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Spain's Climate Change Risks and Impacts Assessment

Executive summary

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Contenido

1. Introduction and purpose of the report

Spain´s Climate Change Risks and Impacts Assessment *(Evaluación de Riesgos e Impactos derivados del Cambio Climático en España)* **ERICC-2025** constitutes the first comprehensive national-scale exercise aimed at **identifying, characterising and prioritising the climate-related risks** that affect the country's natural, productive and social systems. Its purpose is to provide a **sound scientific and methodological basis** to guide the planning of public adaptation policies, climate-risk management and the integration of the climate variable into strategic decision-making.

The development of ERICC-2025 fulfils **Article 18 of Law 7/2021 of 20 May on Climate Change and Energy Transition**, which establishes the obligation to carry out periodic assessments of climate impacts and risks at least every five years.

This assessment is an essential step in the adaptation-policy cycle and is key to implementing the **Plan Nacional de Adaptación al Cambio Climático 2021-2030 (PNACC)**, the main planning instrument promoting coordinated and coherent action in response to the effects of climate change in Spain. Within this context, ERICC-2025 plays a fundamental role in knowledge generation – one of the strategic components of the PNACC – by operationalising the assessment of climate risk. It also constitutes the technical reference underpinning the forthcoming **2026-2030 work programme**, which will focus on implementing sectoral and territorial adaptation measures.

The report was prepared between 2023 and 2025 by a **scientific-technical consortium comprising the Instituto de Hidráulica Ambiental de la Universidad de Cantabria (IH Cantabria)**, **Tecnalia Research & Innovation and the Basque Centre for Climate Change (BC3)**, under the coordination of the OECC and with the collaboration of **Fundación Biodiversidad**. The process entailed an extensive scientific and technical review, as well as the participation of experts and organisations from diverse sectoral fields, thereby ensuring traceability, consistency and methodological coherence across chapters.

1.1. Legal and strategic context

The legal framework underpinning this assessment is established in **Law 7/2021**, which incorporates the principle of adaptation as a cross-cutting element of public policy and promotes the integration of climate risk into sectoral, territorial and financial planning. In line with Spain's international commitments under the **United Nations Framework Convention on Climate Change (UNFCCC)** and the **Paris Agreement (2015)**, the Law mandates the General Administration of the State to periodically assess climate risks and impacts, identifying the most vulnerable sectors and the priority measures for adaptation.

At the strategic level, ERICC-2025 continues the process initiated with the 2020 national assessment *(Impactos y riesgos derivados del cambio climático en España)* and updates the analyses in light of **the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC)**, **the new regionalised climate scenarios** and the scientific and technical advances in observation, modelling and risk management. The study also responds to the guidelines of the **European Union Strategy on Adaptation to Climate Change (2021)** and **the European Green Deal**, which promote climate resilience as a cross-cutting priority for the continent's energy, food and social security.

1.2. Main objectives of ERICC-2025

The key objectives of the assessment are to:

- **Identify and characterise the main climate risks** affecting Spain's natural, productive and social systems, applying a homogeneous and replicable methodological framework.
- **Assess the severity, imminence and recovery capacity** in relation to these risks, determining their urgency for action.
- **Analyse interdependencies among sectors and systems**, identifying complex risks and cascading effects.
- **Establish a scientific basis for the prioritisation of adaptation measures**, guiding the planning of PNACC 2026-2030 and ensuring its coherence with European and international strategies.
- **Strengthen the capacity for monitoring and assessing climate risk** by defining common criteria for future observation and evaluation.

The report synthesises the results of **14 sectoral domains** defined in the PNACC 2021-2030: health, water and hydrological resources, natural heritage and biodiversity, forestry, agriculture and food, coasts and marine environment, energy, mobility and transport, industry and services, tourism, financial system and insurance, cultural heritage, peace-security-social cohesion and city-urban development-building.

Altogether, **141 relevant risks (RR)** and **51 key risks (KR)** were identified, grouped into three major systems: natural, productive and social-institutional.

1.3. Spatial and temporal scope of the assessment

ERICC-2025 has a national territorial scope, with differentiated representations across major **bio-climatic areas** (Atlantic, Mediterranean, Continental and Insular), reflecting the particular exposure and vulnerability conditions of each region.

Although the scale of analysis is aggregated, the report stresses the need to deepen regional and local assessments to design responses suited to specific territorial realities.

The **temporal horizon** of the analysis covers both observed climate evolution (1961-2020) and projections for the twenty-first century under different emission scenarios (SSP2-4.5 and SSP5-8.5), considering **medium-term (2040-2060)** and **long-term (2080-2100)** outlooks.

This approach makes it possible to identify **observed trends**, project the evolution of key **climate hazards** (e. g. increase in mean temperature, reduced precipitation, heightened aridity, more intense droughts, compound extreme events, sea-level rise and ocean acidification), and to evaluate their interaction with exposure and vulnerability factors.

1.4. Links with European and international frameworks

ERICC-2025 is situated within an **international strategic alignment** framework, adopting the methodological standards of the **IPCC (AR6)** and the **European Climate Risk Assessment** *(EUCRA, 2024)* to ensure **comparability and coherence** with European and international reporting systems.

The study could also help reinforce connections with **EIONET** (the European Environment Information and Observation Network coordinated by the European Environment Agency) and with the **Climate-ADAPT** platform, which hosts harmonised information on climate risks and adaptation measures across Europe. Such interoperability seeks to position Spain as a **European reference in climate risk assessment and management,** thus contributing to the objectives of the **EU Adaptation Strategy** and the **European Green Deal**.

Overall, ERICC-2025 serves as a strategic tool to guide **adaptation planning in Spain** over the coming decade, offering **an integrated vision of climate risk** that combines scientific rigour, methodological coherence and policy applicability. Its dynamic and updatable nature will enhance the resilience of territories, ecosystems and productive sectors in the face of the challenges of the twenty-first century.

