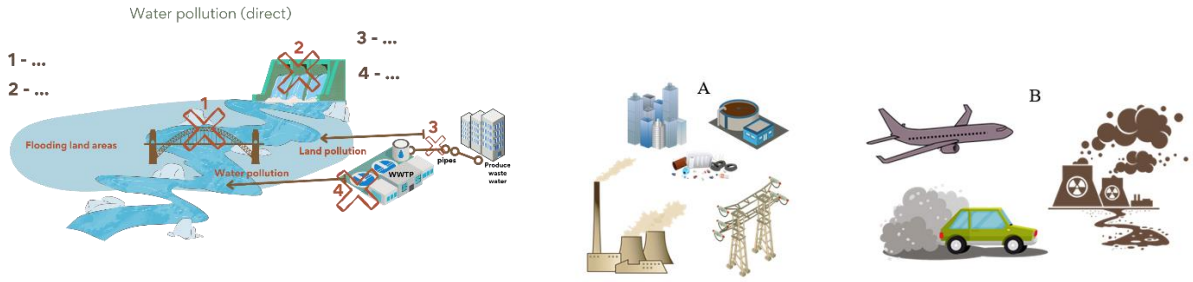
Control questions for students

1. What do you know about the environmental pollution? Describe them
2. What do you know about the environmental impacts? Describe them
3. What do you know about the direct and indirect sources pollution? Describe them. Give examples.
4. What do you know about anthropogenic sources of pollution? Describe them. Give examples.
5. What is environmental justice? Describe the main concept.

[70] Justice in social housing: Towards a people-centred energy renovation process. DOI:10.1016/j.erss.2022.102527 URL: https://www.researchgate.net/publication/358413947_Justice_in_social_housing_Towards_a_people-centred_energy_renovation_process

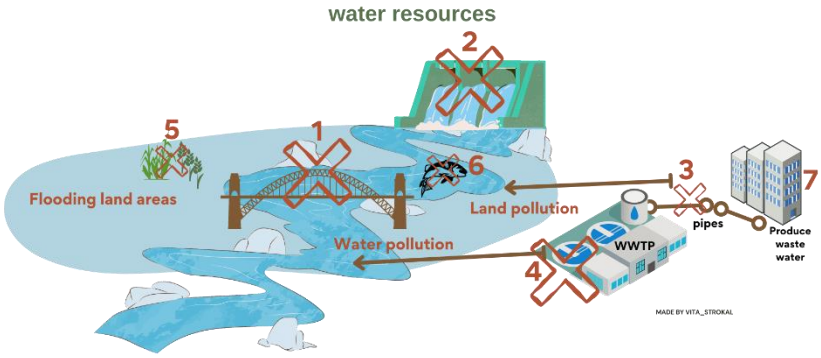
Interactive task: fill in the nessecery information

1. What are the maine type of pollution, cauces and effects?

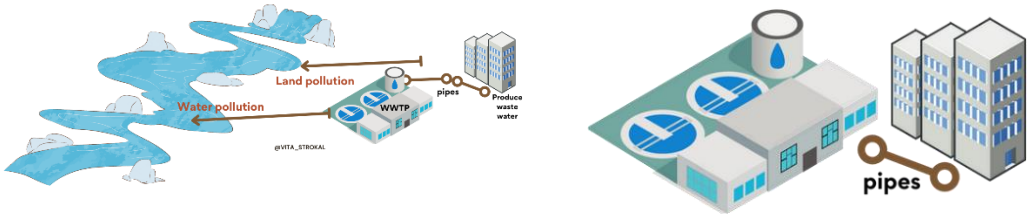


2. How can landfill sites impact on the environment? Identify consequences for water resources, natural resources, and soil resources. How can landfill increase air pollution?

3. Using a picture, try to identify the impacts (direct or indirect) on water quality. It is highly recommended to describe the main consequences of the process shown in the picture (using numbers 1-6).



4. What kind of source is in the picture? (Point or NPS). How can WWPTs influence the environment? Identify consequences for soil and water pollution

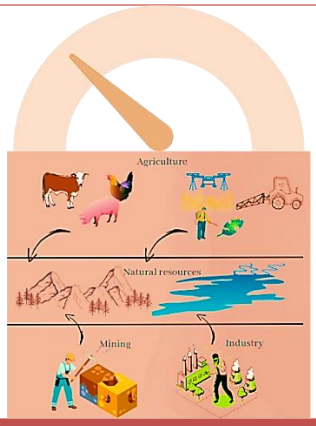


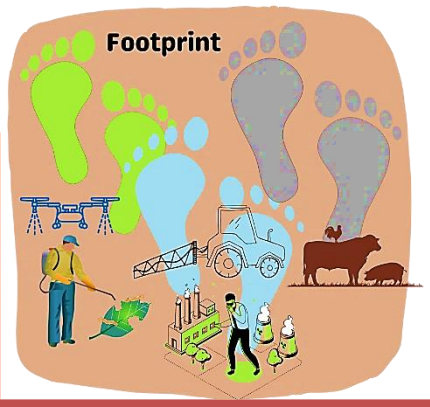
6. Human activities – ecological footprint

6.1. Urbanization

6.2. Agriculture

6.3. Military invasion





Vocabulary	
The ecological footprint	is a method that determines how dependent humans are on natural resources. It is a measure that indicates how much resources from the environment are required to support a specific way of life or business.
Carbon footprint	is a term that represents the amount of carbon dioxide (CO_2) and methane (CH_4) released into the atmosphere as a result of the human activities and choices of a person, group, or business. These human activities can produce greenhouse gases.
Green water footprint	rain water – water consumed from rainwater; it does not become runoff, is water from precipitation that is saved in the root zone of the soil, transpired or incorporated by plants. It is particularly relevant for agricultural, horticultural and forestry products
Blue water footprint	irrigation water – water consumed from surface and groundwater; is water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product or taken from one body of water and returned to another, or returned at a different time. Irrigated agriculture, industry and domestic water use can each have a blue water footprint.
Gray water footprint	pollution management – water is needed to dilute pollutants down to safe concentrations. A grey-water footprint deals with wastewater and pollution

Footprint concepr

Ecological Footprint accounting measures the *demand* on and *supply* of nature

On the demand side, the Ecological Footprint adds up all the biologically productive areas for which a population, a person, or a product competes (including plant products, livestock, and fish products, forest products, and space for urban infrastructure)

Produce:

waste, especially carbon emissions

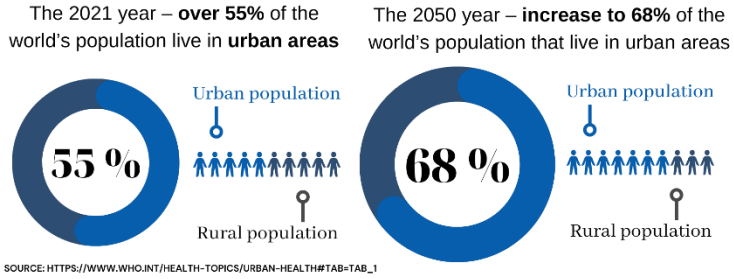
On the supply side, the Ecological Footprint presents a state or nation's biocapacity that represents the productive surface areas (including cropland, grazing land, forest land, fishing grounds, and built-up land)

Produce:

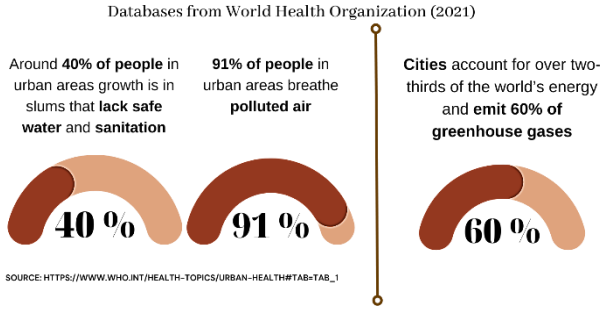
waste, especially our carbon emissions from burning fossil fuel

6.1. Urbanization

Urbanization (or urbanization) refers to the population shift from rural to urban areas, the corresponding decrease in the proportion of people living in rural areas, and the ways in which societies adapt to this change.



