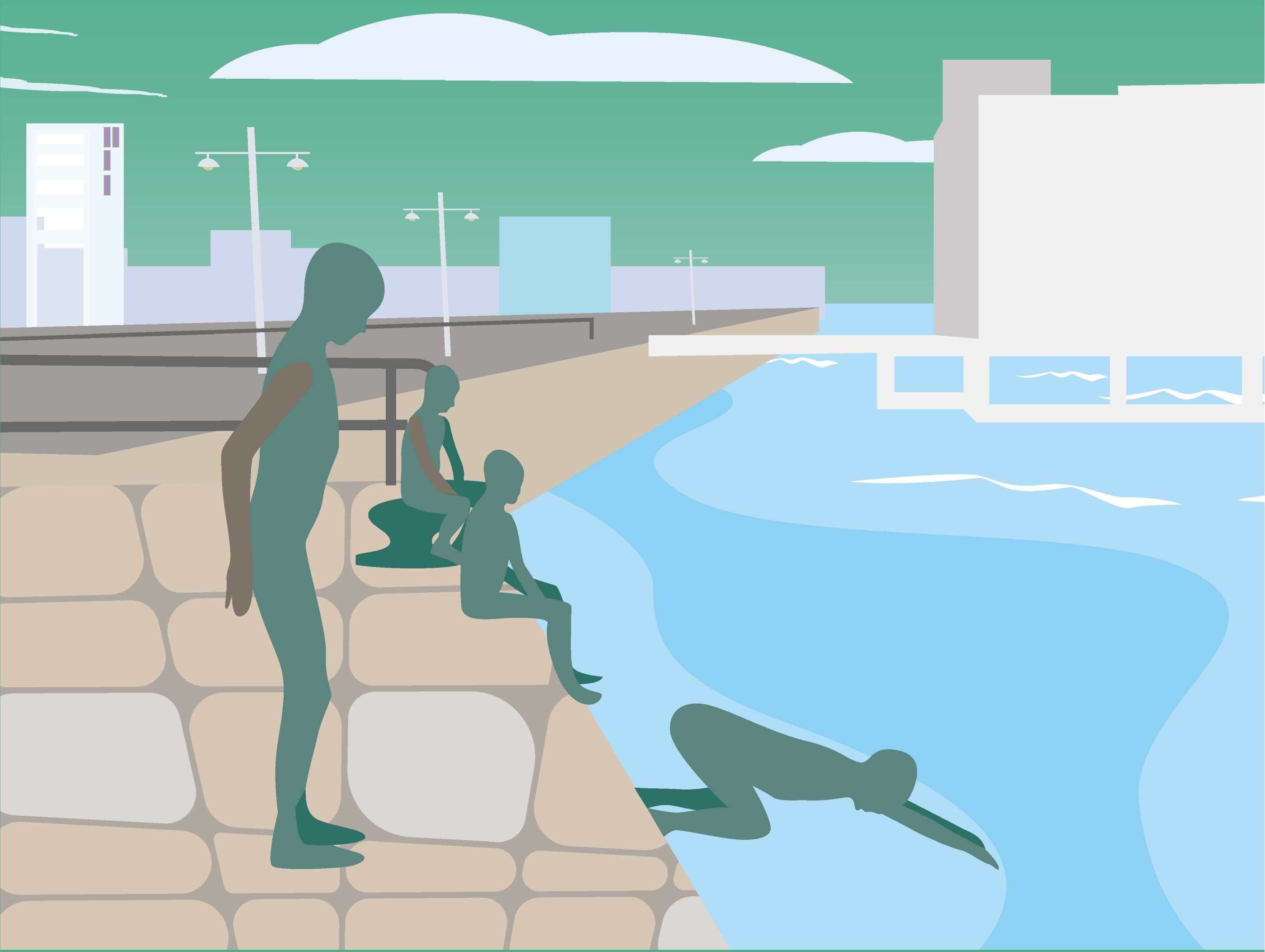
SANTANDER
CAPITAL
NATURAL

Climate Change
Adaptation Plan



GOBIERNO DE ESPAÑA
VICEPRESIDENCIA TERCERA DEL GOBIERNO
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO
Fundación Biodiversidad
Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea
NextGenerationEU
SANTANDER CIUDAD
fic
SEO BirdLife
amica
UC

CLIMATE CHANGE ADAPTATION PLAN
SANTANDER CAPITAL NATURAL

BIODIVERSITY FOUNDATION
Ministry for the Ecological Transition and the Demographic Challenge (MITECO)
of the Government of Spain
Recovery, Transformation and Resilience Plan (PRTR)
Funded by the European Union - NextGenerationEU.

The Climate Change Adaptation Plan has been developed within Santander Capital Natural project.
Santander Capital Natural is a project led by Santander City Council whose main objective is to strengthen the role of the network of urban green areas in the conservation of biodiversity at a local level, enhancing the environmental services that help to improve the quality of life of the citizens of Santander. The project relies on strategic planning, citizen participation and the involvement of Santander's society.
This project will last until December 2025 and its partners include Santander City Council, SEO/BirdLife, the Asociación Amica, the Climate Research Foundation (Fundación para la Investigación del Clima) and the University of Cantabria.
Santander Capital Natural has the support of the Biodiversity Foundation of the Ministry for the Ecological Transition and the Demographic Challenge (MITECO) of the Government of Spain, within the framework of the Recovery, Transformation and Resilience Plan (PRTR), funded by the European Union - NextGenerationEU.

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea
NextGenerationEU

CLIMATE CHANGE ADAPTATION PLAN SANTANDER CAPITAL NATURAL

Coordination

Francisco García Sánchez, Cecilia Ribalaygua Batalla and Laura Asensio Martínez

Authors

Universidad de Cantabria. Dept. of Geography, Urban and Regional Planning

Francisco García Sánchez
Cecilia Ribalaygua Batalla
Nareme Herrera López
Pablo Fernández de Arroyabe Hernáez
Domingo Fernando Rasilla Álvarez
Carmen Gil de Arriba
Juan José González Trueba
Sebastián Pérez Díaz
Francisco Conde Oria

Fundación para la Investigación del Clima (FIC)

Laura Asensio Martínez
Jaime Ribalaygua Batalla
Luis Torres Michelena
Emma Gaitán Fernández
Carlos Prado López
Lorena Galiano Sánchez

Other Project Team Members: UC: Elena Martín Latorre | FIC: Robert Monjó Agut, César Paradinas Blázquez, María del Carre Díaz, Francisco Cartas Martínez

Contributors: Lourdes Galindo Delgado, Mario González Ceballos, Sara Núñez de la Fuente

Graphic Design: Karma Webs

The present work has been submitted to a double blind external scientific evaluation following the DORA and COARA principles, and has passed the review of Fundación Biodiversidad and the Editorial Committee.

Acknowledgements

Dª Gema Igual Ortíz (Alcaldesa de Santander); Margarita Rojo Calderón, Belén Domínguez Fernández-Viña, Pablo Ruiz Rodríguez (Concejalía de Medioambiente, Ayto. de Santander); José Trojaola Gutiérrez (Santander Fire Department); Rosa García Borbolla (Oficina de Turismo, Santander); Mariano Sánchez García (CSIC Real Jardín Botánico); Antonio Bezanilla Cacidedo (Architect); Iñaki Romero Fernández de Larrea (Paisaje Transversal); Daniel González Bedia (Karma Webs); Aurora Ortega (AEMET D.T. de Cantabria); Verónica Gutiérrez Polidura (Telefónica, SMART CITY Santander); Jesús Ignacio Jiménez Chaparro (UC); Cristina Torre Balseiro (EUTA); Mª Mato Vallecillo (Empresa Municipal de Turismo de Santander).

Cover image:
Daniel González Bedia (Karma Webs)

Vallehermoso, 34. 28015 Madrid
Teléfono: 91 593 20 98
www.sintesis.com

ISBN: 978-84-1357-933-7

Impreso en España. Printed in Spain

CONTENT

CONTENT

SUMMARY

The Santander Climate Change Adaptation Plan is being developed within the framework of the Santander Capital Natural project, led by Santander City Council. The Plan has been carried out with the scientific support of researchers from the Department of Geography, Urban and Regional Planning, led by the CINCc Research Group (City, Infrastructures and Climate Change) of the University of Cantabria (UC, Universidad de Cantabria), together with the Climate Research Foundation (FIC).

Santander Capital Natural is supported by the Fundación Biodiversidad of the Ministry for Ecological Transition and the Demographic Challenge (MITECO) in the framework of the Recovery, Transformation and Resilience Plan (PRTR), funded by the European Union - NextGenerationEU. The main objective of the project is to strengthen the role of the network of urban green areas in the conservation of biodiversity at the local level, enhancing the environmental services that help to improve the quality of life of the citizens of Santander, and to establish strategies and actions to make Santander a more resilient city. The project partners include Santander City Council, SEO/BirdLife, the Asociación Amica, the Climate Research Foundation, and the University of Cantabria.

The document proposes 85 adaptation measures based on the generation of robust future climate scenarios and a detailed calculation of the risk to the different foreseeable hazards, based on the exposure, sensitivity and adaptive capacity of the city and its population. These future climate scenarios have been developed by updating the methodology to the Sixth Report of the Intergovernmental Panel on Climate Change (IPCC6), placing Santander at the international forefront of adaptation. In addition to this robust scientific basis, the plan has been developed over 2023 and 2024 in a continuous participatory process with different institutions and local stakeholders, involving citizens through various workshops. Various management areas, councils and functional units of Santander City Council, such as the Fire Brigade and Civil Protection, as well as regional and state bodies such as CIMA - Research Centre of Environment (Centro de Investigación del Medio Ambiente), Police (Guardia Civil) and AEMET - Meteorological State Agency (Agencia Estatal de Meteorología), have been involved in defining a set of potential threats.

Based on the 'most recent' future climate scenarios, the study includes exposure to coastal flooding and rainfall, as well as the impacts of rising temperatures with drought and heat waves. As a result of this work, the Santander Adaptation Plan includes a detailed risk study for the years 2050 and 2100, identifying four adaptation goals: Biodiversity; Resilient City; Health; and Adapted Society and Economy. The structure of the Plan is articulated around these goals, with

various adaptation objectives for each of them. Measures that will enable Santander to achieve these goals have been defined in participatory processes.

The main contributions of the Santander Climate Change Adaptation Plan consist of:

1. The definition of the most up-to-date future climate scenarios for the city of Santander, taking into account the latest scientific advances in the field and positioning the city at the forefront of local information on future climate.

2. The participatory approach, which has made it possible to base both the analysis and the adaptation solutions on the results of the successive participatory processes, which have involved citizens and various social groups, as well as the active participation of local agents involved in the city.

3. Solutions from a multidisciplinary approach, avoiding 'maladaptation'. The multidisciplinary scientific team drafting the project is made up of 17 researchers from different areas such as Physics, Meteorology and Climate, Engineering, Geography, Architecture, Urban Planning, Sociology, Archaeology and Tourism.

4. The definition of the risk index at census section level and for each of the hazards detected, which allow for the establishment of control actions, both in terms of exposure to these hazards and their sensitivity at the micro level, representing a considerable methodological advance in Municipal Adaptation Plans.

5. The identification of 85 adaptation measures, with key information and resources to be implemented in subsequent action plans. Each measure has specific objectives, baseline information, in many cases with geolocation of points of interest, degree of urgency and monitoring indicators, among other aspects.

6. Integration with other studies and strategies of the city. The document is configured in coordination with and on the basis of previous work on the city of Santander, making it a reference document. For its preparation, the Plan has rigorously compiled and updated more than a hundred databases related to its population, economic activities, open spaces, health, safety and civil protection, climate impacts, etc.

TEN REASONS FOR AN ADAPTATION PLAN

1

Cecilia Ribalaygua, Francisco García Sánchez

The Santander Climate Change Adaptation Plan is being developed within the framework of the Santander Capital Natural project, led by the Santander City Council. The document has been prepared with the scientific support of researchers from the Department of Geography, Urban and Regional Planning, led by the CINCc Research Group (City, Infrastructures and Climate Change) of the University of Cantabria (UC), together with the Climate Research Foundation (FIC).

Santander Capital Natural (SCN) is supported by the Fundación Biodiversidad of the Ministry for Ecological Transition and Demographic Challenge (MITECO) in the framework of the Recovery, Transformation and Resilience Plan (PRTR), funded by the European Union - NextGenerationEU. The main objective of the project is to strengthen the role of the network of urban green areas in the conservation of biodiversity at the local level, enhancing environmental services that help to improve the quality of life of the citizens of Santander, and to establish strategies and actions to make Santander a more resilient city. Its partners include Santander City Council, SEO/BirdLife, the Asociación Amica, the Climate Research Foundation, and the University of Cantabria.

This Adaptation Plan is part of the SCN project, being one of the three actions leading to the municipal strategy (A1 SCN Strategy), such that by consolidating the results from the climate adaptation perspective of this Plan (Action A2) and those of the Biodiversity Strategy Update (Action A3), an integrated municipal green infrastructure project (Action A4) can be developed. Specifically, this document adds to the results of the other actions of the SCN project, the analysis of future climate and the risks associated with it, as well as the advisable adaptation measures to avoid it, with solutions based on nature, and largely supported by the municipal green infrastructure.

The Adaptation Plan document is divided into 8 chapters, consisting of the following process and expected results:

- This first, introductory section is articulated around the answers to three key questions about the need for, and the features of this report.
- The second chapter reviews the objectives and approach of the report, while the third chapter develops the general methodology being followed in this document, including the phases that led to the development of the plan, its scope and basic unit of representation.

- Chapters 4 and 5 condense this report's technical analysis, with Chapter 4 assimilating the results of Climate Hazards from a study of past and present climate scenarios and their projection into the future. The fifth chapter, on the other hand, integrates all studies leading to the Risk Indices, which present the results from the study on exposure and vulnerability. Chapter 5 ends with the diagnosis and the strategic adaptation proposals of this research study.
- Chapter 6 includes 85 Adaptation Measures, including a description of the Adaptation Goals and Objectives, as well as the details of all the Measures in the form of fact sheets.
- The last two chapters incorporate the accompanying plans necessary for the elaboration of this plan: the Measure Monitoring Indicators (Chapter 7) and the Participation Plan developed throughout the project (Chapter 8).
- Finally, a cartographic information and risk level tables for the census sections has been included at the end of the document.

1.1 WHAT IS AN ADAPTATION PLAN?

Adaptation plans emerge as planning and action tools for municipalities once the need to adapt to the consequences of expected variations in the local climate has been identified. These are documents that enable adaptation decisions for the risks that the municipality will face as a result of climate change. These changes are accelerating and are already having an impact on cities, which is why municipalities are looking for agile and efficient tools to organise their strategies for adapting to this new situation.

What is climate change?

The Intergovernmental Panel on Climate Change or IPCC (2022) in its Sixth Assessment Report (AR6)[1] defines climate change as a variation in the state of the climate, which can be identified in the mean and/or variability of its properties, and which persists for an extended period over decades or longer. Due to human action, since the Industrial Revolution, the concentration of Greenhouse Gases (GHG) in the atmosphere has been steadily increasing, which has already led to modifications in physical-biological systems. Despite efforts to mitigate GHG emissions, including CO_2, the impact of this change is inevitable. Hence, strategies and plans to combat climate change must include mechanisms for anticipation, prevention and preparation to deal with the occurrence of extreme events and climate variability.

Why are cities key to adaptation?

Cities are particularly sensitive to the effects of climate change, but they are also the best-placed decision domains to address adaptation (Dodman et al., 2022)[2]. The term 'adaptation' is used to describe the process of adjustment to actual or projected climate and its effects, with 'adaptive capacity' defined as the ability of systems, institutions, humans and other organisms to adapt to potential harms, take advantage of opportunities or cope with the consequences[3]. Cities are, therefore, best placed to develop this adaptive capacity, min-

[1] IPCC (2022) Annex II: https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/ IPCC, 2022: Annex II: Glossary [Möller, V., R. van Diemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (eds.)]. En: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897–2930, doi:10.1017/9781009325844.029.

[2] Dodman, D., B. Hayward, M. Pelling, V. Castan Broto, W. Chow, E. Chu, R. Dawson, L. Khirfan, T. McPhearson, A. Prakash,Y. Zheng, and G. Ziervogel, 2022: Cities, Settlements and Key Infrastructure. En IPCC (2022) Chapter 6.

[3] IPCC (2022). Annex II.

imising negative impacts and taking advantage of the potential opportunities provided by 'this phenomenon'.

What is the background?

Many municipalities have already developed adaptation action plans. More than 900 cities, towns and villages across Europe have committed to adaptation by joining the Covenant of Mayors for Climate and Energy. Many others participate in other networks and initiatives (e.g. 100 Resilient Cities, C40 Cities or ICLEI Resilient Cities), which provide them with knowledge and opportunities to exchange experiences or support in adaptation planning.

Also, participation in EU-funded projects –Life, Interreg or research projects– can also help cities to access adaptation funding, learn from other experiences or obtain much needed local climate knowledge from researchers. In the autonomous community of Cantabria, other adaptation initiatives have been promoted in nearby municipalities such as Suances, Polanco, Miengo, Arnuero or Noja, among others, which, despite not having local adaptation plans, have joined the group of signatories of the Global Covenant of Mayors for Climate and Energy, as is also the case of Santander, which has been a member since 2008.

What is the structure of Local Adaptation Plans?

The general structure of Local Adaptation Plans is based on the creation of future climate scenarios, detecting the future climate scenarios and detecting climate extremes to identify the hazards that this situation might entail. After identifying such hazards, the focus is on identifying the risk[4] of damage due to hazards in different urban areas.

The process of identifying risk varies across different methodologies. The result is more refined when the databases from which exposure and vulnerability are calculated are comprehensive, and exposure and vulnerability are complete and comprehensive. In most Spanish background plans, the future scenario is limited to climate. However, in the case of Santander, a methodological advance is proposed wherein the future climate scenarios are added to the exposure and vulnerability scenarios for the time horizons. For this, it is necessary not only to understand the current state of society, the productive structure and the urban fabric, but also to project their characteristics and morphology into the future.

4 In the context of climate change, risks can arise from the potential impacts of climate change, as well as from human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species. In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards and the exposure and vulnerability of the affected human or ecological system to the hazards. Risk can be minimised by a fourth factor: adaptive capacity. IPCC, 2022, Annex II.

1.2

WHY DOES SANTANDER NEED AN ADAPTATION PLAN?

The municipality of Santander is in a privileged situation with respect to other municipalities where the consequences of climate change are already leaving traces of drought or severe flooding. Even so, the results obtained on the future climate in the municipality project a certain level of risk, both due to the climate and the factors derived from these changes in the urban fabric, infrastructures, biodiversity and the health of the population.

In addition to this external change, the particular social, physical and economic conditions of the city projected for the future show an increasing vulnerability to the risks detected. Aspects such as heat waves, which are projected to increase in duration and intensity, will pose an even greater risk in a scenario where the weight of people over 75 years of age will increase significantly. This is just one example of the importance of knowing the risks that Santander will face in a future climate scenario and, hence, of designing a plan to begin to tackle the situation.

In the light of the scientific studies carried out, and considering the environmental, urban, social and economic variables of the municipality, there are at least 10 reasons for developing an Adaptation Plan in Santander:

1.2.1. There is scientific evidence of climate risks

The studies show a moderate increase in temperatures for the years 2050 and 2100 in Santander, both in winters and summers, along with special effects in the summers, which will

Figure 1.1. *Exposure to intense wave events*

Source: CINCc (UC), 2023.

see a notable increase in the number of heat wave days and tropical nights. A change in the precipitation regime is also foreseen, spacing out over time and increasing the probability of extreme rainfall.

1.2.2. Infrastructures and the urban fabric will be affected

Climate change is putting significant pressure on Santander's infrastructure and urban fabric, and this trend appears to be intensifying over time. Extreme weather events such as flash floods and more intense storms are already impacting the city, highlighting the vulnerability of its existing infrastructure. In addition, the urban fabric faces challenges in terms of stormwater management and drainage, with more frequent and severe urban flooding threatening the habitability and safety of its population. Other extreme weather events, such as more intense and prolonged heat waves, are also putting pressure on urban infrastructure, from energy systems to water supply and sanitation networks. Increasing urbanisation increases soil sealing and reduces the absorption capacity of urban areas, contributing to increased risk of flooding and landslides. To address these challenges, it is crucial to implement adaptation measures that build on the city's green infrastructure and sustainable water management practices.

Figure 1.2. *Impacts on urban infraestructure due to extreme weather events*
Source: CINCc (UC), 2024.

1.2.3. The health of citizens will be affected

Rising temperatures due to climate change may increase the incidence and severity of respiratory diseases in Santander due to the proliferation of allergens and air pollutants, such as pollen and smoke from forest fires, which can trigger or worsen conditions such as asthma and allergic rhinitis. In addition, extreme heat can make breathing more difficult and increase the risk of exacerbations for people with chronic respiratory diseases such as COPD.

In addition, heat waves, tropical and sultry nights can have a significant impact on the health of Santander's citizens and their general well-being.

Some extreme events of this nature can increase the risk of heat-related illnesses such as heat stroke, dehydration, exhaustion and aggravation of pre-existing health conditions such as cardiovascular and respiratory diseases. Also, hot nights, characterised by unusually high night-time temperatures, make it difficult to get adequate rest and can lead to sleep disturbances, which negatively affect mental health and daytime performance. For vulnerable populations, such as the elderly, children and people with chronic illnesses, the impact of these extreme conditions can be even more severe.

Other climate-related threats, such as the transmission of a wide range of diseases, is a trend that has already been observed in Europe, and will continue to be present in the coming decades (EEA, 2021)[5]. Through the Urban Heat Island and other microclimatic conditions, urban environments increase the exposure of their populations to vector-borne diseases that are associated with the increasing presence of exotic species migrating northwards due to climate change. The Aedes albopictus (tiger mosquito) has become a common species in southern Europe and transmits diseases such as Zika, dengue and Chikungunya. As climatic suitability for the tiger mosquito depends on factors such as sufficient rainfall, high summer temperatures and mild winters, climate change is expected to further facilitate the spread of the tiger mosquito across Europe with changing temperature and rainfall patterns, thereby increasing suitable habitat for its proliferation (EEA, 2021).

1.2.4. Local biodiversity will be compromised by climate variations

In addition to other factors of global change, climate is also creating a significant impact on Santander's biodiversity. Rising temperatures and changes in precipitation patterns are altering natural habitats and displacing many plant and animal species to more climatically favourable areas.

The consequence is a loss of biodiversity, as some species may not be able to adapt quickly enough or find new habitats suitable enough. Some studies show that marine ecosystems off

[5] See: https://www.eea.europa.eu/data-and-maps/indicators/vector-borne-diseases-2/assessment

the coast of Santander are experiencing changes in species distribution due to rising water temperatures, which could affect the food chain and local fisheries in the long term.

Figure 1.3. *Water stress under new climatic conditions*
Source: CINCc (UC), 2024.

Climate change may also have impacts on Santander's terrestrial biodiversity, such as the loss of natural habitats due to desertification and soil degradation, as well as an increase in the frequency and intensity of forest fires. Some changes may lead to a decrease in the diversity of plant and animal species, as well as the loss of vital ecosystem services, such as pollination and local climate regulation. Biodiversity conservation in Santander becomes even more crucial in this context, with the need to implement adaptation measures to protect local ecosystems and ensure their resilience to the impacts of climate change.

Other reasons why Santander should have an Adaptation Plan is attributed to its **differential characteristics**. In addition to the frequency and magnitude associated with adverse climate events, local characteristics linked to demographics, socio-economics and the environment constitute what are known as differential risks of climate change. This reality gives rise to the following reasons, described below, why Santander needs a Climate Change Adaptation Plan.

1.2.5. The eminently urban character of the municipality

Urban environments face higher risks of damage from climate change than rural areas due to the high concentration of population, economic activities and critical infrastructure.

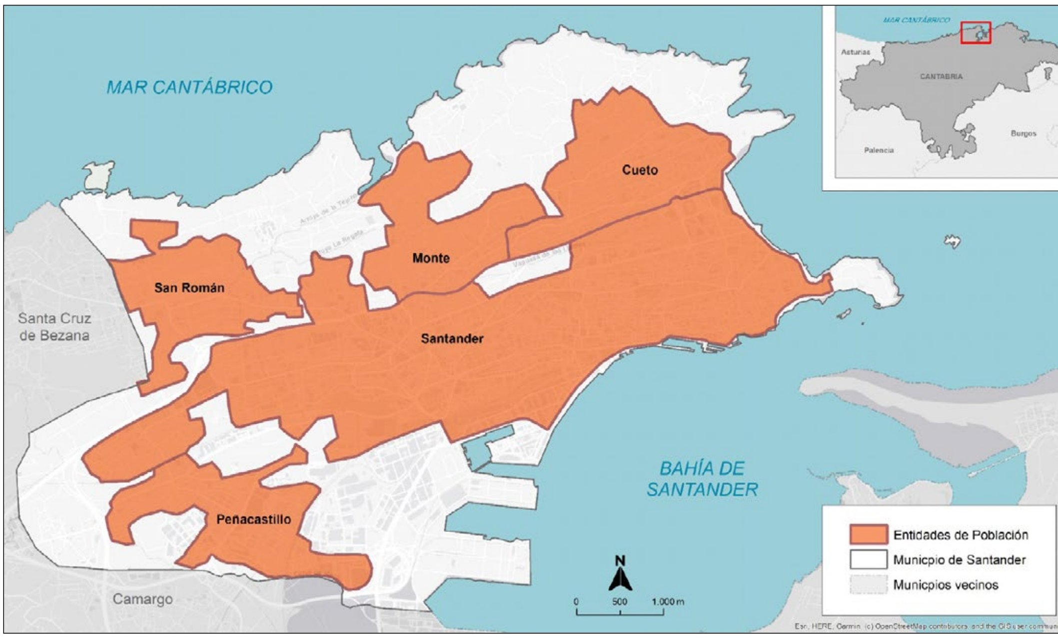


Figure 1.4. *Population entities (residential) that make up the municipality of Santander.*
Source: CINCc (UC) - FIC, 2024 based on Population Entities of the National Geographic Institute.

The municipality of Santander covers an area of approximately 36 km^2 in the heart of the region's coastal strip. In addition to encompassing the city, which is the capital of the Autonomous Community, the municipality includes the towns of Cueto, Monte, Peñacastillo and San Román de la Llanilla, creating an urban continuum with a complex spatial division. The Municipal Register of Inhabitants for 2022 puts the number of residents in the municipality at 171,657, the base value for subsequent calculations; although the national institute of statistics (INE) puts the figure at 171,693 inhabitants (INE, 2023). In Santander, as in other cities, the replacement of natural vegetation by artificialised surfaces and buildings alters temperature, humidity, wind direction and rainfall patterns[6]. Impervious surfaces prevent excessive amounts of rainwater from seeping into the ground and raise temperatures in cities compared to the surrounding region by storing heat and creating the so-called 'urban heat island effect', among others.

[6] Only 37.73% of the municipal land is permeable.

1.2.6. An increasingly ageing population will be increasingly vulnerable

Currently, the municipality of Santander falls into the category of intermediate cities[7] where demographic and economic development have left a mark in several areas of territorial planning. Since 1900, with a population of nearly 55,000 inhabitants, the municipality of Santander has experienced constant residential and industrial growth until almost the end of the last century, when it reached about 200,000 inhabitants in 1995. Thereafter began a period of population decline, with certain fluctuations leading to the current population of under 175,000 inhabitants.

According to the last 10-yearly Population and Housing Census of the INE in 2021, the total population of the municipality of Santander was estimated at 172,002 people (INE, 2023), of which approximately 12% were under 16 years of age, 62% were between 16 and 64 years of age, both included, and almost 26% were over 64 years of age.

In the future projection of the distribution of the population of Santander in 2050 and 2100, the official assumptions (ICANE population projections) of birth rates, migration and current demographic trends have been considered, as well as foreseeable medical and health care improvements. For both horizons, an increase in the proportion of older people in Santander has been observed, in line with the overall demographic trend of an ageing Spanish population, given that advances in medical care and quality of life are expected to contribute to greater longevity. This significant increase in the number of older people highlights an increase in the municipality's vulnerability to risks related to rising temperatures and extreme events, both cold and intense heat.

1.2.7. A large floating population will continue to grow

The current average population density for the municipality of Santander is 4,914 inhabitants/km^2. The census sections with the highest population density are mainly concentrated in the centre of the urban area. It should be noted that, although this population is permanent throughout the year, during the holiday season, mainly in summer, the volume of inhabitants increases considerably, as the city and the region are great tourist destinations. According to ICANE[8] data, the total number of overnight stays in the city of Santander in 2022 was 1,066,050, very similar to the pre-pandemic period. It should be borne in mind that the greatest pressure is being exerted by extra-hotel tourism models, which are not accounted for in these figures. This population also increases in the academic period, without necessarily being reflected in either the national census or the local census.

7 "An intermediate city is one that possesses and provides infrastructure and public services that allow it to be a platform for the integration of its territory and at the same time guarantees the intermediation of flows, whether of goods or people; it has a political and/or administrative function to facilitate territorial management and guarantee citizen participation; its economic function or economic activities contribute a higher percentage to gross value added compared to the surrounding urban agglomerations and it has a population between 50,000 and 1 million inhabitants." (GIZ, 2016).

8 In: https://www.icane.es/data/viajeros-pernoctaciones-estancia-ocupacion-plazas-categorias-zonas

Today, there is an exponential trend in the growth of holiday homes. In the coming years, this trend is expected to continue, with the already significant floating population continuing to increase in a context of climate change and a trend towards deseasonalisation, which implies the need to strengthen the tourism sector with measures covering climate change adaptation, mitigation and awareness.

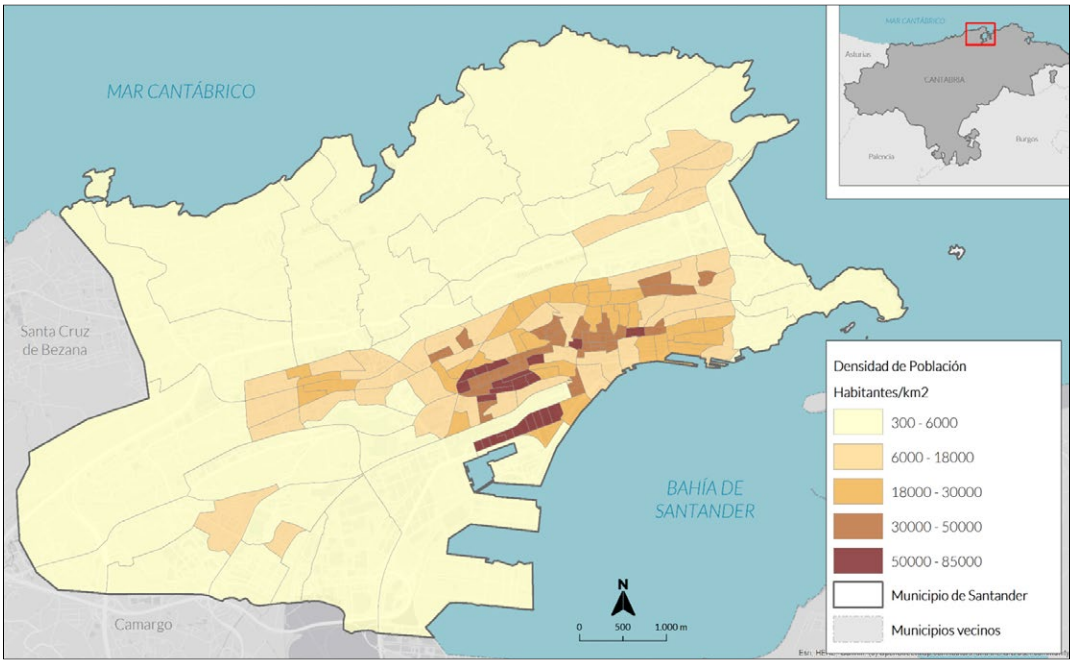


Figure 1.5. *Population density (inhabitants/km²) by census section in the municipality of Santander*
Source: CINCc (UC) - FIC, 2024 based on INE's 2021 Population and Housing Census.

1.2.8. A physical structure will need to adapt to reduce climate impacts

The physical structure of the municipality is characterised by an alternation of parallel elevations and depressions arranged along a north-east to south-west axis. Differences in orography and solar orientation in some places accentuate the vulnerability to certain climatic hazards. The municipality has been developed around the Bay of Santander by filling in and draining the land corresponding to the marshes and estuary areas, mainly for the installation of port and industrial activity.

From a morphological point of view, the whole municipality is characterised by its location on old platforms of marine abrasion, today raised to different levels. In the inner area of the Bay of Santander, the waters flow into several rivers. Also worthy of note is the wetland formed by the Las Llamas stream in the watercourse of the same name and other small streams and marshy areas in the Bay, such as the wetlands of the Raos Canal to the south of the municipality. The morphology of the territory reveals sectors vulnerable to water impoundment that need to be analysed. Likewise, the rise in sea level poses the risk of the beaches receding, with consequent economic and social impacts.

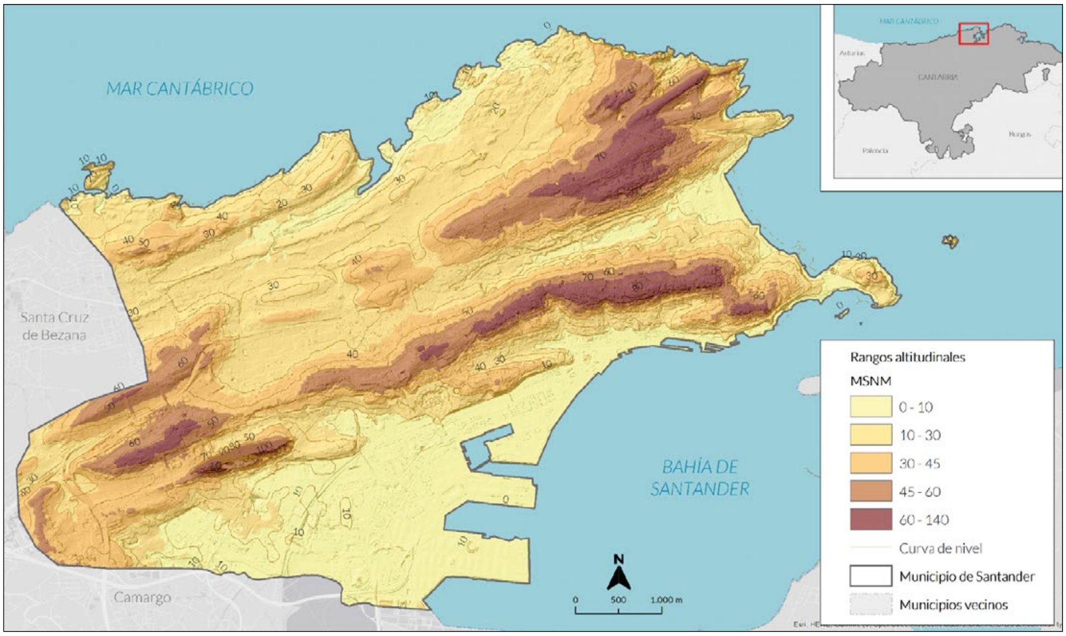


Figure 1.6. *Orography of Santander municipality*

Source: CINCc (UC) - FIC, 2024 based on the Digital Terrain Model at 2 m resolution from LIDAR data of the Military Geographic Institute and contour lines from the National Topographic Base at 1.25.000 scale.

1.2.9. An economic system that will need to adapt

In Santander's current productive structure, the tertiary sector is the driving force of the municipal economy. In addition to the administrative sector, and other minor sectors such as the secondary industrial and repair sector, the set of activities linked to the tourism sector has a very high relative weight, with commerce, hotels and restaurants clearly standing out. The business structure is characterised by a predominance of small and medium-sized enterprises (SMEs), although large companies, to a lesser extent, represent a very relevant aspect with respect to the volume of employment in the municipal economy (Ayuntamiento de Santander, 2016). The tourism sector needs to adapt to a new demand as well as to new climatic conditions, minimising their effects on visitors and involving them in the local Adaptation Plan.

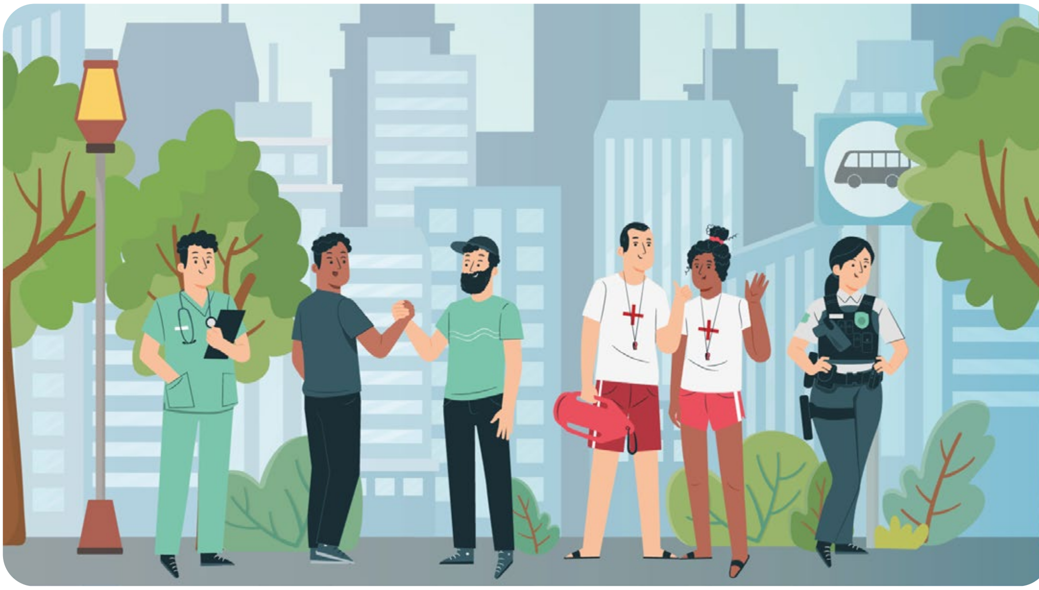
The industrial sector, of great historical relevance, has undergone changes in its location within Santander; its original spaces have been swallowed up by the growth of the city centre. To the southwest, Santander's industrial space currently maintains a notable presence, focusing mainly on the Port and the industrial estates of La Albericia, Candina, Campón-Peñacastillo, Nueva Montaña-Isla de Óleo, Parayas, Mercasantander, Nueva Montaña, Primero de Mayo-Faustino Cavadas, Ciudad del Transporte and Raos. There are also isolated industries and relatively recent developments such as the Parque Científico y Tecnológico de Cantabria, a business deployment area located in the district of Adarzo. These large industrial areas represent impermeable platforms with a strong impact on urban heat islands. Plans to revert and consolidate Santander's green infrastructure necessarily involve identifying these spaces and planning their future in order to help municipal resilience.

1.2.10. Urgency of a Guidance Document

Climate change is already a fact. Data from the last few years on rising temperatures and the floods suffered in some areas, together with some reports of health effects, alert us to the urgency of putting measures in place. These measures, in the short, medium and long term, need to be defined in order to initiate the process of urban adaptation. Santander has a General Urban Development Plan dating from 1997, and despite recent efforts to activate the approval of a new Plan, these urban planning instruments do not have the agility of an Adaptation Plan, which is necessary to incorporate the uncertainty of the reality we are facing.

Finally, Santander needs a Plan that allows society, institutions and all local stakeholders involved to know the future projection of the implications of climate change, with a solid scientific basis. Only with such a document, in which various aspects of each census section have been carefully calculated to identify future vulnerability, will it be possible to make the right decisions. This Plan will also help in raising awareness, one of the main objectives identified in the National Plan and the European strategy, as well as in rigorous monitoring (through indicators) of the improvement of the municipality's adaptive capacity.

A review of these 10 reasons makes it abundantly clear why Santander needs a **Plan**, with **adaptation** measures that optimise the renaturalisation strategy of **Santander Capital Natural**. Moreover, the Plan needs to be implemented in such a way that the increase in the city's biodiversity and improvement of its quality of life is realised under a sustainable framework in time, based on robust projections of future climate, urban and social scenarios for the years 2050 and 2100.



1.3

WHAT FRAMEWORK GOVERNS THIS ADAPTATION PLAN?

This document has been developed on the basis of the **regulatory and methodological frameworks** recognised by scientific and political institutions at different scales.

First, the methodological framework of this document is located at three different scales: it starts from international and European Union (EU) bodies and, in coherence with these supranational guidelines, develops the national and regional frameworks.

The European legislation on climate change and adaptation has been mainly driven by the EU Strategy for Adaptation to Climate Change and the Energy and Climate Union Governance Framework. The EU Strategy for Adaptation to Climate Change (European Commission, 2013), subsequently updated in 2021, focuses on ensuring that adaptation measures are integrated into various sectoral policies. More recently, the European Commission's Communication on guidelines for Adaptation Strategies and Plans (Unión Europea, 2023) details and updates the policy framework for ensuring 'Transformative Adaptation', drawing attention to aspects such as 'maladaptation', fair climate resilience and the promotion of nature-based solutions. Although the directive is designed for National Level Plans, all these aspects have been taken into consideration in the definition of Santander's adaptation measures.

The European Commission's 2023 'Guidelines for Member States' adaptation strategies and plans[9], provides guidance to EU countries on how to develop climate change adaptation strategies and plans. Some of the key aspects of these climate change adaptation policies include:

1. **Developing a common framework for action:** The guidelines establish a common framework for Member States to develop their adaptation strategies and plans ensuring coherence and harmonisation in the response to climate change across the European Union.
2. **Risk-based approach:** A risk management approach is promoted that identifies and assesses the specific climate risks faced by each region or sector, enabling informed decision-making on necessary adaptation measures.
3. **Public participation and consultation:** The importance of public participation and stakeholder consultation in the development of adaptation strategies and plans is emphasised. This ensures that policies are inclusive and reflect the needs and concerns of civil society, the private sector and other relevant stakeholders.
4. **Integrated approach:** Member States are encouraged to integrate climate change adaptation into all relevant policies, such as urban planning, water management, agriculture and public health, among others. In short, a holistic and coordinated response to the challenge of climate change.
5. **Monitoring and evaluation:** Requirements are set out for monitoring and evaluating adaptation strategies and plans, allowing adjustments to be made as necessary, and ensuring that the measures implemented are effective in reducing vulnerability to climate change.

The Santander Adaptation Plan has been adjusted to each of these key aspects developed in the communication. Likewise, and following the criteria developed in the document, in this section we make special mention of the criteria established in the definition and prioritisation of the adaptation options. Thus, according to the third phase of the Guidelines to be developed for the Adaptation Plans established in the document, the following should be undertaken once the risks have been identified:

[9] See the following link: https://www.boe.es/buscar/doc.php?id=DOUE-Z-2023-70034

Define adaptation options

Assess and prioritise adaptation options

Avoid maladaptation

Address uncertainty regarding the effects of climate change

Adaptation strategies and actions should also contribute as far as possible to the reduction of greenhouse gases. On 26 November 2019, the European Parliament adopted a resolution declaring a 'Climate and Environment Emergency' in Europe. The European Commission is, therefore, proposing a framework for EU climate and energy policies for the period 2020-2030 that builds on the progress made in meeting greenhouse gas emissions, renewable energy and energy savings targets. In addition, the European Commission has adopted a set of proposals to adapt EU climate, energy, transport and taxation policies for reducing net greenhouse gas emissions by at least 55% by 2030. The European Green Pact (2019) (European Commission, 2021), ratified by Regulation (EU) 2021/1119 of the European Parliament and of the Council establishing the framework for achieving climate neutrality, which also indicates the need to enhance adaptive capacity and resilience across sectors, takes into account the UN Sustainable Development Goals to help minimise the consequences of climate change and address its unavoidable impacts.