2. Conceptual and methodological framework

ERICC-2025 is grounded in the **conceptual framework for climate risk developed by the IPCC** and adopted in its **Sixth Assessment Report (AR6, 2022)**, applied consistently across all sectors analysed.

According to this framework, climate risk results from the interaction of three fundamental components: **hazard**, **exposure** and **vulnerability**.

Hazards refer to climate-related phenomena capable of generating adverse impacts (e. g., heatwaves, prolonged droughts, extreme precipitation events, sea-level rise or ocean acidification). **Exposure** is defined as the presence of people, ecosystems, infrastructure, or economic and cultural assets in locations that may be affected by such phenomena. **Vulnerability** expresses the propensity or predisposition to suffer damage, encompassing both the sensitivity or susceptibility of systems and their capacity for response and adaptation. **Response risks**—those arising from climate-change management strategies, including unforeseen consequences and long-term societal or climatic effects—are analysed as cross-cutting aspects within this assessment.

This framework enables a **systemic and dynamic** analysis of climate-related risks, identifying how the evolution of climate hazards interacts with the social, economic and territorial factors that determine exposure and vulnerability.

2.1. Multi-criteria approach for identifying relevant and key risks

The methodology follows a three-phase process combining scientific review, multi-criteria analysis and expert validation.

1. **Identification of relevant risks (RR):** A thorough review was carried out of scientific literature, technical reports and national and international databases, together with evidence of observed impacts in Spain since 2020. This process established an initial inventory of **relevant risks** for each of the 14 sectoral areas of the PNACC 2021-2030.

2. **Selection of key risks (KR):** From the list of relevant risks, a **Multi-Criteria Analysis (MCA)** was applied using criteria aligned with IPCC standards. Factors considered included the **spatial scope of the risk, the magnitude of its economic or social impact, the potentially affected population, the irreversibility of impacts, the existence of critical thresholds, transboundary effects, cumulative impacts** and the level of **available scientific evidence**.

   The MCA identified a set of **51 key risks** representing phenomena with the highest potential to critically affect Spain's natural, productive and social systems.

3. **Detailed sectoral analysis:** For each key risk, **conceptual risk models and impact chains** were developed, integrating the three risk components (hazard, exposure and vulnerability) and describing interactions among physical, ecological, economic and social factors.Each risk was documented in **standardised analytical sheets**, ensuring methodological traceability across sectors.

This methodological process guarantees **homogeneity, transparency and replicability** of the assessment, allowing periodic updates and application to more detailed territorial or thematic scales.

2.2. Complex Risks and interdependencies analysis

In addition to sectoral analysis, ERICC-2025 develops a **complex risk model** based on graph theory, with the aim of representing and quantifying the **interconnections between the 51 key risks**. This model allows the risk system to be visualised as a **network of interdependencies** where the nodes represent the risks and the edges represent the relationships of influence between them.

The model allows identifying sectors to which the risks having higher direct impact on other risks and sectors, notably **water, natural heritage and forestry**, as well as the sectors most exposed to direct impact from other risks, such as **peace, the financial system and natural heritage**. Finally, also calls the attention about risks with the greatest capacity to propagate cascading effects belong to the **natural heritage, agriculture, peace, water and city sectors**.

Using centrality metrics (**in-degree, out-degree, closeness and betweenness**), the analysis reveals the critical relationships within the system, facilitating the identification of **systemic risks** that require coordinated and cross-cutting adaptation strategies.

This approach addresses the recommendations of the **IPCC AR6** and the **European Climate Risk Assessment (EUCRA)**, which highlight the need to move beyond sectoral approaches to address **compound effects, feedbacks and cross-sectoral dysfunctions**.

2.3. Urgency criteria

The prioritisation of risks within ERICC-2025 relies on three fundamental criteria:

- **Severity**, understood as the potential impacts if a risk materializes on a given scenario.
- **Imminence**, measuring the likelihood that the impact will occur in the short or medium term under plausible climate scenarios.
- **Recovery capacity**, assessing the time and resources required to restore affected functions after an impact, taking into account social, ecological and institutional resilience mechanisms.

These criteria allow the classification of risks into three priority levels—**maximum, significant and limited**—thereby guiding strategic decision-making and resource allocation for adaptation during the forthcoming PNACC (2026-2030) cycle.

2.4. Confidence level and recommended monitoring

Each key-risk assessment includes an estimate of the **confidence level** in the severity and imminence of the impacts, based on the **quality and consistency of available scientific and technical evidence**.

A qualitative scale *(high, medium or low)* indicates data robustness and degree of consensus among sources.

Where information is insufficient, the report recommends **implementing monitoring and improved climate-observation actions**, particularly in sectors with high uncertainty or strong dependence on non-climatic variables such as the **financial system, health or cultural heritage**.

The methodological chapter also sets out guidance for strengthening the **traceability and transparency of knowledge**, including documentation and validation protocols, sectoral indicators and procedures for periodic data updating.

2.5. Cross-reference to methodological annexes

ERICC-2025 is complemented by several **methodological documents**:

- The **Annex of Climate Variables** compiles observed trends and future projections for temperature, precipitation, aridity, sea-level, wave climate and ocean acidification, all integrated into the sectoral risk models.
- The **Multi-Criteria Analysis** details the indicators used for risk prioritisation, the weighting factors assigned by authors to each criterion, together with justification and aggregated sectoral results.
- The **Glossary** harmonises technical concepts in line with the IPCC AR6 framework, ensuring consistent use throughout the sectoral chapters.

Taken together, this conceptual and methodological framework provides a **coherent, verifiable and replicable structure** for assessing climate risks in Spain, integrating the latest scientific evidence with the operational requirements of adaptation planning.