Urbanization is one of the leading global trends of the 21st century that has a significant impact on health. Over 55% of the world's population live in urban areas – a proportion that is expected to increase to 68% by 2050. As most future urban growth will take place in developing countries, the world today has a unique opportunity to guide urbanization and other major urban development trends in a way that protects and promotes health. This is important, not least because the health and well-being of citizens is perhaps a city's most important asset.



Around 40% of urban growth is in slums that lack safe water and sanitation, and 91% of people in urban areas breathe polluted air. When it comes to healthy diets, *urbanization increases the distance from farm to fork, driving demand for unhealthy, processed foods*. Urban dwellers are also highly vulnerable to the effects of climate change because of their dependence on fossil fuels for transport, cooking and heating. Cities account for over two thirds of the world's energy and emit 60% of greenhouse gases, and those inland may experience temperatures 3–5º C higher than surrounding rural areas because of their large expanses of concrete and limited open green spaces.

All of this puts urban dwellers' health at risk. Most the top 10 causes of death are closely related to rapid and unplanned urbanization, and poor urban design and planning. Cities face the triple health burden of infectious diseases like HIV/AIDS, tuberculosis, pneumonia, dengue and diarrhoea; noncommunicable diseases like heart disease, stroke, asthma, cancer, diabetes and depression; and violence and injuries, including road traffic injuries[71].

In 2021, the share of urban population in Ukraine remained nearly unchanged at around 69.76 percent. Still, the share reached its highest value in the observed period in 2021. A population may be defined as urban depending on the size (population or area) or population density of the village, town, or city. The urbanization rate then refers to the share of the total population who live in an urban setting. International comparisons may be inconsistent due to differing parameters for what constitutes an urban center. Over the observed period, the number of inhabitants in urban regions of Ukraine was always higher than the rural population. In general,

[71] Urban health. World Health Organization. URL: https://www.who.int/health-topics/urban-health#tab=tab_1

both urban and rural population of the country declined. Approximately 28.7 million people (69.7%) lived in urban regions of Ukraine as of January 1, 2022, while the rural population exceeded 12.4 million – 30.3%[72].

Environmental Effects of Urbanization

Urban populations interact with their environment. Urban people change their environment through their consumption of food, energy, water, and land. And in turn, the polluted urban environment affects the health and quality of life of the urban population. People who live in urban areas have very different consumption patterns than residents in rural areas. For example, urban populations consume much more food, energy, and durable goods than rural populations. Urban consumption of energy helps create heat islands that can change local weather patterns and weather downwind from the heat islands. The heat island phenomenon is created because cities radiate heat back into the atmosphere at a rate 15 percent to 30 percent less than rural areas. Many of the effects of urban areas on the environment are not necessarily linear. Bigger urban areas do not always create more environmental problems. And small urban areas can cause large problems. Much of what determines the extent of the environmental impacts (see Fig.29) is how the urban populations behave – their consumption and living patterns – not just how large they are[73].

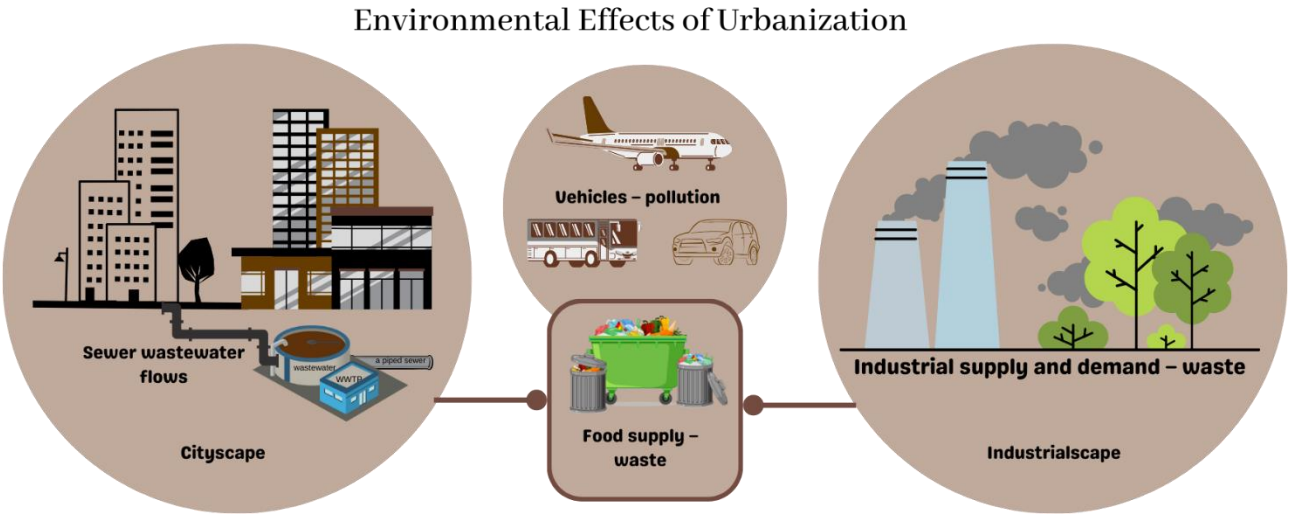


Figure 29. Environmental effects of Urbanization

Affect species interactions and urban biodiversity

Urban people change their environment through their consumption of food, energy, water, and land and in turn, the polluted urban environment affects the health and quality of life of the urban population. Cities are expanding worldwide and urbanisation is considered a global threat to biodiversity. Urban ecology has provided important insights on how urban environmental changes might affect individuals, populations, and species. Species interactions are the backbone of ecological communities and play a crucial role in population and community dynamics and in

[72] Urban and rural resident population of Ukraine from 2000 to 2022. URL: https://www.statista.com/statistics/1006580/ukraine-urban-and-rural-population/

[73]Urbanization: An Environmental Force to Be Reckoned With. URL: https://www.prb.org/resources/urbanization-an-environmental-force-to-be-reckoned-with/

the generation, maintenance and structure of biodiversity. Here, I review urban ecological studies to identify key mechanistic pathways through which urban environmental processes could alter antagonistic and mutualistic interactions among species[74].