The PRTR funds that finance this project are committed to the adaptation of cities to climate change and are based on principles that promote a comprehensive, participatory and risk-based approach. It emphasises the importance of community participation in identifying climate risks and formulating adaptive solutions, as well as building resilience and sustainability into urban planning. It highlights the need for coordination and cooperation between various actors, including local, regional and national governments, to ensure an effective and coordinated response to the challenges of climate change in cities.

Spanish legislation related to climate change and adaptation is primarily developed in the Law on Climate Change and Energy Transition (Gobierno de España, 2021a). This law sets ambitious targets for the reduction of greenhouse gas emissions, with the aim of achieving climate neutrality by 2050. Title V of the Law states that effective adaptation actions reduce the exposure and vulnerability of social, economic and environmental systems to climate change and can also improve their capacity to recover and re-establish themselves after a climate-related disturbance. Consequently, adaptation brings economic and social benefits that justify it.

The law establishes the National Plan for Adaptation to Climate Change (PNACC; Gobierno de España, 2020a) as the basic planning instrument to promote coordinated and coherent action to address the effects of climate change. The current PNACC defines the objectives, criteria, areas of application and actions to promote resilience and adaptation, prioritising ecosystem-based adaptation to climate change. Other reference documents are the National Strategy for Green Infrastructure and Ecological Connectivity and Restoration. Also, although not exclusively focused on climate change, the Spanish Circular Economy Strategy (Gobierno de España, 2020b) holds significant implications for emissions reduction and climate change adaptation.

At the **regional level**, on 12 December 2019, the Government of Cantabria approved the **Declaration of Climate Emergency** in Cantabria to fight against climate change at the regional level, adopting measures to mitigate its effects and promoting strategies in the economic field that contribute to the same ends. With regard to the ordinances on adaptation to climate change, the Interdepartmental Commission on Climate Change of the Government of Cantabria approved the Strategy for Action against Climate Change in Cantabria 2018-2030 in a session held on 4 April 2018, whose priority objective is to promote action against climate change in line with the commitments made by Spain under the Paris Agreement (included in the Energy and Climate Change Policy Framework 2021-2030).

The Government of Cantabria is currently promoting the updating of the **Climate Change Strategy**, which will be one of the tools to guide and facilitate the transition towards a low-carbon economy. This will in turn act as a key lever to achieve the Sustainable Development Goals of the 2030 Agenda as well as the commitments regarding greenhouse gas emissions, and in general the adoption of adaptation and mitigation measures in the face of the effects of climate change, in line with the 2015 Paris Agreement 'Climate Action' and objectives of the aforementioned European Green Pact and the latest IPCC reports.

In addition, the methodological framework that has served as a reference for the elaboration of this Plan is strongly influenced by the Intergovernmental Panel on Climate Change, as well as by some national reference guidelines for the elaboration of Adaptation Plans, as well as some previous documents on municipal risks. The formulation of results in the context of adaptation to climate change must be adjusted to universal reference frameworks for globalising the understanding of these results and adapting the procedures to standards endorsed by the scientific institutions of reference.

The **Intergovernmental Panel on Climate Change** (IPCC) plays a strategic role in understanding and communicating the science of climate change. By bringing together thousands of scientists from around the world to comprehensively and objectively assess the available scientific information, the IPCC provides a solid evidence base for understanding the impacts of climate change, its causes and possible mitigation and adaptation options. Its importance lies in its ability to translate the complexity of climate science into accessible language and regular reports that are essential for informing climate policy at global, national and local levels, as well as for the methodological development of projects such as this. For this Plan, the precepts contained in the methodological documents for the analysis[10,11] of climate vulnerability and risk published by the IPCC in its fifth and sixth reports have been applied.

These IPCC reports, in turn, are synergistic with the methodological supports used for the development of local strategies and plans derived from various international institutions, such as the United Nations[12], the World Bank[13], the European Commission[14] and its specific planning guidelines for urban areas and municipalities[15]. This global framework is considered to be aligned with the precepts contained in official territorial and institutional work guides and plans, through which a practical and operative approach to risk is achieved that focuses on social perception and considers the diverse casuistry that can occur in urban areas and municipalities.

[10] IPCC (2014). Climate Change 2014; Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

[11] IPCC (2022). Summary for Policymakers. In: Climate Change 2021: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

[12] United Nations (2010). How to develop more resilient cities. A Guide for Local Government Leaders. http://www.unisdr.org/files/26462_manualparalideresdelosgobiernosloca.pdf

[13] World Bank (2011). Guide to Climate Change Adaptation in Cities. Accesible in https://openknowledge.worldbank.org/bitstream/handle/10986/27396/653590WP0v200B0Urban0Handbook0Final.pdf?sequence=1

[14] European Comission (2013). EU Climate Change Adaptation Strategy. Brussels, 16.4.2013 COM(2013) 216 final. Accesible in: http://ec.europa.eu/transparency/regdoc/rep/1/2013/ES/1-2013-216-ES-F1-1.Pdf

[15] For further information: https://climate-adapt.eea.europa.eu/en/metadata/guidances/planning-for-adaptation-to-climate-change-guidelines-for-municipalities

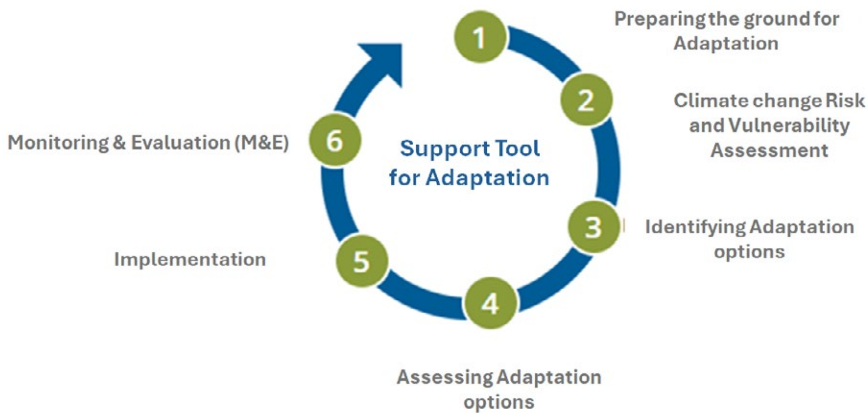


Figure 1.7. *Adaptation support tool Climate-ADAPT*
Source: Climate-ADAPT, 2023. https://climate-adapt.eea.europa.eu/#t-adap

At the **national level**, the methodological supports derived from the **National Plan for Adaptation to Climate Change**[16] have been considered, which establishes a general framework of reference for activities to assess impacts, vulnerability and adaptation to climate change, and which are likewise included in the precepts of regional ordinances, specifically in the Strategy for Action against Climate Change in Cantabria 2018-2030 (Gobierno de Cantabria, 2018).

Finally, with regard to the official plans currently in force in the municipality of Santander, the **Santander Municipal Emergency Plan** - PEMUSAN - (Ayuntamiento de Santander, 2016) is of particular relevance. Its objective is to plan the necessary actions to provide a rapid and effective response to any emergency that may occur within the territorial scope of the municipality, and which, in turn, follows the general guidelines of the Territorial Emergency Plan for Civil Protection of the Autonomous Community of Cantabria (PLATERCANT, 2018).

[16] MITECO (2015). Guide for the preparation of Local Climate Change Adaptation Plans. Ministry of Agriculture, Food and Environment. Available at: https://www.miteco.gob.es/content/dam/miteco/es/cambio-climatico/publicaciones/publicaciones/guia_local_para_adaptacion_cambio_climatico_en_municipios_espanoles_tcm30-178446.pdf

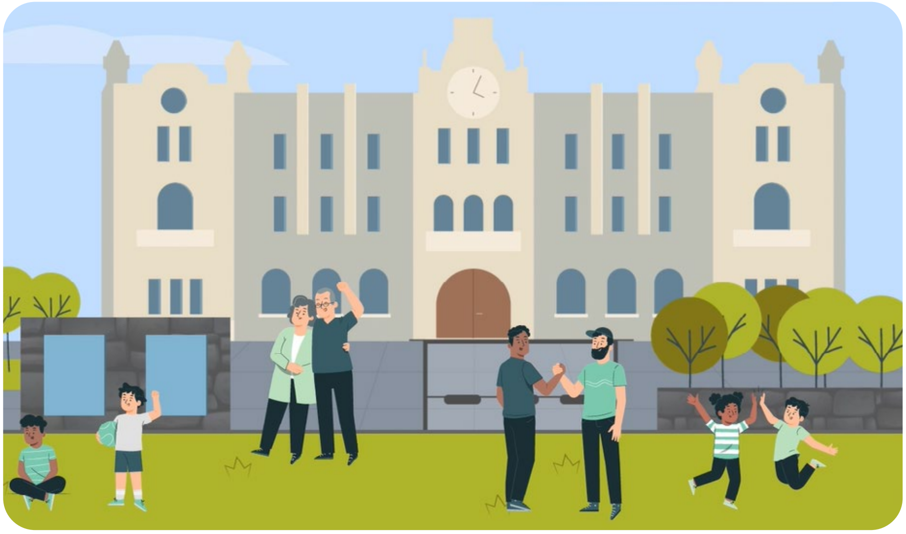
ADAPTATION PLAN: APPROACH AND OBJECTIVES

2

Cecilia Ribalaygua, Laura Asensio Martínez, Francisco García Sánchez

Traditionally, adaptation to Climate Change is dealt with a sectoral perspective in order to facilitate management and responsibility sharing. However, the intrinsic complexity of this reality requires an **integrated multidisciplinary approach**, both for a rational understanding of the problem at its source and to address its management. The analysis of vulnerability and sectoral climate risk is tackled with this approach, arriving at solid criteria that allow the prioritisation of measures that reduce its effects and improve opportunities, avoiding maladaptation. With this objective in mind, the study is tackled from a holistic approach, with a multidisciplinary team of 17 researchers from different areas such as Physics, Meteorology and Climate, Engineering, Geography, Architecture, Urban Planning, Sociology, Archaeology and Tourism, among others, carrying out the whole process in an integrated manner.

In addition, the Plan is based on a **participatory approach**, through the design and organisation of processes of social and institutional participation, from its understanding at the beginning of the process, to the identification of risk, as well as the formulation and prioritisation of measures. This approach has strengthened an integral vision of the results and the adaptation needs in the face of climate change. Participation has also encouraged institutional linkages and support for its implementation, as well as public awareness and involvement.



With this dual multidisciplinary and participatory approach, the Santander Adaptation Plan aims to **increase municipal resilience** by identifying **adaptation strategies** based on the results of risk analysis associated with hazards, exposure and social, environmental and economic vulnerability in all census areas.

The **specific objectives** of the plan are as follows:

Contribute to **local knowledge on climate change** through the generation of local-scale climate scenarios based on the recent outputs of the Sixth IPCC Assessment Report (IPCC AR6).

Identify long-term **adaptation measures**, as well as concrete adaptation targets for each of them, ensuring that the scientific results of the study are transferred and become part of Santander's resilience strategy.

Define the adaptation measures that need to be developed to achieve the adaptation objectives, providing scientific information for their implementation (geolocalised where possible) as well as monitoring indicators for each of them.

Geolocate and delimit geographical areas and sectors of activity highly exposed to the main climate hazards, and identify current and future **vulnerability and risk indices** associated with the municipality of Santander.

Facilitate a **participatory process** to integrate in a consensual manner the perspectives, knowledge and experiences of scientists, decision-makers, managers, citizens and key actors at the local level.

Development of tools to support decision-making in the local adaptation process, based on scientific and technical knowledge and the updating and systematisation of local databases, necessary for monitoring vulnerability and improving adaptive capacity.

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.

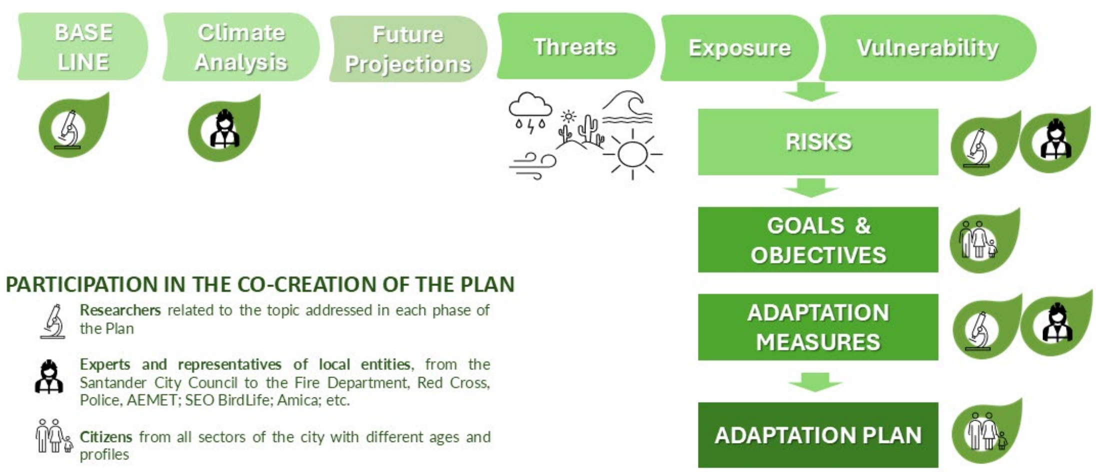


Figure 3.1. *Methodological scheme*
Source: CINCc (UC) - FIC, 2024.

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.

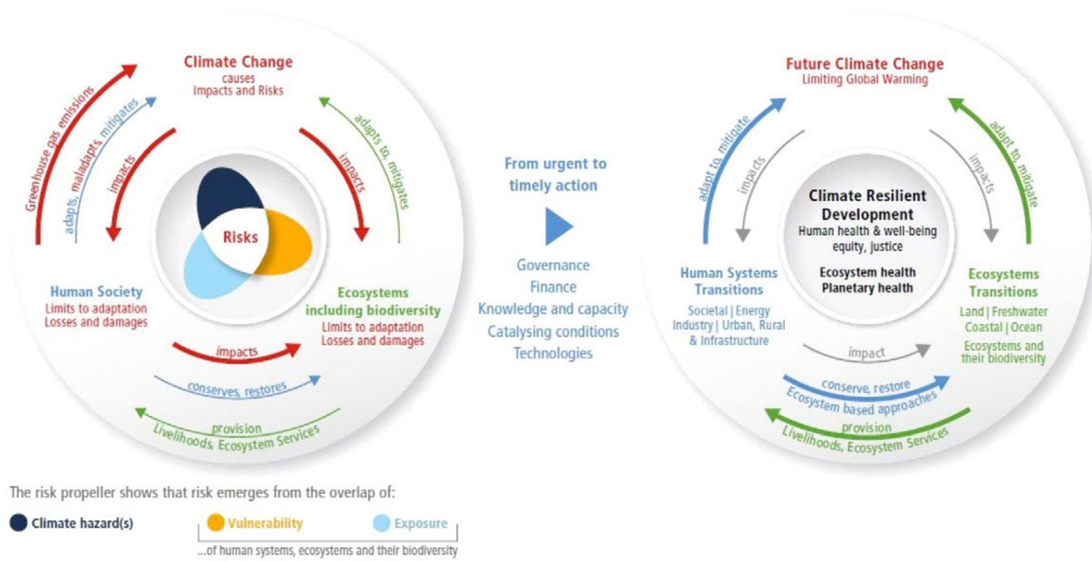


Figure 3.2. *Interactions and risk reduction options*

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 km².

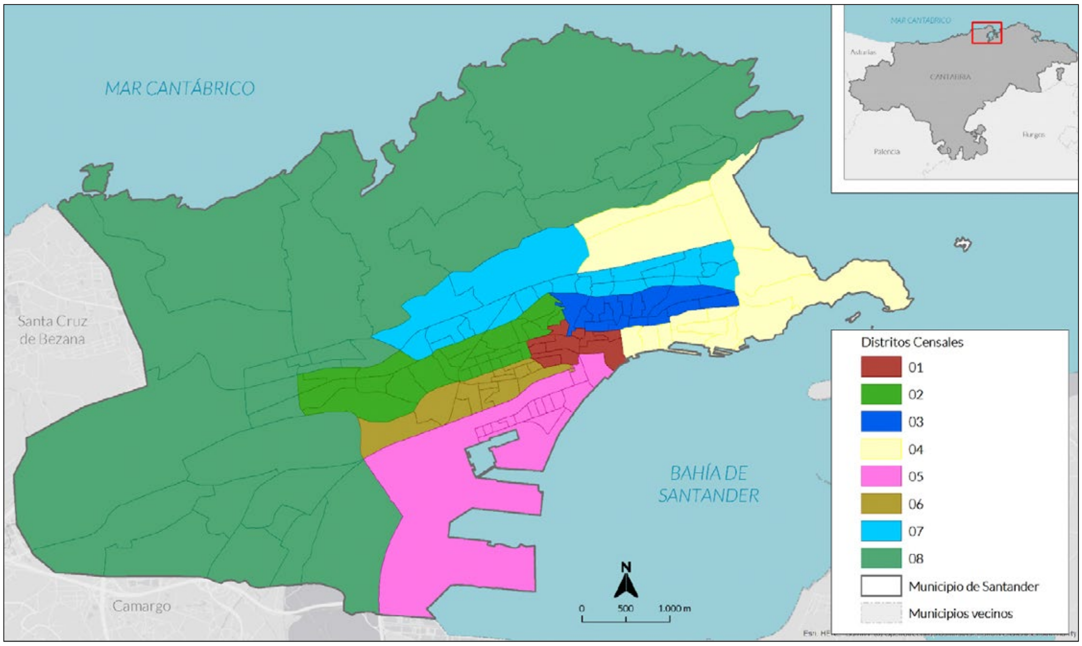


Figure 3.3. *Cartography of census sections and districts in the municipality of Santander.*
Source: CINCc (UC) - FIC, 2024 based on the official cartography of Santander City Council, year 2013.

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).

4 CLIMATE SCENARIOS AND FUTURE THREATS

Laura Asensio Martínez, Jaime Ribalaygua Batalla, Emma Gaitán Fernández,
Luis Torres Michelena, Lorena Galiano Sánchez, Carlos Prado López

Contributors: Domingo Rasilla Álvarez, Pablo Fernández de Arroyabe, Francisco Conde Oria

4.1 IDENTIFICATION AND PRIORITISATION OF CLIMATE HAZARDS

To select the climate hazards to be considered in the Adaptation Plan, it is necessary to have updated contextual information on the existing/observed climate hazard scenario in the municipality, together with the most relevant associated climate parameters in each case and at the specific level. In addition, databases on climate-related disasters or hazards, together with multi-scale indicators of climate vulnerability and human development, or climate action plans, often compose a main and close source of information. Finally, this early detection of climate risks is technically complemented by local support tools, such as the consultation of experts and the analysis of the social perception of climate risks.

In this case, the procedure to identify the climatic hazards with the greatest incidence and relevance in the municipality of Santander consisted of the compilation and analysis of four basic sources of information:

Consultation through existing knowledge and adaptation support tools. Contextual and European level.

Documentary information sources, including regional and local territorial strategies and plans, scientific articles and university publications, among others. Regional and local level.

Public consultation through group workshops with relevant stakeholders. Local level.

Historical records of documented adverse weather damage in the municipality. Local level.

Once each of these sources has been evaluated, climate hazards in the municipality are prioritised using the multi-criteria analysis method, which consists of a semi-quantitative combination of a set of objective criteria that represent the specific incidence of each of the hazards in the territory, including their magnitude and frequency, as well as the damage caused in human and material terms. This process also takes into account two major types of climate hazards:

Direct, i.e., clearly associated with the occurrence of extreme weather events and climate variability, such as heat waves, droughts or extreme rainfall.

Derived, those that are influenced by the climate, generally as an exacerbating factor, but do not have an essentially meteorological or climatic origin, such as disease transmission.

The following sections analyse in detail the results obtained for each of the information sources and, finally, show the procedure and criteria used in the final prioritisation of climate hazards to be considered in this framework.

Preliminary Consultation through Climate Screening Tools

The European Climate Adaptation Platform (Climate-ADAPT)[1] aims to help Europe adapt to climate change by making it easier for users to access and share data and information on expected climate change, climate vulnerability and risk, and adaptation strategies and actions. At the level of climate impacts, coastal areas and floodplains in the western parts of Europe are specifically defined as multi-sectoral hotspots. The Atlantic region in particular is likely to present various challenges related to increased extreme precipitation events, river and coastal flooding or winter storms, among others.

Climate-ADAPT also makes tools available to the public that support adaptation planning. Among the latter, as a case in point, the Urban Adaptation Support Tool (UAST) aims to help cities, towns and other local authorities develop, implement and monitor climate change ad-

[1] The European Climate Adaptation Platform (Climate-ADAPT) is the result of a partnership between the European Commission and the European Environment Agency (AEMA).

aptation plans. The tool provides access to various sets of information generated in European cities, specifically the map viewer collects information from various sources on the observed and predicted spatial distribution and intensity of high temperatures, floods, water scarcity, forest fires and vector-borne diseases. The results of the basic screening of the tool for the city of Santander are shown below:

TABLE 4.1. *Climate-ADAPT climate dataset for Santander.*

TYPE OF HAZARD	INDICATOR USED	VALUE FOR SANTANDER
Extreme Temperatures	Projected number of extreme heatwaves (2020-2052; RCP 8.5; number in 33 years)	1 - Low level
	Annual number of degree-days of cooling or refrigeration (1990 - 2015 average)	31 - Low level
	Variation in the percentage of summer days classified as heatwave[A] between 1951-2000 and 2051-2100	High impact scenario (90th percentile): 40-50 Medium level
Coastal Flooding	Sea level rise in metres (2081-2100)	For RCP 8.5: 0.6-1m Very high level
		For RCP 2.6: 0.2-0.4m Medium level
	Percentage of the city centre flooded in a 1m sea level rise scenario (without defences)	2.08% of the urban core flooded Low level
Pluvial flooding[B]	Projected percentage change in extreme winter precipitation events (from 1971-2000 to 2071-2100; RCP8.5)	5 Low or Moderate level
Shortage, Water Scarcity	Projected trends in drought frequency (2071-2100; months per 30-year period)	5.98 Medium level RCP 8.5
Fires	Wildfire danger (1981-2010; seasonal severity index)	1.15 Low level RCP 8.5
	Predicted wildfire danger (2071-2100; seasonal severity index)	0.99 Low level RCP 4.5

[…/…]

Continuation **TABLE 4.1**

TYPE OF HAZARD	INDICATOR USED	VALUE FOR SANTANDER
Climate suitability for diseases	Climatic suitability for the tiger mosquito (*Aedes albopictus*) 2008-2009	99.96 Very high level (reference city: Bilbao)

Source: CINCc (UC) - FIC, 2024 based on data from the Urban Adaptation Support Tool (UAST) of the European Climate-ADAPT platform.[C]

Available at: https://climate-adapt.eea.europa.eu/en/knowledge/tools/urban-adaptation

A Heat waves are defined as three consecutive days in which both the maximum and minimum temperatures exceed their respective 95th percentiles of the historical period. The analysis is based on 50 climate model projections from the Coupled Model Intercomparison Project Phase 5 (CMIP5) (Taylor et al., 2012), under the RCP8.5 climate scenario.

B Pluvial flooding in urban areas is the result of a combination of heavy rainfall and a high proportion of impervious surfaces. When water cannot infiltrate into the ground, the high amount of surface runoff can exceed the capacity of the drainage system and lead to flooding. Due to climate change, heavy rainfall is likely to become increasingly frequent in many parts of Europe.

C The aim of this tool is to provide an overview of current and future climate hazards facing European cities, rather than at a specific level. The information associated with each indicator can be found at the following link: https://climate-adapt.eea.europa.eu/en/knowledge/tools/urban-adaptation/Urban-Adaptation-viewer-datasets

In Santander, the time series of maximum temperature observed for the period of record from 1971 to 2005 shows a clear trend towards a sustained increase. As it can be seen in figure 11, the observed annual maximum temperature records show averages of 14 - 15°C for the 1970s, reaching averages of around 16.5°C for the last five years of the 20th century.

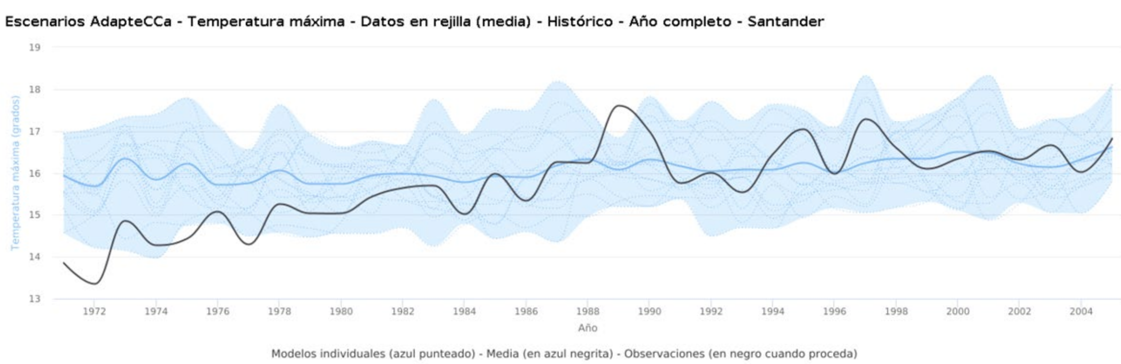


Figure 4.1. *Medium temperature, Adaptecca Scenarios*

Source: Adaptecca, 2022. http://escenarios.adaptecca.es

In 2010, the University of Cantabria prepared the Regional Probabilistic Scenarios of Climate Change in Cantabria in collaboration with the Spanish State Meteorological Agency, based on the outputs of the global models of the 4th IPCC Report, which are considered in the Climate Change Strategy currently in force. The results of these scenarios indicate average temperature increases of 3°C by the end of the century (4 ± 2°C for the worst scenario, A2), wich are somewhat milder for the coastal region. They also confirm a decrease in precipitation throughout the region in the second half of the century with low uncertainty, reaching decreases of 20% throughout the region. They also indicate changes in the distribution of precipitation, with larger decreases in spring and autumn. Consequently, the climate classification for the end of the century based on such projections with the intermediate and pessimistic scenarios indicate a clear trend towards a Mediterranean-type climate for the eastern region, with Mediterranean-oceanic transition climates progressively shifting from the coastal to the current Atlantic climate (Gutiérrez et al., 2010)[2].

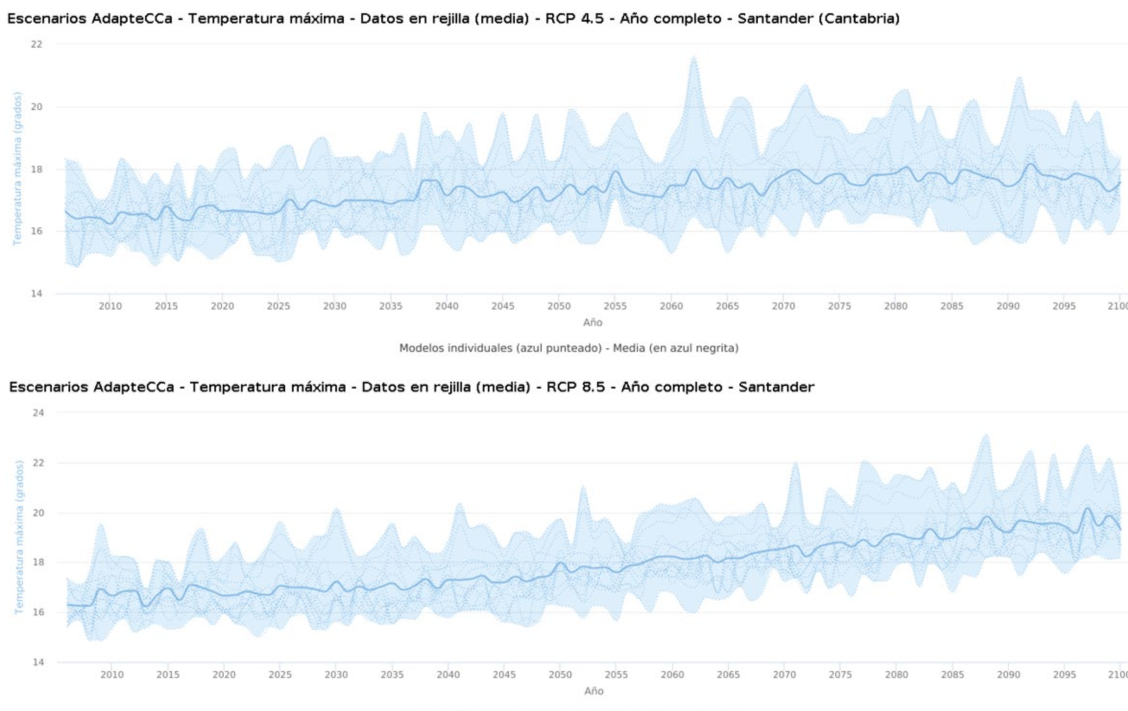


Figure 4.2. *Comparison of RCP4.5 and RCP8.5 Maximum Temperature Scenarios, Adaptecca*

Source: Adaptecca, 2022.

Subsequently, regionalised climate change projections for the whole of Spain were published on the Adaptecca[3] platform, based on the global projections of the IPCC's Fifth Assess-

[2] Gutiérrez, J.M., Herrera, S., San Martín, D., Sordo, C., Rodríguez, J.J., Frochoso, M., Ancell, R., Fernández, J., Cofiño, A.S., Pons, M.R. & Rodríguez, M.A. (2010). Escenarios Regionales Probabilísticos de Cambio Climático en Cantabria: Termopluviometría. Universidad de Cantabria, Consejería de Medio Ambiente, Gobierno de Cantabria.

[3] See the following website: https://escenarios.adaptecca.es/#&model=EURO-CORDEX-EQM.average&variable=tasmax&scenario=rcp85&temporalFilter=year&layers=AREAS&period=MEDIUM_FUTURE&anomaly=RAW_VALUE

ment Report, within the framework of the PNACC Scenarios initiative, particularly the 2017 PNACC Scenarios collection. The available data was mainly drawn from two sources: point projections from the Spanish State Meteorological Agency (AEMET) and gridded projections from the international Euro-CORDEX[4] initiative (CORDEX, 2023). The average maximum temperature observed in the last decade was around 16.5ºC in Santander, which according to these scenarios will increase by approximately 1ºC according to the RCP4.5 (intermediate) scenario by the end of the century, and by approximately 3ºC according to the RCP8.5 (pessimistic) scenario.

These changes, in the case of coastal areas like in Santander, will have an impact on the occurrence of adverse climatic events, such as sea level rise, variations in wave height and intensity, extreme rainfall or increases in water temperature (Gobierno de Cantabria, 2018).

According to the Santander tide gauge, in a period of 55 years (between 1945 and 1999) the sea level has risen by 2mm per year. Identical conclusions are reproduced in the work entitled 'Climate Change on the Spanish Coast' published by the Institute of Environmental Hydraulics and the University of Cantabria (IH Cantabria - UC, 2014), which indicates increases in mean sea level in the Atlantic-Cantabrian area of between 1.5 and 1.9 mm/year during 1900-2010, following the observed global average trend. Considering this average trend scenario, the sea level in 2040 would have risen by 6 cm, which would mean average retreats of close to 3m, including some beaches in Santander.

Santander is also exposed to coastal flooding or sea surges along beaches, and surrounding estuaries and marshes, which serve as flood plains. Flooding in these areas is even more accentuated when the flood peak coincides with the high tide. Especially strong waves affect the northern and eastern coastal areas of the municipality owing to swell, and the interior of the bay mainly due to the southerly wind. The most sensitive areas correspond to Avenida García Lago and the area around 2nd Sardinero Beach (Ayuntamiento de Santander, 2016).

On the other hand, general flooding occurs in the municipality due to *in situ* or pluviometric precipitation, which causes temporary flooding of public roads, infrastructure and buildings. This is mainly due to the accumulations caused by heavy rainfall, which can cause the collapse of the sewerage network, especially when associated with strong tides that act as a risk intensification factor (Ayuntamiento de Santander, 2016).

[4] See the following link: https://www.euro-cordex.net/

4.1.1. Participatory workshops with local stakeholders for hazard screening

In December 2022, the first Technical Workshop on Climate Change Risk Perception in Santander was held as an initial step for the drafting of this Adaptation Plan. This is the first of a series of participatory meetings developed throughout the project, accompanying the different phases of the study, focused on both technicians and citizens.

The main objective of the event was to gather key information from relevant actors in relation to the perception of climate change-related threats in the municipality of Santander. The session was attended by 22 people representing, among others, Civil Protection force and firefighters, in charge of directly managing the risks; the Departments of Environment, Tourism and Health of Santander City Council; CIMA of the Government of Cantabria; AEMET; as well as researchers on climate change, health, urban planning and land use planning, and entities specialised in nature, such as SEO/BirdLife.

The first questionnaire of this consultation process consisted of assessing a long list of plausible hydrometeorological hazards (direct and derived) for the municipality with the final objective of prioritising the importance and frequency of each of them, specifically for Santander.

Figure 4.3. *Participatory session, risk perception workshop*
Source: CINCc (UC) - FIC, 2024.

Results

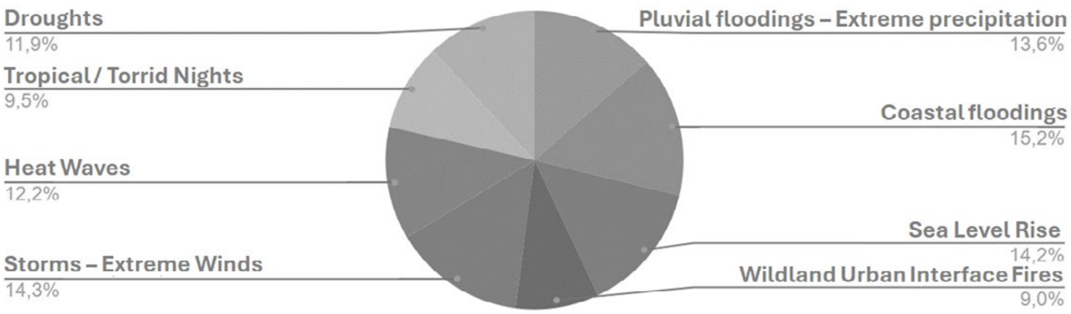


Figure 4.4. *Percentage final score for direct climate hazards, frequency and intensity*
Source: CINCc (UC) - FIC, 2024.

The aggregate rating of all respondents (a total of 21) indicates a higher relevance for **coastal climate hazards**, including coastal flooding and sea level rise, along with **windstorm events accompanied by extreme wind**, followed by pluvial flooding from extreme precipitation events, followed by heat waves, droughts, and tropical nights, and lastly by peri-urban fires. These levels of relevance remain almost unchanged for both criteria analysed, the magnitude and frequency of the hazard.

Regarding the incidence of climate-related hazards, the aggregate assessment of all respondents indicates a higher relevance for the **increase of invasive species** together with an **increase of new disease vectors**, with a final score of 23% and 22%, respectively. This is followed by a proliferation of allergenic pollens and insect pests, both with a final score of approximately 19% and, in last place, an increase in the incidence of Saharan dust, with almost 17% of the final score.

Analysis of Historical Records

Historical records of hazardous weather events in the municipality of Santander were collected through the Transparency Portal of the Insurance Compensation Consortium (*Consorcio de Compensación de Seguros,* CCS)[5], attached to the Ministry of Economic Affairs and Digital Transformation. The databases were provided for the period 1996-2021 and include records of floods, sea surges and atypical cyclonic storms (TCA).

[5] Consorcio de Compensación de Seguros (CCS) is a public business entity attached to the Ministry of Economic Affairs and Digital Transformation, through the Directorate General of Insurance and Pension Funds. It performs multiple functions in the field of insurance, including those related to the coverage of extraordinary risks.

A total of 6,573 damage files have been processed for the registration period, of which almost 77% belong to TCA files. These files correspond to a total of 133 events, of which almost 70% correspond to pluvial floods derived from extreme rainfall, which is the most frequent type of event in the municipality, with an average annual occurrence of between 3 and 4 events, while sea surges and TCA have annual frequencies of less than 1.

In terms of **economic impact**, in the municipality of Santander, the recorded events have caused costs of almost 18.3 million euros, of which 47% are derived from pluvial flooding, 40% from TCA events and around 13% from sea surges.

The information provided by the CCS also makes it possible to analyse the location of the events recorded by postcodes and the types of assets or goods that have been affected by each type of event. Based on their location, about 93% of the accumulated costs due to sea surges occur in Postal Code (PC) 39005, which coincides with the coastal area of the eastern area of the municipality. 75% of economic damage due to flooding occurs in postal codes 39011, 39001, 39005 and 39002, which coincide with the south-western sector and densely populated areas, mainly in the central districts of the capital. Finally, 73% of economic damage due to TCA occurs in PCs 39011, 39001, 39012, with a similar distribution to the previous one.

As for the types of assets or goods that have been affected by each type of event: more than 70% of the costs caused by sea surges occur in shops and warehouses, more than 15% in dwellings and about 13% in vehicles and automobiles. Flooding costs also occur mainly in shops and warehouses causing more than 58% of the total costs. This is followed by costs caused by civil works (almost 17%). TCAs cause the highest costs in housing, shops and warehouses, with 35% and 40%, respectively, and about 23% in industrial buildings.

In addition to the information provided by the Insurance Compensation Consortium (CCS), some **historical records** or ephemerides, defined as relevant meteorological events due to their historical, anecdotal or climatological value, are presented below (AEMET, 2023).

- 10 September 1581. Heavy downpours in Santander, with great loss of life and property.
- 29 December 1777. A strong tornado hit the city of Santander and nearby towns. A letter of the time relates that 'it came out as a kind of volcano with such a strong wind that everyone thought that most of the houses in Santander were going to the ground'.
- 5 February 1915. Southerly windstorm causes the sinking of the steamship 'Alfonso XIII' in Santander.
- 15 February 1941. An Atlantic storm with 951.9 mb, the lowest pressure ever recorded in Santander, produces a *surada* (south winds episode), with winds in excess of 150 km/h, which fanned a fire until it caused a great fire in the city, consuming buildings in 37 streets.
- 7 August 1943. High of 40.2°C in Santander.

- 10 March 1955. In Cantabria, clouds eclipse the sun and it becomes completely dark three times during the morning. The phenomenon is observed in Santander and in a coastal area of about 30 km.
- 27 August 1983. Santander airport recorded 96.2 mm in one hour.
- 7 June 1987. Strong gale along the Cantabrian coast, from Galicia to the French coast, 90 km/h recorded in Santander.
- 16 December 1989. Southern storm with winds reaching 147 km/h at Santander airport.
- 27 December 1999. Gusts of 172 km/h at Santander and 167 km/h at Santander airport.
- 3 October 2006. Gusts of 161 km/h at Santander and 118 km/h at its airport.
- 14 February 2007. Gusts of 130 km/h in Santander.
- 7 March 2007. Wind gusts of 140 km/h in Santander.
- 2014, 2016 and 2018, major impacts on the coast due to winter storms.

In 2016, the municipality of Santander, together with the Fire Brigade, developed a contingency plan to deal with the diversity of phenomena that has occurred in the city throughout its history. In terms of response and defence against risks, including those arising from adverse weather conditions, the **Santander Municipal Emergency Plan** (PEMUSAN) addresses both a risk analysis and a battery of local response measures to the magnitude of the weather events observed. Within this classification, the PEMUSAN first makes a general identification and a final assessment of those risks that have an impact on the municipality of Santander.

Below is a summary table of the climate-related risks analysed in the PEMUSAN, together with their corresponding assessment:

TABLE 4.2. *Risk analysis, PEMUSAN*

CLIMATE-RELATED EVENT	RISK ASSESSMENT [A]	PROBABILITY INDEX [B]	PREDICTED DAMAGE INDEX [C]
Pluvial floods	IR: 15 Medium Risk	3	5
Gravitational movements	IR: 4 Low Risk	2	2
Adverse weather events	IR: 12 Low Risk	6	2
Vegetation fires	IR: 30 Medium Risk	6	5

Source: CINCc (UC) - FIC, 2024 based on PEMUSAN (2016).

A Risk Index (IR): High (A): Greater than or equal to 40. Medium (M): 15 to 30. Low (B): Less than or equal to 12.

B Probability Index (PI): 2 No recorded occurrence. 3 Some occurrence recorded every ten years. 6 More than five recorded occurrences per year.

C Predicted Damage Index (ID): 0 No damage. 2 Minor damage to property and/or a few people slightly affected. 5 Major material damage or many people affected.

For each of these events, the PEMUSAN includes a fact sheet, which also identifies vulnerable sectors, exposed areas, potential damage, risk indicators and preventive measures to be adopted. Pluvial floods have the potential to cause circulatory collapse and a variety of multiple damages.

In the case of adverse meteorological phenomena, these events have the potential to cause housing evictions, possible health impacts on at-risk population groups, and other social and economic implications. Specifically for wind-related phenomena, those with an intensity of more than 80 km/h, or gales, which in turn can be from the sea or land, are indicated as adverse, while vegetation fires have the potential to cause damage to people, property and the environment due to the destruction of flora and fauna in the burnt areas.

Prioritisation of Climate Hazards in the Municipality

The methodology used to prioritise and select the main hydrometeorological hazards in the municipality is based on the **multi-criteria analysis** method, whose objective is to determine the degree of incidence of each hazard based on its occurrence

This method also considers the frequency and magnitude of the hazard, and the potential impact or damage it causes, including human damage in terms of human lives, injuries or casualties, material damage to housing and infrastructure,or the economic and environmental damage caused to the **municipality**.

For each hazard, the final value and order of relevance is obtained according to its occurrence. The formulation used has two advantages:

- (i) It implies that the final assessment depends to a large extent on the scores assigned in the local workshop, because this source of information is local, is developed specifically in the context of climate hazard analysis, and integrates the social and institutional vision of the municipality in a multidisciplinary way.
- (ii) It allows for smoothing of the inherent divergences arising from the use of multiple sources of information with different occurrence indicators, some of which are also subject to interpretation under expert judgement.

The results of the multi-criteria analysis indicate an occurrence of highest relevance for coastal flooding, followed by **windstorms**, **sea level rise** and **pluvial flooding**. Droughts are ranked second, followed by peri-urban fires and, finally, heat waves and tropical nights.

In terms of derived hazards, the emergence of **new disease vectors** is followed by the emergence of **new invasive species** and increased levels of **allergenic pollens**. It is worth mentioning that it is possible that certain threats, mainly those of slow onset such as heat waves, may become more relevant in the future. Therefore, these initial results are combined with the results of the climate analysis, which will improve the level of knowledge on emerging hazards in Santander.

4.2 CLIMATE ANALYSIS AND LOCAL SCENARIO GENERATION

4.2.1. Current Climate Analysis

The coastal location of the municipality provides a mild climate, both in winter and summer, without marked climatic extremes. According to the Köppen climate classification, Santander has a characteristic **oceanic climate of type Cfb** (West Coastal Maritime), with a temperate climate marked by cool summers (average temperature of the warmest month below 22°C), abundant and well-distributed rainfall throughout the year. The annual thermal oscillation of mean monthly temperatures is low (Δ8°C).

