METHODOLOGY 3

Laura Asensio Martínez, Cecilia Ribalaygua, Francisco García Sánchez, Luis Torres Michelena

For the preparation of this document, a methodology of its own has been developed based on the previously mentioned reference frameworks. This methodology aims to adapt to the local institutional and physical reality, adapting to the objectives of the Santander Capital Natural project in which it is embedded, following a multidisciplinary and participatory approach. The following graph shows the methodological scheme followed in this report.

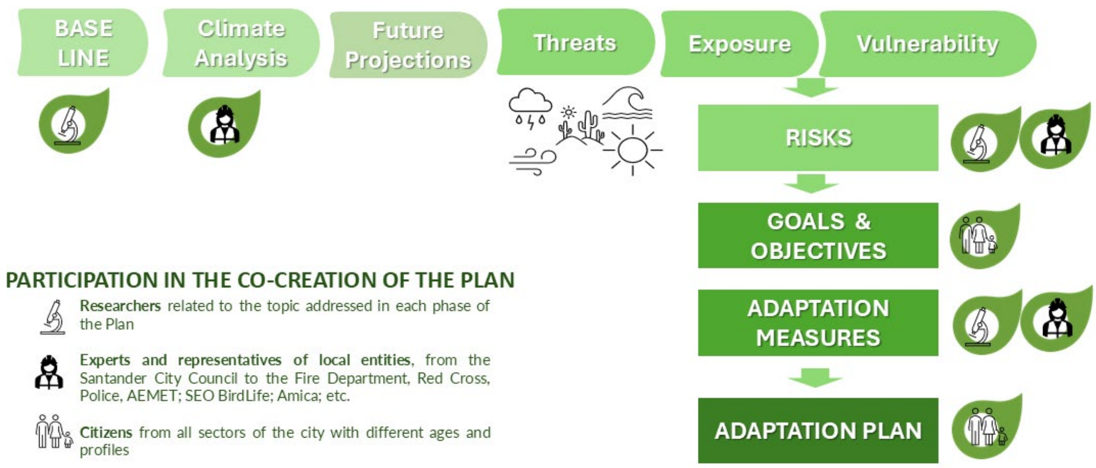

Figure 3.1. *Methodological scheme*

Source: CINCc (UC) - FIC, 2024.

The Adaptation Plan is typically developed in three main phases. In the first phase, climate scenarios and future hazards are analysed. This first objective focuses on designing a baseline study, identifying hazards through participatory workshops, conducting a climate analysis and projecting priority climate hazards into the future. The second phase involves analysing the risks associated with exposure and vulnerability for each identified hazard. It includes analysing zonal and sectoral exposure and vulnerability, as well as conducting participatory workshops to validate the results. In the third phase, adaptation measures are defined based on the results of the risk analysis and citizen participation. Adaptation goals and objectives are established, measures to increase urban resilience are identified and prioritised, and implementation details are defined, including geolocation and identification of monitoring indicators for each measure.

Following this scheme, the Santander Climate Change Adaptation Plan too has been developed in three broad successive phases. Each of these phases has further involved four steps, combining scientific developments with participatory workshops.

3.1

PHASES OF THE ADAPTATION PLAN

3.1.1. Phase 1. CLIMATE SCENARIOS AND FUTURE THREATS

The first part of the work focuses on identifying future threats in different areas of the city. This task, which is key as it is the basis for further work, is divided into four steps:

1.1 **Design of the baseline study** to address climate risk management, including the definition of the state-of-the-art, the technical scope of the results, and the identification of unmet information needs and their technical requirements.

1.2 **Participatory hazard identification** through technical workshops with local stakeholders from sectors such as emergencies, health, tourism, local governance, etc.

1.3 **Climate analysis**, including the assessment of current climate and the generation of local climate change scenarios based on the Common Management Information Protocol (CMIP) outputs of the 6th IPCC Assessment Report.

1.4 **Future projection of each of the identified priority climate hazards**, including their modelling and spatio-temporal representation for each of the scenarios.

3.1.2. Phase 2. RISK ANALYSIS

In this phase, risks that may be caused by exposure and vulnerability to each of the hazards are analysed in order to identify the necessary local adaptive capacity.

2.1 **Analysis of the exposure** (zonal and sectoral) to climate change for each climate hazard and for each time scenario, taking into account the material, human and environmental approach. The sectors exposed to each hazard are also identified.

2.2 **Vulnerability analysis** for each priority hazard. The degree of vulnerability is assessed in this phase, taking into account non-climatic factors of sensitivity and adaptive capacity.

2.3 **Zonal and sectoral analysis of climate risk** for each priority hazard and time scenario.

