

Methodological Handbook for Teaching the Topic

Impacts of Climate Change on Forest Ecosystems

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1. Introduction and Context

Climate change is one of the greatest challenges of the 21st century. It is understood as a persistent change in the planet's climatic patterns, largely caused by the increase in greenhouse gases originating from human activity (such as carbon dioxide, methane, and nitrous oxide). This phenomenon leads to a rise in average global temperatures, changes in precipitation patterns, and a higher frequency of extreme weather events, such as droughts, heatwaves, and forest fires.

Forest ecosystems – a balanced interaction between communities of trees, plants, animals, microorganisms, soil, and climate – play a crucial role in climate regulation, biodiversity protection, and the conservation of soil and water. In Spain, forests cover approximately 55% of the national territory, making them a fundamental element for environmental sustainability and quality of life. In Portugal, forest cover 36% of the national territory (florestas.pt).

However, the impacts of climate change on forests are already evident: rising temperatures, longer periods of drought, an increase in forest fires, the emergence of new pests and diseases, and the gradual disappearance of species adapted to temperate or humid climates. These processes disrupt ecological balance, reduce the forests' capacity to sequester carbon, and threaten their role as a refuge for biodiversity.

This methodological handbook is the result of collaboration between educational institutions from Spain, the Czech Republic, and Portugal within the Erasmus+ programme. Its goal is to provide teachers with a clear, practical, and flexible tool to facilitate teaching about the impact of climate change on forests. It is designed for use in both formal and non-formal educational contexts and can be integrated into subjects such as biology, geography, natural sciences, or environmental education.

It also aims to motivate students to better understand the environmental issues around us, to act locally with a global perspective, and to develop critical awareness and engagement for sustainability, fostering responsible attitudes towards climate change.

2. Educational Objectives

Upon completing the activities outlined in this handbook, students should achieve the following educational objectives, formulated according to the SMART model (Specific, Measurable, Achievable, Relevant, and Time-bound):

1.1. Understand the fundamental concepts of climate change and its relationship to forest ecosystems, identifying at least three main causes and three main consequences in their local environment.



1.2. Investigate and document the impacts of climate change on a local forest area through field observations and analysis of real-world data and create a group report or presentation.
1.3. Recognize plant and animal species affected by climate change using digital identification tools (iNaturalist, Pl@ntNet, eBird, BirdNET, Biodiversity4all) during excursions or practical activities.
1.4. Propose adaptation, mitigation, or regeneration measures applicable in the local context, formulating at least two realistic and sustainable solutions.
1.5. Collaborate with other educational centres or students from different regions or countries, comparing problems and solutions.
1.6. Create a final product (multimedia presentation, poster, or short video) that summarizes the project findings.
1.7. Develop a critical, participatory, and responsible attitude towards climate change, expressing personal and collective commitments to the protection of forest ecosystems.

3. Content and Topics

This handbook covers the following thematic blocks, which serve as the foundation for teaching and learning about the topic "Impacts of Climate Change on Forest Ecosystems":

Thematic Block	Key Content
1. Forest Ecosystems	Forest types (Mediterranean, Atlantic, mountain) and their ecosystem services.
2. Climate Change	Causes, evidence, future projections, and regional impacts.
3. Impacts on Forests	Fires, droughts, pests, biodiversity loss, and invasive species, soil desertification and depopulation.
4. Solutions	Adaptation (reforestation, species change), mitigation (carbon sequestration), and natural regeneration.
5. Youth Engagement and Climate Education	Activating students, developing competencies, transferring learning from theory to practice.



3.1. Forest Ecosystems – Types and Characteristics

Country / Region	Dominant Forest Types and Characteristics	Key Species and Notes
Spain – Mediterranean	Hard-leaved evergreen forests and scrublands (*matorral*), adapted to summer drought and periodic fires.	Holm oak (*Quercus ilex*), cork oak (*Q. suber*), Aleppo pine (*Pinus halepensis*).
Spain – Atlantic region	Humid deciduous and mixed forests with higher biodiversity.	Pedunculate oak (*Q. robur*), European beech (*Fagus sylvatica*), sweet chestnut (*Castanea sativa*).
Portugal – North	Atlantic humid forests, often replaced by plantations of fast-growing tree species.	Pedunculate oak (*Q. robur*), maritime pine (*Pinus pinaster*), eucalyptus (*Eucalyptus globulus*) – extensive commercial plantations.
Portugal – South (Alentejo, Algarve)	Mediterranean cork oak and holm oak - woodlands (*montado*) – a unique agroforestry system with high biological and cultural value.	Cork oak (*Quercus suber*), Holm oak (*Quercus rotundifolia e Quercus ilex)* – Portugal is the world leader in cork production.
Czech Republic	Predominance of coniferous monocultures (spruce, pine) planted in the 19th–20th centuries for economic gain. Natural mixed forests are now a minority.	Norway spruce (*Picea abies*) – the dominant species, currently dying off massively. The natural composition would consist of oak forests, beech forests, and fir-beech forests depending on altitude.

Ecosystem Services:

For all three countries, the following fundamental services apply: climate regulation (carbon sequestration), soil protection, water retention and filtration, biodiversity refuge, recreational and economic functions.

- In the Czech Republic, the service of **water retention in the landscape** is acutely discussed in the current crisis.
- In Portugal, the **economic and cultural function** of woodlands (*montado*) is key, and, in the south, the main discussed problem is soil desertification.
- In Spain, the **anti-erosion and climate-regulating function** of forests in dry areas is crucial.



3.2. Climate Change

Climate change is a global phenomenon consisting of long-term alterations in the Earth's climatic patterns, primarily caused by human activity (mainly the burning of fossil fuels and deforestation). It encompasses an increase in the planet's average temperature, changes in precipitation distribution, and a greater frequency and intensity of extreme weather events [IPCC AR6].

Evidence of Climate Change – Regional Comparison

Region	Main Manifestations and Data Sources
Spain	Faster warming than the European average [1, AEMET]. Significant precipitation decline in the south and more intense heatwaves. Rapidly advancing desertification, especially in southeastern regions [2, MITECO/PNACC].
Portugal	Significant warming, particularly in inland areas [3, IPMA]. Climate change in Alentejo manifests itself through extremely hot and dry summers, with record maximum temperatures (47.3°C in Amareleja) and longer heat waves, according to the Portuguese Institute of the Sea and the Atmosphere. There has been an increase in aridity, severe drought, health impacts. Increased risk of coastal erosion and salinization of river deltas [4, APA].
Czech Republic	Warming of over 2°C since the 1960s, significantly above the global average [5, CHMI]. Change in precipitation patterns – a greater proportion of torrential rains and lengthening periods of spring and autumn drought [6, CzechGlobe/Intersucho]. Significant reduction and shorter duration of snow cover in lowlands and mountainous areas [7, CHMI].

Future Projections and Key Risks

- **Spain:** Projected temperature increase of 2–4°C by the end of the century. High and intensifying risk of desertification in the southeast of the peninsula, threatening agriculture and natural ecosystems [2].
- **Portugal:** A similar warming trend is expected. Increased risk of widespread and intense forest fires across the country, with extreme droughts in the south, endangering the unique cork oak and holm oak (*montado*) ecosystems and water resources [4, 8, ICNF].
- **Czech Republic:** Continued warming and increased weather variability with more frequent extremes [5]. The main risk is the deepening of agricultural and hydrological drought, impacting forests, agriculture, and groundwater supplies [9, CzechGlobe]. Furthermore, destabilisation of extensive coniferous monocultures [10, VÚLHM].