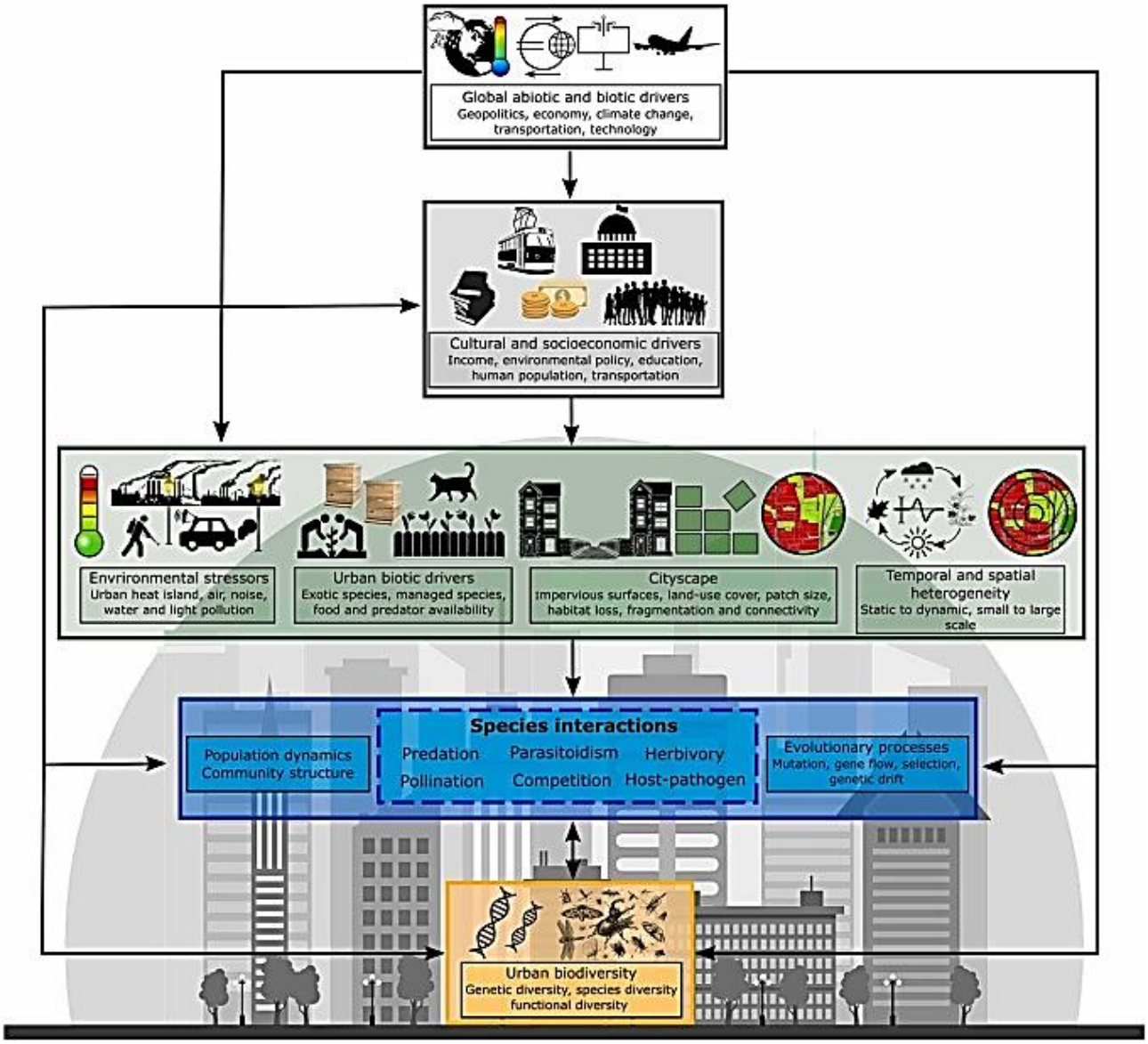


Figure 30. Hypothesised causal model of the mechanisms and processes that can affect species interactions and urban biodiversity[75].

Urban environmental biotic and abiotic drivers (*green box*) could influence population dynamics, community structure, evolutionary processes as well as species interactions (*blue box*) and urban biodiversity (*orange box*). Eco-evolutionary processes, including species interactions and urban biodiversity, could be affected directly and indirectly via global-scale abiotic and biotic conditions (*white box*), as well as cultural and socioeconomic drivers (*grey box*). Urban ecological and

[74] Theodorou, P. (2022). The effects of urbanisation on ecological interactions. Current Opinion in Insect Science, 52, 100922. DOI: https://doi.org/10.1016/j.cois.2022.100922
[75] Theodorou, P. (2022). The effects of urbanisation on ecological interactions. Current Opinion in Insect Science, 52, 100922. DOI: https://doi.org/10.1016/j.cois.2022.100922

evolutionary processes, including ecological-interactions feedback towards society in the form of ecosystem services (e.g. pollination) and disservices (e.g. herbivory).

Urbanization affects the water quality and cycle

Increased impervious cover associated with urbanization alters the natural cycling of water (see Fig.31). Changes in the shape and size of urban streams, followed by decreased water quality, are the most visible effects of increased imperviousness. Greater frequency and severity of flooding, channel erosion, and destruction of aquatic habitat commonly follow watershed urbanization. Alterations in the aquatic environment associated with these hydrological changes greatly compromise the normal functioning of our waterways.

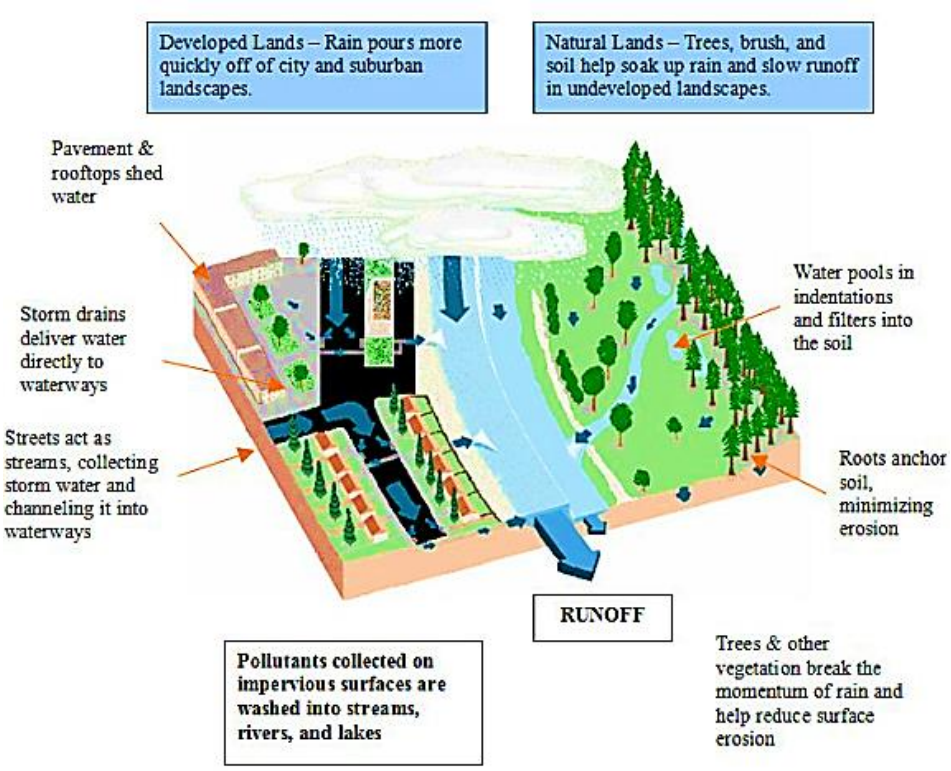


Figure 31. Urbanization affects the water cycle[76]