2.4 **Participatory workshops** with local decision-makers and stakeholders to validate the results of the risk indexes.

3.1.3. Phase 3. DEFINITION OF ADAPTATION MEASURES

Based on the results of the risk assessment, citizen participation and the review of national and international references, measures are identified and then prioritised and defined to achieve the adaptation objectives and targets. This phase involves the following steps:

3.1 **Definition of goals and adaptation objectives.**

3.2 **Identification of measures and mechanisms** to increase the urban resilience of the municipality, its green environment and key sectors to extreme events resulting from climate change and/or climate variability.

3.3 **Participatory process of prioritisation of measures**. Through the exchange of available information on exposure and vulnerability, and technical and training sessions on adaptation options, the degree of prioritisation of measures is assessed.

3.4 **Definition of adaptation measures.** Geolocation and provision of details based on participatory processes for the proper development of the measures. This includes a list of reference cases for each measure.

3.5 **Identification of monitoring indicators** for each measure to assess the achievement of adaptation objectives over time.

3.2 CALCULATION OF THE RISK INDEX

Climate risk analysis is indicative of the probability of damage from climate events with a human, material and environmental focus. The analysis integrates the following basic criteria:

1. The **hazard level** in terms of magnitude and recurrence of the main hydro-meteorological hazards resulting from climate change.

2. The **degree of exposure** to which people, their properties, livelihoods, urban infrastructure and services or the environment may be subjected.

3

Sensitivity to climate change, which will reflect the degree of weakness or susceptibility to damage from a climate-related stimulus or climate variability on a social, material, economic and environmental basis.

4

Adaptive capacity understood as the ability of a system to adjust to change and to moderate potential damages, take advantage of opportunities or cope with consequences. It will be indicative of the set of local capacities, resources and institutions that foster the implementation of effective adaptation measures.

In the IPCC Sixth Assessment Report (AR6) adaptive capacity assumes the benefits of developing policies and documents that integrate risk mitigation and adaptation. However, in defining how to assess risk, the IPPC (2022) assumes the dominant role of the Hazard-Exposure-Vulnerability trinomial, the latter being the essential aspect of sensitivity.

Thus, the IPCC's proposed framework assumes the following interactions as shown in figure 3.2; climate change, through hazards, exposure and vulnerability, generates impacts and risks that can exceed the limits of adaptation and cause loss and damage. Human society can adapt, maladapt and mitigate climate change, while ecosystems can adapt and mitigate within their own limits. Ecosystems and their biodiversity provide livelihoods and ecosystem services. Human society impacts ecosystems and can restore and conserve them.

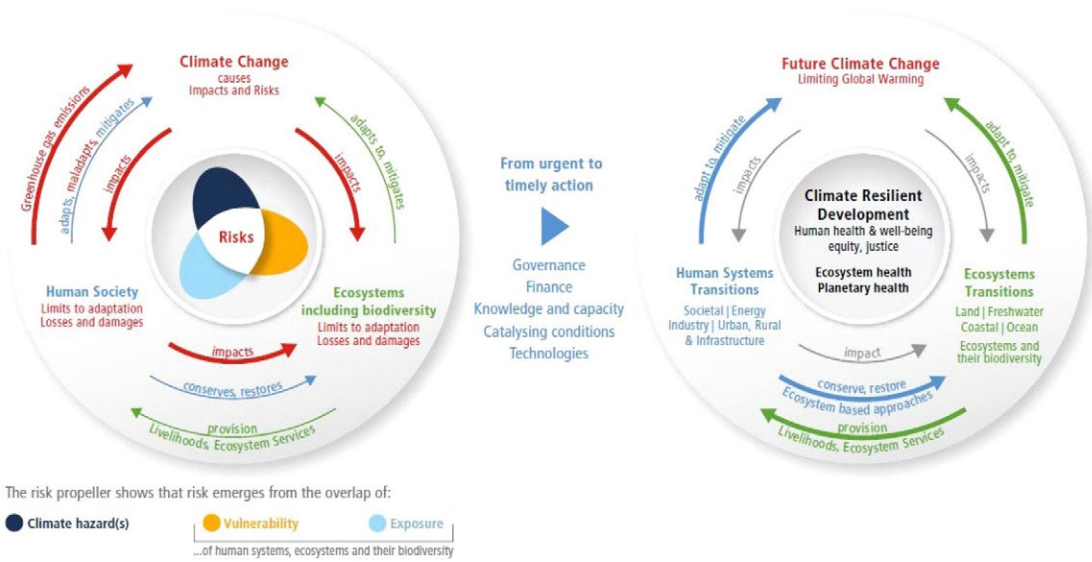

Figure 3.2. *Interactions and risk reduction options*

Source: IPCC, 2022.