3.3. Impacts on Forests

3.3.1. Impacts of Climate Change on Forests – Comparative Table

Threat	Spain	Portugal	Czech Republic
Forest Fires	A primary and annual threat. Catastrophic high-intensity fires (Galicia, Catalonia) [EFI, 2022].	An extreme problem of national importance. Frequent large-scale, fast-spreading, and deadly fires (e.g., 2017 in Pedrógão Grande – 66 fatalities) [8, ICNF]. Eucalyptus and Pinus plantations burn particularly intensely.	Historically a lesser problem, but the risk is increasing rapidly with rising temperatures and drought. An example is the large-scale fire in Bohemian Switzerland National Park (2022) – data from the Fire and Rescue Service of the Czech Republic and CHMI [11].
Drought and Water Stress	Critical in the south and interior. Threatens Mediterranean forests at the limit of their resilience [MITECO, 2021].	Severe across the territory, with critical impacts in the south. Direct threat to long-lived cork oaks [4, APA] and holm oaks too.	The central cause of the forest crisis. Prolonged growing-season droughts especially weaken shallow-rooted spruce monocultures – data from the Intersucho.cz portal [9].
Pests and Diseases	Expansion of the pine processionary moth (*Thaumetopoea pityocampa*) to higher altitudes, bark beetle infestations [MITECO].	Same pests as in Spain. Additionally, diseases of cork and holm oaks (e.g., *Phytophthora*), which spread during wetter periods [ICNF].	Spruce bark beetle (*Ips typographus*) calamity – the largest ecological and economic disaster in modern forestry. Massive dieback of spruce stands [10, VÚLHM].
Loss of Biodiversity	Threat to endemics dependent on specific microclimates (Spanish fir *Abies pinsapo*, the plant *Plantago nivalis*).	Threat to the entire unique *montado* ecosystem and its associated high biodiversity (Iberian lynx, birds of prey) [4].	Decline of species dependent on cooler, stable mountain spruce forests. Change in species composition shifting towards thermophilic and generalist species [12, AOPK ČR].
Invasive Species	Expansion of the tree of heaven (*Ailanthus altissima*) and red swamp crayfish (*Procambarus clarkii*)	Aggressive spread of exotic plants (e.g., Australian acacias) on burnt and disturbed areas [ICNF].	Dominance of invasive woody species like black locust (*Robinia pseudoacacia*) and eastern white pine (*Pinus*

Threat	Spain	Portugal	Czech Republic
	[Spanish Catalogue of Invasive Alien Species].		*strobus*). Risk of southern invasive species spreading is increasing [12, AOPK ČR].



3.3.2. Impacts on Nature and Wildlife

- **Spain & Portugal:** Direct threat to iconic species bound to specific, often already marginalised habitats: the Iberian lynx (*Lynx pardinus*) in Mediterranean scrubland, the great bustard (*Otis tarda*) in steppe areas, some eagles, amphibians, freshwater fish and game species are in danger too, and waterfowl in wetlands (Doñana). Habitat loss is primarily caused by fires, desertification, water depletion and intensive agriculture.

  Impact on birdlife, specifically:
  In this context, the Iberian Peninsula is the most affected region in Europe.
  Rainfall will be lower, more irregular, concentrated and out of time, the climate will be prone to extreme situations such as abnormally high temperatures, intense rainfall and hail; winter will be less clear, with less rain and fewer hours of cold.
  In this scenario, the thermoregulatory incapacity of the frequent destruction of nests and the frequent exceeding of critical temperature and humidity thresholds.
  Critical temperature and humidity thresholds for brooding, there will be increasing the cycle of plants and insects, causing incalculable damage to the juveniles.
  Aggravated facts that have emerged over the last years:
  - Greater difficulties in sheltering the nest, which is more exposed to heavy rains and flooding.
  - More poorly laid, destroyed and late eggs, infertile or fat eggs, chicks that don't hatch.
  - Less fit chicks, less access to food, further away from water, more exposed to unseasonal rains.
  - Exposed to untimely rains and predators.
  - More late birds and less sexually fit for the next breeding season.
  - Adults subject to greater pressure from predators, greater effort in the search for food and water.
  - Adults abandoning spaces, in more isolated clusters and with less genetic variability.
- **Czech Republic:** The impacts are more indirect and structural, caused by the large-scale disintegration of the forest environment:
  1. Massive loss of habitat for species dependent on a closed forest canopy (e.g., certain bird species, fungi, epiphytic lichens) due to clear-cuts following bark beetle infestations.
  2. Changes in microclimate on large clear-cut areas (higher temperatures, lower humidity, greater fluctuations) create inhospitable conditions for forest species.
  3. Landscape fragmentation can hinder the migration of animals between remaining forest tracts.
  4. Drying out of mountain springs and peat bogs threatens specialised species (e.g., the whorl snail *Vertigo angustior*, certain species of mosses and molluscs).



3.4. Solutions and Action Strategies – Common Vision, Regional Emphases

3.4.1. Adaptation

- **Common goal for all three countries:** Transition to species-rich, age-diverse, and spatially varied forests which, due to their complexity, are naturally more resilient to disturbances.
- **Spain/Portugal:** Active selection and promotion of drought-tolerant and fire-resistant native species. Restoration habitats and some of traditional management systems with better practises and with more density and diversity natural systems (holm and cork oak woodlands). Crucial emphasis on prevention, planning, and effective fire management (creating firebreaks, controlled burning).
- **Czech Republic:** Fundamental transformation of spruce monocultures into mixed and deciduous forests with a higher proportion of oak, beech, fir, and other site-appropriate tree species. Promotion of natural regeneration where possible. Creation of ecological corridors. Revision of the forest law to favour the enhancement of resilience. It is also important to maintain a diverse age structure of tree species at the site.

3.4.2. Mitigation

- **Common:** Preservation and enhancement of forests' function as natural carbon sinks (a healthy, growing, and resilient forest is a more effective carbon sink than a collapsing monoculture or one that has been burnt).
- Support for sustainable forestry and agroforestry practices that increase carbon sequestration.

3.4.3. Natural Regeneration and Building Resilience

- **Key principle for all:** Reducing additional stress factors (overgrazing, unsuitable logging techniques, soil compaction), supporting natural recovery processes (succession), and applying principles of adaptive management that is flexible and responds to changing conditions.
- **Specific emphasis:** In the Czech Republic, promoting natural regeneration (beech, oak, fir) is a crucial tool for recovery after the bark beetle calamity and is often ecologically and economically more advantageous than extensive planting. To retain water in the landscape and return nutrients to nature, it is also important to leave **deadwood** in the forest; during the summer period, it can serve as a water reservoir for various animals. In the Iberian Peninsula, it is necessary to comprehensively address the relationship between traditional grazing, fire regimes, and the forest's ability to regenerate.
- A **good practice** is to protect small trees from damage caused by domestic animals. These should be in sufficient numbers to properly aid regeneration through seed dispersal.



- Intensive agriculture over large areas is incompatible with natural regeneration and reduces the resilience of system

3.5. Youth Engagement and Climate Education

This thematic block goes beyond mere knowledge transfer. Its goal is to activate students, develop their competencies for active citizenship, and transfer learning from theory into practice. Climate education in the 21st century must be participatory, action-oriented, and hopeful. This section of the handbook is built upon the following pillars:

- **Citizen Science:** Engaging students in real data collection (phenological observations, bird counts, drought monitoring) using applications like iNaturalist, eBird, or BioLog. It allows them to become part of the real scientific process and contribute to understanding global changes, and promote participation in scientific research projects; Participation in afforestation campaigns or projects.
- **Project-Based and Problem-Oriented Learning (PBL):** Students work on specific local challenges (e.g., "How can we increase water retention around the school?"). They go through the entire cycle from problem analysis, through designing a solution, to presenting it to local authorities or the community.
- **Development of Critical Literacy and Media Education:** The ability to recognise climate misinformation, critically work with various sources (from scientific articles to social media), and effectively communicate environmental topics.
- **Collaboration and Intergenerational Dialogue:** Fostering teamwork, organising debates with experts, local politicians, or seniors about landscape change, sharing ideas within international school partnerships.
- **Strengthening Psychological Resilience ("Climate Resilience"):** Open discussion about climate emotions (eco-anxiety, helplessness) and overcoming them through concrete, meaningful, and collective actions. Emphasis is placed on **"active hope"**.