Rainfall is abundant in spring and autumn in particular, although significant reductions have been detected in recent years. Variations in the percentage of humidity can be significant, although high values predominate. Temperatures are mild throughout the year and there are very few episodes of extreme cold or heat. Summers are generally mild, with mild temperatures and winters are cold, but not extreme due to the thermoregulatory effect of the sea, with temperatures rarely dropping below 0°C and an average of one snow day per year. In general terms, average temperatures in the municipality range from a mean in maximums of 24.5°C in August to a mean in minimums of 5.8°C in February. A characteristic phenomenon in Santander are the episodes of south winds, with a notable intensity of more than 80 km/h, which cause high temperatures and low humidity, with a particular effect on the health of some groups of the population.

4.2.2. Generation of Local Climate Change Scenarios (CMIP6)

Introduction

The most robust tool for simulating climate are **Climate Models** (CMs), by means of which it is possible to simulate the general atmospheric circulation in an efficient way. However, due to their resolution (around 100 km) they are unable to simulate smaller-scale atmospheric phenomena that are of great importance in local climatology. In order to overcome this and other limitations of CMs, what are known as **regionalisation or downscaling techniques** are used.

TABLE 4.3. *Current climate variables in Santander*

CLIMATE PARAMETERS SANTANDER (REFERENCE PERIOD: 1991-2020, EXTREMES: 1957-2016)													
MONTH	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DEC.	ANNUAL
Abs. max Temp. (°C)	25.1	29.9	31.3	30.6	36.8	37.8	37.2	37.3	37.6	33.5	30.0	25.4	**37.8**
Average max Temp. (°C)	13.7	13.9	15.8	16.9	19.4	21.8	23.7	24.5	22.9	20.6	16.5	14.4	**18.7**
Average Temp. (°C)	10.0	9.9	11.6	12.9	15.6	18.1	20.1	20.8	18.9	16.5	12.8	10.8	**14.8**
Average min Temp (°C)	6.3	5.8	7.4	8.7	11.7	14.4	16.6	17.0	14.8	12.3	9.2	7.0	**10.9**
Abs. min Temp. (°C)	–5.4	–5.2	–3.0	0.6	2.6	5.6	6.0	6.0	2.8	1.4	–3.5	–5.2	**–5.4**
Total precipitation (mm)	114.4	97.6	95.9	98.7	76.0	62.6	53.7	57.6	90.8	121.1	172.3	128.3	**1,169**
Days of precipitation (≥1 mm)	12.3	11.1	11.1	11.9	10.4	7.6	7.3	7.6	8.9	11.1	13.3	12.1	**123.6**
Days of snowfall	0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	**0.9**
Sun hours	85	104	135	149	172	178	187	180	160	129	93	75	**1,647**
Relative humidity (%)	72	72	71	72	74	75	75	76	76	75	75	73	**74**

Source: State Meteorological Agency. Parayas Airport Observatory (Camargo)

This project proposes to use a two-step statistical regionalisation methodology developed by the Climate Research Foundation (Ribalaygua et al., 2013) and widely tested in a multitude of national and international projects. This methodology has been applied to the variables temperature (both maximum and minimum) and precipitation.

The method works in **two successive steps**:

- The first step, called **analogue stratification**, consists in selecting, from a reference data bank, those days with atmospheric configurations most similar to those of problem day 'X'. The similarity measure used compares the resemblance between the predictor variables used to characterise the atmospheric synoptic situations. These variables determine the synoptic forcing causing the descents and ascents of air, which generate cloudiness and precipitation. The aim is also to provide information on the direction of the surface wind, which makes it possible to study the effects that topography has on the rising air masses and, therefore, on the spatial distribution of cloudiness and precipitation.
- The second step applies different methods depending on the variable to be calculated:
    - To estimate daily minimum and maximum temperatures, a **multiple linear regression** with automatic forward and backward predictor selection is performed for each variable.
    - In the case of precipitation, it is estimated by **simple averaging** of the k analogous days most similar to 'X'.

The FICLIMA methodology, shown in the figure 4.5 below, has some advantages over other statistical methodologies, which are reflected in the table 4.4 below:

TABLE 4.4. *Advantages of the FICLIMA methodology over other statistical downscaling methodologies*

The problem of stationarity is minimised by the selection criterion of predictors, based on theoretical considerations, reflecting the physical relationships between predictors and predictands, physical relationships that should not change over time.
When using the analogue selection method alone, and given that the final simulation will be based on the most analogue days, the value assigned to the studied meteorological variable will be limited by the observed value it has on those analogue days, i.e., its margin of variability will be given by the variability of the past itself (higher or lower values would never be calculated). However, the second step introduced in the FICLIMA methodology allows us to overcome this limitation: the daily linear relationships established for temperature and the redistribution of precipitation based on the distribution function allow us to simulate values that can exceed the limitation of the initial observed values.

[…/…]

Continuation **TABLE 4.4**

The verification results are considerably better than those of the vast majority of statistical and dynamic methodologies with which they have been compared in various national and international projects. These excellent verification results have been verified in the different areas of the planet where it has been tested, and are justified by the solid theoretical foundations on which FICLIMA is based.

Source: FIC.

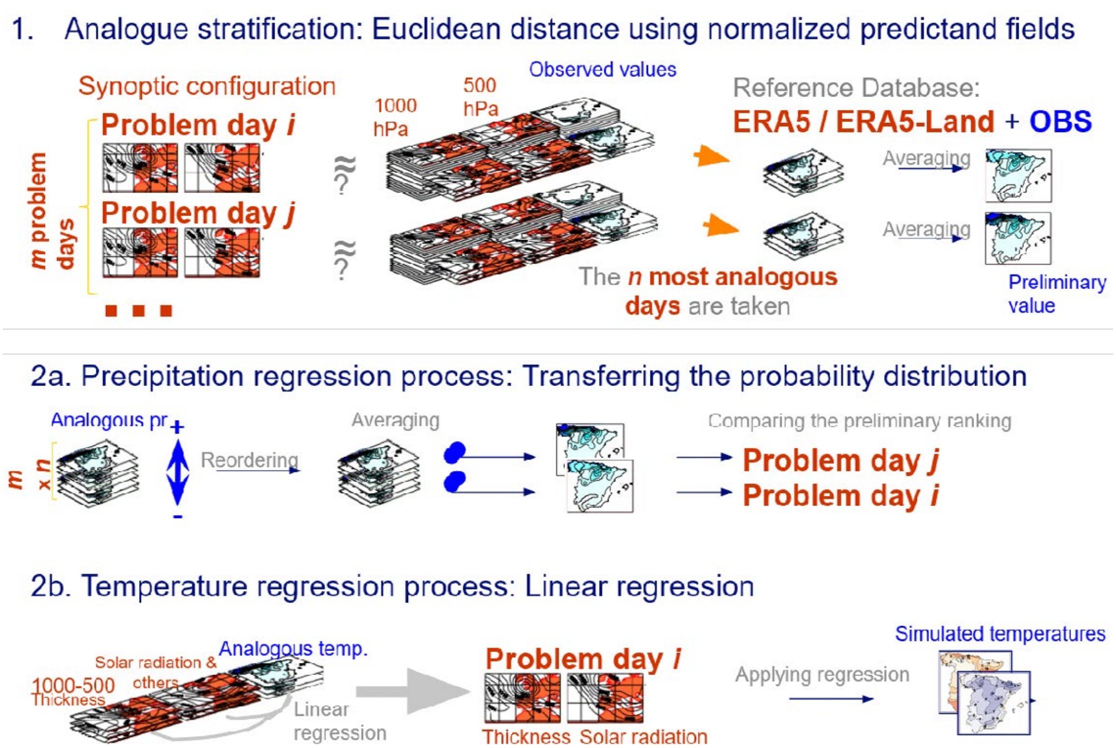


Figure 4.5. *Outline of FICLIMA methodology*

Source: FIC.

Data and study area

The location of the municipality in the north of the Iberian Peninsula, bordering the Cantabrian Sea, implies climatic characteristics of the temperate oceanic type, with mild, rainy winters and cool, relatively rainy summers. In order to carry out the regionalisation process, it is necessary to have a set of data, which are summarised in figure 4.6.

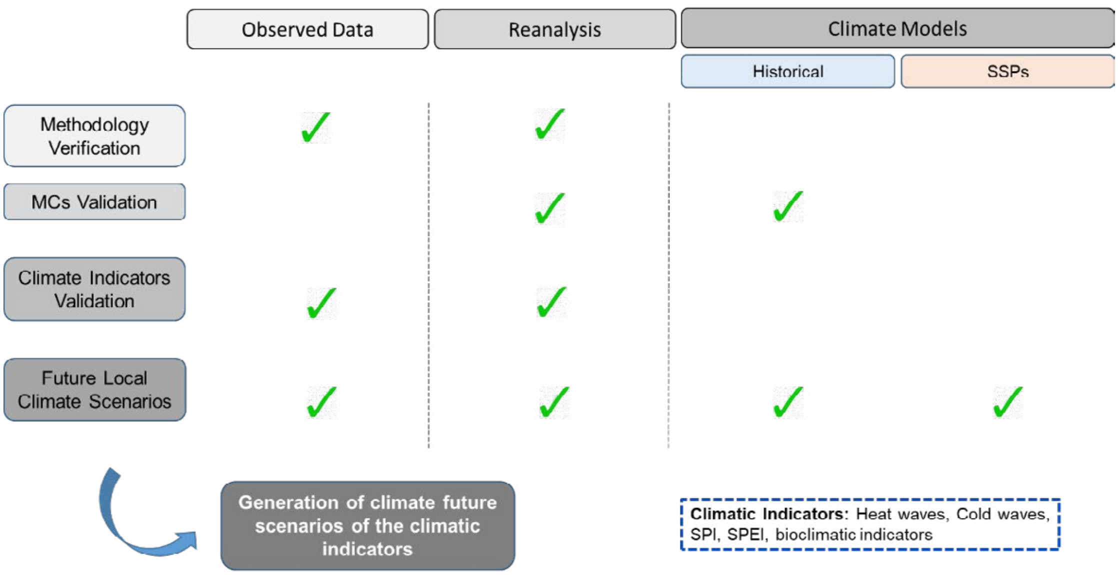


Figure 4.6. *Outline of data required for the study.*
Source: FIC.

For the study, a set of observed data obtained from meteorological stations of the network of the State Meteorological Agency (AEMET) is available. figure 4.7 shows the location of the observatories with data for each of the variables.

TABLE 4.5. *Set of Climate Observatories*

VARIABLE	NUMBER OF OBSERVATORIES
Temperature	28
Precipitation	18
Wind	8
Relative Humidity	9
Pressure	4

Source: FIC.

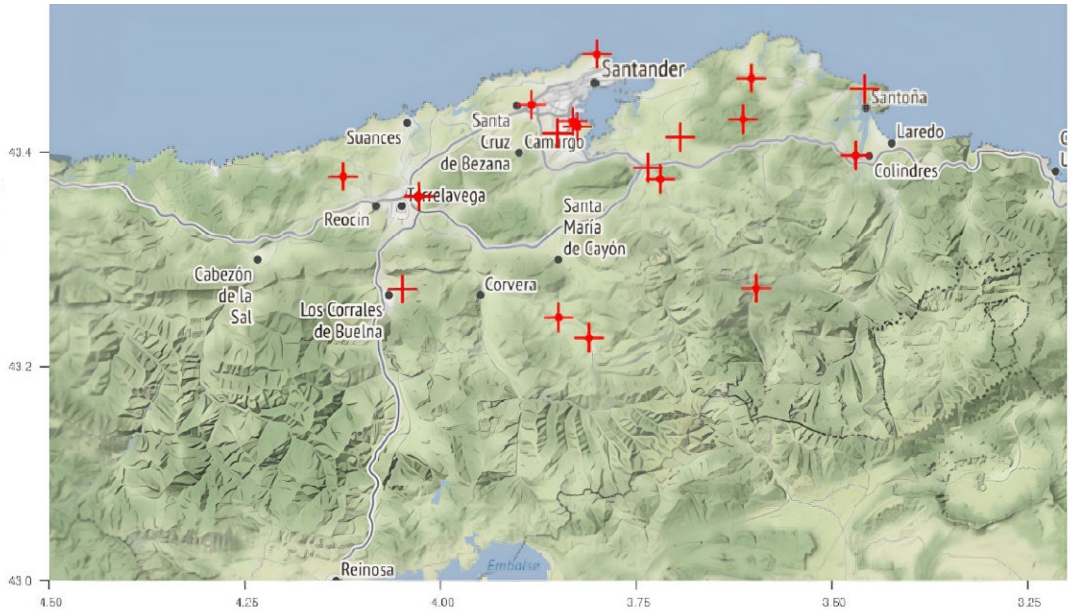


Figure 4.7. *Available observatories of the AEMET network*

Source: FIC.

The observed data are subjected to strict quality control and homogenisation (Monjo et al., 2013), discarding such data that do not exceed the established quality standards.

The ERA5 and ERA5-Land Reanalysis database and the different climate models complete the generation of scenarios.

Climate Models

The project has been developed with the climate models of the 6th phase of the CMIP **(CMIP6)** as well as the emissions scenarios defined within this phase, the **Shared Socioeconomic Pathways (SSPs)**. Statistical techniques, due to their computational speed, allow working with a large number of climate models (n) and SSPs (m), so that a set of (n x m) climate projections will be obtained. The climate models are run continuously from the past into the future; once the control period is simulated, the run is separated into as many runs as SSPs are considered. For each climate model there is, therefore, a control simulation called 'Historical' for the period 1951-2014 (although the reference period here is taken as 1985-2014) and 4 SSPs for the period 2016-2100 (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5).

Ten daily resolution climate models, collected within CMIP6, have been used. Throughout the different phases of this project, improvements have been made to the quality of the climate models up to the current **Earth System Models** (ESM) (Benestad, 2010). Furthermore, new emission scenarios have been defined in each of the phases, adjusting to the new adaptation and mitigation needs in the face of climate change. CMIP6 has a common set of future scenarios comprising land use and emissions, as required for future SSPs (Eyring et al., 2016).

TABLE 4.6. *Set of models from CMIP6 used in the study*

CMIP6 MODELS	RESOLUTION	RESPONSIBLE AGENCY	REFERENCES
ACCESS-CM2	1.258° x1.8758°	Australian Community Climate and Earth System Simulator (ACCESS), Australia	Bi et al. (2020)
BCC-CSM2-MR	1.125° x 1.121°	Beijing Climate Center (BCC), China Meteorological Administration, China	Wu et al. (2019)
CanESM5	2.812° x 2.790°	Canadian Centre for Climate Modeling and Analysis (CC-CMA), Canada	Swart et al. (2019)
CESM2-WACCM	0.95° × 1.25°	National Center for Atmospheric Research (NCAR), USA	Gettleman et al. (2019)
CNRM-ESM2-1	1.406° x 1.401°	CNRM (Centre National de Recherches Meteorologiques), Meteo-France, France	Seferian (2019)
EC-EARTH3	0.703° x 0.702°	EC-EARTH Consortium	EC-Earth Consortium (2019)
MPI-ESM1-2-HR	0.938° x 0.935°	Max-Planck Institute for Meteorology (MPI-M), Germany	Gettelman et al. (2017)
MRI-ESM2-0	1.125° x 1.121°	Meteorological Research Institute (MRI), Japan	Yukimoto et al. (2019)
NorESM2-MM	1.250° x 0.942°	Norwegian Climate Centre (NCC), Norway	Bentsen, M. et al. (2019)
UKESM1-0-LL	1.875° x 1.250°	UK Met Office, Hadley Centre, United Kingdom	Good et al. (2019)

Source: Author's elaboration.

Note: The models were provided by the Climate Model Diagnostics and Intercomparison Programme archives (PCMDI).

Results of the Climate Projections

The climate projections have been generated for each of the observatories available for each variable. The results obtained in the generation of **future climate scenarios** for the different variables are shown below, based on the results presented below by the medians of each SSP (thick lines). The '1109X' observatory at Santander Airport is taken as a reference:

- Both maximum and minimum temperatures are expected to **increase progressively** throughout the 21st century. In the case of **maximum** temperatures, increases of between 1.38°C and 2°C are expected by mid-century, depending on the emissions scenario considered, and between 1.41°C and 3.83°C by the end of the century. These increases would mean that the average maximum temperature would increase from around 18.94°C to between 20.32°C and 21.02°C by mid-century and between 20.35°C and 22.77°C by the end of the century.
- In the case of **minimum temperatures**, the expected mid-century increases range from 1.65°C in the most favourable case to 2.41°C in the least favourable case, which would mean that the average minimum temperature would reach values of between 11.94°C and 12.70°C. By the end of the century, the average minimum temperature is expected to rise between 1.67°C and 4.63°C, so that the average minimum temperature values would be between 11.96°C and 14.92°C.
- No significant changes in annual accumulated **precipitation** are expected. All emission scenarios show a similar behaviour in terms of the future evolution of precipitation, so that it will be around 1200-1300 mm/year. The rainfall distribution is expected to be altered with respect to the current distribution. Rainfall is expected to be more intense and concentrated over time than evenly distributed over longer periods.
- **Humidity** is expected to behave very similarly to the current climatic situation in the region, without significant changes, especially in the middle of the century. Depending on the model and the scenario considered, at the end of the century, maximum humidity may vary between -2.5% and 1%, while minimum humidity may vary between -5% and 2.5%.
- The expected **pressure** behaviour is very similar to that observed today with oscillations of ±1 hPa at the end of the century.
- For the mean **wind**, very slight decreases are observed, ranging from 0.25 m/s (0.9 km/h) to 0.5 m/s (1.8 km/h). The expected variations in the maximum gust, both mean and maximum, are expected to be very similar to those expected in the mean wind. In the case of **maximum gusts**, these will decrease from a maximum intensity of about 93-94 km/h to 88-92 km/h by the end of the century.

Future climate scenarios for temperature (maximum and minimum)

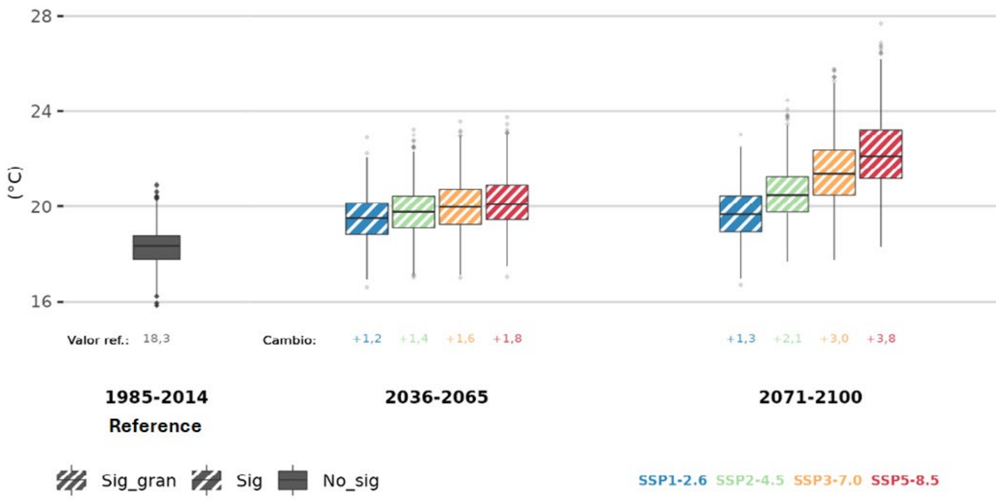


Figure 4.8. *Expected maximum temperature increases for the 21st century.*

Note: Represented as 30-year moving averages, according to the SSPs represented with respect to the average of the period 1976 - 2015 (taken as reference). Simulations of all models on the observatory '1109X'. The lines show the median of all values for each SSP; the shadows cover from the 10th to the 90th percentile.

Source: FIC.

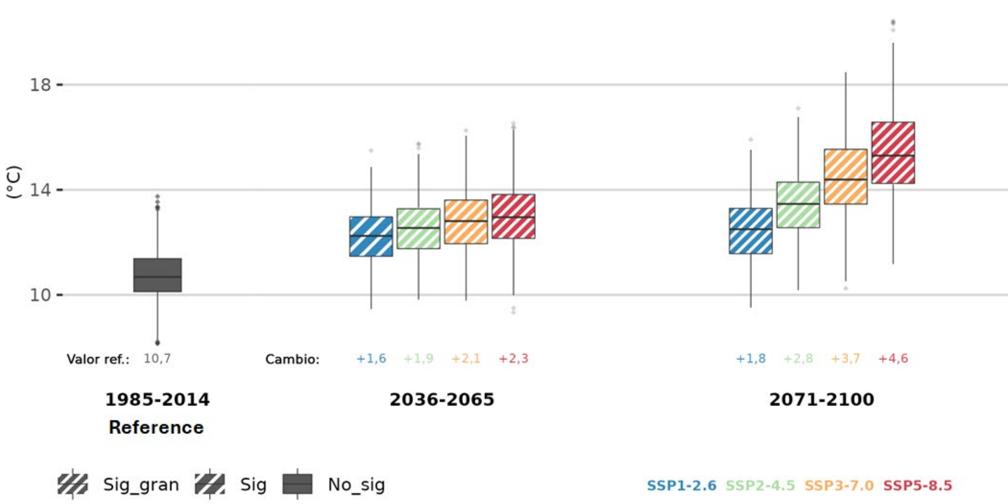


Figure 4.9. *Expected minimum temperature increases for the 21st century.*

Note: Represented as 30-year moving averages, according to the SSPs represented with respect to the average of the period 1976 - 2015 (taken as reference). Simulations of all models on the observatory '1109X'. Lines show the median of all values for each SSP; shadows cover from the 10th to the 90th percentile.

Source: FIC.

Future climate scenarios for precipitation

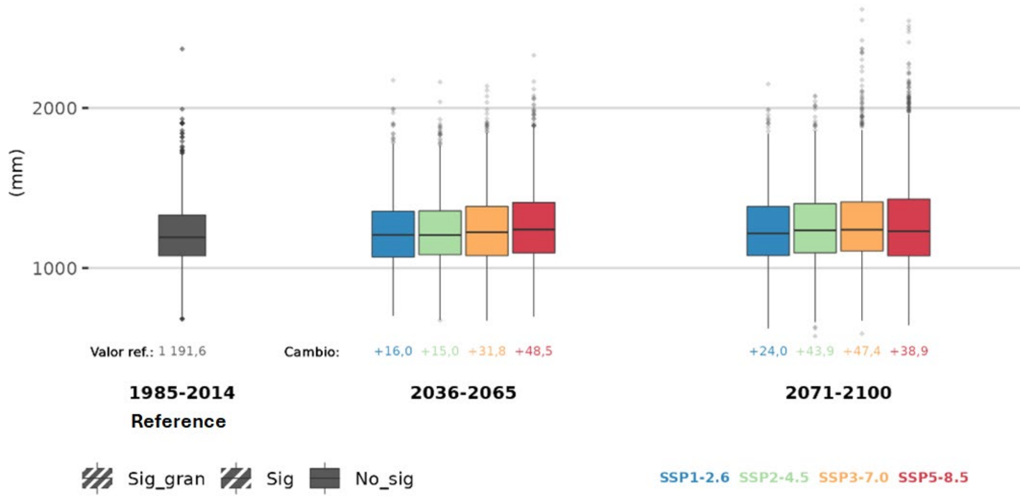


Figure 4.10. *Expected absolute precipitation values (mm) for the 21st century.*

Note: Represented as 30-year moving averages, according to the SSPs represented with respect to the average of the period 1976 - 2015 (taken as reference). Simulations of all models on the observatory '1109X'. The lines show the median of all values for each SSP; the shadows cover from the 10th to the 90th percentile.

Source: FIC.

Future climate scenarios for relative humidity

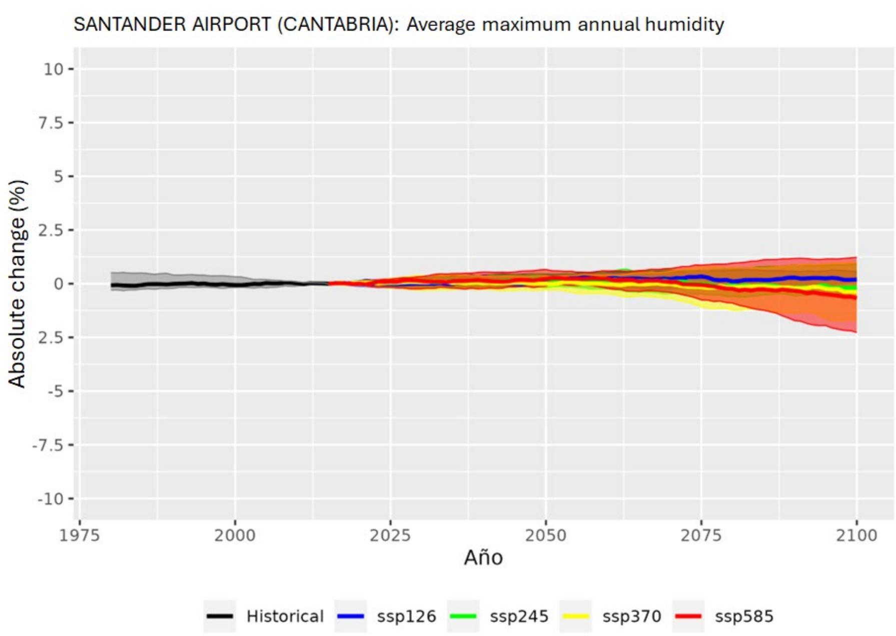


Figure 4.11. *Expected increases in maximum humidity for the 21st century*

Source: FIC.

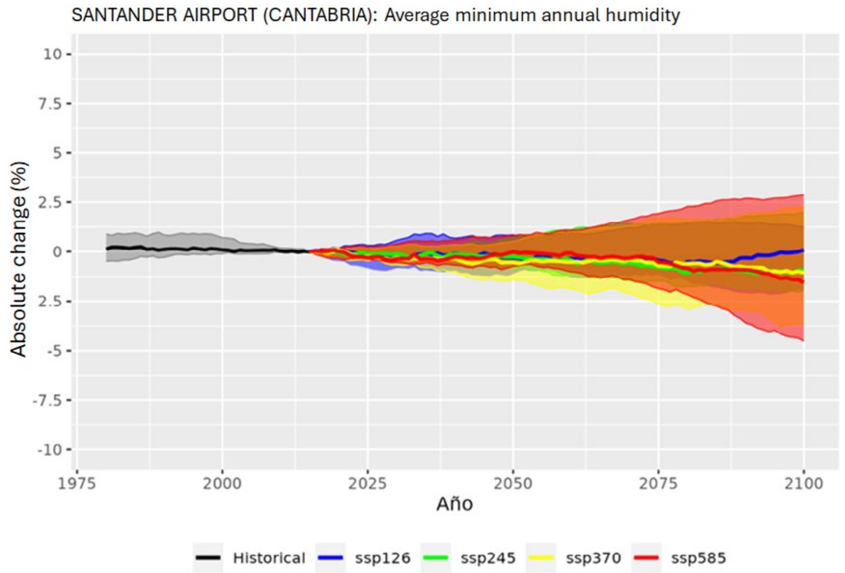


Figure 4.12. *Expected minimum humidity increases for the 21st century.*

Note: Represented as 30-year moving averages, according to the SSPs represented with respect to the average of the period 1976 - 2015 (taken as reference). Simulations of all models on the observatory '1109X'. Lines show the median of all values for each SSP; shadows cover from the 10th to the 90th percentile.

Source: FIC.

Future climate pressure scenarios

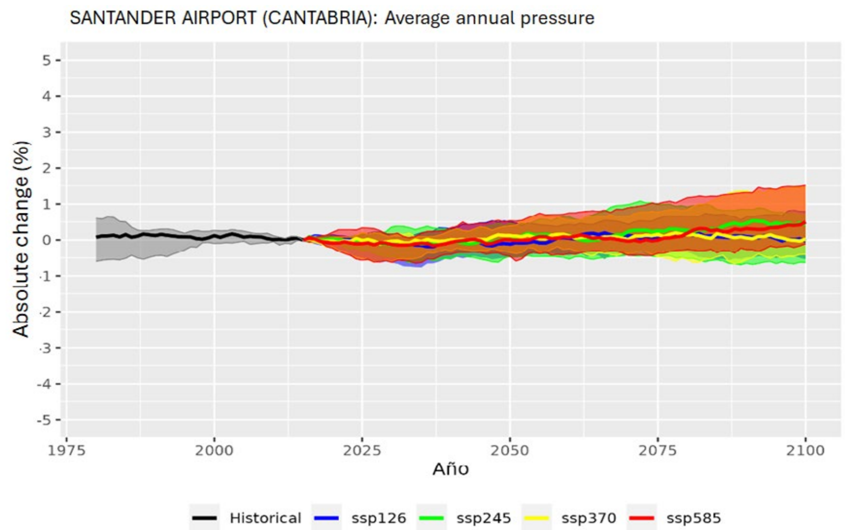


Figure 4.13. *Expected pressure changes for the 21st century*

Note: Represented as 30-year moving averages, according to the SSPs represented with respect to the average of the period 1976 - 2015 (taken as reference). Simulations of all models over the observatory '1109X'. Lines show the median of all values for each SSP; shadows cover from the 10th to the 90th percentile.

Source: FIC.

Medium wind future climate scenarios

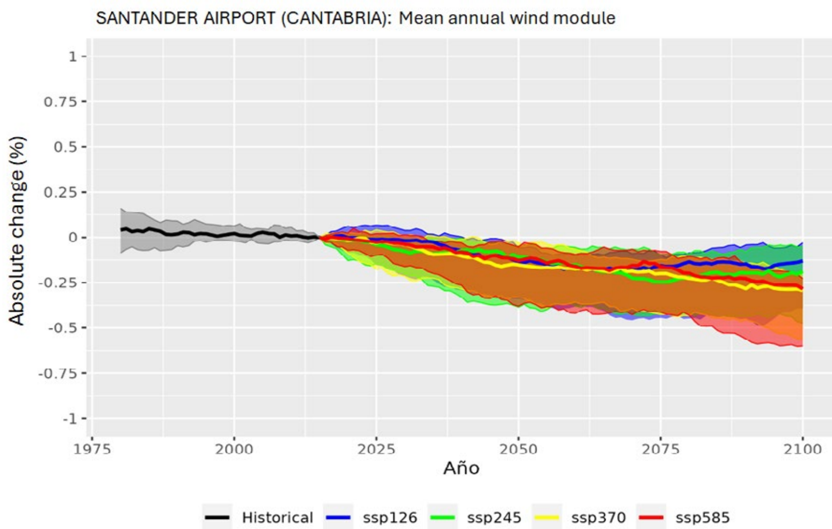


Figure 4.14. *Expected average wind increases for the 21st century.*

Note: Represented as 30-year moving averages, according to the SSPs represented with respect to the average of the period 1976 - 2015 (taken as reference). Simulations of all ace models over the '1109X' observatory. The lines show the median of all values for each SSP; the shadows cover from the 10th to the 90th percentile

Source: FIC.

Future climate scenarios for maximum wind speed

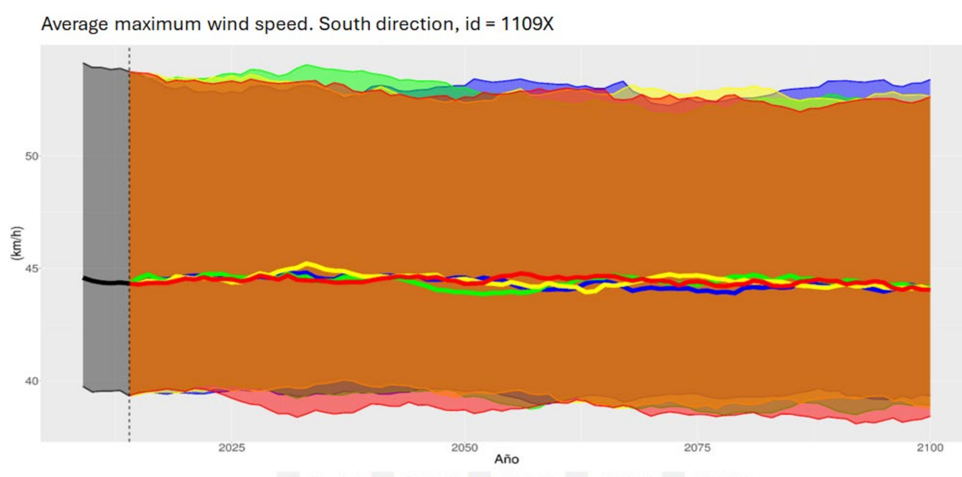


Figure 4.15. *Expected values of average maximum southerly wind gust for the 21st century.*

Note: Represented as 30-year moving averages, according to the SSPs represented with respect to the average of the period 1976 - 2015 (taken as reference). Simulations of all models on the '1109X' observatory. Lines show the median of all values for each SSP; shadows cover from the 10th to the 90th percentile.

Source: FIC.

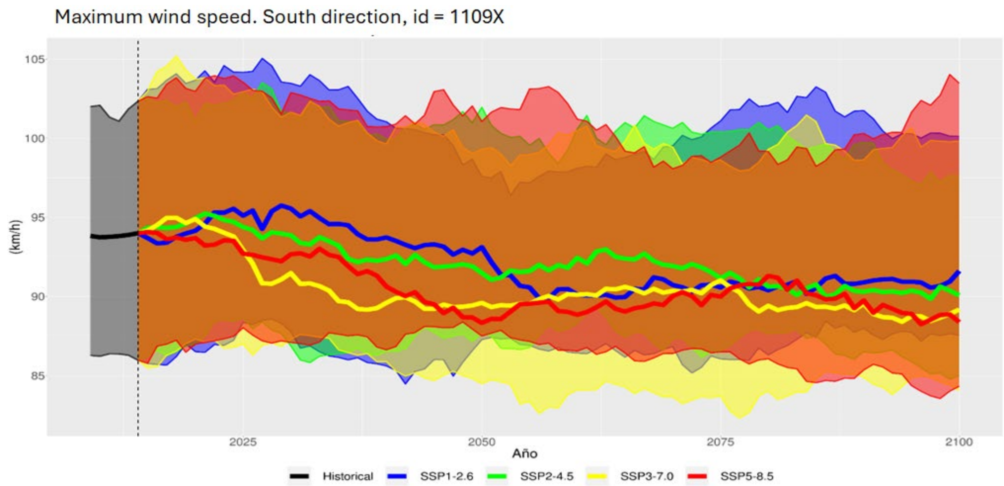


Figure 4.16. *Values of maximum wind gusts from the South for the 21st century*

Note: Represented as 30-year moving averages, according to the SSPs represented with respect to the average of the period 1976 - 2015 (taken as Reference). Simulations of all models on the observatory '1109X'. The lines show the median of all values for each SSP; the shadows cover from the 10th to the 90th percentile.

Source: FIC.

4.2.3. Climate Scenarios Summary

According to the climate data obtained from the historical period and projected to 2100, the anallysis conclude the following values for all climate scenarios:

- **Average maximum temperature:** From a historical value between 16-19°C, a maximum temperature range of 21-23°C is projected for 2100.
- **Average minimum temperature:** From a historical value between 8-11°C, a minimum temperature range of 13-15°C is projected for 2100.
- **Precipitation:** Averages similar to the present are maintained with slight variations. The annual distribution may be altered, with total precipitation concentrated in shorter periods.
- **Heat waves:** From a historical value between 3-4 days, an increase to 9-10 days of heat wave duration is projected for 2100.
- **Temperature heat wave (intensity):** From a historical value between 26-29°C, a temperature of 29-32°C is projected for 2100, implying an increase in total intensity.
- **Torrid Nights:** From a historical value between 0-1 day/year, a notable increase to 6-9 days/year is projected for 2100.

In summary, results state that the future climate context in Santander will continue the following pattern:

- Progressive temperature increases throughout the 21st century, 1.3°C-3.8°C in 2100.
- Slight variations in rainfall patterns, but more torrential rainfall.
- Increases in the number of hot days with a consequent increase in the frequency of heatwave episodes, as well as in their duration and maximum intensity.
- Significant increases in the number of progressively tropical, equatorial and torrid nights throughout the 21st century.

4.3 CLIMATE HAZARD ANALYSIS AND PROJECTION

The objective of this phase is to analyse the selected climate hazards for the municipality of Santander for both the historical or current period and for projected future periods.

The hazards selected from the participatory process and the analysis of historical events are as follows:

- Pluvial Flooding from Extreme Precipitation
- Atypical Cyclonic Storm (TCA)
- Fluvial Flooding
- Urban Heat Islands
- Heat Waves
- Episodes of Warm Nights
- Meteorological Drought
- Extreme Wind, *Galernas* and South Wind
- Coastal Flooding

The **occurrence** (distribution, intensity, duration and frequency) of these events is modelled through the main climate variables analysed (temperature, precipitation, wind and humidity) from the regionalised climate change scenarios for Santander, based on the CMIP outputs of the IPCC 6th Report. This modelling process is specifically applied to climate hazards such as **droughts**, **heat waves**, **extreme wind events**, and **pluvial floods**, among others. For coastal flooding and sea level rise hazards, the assessment is based on the recent results obtained by the **PIMA-Adapta**[6] Costas project, within the framework of the Climate Change Adaptation Strategy.

[6] PIMA Adapta Costas (2020). Conocimiento y acción frente a los riesgos derivados del cambio climático. Oficina Española de Cambio Climático. Ministerio para la Transición Ecológica y el Reto Demográfico, Madrid.

EXTREME PRECIPITATION EVENTS

This block analyses the roads in the municipality with a **probability of flooding** due to the occurrence of extreme precipitation events, defined as episodes when the accumulated precipitation in one hour or less is of an intensity equal to or greater than 15mm/h, or whose accumulated precipitation in 12 hours is of an intensity equal to or greater than 40mm/h (Ayuntamiento de Santander, 2016). It is important to consider that this procedure does not address a detailed modelling of the flood hazard for roads, which should consider, among others, the municipal drainage system at a detailed scale, as well as the runoff and accumulation of flow generated by extreme precipitation events considering current and future conditions for different return periods. However, with the consideration of the CMIP6 climate scenarios, it will be possible to delimit a valid cartography that allows the calculation of the potential exposure to this hazard.

The methodology proposed for the analysis of roads with a high probability of flooding in the municipality of Santander includes the following steps:

(i) Analysis of topographic subsidence conditions in the longitudinal profile of the municipality's roads (**Blue Spots**[7] modelling).

(ii) Analysis of the documented areas of waterlogging, obtained from the mapping provided by the Santander City Council (2016), and from the records of interventions carried out by the Fire Brigade of the municipality from 2018 to 2022 due to extreme rainfall events.

(iii) Validation and final delimitation of areas of **high probability** of road flooding in the municipality, based on the results of Blocks 1 and 2.

(iv) Assessment of the trend of extreme rainfall events in the municipality under climate change conditions in the short, medium and long term, based on local scenario outputs derived from CMIP6 models.

In the last step of this procedure, a rigorous assessment of the **projected trend** in the occurrence of extreme rainfall events in the municipality of Santander is provided, in terms of intensity, duration and frequency, as well as for each of the local-scale climate change scenarios, based on the recent outputs of the IPCC 6th Assessment Report.

The Hazard Index for rainfall events in Santander is obtained by normalising the mean frequency value obtained for the different climate scenarios for each time horizon. As shown in table 4.7, the normalised index presents values above 0.6 for all periods, which implies that the mean frequency of extreme rainfall events does not double for the long-term climate projections with respect to their historical frequency. The mean annual frequency of extreme rainfall events for the set of climate scenarios is almost 3 events/year, with mean Hazard Index scores for the Santander census sections around 0.63 in the historical peri-

[7] https://climate-adapt.eea.europa.eu/en/metadata/tools/the-blue-spot-model-a-key-tool-in-assessing-flood-risks-for-the-climate-adaptation-of-national-roads-and-highway-systems

od. For the projected periods, absolute increases of around 0.5 events/year on average are expected, reaching a frequency of 4.5 events/year for the long-term projection period.

TABLE 4.7. *Mean annual frequency and mean hazard indexes*

	AVERAGE FREQUENCY OF EVENTS	MEDIUM HAZARD INDEX
HISTORICAL PERIOD (1985-2014)	2.97	0.63
SHORT TERM (2016-2040)	3.58	0.77
MEDIUM TERM (2041-2070)	4.05	0.87
LONG TERM (2071-2100)	4.49	0.96

Source: CINCc (UC) - FIC 2024.

Results show the average values of extreme rainfall events and the following Normalised Hazard Index for the municipality of Santander (figure 4.17).

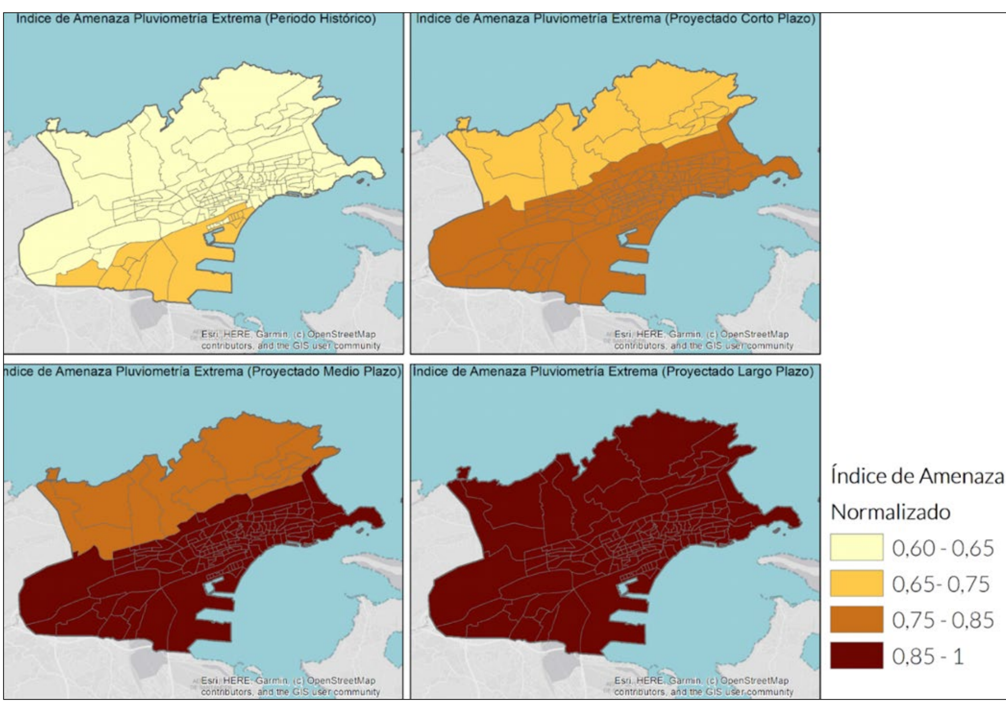


Figure 4.17. *Normalised Hazard Index for extreme rainfall events*

Note: obtained by averaging the frequency for the different climate scenarios and for each time horizon per census section; for historical (top left), projected short (top right), medium (bottom left) and long term (bottom right).

Source: CINCc (UC) - FIC, 2024.

ATYPICAL CYCLONIC STORM

Atypical cyclonic storm (Tormentas Ciclónicas Atípicas [TCA]), is defined as an extremely adverse atmospheric event, including tornadoes and extraordinary winds. For the present study, the TCA phenomena in the municipality of Santander have been analysed as episodes that combine extreme winds, above 84 km/h, and intense precipitation, of more than 40 mm accumulated in one day. For such episodes, two indices of frequency and duration have been analysed:

- Frequency, analysed as the average number of days with TCA per year.
- Average duration of the event, analysed as the average number of consecutive days in the year with TCA.