3. Observed climate evolution and future projections

The analysis of climate evolution in Spain constitutes the empirical basis underpinning the risk assessments conducted in **ERICC-2025**. The study integrates instrumental observations, climate reanalyses and regionalised projections developed within the framework of the **CORDEX-EU** programme and the **AdapteCCa** platform, together with national scenarios derived from CMIP6 models. The main **climate hazards** analysed include temperature, precipitation, drought, aridity, sea level, wave climate and ocean acidification, as well as their interactions, considering both **historical trends** (1961–2020) and **future projections** under different emission scenarios (SSP2-4.5 and SSP5-8.5).

3.1. Observed climate trends

The results confirm that **Spain ranks among the European regions with the highest climate exposure and sensitivity**, particularly in the Mediterranean basin, the archipelagos and the semi-arid interior zones.

The most relevant climate variables exhibit clear trends:

- **Temperature:** An average increase of +1.69 °C since the mid-twentieth century, accompanied by greater frequency and intensity of **heatwaves**, more **tropical nights** and a longer climatic summer.

- **Precipitation:** No clear trend in average annual precipitation, but a predominance of short, torrential episodes over prolonged dry periods.

- **Droughts:** Increasing duration and intensity of meteorological, agricultural and hydrological droughts, with cumulative impacts on ecosystems, agricultural production and water availability.

- **Aridity and soil moisture:** Rising potential evapotranspiration and declining soil moisture, accelerating processes of **desertification** and loss of soil productivity.

- **Sea level:** Mean rise exceeding 3 mm per year, accompanied by an increase in **meteorological tides** and coastal erosion.

- **Waves:** Growing storm energy in the Atlantic and western Mediterranean, producing cumulative effects on ports, beaches and dune systems.

- **Sea temperature and acidification:** Warming of surface waters and a decline in pH levels, affecting marine habitats, fisheries and coastal ecosystems.

- **Compound extreme events:** Increasing frequency of simultaneous heat and drought events, or torrential rain following extended droughts, with cascading effects on economic and social sectors.

These changes are already reflected in multiple environmental and socioeconomic indicators, confirming that **observed impacts** are consistent with projections for the 2030 and 2050 horizons.

3.2. Climate projections for the twenty-first century

The analysed projections confirm the continuation and intensification of the observed trends.

Under the intermediate **SSP2-4.5 scenario**, an average temperature rises of **2 °C by mid-century** and **3 °C by the end of the century** (relative to 1981–2010) is projected; under the **high SSP5-8.5 scenario**, increases could exceed **4 °C** across large areas of the south and southeast.

Heatwaves are expected to become longer and more frequent, and the number and spatial extent of tropical nights (minimum temperature > 20 °C) will grow, particularly in Mediterranean and coastal urban zones, with direct implications for health and energy consumption.

Regarding **precipitation**, models suggest an **annual average reduction of 4–16 %** by the end of the century, although with strong regional heterogeneity. Seasonal irregularity is expected to increase, with wetter winters in the north and drier autumns and summers in the south and east. Conversely, **extreme precipitation events** (>95th percentile) may intensify, heightening the risk of flash floods and erosion.

Hydrological and agricultural droughts are projected to intensify, reducing mean flows and reservoir storage levels. The **Guadalquivir, Segura, Júcar and Ebro** basins show the largest projected decreases in water availability, with consequences for irrigation, urban supply and hydropower generation.

Changes in rainfall regimes, combined with rising temperatures, will create more **favourable conditions for severe and extensive forest fires**, due to the greater volume of fuel exposed to prolonged droughts. Projections indicate an increase in fire danger—up to +14 % under RCP 4.5 and +30 % under RCP 8.5 by century's end—and longer fire-risk seasons.

Sea level is expected to continue rising throughout the century, with **+30 to +45 cm projected for 2100** under the intermediate scenario and **up to +80 cm** under the high scenario, depending on polar ice-sheet melt rates. This rise will combine with more frequent extreme water-level events, exacerbating **coastal flooding and erosion** in deltaic plains and urbanised Mediterranean and Canary Island areas.

In the oceanic environment, **sea-surface temperature** could increase by up to **3 °C** by 2100, while PH could fall by an additional **0.3 units**, intensifying marine biodiversity loss and disruption of trophic networks.

3.3. Compound extreme events and cascading effects

The **Complex Risks and Climate Variables** chapters emphasise the growing importance of **compound extreme events**, understood as the coincidence or interaction of multiple climate hazards (e. g., prolonged heat and drought; marine storms and pluvial flooding; extreme heat and air pollution). Such phenomena produce **non-linear effects** that amplify damages and reduce the response capacity of natural and human systems.

Recent examples include the **2022–2023 drought**, which combined rainfall deficit, heatwaves and high soil temperatures, leading to exceptional declines in agricultural productivity, reservoir levels and significant economic losses. In coastal areas, **the concurrence of marine storms with astronomical and meteorological tides, together with intense rainfall**, has caused simultaneous damage to infrastructure, beaches and coastal wetlands.

The interdependency analysis shows how such events may trigger **cascading risks**: reduced water resources affect hydropower generation and cooling of thermal plants, increasing energy demand and system costs; meanwhile, water scarcity and extreme heat affect labour productivity, public health and the financial stability of certain economic sectors.

3.4. Regionalisation: differentiated patterns by bioclimatic areas

Spain's climatic diversity determines the spatial distribution of impacts:

- **Atlantic region:** More moderate warming but greater frequency of intense precipitation events and increased fluvial flood risk.
- **Mediterranean region:** More pronounced warming and reduced rainfall, intensifying droughts, water stress and soil degradation.
- **Continental interior:** Stronger thermal oscillations and exposure to prolonged heatwaves due to continentality.
- **Archipelagos:** Greater vulnerability arising from sea-level rise, coastal erosion and dependence on imported energy and food.

These bioclimatic patterns are essential for contextualising sectoral risk assessments.Sectors such as **water, agriculture, energy and tourism** exhibit high sensitivity to regional climate gradients and ecosystem dynamics, whereas **health and urban planning** are more affected by exposure factors and population density.