In fact, all insecticides occurre at higher frequencies, and usually at higher concentrations, in urban streams and in agricultural streams. Concentrations of phosphorous also are high in urban areas. Elevated concentrations of phosphorous are, in part, due to effluent from wastewater treatment plants (WWTP)[77]. Untreated sewage and contaminated urban runoff seriously pollute the surface water bodies rendering them unfit to supply fresh water to urban requirements. Littering of sewage and leachate from solid waste landfill sites seriously contaminate urban groundwater. Therefore, the impact of urbanization on water quality has become a major issue that requires urgent attention[78].

[76] How urbanization affects the water cycle?. URL: https://www.bluespringsgov.com/1051/How-Urbanization-Affects-the-Water-Cycle
[77] Barrios, A. (2000). Urbanization and water quality. American Farmland Trust, Center for Agriculture in the Environment. URL: https://fic.briteweb.com/wp-content/uploads/sites/2/2019/09/wp00-1_1.pdf
[78] Agrawal, K. K., Panda, C., & Bhuyan, M. K. (2021). Impact of Urbanization on Water Quality. In Current Advances in Mechanical Engineering: Select Proceedings of ICRAMERD 2020 (pp. 665-673). Springer Singapore. URL: https://link.springer.com/chapter/10.1007/978-981-33-4795-3_60

Urban surface runoff from storms impacts the water quality dynamics of downstream ecosystems. Urban runoff poses more potential ecological harm, while non-urban runoff poses a larger problem for drinking water treatment[79].

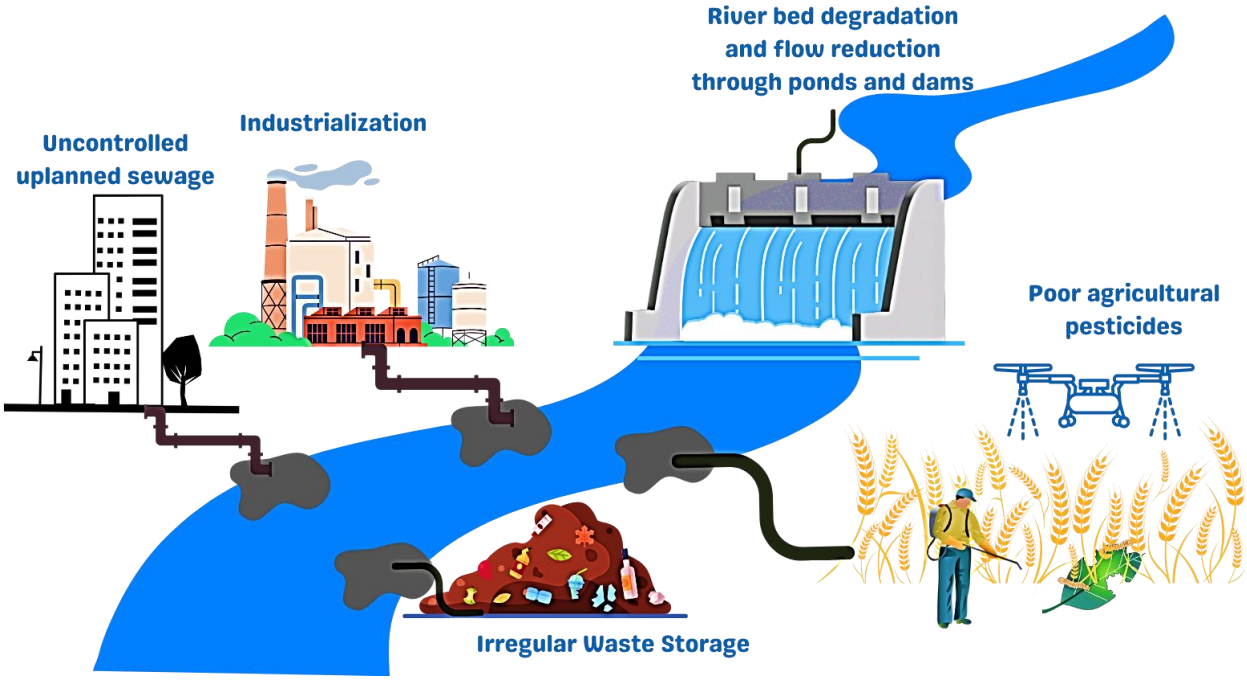
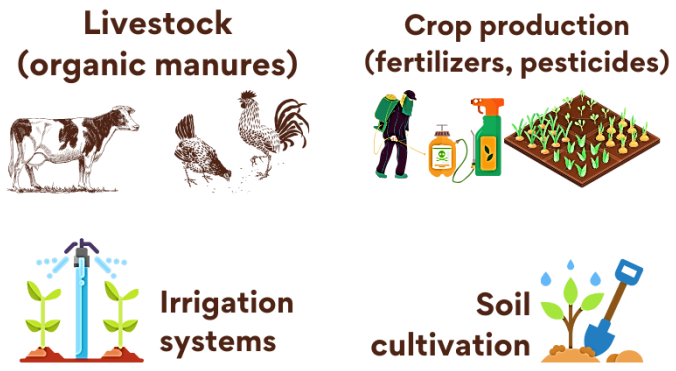


Figure 32. Pollution sources that affect water quality



6.2. Agriculture

Agricultural activities – farming is the practice of growing crops and raising livestock for consumption. Mostly in the rise of physically active human civilization, agriculture played a pivotal role, as crop production of domesticated species resulted in food surpluses that allowed people to settle in urban environments. *Agricultural activities are defined as income-producing activities or uses that are characterised by the crop cultivation, not all of which are restricted to floral, fruits and veggies, vegetation, graze, and wood; and farming or raising livestock activities or uses that are connected to livestock farming, fish farming, and often game and fish propagation*. Activities that are undertaken to convert a land area into farmland use really aren't considered to be part of a continuing operation.

[79] Water quality impacts of urban and non-urban arid-land runoff on the Rio Grande. *Science of The Total Environment*. DOI: https://www.sciencedirect.com/science/article/abs/pii/S0048969720319562

6.2.1. Types of Agriculture activities[80]

There are many multiple kinds of agricultural activities carried out all over the world.It is split into groups based on the type of crop cultivated, the size of cultivation, the severity of agriculture, the level of mechanisation, livestock combinations, and the manner in which farm produce is distributed.

1.Subsistence Farming: Land holdings are small and dispersed, and primitive tools are used to cultivate the land.Farmer poverty prevents them from using chemical fertilizer and high yielding varieties of seeds to the extent that they should in their fields.