The outcome of this block should be not only an understanding of the problems but also the students' personal and collective conviction that their voice and actions matter. The handbook in the following chapters (particularly in sections 5 and 8) offers specific tools and activities on how to achieve these goals.

4. Methodological Guidelines for Teachers

This section offers practical guidelines for teachers, including classroom activities, practical exercises, worksheets, suggestions for excursions, case studies, and methodological strategies. Its aim is to facilitate the development of skills related to observing, analysing, and understanding the impacts of climate change on forest ecosystems.

4.1. Classroom Activities – Ideas and Resources by Country

The following activities are designed to activate prior knowledge, motivate students, and introduce them to the topic. They are structured to utilise the specific local context and available resources.

Activity / Objective	Proposal and Resources for Spain	Proposal and Resources for Portugal	Proposal and Resources for the Czech Republic
Brainstorming / Introduction Activating knowledge about local forests and climate.	**Questions:** "What main types of forests do we have in our region? What extreme events (fires, droughts) have we experienced?" **Maps:** MITECO - Map of Forest Types.	**Questions:** "What is a forest and how would you describe it?" "What is 'montado'? Why are fires in Portugal so devastating, especially in the North and Center? How has summer changed over the last 20 /30 years?" **Research:** Official reports and interview with grandparents. **Images:** Photos of holm and cork oaks and burnt areas.	**Questions:** "Why are there suddenly clear-cuts all around us? What is the 'bark beetle calamity'? Do you feel winters are milder?" **Local example:** Discussion about the state of forests near the school (Bohemian Switzerland, Krkonoše, Šumava, Beskydy...).
Image and Report Analysis Working with current evidence of change.	**Materials:** Satellite images of snow retreat in Sierra Nevada (Google Earth Timelapse). AEMET reports on record heatwaves. Articles about fires in the Valencia region.	**Materials:** Before/after photos of a devastating fire (Pedrógão Grande, 2017). IPMA reports on lack of rainfall in Alentejo. **Sources:** ICNF	**Materials:** Satellite or aerial photos of the bark beetle calamity extent in Šumava (Bohemian Switzerland). Articles about the impacts of the fire in Bohemian

Activity / Objective	Proposal and Resources for Spain	Proposal and Resources for Portugal	Proposal and Resources for the Czech Republic
	Sources: AEMET, MITECO, newspapers (El País - Climate section).	(annual fire reports), IPMA (climate bulletins), APA.	Switzerland National Park (2022). **Sources:** Portál Intersucho.cz (drought maps), Lesní svět (calamity maps), national park press releases.
Structured Debate Developing critical thinking and argumentation.	**Topic:** "Is the extraction of groundwater for strawberry farming in Doñana sustainable in times of climate change?" **Roles:** farmer, nature conservationist, local resident, tourist.	**Topic1:** "Should eucalyptus and pinus plantations in northern Portugal be banned due to fire risk?" **Topic 2**: "What adaptations should we promote in the "montado" to make it more biodiverse and resilient? **Roles:** paper mill owner, firefighter, biologist, village mayor, scientists.	



4.2. Practical Activities – Ideas for School Projects and Fieldwork

Activity / Skill	Proposal for Spain	Proposal for Portugal	Proposal for the Czech Republic
Ecosystem Model (3D model, mural, diorama)	**Theme:** Mediterranean forest (cork oak, holm oak) affected by drought and fire. **Elements:** Dry soil, withered leaves, model of fire, pioneer plants.	**Theme:** Montado system (cork and holm oak, pasture) and the threat of desertification. **Elements:** Tree with stripped bark, arid soil, flock of sheep.	**Theme:** Transformation of a spruce monoculture into a species-rich forest after bark beetle calamity. **Elements:** Dry standing spruce trees, clear-cut area, birch and rowan colonisers, beech saplings.
Map of Affected Areas/Species (Work with maps, GIS)	**Task:** Mark on a map of Spain the areas with the highest fire risk (Galicia, Catalonia) and desertification (Almería). **Tool:** Google My Maps, MITECO layers.	**Task:** Create a map of Portugal with main fire areas (ICNF data) and cork cultivation areas. **Tool:** ICNF – interactive fire maps.	**Task:** Mark on a map of the Czech Republic the areas with the highest intensity of bark beetle calamity (VÚLHM data) and hydrological drought (Intersucho.cz). **Tool:** Lesní svět, Intersucho.cz – map export.
Field/School Measurements (Simple scientific monitoring)	**Activity:** Comparing temperature and humidity in the shade of a tree vs. on a dry patch on school grounds. **Extension:** Measuring during a heatwave.	**Activity:** Monitoring rainfall with a rain gauge and comparing it with IPMA long-term averages. Observing the drying of a local stream.	**Activity:** Measuring temperature and humidity in a forest vs. on a clear-cut area (e.g., during an excursion). Monitoring water level in a local stream or pond.
Forest Diary / Phenological Calendar (Documenting long-term changes)	**Focus:** Recording the flowering date of typical Mediterranean plants (e.g., rosemary) and the arrival of migratory birds. Seeking connections with temperatures.	**Focus:** Documenting the state of a cork and holm oak (if nearby) – foliage, fruits. Recording the first and last fires of the season based on reports.	**Focus:** Keeping records on the state of a selected forest stand (photographs of crown health, presence of bark beetle wood). Observing and recording phenological phases of native tree species (birch budding, spruce yellowing).

Activity / Skill	Proposal for Spain	Proposal for Portugal	Proposal for the Czech Republic
Bird Migration Monitoring (Citizen science, working with databases)	**Activity:** Participation in the "Spring Alive" project (BirdLife), monitoring the arrival of swallows or storks and comparing with historical data. **Tool:** eBird, local birdwatching groups.	**Activity:** Monitoring bird migration across the Strait of Gibraltar (collaboration with Spanish schools). Observing changes in wintering bird populations in the Tagus River estuary. **Tool:** eBird, SPEA (BirdLife Portugal).	**Activity:** Long-term school project at the "Ptačí park Mnišské louky" (Bird Park) or in the school vicinity: 1. Regular counts using the eBird or BioLog app (e.g., once a month). 2. Focus on indicator species: first arrival of songbirds (cuckoo, swallow), timing of departure, changes in numbers of wintering species. 3. Data analysis: Comparing own records with historical data from the birds.cz portal and seeking connections with temperatures (CHMI data). **Output:** Graph of selected species occurrence over time, report on observed trends.



4.3. Suggestions for Technical Visits

Excursions allow students to connect theory and practice through direct observation of the impacts of climate change on various natural ecosystems. The proposals below cover key environmental types in each of the partner countries.