The **measurement of TCA** occurrence is analysed for the historical period (1985-2014) and projected into the future, for the short (2016-2040), medium (2041-2070) and long term (2071-2100). Future projections are obtained from the average of the outputs of 10 climate models for a total of 4 emission scenarios, as set out in the IPCC 6th Report (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5). The representation of these phenomena by census section is based on the average number of nights per year for each time horizon, as a representative measure.

The **results** for each of the TCA occurrence indices in the municipality of Santander are presented below (table 4.8).

TABLE 4.8. *Average number of TCA per year in Santander*

HISTORICAL AVERAGE: 0.141575	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Short Term (2016-2040)	0.124126	0.139725	0.152720	0.140067
Medium Term (2041-2070)	0.134185	0.178395	0.130459	0.125216
Long Term (2071-2100)	0.109309	0.140246	0.167540	0.126663

Source: CINCc (UC) - FIC, 2024 based on local climate scenarios from the outputs of the sixth IPCC report

With regard to the **average temporal frequency**, TCA episodes in Santander occured on average once every 7 years in the historical period, and are expected to have a moderately stable frequency in the future, with an event occurring every 5 to 9 years depending on the scenario considered. In the case of the average duration of the TCAs, no table of values is included for each scenario, since it remains at 1 both for the historical period as well as for all the projected scenarios, i.e., they are one-off events, or events that occur on specific, non-consecutive days.

FLUVIAL FLOODING

The hazard of fluvial flooding is considered on the basis of the flooding results generated within the National Floodplain Mapping System for return periods of 10, 100 and 500 years (MITECO, 2020). Fluvial flooding has a relatively low incidence within the municipality of Santander, with flood zones only appearing in the west of the municipality, coinciding with areas bordering the Otero Stream, which is approximately 1.3 km in length, belonging to the Pas-Miera System of the Western Cantabrian Hydrographic Demarcation.

The fluvial flood area, in particular, covers a total surface area of 8.22 ha within the municipality, of which 5.72 ha correspond to areas with a return period of 10 years (high probability), 1 ha corresponds to areas with a return period of 100 years (medium probability), and the remaining 1.50 ha corresponds to areas with a return period of 500 years (low probability). The fluvial flood area would affect a single census section of the municipality, where the percentage of threatened surface area would be 0.027%.

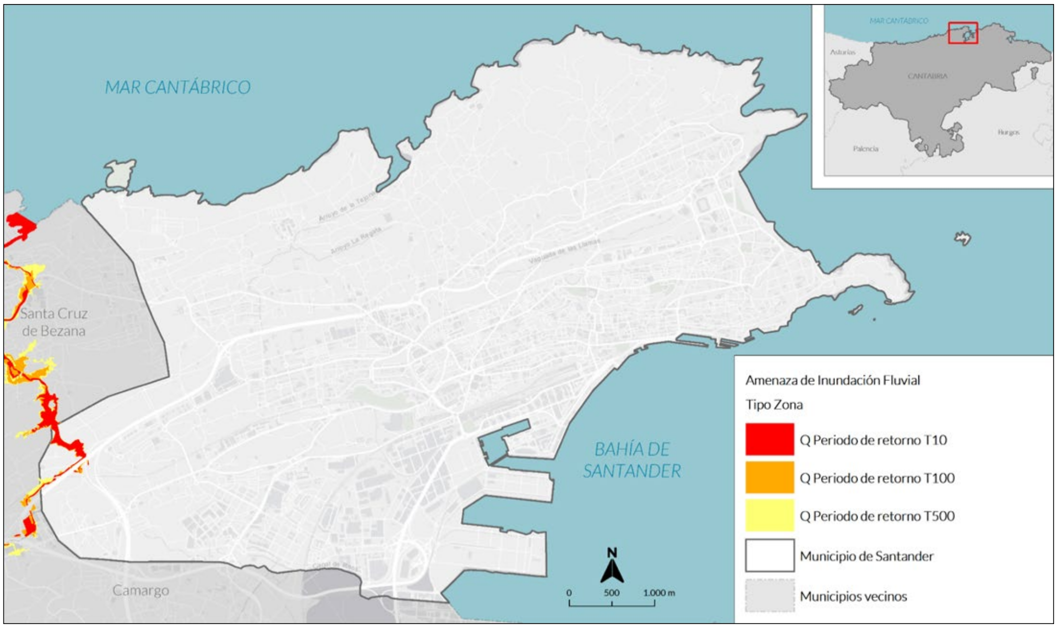


Figure 4.18. *Fluvial Flood Hazards 10, 100 and 500 year return periods*

Source: CINCc (UC) - FIC, 2024 based on SNCZI data (MITECO, 2020)

URBAN HEAT ISLANDS

Heat islands are a phenomenon of urban areas that experience higher temperatures than the surrounding areas due to human activity. The heat island effect is characterised by higher temperatures in cities than in the surrounding areas and is more pronounced at night.

The **main causes** are the heat accumulation on structures, such as buildings, pavements or asphalt, which absorb more heat and release it more slowly. Added to this is the heat and air pollution generated by traffic and industry, which trap solar radiation and prevent heat dissipation, which in turn increase air temperatures.

This exacerbates the consequences of climate change in cities and reduces the quality of life of city residents. High temperatures, especially, can affect the health of urban citizens, causing general unrest, respiratory problems, sunstroke, dehydration, fatigue and even increased mortality from heat stroke. In addition, they have direct energy and economic impacts. Mainly in summer, heat islands generate an increase in energy demand from air conditioning, which in turn increases the price of electricity.

The detection of **Urban Heat Islands** (UHI) can be approached from ambient temperature data collection with remote sensors such as weather stations or tools that allow temperature records on the ground, or from obtaining data through satellite images. In this sense, the use of remote sensing images allows the calculation of **Land Surface Temperature** (LST). The LST data collected from the satellite, in this case, have been compared and correlated with selected ambient temperature data from nearby surface weather stations. As a result of this correlation, it has been possible to apply the equation for the conversion of LST values to ambient temperature per pixel, cropped to the municipal area of Santander. Finally, the geometry of the islands in areas of high urbanisation has been spatially delimited, applying the criterion of selecting areas with an ambient temperature 2°C above the peripheral ambient temperature. Finally, a validation procedure has been carried out by applying the Expert Criteria, using temperature data taken in Santander by the Smart City project.

As a result, the LST has been obtained through Landsat 8 images for 1 July as an example scenario to subsequently address the delimitation of potential heat islands (figure 4.19).

Finally, a **validation** process of the potential areas delimited in the previous step has been carried out, which includes validation through the temperature data taken in Santander by the Smart City project from 2012 to 2023, and a validation based on expert criteria. This procedure consisted in testing the results of the potential delimitation of heat islands by the team of local experts with extensive knowledge of the subject. Taking into account the two previous aspects and considerations, the delimitation of the UHI proposed for Santander should be considered as a first analytical approximation that should, in any case, be complemented with ambient temperature data in the city with adequate coverage and distribution in future initiatives.

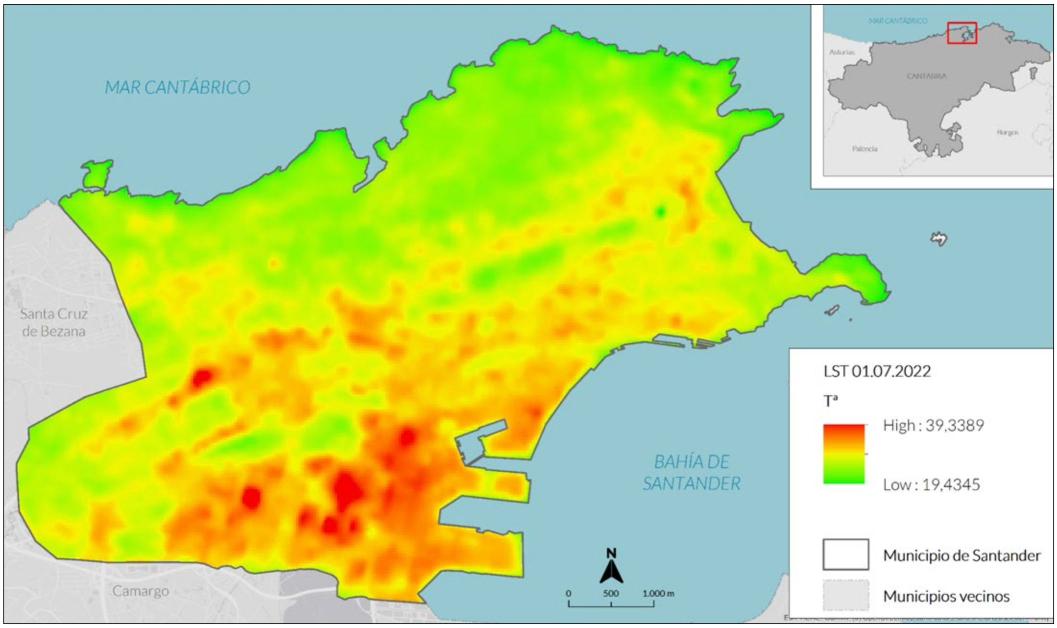


Figure 4.19. *Results of the Land Surface Temperature calculation*
Source: CINCc (UC) - FIC, 2024 based on Landsat 8 image (01/07/2022)

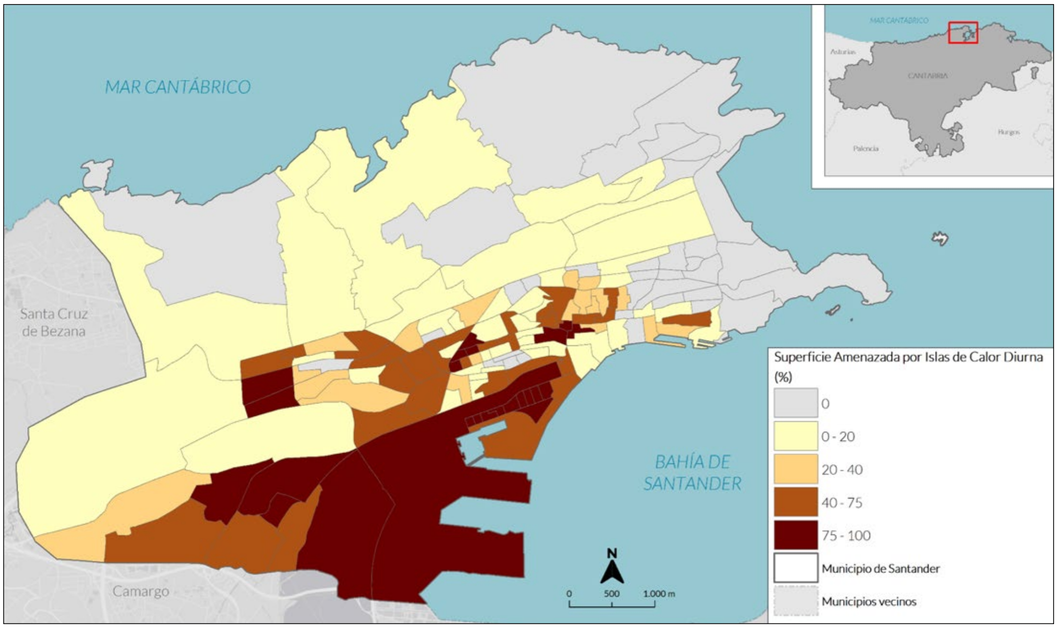


Figure 4.20. *Percentage of Area Threatened by Potential Diurnal Heat Islands by Census Sections*
Source: CINCc (UC) - FIC, 2024.

The hazard of Urban Heat Island episodes in Santander is represented in figure 4.20 by the percentage of surface area threatened by the Diurnal Urban Heat Island phenomena through the census section. The areas with the highest percentages of surface area threatened by UHI, above 75% of their surface area, are concentrated in the south, southwest and centre of the municipality. The coastal sections to the east, southwest and east, on the other hand, show no or very low values of threatened surface area.

HEAT WAVES

Heat waves have been defined as episodes of at least three consecutive days with maximum temperatures above the 95th percentile of the historical series of maximum daily temperatures for the months from April to September.

The following heat wave threat indices have been analysed within this framework:

- Number of heat waves per year
- Average duration of heat wave
- Number of heat wave days per year
- Average and maximum heat wave intensity

In order not to extend the information related to this type of event, the project shows the most characteristic indices that display the future dynamics of the phenomenon (number of heat waves and average duration). According to the historical series observed for the period 1985-2014, the average number of heat waves per year in the municipality of Santander is approximately 1.2. The scenarios projected in the short term predict a **notable increase in the average number of heat waves per year**, rising to values between 2 and 2.5 heat waves per year for the most optimistic scenario, SSP1-2.6, and the pessimistic scenario, SSP5-8.5, respectively. That is, the occurrence of these occurrence of these episodes will double in the coming years. In the medium term, the number of heat waves per year is around 3, reaching 4 for the SSP5-8.5 scenario. This trend continues towards the end of the century, reaching 6 heat waves per year for the SSP3-7.0 scenario, and exceeding 7 heat waves per year for the most pessimistic scenario, SSP5-8.5 (table 4.9).

The **average duration** of heat wave episodes in Santander, according to the average of the climate models for the period 1985-2014, is approximately 4.5 days. The projected scenarios also indicate an increasing trend in the average duration of such episodes in the medium and long term, albeit more moderately. For the short term, the climate scenarios predict an average duration between 5 and 5.5 days, with this threshold being maintained for the middle and end of the century in the most optimistic scenario. For the intermediate scenarios, SSP2-4.5 and SSP3-7.0, the mid-century and end of the century periods are expected to last between 6 and 7 days on average, respectively. In the most pessimistic scenario, SSP5-8.5, the average duration of the heat wave could double compared to the historical average, reaching values of 9.7 days of average duration of these episodes (table 4.10).

TABLE 4.9. *Average number of heat waves per year in Santander*

HISTORICAL AVERAGE: 1.22717	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Short Term (2016-2040)	2.19313	2.09226	2.45672	2.55703
Medium Term (2041-2070)	2.65326	3.10226	3.96508	4.22697
Long Term (2071-2100)	2.77366	4.32831	5.99306	7.01242

Source: CINCc (UC) - FIC, 2024 based on local climate scenarios based on the outputs of the sixth IPCC report

TABLE 4.10. *Average duration of heat wave episodes in Santander*

HISTORICAL AVERAGE: 4.45443	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Short Term (2016-2040)	5.13939	4.80084	5.20159	5.52596
Medium Term (2041-2070)	5.65013	6.09086	6.04402	7.03383
Long Term (2071-2100)	5.38460	6.82348	7.38716	9.7208

Source: CINCc (UC) - FIC, 2024 based on local climate scenarios based on the outputs of the sixth IPCC report

Two combined indicators have been used to represent the threat of heat wave events in Santander by census sections:

(i) **Number of heat wave days** per year which, in turn, includes forecasts of the average duration and frequency of such episodes.

(ii) **Maximum intensity** of the heat wave. For each of the time horizons considered, average values representative of the set of scenarios analysed, previously normalised, are obtained and combined.

Both heat wave days and maximum intensities show significant changes for all projected climate scenarios in each time scenario compared to the historical average. This means that the normalised heatwave threat levels tend to almost double by the end of the century compared to historical values.

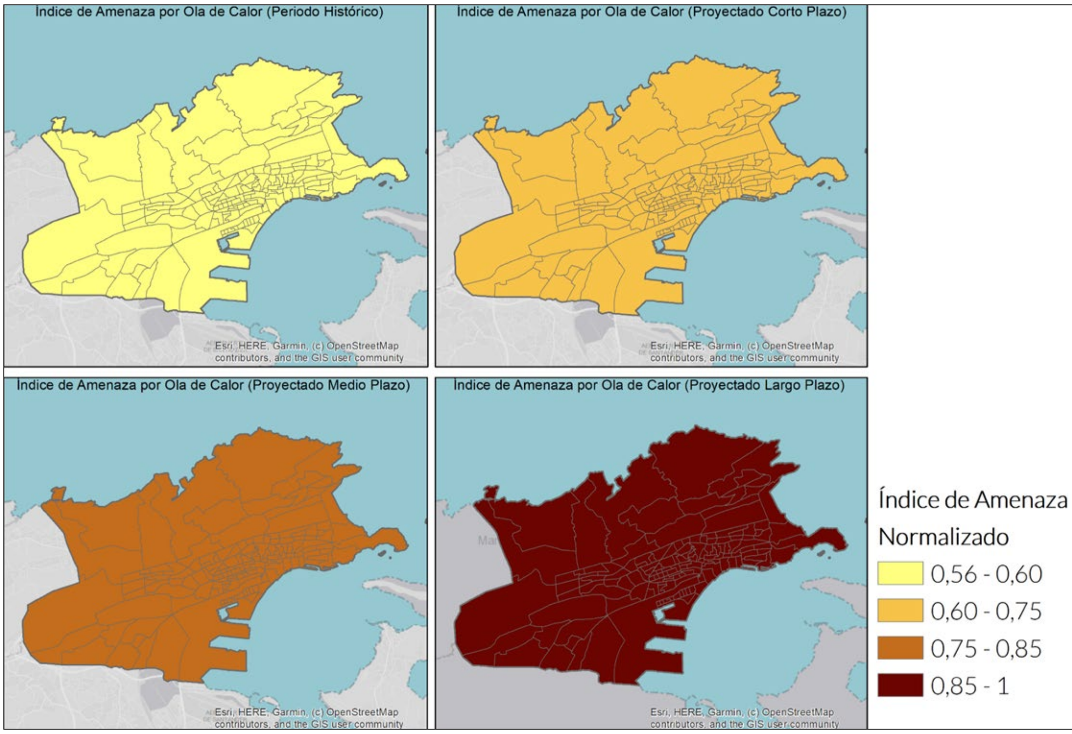


Figure 4.21. *Heat wave Hazard Index for Santander*

Note: Historical period (top left), projected short (top right), medium (bottom left) and long term (bottom right).
Source: CINCc (UC) - FIC, 2024.

TABLE 4.11. *Average values per time horizon of maximum intensity and heatwave days per year*

	HEAT WAVE DAYS PER YEAR	MAXIMUM HEAT WAVE INTENSITY	HEAT WAVE HAZARD INDEX
Historical Average (1985-2014)	10.23	29.06	0.57
Short Term (2016-2040)	19.41	29.52	0.66
Medium Term (2041-2070)	30.02	29.79	0.77
Long Term (2071-2100)	51.48	30.19	0.95

Source: CINCc (UC) - FIC, 2024.
Note: For set of climate scenarios and average results of the combined Hazard Index.

TROPICAL AND TORRID NIGHTS

A tropical night is one in which minimum temperatures do not fall below 20°C, while equatorial or torrid nights are those in which the minimum temperature does not fall below 25°C, according to the AEMET.

Results of the Analysis of Tropical Nights in Santander

The average annual frequency of tropical nights in Santander, referring to **consecutive day** events, for the series observed in the historical period from 1985 to 2014 is 1.160349. According to local climate change scenarios, based on recent IPCC outputs (6th IPCC Report), the projected mean frequency of tropical nights in Santander for the short term is around annual mean values close to 3, for all emission scenarios. For the medium term, it is around annual mean values between 3 and 6; and for the long term, it is around annual mean values between 3 and 10 consecutive nights.

TABLE 4.12. *Average frequency of Tropical Nights events with minimum temperature of 20°C in Santander*

	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Short Term (2016-2040)	2.787025	3.190978	3.348073	3.036371
Medium Term (2041-2070)	3.636427	4.493451	5.924965	6.181109
Long Term (2071-2100)	3.475246	6.361529	9.097015	9.889041

Source: CINCc (UC) - FIC, 2024 based on local climate scenarios based on the outputs of the sixth IPCC report

The **mean annual duration**, referring to consecutive days, of tropical nights or nights with minimum temperatures of 20°C in Santander for the series observed in the historical period from 1985 to 2014 is 1.837181. According to local climate change scenarios, based on recent IPCC outputs (6th IPCC Report), the projected average duration of tropical nights in Santander for the short term is around 3 to 4 annual mean values, depending on the emission scenario; for the medium term, it is around 4 to 6 annual mean values; and for the long term, it is around 4 to 9 annual mean values.

TABLE 4.13. *Average duration of Tropical Nights with a minimum temperature of 20°C in Santander*

	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Short Term (2016-2040)	3.458352	3.331906	3.822967	3.823205
Medium Term (2041-2070)	4.042616	4.578436	5.205120	5.751033
Long Term (2071-2100)	3.792237	6.093193	7.215842	8.758299

Source: CINCc (UC) - FIC, 2024 based on local climate scenarios based on the outputs of the sixth IPCC report

Results of the Equatorial or Torrid Nights Analysis in Santander

The average climate projections for the medium term increase the values to approximately 0.8 hot nights per year on average in Santander, with projected minimum values of around 0.23 for the SSP1-2.6 scenario, and maximum values of 1.78 for the SSP5-8.5 scenario (table 4.14).

For the long term they increase the values to approximately 4 torrid nights per year on average in Santander, with projected minimum values of around 0.19 for the SSP1-2.6 scenario, and maximum values of 9 for the SSP5-8.5 scenario (table 4.15).

TABLE 4.14. *Average frequency of Torrid Night events with minimum temperature of 25°C in Santander*

HISTORICAL = 0.005508	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Short Term (2016-2040)	0.046056	0.053913	0.091899	0.05374
Medium Term (2041-2070)	0.089231	0.222254	0.314885	0.494965
Long Term (2071-2100)	0.076732	0.350549	1.490410	2.632053

Source: CINCc (UC) - FIC, 2024 based on local climate scenarios based on the outputs of the sixth IPCC report

TABLE 4.15. *Average duration of Torrid Nights with a minimum temperature of 25°C in Santander*

HISTORICAL = 0.005508	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Short Term (2016-2040)	0.126627	0.116973	0.134218	0.09728
Medium Term (2041-2070)	0.138409	0.314264	0.49166	0.895114
Long Term (2071-2100)	0.135956	0.554091	2.181558	3.03577

Source: CINCc (UC) - FIC, 2024 based on local climate scenarios based on the outputs of the sixth IPCC report

METEOROLOGICAL DROUGHT

The importance of drought lies in its impact and the sectors it affects. What differentiates the different types of droughts are the **intensity**, **duration** and **spatial coverage** of the phenomenon and the sector it affects (Hayes et al., 2011). Understanding the short-term behaviour of these phenomena is of great importance to minimise negative impacts. The risk associated with a drought event is a consequence of the natural characteristics of the event itself and the vulnerability of society to it.

The analysis of meteorological drought episodes, by their very nature, is not limited to the administrative areas of a municipality. Its incidence has a regional character with a direct implication on the availability of water resources for human consumption.

The mean values expected for the SPI (Standardised Precipitation Index) have a general negative trend but are considered normal. The mean values expected for SPI are estimated to be normal for the short and medium term and moderately dry and very dry for the long term. As shown in the figure 4.22, the short-term drought hazard level presents a negative trend but within the threshold of natural climate variability in Santander. This negative trend increases in the medium term. Finally, for the long term, a severe threat level is expected, showing a moderately dry drought threshold with respect to the medium-term accumulated drought.

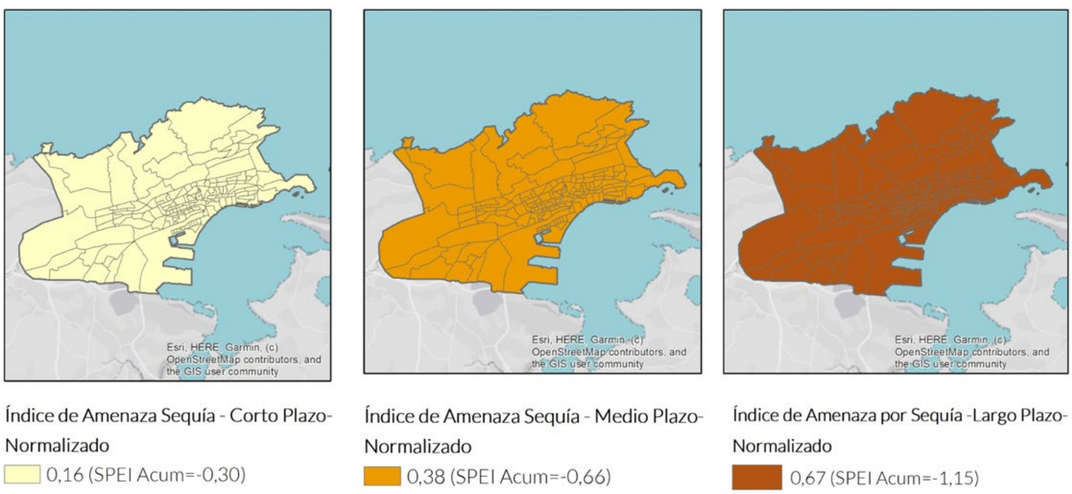


Figure 4.22. *Drought Hazard Index*
Source: CINCc (UC) - FIC, 2024.

EXTREME WIND, *GALERNAS* AND SOUTHERLY WIND

In the municipality of Santander, the predominant wind direction is west, with north-westerly winds also being very frequent, having average speeds of 13.87 km/h and 13.43 km/h respectively (Ayuntamiento de Santander, 2016). Winds of more than 91 km/h occur between September and April. Every year there are storms from both the north-west and south-west, with gusts of over 100 km/h. In general, the wind conditions two types of weather situations:

- **Humid situations:**

They are produced when winds blow from the north to the west, laden with humidity due to their maritime origin. These, when they meet the Cantabrian mountain range, rise and cool down, producing condensation phenomena. This causes clouds to form and stagnate against the mountain range, causing more or less persistent rainfall.

- **Dry situations:**

Originating from north-easterly and easterly winds, these are of continental origin, dry and cold. In this situation the sky is usually clear, although heavy frosts occur.

When caused by southerly winds, these situations are dry with an abnormal increase in temperature. Humidity can drop to 40% and the temperature can reach 30ºC, even in the middle of winter.

Any area of the municipality is exposed to episodes of extreme wind, although to a greater extent in coastal areas and exposed slopes. It should be noted that the upper area of the municipality is divided into the northern and southern slopes, so that more interventions are recorded along the southern slope when the wind blows from this side and vice versa. Specifically, southerly winds represent the most common risk situations in the municipality. According to the PEMUSAN, extreme winds are defined as winds with an intensity of more than 80 km/h, regardless of their direction. Winds in Santander have an impact on the occurrence of coastal storms F7, (50-61 km/h), rough seas, swells of 3 to 4 metres, and the occurrence of *galernas*, a characteristic wind storm of the Cantabrian sea, consisting in the shift from south winds or calm conditions to:

- At sea, sudden change of wind, increasing and turning north-west with F7.
- On land, a sharp turn of the wind to the north-west, increasing suddenly with strong gusts of more than 60 km/h along the coast.

For the present study, both types of episodes have been analysed: (i) winds of intensity greater than 80 km/h, and (ii) gusty winds from a southerly direction. For each of these variable intensity events, the following frequency and duration indices have been analysed:

- Frequency, analysed as the average number of extreme wind events per year.
- Average duration of the event, analyzed as the average number of consecutive days per year that extreme wind events occur.

In order to represent the threat from extreme wind events in Santander by census sections, the mean normalised value per census section of the maximum gust of a southerly component has been used. As shown in the figure 4.23, the level of hazard due to the occurrence of episodes of extreme wind shows geographical variability within the municipality, generally tending towards relatively higher values for the north-eastern sections, but nevertheless remaining with values between 0.86 and 1, i.e., with a low amplitude range. This is due to the fact that, as a result of the analysis carried out, the average or maximum south wind gusts, as well as, in general, the extreme wind episodes will have a very slight **downward trend** in both absolute and relative terms, with respect to the historical period, where the maximum values are reached.

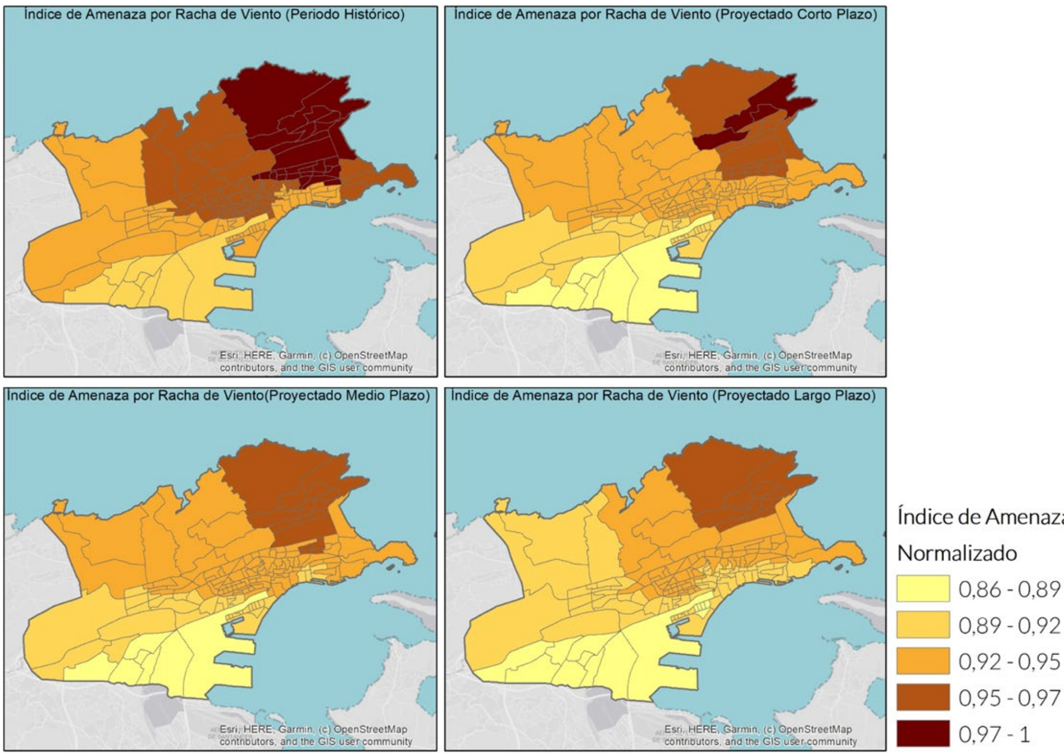


Figure 4.23. *Extreme wind hazard index for Santander*

Note: Historical period (top left), projected short (top right), medium (bottom left) and long term (bottom right).

Source: CINCc (UC) - FIC, 2024.

Therefore, the occurrence of extreme winds and maximum gusts of the southern component for the set of climate scenarios projected in each time scenario does not present very notable changes with respect to the historical average, which means that the normalised hazard levels for extreme wind episodes tend to remain above 0.86 in all the time scenarios.

TABLE 4.16. *Mean values of maximum gust in km/h and Combined Threat Index*

	MAXIMUM GUST (AVERAGE)	MAXIMUM GUST (RANGE)	MEDIUM HAZARD INDEX
Historical Period (1985-2014)	103.21	96.67-108.27	0.95
Short Term (2016-2040)	100.67	94.53-105.49	0.93
Medium Term (2041-2070)	100.32	94.46-104.97	0.92
Long Term (2071-2100)	99.44	93.54-104.10	0.92

Source: CINCc (UC) - FIC, 2024.

Note: By time horizon and for set of climate scenarios

COASTAL FLOODING

In the field of coastal areas, **PIMA Adapta**[8] has been developing a wide range of coastal habitat restoration and shoreline stabilisation actions along the entire Spanish coastline. This initiative, framed within the Spanish Coastal Climate Change Adaptation Strategy, which was approved in 2017, has a repository of high-resolution databases generated for the assessment of coastal flooding, including areas of coastal flooding and flood depth for both the historical period and the future for the 2050 and 2100 horizons with a return period of 100 years. This future modelling is also established for the RCP4.5 and RCP8.5 emissions scenarios, intermediate and pessimistic, respectively.

For the Community of Cantabria, the results of the Adapta Costa Report (2019-2021) are accessible through the official Geographic Information Viewer of the Government of Cantabria. The areas and depths of coastal flooding for the historical period and for the most pessimistic scenario (RCP8.5 in the period 2100) are shown in figure 4.24 and table 4.17.

At the municipal level, the area of coastal flooding for the historical period and with a 100-year recurrence is 108 ha with maximum depth levels close to 10 m in the lowest areas.

The mid-century projections indicate increases in flood area of approximately 5%, being a few tenths higher for the RCP8.5 scenario. And finally, the projection scenarios for 2100 indicate increases in coastal flood area of approximately 24% for RCP4.5 and 30% for RCP8.5, with maximum flood depth levels close to 11.4m. The results of the incidence of coastal flooding in the municipality of Santander for each of the scenarios considered are shown in figure 4.24 and table 4.17.

[8] See: https://www.miteco.gob.es/es/cambio-climatico/planes-y-estrategias/pima-adapta.html

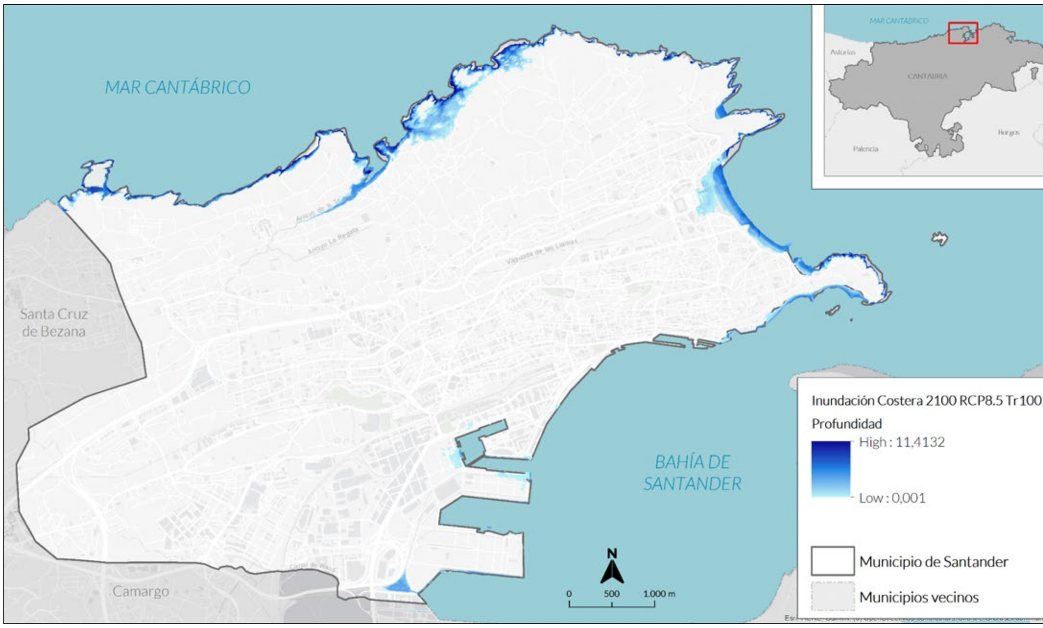


Figure 4.24. *Coastal Flood Areas and Flood Depth 2100 RCP8.5*

Source: CINCc (UC) - FIC, 2024 based on data from the Adapta-Costa Cantabria Report (2019-2021)

TABLE 4.17. *Index changes due to sea level rise*

MEDIUM SCENARIO (TR100 YEARS)	FLOOD AREA (Ha)	RANGE DEPTH (m)	CHANGE FROM HISTORICAL (Ha)	%CHANGE FROM HISTORICAL
Historical	108.34	0.001 - 9.9008		
Projection RCP4.5 2050	113.37	0.001 - 10.059	+5.03	+4.64%
Projection RCP8.5 2050	114.24	0.001 - 10.1473	+5.90	+5.44%
Projection RCP4.5 2100	131.90	0.001 - 10.8353	+23.56	+21.75%
Projection RCP8.5 2100	141.35	0.001 - 11.4132	+33.01	+30.47%

Source: CINCc (UC) - FIC, 2024 based on data from the Adapta-Costa Cantabria Report (2019-2021)

RISK ANALYSIS 5

Laura Asensio Martínez, Francisco García Sánchez, Nareme Herrera López, Cecilia Ribalaygua

5.1 CLIMATE EXPOSURE ANALYSIS

According to the definition in the 6th IPCC Assessment Report (MITECO, 2022[1]), **exposure** is defined as the presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructures or economic, social or cultural assets in places and environments that could be adversely affected. For the present framework, this is directly related to the occurrence of climate-related hazard events, both for the current horizon and for the projected short-, medium- and long-term horizons. The steps to address the exposure analysis are as follows:

- **Identification of the set of elements** that may be affected by each of the priority climate hazards in the municipality of Santander. In this sense, and in general, five large sets of elements or exposure components have been identified:

    1. Resident population
    2. Residential buildings and housing
    3. Infrastructure, utilities and recreational facilities (roads, power lines, railway infrastructure, port area, buildings for public services, such as sports complexes, industrial or recreational facilities, etc.)
    4. Economic assets (shops, offices, industrial or agricultural buildings and hotels)
    5. Areas of interest and natural resources (beaches, coastal habitats, ecosystems, etc.).

- **Obtaining the set of exposed elements** by means of **cartographic intersection** in a Geographic Information System (GIS) environment for each of the hazard scenarios analysed in the previous section. As a result of this intersection, the level

[1] Climate Change: Impacts, Adaptation and Vulnerability (Summary Guide to the IPCC Sixth Assessment Report, Group II) Available at: https://www.miteco.gob.es/content/dam/miteco/es/cambio-climatico/publicaciones/publicaciones/guia_local_para_adaptacion_cambio_climatico_en_municipios_espanoles_tcm30-178446.pdf

of climatic exposure is obtained at the municipal level for each of the elements considered.

- **Calculation of indicators of the level of climate exposure** per census section per set of elements and climate scenario. This phase is dedicated to the generation of standardised climate exposure indicators at census section scale, understood as a representative measure of the level of climate exposure by group or set of elements.
- Calculation of the **Final Combined Exposure Index** for each of the climate scenarios considered. This includes an initial summation of the values obtained per component and a new normalisation of the data series, taking as maximum value the highest value of the census section for the most pessimistic scenario.

Below, we present Santander's exposure results for each of the hazards analysed.

EXTREME RAINFALL EVENTS

The exposure results for this hazard have been obtained through the analysis of **water-logging points** in extreme rainfall conditions with a special effect on floodable roads by census section.

For the study of the trend of extreme rainfall events in Santander, the periodicity of episodes of accumulated rainfall of 40 mm per day or more has been analysed for the historical series of 1985-2014. Thereafter, these results have been projected under local scenarios of climate change in the short, medium and long term.

According to the average of the climate models for the historical series, there are about 3 extreme rainfall events per year in the municipality of Santander. In the short term, an increase in the frequency of such events is expected, reaching values of 3.5 events/year on average for all the scenarios analysed. In the medium term, extreme rainfall events could occur between 3.5 and 4.5 times a year on average and depending on the scenario, and around 5 events/year in the long term in the most pessimistic scenario, SSP3-7.0.

TABLE 5.1. *Results of the Frequency of Extreme Rainfall Events in Santander*

HISTORICAL AVERAGE: 2.93878	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Short Term(2016-2040)	3.59749	3.56932	3.54964	3.51727
Medium Term (2041-2070)	3.63165	3.88392	4.18938	4.46125
Long Term (2071-2100)	3.73712	4.42478	4.83402	5.15589

Source: CINCc (UC) - FIC, 2024 based on local climate scenarios from the outputs of the sixth IPCC report

The analysis combines different processes and data sources, such as the analysis of **topographic subsidence conditions (Blue Spots)**, the analysis of waterlogging areas documented by PEMUSAN, and the evaluation of trends of extreme rainfall events under climate change conditions.

Based on its validation, it has been established that:

- The set of road sections coinciding with local depressions in the terrain or modelled blue points are considered to be floodable sections with high uncertainty.
- On the other hand, the roads coinciding with the flood risk areas established by the PEMUSAN are considered floodable sections with low uncertainty and high probability, with variation at P10 years.

Endorheic zones or sinkholes have been detected, using the 'Blue Spots' level 1 modelling methodology, which allows an initial detection of local depressions in the territory. For this purpose, a Digital Elevation Model (DEM) with a sufficient level of detail has been used to obtain an adequate representation of the transformations introduced by the layout of the road. For this purpose, the 2 m resolution Digital Terrain Model of the National Geographical Institute has been used, obtained from the LiDAR data (2nd Coverage).

From this DEM, the process needs to calculate those areas that, due to their relief morphology, could become waterlogged in situations of intense rainfall.

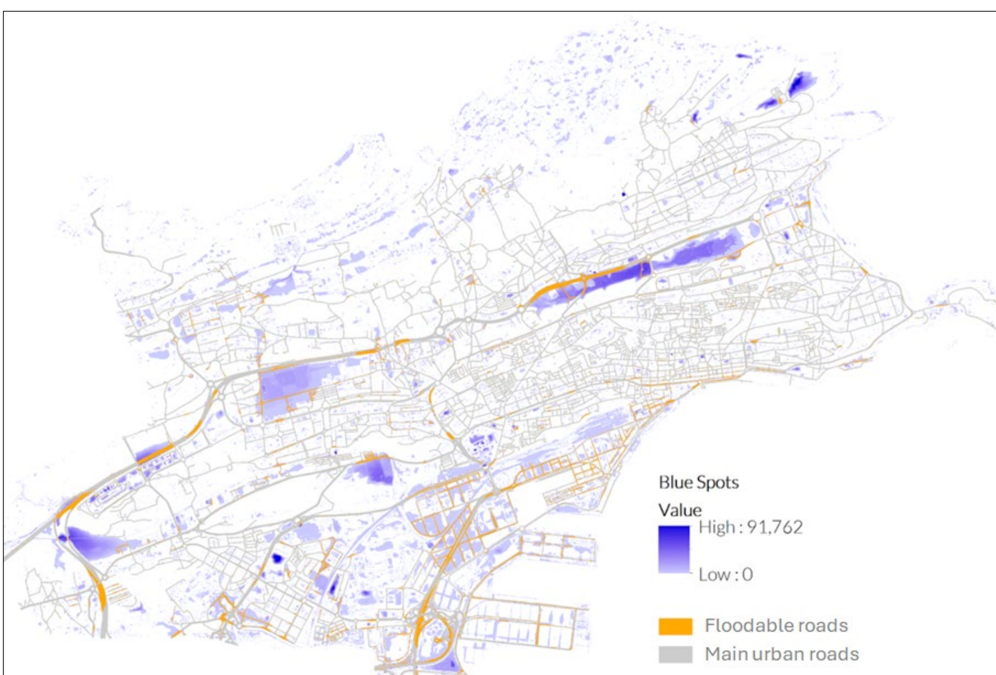


Figure 5.1. *Roads susceptible to waterlogging from Blue Spots modelling*
Source: CINCc (UC) - FIC, 2024.

Subsequently, by means of flood risk mapping provided by the Santander City Council, based on the Municipal Emergency Plan drawn up in 2016 and the geolocation of the records of interventions carried out from 2018 to 2022 by the Fire Brigade of the municipality, the points of conflict that may be exacerbated by periods of extreme rainfall in the future have been validated.

The process of delimiting flood-prone roads likely to flood due to extreme rainfall events in the municipality of Santander integrates the results obtained and analysed in the previous steps with the following criteria:

- The set of road sections coinciding with local depressions in the terrain or modelled blue points are considered to be flood-prone sections with **high uncertainty**. The possible occurrence of flooding along them will depend on the magnitude of an extreme rainfall event and the state of the drainage system and municipal sewers.
- All roads coinciding with the flood risk areas established by the PEMUSAN are considered flood-prone sections with low uncertainty and high probability, taking into account return periods of 10 years. These areas also assume a low capacity, insufficiency or deterioration of the municipal drainage system.
- The set of roads included in the intervention records, which coincide in geolocation and description, are considered to be flood-prone sections with low uncertainty and variable probability, as the magnitude of the events that generate these interventions are not documented.