It also defines the following risk reduction options. The recognition of climate risks can strengthen adaptation and mitigation actions as well as risk-reducing transitions. Action is enabled by governance, financing, knowledge and capacity building, technology and catalytic conditions. Transformation involves systems transitions that strengthen ecosystem and societal resilience[1].

The **overall integration** of the risk components for each of the hazards analysed is generally formulated as follows:

V = S/AC	V = Vulnerability Index
R = H1/3 + E1/3 + V1/3	R = Risk Index

The **time horizon** of the climate risk indices is applied to the current situation to determine the baseline, which is then calculated with future climate information (climate variables) taking into account the uncertainty levels of climate projections associated with extreme events. The basic climate scenarios of the CMIP6 models are analysed as: SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5, which form the so-called *Tier 1*.

With regard to the **time horizon**, short-term climate conditions are analysed (2010-2040) for deriving the most pressing recommendations in the climate context and focusing attention on the most relevant information for policies in the coming years. This is carried out along with the analysis for the medium (2041-2070) and long term (2071-2100), so as not to lose sight of the end of the century, when the expected changes will be more pronounced and the interventions needed to deal with their impacts will be of greater magnitude. In turn, it allows the approaches reflected in the Adaptation Plan to be aligned with the adaptation policies at the national level through the National Plan for Adaptation to Climate Change (PNACC) 2021-2030, and at the regional level through the Cantabria Climate Change Strategy 2018-2030.

This **scope of results** is developed under the impact chain analysis approach. For each impact chain, maps of climate hazard (H), exposure (E) and vulnerability (V) of the affected system are developed, including population, housing, infrastructure, environment and biodiversity, economy and tourism. In turn, each of these impact chains can consider one or several dimensions of study, human, material or environmental approach, depending on the case.

With regard to the unit of representation of risk, the development of indicators and the results of the vulnerability and climate risk indices are applied as a functional unit of analysis and representation the **census section** from the official cartography of the Santander City Council (year 2021). This division of the municipal territory of Santander into 8 districts and 148 census sections is carried out according to the operational criteria, such as facilitating sta-

[1] In a), the colours of the arrows represent the main human society interactions (blue), ecosystem interactions (including biodiversity) (green) and the impacts of climate change and human activities, including loss and damage, under continued climate change (red). In b), the colours of the arrows represent human system interactions (blue), ecosystem interactions (including biodiversity) (green) and reduction of impacts of climate change and human activities (grey).

tistical studies, and is defined, fundamentally, by a criterion of population volume. The census sections of Santander comprise a population area of 1,500-2,000 inhabitants (Ayuntamiento de Santander[2]).

This division has been modified in two of its census sections, Sections 011 and 009 have been specifically grouped together in order to enable their correspondence with the cartography and census section codes published by the National Statistics Institute (INE) in its latest update in 2021. The municipality of Santander is finally divided into 147 census sections distributed across 8 census districts covering an area of 35.8 km^2.