2.Shifting Agriculture: The first step in this type of practice is the clearing of a portion of forest land, which is accomplished by cutting down forests and burning the trunks and branches of trees.Immediately following clearing of the land, crops are planted for 2 – 3 years before the land is neglected due to a decrease in the soil nutrients.The farmers then relocate to new locations, and the cycle is repeated once more.

3.Plantation Agriculture: Rubber, tea, coffee, cocoa, spices, coconut, and fruit crops such as apples, grapes, oranges, and other citrus fruits are grown as a single crop.This is also a capital-intensive industry that necessitates strong managerial abilities, specialized know, advanced industrial equipment, fertilisers, irrigation, and transportation infrastructure to be successful.Plantation agriculture is a type of agriculture that is focused on exports. The majority of the agricultural production in agriculture have a cycle time of even more than two years, making them ideal for long-term storage.

4.Intensive Farming: Farmer use of fertilisers and pesticides is widespread in regions in which irrigation has been made possible. A high yielding variety of seeds has also been introduced to their land. Through the use of machines in various farming processes, they have mechanised agriculture.

5.Mixed and Multiple Agriculture: Mixed farming refers to the practise of cultivating crops while also raising animals at the same time.The term "'Multiple farming' is the technique of growing a wide range of crops in proximity to each other in order to maximise yield.

6.2.2. Impact of livestock sector on the environment

Literature[81] shows that farms can lead to a reduction of Greenhouse gases (GHG) and ammonia (NH_3) emission in air, nitrates and antibiotics pollution in water bodies, phosphorus, antibiotics and heavy metals in the soil. In addition to the increase in animal number, significant intensification in livestock farming has also occurred, achieved by increasing animal densities and production units; using concentrated feed, pharmaceuticals, and vaccinations; improving infrastructure and feed efficiencies. Industrial-scale livestock production is the most common and

[80] Agricultural Activities. URL: https://unacademy.com/content/neet-ug/study-material/biology/agricultural-activities/

[81] Tullo, E., Finzi, A., & Guarino, M. (2019). Environmental impact of livestock farming and Precision Livestock Farming as a mitigation strategy. Science of the total environment, 650, 2751-2760. DOI: https://doi.org/10.1016/j.scitotenv.2018.10.018

widespread means of livestock production and occurs within facilities known as concentrated, or confined, animal feeding operations. The livestock sector is an important user of natural resources and has significant influence on air quality, global climate, soil quality, biodiversity and water quality, by altering the biogeochemical cycles of nitrogen, phosphorus and carbon, giving rise to environmental concerns (see Fig.33).

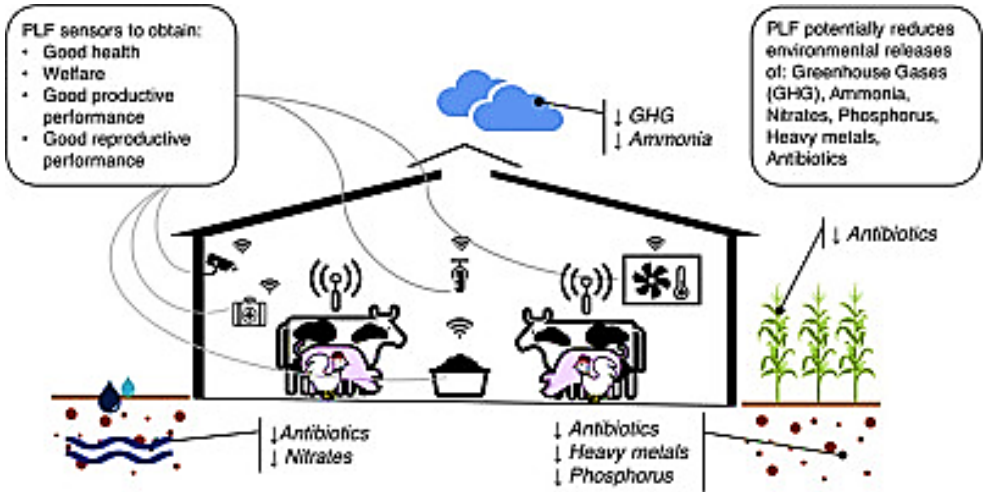


Figure 33. Environmental impact of livestock farming[82]

The animal agriculture industry is the leading cause of most environmental degradation that is currently occurring. These detrimental effects happen due to overgrazing, habitat loss, overfishing, and more. We are currently in the next mass extinction and animal agriculture is only fueling this catastrophe. Waste in the meat industry, too, is a major problem in of itself.

One pound of beef takes 2500 gallons of water, eggs 477 gallons of water, and cheese nearly 900 gallons (see Fig.35). A really terrifying fact about burning too many fossil fuels as the leading cause of climate change is they all load up the atmosphere and the greenhouse effect makes the temperatures soar at a rate that has never existed in the entire history of the earth. 82% of the world's starving children live in countries where food is fed to animals in livestock and then sold to wealthier and developed countries.

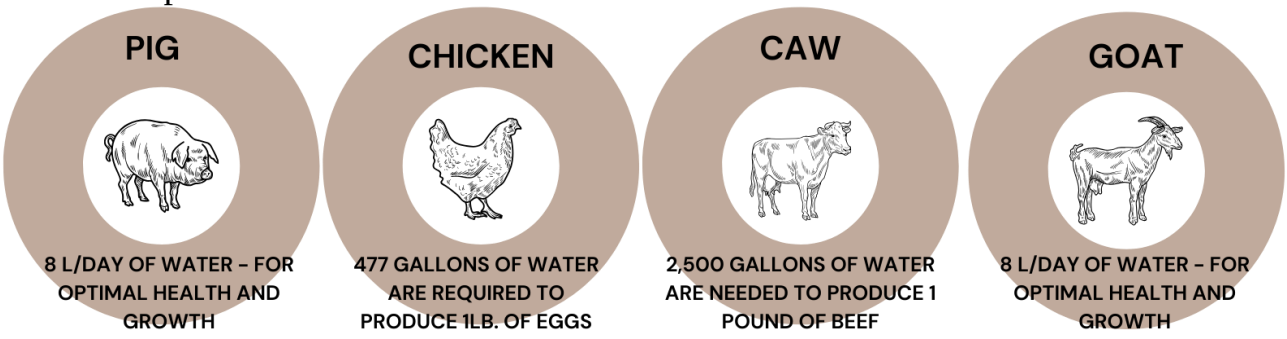


Figure 35. Water use by animals

[82] Tullo, E., Finzi, A., & Guarino, M. (2019). Environmental impact of livestock farming and Precision Livestock Farming as a mitigation strategy. Science of the total environment, 650, 2751-2760. DOI: https://doi.org/10.1016/j.scitotenv.2018.10.018

Animal agriculture produces 65% of the world's nitrous oxide emissions which has a global warming impact 296 times greater than carbon dioxide. Raising livestock for human consumption generates nearly 15% of total global greenhouse gas emissions, which is greater than all the transportation emissions combined. It also uses nearly ***70%*** of agricultural land which leads to being the major contributor to deforestation, biodiversity loss, and water pollution. Ending our meat and dairy production could pause the growth of greenhouse gas emissions for 30 years, new study suggests. All we need to do is adapt to a plant-based food system! Also, this Forbes article discusses if animal agriculture costs more in health damage than it contributes to the economy[83].