Country	Location Name and Area	Thematic Focus of the Excursion	Suggested Activities and Practical Information
Spain	**Doñana (National Park)** (Huelva, Sevilla, Cádiz)	**Impact on wetlands and water systems:** Declining groundwater levels, long-term drought, threat to dependent species.	Guided tour with a park ranger, observation of waterfowl, analysis of historical and current maps of lagoon extent. **Transport/Organization:** Advance group booking is required.
Spain	**Sierra Nevada (National Park)** (Granada, Almería)	**Impact on high-mountain ecosystems:** Retreat of snow cover, changes in alpine vegetation, monitoring of changes.	Interpretive trail in the Hoya de la Mora area, collection and identification of alpine species, discussion on water as a key resource. **Suitable Period:** June-September (accessibility of high-mountain areas).
Portugal	**Serra da Estrela (Natural Park)** (Central Portugal)	**Impact on Atlantic/mountain ecosystems:** Changes in water regime, consequences of fires, vegetation adaptation.	Hike to glacial valleys and the Poço do Inferno waterfalls, documentation of vegetation belts, analysis of fire management. **Data Source:** ICNF – park administration.
Portugal	**Alentejo Region** (e.g., around Évora)	**Impact on agroforestry systems with a different management** "Montado do Freixo do Meio" - a private protected area. **How to restore semi-arid soils:** Effect of a different management to reverse the desertification processes. Visit to the Centre for agroecology and regeneration in the semi-arid region (Mértola)	Visit to a traditional cork farm, observation of stress symptoms in trees (thin canopies, drying branches). **Connection:** Economic and cultural importance of cork.

Country	Location Name and Area	Thematic Focus of the Excursion	Suggested Activities and Practical Information
Czech Republic	**Bohemian Switzerland National Park** (area around Hřensko, Děčín)	**Impact of fires and drought on sandstone ecosystems:** Extent and causes of the 2022 fire, vegetation recovery, microclimate change.	**Proposed Route:** Interpretation at an informational panel about the fire (e.g., near Jetřichovice), observation of succession on burnt areas, comparison with a healthy forest. **Transport:** Easy access from Děčín (bus, train). **Key Question:** How does a forest recover after such an intense disturbance?
Czech Republic	**Mnišské Louky Bird Park** (near Heřmanice village, approx. 15 km from Děčín)	**Adaptation measures and water regime in the landscape:** Artificial wetland restoration as an adaptation tool, water retention, biodiversity support.	Bird and amphibian observation, inspection of ponds and depressions, discussion on how such measures help manage weather extremes (drought/floods). **Organizer:** Czech Society for Ornithology – possibility to arrange a guided tour with an expert.
Czech Republic (Alternative)	**Labské Pískovce Protected Landscape Area** (area around Děčín)	**Impact of drought and heat on forest stands in lower and middle altitudes:** Health status of spruce and pine, spread of bark beetle.	Field survey of forest stands, measurement of temperature and humidity at different sites (south/north-facing slope), identification of infested trees. **Link:** Direct connection to the local landscape.



4.4. Regional and International Comparison: Spain vs. Portugal vs. Czech Republic

Objective: To analyze how climate change affects forest ecosystems in different ways across various European regions, identifying similarities and differences in impacts, affected species, and adaptation strategies.

Activity – Comparative Study of Three Ecosystems:

Students, working in groups, will investigate one assigned ecosystem using provided resources and case studies.

1. Spain (Andalusia) – High-Mountain/Mediterranean Ecosystem:
    - Location: Sierra Nevada (National Park) or Doñana (National Park).
    - Key Topics: Snow cover retreat, desertification, water stress, threat to endemic species.
    - Resources: MITECO (Ministry for Ecological Transition), Observatorio de Cambio Global de Sierra Nevada.
2. Portugal – Atlantic/Agroforestry Ecosystem:
    - Location: Serra da Estrela (Natural Park) or the Alentejo region (holm and cork oaks and others Mediterranean trees).
    - Key Topics: Increase in wildfires, impact of drought on *montado* changes in hydrology, reverse the impact of fires, droughts in these areas; Good practises.
    - Resources: ICNF (Institute for Nature Conservation and Forests – wildfire data), APA (Portuguese Environment Agency – drought), IPMA (Portuguese of the Sea and the Atmosphere), Project Adapt for Change and "+Solo, +Vida" (Association for the defence of Mértola's heritage).
3. Czech Republic – Central European Temperate Ecosystem:
    - Location: Bohemian Switzerland National Park (fire impact) and Šumava/Beskydy (bark beetle calamity).
    - Key Topics: Fires in a new context, bark beetle calamity and monoculture collapse, forest restoration approaches.
    - Resources: Administration of Bohemian Switzerland NP (fire reports), VÚLHM (Forestry and Game Management Research Institute) – Report on the State of Forests, Intersucho.cz portal.

Output and Assessment: Students will create a comparative poster or presentation that visualises the main differences and common challenges. Assessment will focus on the ability to work with data, scientific accuracy, and the quality of argumentation when comparing regions.



4.5. Interactive Methods and Digital Tools

This section provides an overview of tools for modern and engaging teaching. The tools have been selected with consideration for their availability and usefulness in the context of each country.

Category / Goal	Proposal and Tools for Spain	Proposal and Tools for Portugal	Proposal and Tools for the Czech Republic
A. Online Simulations Understanding complex ecological dynamics.	**Tools:** FireSim, Canopy Virtual Forest, BBC Climate Challenge. **Activity:** Simulating fire spread under different conditions (wind, drought).	**Tools:** Same as for Spain (FireSim is universal). **Activity:** Simulating fire management in a landscape with eucalyptus or pinus plantations.	**Tools:** Canopy Virtual Forest (forest growth), Global Forest Watch (monitoring cover changes). **Activity:** Simulating the growth of a mixed forest vs. a monoculture under drought conditions.
B. Mobile Apps for the Field and other techologies (like install and analyse camera traps) or use a telescope for observing biodiversity and data collection.	**Tools:** iNaturalist, PlantNet, eBird, AEMET Escolar (local data). **Activity:** Identifying Mediterranean species and analyzing their climate tolerance.	**Tools:** iNaturalist, PlantNet, eBird. **Activity:** Documenting species in the *montado* system and on burnt areas.	**Tools:** iNaturalist/BioLog (official Czech database), PlantNet, eBird, Lesní svět (bark beetle), Intersucho.cz (mobile version). **Activity:** See new activity 5.2 - Bird migration monitoring.
C. Creative Task: Video/Podcast Creative communication of problems.	**Topics:** Decline of the Spanish fires in Valencia, Doñana and water. **Tools:** Canva, CapCut, Audacity.	**Topics:** Pedrógão big fire, cork oak and drought, birds of the Tagus estuary, steppe cereal birds or the forest-gardens planted in Mértola **Tools:** Same.	**Topics:** The story of one spruce tree (from monoculture to clear-cut), wetland restoration at Mnišské Louky, one year after the fire in Bohemian Switzerland. **Tools:** Canva, CapCut, Audacity. Source material: Czech Television Archive (documentaries "Bark Beetle", "Fire in Bohemian Switzerland").



4.6. Reflection and Evaluation Activities

A. Collaborative Synthesis
Objective: To integrate acquired knowledge.
Methodology (for all countries):

- Creation of concept maps linking themes: Climate Change → Regional Impacts → Specific Ecosystem → Affected Species → Proposed Solutions.
- Discussion circles ("reflection circles") to reflect on what was learned and the emotions associated with the topic.

B. Personal Reflection and Action
Objective: To foster a responsible attitude and the transition from knowledge to action.
Activity (for all countries):

- **Phase 1:** Brainstorming "What can I do, our SCHOOL, our LOCALITY do?" (personal, school, community actions).
- **Phase 2:** Formulation of concrete individual or class commitments. Digital tools like Padlet or Mentimeter can be used for anonymous collection and sharing.

C. Project Evaluation (Metacognition)
Objective: To evaluate both content mastery and the personal learning process.
Tools (universal):

- Rubrics for self-assessment and peer assessment (collaboration, effort, quality of argumentation).
- Final questionnaire or "exit ticket" with questions: 1) Most important insight? 2) Most difficult concept? 3) How has the topic influenced my view of the surrounding landscape?