The set of roads included in the intervention registers, which coincide in geolocation and description, are considered to be floodable stretches with low uncertainty and variable probability. The results show the surface area exposed in both conditions and the percentage of the total km^2 of roads in the affected municipality.

TABLE 5.2. *Characteristics according to level of uncertainty*

CATEGORY	DESCRIPTION	ESTIMATED Km^2 OF FLOODABLE ROADS	% OF TOTAL Km^2 OF MUNICIPAL ROADS IN THE MUNICIPALITY
Floodable roads with High Uncertainty	Roads located in local ground depressions. No flooding events have been documented.	0.645985	13.24%
Floodable roads with Low Uncertainty	Roads with documented flooding events at local level, PEMUSAN and Firefighters Intervention Record	0.17079	3.5%

Source: CINCc (UC) - FIC.

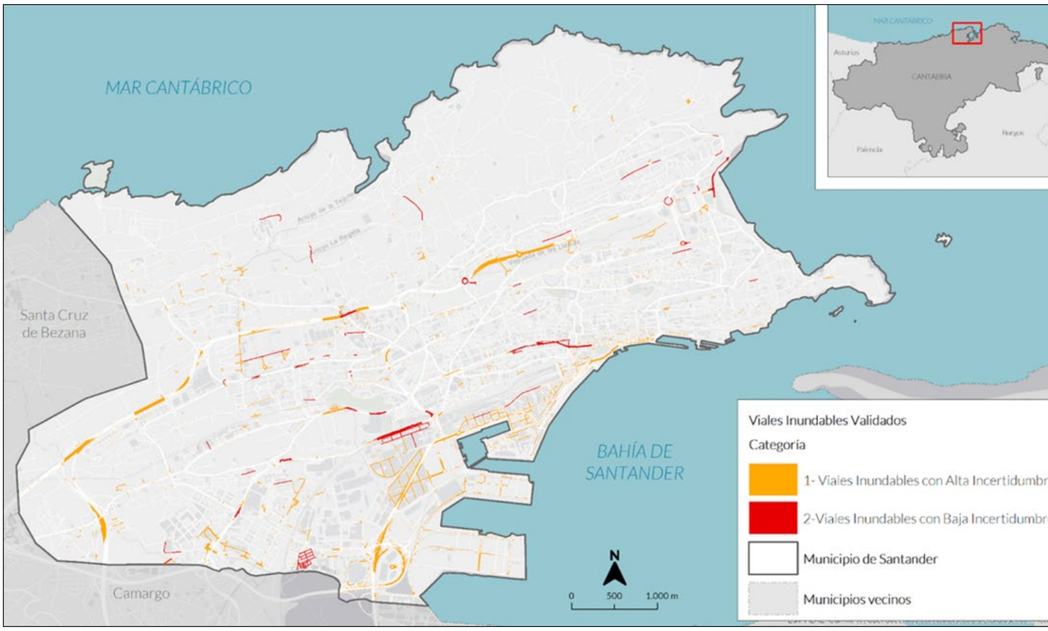


Figure 5.2. *Location of roads susceptible to waterlogging*
Source: CINCc (UC) - FIC, 2024.

This analysis and modelling does not consider the municipal drainage system on a detailed scale, such as **runoff** and **accumulation** of flow generated by extreme rainfall events, considering current and future conditions for different return periods, as this technical information is not managed by the entity managing the drainage network. However, in technical meetings held with local technical managers, the current capacity of the system to resolve specific flooding events and adequately drain the public space has been reported. In any case, the information accumulated is sufficient for the municipality to have a map of exposure that allows it to focus on and prioritise strategies for action

FLUVIAL FLOODING

For the fluvial flooding areas analysed, two main sets of **exposure elements** or components have been identified:

1. **Road infrastructure**, especially roads and railway infrastructure. The base cartography comes from the National Topographic Base at detailed scale (IGN, 2022).
2. **Economic assets**, specifically herbaceous crop areas, and natural resources, specifically natural land areas covered by woodland, scrubland, grassland or natural pasture. The base mapping is from the high-resolution SIOSE Land Cover and Uses (PNOA, 2017).

Exposed Road Infrastructure

A total of 6 sections of **secondary paths**, with a length of 381.3 metres, are located in areas threatened by river flooding within the municipality of Santander. The cutting off of these roads due to fluvial flooding events could temporarily limit access to certain nearby private properties.

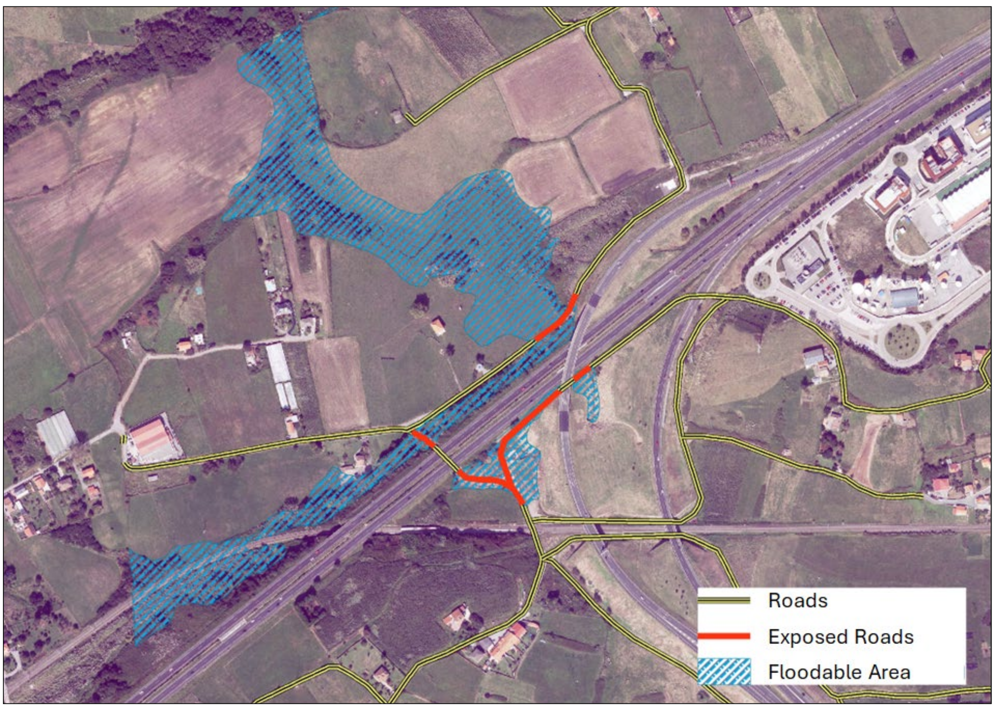


Figure 5.3. *Detail of the section of the conventional railway line that is located in areas of river flooding*

Source: CINCc (UC) - FIC, 2024.

In addition, a small section of the **conventional railway** line with a length of 152.5 metres is also exposed to the hazard of fluvial flooding, which specifically corresponds to the first section of the entrance to the municipality at its western end. In this case, although the length of the section is shorter, the occasional flooding could generate a temporary interruption in the regular transit of the railway line.

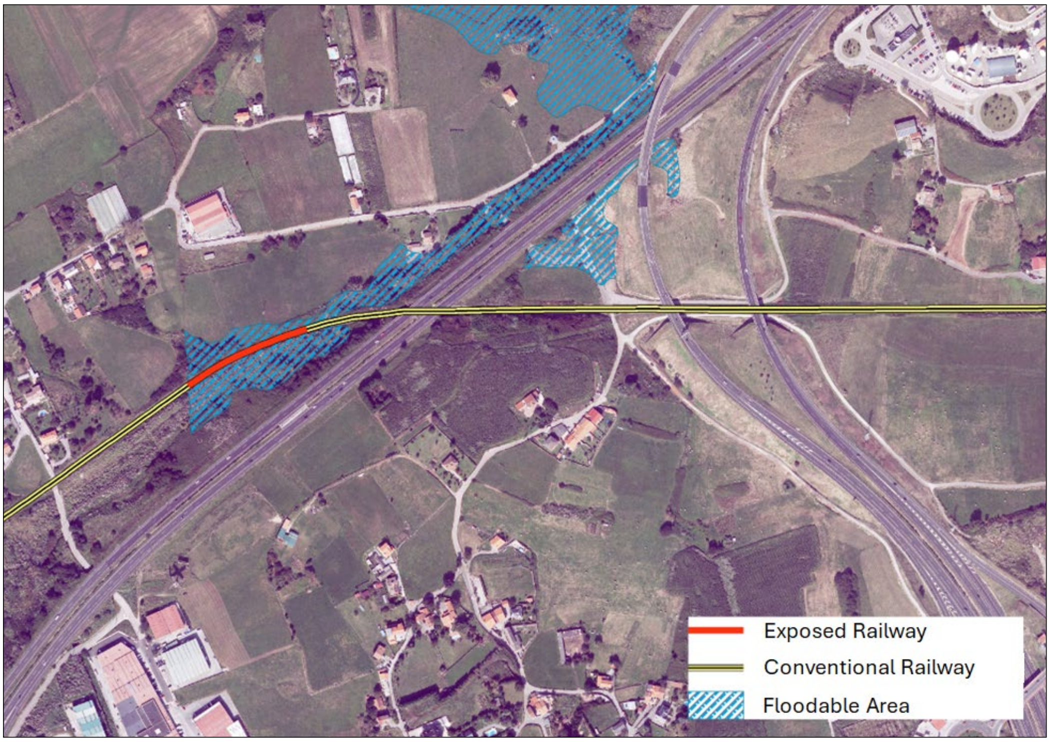


Figure 5.4. *Detail of the section of the conventional railway line that is located in areas of river flooding.*

Source: CINCc (UC) - FIC, 2024.

Exposed Crops and Exposed Natural Terrestrial Areas

TABLE 5.3. *Distribution of vegetation cover in the flood zone*

COVERAGE	AREA (Ha)
Woodland	0.08361
Herbaceus crops	0.074942
Scrub	0.204449
Pasture	1.918821
Pasture - scrub	1.622782
Grassland	2.170966
Land with little or no vegetation	1.342482
Artificial green area and urban treees	0.048441

Source: CINCc (UC) - FIC, 2024.

The fluvial flooding area contains an area of 749.4 m^2 for arable crops and a remaining area of 7.34 ha with various natural vegetation covers, including natural grasslands, pastures and scrubland.

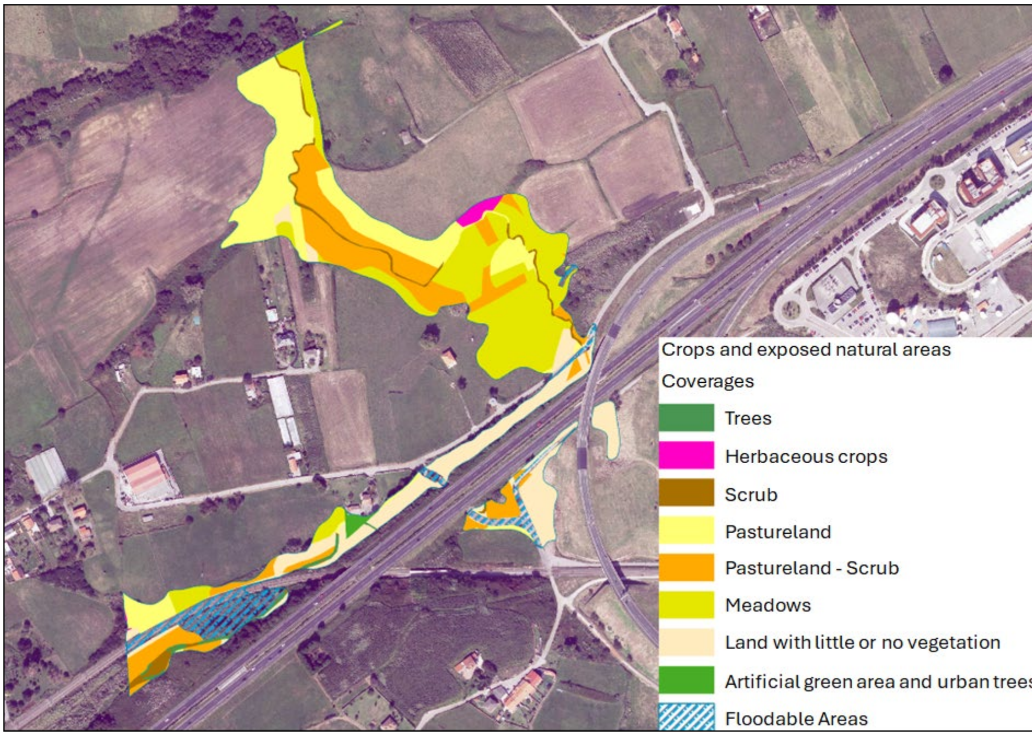


Figure 5.5. *Crops and natural areas exposed to river flooding events*
Source: CINCc (UC) - FIC, 2024.

URBAN HEAT ISLANDS

The resident population exposed to diurnal urban heat islands (UHI) has been obtained from the intersection between the area proposed as UHI and the official mapping of inhabitants per plot of the Santander City Council, using the approximation estimation method through population densities per plot, for those areas exposed.

A total of 58,964 people reside in plots located within the areas proposed as ICU for the municipality of Santander as a whole. At census section level, the percentage of exposed resident population shows a high variability. The highest percentage values are concentrated in certain central sections coinciding with the consolidated urban centre of the municipality, together with the south-western sections, including the industrial areas and the port area. On the other hand, the east coast and a large part of the north coast have zero values.

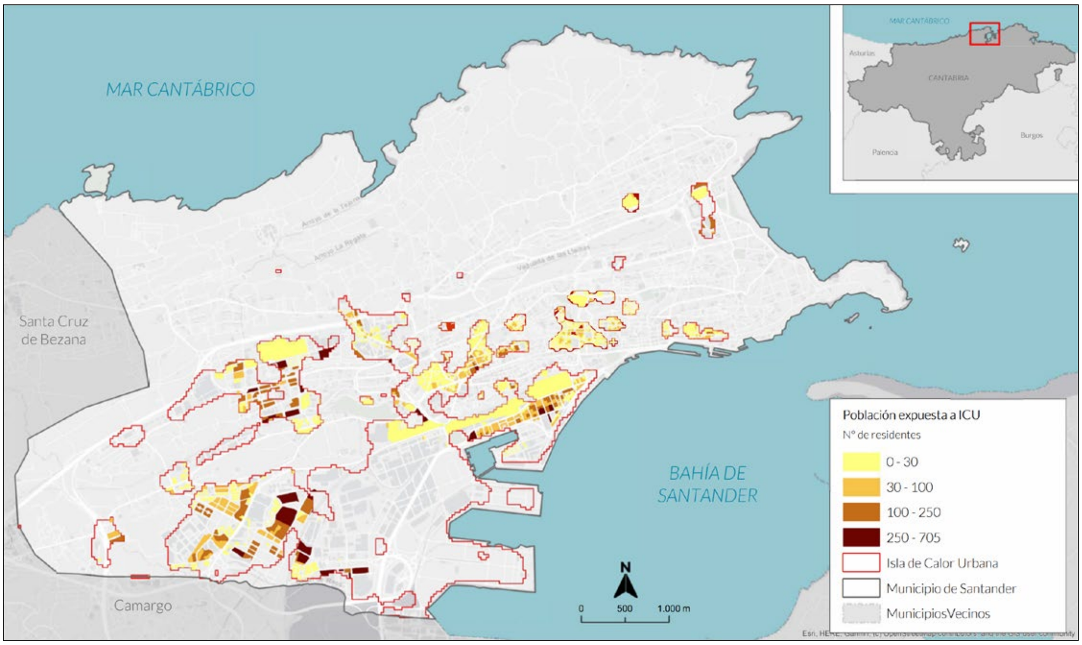


Figure 5.6. *Resident Population Exposed per plot to Potential Diurnal Heat Islands*

Source: CINCc (UC) - FIC, 2024.

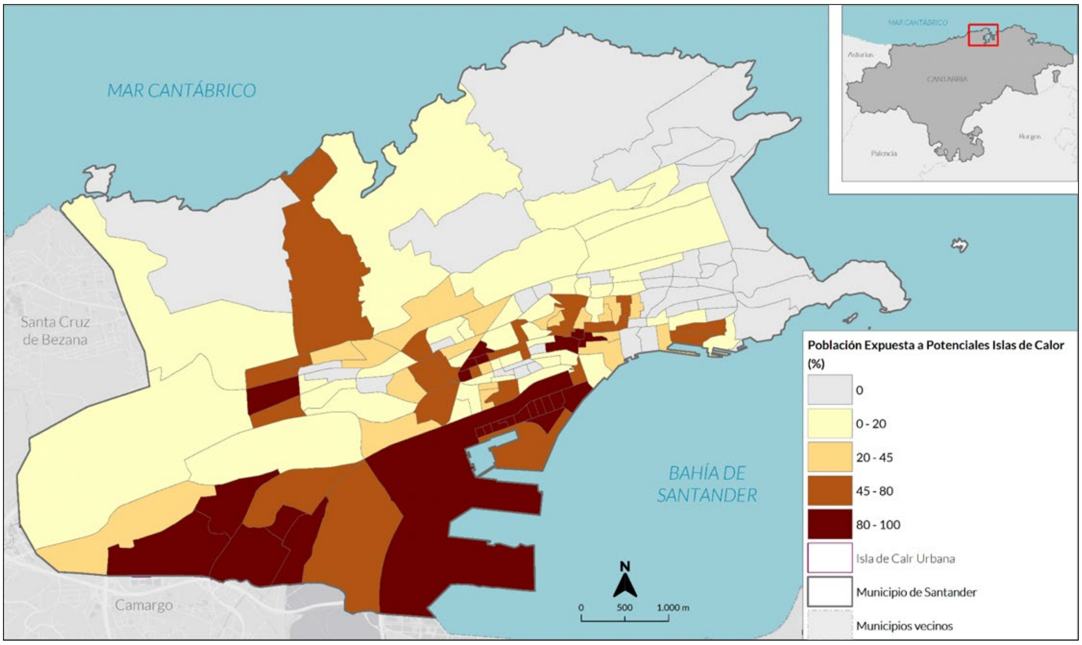


Figure 5.7. *Percentage of Resident Population Exposed to Potential Diurnal Heat Islands*

Source: CINCc (UC) - FIC, 2024.

EXTREME SOUTHERLY WIND

In the case of extreme wind events, the PEMUSAN zoned the municipality into two large areas, those experiencing north winds and Galician winds, and those exposed to south winds, with these slopes experiencing the greatest number of interventions.

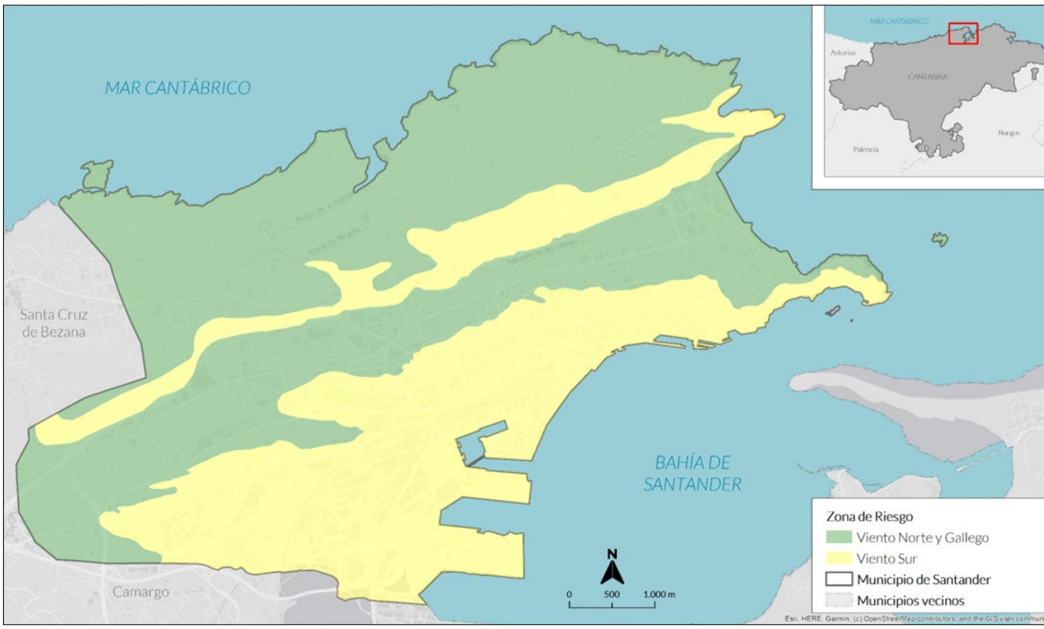


Figure 5.8. *Zones at risk from strong winds in the municipality of Santander*
Source: CINCc (UC) - FIC, 2024 based on information from the Santander Municipal Emergency Plan, Santander City Council, 2016.

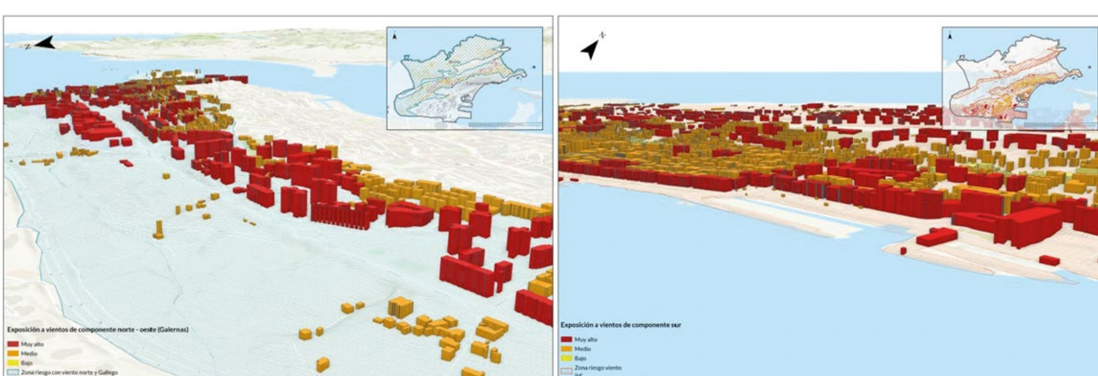


Figure 5.9. *Exposed Elements and Degree of Exposure to Extreme Wind*
Source: CINCc (UC), 2024.

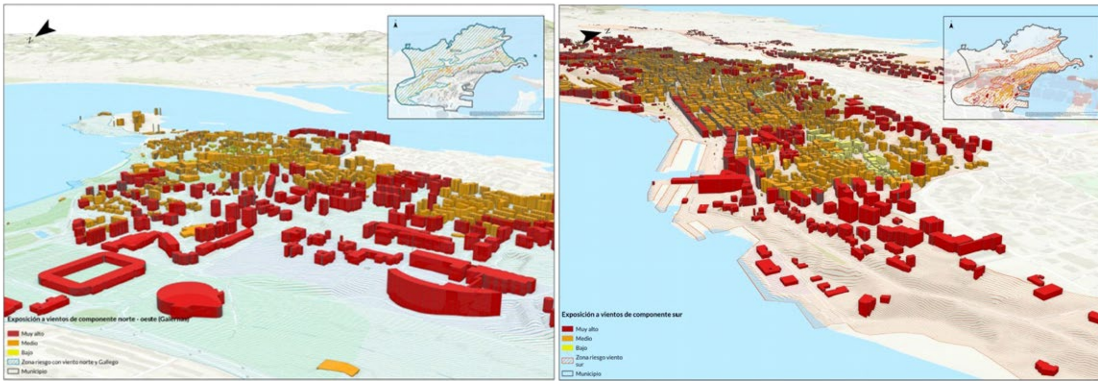


Figure 5.10. *Exposure to north-northwest and south-southwest winds in the areas defined by PEMUSAN (2016)*

Source: CINCc (UC), 2024.

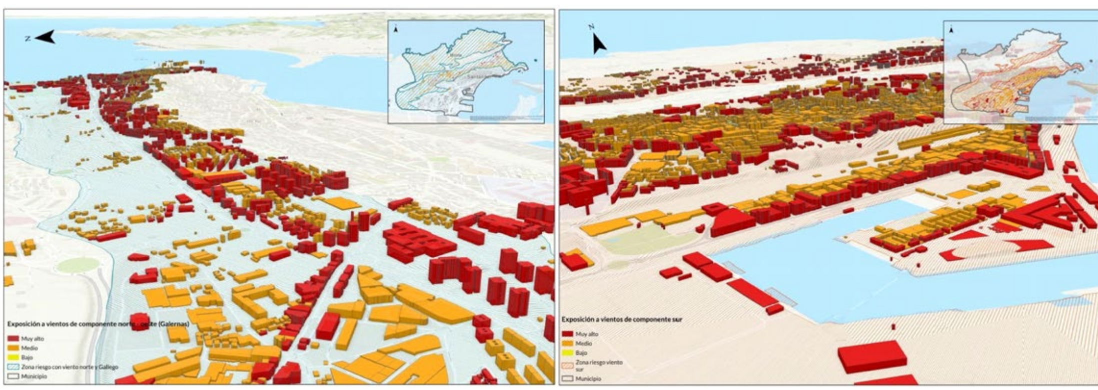


Figure 5.11. *Distribution of extreme wind exposure in different areas of the city*

Source: CINCc (UC), 2024.

The previous images (figures 5.8-5.11) show some areas of exposure to extreme wind, both in the case of north-westerly and southerly wind phenomena. However, for the purposes of calculation, the southern wind has been considered as a priority.

The level of exposure derived from southerly winds has been analysed on the basis of the percentage of the surface area of the census section whose slopes have this orientation.

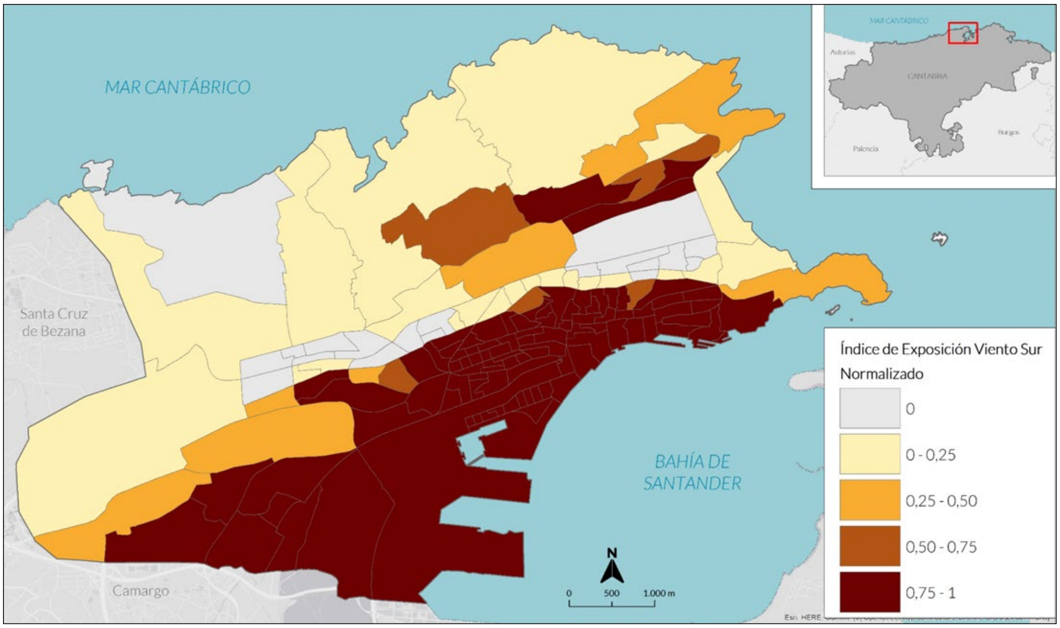


Figure 5.12. *Normalised Index of Exposure to Southerly Wind Gust*

Note: Obtained as a percentage of the area of the census section that is south-facing.

Source: CINCc (UC) - FIC, 2024.

COASTAL FLOODING OR SEA SURGES

Resident Population Exposed

The resident population exposed to coastal flooding events is obtained from the intersection between the flood stain of each scenario and the available official mapping of inhabitants per plot. The use of this approximation method has certain limitations, as it does not take into account, for example, those residing on the upper floors of these plots; and must, therefore, be interpreted under conditions of overestimation and high uncertainty. Another issue to take into account is the presence of a floating population that may be potentially exposed to coastal flooding events, i.e., tourists and visitors or related population. Due to their high spatio-temporal dynamism, their estimation is highly complex.

For the scenario projected to 2050 and RCP 8.5, the estimated population in flood areas is approximately 341 people, which represents an overall increase of 1496% compared to the historical one. Again, there is an increase in the values for the neighbourhoods exposed in the historical period, as well as affecting new neighbourhoods, specifically in the north and south of the municipality, coinciding with urban land of a residential nature.

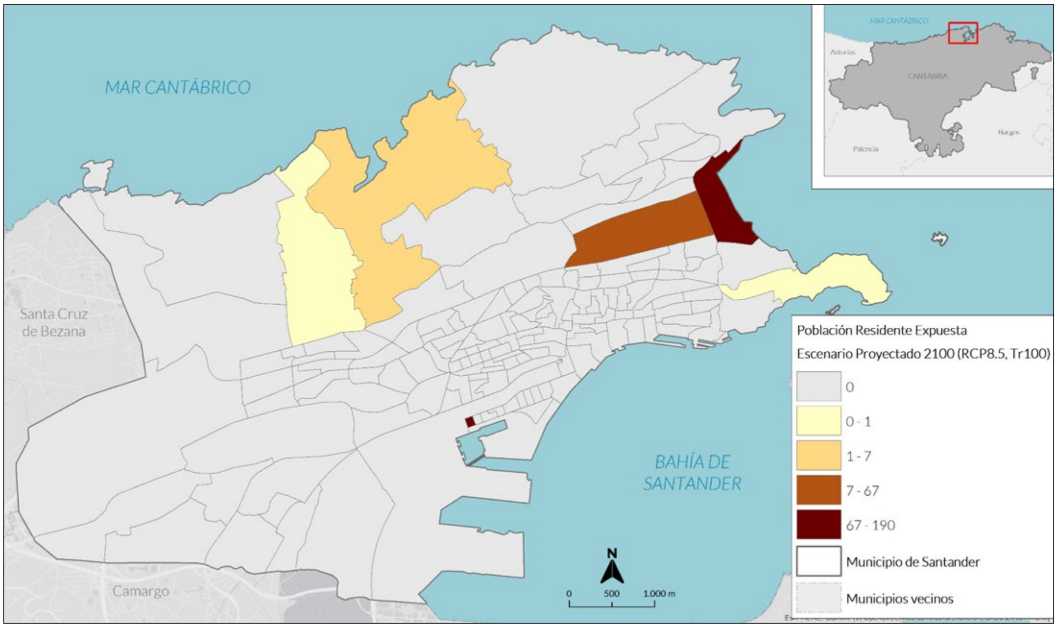


Figure 5.13. *Resident population exposed to coastal flood hazards*

Note: For the projected scenario RCP8.5 to 2100 with a return period of 100 years by census sections.
Source: CINCc (UC) - FIC, 2024.

TABLE 5.4. *Resident population exposed by coastal flooding and scenarios, historical and projected.*

MEDIUM SCENARIO (TR100 YEARS)	EXPOSED RESIDENT POPULATION TOTAL	INCREASE OVER HISTORICAL (%)
Historical	27 residents	
Projected RCP4.5 2050	96 residents	255.5%
Projected RCP8.5 2050	120 residents	344.4%
Projected RCP4.5 2100	197 residents	629.6%
Projected RCP8.5 2100	431 residents	1496.3%

Source: CINCc (UC) - FIC, 2024.

Residential Construction and Exposed Housing

The residential buildings exposed to coastal flood hazard in each of the scenarios considered have been obtained from the mapping of buildings of the General Directorate of Cadastre (Catastro, 2023). Exposed residential buildings may be totally or partially contained within the flood areas. In addition, the number of ground floor housing corresponding to exposed residential buildings has been estimated for each scenario, through specific queries to the open data of the electronic headquarters of the cadastre. There are 5 dwellings on the ground floor that are exposed to coastal flooding for the municipality as a whole, both for the historical scenario and for the scenarios projected at mid-century. This figure increases to 7 and 9 dwellings exposed for the scenarios at the end of the century, RCP 4.5 and 8.5, respectively. The results obtained for each of the coastal flood hazard scenarios are presented in table 5.5 and figures 5.14 and 5.15 below.

TABLE 5.5. *Results for Residential Construction and Exposed Housing*

MEDIUM SCENARIO (TR100 YEARS)	EXPOSED RESIDENTIAL BUILDINGS			ESTIMATED EXPOSED GROUND FLOOR DWELLINGS
	N.°	AREA (m²)*	INCREASE OVER HISTORICAL (%)	
Historical	8	10,112		5
Projected RCP4.5 2050	8	10,112	0	5
Projected RCP8.5 2050	12	11,759	16.3	5
Projected RCP4.5 2100	19	14,485	43.2	7
Projected RCP8.5 2100	27	18,101	79.0	9

** Built-up floor area*
Source: CINCc (UC) - FIC, 2024.

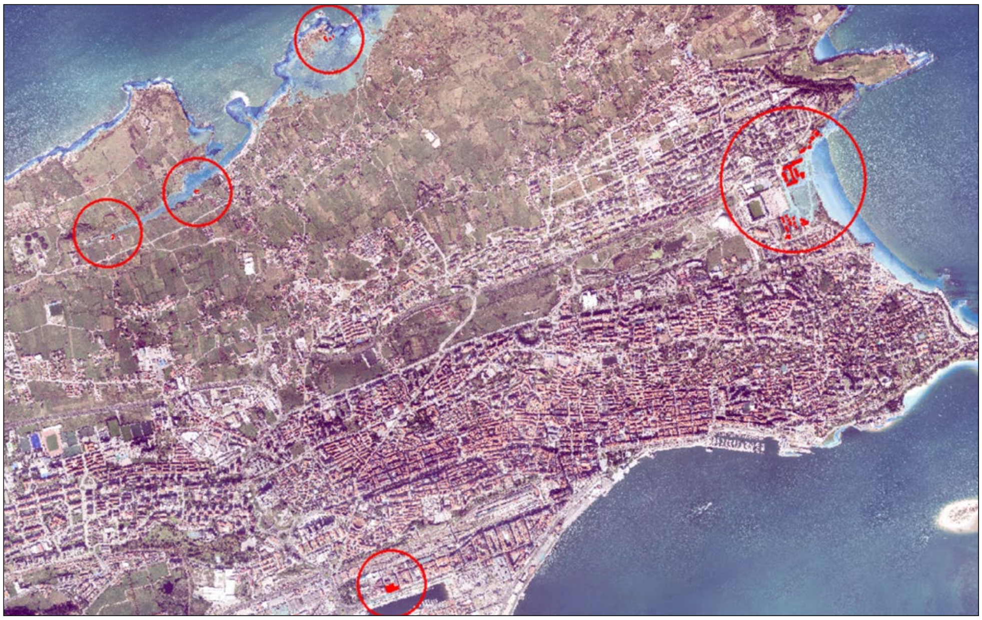


Figure 5.14. *Detail of the location of residential buildings exposed to coastal flooding in the N, E and S.*
Note: For the scenario projected to 2050 (RCP8.5, Tr100 years).
Source: CINCc (UC) - FIC, 2024.

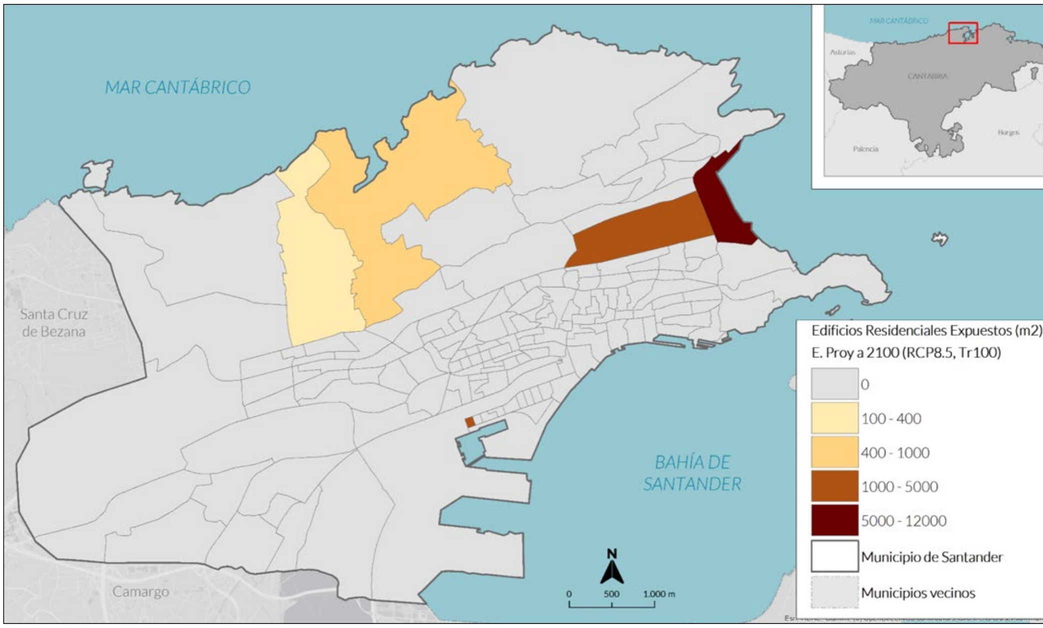


Figure 5.15. *Area (m²) of residential buildings exposed to coastal flooding*

Note: For the projected scenario to 2100 (RCP8.5, Tr100) in the municipality of Santander

Source: CINCc (UC) - FIC, 2024.

It can be observed that in the port sector, the flood stain could affect some residential areas. However, it is plausible that given the protection conditions of the Varadero sector, and with constructive actions of a defensive and punctual nature, these properties would not be affected.

EXPOSED INFRASTRUCTURE AND FACILITIES

This block assesses the municipal infrastructure located in the coastal flooding areas for each of the scenarios, including road and port infrastructure, buildings used for public services, industrial and recreational facilities, and the municipality's historical complexes. The databases used come from the National Topographic Base (IGN, 2022) at a detailed scale (1:2000) and from the building databases of the General Directorate of Cadastre (INSPIRE Servicio Catastral, 2023).

The assessment of the exposed infrastructure as a whole presents several different units of measurement, depending on the specific type of element analysed. In order to analyse the level of exposure for the set of elements contained in this group at the census section scale, the results obtained for each scenario and element have been previously normalised on a scale of 0 to 1. This allows, firstly, to compare the level of exposure between each of the scenarios and between each of the census sections, while identifying those sections with a higher concentration of infrastructure and facilities exposed to coastal flooding in a comprehensive manner. The results of the level of exposure in infrastructure and facilities, obtained for the year 2100 and the scenario RCP8.5, are presented in table 56 and figure 5.16 below.

TABLE 5.6. *Set of infrastructures and facilities exposed to coastal flooding*

MEDIUM SCENARIO (TR100 YEARS)	EXPOSED VIALS			PUBLIC BUILDINGS, INDUSTRIAL AND RECREATIONAL FACILITIES		HISTORIC SITES (m^2)
	ROADS (Km)	PATHS (Km)	STATION PORT OF FC (m^2)	N.°	AREA (m^2)*	
Historical	1	2	298	7	40,770	4,538
Projected RCP4.5 2050	1.3	2.3	298	8	42,789	6,765
Projected RCP8.5 2050	1.9	2.3	298	8	42,789	8,016
Projected RCP4.5 2100	3.2	3.1	1,357	10	44,851	12,977
Projected RCP8.5 2100	4.1	3.5	3,100	12	58,377	18,045

** Built on Ground Floor*
Source: CINCc (UC) - FIC, 2024.

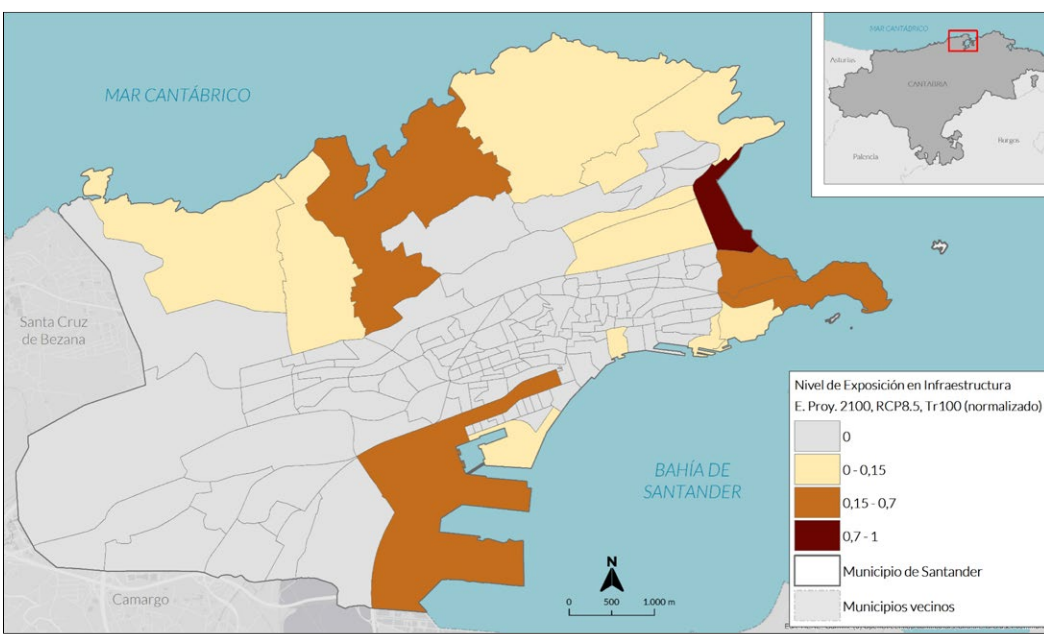


Figure 5.16. *Level of Exposure in Infrastructure and Facilities due to Coastal Flood Hazards*
Note: For the scenario projected to 2100 (RCP8.5, Tr100) by census sections in the municipality of Santander.
Source: CINCc (UC) - FIC, 2024.

ECONOMIC ASSETS EXPOSED

The analysis of economic assets exposed to coastal flooding events is carried out through the identification of commercial premises, offices, buildings used for agricultural activities, restaurants and hotels located totally or partially in the areas of incidence of each of the scenarios considered. The databases used come from the National Topographic Base (IGN, 2022) at a detailed scale (1:2000) and from the building databases of the General Directorate of Cadastre (INSPIRE Servicio Catastral, 2023).

TABLE 5.7. *Set of economic assets exposed to coastal flooding for each of the scenarios*

MEDIUM SCENARIO (TR100 YEARS)	COMMERCIAL STORES, HOTELS AND OFFICES			CONSTRUCTIONS INTENDED FOR AGRICULTURAL ACTIVITIES		
	N.°	AREA (m^2)	INCREASE OVER HISTORICAL (%)	N.°	AREA (m^2)	INCREASE OVER HISTORICAL (%)
Historical	5	10,253	–	27	2,376	–
Projected RCP4.5 2050	5	10,253	0	28	2,390	0.6
Projected RCP8.5 2050	7	11,576	13	28	2,390	0.6
Projected RCP4.5 2100	9	12,824	25	31	2,594	9.2
Projected RCP8.5 2100	12	14,334	40	38	2,903	22.2

Source: CINCc (UC) - FIC, 2024.