Working conditions have then to be also optimize for farmers/breeders. If production of goods such as meat, eggs or milk is attended, animal production also produce wastes, gases dust... that also be taken in consideration (see Fig.36).

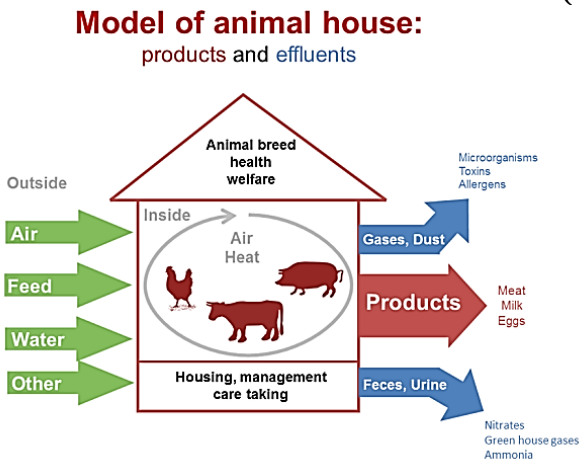


Figure 36. Model of animal house[84]

Animal manure used to be the major source of additional nutrients and crucial for maintaining soil fertility and crop yield in traditional farming systems. However, it is increasingly not recycled, wasting vital resources and damaging the environment.

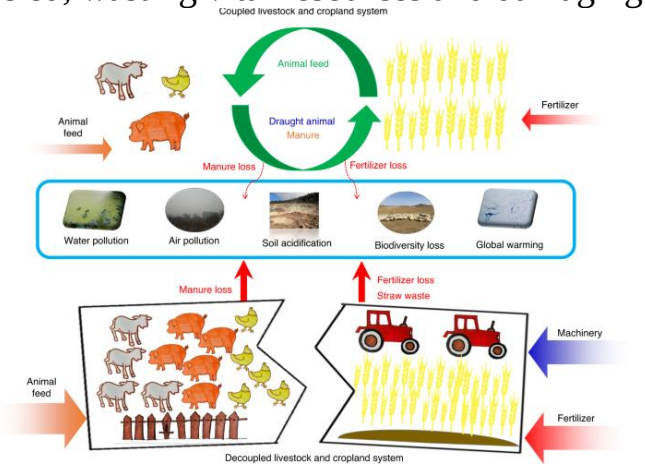


Figure 37. Livestick and crop land systems[85]

[83] It May Be Uncomfortable, But We Need to Talk About It: The Animal Agriculture Industry and Zero Waste. URL: https://www.colorado.edu/ecenter/2022/03/15/it-may-be-uncomfortable-we-need-talk-about-it-animal-agriculture-industry-and-zero-waste

[84] Which housing conditions and evaluation of environmental impacts? URL: https://tice.agrocampus-ouest.fr/pluginfile.php/59209/mod_resource/content/7/co/u223.html

[85] Jin, S., Zhang, B., Wu, B., Han, D., Hu, Y., Ren, C., ... & Chen, J. (2021). Decoupling livestock and crop production at the household level in

Livestock in Ukraine, as part of agriculture, represents a threat towards the environment and is one of the main drivers for deforestation in the world, either from grazing, fodder and feed production. The life cycle of livestock also requires large amounts of water and has a severe impact on the atmosphere of our planet. If not properly managed, livestock production could cripple the life supporting systems of our biosphere and all other living beings sharing our planet.

Ukraine is a key player in global agriculture, and how these conflicts play out will have international impacts. Ukraine has more than 41.5 million hectares (or 102.5 million acres) of agricultural land that cover 70% of the country. The country's main crops are sunflowers, corn, soybeans, wheat and barley. Globally, Ukraine ranks[86]:

- 1st in global sunflower production
- 6th in global corn production
- 6th in global barley production
- 7th in global rapeseed production
- 9th in global soybean production
- 9th in global wheat production

6.2.3. Water pollution and agriculture[87]

Agriculture is an important cause of multiple pollutants in water. With population growth and increasing food demand, more nutrients, plastics, pesticides, pathogens and antibiotics are expected to enter water systems in the 21st century. As a result, water science has been shifting from single-pollutant to multi-pollutant perspectives for large-scale water quality assessments. This perspective paper summarizes and discusses four main highlights related to water pollution and agriculture from the multi-pollutant perspective. These highlights reveal the spatial and temporal distribution and main sources of multiple pollutants in waters. Based on the highlights, a scientific agenda is proposed to prioritize solutions for sustainable agriculture (UN Sustainable Development Goal 2) and clean water (UN Sustainable Development Goals 6 and 14). This agenda points out that when formulating solutions for water pollution, it is essential to take into account multiple pollutants and their interactions beyond biogeochemistry.

Today, water quality, when influenced by multiple pollutants, remains poorly understood, especially at large scales such as national and global. In the past, water pollution issues were often related to nutrients and eutrophication. Today, it is different. With the increase in agricultural activities and technological developments, water systems experience new challenges associated with emerging pollutants such as

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China. Nature sustainability, 4(1), 48-55. URL: https://www.nature.com/articles/s41893-020-00596-0

[86] Ukraine-Russia Tensions: What it Could Mean for Agriculture. URL: https://www.agweb.com/markets/world-markets/ukraine-russia-tensions-what-it-could-mean-agriculture

[87] Mengru WANG (2023). Water pollution and agriculture: multi-pollutant perspectives. *LETTER*. DOI: 10.15302/J-FASE-2023527 URL: https://journal.hep.com.cn/fase/EN/10.15302/J-FASE-2023527

plastics, antibiotics and chemicals (Fig.38). Climate chang and unforeseen crises (e.g., COVID-19) accelerate these challenges. For example, the intensified agricultural activities are one of the main sources that release various pollutants to water systems, such as nutrients (e.g., used as fertilizers for crop production), plastics (e.g., used for crop mulching), antibiotics (e.g., used for animal disease protection), pathogens (e.g., via animal manure) and pesticides (e.g., used for crop protection). As a result, many water systems such as groundwater, rivers, lake and coastal seas are more polluted than in the past[88].