3.5. Connection with the "Climate variables" chapter

The **Climate Variables chapter** constitutes a transversal reference within ERICC-2025, providing the quantitative inputs for risk modelling. It integrates both basic indicators (temperature, precipitation, wind, sea level) and derived indicators (drought indices, aridity, extreme events, ocean acidification), as well as their **sectoral translation** through composite indicators and specific variables—e. g. reference evapotranspiration in agriculture, mean annual flow in water resources, coastal overtopping in marine systems, or cooling degree-days in energy.

The combination of observations, projections and sectoral variables forms the **backbone of the risk analysis**, enabling an integrated assessment of territorial exposure, vulnerability and inter-sectoral dependencies.

4. Results of the risk assessment

4.1. General overview

ERICC-2025 identifies a total of **141 Relevant Risks (RR)** and **51 Key Risks (KR)** distributed across the **14 sectoral domains** defined in the **Plan Nacional de Adaptación al Cambio Climático 2021-2030 (PNACC).**

Each key risk represents a critical interaction between **climate hazards, exposure and vulnerability**, and has been analysed in terms of severity, imminence, urgency and recovery capacity.

The set of risks reveals that climate change is acting as an **amplifier of pre-existing structural pressures**—such as ecosystem degradation, intensive resource use, urban concentration and territorial inequality—creating **cumulative and systemic effects** that simultaneously affect natural, productive and social systems.

In aggregate terms, ERICC-2025 highlights the following general patterns:

- **Node sectors (water, energy and health)** act as the main axes structuring the risk system, due to their high interconnection with other sectors and their capacity to generate cascading impacts.
- **Sectors most exposed** to direct physical hazards are **coasts and the marine environment, agriculture, natural heritage and biodiversity, and forestry**, owing to their direct dependence on climatic variables.
- **Seventeen risks of low or null reversibility** are identified, mainly associated with habitat loss, soil degradation, coastal erosion and desertification, requiring immediate preventive measures.
- The **greatest urgency for action** is concentrated in sectors directly affecting human well-being and socio-economic security (health, water, energy and food), where impacts are projected in the short and medium term.

- **Compound effects and interdependencies** among sectors increase the probability of systemic dysfunction, notably in the *Water–Energy–Food, Coasts–Tourism–Infrastructure*, and *Health–Labour–Energy* linkages.

From the perspective of risk components:

- The predominant **climate hazards** include the sustained increase in mean temperature, intensified heatwaves, reduced precipitation and more frequent extreme events (floods, marine storms, forest fires).

- **Exposure** is especially high in coastal areas, river corridors, intensive agricultural zones and large urban agglomerations.

- **Vulnerability** is concentrated in territories with lower adaptive capacity—depopulated rural areas, densely urbanised coastal zones, degraded ecosystems or economic sectors dependent on natural resources.

Confidence in the results is high in well-documented sectors (water, coasts, energy, health) and medium in those with greater uncertainty due to limited data or strong non-climatic influences (cultural heritage, financial system, social cohesion).

4.2. Synthetic sectoral results

Sectoral analysis clarifies how climate-change impacts manifest differently yet interconnected across the **natural**, **productive** and **social-institutional** systems.

Each system combines unique levels of exposure, vulnerability and adaptive capacity, but all share common dependencies—on water resources, energy, health and ecosystems—that shape Spain's overall risk structure.

a. Natural system

The natural system forms the **ecological core of territorial resilience** and the essential support for productive and social systems. However, it is also the most directly exposed to climate change, as its processes depend immediately on temperature, precipitation and hydrological dynamics.

Results show intensifying pressures on ecosystems and a growing risk of **loss of functionality and environmental services**.

In **water and hydrological resources,** the observed and projected trends confirm a gradual decline in resource availability and a greater frequency of extreme episodes.**Prolonged droughts and declining rainfall** reduce aquifer and reservoir recharge, while **increasing torrentiality** raises the risk of fluvial and pluvial flooding. These phenomena strain water security for agricultural, urban, industrial and energy uses and constitute **one of the most urgent key risks**. Vulnerability is especially high in southern and eastern basins, where competition for water and aquifer over-exploitation exacerbate climate-change impacts.

The impacts on **natural heritage and biodiversity** are equally significant. Rising temperatures, altered rainfall regimes and habitat fragmentation are driving **species redistribution**, loss of suitable habitats and disruption of ecological processes such as pollination and migration. Aquatic ecosystems and protected areas of the Mediterranean arc and Canary Islands are particularly vulnerable. Biodiversity loss also diminishes essential ecosystem services—water regulation, soil fertility, carbon capture and provision of natural goods—directly affecting human well-being and dependent sectors such as agriculture and tourism.

The **forestry sector** exhibits a complex dynamic, where expansion of wooded area coexists with increasing degradation risks. **Water stress, pest proliferation and more frequent wildfires** are altering forest composition and structure, reducing carbon-storage capacity and accelerating soil erosion. Desertification, particularly in the south-eastern peninsula, stands out as one of the most severe and **least reversible** processes. These phenomena have direct repercussions on forest-based industries, water-resource management and the maintenance of natural carbon sinks.

Overall, the natural system is characterised by **high urgency and high confidence**, as impacts are observable and strongly supported by scientific evidence. Loss of ecological resilience acts as a risk multiplier for human-productive systems, linking environmental degradation with economic and social stability.

b. Productive system

Spain's productive system—comprising agriculture, coasts and the marine environment, energy, mobility, industry and tourism—combines **high physical exposure** with **high economic sensitivity** to climatic change. Associated risks are heterogeneous but share a common feature: structural dependence on increasingly scarce natural resources and the need for resilient infrastructure.

In **agriculture, livestock and fisheries,** climate change manifests through **declining yields, loss of fertile soil and greater inter-annual variability of harvests**. Longer droughts, heat stress and disrupted phenological cycles threaten food security and rural livelihoods. The south and central regions suffer the most severe impacts, with irrigated systems and surface-water-dependent farms particularly vulnerable.Economic losses in the primary sector have direct implications for the financial system and rural employment.