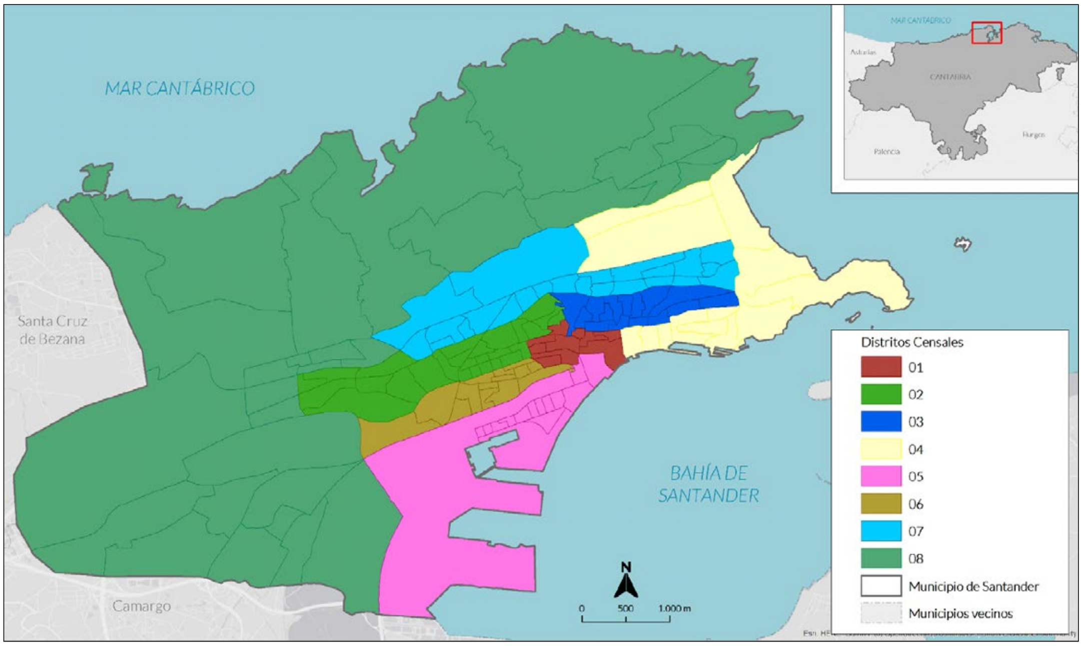

Figure 3.3. *Cartography of census sections and districts in the municipality of Santander.*
Source: CINCc (UC) - FIC, 2024 based on the official cartography of Santander City Council, year 2013.

This unit (census sections) has been selected for several reasons:

(i) On the one hand, its use offers the possibility of associating relevant thematic information from official sources, available for example through the Population and Housing censuses, which finally allows the generation of specific vulnerability indicators at the most detailed level possible, covering the entire municipality of Santander.

2 See the following web link: http://datos.santander.es/resource/?ds=distritos-secciones&id=4df3d23-3784-4eea-99bc-2dac7dab6576

(ii) As these mapping units have an official status, it enables their common use by local staff and regional, even national, authorities to identify urban areas that are particularly exposed and vulnerable to various climate hazards.

(iii) Due to its detailed territorial scale, its use is appropriate to capture the physical and socio-economic reality of the municipality and to highlight the inequalities present in the territory that affect the climate risk pattern of the municipality. Therefore, its consideration represents not only a statistical unit but also a physical or local control and planning unit.

Finally, it should be noted that the results will be applicable to the entire municipality of Santander; although the adjacent area will be analysed for such physical-environmental and socio-economic conditioning factors that may have a direct influence on the municipality.

3.3 METHODOLOGICAL ADVANCES OF THE STUDY

This study has a strong methodological basis in national and international frameworks, as detailed in the previous section. However, the access to spatialised sources and databases has made it possible for the study to make some significant methodological advances, which will enable us to have a robust Adaptation Plan. The main methodological advances are as follows:

3.3.1. High degree of robustness in defining the future climate as a basis for work

A rigorous scientific analysis starts with a study of the possible outcomes of the climate change simulation, and then quantifies in some detail the likely effects of climate change in each of the different scenarios. These simulations of future climate represent what we have to adapt to and form the basis on which vulnerability, risk and adaptation analysis is built. It is, therefore, essential that these simulations meet the technical and scientific requirements for their use in adaptation, in line with the state-of-the-art of climate science.

- Firstly, work has been done on a **local scale**, because although climate change is a problem with global causes (GHGs all over the planet), its consequences are and will be local. These changes will also be very different at quite close points, especially in topographically complex terrains. For this reason, it is often necessary to resort to downscaling techniques.
- Another important requirement is **the need to adequately consider and quantify the uncertainties** inherent in any climate simulation, for which it is necessary to work with as many projections as possible, obtained from different global Climate Mod-

els, different assumptions of future GHG concentrations, and different downscaling tools, etc.

- Since assessing the effects of each of these projections may be too time-consuming, a proper quantification of uncertainty requires the application of specific methodologies to get an idea of the range of **possible effects**.
- It can also be argued that before simulating the future, the simulation tools should be tested by estimating the observed climate at the study area in recent times, through extensive verification of the downscaling tools and verification of the Climate Models. This analysis must be carried out for each study area and on a local scale, as both the **downscaling tools and the Climate Models** may perform well in a given area, but not in other areas of the planet, or even in other nearby locations.

These verification and validation processes, in addition to allowing the rejection of those models or tools that do not exceed a minimum level of reliability, are essential for a better quantification of uncertainties (the better the results, the lower the uncertainties) and for creating a solid base.

3.3.2. Detailed definition and spatialisation of exposure and vulnerability

The second step in addressing climate risks is to analyse the vulnerability of the elements and the set of **systems exposed** to climatic events. Recent impacts related to extreme weather events such as heat waves, droughts, floods, cyclones and forest fires reveal important differences between the vulnerability and exposure of ecosystems and human systems to current climate variability. In other words, observed damages are not directly and solely correlated with the level of hazard (intensity and frequency) at which hydrometeorological events occur, but are also affected by non-climatic factors, such as the multidimensional inequalities that often result from uneven development processes. These differences shape the differential risks of climate change, which in turn can be sectoralised. Thus, in order to address climate change risk and impact analysis, there is a widely agreed framework on the need to consider vulnerability as an indispensable variable in the risk equation.