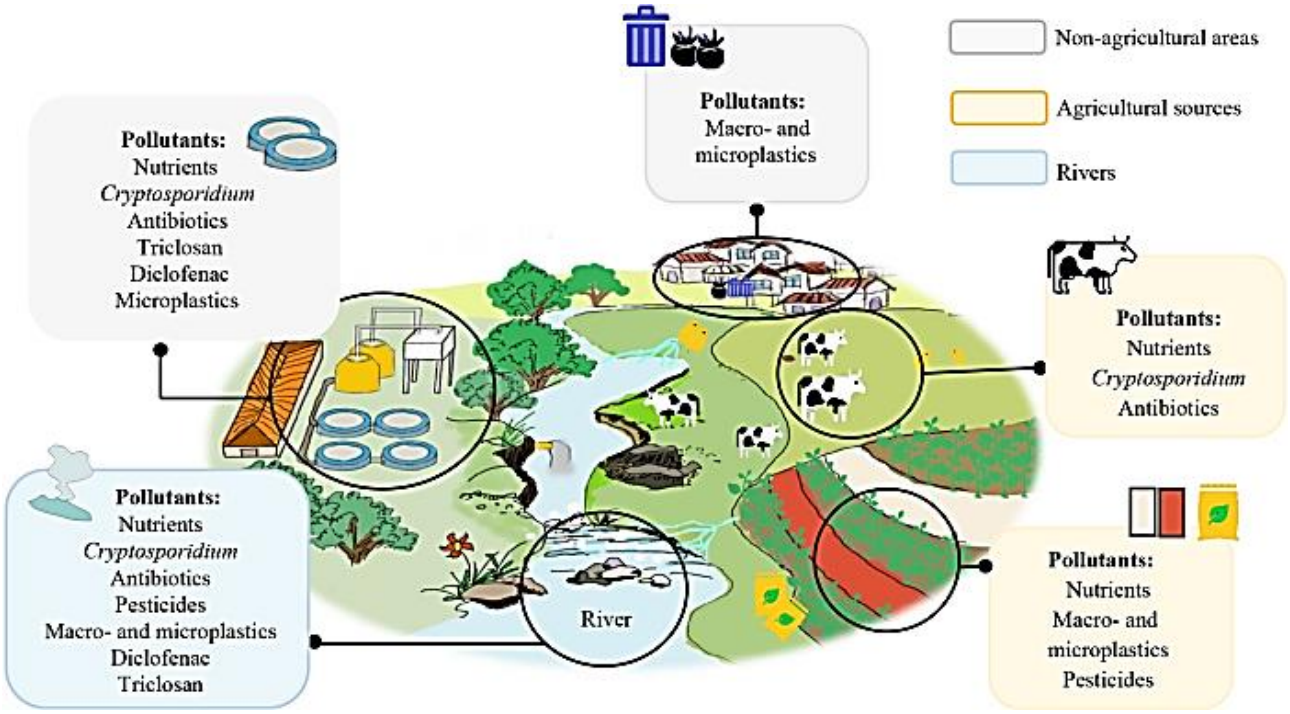

Figure 38. Concept model of multiple pollutant inputs to rivers from agricultural sources and non-agricultural areas [88].

This concept model includes pollutants for which global or regional modeling approaches exist. Tab.1 summarizes the information from conceptual modeling approaches. Agricultural sources include pollutants from crop production and livestock production (*yellow box*). Pollution sources from non-agricultural areas include pollutants from mismanaged plastic waste and sewage systems (*gray box*). The blue box indicates all pollutants from agriculture sources and non-agricultural areas enter rivers.

[88] Mengru WANG (2023). Water pollution and agriculture: multi-pollutant perspectives. *LETTER*. DOI: 10.15302/J-FASE-2023527 URL: https://journal.hep.com.cn/fase/EN/10.15302/J-FASE-2023527

6.2.4. Agricultural activities lead to eutrophication[89]

Eutrophication is defined as the moderate increase in initial amount of phosphorus, nitrogen, as well as other nutrient cycling in an aging aquatic ecosystem, such as a pond. Increases in the organic content which can be eliminated into nutrients result in natural productivity gains or fertility of an ecosystem.

Dead zones, toxic algal blooms, and fish kills are all caused by eutrophication, a process called when the environment is becoming more rich in nutrients, raising the amount of vegetation and algae growth in coastal and estuarine waters. Eutrophication is a process that has been around for thousands of years.

Agricultural practices and the application of fertilisers and pesticides both give back to the formation of nutrients. The nutrients are carried by rainwater into rivers and groundwater, which then flow into lakes and oceans when their concentrations reach dangerously high levels and the soil is no longer able to absorb them.

Agriculture is responsible for the vast majority of water pollution because of the too much use of chemical fertilizers and pesticides, which eventually leach into underground water as well as drain into freshwater bodies. Transformation in Physical and chemical properties of water as a result of agricultural activities is detrimental to the aquatic ecosystem.

In sumorize, for developing countries, agriculture is regarded as the backbone of the economic system because of its importance to the economy and its role in food production. Agriculture has been associated with increased formation of essential food crops for many decades. Dairy, fruit, forestry, poultry, beekeeping, and arbitrary farming are all part of the current farming era, among other things.Like all other parts of the economy, it is going through a period of economic liberalization, which will bring about significant changes in society, legal, structural, productive, and supply structures.Eutrophication occurs once the landscape becomes richer in nutrients than it originally was. In marine environments such as lakes, this can pose a problem due to the possibility of causing algal blooms. A common practise in farming is the use of fertilisers, which can cause runoff into nearby water bodies, increasing the amount of nutrients present.

6.3. Military invasion[90]

The natural resources of Ukraine are under risks of the Russian-Ukrainian war. This is associated largely with environmental and ecological implications covering not only the natural resources, but also human activities.

This paragraph aims to discuss and reflect on the main consequences of the Russian-Ukrainian war on the land, water, and biological resources of Ukraine (see Fig.39). **For the land resources, the main implications are:**

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[89] Agricultural Activities. URL: https://unacademy.com/content/neet-ug/study-material/biology/agricultural-activities/

[90] Вплив російської агресії на стан природних ресурсів України : монографія / В. П. Строкаль [та ін.]. - К. : Видавничий центр НУБіП України, 2023. - 222 с. URL: https://dglib.nubip.edu.ua/handle/123456789/10632

1. Economic losses of the agricultural sector in Ukraine due to the war consist of 8,73 billion dollars (considering the conversion rate at 31 October 2023). Among this amount, 6,0 billion dollars is for the losses for destroyed or damaged agricultural machineries, 2,0 billion dollars is for the stolen or lost agricultural products, 0,5 billion dollars is for the lost plantations, 0,23 billion dollars is for the lost animals and aquaculture. These losses are based on the information from the Kyiv school of Economics (the status of 24.04.2023).

2. Approximately 35% of the Ukrainian territories have been experiencing the soil destruction processes due to the war implications. For example, 130 thousand km^2 of the land is mined or damaged based on the information of January 2023. As a result, part of the agricultural land for growing crops are not suitable especially in regions (oblasts) such as Kharkiv, Mykolaiv, Kherson, Zaporizhzhia, Kyiv and Chernihiv. The mined area consists of 8 billion ha (according to the information of May 2023).

3. Within 500 days of the war, losses of the land resources due to the war implications are as follows: 929,7 billion of the Ukrainian hryvnia for littering of land (covering 16,6 billion m^2), and 12,7 billion for polluted soil (408,7 thousand m^2) according to the State Environmental Inspection of Ukraine (July 2023).

4. As a result of the damaged Kakhovka Hydropower Dam, losses of crop yields on the part of the Kherson region consist of 100 thousand ton, 31 irrigation systems are left without access to water supply in the south part of Ukraine. These irrigation systems relied heavily on the water in the Kakhovka Reservoir.