Regarding the **coastal and marine environments,** results confirm **very high physical and ecological exposure**. Sea-level rise, coastal erosion and more intense storms cause sustained loss of land surface and damage to infrastructure, ports and coastal urban areas. **Ocean acidification** undermines marine-habitat integrity and fishery productivity, with cascading effects on the coastal economy. The Mediterranean coasts, deltas and archipelagos exhibit the greatest system vulnerability and are priority areas for preventive and ecological-restoration action.

As a cross-cutting sector, **energy** represents a critical node in the risk network.**Reduced water availability, high temperatures and demand peaks** simultaneously compromise generation, distribution and consumption. Projections indicate lower hydroelectric output, losses of grid efficiency due to overheating, and increased electricity consumption during heatwaves. These impacts generate systemic vulnerabilities requiring planning that integrates adaptation and energy transition, reinforcing supply security and flexible demand management.

The sectors of **mobility, transport, industry and services** share risks related to **exposure of critical infrastructure** and **disruption of logistics chains**. Extreme events (floods, heat, strong winds) can cause temporary interruptions in mobility, structural damage and productivity losses. Although **urgency is moderate**, their transversal nature makes them amplifiers of vulnerabilities in other sectors such as energy and trade.

Tourism exemplifies climate sensitivity. **Heatwaves** and **loss of thermal comfort** reduce visitor numbers to inland and urban destinations during summer, while degradation of natural and coastal resources undermines the competitiveness of “sun-and-beach” destinations. Vector-borne diseases and landscape deterioration reinforce this trend. Although parts of the sector are diversifying and extending the season, overall exposure remains high, especially in Mediterranean and island regions.

The productive system thus combines **significant urgency and high confidence**, grounded in robust empirical evidence. Adaptation will require integrated measures combining resource efficiency, technological innovation and territorially coordinated management with the natural and social systems.

c. Social and institutional system

The social-institutional system concentrates the impacts directly affecting **human well-being, health and social cohesion**, as well as the stability of economic and governance structures. Climate change constitutes not only an environmental risk but also a **social and distributive challenge**, magnifying inequalities and testing institutional response capacity.

Health is one of the most affected and urgent areas. Rising temperatures and more frequent heatwaves increase **heat-related morbidity and mortality**, particularly among older people, outdoor workers and vulnerable groups. Additional risks stem from **air pollution** and the spread of **vector-borne diseases** (e. g., dengue, West Nile virus) whose geographic range is expanding northward. These impacts require integrating climate surveillance into public-health systems and occupational and urban-planning protocols.

The **financial and insurance system** is facing double exposure: **physical risks** from direct damage to assets, infrastructure or crops, and **transition risks** linked to regulatory change and asset revaluation. Losses from extreme events, higher insurance payouts and potential devaluation of climate-sensitive investments depict a landscape of growing vulnerability, though current confidence in projections remains medium.

Cultural heritage is exposed to **material degradation and hazards such as flooding or erosion**, implying not only material losses but also loss of collective identity and tourism appeal. These impacts highlight the need to integrate **climate adaptation** into heritage and urban-management planning.

In the area of p**eace, security and social cohesion**, climate change acts as a **multiplier of tensions**. Combined effects of droughts, agricultural losses and resource pressures may worsen territorial inequalities and trigger conflicts over access to water or energy.Internal displacement linked to environmental degradation and declining habitability in rural or coastal zones is expected to increase.

Finally, **cities and urban environments**, concentrate much of the system's exposure: high population densities, critical infrastructure and impermeable surfaces.The ***urban heat-island effect***, **flood risk** and pressure on basic services pose structural challenges for urban and building planning. Nevertheless, cities also offer the greatest opportunities to implement Nature-Based Solutions (NbS) and early-warning systems.

Overall, the social-institutional system presents **high urgency and medium-to-high confi-**

dence, with immediate impacts on health and cohesion and indirect effects on economy and governance. Adaptation will require inclusive policies, sensitive to territorial inequality, and closer coordination among social, health and environmental domains.

4.3. General synthesis

The sectoral results of ERICC-2025 depict a **highly interdependent climate-risk system**, in which ecological, productive and social dysfunctions mutually reinforce and amplify each other. Vulnerability in natural sectors (water, forests, biodiversity) directly affects the stability of the productive system and, ultimately, social cohesion.

5. Complex Risks and Interdependencies analysis

ERICC-2025 adopts a systemic approach to understanding how climate risks do not operate in isolation, but rather as part of an **interdependent network of impacts** that amplify and feedback into each other. This analysis constitutes one of the most relevant methodological advances of the study, since, along the content of all the sectoral chapters, allows identifying **cascading effects, shared vulnerabilities and critical failure points** within the Spanish socio-ecological and economic system.

The **51 key risks** identified in the assessment have been represented using a **complex risk model**, where each risk is conceived as a node and the relationships between them as connections weighted according to their intensity and direction.

This model, developed using **graph analysis** methodologies, allows the functional dependencies between sectors to be visualised and the centrality of each node to be quantified, i.e. its capacity to generate or receive impacts. The complex risk analysis, together with the individual analyses of each sector, presents a **highly interconnected** risk structure.

As mentioned above, the complex risk analysis is a fundamental phase of the project, developed through a participatory approach. One of the most notable aspects has been the extensive involvement of stakeholders from various fields, which has allowed incorporating multiple perspectives. This diversity has been key to enrich the analysis, strengthening both the validity and robustness of the obtained results.

In order to analyse the dynamics and relevance of each risk within the system, various metrics are calculated to characterise their behaviour and interactions:

- **Out-degree**: indicates the risks with the greatest capacity to generate impacts on other elements of the system.
- **In-degree**: identifies those risks most vulnerable to external influences.
- **Closeness**: reflects how quickly a risk can be affected by the rest of the system, considering the distance in the network of interdependencies.