Vulnerability is a complex term, subject to continuous institutional and governmental debate, which encompasses both sectoral fragilities (sensitivity) and opportunities to benefit from or adapt to expected change (adaptive capacity). According to the definition given by the current framework proposed by IPCC Working Group II[3], the term vulnerability is defined as the "propensity or predisposition to be adversely affected. Vulnerability comprises a variety of concepts including sensitivity or susceptibility to damage and lack of capacity to respond and adapt". Although vulnerability is a factor independent of exposure, its analysis is not key for systems that are not threatened by any hazard. Such assessments have not only been shown to increase knowledge about risks and potential impacts of climate change, but have also be-

[3] See IPCC (2022).

come one of the main tools used by decision makers responsible for creating and developing regulations, legal instruments, plans and actions for climate change mitigation and adaptation at national, regional and global scales (Füssel & Klein, 2006).

Finally, the **integration of the results** of the three previous components (hazard, exposure and vulnerability) makes it possible to obtain the risk and impact associated with each analysed event.

The general relationship between these three component is given by: R (risk) = H (hazard) x E (exposure) x V (vulnerability). And its general definition is as follows: ''Potential for consequences where something of human value (including humans themselves) is at risk with an uncertain outcome''. Risk is often represented as the probability of occurrence of hazardous events or trends multiplied by the consequences should such events occur. Risks result from the interplay of vulnerability, exposure and hazard (IPCC, 2022b; MITECO, 2022). Risk assessment has, therefore, the objective of defining a qualitative and/or quantitative synthetic coefficient that represents the convolution of the probabilities of different hazard intensities (H), in relation to the conditions of exposure (E) and vulnerability (V) in a given area.

3.3.3. Integration of territorial and population scenarios for risk calculation

The calculation of future territorial and population scenarios is essential for a rigorous projection of risk in the face of climate change. Scenarios make it possible to anticipate how the geographic distribution of the population and land use will evolve in the future, which is crucial for understanding how the population, its urban fabric and ecosystems may be affected by climate impacts. By projecting urban expansion, for example, it has been possible to identify areas at risk of floods, droughts or other extreme weather events, but also to count on the future adaptive capacity of the nucleus. Similarly, by estimating population growth, it has been possible to integrate the distribution of the population and the population profile of Santander in the 2050 and 2100 scenarios into the calculation. This information provides a solid basis for adaptation planning, allowing the implementation of specific measures to reduce vulnerability in areas identified as critical in the future scenarios.

The reference documents for these calculations are based on the current General Urban Development Plan, which establishes the sectors with residential and industrial land use as well as with objective variables for buildability and the provision of open spaces and green areas. As for socio-economic variables, the main documents that define future trends on society, productivity and competitiveness are those published by the Ministry of the Presidency (Gobierno de España, 2021b)[4] and the determinations as defined by the Independent Authority for Fiscal Responsibility "AIREF" (AIREF, 2023)[5].

[4] Oficina Nacional de Prospectiva y Estrategia del Gobierno de España (coord.). España 2050: Fundamentos y propuestas para una Estrategia Nacional de Largo Plazo. Madrid: Ministerio de la Presidencia. 2021.

[5] See the document at: https://www.airef.es/wp-content/uploads/2023/03/OPINI%C3%93N-SOSTENIBILIDAD/230324.-Opinio%CC%81n-sostenibilidad-largo-plazo-AAPP.-Incidencia-demografi%CC%81a.-web.pdf

3.3.4. Monitoring the impact of adaptation measures

The development of a tool for monitoring the effect of measures on local adaptive capacity through indicators is critical for several reasons. First, it provides a mechanism for evaluating the effectiveness of implemented adaptation measures, allowing policy makers and stakeholders to monitor and adjust actions as needed to ensure that the desired results are being achieved. In addition, these tools provide a way to measure and communicate progress toward adaptation goals, facilitating accountability and transparency in the decision-making process. Finally, by providing objective, evidence-based data on the impact of adaptation measures, these tools can inform future adaptation strategies and policies, helping to strengthen the resilience of the city of Santander to the impacts of climate change.

With these objectives, approach and methodology, the Adaptation Plan has been elaborated, the results of which are included in the three phases of this document: climate scenarios and future threats (chapter 4); risk indices by census areas (chapter 5); and definition of adaptation measures (chapter 6).