For the water resources, the main implications are:

1. Economic losses due to the damaged or destroyed water resources are 7,9 billion dollars (considering the conversion rate at 31 October 2023). Among this amount, 4 billion dollars is for the disruption of the Kakhovka Hydropower Dam, 2,3 billion dollars for the damaged treatment and sewage systems, 1,2 billion dollars for polluted waters, 0,4 billion dollars for the illegal use of water resources, 0,001 billion dollars for destroyed or damaged hydraulic systems (according to the Ministry of Ecology and Natural Resources of Ukraine, 04.07.2023).

2. According to the status of July 2023: 724 hydrotechnical systems (hydraulic structures), 160 of treatment and sewage systems (water treatment and sewage facilities), and 22 dams are destroyed, up to 90% of the irrigation system in the south of Ukraine is lost, and 67% less fishing due to damaged or destroyed hydraulic systems.

3. The disruption of the Kakhovka Hydropower Dam has resulted in the flooded areas. Water from the dammed reservoir was flushed and flooded the surrounded areas and households. As a result, a lot of pollution was released into water from untreated humna waste, products of animals etc. Around 31 water supply and drainage facilities were affected, 13 villages left without centralized water supply and 4 landfills of solid household waste became flooded. Furthermore, there is an assumption that 150 tons of machinery oil were released into the Dnipro River that can export further this pollution to the Black Sea. All these factors contribute to water pollution in the Dnipro Basin and the coastal waters of the Black Sea in Ukraine.

4. Generally, 6 million people in Ukraine do not have access or limited access to clean water (based on the status of July 2023).

For the biological resources, the main implications are:

According to the status of July 2023, 72 278 animals were damaged or destroyed (economic losses of around 50 million dollars), 149 rare Danube newts were killed by the blowing up of the Kakhovkadam, 333 species of plants and animals have threatened extinction due to blowing up of the Kakhovka dam, 25 parks and nature reserves are or have been under occupation or in the war zone, 900 dolphins died in the Black and Azov Seas because warships use sonars, 183.2 thou. ha area of burned forests and other plantations.

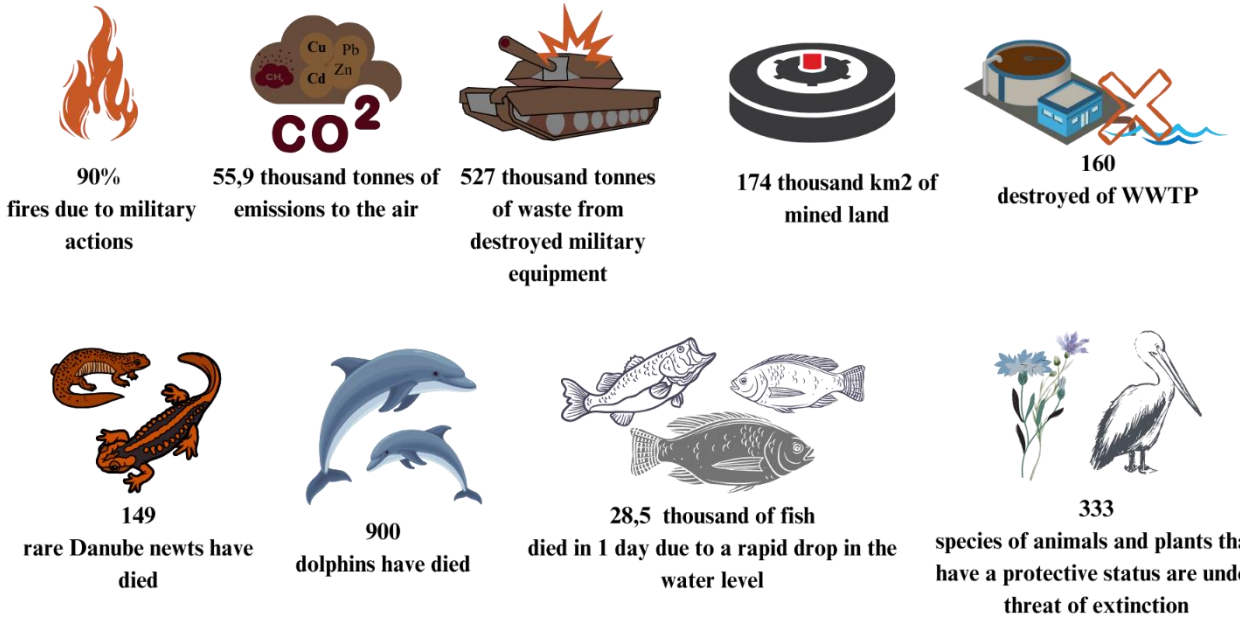


Figure 39. Generalized information on crimes of the Russian Federation against the environment of Ukraine (up to September 2023)

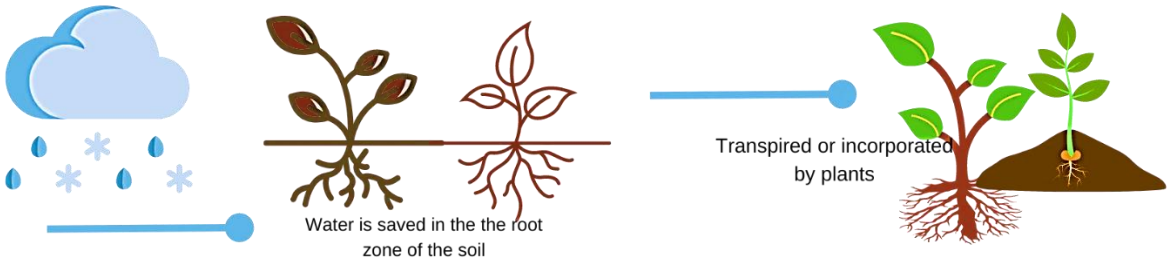
Control questions for students

1. What are the maine environmental effects of urbunization? Give some examples.
2. What are the main inteructions between carbon (ecological) footprint and urbunization? Give some examples.
3. What are the maine environmental effects of agricultural activities? Give some examples.
4. What are the main inteructions between water footprint and agricultural activities? Give some examples.
5. What is meining “Ecocide”? Discribe 10 environmental consequences of Russion-Ukrainian war in Ukraine (up to September, 2023)

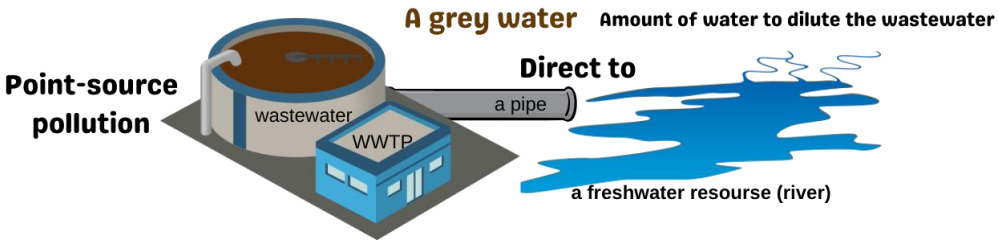
Interactive task: fill in the nessecery information

1. What type of footprint is shown in the picture? Where we can use this kind of water?

2. What type of footprint is shown in the picture? Where we can use this kind of water?



3. What type of footprint is shown in the picture? Where we can use this kind of water?



4. Using a picture, try to explore the main implications of livestock for producing greenhouse gasses, and crop production for increasing soil and water pollution.