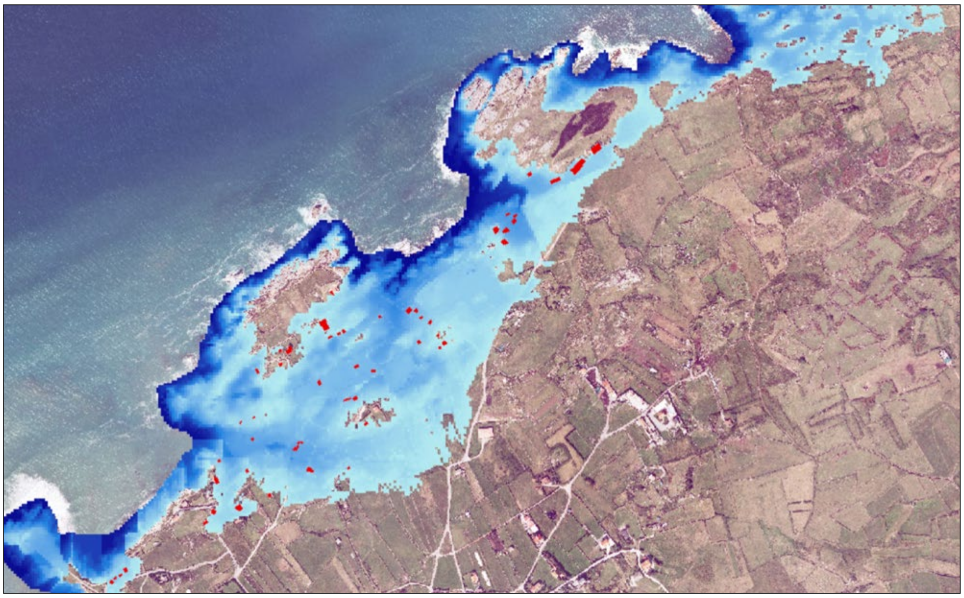


Figure 5.17. *Detail of concentration of buildings exposed to coastal flooding*

Note: For agricultural activities and for the scenario projected to 2100 (RCP8.5, Tr100) in the northern sector

Source: CINCc (UC) - FIC, 2024.

Figure 5.18. *Detail of the concentration of economic assets in the East Coastal Sector*
Note: For the scenario projected to 2100
Source: CINCc (UC) - FIC, 2024.

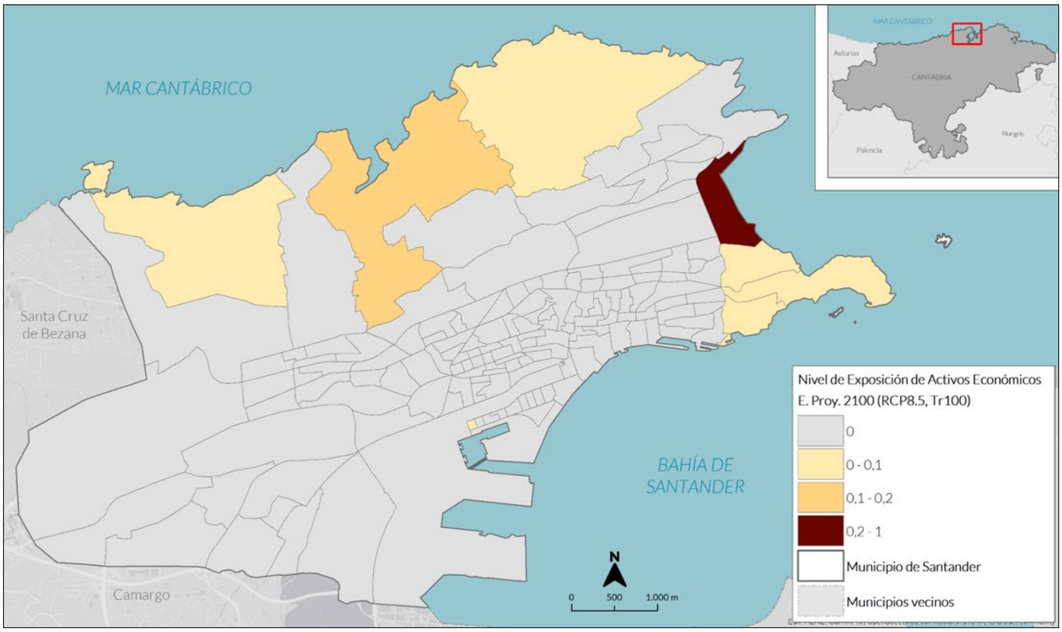


Figure 5.19. *Level of Exposure of Economic Assets to coastal flooding*
Note: For the scenario projected to 2100 RCP8.5, (Tr100) by census section in Santander
Source: CINCc (UC) - FIC, 2024.

The results obtained for each of the scenarios are calculated at census section level, including the exposed surface area. The normalised exposure results in economic assets to flood hazards for the end-of-century scenario RCP8.5 are presented in figure 5.19 from the previous page.

AREAS OF INTEREST AND NATURAL RESOURCES ON DISPLAY

The analysis of areas of interest and natural resources exposed to coastal flooding events is carried out through the identification of beaches and coastal habitats located in the areas of incidence of coastal flooding for each of the scenarios considered. The mapping of beaches in the municipality comes from the Adapta-Costa Cantabria Report (2019-2021), and the mapping of coastal habitats considered comes from the National Inventory of Terrestrial Habitats (MITECO, 2005).

TABLE 5.8. *Set of natural resources exposed to coastal flooding*

MEDIUM SCENARIO (TR100 YEARS)	EXPOSED BEACHES			EXPOSED COASTAL HABITATS		
	AREA (Ha)	(% SUP)	INCREASE OVER HISTORICAL (%)	AREA (Ha)	(% SUP)	INCREASE OVER HISTORICAL (%)
Historical	32.89	87.15	–	41.87	24.2	–
Projected RCP4.5 2050	33.72	89.34	2.5	42.3	24.5	1.23
Projected RCP8.5 2050	33.78	89.50	2.7	42.3	24.5	1.23
Projected RCP4.5 2100	34.84	92.32	5.9	46.6	26.9	11.3
Projected RCP8.5 2100	35.20	93.30	7.1	48.4	28.0	15.6

Source: CINCc (UC) - FIC, 2024.

The municipality has 15 beaches covering an area of almost 38 hectares, of which 7 correspond to sandy beaches within the urban area. In general, the percentage of beaches exposed to coastal flooding events is very high in all the scenarios considered, from values of more than 87% for the historical scenario, to more than 93% of the exposed beach area for the most pessimistic scenario, RCP8.5 projected to 2100 (figure 5.20).

The exposure results obtained for each of the scenarios are also calculated in this case at the census section level. For each of the scenarios and for each section, the percentage of exposed beach area in relation to the total beach area of the census section has been obtained. figure 5.21 shows the results obtained for the historical scenario and for the scenario projected to 2100, RCP8.5, Tr100 years.

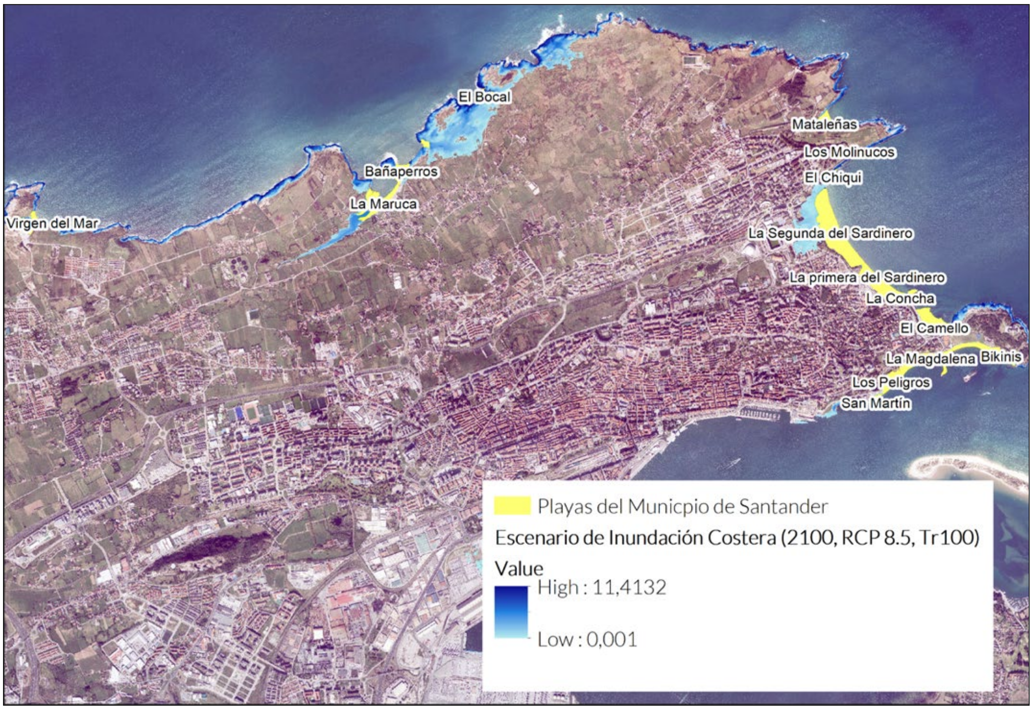


Figure 5.20. *Coastal Flood Exposure Map*

Source: CINCc (UC) - FIC, 2024.

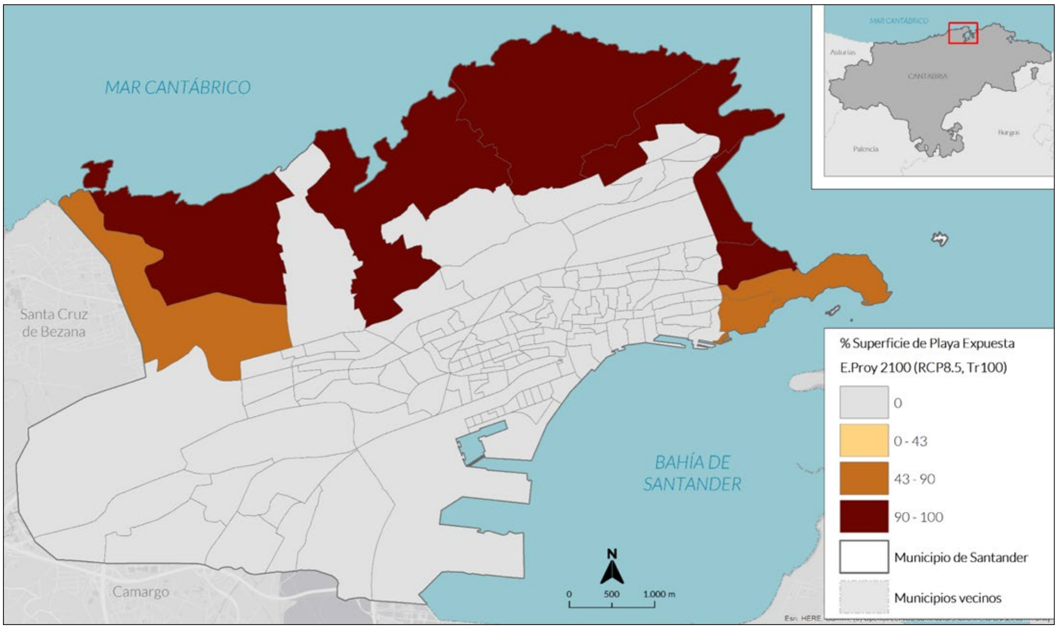


Figure 5.21. *Percentage of beach area exposed to coastal flooding*

Note: Per census section for the scenario projected to 2100 (RCP8.5, Tr100)

Source: CINCc (UC) - FIC, 2024.

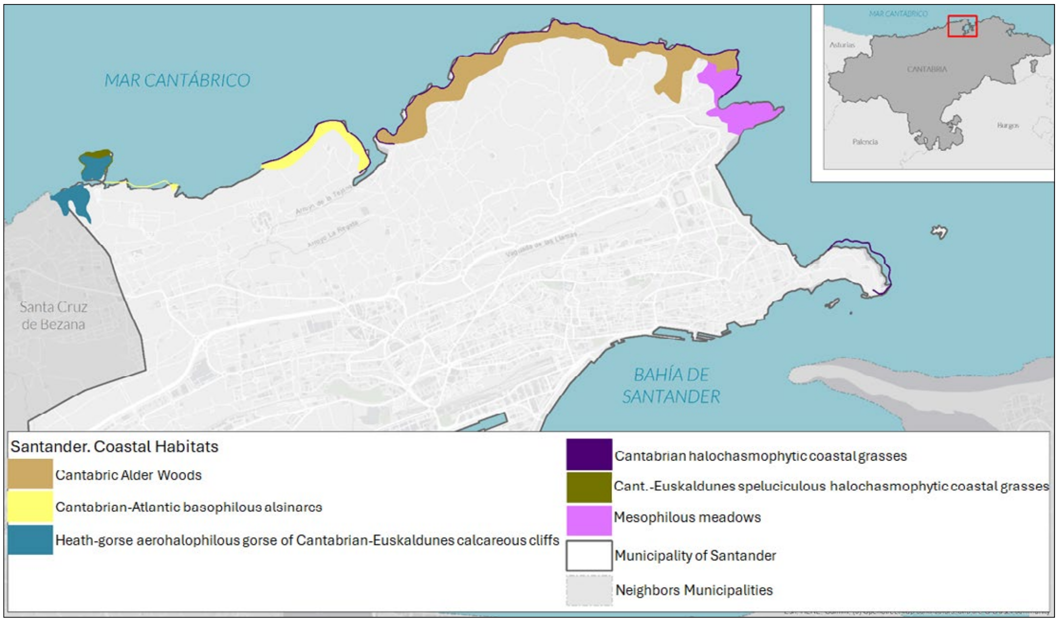


Figure 5.22. *Coastal habitats of Santander.*

Source: CINCc (UC) - FIC, 2024.

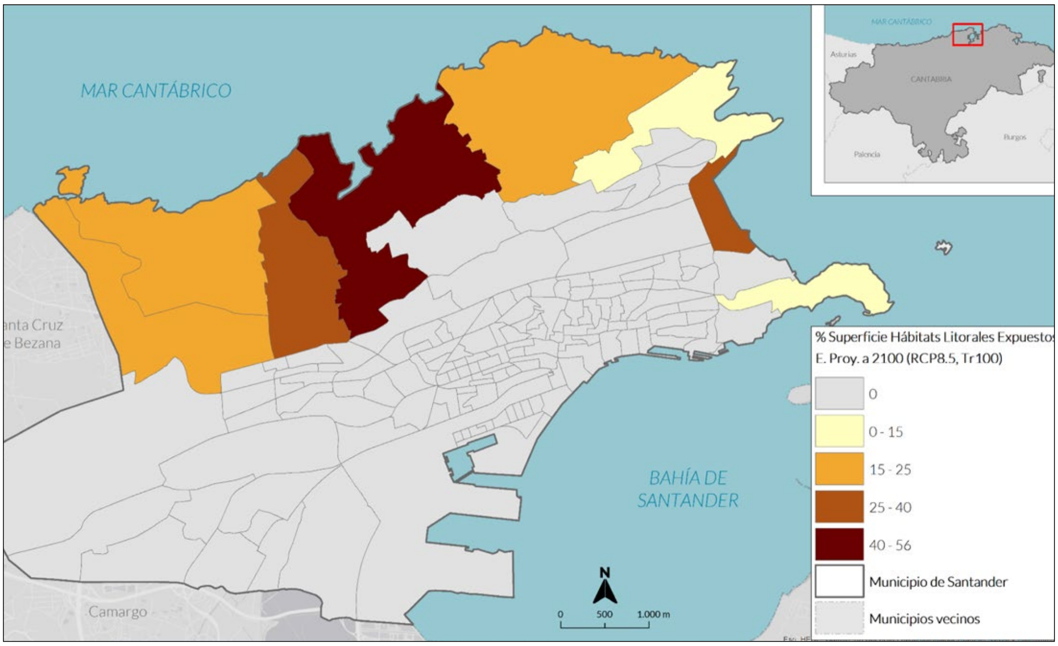


Figure 5.23. *Percentage of area of coastal habitats exposed to coastal inundation*

Note: Per census sections for the projected scenario to 2100 (RCP8.5, Tr100)

Source: CINCc (UC) - FIC, 2024.

On the other hand, the municipality of Santander has an area of approximately 173 hectares of terrestrial coastal habitats, mainly represented by coastal vegetation present on the cliffs, and various alliances of species, such as quercineae, Cantabrian alder groves, mesophyll meadows, Erica heaths, gorse heaths, among others, which are mainly distributed to the north, north-east of the municipality (figure 5.22).

The area of **terrestrial coastal habitats** exposed to coastal flooding events ranges in absolute values from 41 to 48 ha, for the historical and projected scenario to 2100 (RCP8.5, Tr100), respectively, which represents 24% to 28% of the total area of coastal habitat in the municipality in percentage terms, with a projected increase of approximately 15% for the most pessimistic scenario compared to the historical scenario (figure 5.23).

Combined Exposure Index for Coastal Flood Hazards

In the previous sections, exposure indicators have been obtained for each of the components analysed for coastal flood hazard events, as a sum of the exposure values normalised by type of element included in each component. However, the **Combined Exposure Index** allows for:

1. An identification of those census sections with the **highest concentration** of elements exposed to coastal flooding using a multi-dimensional or multi-sectoral approach.
2. A **holistic view of the information**, i.e., a comprehensive and combined assessment that, nevertheless, can be broken down into different components in a coherent and consistent manner, as they are derived from precise elementary quantifications of the territory.
3. A relative comparison o the level of exposure between **multiple climate scenarios**, assessment the level of change, analysis of the trends in the territory and derivation of possible higher priority intervention points from the exposure component.

The final results of the Combined Exposure Index for the historical scenario, the projected 2050 and RCP8.5 and the projected 2100 and RCP8.5, are presented below.

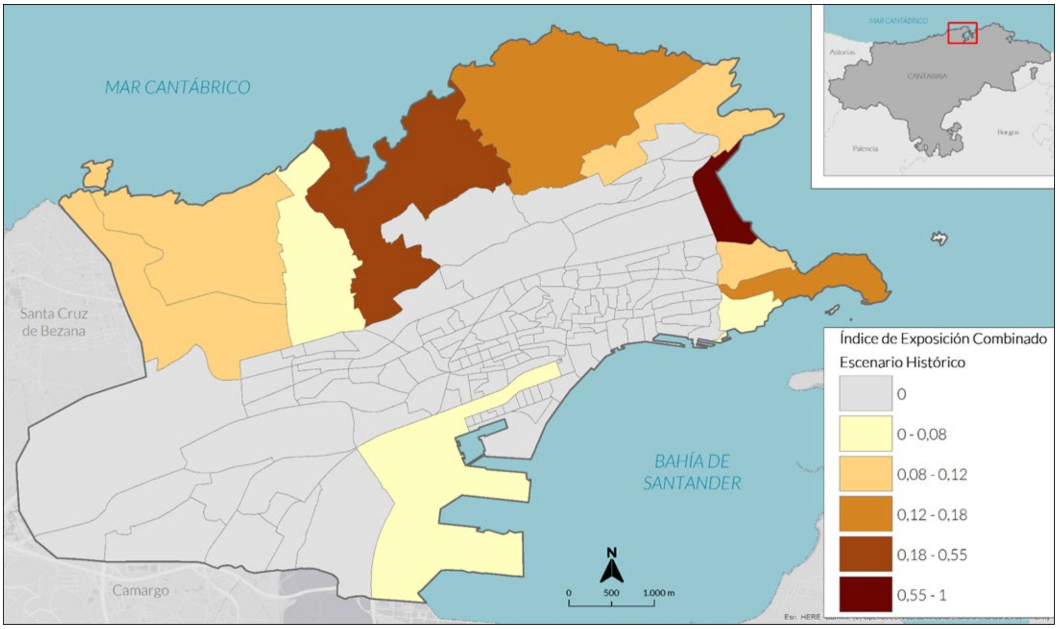


Figure 5.24. *Combined Exposure Index (dimensionless) to Historical Coastal Flood Hazards*

Source: CINCc (UC) - FIC, 2024.

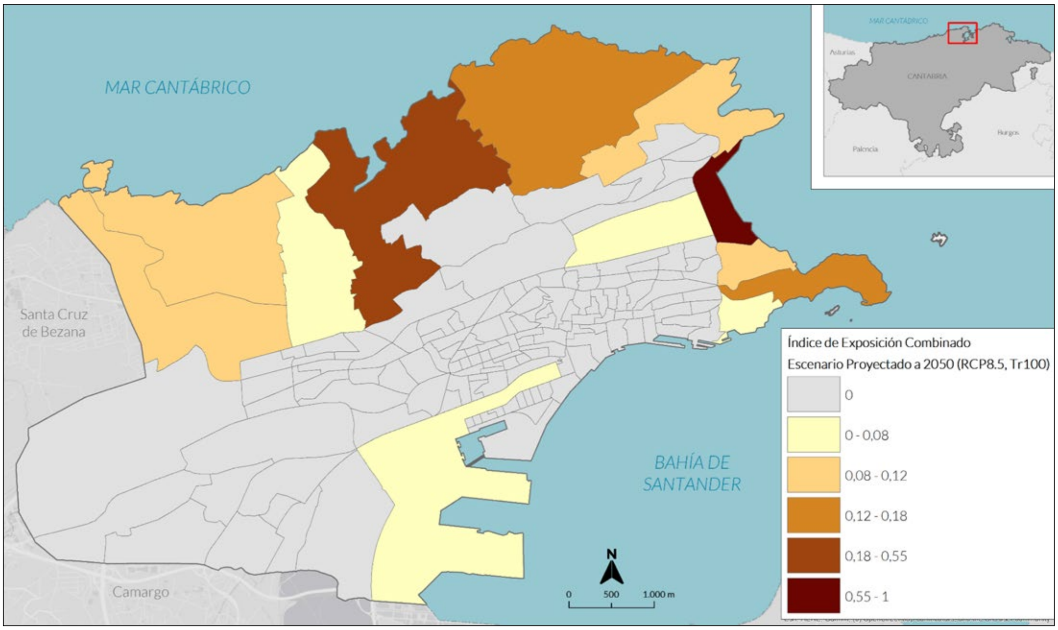


Figure 5.25. *Combined Exposure Index (dimensionless) to Coastal Flood Hazard 2050*

Source: CINCc (UC) - FIC, 2024.

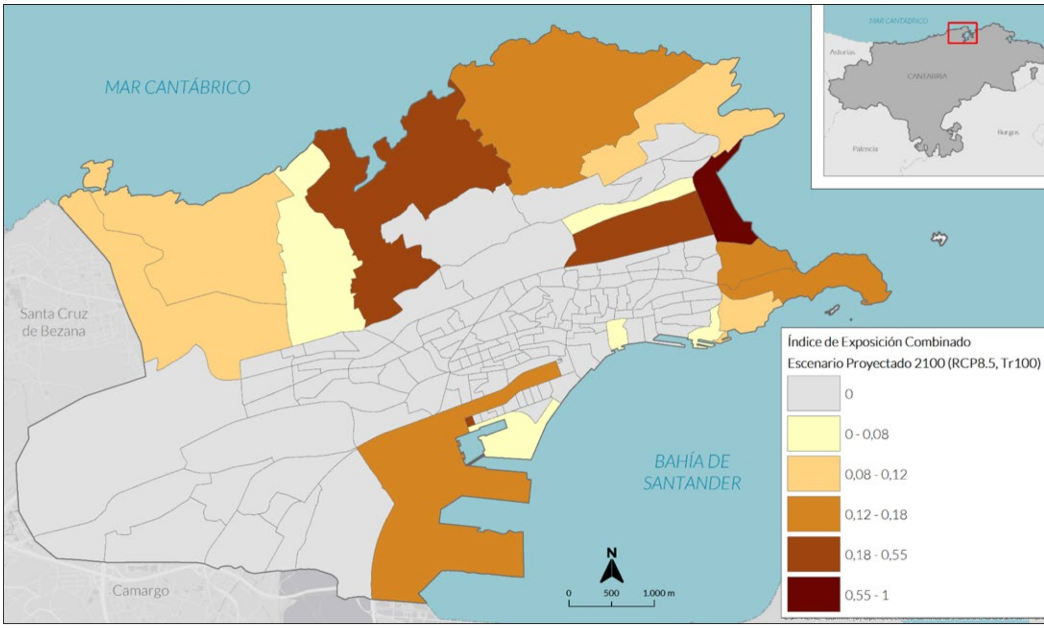


Figure 5.26. *Combined Exposure Index (dimensionless) to Coastal Flood Hazard 2100*

Source: CINCc (UC) - FIC, 2024.

5.2 VULNERABILITY ANALYSIS

Vulnerability is defined as the 'propensity or predisposition to be adversely affected'. Vulnerability encompasses a number of concepts and elements, such as **sensitivity** or susceptibility to harm and **adaptive capacity**, which involves being prepared to cope and adapt to the problem (IPCC, 2022a). In general, the vulnerability of ecosystems and people to climate change differs substantially between regions. Even within regions, it is influenced by aspects such as intersecting socio-economic development patterns, unsustainable land and ocean use, inequity, marginalisation, historical and current patterns of inequality, among many other demographic issues.

During 2010-2020, human mortality from floods, droughts and storms was 15 times higher in highly vulnerable regions compared to regions with very low vulnerability (IPCC, 2022b). Vulnerability at different spatial levels is typically exacerbated by inequality and marginalisation linked to gender, ethnicity, low income or combinations of these, especially for many indigenous peoples and local communities. Also in the future, human vulnerability will continue to be concentrated where the capacities of local, municipal and national governments, communities and the private sector are least able to provide basic infrastructure and services. Key infrastructure systems such as sanitation, water, health, transport, communications and energy will become increasingly vulnerable, if design standards do not take into account changing climatic conditions.

VULNERABILITY ANALYSIS METHODOLOGY AND PHASES

The methodology for approaching the vulnerability study is centred on a mixed process that combines the assessment of specific factors of sensitivity and adaptive capacity at the local level with a social, economic, material and environmental approach, together with expert judgement, through the following phases of development:

- Phase 1: **Identification of climate vulnerability factors** for each of the prioritised hazards. This phase includes the initial development of a list of climate vulnerability factors derived from local literature and document review processes. This initial list of potential factors is subjected to public assessment through citizen workshops with key institutional participation.
- Phase 2: **Collection of information and assessment** of vulnerability indices. For the relevant vulnerability factors, the available official sources of information that enable their evaluation are analysed. Once these sources of primary information have been collected, contrasted and validated, the vulnerability assessment is addressed through indicators, understood as a measure that characterises the vulnerability of a system, specifically for the socio-economic, environmental and material components. For each of the key vulnerability factors, at least one representative vulnerability indicator is developed.
- Phase 3: **Normalisation of the values** of the evaluated indices with respect to the highest value that the series can reach. This normalisation makes it possible to relativise the magnitude of the index and enables its comparison and subsequent integration. For this purpose, the linear normalisation method is applied to obtain values from 0 to 1.
- Phase 4: **Integration and development of a final climate vulnerability index** for each of the key hazards, obtained by combining each of the normalised vulnerability indices and weighted according to their relevance. This relevance is analysed by combining the relevance value given by the set of respondents in the risk perception workshop, together with the relevance value given under expert judgement. This weighting makes it possible to establish an order of hierarchy and relevance between the standardised indices for each of the hazards.
- Phase 5: **Analysis of projected vulnerability** to 2050 and 2100. This last phase includes the definition of hypotheses and scenarios of change for each of the sensitivity factors analysed for 2050 and 2100. As a result of these hypotheses, percentage change forecasts will be established, which will be applied at census section level with respect to the value obtained for the current horizon.

STANDARDISATION AND COMBINATION OF INDICATORS

Once phases 1 and 2 of defining indicators and obtaining specific data for them have been completed, the standardisation of the set of sensitivity indicators assessed will enable their subsequent integration. The final vulnerability index for each of the hazards is usually based on a combination of quantitative data or indicators, so it is necessary to incorporate a method of control and standardisation of variables that makes them comparable with each other while allowing their standardised integration into a final indicator. The 'objectivity' of quantitative data is maintained after the standardisation process, providing essential information relating to the context or factor analysed in each case.

The normalisation process is carried out using the simple linear method to obtain values from 0 to 1, therefore, as a result of the normalisation process, rates are obtained with values that are presented in a constant range between 0 and 1, taking into account the minimum and maximum values reached by the series, by means of the following equation:

$$\mathbf{Z_i = (x_i - minimum\ (x)) \ /\ (maximum\ (x) - minimum\ (x))}$$

where:

- **Z_i**: The i- umpteenth normalized value in data set.
- **x_i**: The i- umpteenth value in data set.
- **minimum (x)**: The minimum value in the data set.
- **maximum (x)**: The maximum value in the data set.

For certain sensitivity factors, an additional process of **combining indicators** is carried out, with the aim of comprehensively assessing complex circumstances that do not depend on a single indicator or several independent indicators. In other words, a given reality under a specific context, such as precarious housing, depends, in turn, on several specific multidimensional variables or circumstances that have a synergistic effect. For these cases, the sum of the values of their respective indicators per census section is first calculated and then the result is normalised using the same linear procedure. The following tables show the **Sensitivity Indicators** (socio-economic, material and environmental), which include the set of factors and indicators evaluated, together with the normalisation and combination method used in each case.

TABLE 5.9. *Socio-economic sensitivity*

TYPE	N.°	SENSITIVITY FACTOR	INDICATOR OF SENSITIVITY	METHOD STANDARDISATION
SOCIO-ECONOMIC SENSITIVITY	SE 1	Level of social poverty by income	SE1-1: Percentage of population with income per consumption unit below 60% of the median at the national level	LINEAR 0 TO 1
	SE 2	Level of social poverty due to housing precariousness	SE2-1: No. of Dwellings <45m^2 low-income sections / No. of Dwellings census section	LINEAR 0 TO1 (COMBINED)
			SE2-2: No. of 1-bedroom dwellings / No. of dwellings census section	
			SE2-3: No. of Dwellings without collective or private heating / No. of Dwellings census section	
	SE 3	Unemployment level	SE3-1: % Unemployed population / Labour force by census section	LINEAR 0 TO 1
	SE 4	Level of social inequality	SE4-1: Gini index	LINEAR 0 TO 1
	SE 5	Insufficient education level	SE5-1 % Population illiterate, uneducated or with first degree / Population >15 years old by census section	LINEAR 0 TO 1
	SE 6	Insufficient level of health coverage	SE6-1: Percentage of population residing outside the optimal service areas of public health facilities.	LINEAR 0 TO1 (COMBINED)
			SE6-2: Percentage of census section area outside the optimal service areas of public health facilities	
	SE 7	Population density level	SE7-1: N° inhabitants / km^2	LINEAR 0 TO 1
	SE 8	Presence of vulnerable groups	SE8-1: % Population aged >65 years / Total population of the census section	LINEAR 0 TO 1
			SE8-2: % Population aged <5 years / Total population of the census section	LINEAR 0 TO 1
	SE 9	Level of sectoral climate dependence (employed in climate-dependent sectors	SE9-1:Percentage of employed in dependent sectors / Total Employed Population by census section	LINEAR 0 TO 1
	SE 10	Gender differences	SE10-1:Percentage of women by census section	LINEAR 0 TO 1

Source: CINCc (UC) - FIC, 2024.

TABLE 5.10. *Material sensitivity*

TYPE	N.°	SENSITIVITY FACTOR	INDICATOR OF SENSITIVITY	METHOD STANDARDISATION
MATERIAL SENSITIVITY	M1	Age of dwellings	M1-1:Percentage of Dwellings in pre-1940 buildings / total dwellings by census section	LINEAR 0 TO 1
	M2	Construction quality deficiency in housing	M2-1: % of dwellings with poor construction quality / Total No. of dwellings per census section	LINEAR 0 TO 1
	M3	Poor state of maintenance of dwellings	M3-1% dwellings in dilapidated, bad or substandard condition / Total number of dwellings in the census section	LINEAR 0 TO 1
	M4	Building density level	M4-1: No. of dwellings / ha	LINEAR 0 TO 1

Source: CINCc (UC) - FIC, 2024.

TABLE 5.11. *Environmental Sensitivity, Quality of Life and Social Well-being*

TYPE	N.°	SENSITIVITY FACTOR	INDICATOR OF SENSITIVITY	METHOD STANDARDISATION
ENVIRONMENTAL SENSITIVITY, QUALITY OF LIFE AND SOCIAL WELL-BEING	A1	Level of social poverty due to housing precariousness	A1-1 Built-up volume / census section surface area	LINEAR 0 TO1 (COMBINED)
			A1-2 % Impervious urban area / census section area	
	A2	Noise level and air pollution	A2-1 Estimated % pop affected by noise > 65 dB per census section (FB indicator CBA- 004)	LINEAR 0 TO1 (COMBINED)
			A2-2 Air Pollution Level Atmospheric Pollution from Vehicular Traffic	
	A3	Tourist pressure level	A3-1: Tourist Function Rate (bed places/100 inhab)	LINEAR 0 TO1 (COMBINED)
			A3-2: Socio-environmental Pressure Index taking into account tourist areas (Mobiles)	
			A3-3: Unregulated Accommodation Tourist Function Rate (Airbnb)	
	A4	Level of anthropic pressure	A4-1: Deficit of m^2 of green areas per inhabitant compared to the optimum of $20m^2$ / inhabitant per census section	LINEAR 0 TO 1

[…/…]

Continuation **TABLE 5.11**

TYPE	N.°	SENSITIVITY FACTOR	INDICATOR OF SENSITIVITY	METHOD STANDARDISATION
ENVIRONMENTAL SENSITIVITY, QUALITY OF LIFE AND SOCIAL WELL-BEING	A5	Presence of environmentally degraded areas	A5-1: % Surface area of degraded areas by census section	LINEAR 0 TO 1
	A6	Inadequate coverage of the municipal waste management system	A6-1: Estimated population of the census section outside the optimal coverage level of waste management	LINEAR 0 TO 1
	A7	Presence of buildings without energy certification	A7-1: % of Buildings with no energy certification or with certification below class E	LINEAR 0 TO 1
	A8	Population far from green areas	A8-1: % Population >400m of public green area of 0.5Ha minimum sup. (CBS-002 of the BF)	LINEAR 0 TO 1
	A9	Population without private green spaces	A9-1: % Estimated population by census section without private green spaces	LINEAR 0 TO 1

Source: CINCc (UC) - FIC, 2024.

Integration of Climate Sensitivity Indicators

Once the process of standardisation of the set of indicators has been completed, the final integration of the indicators for each of the climate hazards is carried out. The **integration process** involves the development of the following successive tasks:

1. Identification and selection of climate sensitivity indicators that impact each of the climate hazards
2. Assessment of the level of relevance ('weight') of each of the indicators by climate hazard
3. Calculation of the final Climate Sensitivity Index for each of the hazards assessed in the municipality, through the sum of values achieved for the set of indicators per census section, weighted by their relative weight or level of importance. This integration, therefore, offers the possibility of combining several inputs to create an integrated analysis of sensitivity, incorporating weights or relative importance with a double analytical focus, importance given for each indicator and for each hazard assessed.

$$\text{Weighted average} = \sum_{i=1}^{N} x_i P(x_i) = x_1 P(x_1) + x_2 P(x_2) + x_3 P(x_3) + \ldots + x_N P(x_N)$$

Both the selection process and the importance of sensitivity indicators are based on two sources of information:

(i) Results obtained in the participatory workshop with key actors, specifically those related to the vulnerability and sensitivity block (social and institutional perception);

(ii) Results obtained from the expert analysis based on the survey of 5 researchers from the team of the University of Cantabria and the Climate Research Foundation. The specific weight per indicator is obtained by adding the final score obtained per indicator (i+ii), divided by the final score captured for the set of indicators for each threat, as a factor of one.

In this method, the result of each indicator has been projected into the future for the 2050 and 2100 scenarios by incorporating official projections. For each of the climate sensitivity indicators analysed in the municipality of Santander, hypotheses of change for 2050 and 2100 have been established on the basis of a wide range of official documentary references with implications for territorial and political trends at the municipal level.

Results of the Projected Climate Sensitivity Index to 2050 and 2100

Projected Climate Sensitivity to Pluvial Flooding

For the flood hazard from extreme rainfall events, the mean value of the Santander sensitivity index is 0.56, approximately 12% higher than the base value of the index. For this scenario projected to the middle of the century, the highest minimum values, around 0.22, are expected. Also higher maximum values, reaching a value of 1 in neighbourhoods in the south of the capital, higher than the maximum of 0.9 are reached in the current horizon. The sharpest increases are reached mainly in peripheral neighbourhoods to the north, south and east of the municipality (figure 5.27).

For the projected scenario (2100), a decreasing trend is observed in the sensitivity index, with an average value of 0.52, 4.18% higher than the base scenario. The largest decreases occur in sections located along the south coast and in the centre of the capital (figure 5.28).

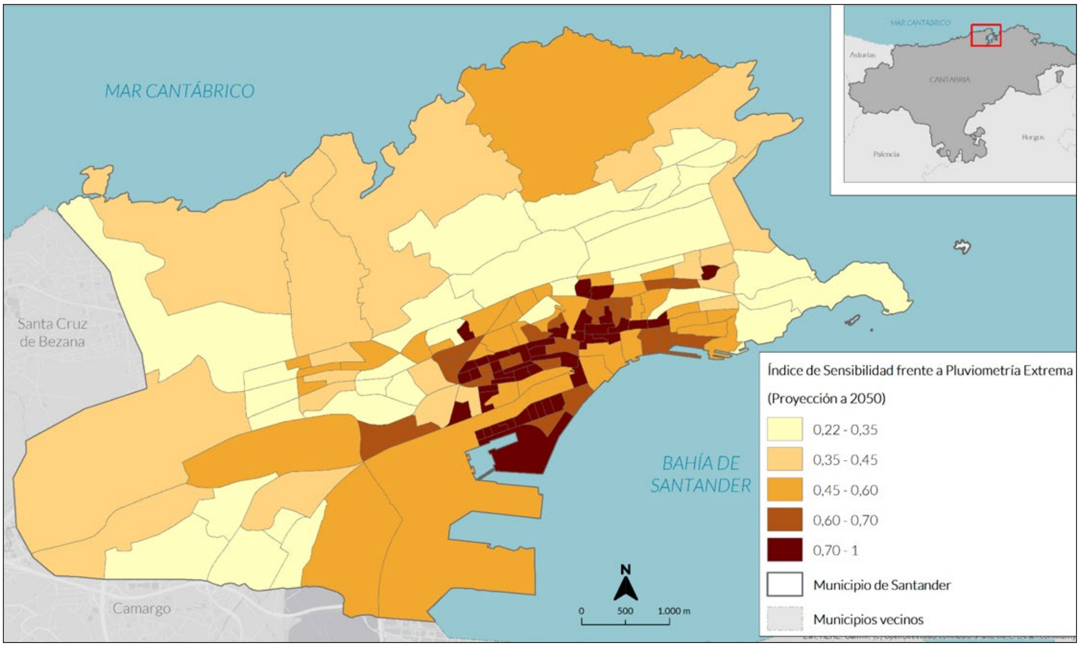


Figure 5.27. *Normalised Index of Climate Sensitivity to Rainfall Flood Events 2050*
Source: CINCc (UC) - FIC, 2024.

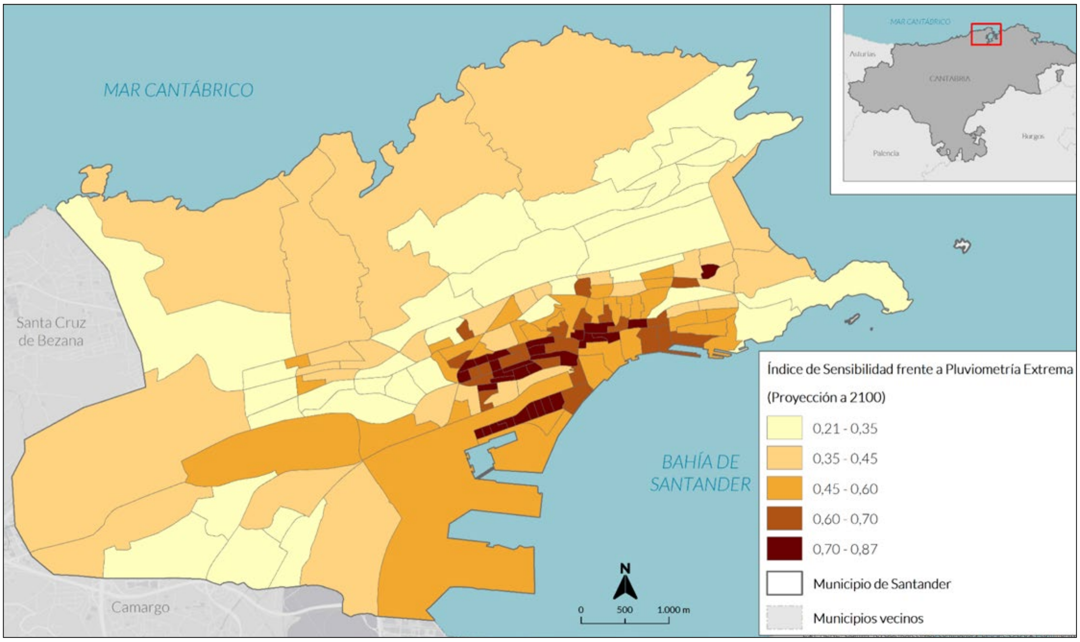


Figure 5.28. *Normalised Index of Climate Sensitivity to Rainfall Flood Events 2100*
Source: CINCc (UC) - FIC, 2024.

Projected Climate Sensitivity to Extreme Temperature Events

Finally, for the extreme temperature event hazard, the mean value is 0.59, 9.7% lower than the base value of the index. For this projected mid-century scenario, a generalised decrease in the sensitivity index values is expected.

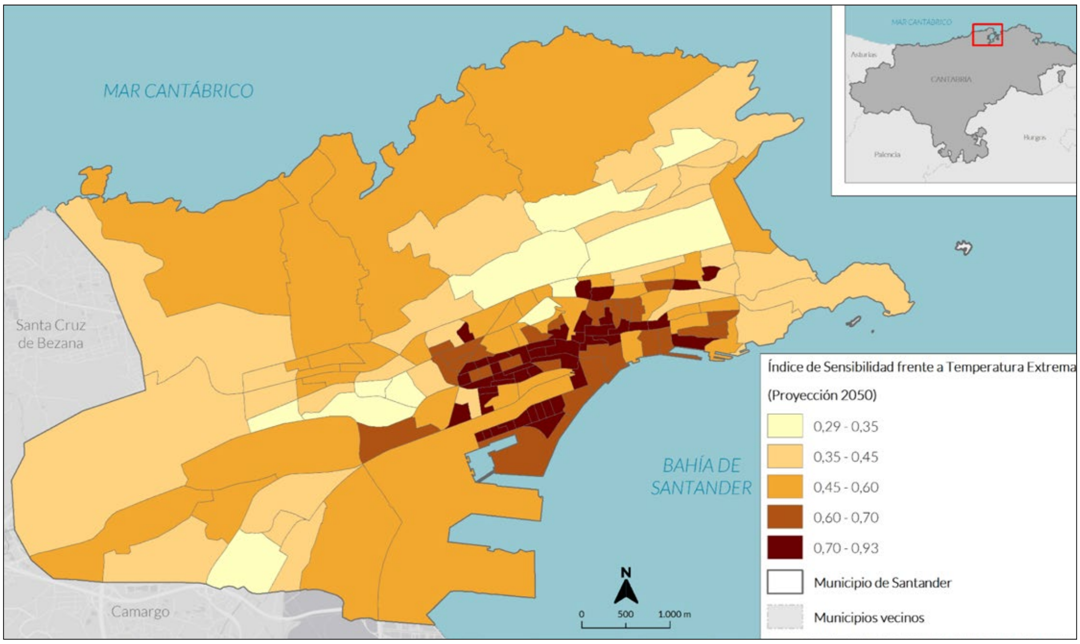


Figure 5.29. *Normalised Index of Climate Sensitivity to Extreme Temperature Events 2050*

Source: CINCc (UC) - FIC, 2024.