- **Betweenness**: indicates the risks that act as bridge nodes in the propagation of effects, playing a critical role in the connectivity of the system.

These are some of the most relevant conclusions regarding the **out-degree** and **in-degree** of the analysed risks:

5.1. Out-degree

Refers to the capacity of a risk to generate or amplify other risks within the system, acting as a driver or propagator of impacts. Risks with a high out-degree play a structural role in the dynamics of the risks system, and their management can have positive multiplier effects.

Risks with the highest **out-degree** are those that trigger multiple cascading impacts, affecting economic sectors as well as ecological and social systems. Prioritising their management can significantly reduce systemic exposure:

- **Damage caused by prolonged extreme droughts stands out** for its **potential to trigger more than 26 key risks**. These include the loss of ecosystem services and reduced water availability for different uses and demands due to reduced water resources.

- **Damage from pluvial and fluvial flooding is a driver of 18 key risks**, including risks that are essential to people’s lives, such as the destruction or degradation of livelihoods, serious disruptions of supply and shortage of basic services, especially water, energy and communications, or damage to critical infrastructure and transport infrastructure.

- **Global biodiversity loss** is a high-output risk, resulting from the accumulation of impacts from climate change at multiple levels (loss of genetic, species and ecosystem diversity). This risk has a direct impact on 17 key risks, including the **degradation of ecosystem services**.

- The **loss or degradation of ecosystem services** due to alterations in ecosystem functionality caused by changes in climate variables also acts as a driver of significant sectoral impacts. Among the most relevant effects are the **decline in agricultural productivity, the loss of forest ecosystems’ capacity to absorb and store carbon, and the alteration of essential ecological processes such as pollination**.

5.2. In-degree

Reflects the level of **dependence of one risk on others** within the system. Risks with a high in-degree are influenced by multiple risks, making them **critical points of impact accumulation**. Identifying them allows us to anticipate possible **collapse points** or accumulation of stress, being crucial to design effective **adaptation and resilience** strategies.

Among the risks with the highest in-degree are:

- **Risk of destruction or degradation of livelihoods and subsistence** (in-degree: 29), reflecting high vulnerability to multiple climate hazards, especially in fragile social and economic contexts.

- **Risk to security due to severe disruptions in water, energy or food supplies**, as well as damage to critical infrastructure (in-degree: 20). This risk, which falls under the peace, security and social cohesion sector, is highly sensitive to cascading impacts.

- In urban areas, the **risk of serious disruptions to the supply of basic services** (water, energy, communications) due to extreme events such as floods, droughts or extreme temperatures has an in-degree of 14. It also acts as impacts spreader, with an out-degree of 13, making it a doubly relevant node.

- The **risk of loss or degradation of ecosystem services** due to disruptions in ecosystem functionality has an in-degree of 17, as well as a high out-degree (16), positioning it as a strategic node in the risk network.

- In the financial sector, risks such as **asset price corrections** and **reduced financial activity** due to falling investment and savings in areas highly disrupted by extreme weather events, standing out with in-degree of 22 and 19 respectively. Both act as recipients of systemic impacts.

- Sectors such as **tourism** are also identified as important **receptors of climate impacts**, especially due to their dependence on stable environmental conditions and sensitive infrastructure.

5.3. Integrated and systemic management

The analysis of climate change from a complex risk perspective, using graph theory, has provided a **structural and relational view** of the risks system. The results points a highly interconnected network that highlights the need to adopt **integrated and systemic management** approaches that consider not only individual risks, but also their interactions and cascading effects.

In addition, the analysis of complex risks also allows informing policies and stakeholders who are interested in **specific risks** and want to know which other risks may **directly affect** them or those they may affect.

6. Prioritisation of policies and adaptation measures

ERICC-2025 proposes an integrated framework for prioritising climate action based on three complementary dimensions: **temporal urgency, level of knowledge and monitoring, and governance and management modality**. This approach links scientific evidence with the planning requirements of the **PNACC 2026-2030**, allowing decision-makers to determine where to concentrate public efforts and which risks require immediate response, enhanced knowledge or advanced inter-sectoral coordination.

6.1. Urgency dimension

The first dimension assesses the **temporal need for intervention**, combining three factors: expected impact severity, risk imminence and recovery capacity.This assessment distinguishes among **maximum, significant and limited urgency**, thereby establishing a basis for sequencing policies and measures over the short and medium term.

ERICC-2025 identifies **13 risks of maximum urgency** which demand **immediate intervention and top-priority consideration** due to their high imminence, probability and severity. These risks are concentrated in the domains of **Human Health**, **Water and hydrological resources**, **Natural Heritage**, **Urban areas**, and **Peace-Security-Social Cohesion**. They represent areas where climate change is already producing tangible effects or where the window of opportunity for action is narrow. Notable examples include increased heat- and pollution-related morbidity and mortality; extreme droughts and floods; biodiversity loss; urban damage from severe hydrometeorological events; and social risks linked to disruption of critical supplies.

A further **31 risks** show **significant urgency**, requiring near-term planning and preparedness, while **7 risks** have **limited urgency**, associated with slower-manifesting processes or greater sectoral-management capacity.

Altogether, this dimension provides temporal prioritisation for adaptation, identifying areas where measures must be anticipatory, preventive and high-impact.

6.2. Monitoring dimension

The second dimension concerns the **confidence level in the available evidence** and the **need for additional monitoring or research**. Three degrees are defined—**advanced, intermediate and basic monitoring**—according to data robustness, methodological consistency and phenomenon complexity.

ERICC-2025 identifies **18 risks requiring advanced monitoring**, mainly in the domains of **Cities and urban planning, Cultural Heritage, Energy, Transport, Industry and Services, Tourism, Financial and Insurance System, and Peace-Security-Social Cohesion**. These risks exhibit **high uncertainty or complexity** and thus **call for increased effort in applied research, data collection and continuous observation**. Information gaps affect both impact characterisation and quantification of inter-sectoral interdependencies—for instance, the relationship between extreme heat and labour productivity, or the financial repercussions of extreme climate events.