4.7. Sample Lesson Plan

Title: Climate Change and Our Forests: From Problem to Solution
Duration: 6-8 teaching hours (can be spread over several weeks).
Target Group: Upper elementary school students and high school/secondary school students.
Key Competencies: Analytical thinking, data literacy, scientific argumentation, teamwork, environmental citizenship.

Structure of the Teaching Unit (Modular Guide):

Phase / Module	Phase Objective	Suggested Activities (Teacher chooses based on national context)	Example for the Czech Republic	Example for Spain	Example for Portugal
1. Introduction and Context	**To introduce the topic and activate prior knowledge.**	**Brainstorming, analysis of a shocking image (photo of a burnt area/clear-cut).**	**Drone image of clear-cuts in Šumava.**	**Satellite image of a fire in Catalonia.**	**Photograph of the burnt area in Pedrógão Grande or eroded and desertified soils in the south**
2. Theoretical Foundation	**To understand causes and global connections.**	**Lecture with presentation, working with text (IPCC summary for youth).**	***Same global content for all.***		
3. Local Impacts	**To apply theory to a local example.**	**Working with a case study. Group analysis of an assigned case.**	**Case Study: Bark beetle calamity in the Beskydy Mountains.**	**Case Study: Fires in Sierra de Culebra.**	**Case Study: Drought and holm and cork oaks in Alentejo or the regeneration in Agroecology Center (Mértola) and in Montado do Freixo do Meio**



Phase / Module	Phase Objective	Suggested Activities (Teacher chooses based on national context)	Example for the Czech Republic	Example for Spain	Example for Portugal
4. Fieldwork / Practical Part	**Direct observation and data collection.**	**Excursion or practical activity at school/in the local area.**	**Excursion to Mnišské Louky (bird monitoring).**	**Measuring microclimate in different vegetation types.**	**Identifying drought-resistant species.**
5. Solution Design and Debate	**To develop critical thinking and creativity.**	**Simulation of negotiations or a design-thinking workshop.**	**Role-play: Negotiations on forest restoration after bark beetle (forester, conservationist, mayor).**	**Debate: Water management in Doñana.**	**Workshop: Designing a resilient *montado*.**
6. Presentation and Reflection	**To summarise, present, and reflect.**	**Creation of a final product (poster, video, presentation) + final reflection.**	**Presentation "Our Plan for a More Resilient Forest".**	**Short documentary about a local problem.**	**Proposal for an information campaign.**

Note for Teachers: This structure is flexible. Any module can be omitted or extended. The key is connecting the **global principle → local manifestation → personal action**.



5. Case Studies and Practical Examples

5.1. Case studies of Spain

These case studies connect theoretical learning with real field experiences and direct observation. The examples below focus on Andalusia and demonstrate how climate change manifests across various forest ecosystem types. These proposals combine scientific analysis, observation, and environmental reflection, fostering an understanding of the Andalusian territory and its natural wealth.

Case S1. Doñana National Park (Huelva, Sevilla, and Cádiz)

- **Theme:** Drought, biodiversity loss, and sustainable water management.
- **Description:** Doñana is one of Europe's most iconic natural areas. Its system of marshes, lagoons, and forests hosts exceptional biodiversity. Climate change and excessive groundwater extraction are causing a drastic drop in the water table, affecting species such as the Iberian lynx and the Spanish imperial eagle.
- **Key Takeaways for Teaching:**
  - Analyze the relationship between climate change, water management, and nature conservation.
  - Observe the loss of wetland habitats and its impact on wildlife.
  - Understand the role of ecological restoration in wetlands.
- **Suggested Activity:** Simulated debate among stakeholders (farmers, scientists, park managers, environmental NGOs).
- **Supplementary Resources:** Satellite imagery (Google Earth / Copernicus), informational materials from the LIFE Adaptamed project.

Case S2. Sierra Nevada National Park (Granada and Almería)

- **Theme:** Impacts of climate change on high-mountain ecosystems.
- **Description:** Sierra Nevada is home to more than 80 endemic species and serves as a natural laboratory for studying ecosystem responses to global warming. The retreat of snow, reduction of water resources, and shifts in species distribution are becoming increasingly evident.
- **Key Takeaways for Teaching:**
  - Observe the effects of rising temperatures on alpine flora.
  - Analyze seasonal changes and the role of water in ecosystem resilience.
  - Identify conservation strategies in the context of climate change.
- **Suggested Activity:** Interpretive trail (e.g., Hoya de la Mora or the Cortijuela Botanical Garden) and analysis of species adapted to cold temperatures.
- **Supplementary Resources:** Sierra Nevada Global Change Observatory, documents and educational materials from MITECO.

Case S3. Sierra de las Nieves National Park (Málaga)

- **Theme:** Conservation of the Spanish fir and adaptation of Mediterranean forests.
- **Description:** Sierra de las Nieves, declared a national park in 2021, protects the last forests of the Spanish fir (Abies pinsapo), a relict Tertiary species highly sensitive to rising temperatures and drought. This area serves as an example of adaptive forest management in response to climate change.
- **Key Takeaways for Teaching:**
  - Understand the vulnerability of Mediterranean relict forests.
  - Observe conservation and natural regeneration strategies.



- Analyze the ecological function of the Spanish fir as an indicator species.

- **Suggested Activity:** Create a poster or presentation about Spanish fir forests and the climatic threats they face.
- **Supplementary Resources:** LIFE Pinzapo project, photographs and fact sheets from Sierra de las Nieves National Park.

Case S4. Sierras de Cazorla, Segura y Las Villas Natural Park (Jaén)

- **Theme:** Adaptation of forest ecosystems to water stress and biodiversity loss.
- **Description:** This is the largest protected area in Spain and a reference example of ecological restoration. Prolonged droughts, fires, and pests are affecting its pine and oak forests. However, reforestation and sustainable forestry measures demonstrate how to increase forest resilience.
- **Key Takeaways for Teaching:**
  - Analyze the effects of climate change on mid-mountain forests.
  - Study reforestation practices and sustainable forest management.
  - Understand the importance of water management in inland areas.
- **Suggested Activity:** Workshop on identifying native species and observing signs of climatic stress in the environment.
- **Supplementary Resources:** Vadillo-Castril Forestry Training and Experimental Centre, materials from the regional government of Andalusia's "Grow with Your Tree" programme.

Case S5. Cabo de Gata-Níjar Natural Park (Almería)

- **Theme:** Desertification and resilience in arid ecosystems.
- **Description:** Cabo de Gata-Níjar represents one of the driest ecosystems in Europe. Lack of rainfall, rising temperatures, and loss of fertile soil are evidence of advancing climate change. This area also shows how native species can adapt to extreme conditions.
- **Key Takeaways for Teaching:**
  - Identify desertification processes and soil loss.
  - Recognise biological adaptations in xerophytic species.
  - Analyze local conservation and sustainable management strategies.
- **Suggested Activity:** Create a map of xerophytic vegetation and discuss water management in semi-arid environments.
- **Supplementary Resources:** LIFE Adaptamed project (Cabo de Gata), guides to the Natural Park and the Las Amoladeras Visitor Centre.

Section Conclusion:

These case studies allow students to understand how climate change differently affects Andalusian ecosystems. From wetlands to mountains and arid areas, Andalusia offers an ideal mosaic for studying adaptation, mitigation, and ecological regeneration processes in a Mediterranean context.