In the scenario projected at the end of the century, the average value of the lowest sensitivity index of the municipality, of around 0.49 is reached, almost 20% lower than the base value of the index. For this scenario, the lowest sensitivity values are foreseen for both the lower and upper end of the index, reaching maximums of up to 0.78 in certain sections of the consolidated urban centre. This decreasing trend is also generalised, mainly associated with the northern and western suburbs.

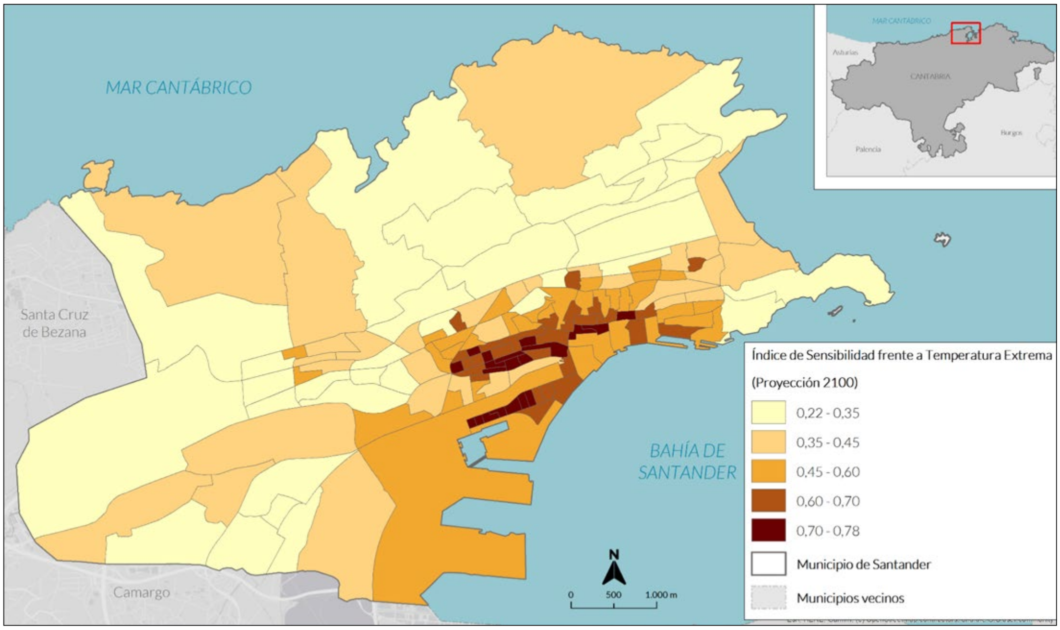


Figure 5.30. *Normalised Index of Climate Sensitivity to Extreme Temperature Events 2100*
Source: CINCc (UC) - FIC, 2024.

Projected Climate Sensitivity to Meteorological Drought Events

For the meteorological drought hazard, the average value of the municipal sensitivity index is 0.55, approximately 9% lower than the base value of the index. For this projected mid-century scenario, a generalised decrease in sensitivity index values is expected, which is mainly observed in the northern, western and southern suburbs, together with some highly sensitive neighbourhoods in the centre of the capital (figure 5.31).

For the scenario projected at the end of the century, the lowest average value of the municipality's sensitivity index, of around 0.48, is reached. For this scenario, the lowest values are expected for both the lower and the upper end of the index. This decreasing trend is also generalised, mainly associated with the northern and western suburbs (figure 5.32).

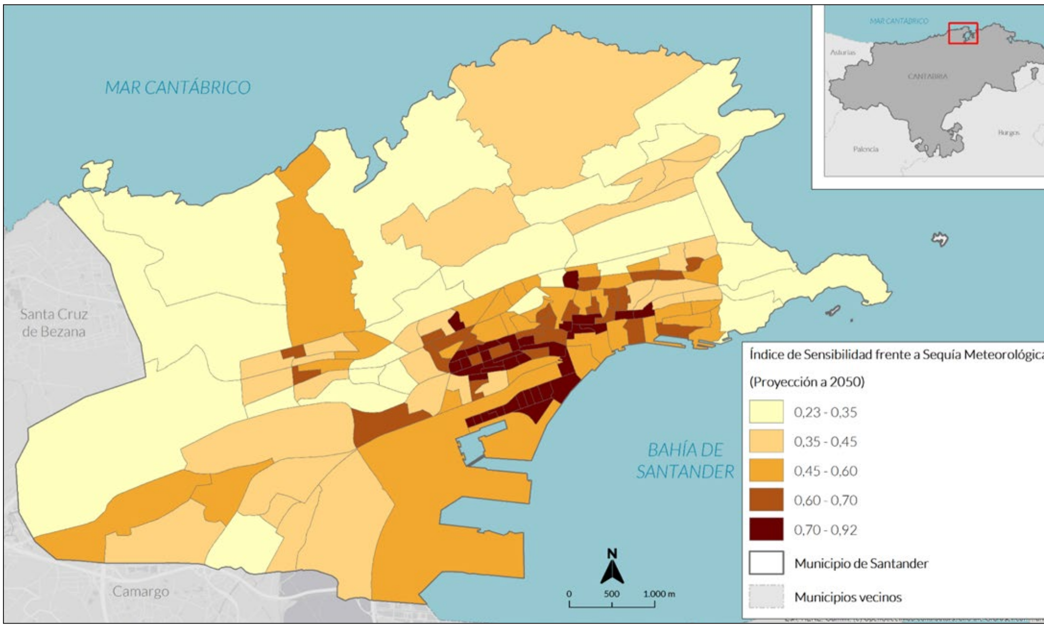


Figure 5.31. *Normalised Index of Climate Sensitivity to Meteorological Drought Events 2050*

Source: CINCc (UC) - FIC, 2024.

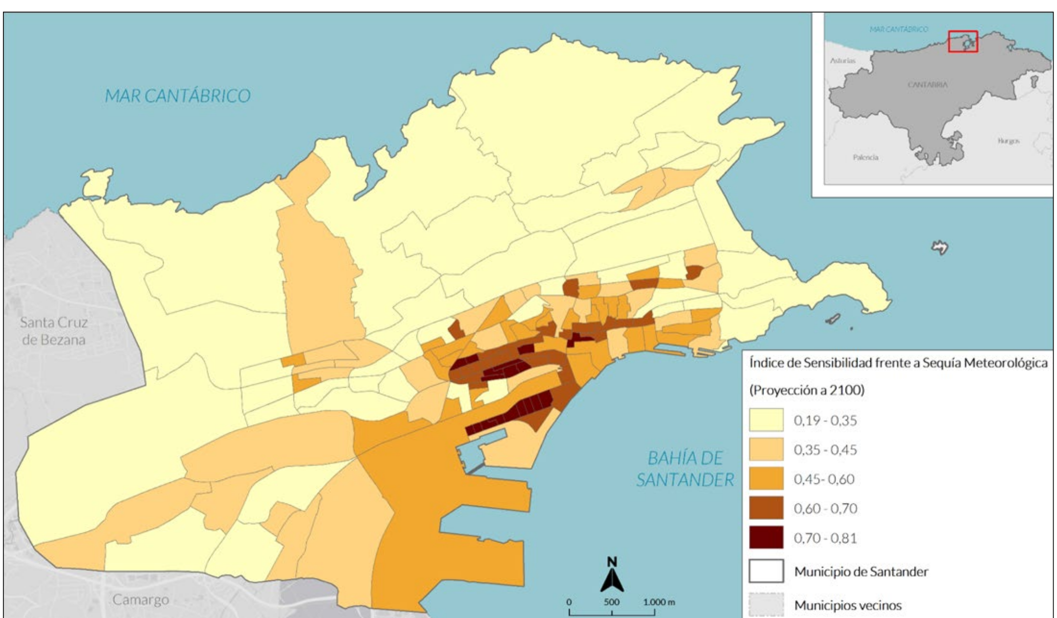


Figure 5.32. *Normalised Index of Climate Sensitivity to Meteorological Drought Events 2100*

Source: CINCc (UC) - FIC, 2024.

Projected Climate Sensitivity to Extreme Wind Events

For this hazard, the average value of the sensitivity index is 0.56, 9.3% lower than the base value of the index. For this scenario projected to the middle of the century, a generalised decrease in the values of the sensitivity index is foreseen, reaching minimum values above 0.31 for some neighbourhoods located along the diagonal that runs through the municipality (figure 5.33).

For the scenario projected at the end of the century (figure 5.34), there is a general downward trend and a marked decrease in the sensitivity index compared to the previous scenario, with an average value of 0.45 for the municipality, 27% lower than the base scenario.

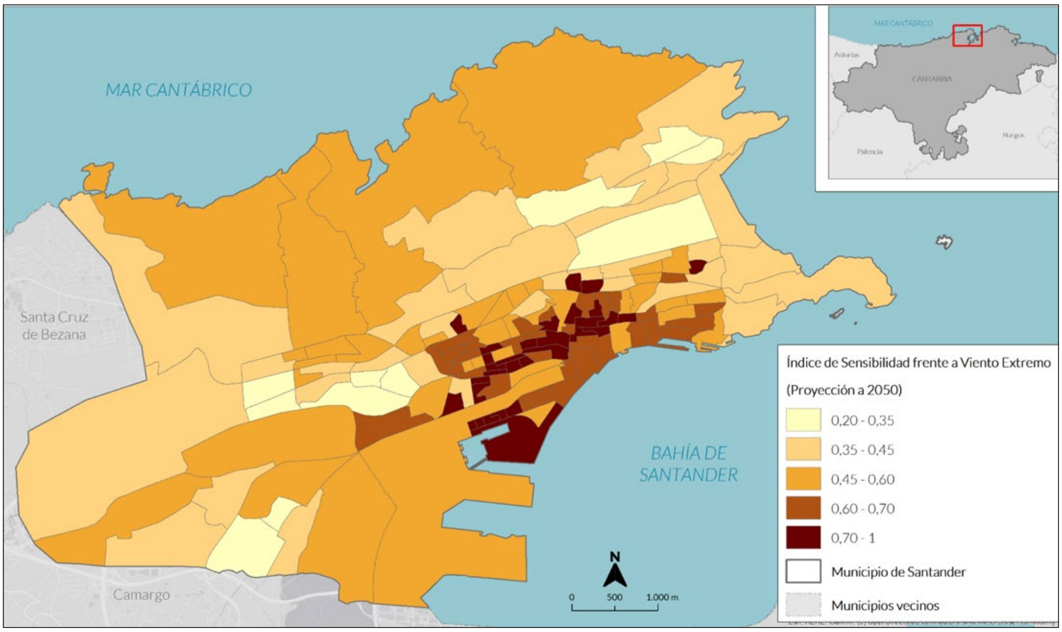


Figure 5.33. *Normalised Index of Climate Sensitivity to Extreme Wind Events 2050*

Source: CINCc (UC) - FIC, 2024.

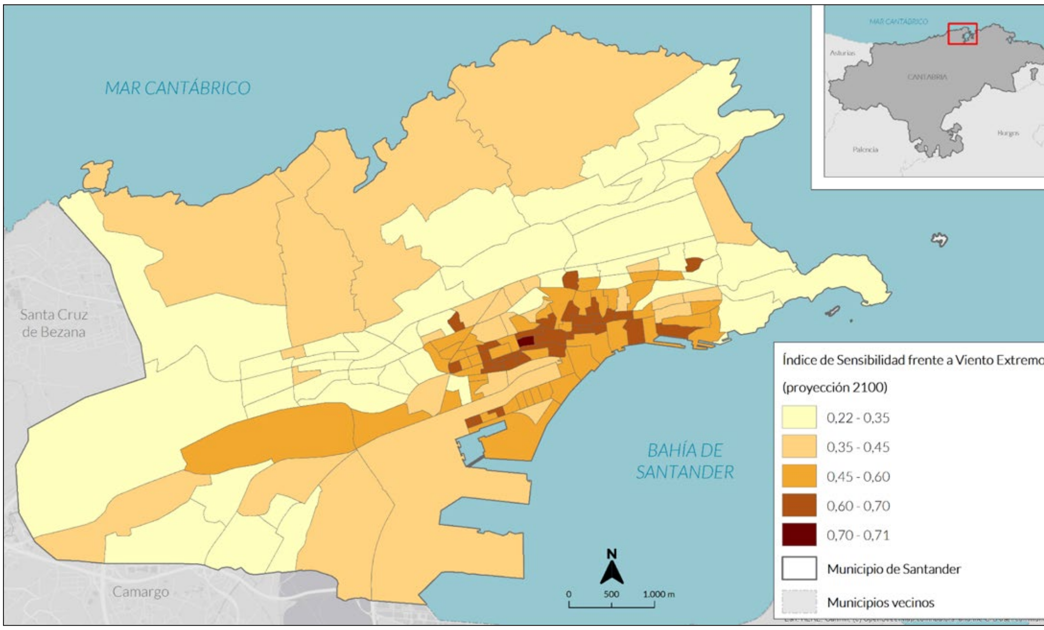


Figure 5.34. *Normalised Index of Climate Sensitivity to Extreme Wind Events 2100*

Source: CINCc (UC) - FIC, 2024.

Projected Climate Sensitivity to Coastal Floods

The mean value of the normalised climate sensitivity index for coastal flooding is 0.54 for 2050, which is a final increase of about 3.3% compared to the mean value obtained for the current horizon. Overall, the climate sensitivity to coastal flooding tends to decrease in the medium term in the northern peripheral sectors, while it displays an increasing trend in the urban centre sections (figure 5.35).

By the end of the century, the sensitivity to coastal flooding is around average values of 0.49, which represents a reduction of 5.9% with respect to the base value of the index. In this scenario there is a general downward trend in the municipality as a whole, with minimum values below 0.19 in sections to the north of the capital, and sharp decreases in sensitivity for sections of the south coast and the centre of the capital.

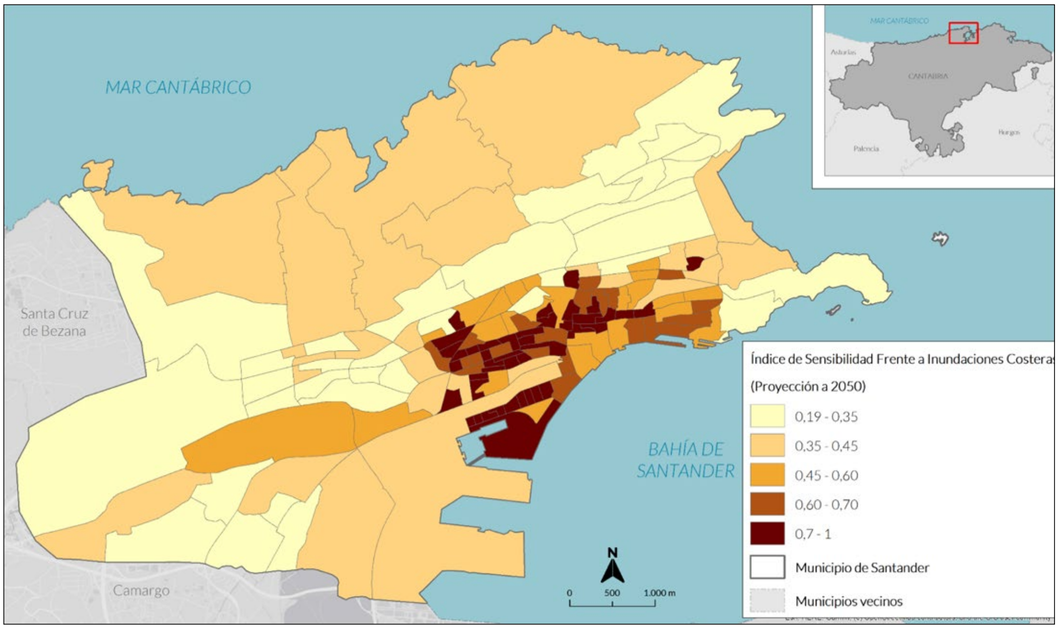


Figure 5.35. *Normalised Coastal Flood Climate Sensitivity Index 2050*

Source: CINCc (UC) - FIC, 2024.

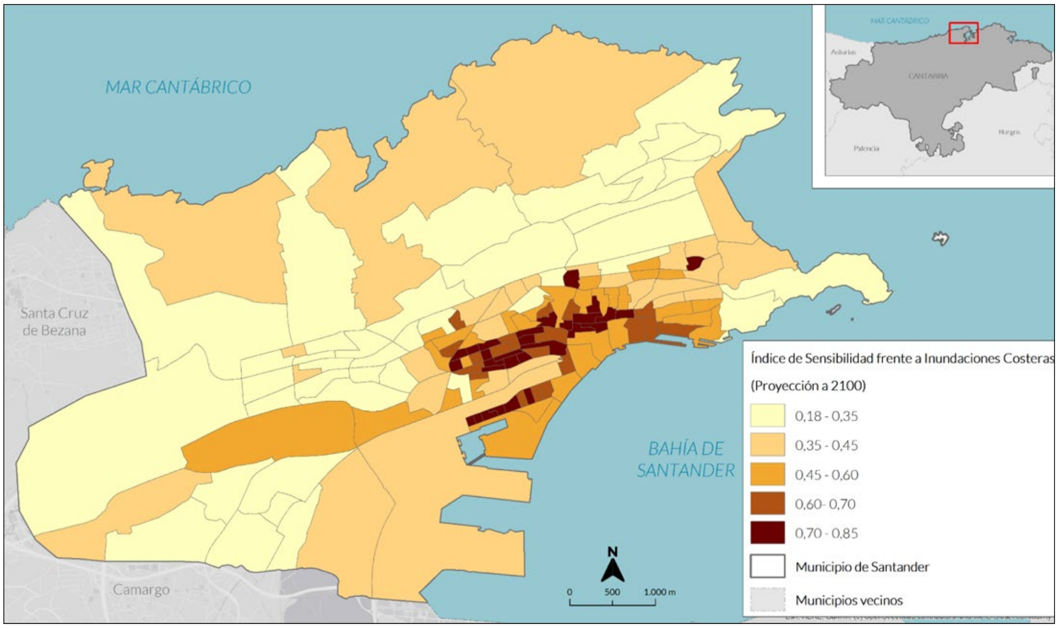


Figure 5.36. *Normalised Index of Climate Sensitivity to Coastal Floods 2100*

Source: CINCc (UC) - FIC, 2024.

5.3

CLIMATE RISK ANALYSIS

Risk represents the potential for losses that may occur to an exposed subject or system as a result of the convolution of **hazard**, **exposure** and **vulnerability**. Risk can be expressed mathematically as the probability of exceeding a certain level of economic, social or environmental consequences at a certain location and over a certain period of time.

$$\text{RISK INDEX} = \text{HAZARD} + \text{EXPOSURE} + \underbrace{[\text{Sensitivity} - \text{Adaptative Capacity}]}_{\text{VULNERABILITY}}$$

In this framework, risk is conceptualised holistically or integrally, according to the integration of social, economic, material and environmental approaches. Therefore, for the urban scale considered, risk is not only related to the potential occurrence of an event, but also to the vulnerability of the municipality as an internal risk factor, i.e., its capacity to withstand the hazard and its implications.

This vulnerability is analysed through a broad set of sensitivity factors at the census section scale, considering that the adaptive capacity will be implemented through the adaptation measures included in this document, including key aspects such as the updating of the various risk management and urban planning documents, as well as management, awareness and training mechanisms.

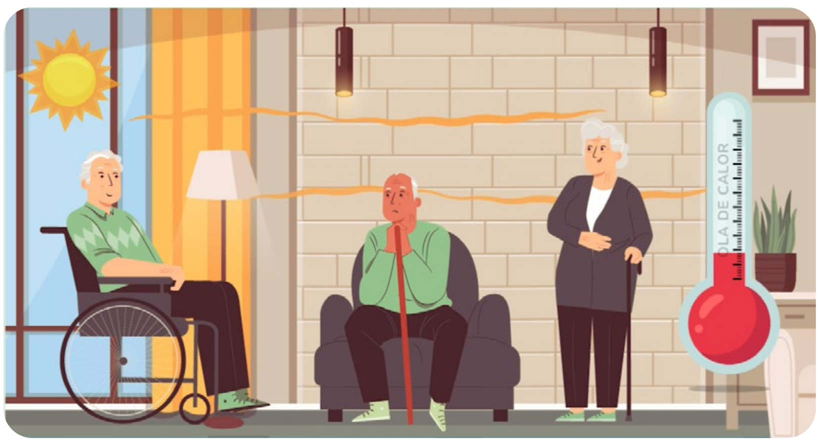
Figure 5.37. *Risk Components*

Source: IPCC, 2022b.

The IPCC 6th Assessment Report incorporates the inherently complex nature of climate risk, vulnerability, exposure and impacts, including feedbacks, cascades, non-linear behaviour and the potential for surprise.

By assessing the degree of exposure and vulnerability (socio-economic, material and environmental) to the hazards analysed, four types of risk have been identified. The first group includes risks related to **extreme rainfall**, which mainly affects roads in the urban area, with phenomena of flooding or surface runoff, and may also involve periods of flooding in watercourses and troughs.

Another large risk group includes phenomena derived from **extreme temperatures**, with a special incidence on surface temperatures. These situations contribute to urban heat islands, heat waves and the occurrence of hot nights with particular health impacts. In addition, periods of meteorological drought can be exacerbated by this phenomenon. A third group is related to **extreme wind**. This document, in particular, has focused on the impacts of southerly winds. Finally, the fourth group includes **coastal flooding** due to the set of impacts from sea level rise, combined with storm surges or the influence of stormy periods, or the south wind.



5.3.1. Risks from Extreme Rainfall

Risk from Pluvial Flood Events on Roads

The risk index for pluvial flooding events on roads for each time horizon and census section is obtained by combining and normalising three variables: (I) the Hazard Index, obtained from the average of the frequency of extreme rainfall events in the different climate scenarios; (II) the result of floodable roads as a representative measure of the level of Exposure, calculated as a percentage of km^2 of roads with a probability of flooding with respect to the total km^2 of roads in the municipality; and (III) the Climate Sensitivity Index for current and projected extreme rainfall events in 2050 and 2100.

The normalised risk index for flooding on roads due to extreme precipitation events maintains low to moderate values for both the historical and projected short-term periods in almost the entire municipality, except for certain neighbourhoods in the centre of the capital and the southern coast, where relatively higher values are reached, below 0.88. The average risk index in the municipality is 0.45 and 0.49 for the historical and projected short-term periods, respectively. For the medium and long term, a generalised increasing trend is observed, mainly towards medium or medium-high values in the normalised risk index, maintaining in both cases very moderate values in the northern and eastern sectors of the municipality. The average for the medium and long term is 0.55 and 0.57, respectively, reaching maximum values, mainly associated with residential neighbourhoods in the south, coinciding with the consolidated sector of the capital.

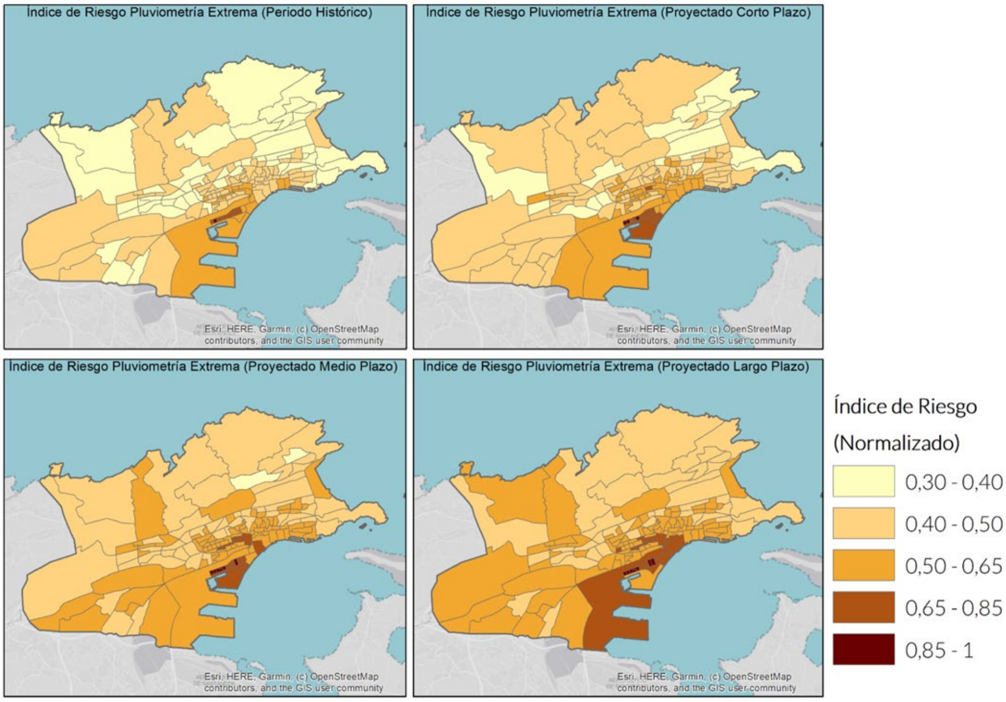


Figure 5.38. *Normalised Risk Index for Pluvial Flood Events on Roadways*

Note: For historical period (top left), projected short (top right), medium (bottom left) and long term (bottom right) by census sections.

Source: CINCc (UC) - FIC, 2024.

The **normalised risk index** for rainfall flooding events with significant impact on roads in the city centre shows a severe impact in different sections of the Castilla-Hermida neighbourhood, and with smaller but equally important values in other areas of the centre, in the area around the Estaciones, as well as in neighbourhoods such as Calle Alta and San Fernando. It should be borne in mind that the variability of rainfall can compromise the existing drainage system, so specific studies related to extreme rainfall in short periods should be considered for the sectors indicated. The detailed analysis of the real conditions of the drainage network in the face of these projections makes it possible to define the need to extend the network with a separate system or increase the sections of the existing collectors.

In any case, the proposal of the Adaptation Plan follows the criteria of sustainability and environmental protection, prioritising the creation of a separative network with rainfall harvesting measures and the combined implementation of nature-based solutions, sustainable drainage systems and increasing the permeability of urbanised soils to favour sustainable management of extreme rainfall. Given the high cost of these measures, it is considered necessary to prioritise urban sectors in which to develop adaptation solutions. Therefore, the urban sector of Castilla-Hermida and the central areas of the city of Santander should be placed on the priority list of investments aimed at reducing the impact of extraordinarily intense rainfall in short periods of time.

TABLE 5.12. *Neighbourhoods and census sections at high risk of Extreme Rainfall impacts*

NEIGHBOURHOOD	CENSUS SECTION	EXTREME RAINFALL			
		CURRENT	SHORT TERM	MEDIUM TERM	LONG TERM
Calle Alta - Cabildo	3907501009				
Castilla - Hermida - Pesquero	3907505005				
	3907505006				
	3907505007				
	3907505008				
	3907505009				
	3907505011				
	3907505012				
	3907505014				
	3907505015				
	3907505013				
Centro	3907501001				
	3907501002				
	3907501008				
Estaciones - Catedral	3907505001				
	3907505002				
	3907505004				
	3907505010				
	3907505003				
San Fernando	3907502004				
	3907502012				
	3907506001				
	3907506003				

Source: CINCc (UC) - FIC, 2024.

Risk from Fluvial Flood Events

The risk index for fluvial flood events is obtained by combining the normalised values of hazard, which is indicative of the percentage of the area under threat, exposure, expressed as the percentage of exposed roads, and the sensitivity values for flood events in the current period (figure 5.39).

Fluvial flooding has a relatively low incidence within the municipality of Santander. Flood zones only appear to the west of the municipality, coinciding with areas bordering the Arroyo Otero stream, which is approximately 1.3 km long and belongs to the Pas-Miera system of the Western Cantabrian Hydrographic Demarcation. This fluvial flood zone would affect a single census section of the municipality. The percentage of surface area threatened for this section would be 0.027%. Furthermore, within this sector, the exposed roads barely reach 0.5% of the total roads, so that, in general, the risk from fluvial flooding is low in Santander, with the possibility of triggering occasional impacts by cutting off access to private properties, or by temporary interruptions of the railway line.

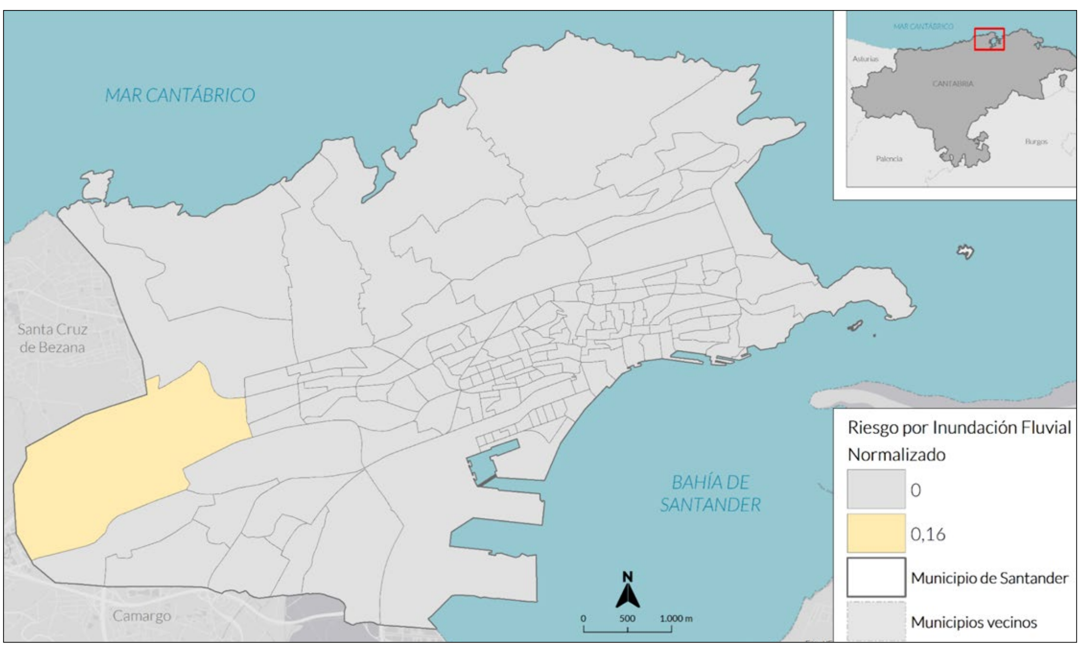


Figure 5.39. *Normalised Risk Index for Fluvial Flood events*

Source: CINCc (UC) - FIC, 2024.

As indicated above, the only census section affected, and with a low level of risk of river flooding, is in the Camarreal - Ojáiz / El Alisal neighbourhood. Although the impact of this threat on the territory is very low, the natural value of this sector should be enhanced and the area should be environmentally restored in coordination with the municipality of Santa Cruz de Bezana, with the aim of reducing possible impacts on the railway infrastructure and the natural environment.

TABLE 5.13. *List of neighbourhoods with the highest risk indexes for river flooding*

NEIGHBOURHOOD	CENSUS SECTION	RIVER FLOOD
Camarreal - Ojaiz / El Alisal	3907508004	

Source: CINCc (UC) - FIC, 2024.

5.3.2. Risks from Extreme Temperatures

Risk from Diurnal Heat Island Episodes

The normalised risk index for diurnal urban heat island phenomena in the municipality of Santander shows low or null values for the northern and eastern sections of the municipality. The southern areas of the municipality, coinciding with the port sector and residential sections of the centre, constitute the areas with the highest level of risk for the diurnal urban heat island phenomena. Several risk factors converge in these areas, as they concentrate high percentages of surface area exposed to such hazards, with high percentages of population and, in general, several conditions of human and environmental sensitivity.

These risk levels are mainly applicable to human health, and can cause general malaise, respiratory problems, sunstroke, dehydration or increased fatigue. Therefore, it can have an impact on the number of deaths or hospitalisations due to heat stroke from extreme temperature events, mainly for older population groups. These phenomena also aggravate the consequences of climate change in cities, for example by increasing the number or intensity of warm (torrid or equatorial) nights (figure 5.40).

The list of census sections and neighbourhoods with the highest risk indices corresponds to those defined in table 5.14. Given the volume of people living in the area around Castilla-Hermida, and some sectors of the city's central areas, priority should be given in these neighbourhoods to carrying out actions to adapt to this phenomenon. Likewise, as has been pointed out in terms of the degree of exposure, the industrial estates close to the port sector, Parayas and Candina in particular, present high levels of risk with a direct effect on the people who work in these areas.

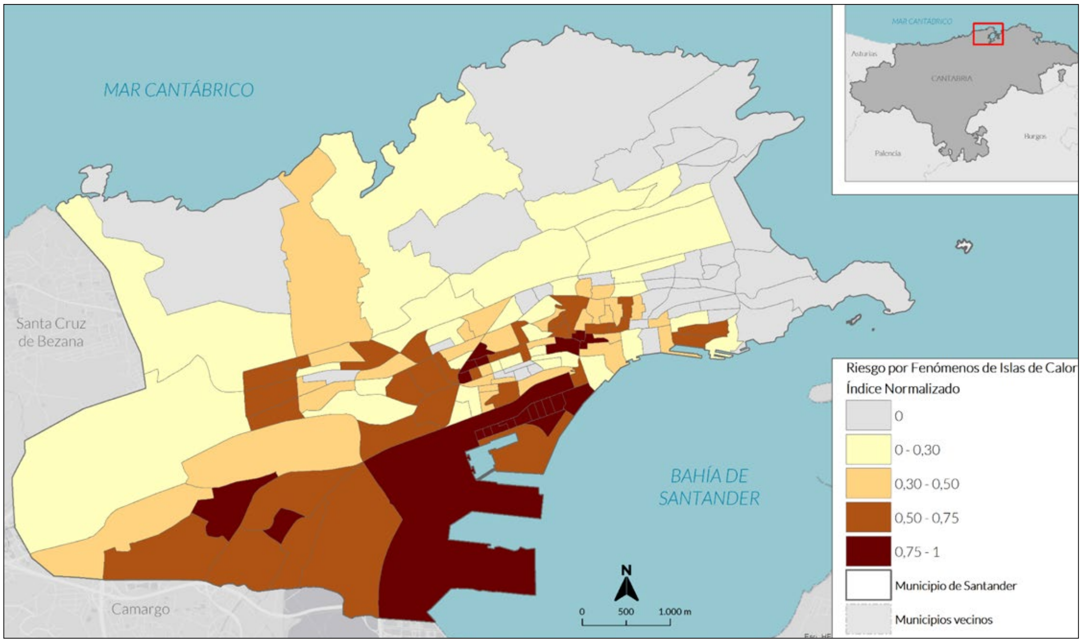


Figure 5.40. *Risk Index for Potential Diurnal Heat Islands*

Source: CINCc (UC) - FIC, 2024.

Some of these areas should be identified as Priority Adaptation Areas and the necessary corrective measures established, with a notable increase in vegetation, soil permeability and the use of high albedo materials.

TABLE 5.14. *List of neighbourhoods with the highest heat island risk indices*

NEIGHBOURHOOD	CENSUS SECTION	HEAT ISLAND
Castilla - Hermida - Pesquero	3907505005	
	3907505006	
	3907505007	
	3907505008	
	3907505011	
	3907505012	
	3907505014	
	3907505015	
Estaciones - Catedral / Castilla - Hermida - Pesquero	3907505003	
	3907505013	

[.../...]

Continuation **TABLE 5.14**

NEIGHBOURHOOD	CENSUS SECTION	HEAT ISLAND
Centro	3907501001	
	3907501004	
	3907501005	
Estaciones - Catedral	3907505004	
	3907505010	
La Tierruca	3907502007	
Peñacastillo – Hermanos - Calderón	3907508021	
	3907508029	
San Fernando	3907502010	
	3907502012	
	3907502026	

Source: CINCc (UC) - FIC, 2024.

Risk from the Occurrence of Warm Nights

The risk level for the occurrence of warm nights is applicable to **human health** and to the whole of the territory covered by the municipality of Santander. According to various sources, the ideal temperature for a good night's rest is between 16°C and 20°C, so that the occurrence of these events has a direct effect on the well-being of society, associated with difficulty in falling asleep and which, in turn, is related to other conditions such as accumulated fatigue or anxiety.

For the evaluation of the risk derived from the occurrence of warm nights, the results of the analysis of nights with minimum temperatures of 22ºC in Santander have been used, specifically, through the average number of nights with minimum temperatures of 22ºC, as a representative measure of the hazard, together with the results of climate sensitivity obtained for extreme temperature events for the current horizon and projected to 2050 and 2100, both previously normalised.

The normalised risk index for the occurrence of warm nights maintains low to moderate values for both the historical and projected short-term periods in almost the entire municipality, with the exception of certain neighbourhoods in the centre of the capital and the south coast, where relatively higher values are reached, always below 0.55. The average risk index for the municipality is 0.34 and 0.38 for the historical and projected short-term periods, respectively. These values are also strongly influenced by the **sensitivity component** with respect to the hazard component, which maintains a very insignificant incidence until the middle of the century.

For the medium term, there is a general increasing trend towards medium to high values in the normalised risk index. The average in this case stands at 0.46, reaching peaks of up to 0.65, mainly associated with neighbourhoods in the consolidated sector of the capital. For these projections, a relatively large decrease in the climate sensitivity component is expected, but this is not sufficient to offset the increase in the hazard index (figure 5.41).

This trend continues and increases towards the end of the century, where the highest risk levels are expected in general terms, with averages of around 0.7 and maximums of up to 0.87. This strong increase in the level of **risk for the end of the century** is mainly due to a strong increase in the average number of warm nights expected with respect to previous periods, which will also be accompanied by a higher incidence in residential neighbourhoods in the south, including an important part of the centre of the capital.

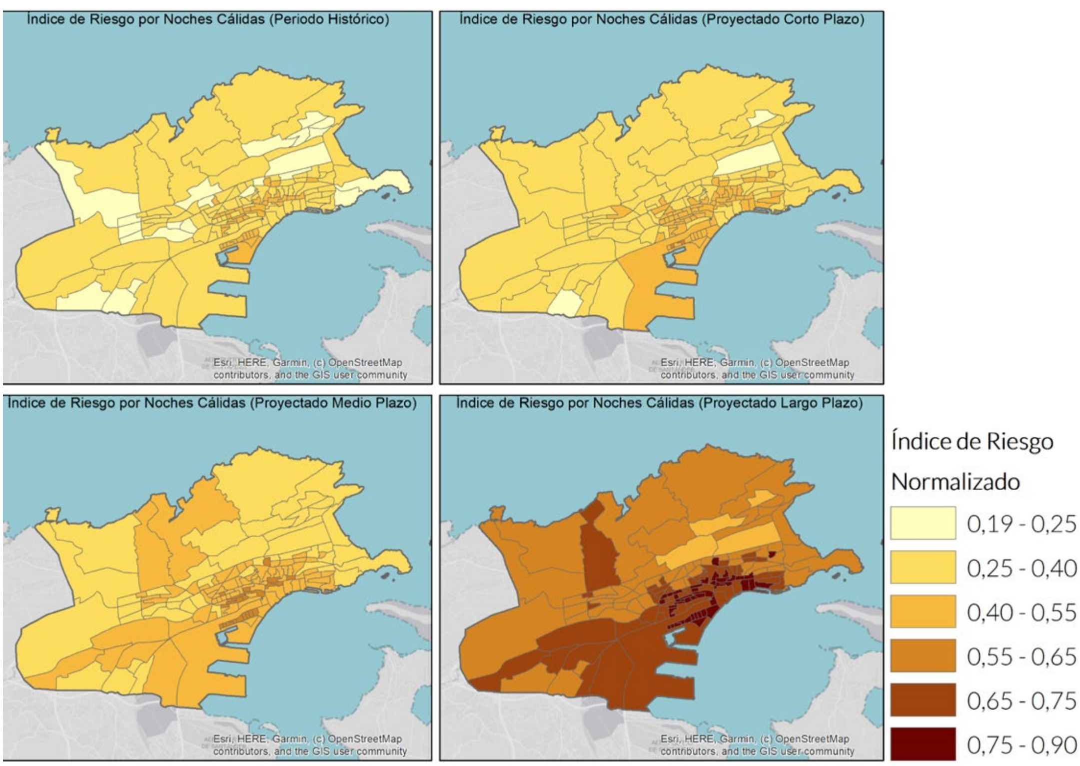


Figure 5.41. *Normalised Risk Index for the Occurrence of Warm Nights*

Note: For historical (top left), projected short (top right), medium (bottom left) and long term (bottom right) periods by census sections.

Source: CINCc (UC) - FIC, 2024.

The impact of warm nights will be very palpable in the long term in the neighbourhoods and census sections identified in the following table 5.15. The areas around Calle Alta, Estaciones, some sectors of the centre and Castilla-Hermida have high values along with other sectors of lower urban density.

TABLE 5.15. *Neighbourhoods and census sections affected by high risk indexes due to Warm Nights*

NEIGHBOURHOOD	CENSUS SECTION	WARM NIGHTS LONG TERM
Calle Alta - Cabildo	3907501009	
	3907501010	
	3907506002	
	3907506013	
Calle Alta - Valdecilla	3907506006	
	3907506007	
	3907506014	
Castilla - Hermida - Pesquero	3907505005	
	3907505006	
	3907505007	
	3907505011	
	3907505012	
	3907505014	
	3907505015	
	3907505013	
Centro	3907501003	
	3907501004	
	3907501005	
	3907501007	
	3907501008	
	3907503004	
	3907503006	
Estaciones - Catedral	3907505002	
	3907505004	
	3907505010	
	3907505003	
Los Castros - Fndo de Los Ríos	3907507008	
Los Castros - Pinares - V. C°	3907507018	
Prado - San Roque	3907503005	
Puerto Chico	3907503009	
	3907503010	
	3907504002	
San Fernando	3907502005	
	3907502010	
	3907502012	
	3907502025	
	3907502026	
	3907506001	
	3907506003	
Tetuán Vía Cornella	3907504004	
	3907501006	
	3907503002	

Source: CINCc (UC) - FIC, 2024.

In any case, this phenomenon has severe implications for people's health, particularly affecting vulnerable elderly people. The adaptation of dwellings, with improved insulation, favouring cross or forced ventilation, as well as control and management through early warnings and monitoring of the most vulnerable population are measures that should be prioritised in the urban sectors identified here.

Risk from Heat Wave Episodes

For the assessment of the risk from heat wave episodes, the results of the **normalised heat wave hazard index** obtained for the historical period and projected in the short, medium and long terms, which combine the intensity and frequency of these episodes, together with the results of climate sensitivity captured for **extreme temperature** events for the current horizon and that projected to 2050 and 2100, are used (figure 5.42).