An additional **24 risks** require **intermediate monitoring**, implying periodic surveillance and targeted studies on specific aspects, whereas **9 risks** are considered sufficiently characterised and need only **basic monitoring** to validate their evolution.

This dimension helps direct scientific and observational policy, linking research needs with risk management and indicator generation for PNACC tracking and European-Union reporting.

6.3. Management dimension

The third dimension analyses the **governance modality** necessary to address each risk, distinguishing between **sectoral management** and **coordinated management**. Some risks can be handled through specific policies within a given field, while others require **shared decision-making structures, joint planning and inter-administrative cooperation.**

A total of **24 risks** demand **coordinated management**, spanning most domains but especially prominent in **Water and hydrological resources**, **Natural Heritage**, **Forestry**, **Agriculture**, **Urban areas**, and the **Financial and Insurance System**.These are characterised by **high interconnectivity** and the need to integrate environmental, economic and social policies.

For example, the managements of extreme droughts necessitate coordination among water, energy and agricultural authorities. Addressing biodiversity risks requires alignment between conservation and land-use planning policies. Financial impacts from climate events call for governance mechanisms linking the insurance sector with public-planning authorities.

The remaining **27 risks** can be managed primarily at the sectoral level, though basic coordination mechanisms should be maintained to prevent maladaptation or vulnerability transfer between domains.

6.4. Multi-priority risks and integrated vision

Cross-analysis of the three dimensions—urgency, monitoring and management—identifies risks that exhibit **multiple priorities**, i.e., those that are simultaneously high-urgency, low-confidence and highly interdependent with other sectors.

ERICC-2025 highlights **14 such multi-priority risks**, distributed among the domains of **Water and hydrological resources**, **Natural Heritage**, **Urban development**, **Industry and services**, **Financial and Insurance System**, and **Peace-Security-Social Cohesion**. These cases represent **strategic nuclei of national adaptation**, where early action, knowledge enhancement and cross-governance are essential to prevent systemic impacts and irreversible losses.

6.5. Strategic orientations for action

Combining these three dimensions yields an **operational prioritisation framework** for **the 2026-2030** period, which encompasses the following aspects:

1. **Immediate action** on maximum-urgency risks, reinforcing prevention and resilience in the critical sectors of health, water, ecosystems, urban areas and social cohesion.

2. **Investment in knowledge and observation,** prioritising advanced-monitoring risks through applied-research programmes and integrated monitoring systems.

3. **Promotion of coordinated governance** for highly complex risks, establishing stable spaces for inter-sectoral cooperation and strengthening institutional capacity for shared risk management.

4. **Synchronisation with European frameworks,** ensuring coherence with the **European Climate Risk Assessment (EUCRA), EIONET and Climate-ADAPT**.

Overall, **ERICC-2025**'s prioritisation framework provides a robust basis for guiding Spain's adaptation policy in the coming decade. This three-dimensional approach (urgency, monitoring and management) enables a transition from diagnostic evaluation to a **strategic climate-action agenda**, reinforcing the resilience of natural, productive and social systems and consolidating Spain's position as a European reference in integrated climate-risk management.

7. Strategic conclusions

Spain´s Climate Change Risks and Impacts Assessment (ERICC-2025) represents the most comprehensive exercise undertaken to date to understand how climate change simultaneously and systemically affects the country's natural, productive and social systems. Its results provide an integrated vision of climate risk, structured around three pillars: **scientific diagnosis, cross-sectoral interdependence, and strategic orientation toward action.**

7.1. Main aggregated findings

The analysis confirms that Spain faces a **highly interconnected system of climate risks**, where physical, ecological and socio-economic impacts mutually reinforce each other. The most exposed sectors—water, agriculture, coasts, natural heritage and forestry—are directly affected by intensifying droughts, heatwaves, biodiversity loss and sea-level rise. In turn, these impacts propagate through the energy, tourism, health and social-cohesion sectors, producing **cascading effects** that compromise well-being, security and economic stability.

The **complex-risk model and sectoral analysis** show that the **water, energy and health nodes** structure the national network of vulnerabilities. Declining water resources, stress on the energy system and population exposure to extreme heat or pollution are the principal vectors connecting environmental degradation with social and financial impacts.

7.2. Most vulnerable sectors and territories

Territorial vulnerability displays a clear **latitudinal and climatic gradient**. **Mediterranean and southern regions** concentrate the highest risks associated with water scarcity, desertification and heatwaves. The **archipelagos** and low-lying coastal zones are especially sensitive to sea-level rise and coastal erosion. The **continental interior** is characterised by exposure to thermal extremes and uneven adaptive capacity, conditioned by resource availability, population density and socio-economic structure.

From a sectoral perspective, **natural systems** (water, forests, biodiversity) are most affected by intensifying physical hazards. **Productive systems** (agriculture, energy, tourism, industry) suffer increasing impacts due to dependence on these natural resources. And **social and institutional systems** (health, finance, cohesion) experience indirect consequences, amplifying inequalities and territorial tensions.

7.3. Additional conclusions

The analysis of interdependencies across the various sectoral chapters shows that the national climate risk system functions as a **dense network**. Within this network, direct impacts on one sector can trigger secondary effects in several others. These **cascading effects** describe how an initial impact causes a series of consequences in different sectors or at different scales. The ERICC-2025 identifies **critical interdependencies** due to their high degree of connectivity and their ability to amplify impacts. Three significant examples are presented below.

The **domain of water and water resources** emerges as a **central node and catalyst for vulnerabilities**, given its direct relationship with natural, productive and social systems. The reduction of water resources, for example, not only affects agriculture and hydroelectric power generation, but also the cooling of industrial facilities, urban supply and public health, creating a domino effect that can simultaneously compromise food production, energy stability and human well-being.