5.2. Case studies of Portugal

Case P1. Wildfires in Central Portugal – Pedrógão Grande (2017)

- **Theme:** Extreme forest fires, climate change, and landscape vulnerability.
- **Description:** In June 2017, a wildfire in the Pedrógão Grande region killed 66 people and destroyed over 53,000 hectares of forest. It was one of the largest fire-related humanitarian disasters in modern European history. The event revealed a combination of extreme climatic conditions (heatwave, drought, strong winds), the flammability of eucalyptus and maritime pine monocultures, and the limitations of firefighting capabilities.
- **Key Takeaways for Teaching:**
    - The connection between climate change (longer and more intense droughts) and increased risk of catastrophic fires.
    - The problem of planted monocultures of fast-growing tree species (eucalyptus), which are highly flammable.
    - The importance of spatial planning, creating firebreaks, and early warning systems for the population.
- **Suggested Activity:** Analysis of the official report – Students work with the summary report on the fire (available from ICNF or the independent commission). Their task is to create an infographic illustrating the main causal factors (climatic, vegetation-related, infrastructural, human).
- **Resources and Further Materials:** Official "Relatório Técnico Independente" report (2017), ICNF data on the area burnt that year, NASA Earth Observatory satellite images before/after the fire.

Case P2. Holm and Cork Oak Woodlands (Montado) in Alentejo

- **Theme:** Adaptation of a traditional agroforestry system to drought and climate change.
- **Description:** *Montado* is a unique Portuguese agroforestry system based on the cork oak (*Quercus suber*), combining cork production, grazing, and cereal cultivation. It is a biodiversity hotspot and cultural heritage. However, this system is under increasing pressure due to longer and more intense summer droughts, which weaken the trees and increase their susceptibility to diseases (e.g., *Phytophthora*). Its economic sustainability is threatened.
- **Key Takeaways for Teaching:**
    - Traditional landscape systems can have high adaptive value, but their limits are also being tested.
    - Landscape multifunctionality (production, biodiversity, carbon sequestration) as a model for sustainable management.
    - The economic, ecological, and social impacts of climate change on rural regions.
- **Suggested Activity:** Designing an adaptation plan – In the role of farm advisors, students develop a proposal of measures for a more resilient *montado* (e.g., income diversification, tree health monitoring, introducing irrigation for young trees, promoting natural regeneration). They discuss the trade-offs between costs and benefits.
- **Resources and Further Materials:** Materials from the Portuguese APA agency on climate change and agriculture, the website of Corticeira Amorim (the world's

largest cork processor), FAO documents on agroforestry.

Case P3. Retreat of Glacial Features and Water Resources in Serra da Estrela

- **Theme:** Impacts of warming on high-mountain ecosystems and water balance.
- **Description:** Serra da Estrela is Portugal's highest mountain range and hosts the only traces of glacial activity in the country (glacial valleys, moraines). With rising temperatures, snow cover is dramatically decreasing, seasonal snowfields are disappearing, and groundwater recharge is diminishing. This directly impacts the entire region's water regime, mountain heathland ecosystems, and tourism.
- **Key Takeaways for Teaching:**
    - Mountain areas as sensitive indicators of climate change ("natural laboratories").
    - The interconnection between temperature, snowfall, hydrology, and human activities.
    - The concept of ecosystem services (water provision, recreational value) in a concrete example.
- **Suggested Activity:** Virtual excursion and time series analysis – Students use Google Earth Pro to explore a glacial valley (e.g., Vale do Zêzere) and compare historical and current photographs. Subsequently, they analyze a simple time series of average annual temperatures from a meteorological station in the mountains and discuss the impacts.
- **Resources and Further Materials:** Data and studies from IPMA (Portuguese Institute for Sea and Atmosphere), scientific articles on snow retreat in Serra da Estrela, tourist maps and guides for the Serra da Estrela Natural Park.



5.3. Case studies of the Czech Republic

Case C1. Bohemian Switzerland National Park – The 2022 Wildfire

- **Theme:** A new generation of wildfires in temperate forests and the challenges of restoration.
- **Description:** In July 2022, the largest forest fire in the modern history of the Czech Republic broke out in Bohemian Switzerland National Park. Over three weeks, more than 1,000 hectares of forest, predominantly pine and spruce monocultures on sandstone bedrock, burned. The fire was uncontrollable, and firefighters had to use aerial support. It revealed the high vulnerability of dry coniferous monocultures and the need for a change in prevention and protection approaches.
- **Key Takeaways for Teaching:**
    - Climate change is bringing risks to Central Europe that were once typical for southern regions.
    - The connection between species composition (monoculture), drought, and fire spread.
    - The complexity and cost of restoring the affected area while respecting natural values (sandstone rocks, rare treeless ecosystems).
- **Suggested Activity:** Crisis simulation exercise – Students divide into teams (firefighters, park administration, mayors, biologists). Based on real materials from the first hours of the fire, they must decide on intervention priorities, evacuation, and public communication. They then compare their decisions with the actual course of events.
- **Resources and Further Materials**: Special website of the Bohemian Switzerland NP administration dedicated to the fire (with maps, photos, regular updates on restoration), Czech Television reports, expert statements from the Ústí Region Fire and Rescue Service.

Case C2. Mnišské Louky Bird Park (Czech Society for Ornithology)

- **Theme:** Active landscape adaptation – wetland restoration as a tool for mitigating climate change impacts.
- **Description:** The Mnišské Louky Bird Park near Česká Lípa is an example of the successful transformation of agricultural land into a species-rich wetland. The Czech Society for Ornithology purchased the land, removed overgrown willow trees, and created a system of ponds and depressions. The project has a primary conservation goal (supporting wetland birds) but also performs a crucial adaptation function: it retains water in the landscape, increases humidity, and locally cools the microclimate. It shows how targeted interventions can build landscape resilience to drought and floods.
- **Key Takeaways for Teaching:**
    - A concrete example of a "nature-based solution" in practice.
    - The connection between biodiversity conservation and climate change adaptation.
    - The importance of civil society and local communities in landscape care.
- **Suggested Activity:** Design study for the school grounds – Based on the principles seen at the Bird Park (water retention, creation of microhabitats), students create a concept for modifying part of the school grounds or a fictional municipal plot to

make it more resilient to drought and beneficial for nature. They evaluate the costs and benefits.

- **Resources and Further Materials:** Official website and social media of Mnišské Louky Bird Park (regular reports, lists of observed species), Czech Society for Ornithology methodologies for creating ponds, data from the BioLog portal on species occurrence at the site.

Case C3. Bark Beetle Calamity in the Šumava National Park and Bavarian Forest National Park Area

- **Theme:** Large-scale forest ecosystem collapse as a consequence of climatic stress and historical management.
- **Description:** Extensive spruce monocultures in the mid-altitudes of Šumava became the epicentre of a massive bark beetle (European spruce bark beetle) calamity after a series of dry and warm years. Unlike traditional localised outbreaks, a widespread collapse of forests occurred across tens of thousands of hectares. This crisis sparked intense social and professional debate about proper management (salvage logging vs. non-intervention) and the future form of Šumava's forests.
- **Key Takeaways for Teaching:**
    - Forest monocultures are extremely vulnerable to a combination of climatic stressor (drought) and biological agent (bark beetle).
    - Climate change brings ecosystem changes that alter the "rules of the game" for traditional forestry.
    - The social dimension of an environmental crisis – conflict of interests between nature conservation, economics, and landscape perception.
- **Suggested Activity:** Role-play: Roundtable on the future of Šumava – Students are assigned roles with clear interests (NP director, forest manager, eco-activist, tourist accommodation owner, local mayor). Their task is to find a compromise solution for managing a selected zone based on facts (data on calamity extent, climate forecasts).
- **Resources and Further Materials:** Annual Report on the State of Forests (VÚLHM), bark beetle spread maps on the Lesní svět portal, Czech Television documentaries ("Bark Beetle", "Šumava: An Endless Story"), statements from the Šumava NP Administration and scientific institutions.

Case C4. Bohemian Switzerland National Park – Long-term Restoration and Building Resilience After the Fire

- **Theme:** Ecological succession, natural regeneration, and active management in the restoration of affected areas.
- **Description:** The summer 2022 fire created a large area (over 1,000 ha) with dead forest stands in the heart of the national park. This "disaster" also presents an opportunity for scientific monitoring of natural processes and testing different restoration approaches. The park administration combines several strategies: it leaves natural processes (succession) to occur on most of the territory, supports natural regeneration of native tree species in selected locations (e.g., by protecting seedlings from browsing), and implements planting of mixed stands with a higher proportion of broadleaves (oak, beech, maple) in peripheral areas. The goal is to



create, in the long term, a species-richer and more climate-resilient forest to replace the original spruce monocultures.

- **Key Takeaways for Teaching:**
  - Fire as a natural disturbance that resets the ecosystem and opens space for change.
  - The difference between passive (non-intervention) succession and active management interventions.
  - The concept of natural regeneration as a key and often more effective tool for building the resilience of a new forest.
  - The long-term timescale of forest ecosystem restoration (decades to hundreds of years).
- **Suggested Activity:** Comparative succession study – project "How a New Forest Grows" – Students select two sites within the burnt area (one with natural succession, another with planting) and establish a long-term monitoring project. Regularly (1-2 times a year), they will document ground cover, species composition of the herb layer, and tree height. They will compare their observations with the park administration's official reports.
- **Resources and Further Materials:** Long-term monitoring and annual restoration reports of the Bohemian Switzerland NP Administration, scientific articles on post-fire succession in sandstone areas, photo documentation and maps on the park's website, methodologies of the AOPK ČR (Nature Conservation Agency of the Czech Republic) for natural forest regeneration.



6. Interactive and Multimedia Content

Modern teaching of environmental topics requires an attractive and interactive approach. This section gathers verified digital tools, multimedia resources, and online platforms that teachers can immediately use to enrich their lessons. All resources are selected with consideration for their educational value, accessibility, and relevance to the topic of climate change impacts on forests.

6.1. Videos and documentaries

Short video clips and documentaries serve as an excellent introduction to the topic or a basis for discussion.

- Global/European: The "Our Planet" series (Netflix/BBC), the documentary "David Attenborough: A Life on Our Planet," short videos by the "Kurzgesagt – In a Nutshell" channel about climate.
- Spain: RTVE documentaries ("El Bosque Protector"), news reports on fires and drought (El País, La Sexta).
- Czech Republic: Czech Television documentaries – "Kůrovec" (Bark Beetle), "Požár v Českém Švýcarsku" (Fire in Bohemian Switzerland), "Suchý úděl" (Dry Fate). Reports from the "Stream.cz" portal (Science section).
- Portugal: News reports on fires (RTP), documentaries about the *montado* ecosystem (SPEA, APA), nature documentaries: "Guadiana Selvagem", "Cante da Terra", "Alentejo Natural" (Daniel Pinheiro) e "Montado" (Joaquín Gutíerrez Acha).

6.2. Online Simulations and Modelling

They allow students to experiment with complex systems and see the consequences of different decisions.

- **Global Forest Watch:** An interactive map for monitoring deforestation and fires in near real-time.
- **Canopy Virtual Forest / FireSim:** Forest growth and fire spread simulators (suitable for demonstrating the influence of species composition and weather).
- **En-ROADS Climate Simulator (Climate Interactive):** An advanced simulation model that shows the impact of various policies on global warming (suitable for older students).



6.3. Mobile Applications for Fieldwork and Citizen Science

- **Species Identification:** iNaturalist / Seek (universal), PlantNet (plants), BirdNET (birds by song), eBird (birds – records and database), Biodiversity4all.
- **Specific for the Czech Republic:** BioLog (official database of the Nature Conservation Agency of the Czech Republic - AOPK ČR), Lesní svět (bark beetle calamity maps).
- **Meteorology and Drought:** Windy (weather forecast), mobile version of the Intersucho.cz portal.

6.4. Virtual Excursions and 360° Environments

They bring distant or hard-to-reach locations closer to students.

- **Google Earth / Google Earth Studio:** Tools for creating virtual tours and animations of landscape changes over time (e.g., glacier retreat, extent of burnt areas).
- **Official virtual tours of national parks:** Many parks (Šumava NP, Bohemian Switzerland NP, Doñana) offer 360° tours or live cameras on their websites. Google Street View (Maravilhas de Portugal, including Portuguese Natural Parks).

6.5. School Multimedia Production

Guide to Creating Your Own Content.

- **Tools:** Canva (posters, presentations, short videos), CapCut or DaVinci Resolve (video editing), Audacity (audio editing), Anchor (podcast creation).
- **Topics for Student Projects:** "An Interview with a (Virtual) Forester," "A Documentary About Change in the Local Forest," "A Podcast on Invasive Species."

6.6. Identification Keys and Artificial Intelligence Tools

- **Online identification keys:** For example, the PHOTOATLAS of plants for the Czech Republic, keys on botanical garden websites like https://flora-on.pt/ about interactive flora of Portugal.
- **AI assistants:** Can be used to create quizzes, explain complex concepts, or brainstorm on solution topics. It is essential to emphasize the critical verification of generated information.

6.7. Interactive Quizzes and Online Discussions

- **Tools for assessment and engagement:** Kahoot, Quizizz, Mentimeter, Slido. They can be used for ongoing knowledge checks, anonymous opinion polling, or brainstorming.
- **Online discussion platforms:** Padlet (virtual board for idea collection), Flip (short student video responses).



6.8. Gamification and Educational Games

- **Board/virtual games with an environmental theme:** "Carbon Cycles", "Ecosystem".
- **Creating your own simple game:** For example, using Wordwall or LearningApps, you can create crosswords, matching exercises, or "escape games" on the topic of forest protection.

6.9. Supplementary International Resources

- **NASA Climate Kids / ESA Kids:** Friendly resources for younger pupils.
- **World Bank Climate Change Knowledge Portal:** Data and country profiles.
- **UNESCO Associated Schools Network (ASPnet):** Projects and materials on sustainable development.
- **United Nations** (https://www.un.org/pt/climatechange/science/causes-effects-climate-change.
- **The Intergovernmental Panel on Climate Change** (IPCC) https://www.ipcc.ch/



7. Ideas for International Cooperation

This handbook is itself a product of international partnership. The ideas below serve as inspiration for teachers and students from all partner countries on how to build upon this collaborative work, deepen mutual understanding, and develop their projects within a European context.

7.1. Joint Projects and Exchanges

- **Virtual project collaboration (eTwinning):** Establishing a joint project on the eTwinning platform. Themes: "Forest Diary of Three Countries", "Tracking the Migration of a Common Bird Species", "Designing Adaptation Measures for Our Schools".
- **Short-term pupil/staff exchanges (Erasmus+):** Organizing thematic stays focused on fieldwork. For example: Spanish and Portuguese students visit Šumava to study post-bark beetle restoration; Czech and Spanish students travel to Portugal to explore the *montado* system.
- **"Twin" local studies:** Parallel implementation of the same research (e.g., measuring microclimate in a forest vs. on a clear-cut) on school grounds in all three countries, followed by joint evaluation and comparison of data.