Another example of significant interdependence focuses on the **combined impact of extreme heat on health, energy and labour productivity**. During episodes of intense heat, health and labour systems face increased demand and reduced response capacity, with effects on morbidity and mortality, especially among the **most vulnerable groups**. Prolonged heat waves increase electricity consumption for cooling, putting pressure on the energy system's capacity just when its efficiency is at its lowest. The increase in demand coincides with peaks in air pollution and loss of productivity in sectors involving outdoor work or in dense urban environments. This leads to economic losses, saturation of health services and greater exposure of the most vulnerable workers. In the long term, the persistence of these events **alters the organisation of work and social behaviour**, requiring structural measures in occupational health, urban design and energy management.

A third example can be found in coastal areas. **Rising sea levels, extreme storms and coastal erosion** generate a series of chain reactions that affect tourism, the local economy and critical infrastructure. Damage to beaches, promenades, ports and urban areas reduces the quality of the tourist destination, causes economic losses and alters land use patterns. In turn, the degradation of coastal ecosystems such as dunes and marshes reduces natural protection against storms, exacerbating future impacts. The cost of recovery is transferred to the financial system and public budgets, closing a cycle of cumulative vulnerability. This complex is one of the clearest examples of how **physical and economic risks are intertwined**, and of the need to **plan coastal adaptation with integrated conservation, urban planning and economic criteria**.

The interdependencies between these three examples form the **backbone of the risk network** and reflect a negative feedback loop, where each component amplifies the vulnerability of the others. Based on these, various **interaction subsystems** are structured, grouping the rest of the sectors into specific impact chains, each with its own dynamics and different levels of urgency.

Beyond the main chains, the analysis reveals the existence of **cross-feedback loops** that amplify the magnitude of the risk. For example, the loss of vegetation cover due to forest fires reduces infiltration and increases runoff, raising the risk of flooding. In turn, flooding damages electrical and transport infrastructure, causing interruptions in supply and economic activity.

Similarly, the degradation of natural ecosystems reduces carbon absorption capacity, contributing to a **further increase in greenhouse gas concentrations** and reinforcing the climate change cycle. Such complex feedbacks require **adaptive governance** approaches that integrate environmental management with economic and territorial planning.

Non-linear effects are also evident in the **social dimension**. Cumulative impacts on health, income, or employment tend to increase inequality and reduce the adaptive capacity of the most vulnerable groups, creating a **loop of reinforced vulnerability**. For this reason, ERICC-2025 emphasises that adaptation cannot be addressed solely from a sectoral management perspective, but rather from a **systemic and inclusive vision**, where the reduction of social vulnerabilities is an integral part of climate policy.

7.4. Representation of the risk system and strategic priorities

The network of interdependencies identified shows that risks must be analysed in the context of the **national climate risk system**, where hazards and risks are connected to second-order subsystems (e. g., agriculture, tourism, coasts, transport, finance) and a set of support sectors (e. g., governance, social cohesion). This shows that the most influential nodes are not always the most exposed, but rather those whose alteration can generate the greatest indirect effects.

This confirms the need to prioritise adaptation measures based **on their ability to prevent cascading impacts**, not just their direct exposure.

Among the most notable operational conclusions are:

- The importance of strengthening **integrated water cycle management** as a cornerstone of water, energy and food security.
- The need to incorporate **climate resilience into energy and urban planning** to reduce the spread of cross-sectoral impacts.
- The strategic role of **Nature-Based Solutions (NbS)** and ecosystem restoration as preventive infrastructure against compound risks.
- The urgency of developing **cross-sectoral information and early warning systems** to anticipate chain effects and activate coordinated responses.

Overall, ERICC-2025 demonstrates that climate change must be understood as a **systemic risk**, capable of simultaneously affecting multiple sectors and scales. Its management requires moving beyond linear approaches and advancing towards **integrated adaptation planning** that strengthens the resilience of the country as a whole through cooperation between sectors, territories and institutions.

7.5. Knowledge and action areas to be strengthened

The assessment identifies **information and capacity gaps** that must be addressed to improve the precision and effectiveness of adaptation policy.

In particular, it is necessary to:

- **Strengthen climate observation and monitoring**, especially in sectors with advanced-monitoring needs (energy, transport, cultural heritage, tourism and finance).
- **Develop homogeneous indicators** to evaluate risk evolution, measure policy effectiveness and ensure coherence with European and international frameworks.
- **Promote interdisciplinary research** integrating physical, social and economic sciences to better understand interdependencies and non-linear effects of climate impacts.
- **Enhance institutional capacity** for coordination and risk governance, linking climate adaptation with territorial, urban and economic planning.

ERICC-2025 underlines that knowledge must not be merely cumulative but operational—translated into decision-support tools, early-warning systems and periodic policy-effectiveness assessments.

7.6. Relevance for adaptation policy

The findings of ERICC-2025 provide the technical foundation for **for the planning of the 2026–2030 Work Program of the PNACC** and aligning it with European resilience-building strategies.

The assessment delivers a **clear hierarchy of priorities**—based on the dimensions of urgency, monitoring and management—guiding the allocation of resources toward the most critical risks and those with the highest multiplier effect.

The findings from ERICC may offer valuable insights and evidence-based guidelines to progress in the following aspects:

1. **Integrate adaptation as a structural policy:** not only as a sectoral or environmental response, but also as a cross-cutting axis of economic, urban, and social policies.
2. **Act preventively** on maximum-urgency risks, reinforcing structural measures in health, water, ecosystems, coasts and social cohesion.
3. **Promote multi-level governance and inter-sectoral coordination**, integrating climate-risk management into financial, planning and regional-development decisions.
4. **Foster Nature-Based Solutions and territorial resilience,** harnessing their capacity to reduce risks, improve environmental quality and generate socio-economic co-benefits.
5. **Align national policies** with European and international frameworks, ensuring methodological coherence and data interoperability.