7.2. Data Exchange and Collaborative Research

- **Shared observation database:** Using the iNaturalist platform to create a joint project where students from all schools upload observations of plants and animals affected by climate change. The data is then used for analysis.
- **Climate diary of three countries:** Throughout the school year, students regularly record selected meteorological data (temperature, precipitation), phenological observations (e.g., birch budburst), and a subjective description of the landscape. At the end of the year, they create a comparative report.
- **Analysis of satellite imagery:** Groups composed of students from different countries jointly analyze time series of satellite imagery (Google Earth Engine) of selected locations (e.g., Doñana NP, Šumava, Serra da Estrela) and look for signs of change.

7.3. Virtual Debates and Meetings

- **Online student conferences/roundtables**: Regular meetings via platforms like Zoom or Teams, where student teams present the results of their local projects and discuss them with international peers. Topics: "Forest Fires: Different Experience, Common Problem?", "The Future of Forests in Our Region".
- **Expert interviews:** Inviting scientists, foresters, or conservationists from one partner country for an online lecture for students from all three schools.
- Language and culture corners: Short student presentations on how the theme of forests and climate is reflected in their national languages, literature, folklore, or art.



7.4. Shared Final Products

- **Multilingual project website or blog:** A student editorial team from each country creates content in their own language (with an English summary) about the progress of their activities, findings, and reflections.
- **Joint exhibition:** A digital or travelling exhibition of photographs, posters, and student artworks on the theme "Forests and Climate Change: A View from Three Corners of Europe". The exhibition can be installed in all partner schools and local visitor centres.
- **Collective video documentary or podcast series**: Each national group films/records a segment about their region. A joint student team then edits the materials into a coherent whole with a unified structure and theme music.
- **Manifesto or open letter:** The joint drafting of a document in which students summarise their main findings, concerns, and proposed solutions, and address it to local, national, or European politicians and institutions.

These activities not only deepen subject-specific knowledge but also develop students' linguistic, digital, and intercultural competencies and strengthen their sense of belonging to a European community that faces a global challenge together.



8. Recommended Bibliography and Resources

This section contains selected resources for further study, lesson preparation, and verification of the information contained in the handbook. The resources are divided by country and thematic area to facilitate the work of teachers from all partner countries.

8.1. Official Sources and Data Portals by Country

- **Global and European Sources:**
  - **IPCC (Intergovernmental Panel on Climate Change):** Sixth Assessment Report (AR6), especially the Summary for Policymakers. [*Primary source for scientific consensus*].
  - **European Environment Agency (EEA):** Publication "Climate change, impacts and vulnerability in Europe". [*Comparative data for Europe*].
  - **European Forest Institute (EFI):** Studies and policy briefs on forests, fires, and adaptation.
  - **Copernicus Climate Change Service (C3S) & Land Monitoring Service:** Freely available satellite data and climate indicators.
- **Spain (España):**
  - **[1] AEMET (State Meteorological Agency):** "Report on the state of the climate in Spain" – annual reports. [https://www.aemet.es/en/serviciosclimaticos/cambio_climat]
  - **[2] MITECO (Ministry for Ecological Transition and the Demographic Challenge):** "National Climate Change Adaptation Plan (PNACC)", reports on desertification and national forest inventories. [https://www.miteco.gob.es/]
  - **Official National Park portals:** Doñana, Sierra Nevada, Sierra de las Nieves (contain educational materials and data).
- **Portugal:**
  - **[3] IPMA (Portuguese Institute for Sea and Atmosphere):** Climatological data, normals, and projections. [https://www.ipma.pt/]
  - **[4] APA (Portuguese Environment Agency):** State of the environment reports, section on climate change and water resources (e.g., "Climate Change Adaptation in Portugal"). [https://apambiente.pt/]
  - **[8] ICNF (Institute for Nature Conservation and Forests):** "Relatório Anual de Áreas Ardidas" (Annual Burnt Area Report) and forest data. [https://www.icnf.pt/]
- **Czech Republic:**
  - **[5] CHMI (Czech Hydrometeorological Institute):** Publication "Climate Change in the Czech Republic", historical data and climate scenarios. [https://www.chmi.cz/]
  - **[6], [9] Global Change Research Institute CAS (CzechGlobe):** Portal Intersucho.cz – drought monitoring, forecasts, impacts on vegetation. [https://www.intersucho.cz]
  - **[7] CHMI:** Data and analyses concerning snow cover.
  - **[10] VÚLHM (Forestry and Game Management Research Institute):** "Report on the State of Forests and Forestry in the Czech Republic" (annual report). [https://www.vulhm.cz/]
  - **[11] Directorate General of the Fire and Rescue Service of the Czech**



Republic: Statistics and reports on wildfires in the natural environment. [https://www.hzscr.cz/]

- **[12] AOPK ČR (Nature Conservation Agency of the Czech Republic):** BioLog portal (database of nature observations), red lists of species, data on protected areas. [https://portal.nature.cz]

8.2. Educational Projects, Platforms, and Non-Governmental Organizations

- **International:**
  - **LIFE Programme (EU):** Specific adaptation projects: LIFE Adaptamed (ES), LIFE Montado-Adapt (PT), LIFE for Forests (CZ).
  - **LEAF (Learning About Forests – Foundation for Environmental Education):** International educational programme and resources. [https://leaf.global].
  - **Project Learning Tree (PLT):** Module "Southeastern Forests and Climate Change". [https://www.plt.org].
  - ABAE - European Blue Flag Association(https://enea.apambiente.pt/)
  - FACE – European Federation for Hunting and Conservation (https://www.face.eu/)
  - GWCT – Game and wildlife Conservation Trust (https://www.gwct.org.uk/)
- **National (selection):**
  - **Spain:** Ecoherencia (environmental education and restoration), Fundación Gypaetus (vulture conservation and EE in Andalusia).
  - **Portugal:** SPEA (Portuguese Society for the Study of Birds) – BirdLife International partner; CIBIO (Research Center in Biodiversity and Genetic Resources) Portugal; LPN (Nature Protection League); Centre of Expertise for the Study, Management and Sustainability of Game Species and Biodiversity; ADPM (Association for the Defence of Mértola's Heritage).
  - **Czech Republic:** Czech Society for Ornithology (Mnišské Louky Bird Park project), TEREZA, Educational Centre (EE methodologies), Nadace Partnerství (School for Sustainable Life programmes).

8.3. Interactive Tools and Applications for Teaching

- **Universal:**
  - **Google Earth Engine / Timelapse:** Visualising landscape changes over time.
  - **Global Forest Watch:** Online platform for monitoring forest cover change in near real-time. [https://www.globalforestwatch.org].
  - **iNaturalist / Seek by iNaturalist:** Platform for species identification and citizen science.
  - **PlantNet, eBird:** Applications for identifying plants and recording bird observations.
- **Specific for the Czech Republic:**



- **Lesní svět:** Interactive maps and information about Czech forests, including the bark beetle calamity. [https://www.lesnisvet.cz].
- **FOTOATLAS rostlin:** Detailed online identification key for plants of the Czech Republic.
- **Public Administration Portal:** Environmental data and reporting from the Ministry of the Environment.

8.4. Audiovisual and Supplementary Materials

- **Documentaries and reports:**
  - "Our Planet" – Netflix/BBC series.
  - "El Bosque Protector" (The Protective Forest) – RTVE documentary series on Iberian ecosystems.
  - For the Czech Republic: Czech Television documentaries – "Kůrovec" (Bark Beetle), "Požár v Českém Švýcarsku" (Fire in Bohemian Switzerland), "Suchý úděl" (Dry Fate - impacts of drought).
- **Online courses and webinars:** Offerings from organisations such as the FAO e-Learning Academy (course "Forests and transparency in the Paris Agreement") or national educational institutions.

  Webinars from ICNF (Institute for Nature Conservation in Portugal): https://natural.pt/news/webinares-terca-outras-palestra-2022-3-gravacoes?locale=pt



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