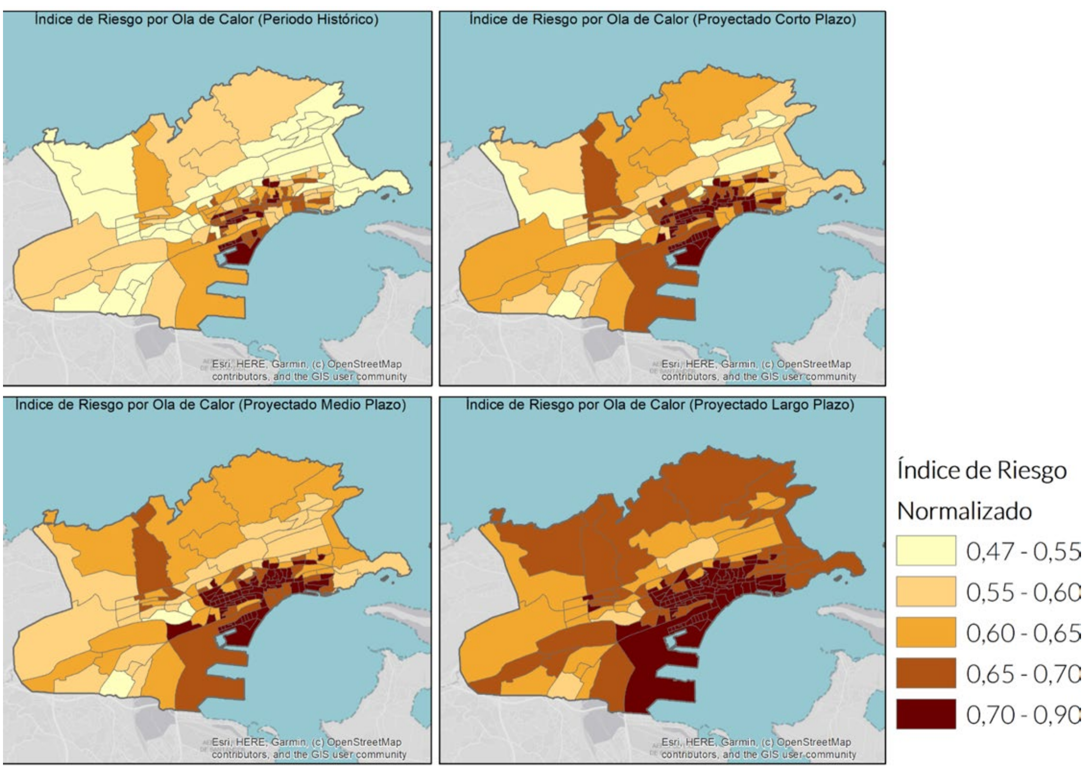


Figure 5.42. *Normalised Risk Index for the occurrence of heat waves*

Note: For historical (top left), projected short (top right), medium (bottom left) and long term (bottom right) periods by census sections.

Source: CINCc (UC) - FIC, 2024.

The normalised risk index for the occurrence of heat waves maintains values of relative importance for all the periods analysed, with minimum values above 0.47. Furthermore, it is expected that these adverse episodes will have a greater incidence in the central districts of the capital, maintaining relatively lower values for the rest of the peripheral sectors of the municipality.

The normalised risk index presents average values of 0.6 in the historical period and 0.66 for the projected period in the short and medium terms, with maximums below 0.78, 0.83 and 0.85 respectively. For the long term, there is a generalised upward trend in the risk index, reaching an average value of 0.73 and peaks of 0.87, mainly associated with neighbourhoods in the consolidated sector of the capital and the port sector. For the projected periods, a relatively large decrease in the climate sensitivity component is expected, but this is not sufficient to offset the increase in the hazard index. Therefore, this strong increase in the risk level by the end of the century is mainly due to a strong increase in the expected hazard index compared to previous periods.

The neighbourhoods and census sections that reach very high risk values at the end of the century are shown below. The identification of vulnerable people in these sectors makes it possible to establish guidelines and programmes for risk management in the face of events of these characteristics. Areas of the city centre and the neighbourhood of Cabildo, Calle Alta, in Castilla-Hermida, Fernández de los Ríos and San Fernando, are particularly sensitive to this phenomenon and already have census sections that exceed very high risk thresholds (table 5.16).

In these sectors, priority should be given to a series of actions focused on controlling the most vulnerable populations exposed to this type of phenomena, with early warning protocols and emergency health management.

TABLE 5.16. *Neighbourhoods and census sections with high long-term heat wave risk indices*

NEIGHBOURHOOD	CENSUS SECTION	HEAT WAVES			
		HISTORICAL	SHORT TERM	MEDIUM TERM	LONG TERM
Calle Alta - Cabildo	3907501009				
	3907501010				
	3907506002				
	3907506013				
Calle Alta - Valdecilla	3907506006				
	3907506007				
	3907506009				
	3907506014				

[.../...]

Continuation **TABLE 5.16**

NEIGHBOURHOOD	CENSUS SECTION	HEAT WAVES			
		HISTORICAL	SHORT TERM	MEDIUM TERM	LONG TERM
Campogiro - Cajo	3907506010				
Castilla - Hermida - Pesquero	3907505005				
	3907505006				
	3907505007				
	3907505008				
	3907505009				
	3907505011				
	3907505012				
	3907505014				
	3907505015				
Castilla -Hermida	3907505013				
Cazoña	3907502024				
	3907508006				
Centro	3907501001				
	3907501002				
	3907501003				
	3907501004				
	3907501005				
	3907501007				
	3907501008				
	3907503004				
	3907503006				
Centro / Estaciones	3907505001				
Ciudad Jardín - Cuatro Caminos	3907502008				
	3907502009				
	3907502013				
Estaciones - Catedral	3907505002				
	3907505004				
	3907505010				
Estaciones - Castilla	3907505003				
G. Dávila - Los Castros	3907507005				
La Tierruca	3907502002				
	3907502007				
	3907502022				

[.../...]

Continuation **TABLE 5.16**

NEIGHBOURHOOD	CENSUS SECTION	HEAT WAVES			
		HISTORICAL	SHORT TERM	MEDIUM TERM	LONG TERM
Los Castros - Fernando de Los Ríos	3907507008				
	3907507009				
Los Castros - Los Pinares - V. Del Camino	3907507013				
	3907507014				
	3907507015				
	3907507018				
Prado - San Roque	3907503003				
	3907503005				
	3907503007				
	3907503008				
	3907503013				
	3907503014				
Puerto Chico	3907503009				
	3907503010				
	3907504001				
	3907504002				
	3907504003				
San Fernando	3907502004				
	3907502005				
	3907502006				
	3907502010				
	3907502011				
	3907502012				
	3907502015				
	3907502025				
	3907502026				
	3907506001				
	3907506003				
	3907506005				
San Francisco - Pronillo	3907507002				
	3907507003				

[…/…]

Continuation **TABLE 5.16**

NEIGHBOURHOOD	CENSUS SECTION	HEAT WAVES			
		HISTORICAL	SHORT TERM	MEDIUM TERM	LONG TERM
Tetuán	3907504004				
	3907504005				
	3907504006				
	3907504007				
	3907504008				
Vía Cornella	3907501006				
	3907502020				
	3907502021				
	3907503001				
	3907503002				

Source: CINCc (UC) - FIC, 2024.

Heat waves are evolving into events of greater magnitude, duration and affecting more people, requiring a comprehensive approach that incorporates a public health perspective, **preparedness** and **response**, and **early warning** (OPS, OMS, 2019). The number of deaths attributable to heat during the period 2000-2009 for Santander was 16 people (Carmona et al., 2016). However, we do not have up-to-date detailed figures on the impact of excessive heat. Absolute values are available for the whole community of Cantabria. The system for monitoring daily all-cause mortality (MoMo)[2] was developed in 2004, within the framework of the 'Plan of preventive actions against the effects of excessive temperatures', coordinated by the Ministry of Health, to reduce the impact on the health of the population as a consequence of excess temperature.

The MoMo Panel (Ministerio de Sanidad, 2023) updates daily estimates of excess mortality due to all causes and attributable to an excess or defect in temperature, by population (national, Autonomous Community and provincial), sex and age group. The evolution of deaths attributable to excess temperature has been very erratic in recent years, with 3 deaths in 2019, 7 in 2020, 2 in 2021 and 3 in 2022. However, Cantabria suffers a notable increase in the period studied (1 May to 31 October), with the figure rising to 76 deaths in 2023.

It should be noted that the episodes of heat waves in 2023 were extraordinary and unusual, with a very high incidence between the months of August and September. The orographic conditions of the community of Cantabria determine the propensity for increased heat impact

2 See: Ministerio de Sanidad (2023). https://momo.isciii.es/panel_momo/

in some valleys in mountainous areas, where high ozone concentrations occur. In sectors where the physical limits imposed by the topography are not so evident, generally along the coast, the situations are less agressive. However, in the light of the data, we cannot rule out the impact that heat waves have on coastal municipalities such as Santander.

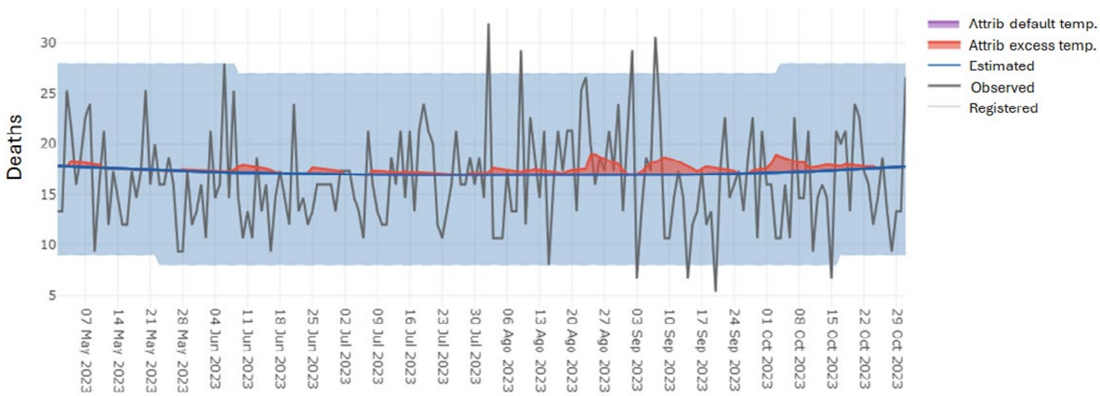


Figure 5.43. *Observed and estimated deaths, attributable to excess temperature*

Source: MOMO, 2024.

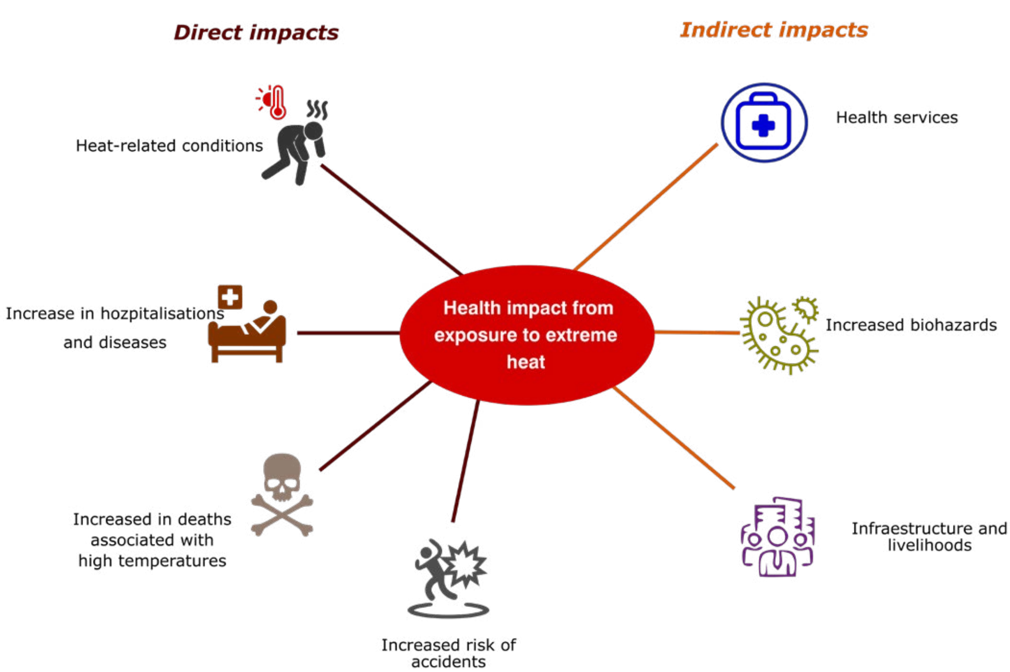


Figure 5.44. *Direct and indirect impacts of extreme heat exposure*

Source: CINCc (UC), 2024, based on data from OPS, OMS (2019).

The excess mortality recorded in 2023 shows a temporary situation that cannot be extrapolated to future episodes; however, we must be aware of the magnitude of the phenomenon and ensure an adequate response for the management of heat waves.

The direct and indirect impacts of exposure to extreme heat are reflected in figure 5.44 and involve a set of situations that can put health and assistance services in a critical situation, while entailing a considerable cost in resources and materials for the public health and civil protection system.

Risk from Meteorological Drought Episodes

The Meteorological Drought Risk Index in Santander is obtained by integrating the results of the **Drought Hazard Index** for each time horizon, captured as a normalised average value of the SPEI accumulated at 24 and 60 months, together with the results of the current and projected climate sensitivity index in the medium and long terms. The Drought Risk Index for the short, medium and long terms is analysed as a relative value that tries to establish a deviation with respect to the historical period, considering the historical drought as the reference or base value (figure 5.45).

The normalised risk index for drought episodes maintains low to moderate values in the short term, with average values around 0.38 and maximum values below 0.58, remaining at the risk threshold with respect to the historical period and with a higher incidence for the southern areas, mainly due to their greater sensitivity.

The risk for successive periods is increasing, mainly due to increases in the 24-month and 60-month cumulative SPEI, indicating a trend towards drier thresholds, respectively. The medium and long-term normalised risk index has mean values around 0.46 and 0.58, and maxima below 0.65 and 0.75, respectively. In both cases, it is expected that these adverse episodes will have a higher incidence in the central districts of the capital, maintaining relatively lower values for the rest of the peripheral sectors of the municipality.

For the projected periods, a relatively significant decrease in the climate sensitivity component is expected, which, however, is not sufficient to counteract the increase in the hazard index. Therefore, this increase in the risk level by the end of the century is mainly due to the successive increase in the expected hazard index compared to the reference period.

It should be noted that the phenomenon of drought will be exacerbated by the end of the century and there are numerous neighbourhoods and census sections that may be affected with high risk index (table 5.17). The neighbourhoods of El Cabildo, Calle Alta, Castilla-Hermida and Pesquero, as well as San Fernando, have been identified as very high risk sectors in the medium and long terms. It is, therefore, necessary to establish and prioritise a control-monitoring and response programme in these urban sectors given the numerous effects that they have on services and public risk management.

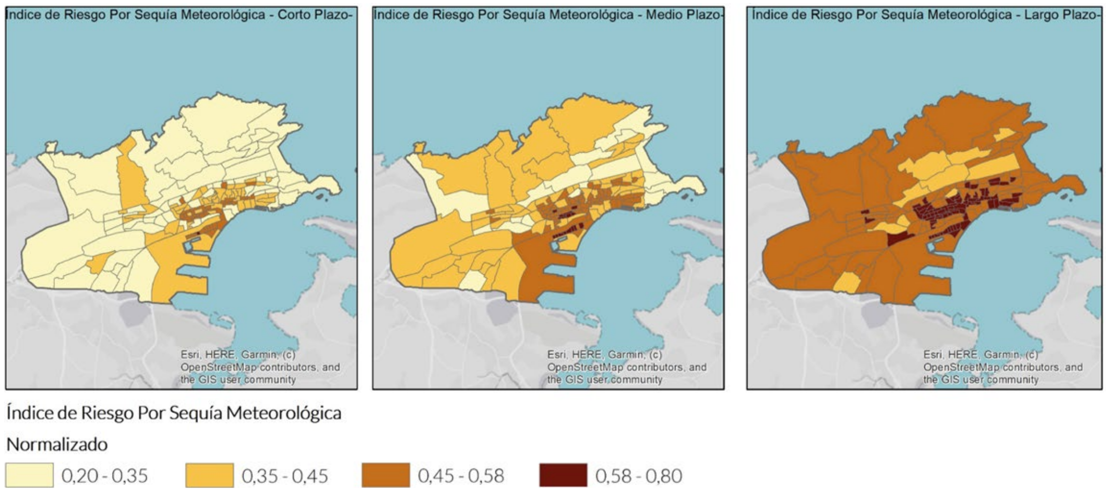


Figure 5.45. *Meteorological Drought Risk Index*

Source: CINCc (UC) - FIC, 2024.

TABLE 5.17. *Set of neighbourhoods and census sections with high drought risk indices*

NEIGHBOURHOOD	CENSUS SECTION	DROUGHT		
		SHORT TERM	MEDIUM TERM	LONG TERM
Calle Alta - Cabildo	3907501009			
	3907501010			
	3907506002			
	3907506013			
Calle Alta - Valdecilla	3907506006			
	3907506007			
	3907506014			
Campogiro - Cajo	3907506010			
Castilla - Hermida - Pesquero	3907505005			
	3907505006			
	3907505007			
	3907505011			
	3907505012			
	3907505014			
	3907505015			
	3907505013			
Cazoña	3907502024			
	3907508006			

[…/…]

Continuation **TABLE 5.17**

NEIGHBOURHOOD	CENSUS SECTION	DROUGHT		
		SHORT TERM	MEDIUM TERM	LONG TERM
Centro	3907501001			
	3907501003			
	3907501004			
	3907501005			
	3907501007			
	3907501008			
	3907503004			
	3907503006			
Ciudad Jardín - Cuatro Caminos	3907502008			
	3907502009			
	3907502013			
Estaciones - Catedral	3907505002			
	3907505004			
	3907505010			
	3907505003			
La Tierruca	3907502002			
	3907502007			
Los Castros - Fernando de Los Ríos	3907507008			
	3907507009			
Los Castros - Los Pinares - V. Del Camino	3907507013			
	3907507014			
	3907507015			
	3907507018			
Prado - San Roque	3907503005			
	3907503008			
	3907503013			
Puerto Chico	3907503009			
	3907503010			
	3907504002			
	3907504003			
San Fernando	3907502004			
	3907502005			
	3907502006			
	3907502010			

[…/…]

Continuation **TABLE 5.17**

NEIGHBOURHOOD	CENSUS SECTION	DROUGHT		
		SHORT TERM	MEDIUM TERM	LONG TERM
San Fernando	3907502011			
	3907502012			
	3907502015			
	3907502025			
	3907502026			
	3907506001			
	3907506003			
	3907506005			
San Francisco - Pronillo	3907507002			
	3907507003			
Tetuán	3907504004			
	3907504006			
	3907504007			
Vía Cornella	3907501006			
	3907502020			
	3907502021			
	3907503002			

Source: CINCc (UC) - FIC, 2024.

5.3.3. Extreme Wind Risk

Risk from Episodes of South Wind Gusts

For evaluating the risk from the occurrence of southerly wind gusts, the results of the **normalised hazard index** are used, obtained through the mean value per census section of the maximum southerly wind gust for the historical period, and projected in the short, medium and long terms, together with the results of climate sensitivity captured for extreme wind events for the current horizon and projected to 2050 and 2100. This is done together with the results of exposure, obtained through the percentage of south-facing surface area per census section.

The normalised risk index for the occurrence of southerly wind gusts maintains values of relative importance for all the periods analysed, with minimums of 0 for the sections free of south-facing slopes, and minimums above 0.39 for the remaining sections (figure 5.46). Furthermore, it is expected that these adverse episodes will have a greater incidence in the southern sector of the municipality, including the port area and central districts of the capital, maintaining relatively lower values for the rest of the peripheral sectors of the municipality.

The normalised risk index presents average values of 0.69 in the historical period and 0.68 and 0.66 for the projected period in the short and medium term, with maximums reaching levels of 0.97, 0.96 and 0.92, respectively. For the long terms, there is a general downward trend in the risk index, reaching an average value of 0.62 and peaks of 0.87, mainly associated with neighbourhoods in the consolidated sector of the capital. This decrease in the projected periods is mainly due to a decrease in the future climate sensitivity index, together with a decrease, in this case, not very noticeable in the hazard index.

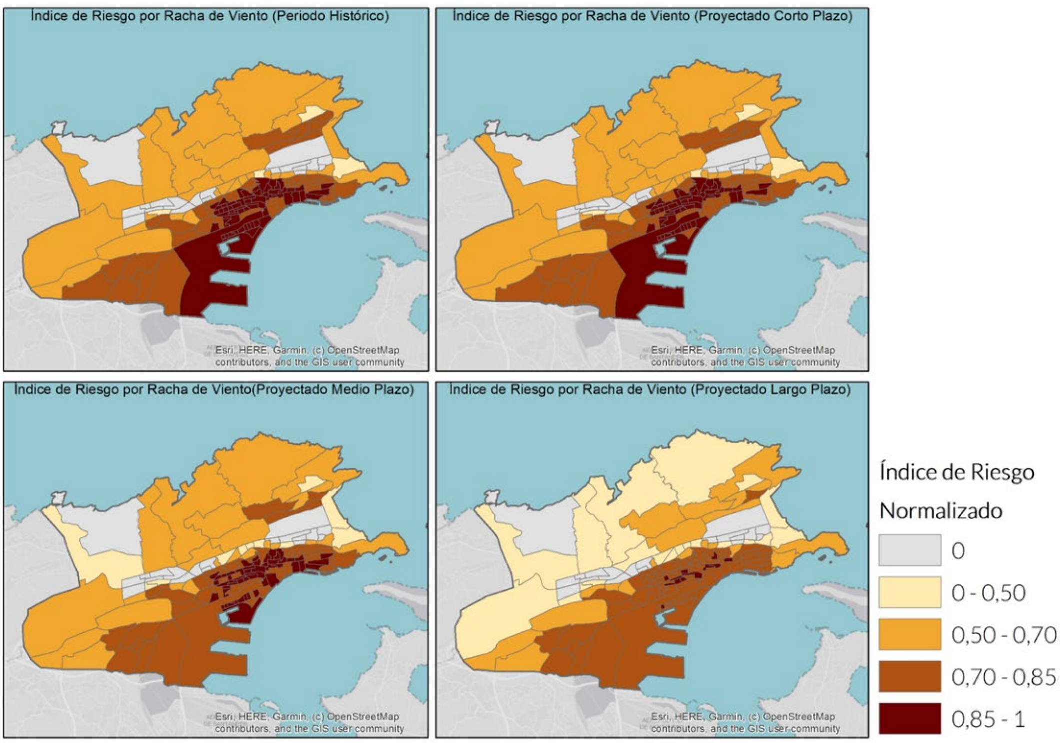


Figure 5.46. *Normalised Wind Risk Index for Southerly Wind Gusts*

Source: CINCc (UC) - FIC, 2024.

The following is a list of neighbourhoods with their census sections that maintain very high risk indices for south wind gusts, despite the general reduction of wind in the long term (table 5.18). With a very uneven distribution, the impact of this phenomenon on buildings can be considerable, which is why their maintenance with the revision of façade elements and possible loose parts in roofs and ceilings must be programmed and managed by the private sector.

Dwellings located on high points and facing south, south-east along with heights of more than five storeys are particularly vulnerable to this phenomenon.

On the other hand, the health effects of this climatic component must be considered by the health services and the vulnerable population in these sectors must be monitored.

TABLE 5.18. *Neighbourhoods and sections that maintain high long-term Extreme Wind Risk Indices*

NEIGHBOURHOOD	CENSUS SECTION	EXTREME WIND			
		CURRENT	SHORT TERM	MEDIUM TERM	LONG TERM
Calle Alta - Cabildo	3907501009				
	3907506002				
	3907506013				
Calle Alta - Valdecilla	3907506014				
Castilla - Hermida - Pesquero	3907505007				
Centro	3907501003				
	3907501004				
	3907501008				
Puerto Chico	3907503009				
San Fernando	3907502025				
	3907506001				

Source: CINCc (UC) - FIC, 2024.

5.3.4. Coastal Flood Risk

Risk from Coastal Flood Events on the Urban Environment

The **Normalised Risk index** for coastal flooding events shows very high values for the sector coinciding with the Sardinero coasts in all the scenarios analysed with respect to the rest of the coastal sectors of the municipality.

For the historical scenario (figure 5.47), the risk index maintains moderate values for the coastal sector in the north of the municipality, including the coastal area bordering the San

Pedro del Mar estuary, Bañaperros and El Bocal. The same shows relatively low values for the rest of the threatened coastal neighbourhoods to the north, east and south of the municipality.

In the middle of the century (figure 5.48), for the RCP8.5 emission scenario, a similar level of risk is foreseen with respect to the historical scenario. This could also affect the urban neighbourhood adjacent to the Sardinero sector, due to the greater extension of the coastal flooding area in that sector for that period.

At the end of the century (figure 5.49), for the RCP8.5 emission scenario, greater increases in the level of risk are expected, mainly for the eastern and southern sectors of the municipality, as well as new neighbourhoods that could be impacted by coastal flooding events. The risk index reaches its highest value in this scenario in the Sardinero sector, followed by the consolidated urban sector in the south of the municipality.

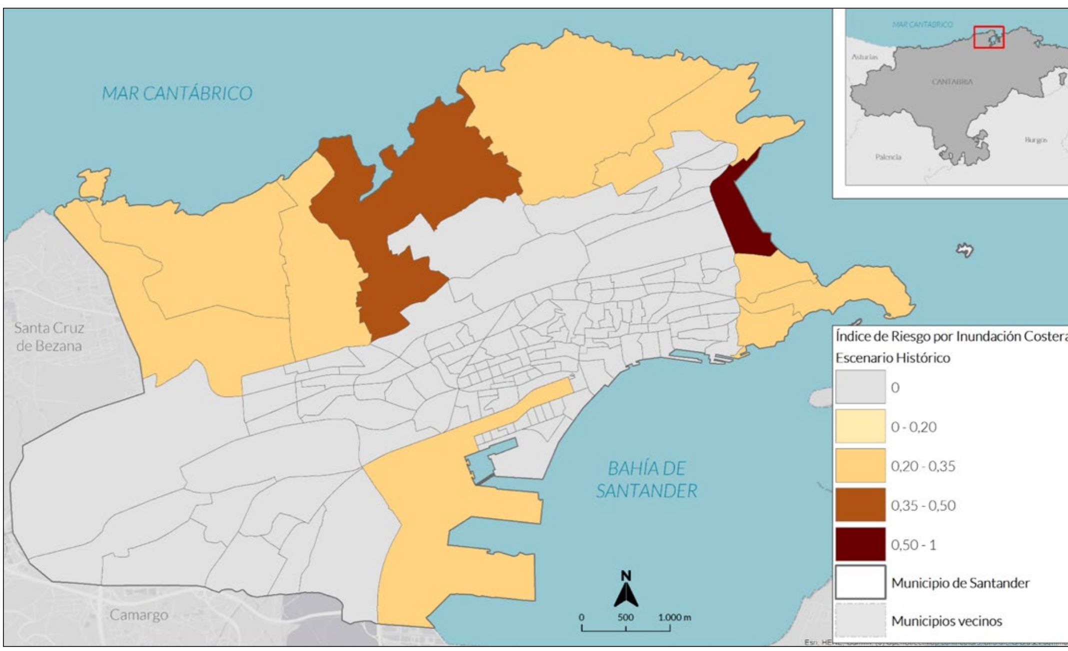


Figure 5.47. *Normalised Coastal Flood Hazard Index, Historical Scenario*

Source: CINCc (UC) - FIC, 2024.

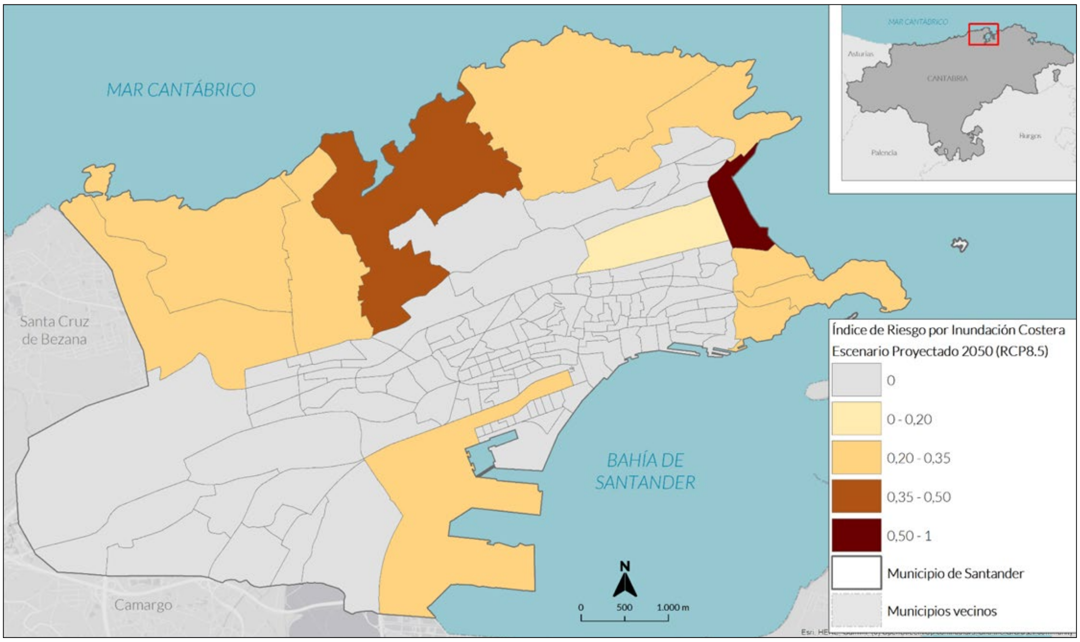


Figure 5.48. *Normalised Coastal Flood Risk Index, Projected Scenario to 2050 (RCP8.5)*
Source: CINCc (UC) - FIC, 2024.

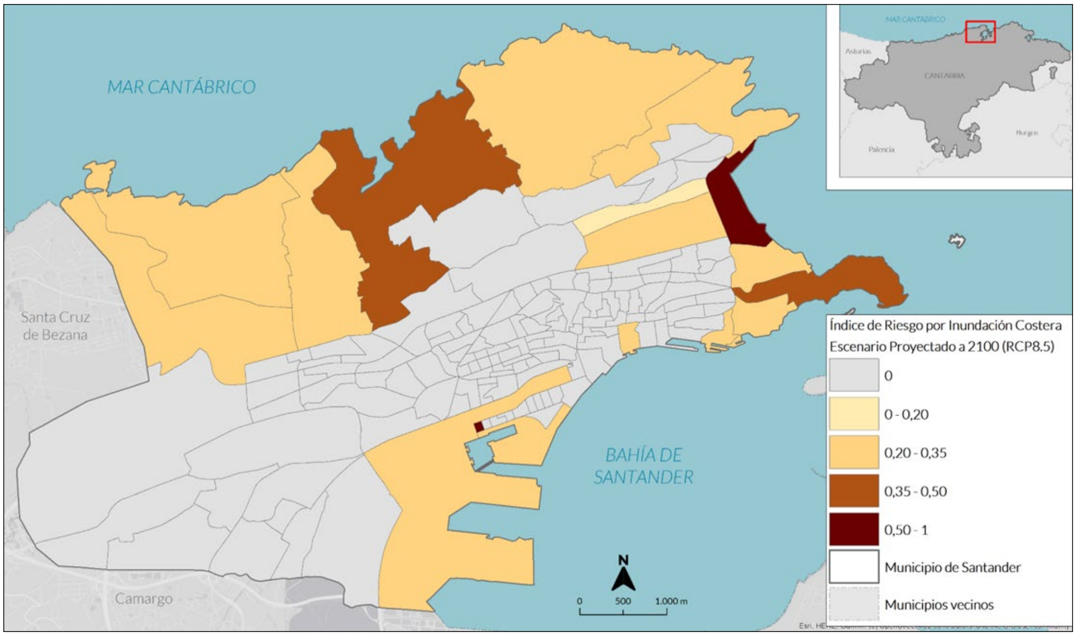


Figure 5.49. *Normalised Coastal Flood Hazard Index, Projected Scenario to 2100 (RCP8.5)*
Source: CINCc (UC) – FIC, 2024.

TABLE 5.19. *Neighbourhoods and census sections at medium, high and very high long-term risk of Coastal Floods*

NEIGHBOURHOOD	CENSUS SECTION	COASTAL FLOODING		
		CURRENT	MEDIUM TERM	LONG TERM
Puerto Chico	3907504001			
Tetuán	3907504008			
Sardinero	3907504009			
	3907504010			
	3907504011			
	3907504012			
	3907504013			
Castilla - Hermida - Pesquero	3907505008			
	3907505009			
	3907505015			
Monte	3907508009			
Cueto	3907508011			
	3907508012			
San Román de la Llanilla	3907508007			
	3907508024			

Source: CINCc (UC) - FIC, 2024.

Rising sea levels, with extreme phenomena such as storm surges, pose a clear risk to the coastline of the city of Santander. The most significant impacts occur on the beaches of the municipality, with retreat and loss of sand, putting pedestrian areas and infrastructures at risk. The neighbourhood of El Sardinero and the surrounding beaches, especially the Second Beach, is a highly vulnerable sector, which has maintained very high risk indices throughout the different periods analysed. This situation can cause the height to rise in certain coastal areas where, in periods of intense southerly winds, the water can affect various sectors of Castilla-Hermida and Puerto Chico. Likewise, the northern beaches along the neighbourhoods from Cueto to San Román de la Llanilla may be affected and increase the risk values.

5.4 DIAGNOSTIC AND STRATEGIC PROPOSALS FOR SCN

F. García, C. Ribalaygua, N. Herrera, L. Asensio, C. Gil, J. González, D. Rasilla, P. Fernández, S. Pérez, F. Conde

Based on a comprehensive diagnosis, several **strategic proposals** for Santander Capital Natural have been proposed. These are thematic projects that bring together the main ideas and solutions contributed throughout the process, both in the technical and citizen workshops as well as in the technical sessions held with experts.

5.4.1. Diagnostic

Following the development of hazard-specific risk indices, the cross-cutting conclusions identify four main risk groups facing Santander. The impact of **extreme precipitation**, **high temperatures**, potential health and building impacts caused by **extreme wind** and, finally, impacts on the coastline due to **coastal flooding**. These risk groups highlight the need to address a set of adaptation measures for an effective response to Santander's climate resilience.

Addressing the risks associated with **pluvial flooding** events, especially in critical urban areas such as Castilla-Hermida and Santander city centre, requires priority attention. These locations show a severe impact due to rainfall variability, which compromises the existing drainage system and requires the extension of the network with separative systems or the increase of collector sections.

Although the risk of **fluvial flooding** is practically non-existent, it is advisable to identify and protect these areas that are currently little affected in order to reduce future risks, and to work with the municipality of Santa Cruz de Bezana to restore these areas environmentally.

Also noteworthy is the risk associated with **high temperatures**, which requires the definition of Urban Adaptation Areas (García, 2019), emphasising the need to implement adaptive actions in industrial estates close to the port, as well as in areas with a high density of vulnerable population. Heat waves, prolonged drought and the threat of hot nights also require attention, especially in densely populated neighbourhoods such as Calle Alta, Las Estaciones and Castilla-Hermida, where it is recommended to improve housing conditions and establish early warning protocols to protect the vulnerable population.

Exposure to **extreme winds**, especially those of a southerly component, has a special effect on the vulnerable population as well as on high-rise buildings along the first line of impact of wind gusts.

To complete this diagnosis, it highlights the risk associated with rising **sea levels** in combination with storm events or storm surges, mainly affecting the beaches of the municipality, such as El Sardinero, and the need to establish various protection measures in other vulnerable coastal areas.

It, therefore, highlights the need to take measures to protect the population and infrastructure from the risks associated with climate change in the city of Santander, favouring early recovery from extreme events. The set of measures proposed below seek to respond to these risks by controlling and managing the impacts associated with them.

5.4.2. Strategic Proposals for Santander Capital Natural

In coherence with the previous diagnosis, four strategies have been proposed focused on the challenge of facing the main impacts deduced for the future scenario in the municipality of Santander, within the framework of the Santander Capital Natural project. These proposals identify the main adaptation objectives based on the needs detected in the study along with the collaboration of institutions and experts, as well as citizens.

1. Developing Green Infrastructure as a Cross-cutting Adaptation Resource

The benefits that nature brings in terms of health, well-being, environmental sustainability and resilience to climate change, lead to the need to incorporate this resource as a key tool in the improvement of cities. In the context of climate change, some of the services provided by green infrastructure contribute dramatically to the improvement of air quality, the mitigation of greenhouse gases, the regulation of urban climate and the adaptation of the urban fabric to direct threats, especially extreme rainfall and rising temperatures.

Therefore, the identification and development of a strong green infrastructure in the city of Santander is a key cross-cutting measure to achieve a truly resilient city. Green infrastructure must be planned, designed and maintained to maximise its benefits while minimising negative impacts. To ensure its effectiveness, it must consider:

- Connectivity of green spaces.
- Type of vegetation.
- Water management.
- Community participation.

Ecosystem connectivity of green infrastructure is necessary to promote biodiversity and provide strategic ecosystem services for urban adaptation in Santander. Ecological corridors and connectivity between green areas can contribute to increasing the resilience of urban ecosystems to climate change impacts, such as heat waves, floods and droughts, by helping to regulate the water cycle, improve air quality, control soil erosion or provide habitats for pollination and pest control.

Figure 5.50. *Ecosystem Connectivity of Santander's Green Infrastructure*
Source: CINCc (UC), 2024.

In the case of Santander, the **Vaguada de Las Llamas corridor** has become the centre of gravity of a complex multifunctional system that allows connectivity between the rural areas of the north and the landscaped poles, generally in private areas, of the east (El Sardinero) and south-west (Nueva Montaña). A green structure with a very marked **east-west** component, defined by the topographical conditions whose protection and promotion should be a strategic issue, needs to be introduced in the regulatory documents for the development of urban planning.

Therefore, the design of the municipal green infrastructure should optimise the potential for connectivity between public and private green spaces. An initial assessment of private plots of land destined for landscaped or naturalised green spaces, either due to a lack of buildings or specific uses, totals almost three million m^2 of surface area. This is equivalent to 44% of the existing green space of the urban land.

The development of the Green Infrastructure Plan, incorporated as a specific action within the Santander Capital Natural Strategy, offers the opportunity to integrate potential private space sites that can be integrated into the ecosystemic network. These green spaces facilitate the connection of the powerful urban green facilities that function as strategic linear corridors, the Magdalena Peninsula and the coastal cliffs (Peligros - Magdalena - El Camello), the north-eastern coastal green system (El Faro, Mataleñas Park - Mesones Park), the transversal corridors (Las Llamas - Parque de Sotileza or del Agua - Parque del Doctor Morales or de la Vaca - La Remonta) and their extensions towards Peñacastillo as far as the marshes of the Raos Canal. Not to forget the extensive rural space in the north where it is possible to recover, through its network of paths and trails, a linear network of once abundant coastal holm oak wood, which enhances the natural values of the area and protects it from the influence of the north and north-westerly winds.

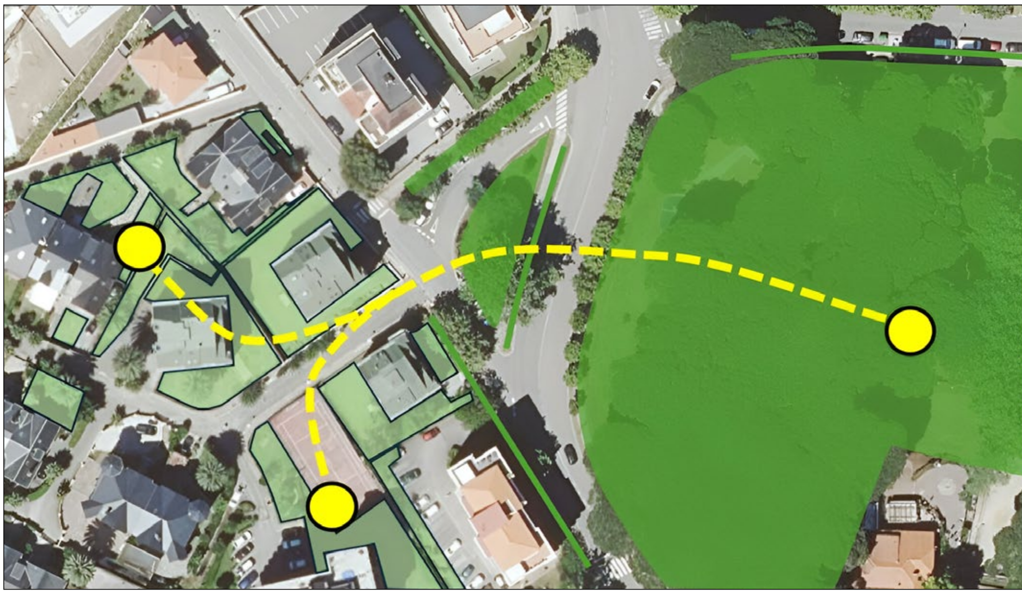
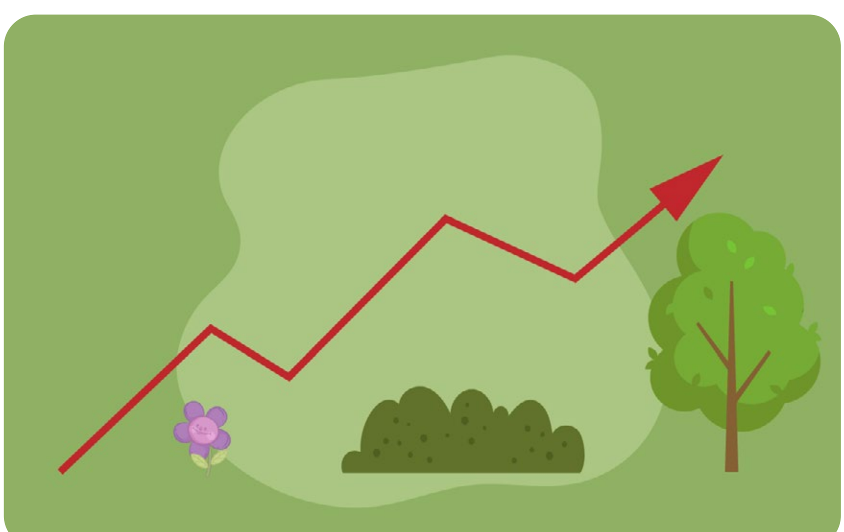


Figure 5.51. *Potential connectivity between private and public green spaces*
Source: CINCc (UC), 2024.



Santander's historical natural conditions[3] are far from the future **climate scenarios** developed by the FIC for this Plan (using the latest statistical downscaling techniques). The future climate scenarios depict a horizon in which a generalised rise in temperatures may compromise the resilience of the traditional tree and shrub species that have developed in the municipality.

In this future climate context, not all contemporary plant species will have a chance of survival. For this reason, the Plan provides a list of **adapted plant species**. The aim is to provide a list of species adapted for planting by the municipal technical services and within the actions included in the Santander Capital Natural project, based on the analysis of the potential behaviour of these species under the new conditions. Although it is worth noting the possibility of finding favourable microclimates in certain areas of the city, the stress that these species may suffer in the near future must be taken into account. In this analysis, the assessment carried out by Dr. Mariano Sánchez García (Real Jardín Botánico de Madrid) at the request of the drafting team stands out, where he identifies the behaviour of the current species in a scenario of increased temperatures and a change in the predicted rainfall regime (see table 5.20).

The table shows **42 tree and shrub species** with their expected behaviour in 2050 and 2100 using a four-colour traffic light. Green represents favourable behaviour in relation to climate change for each horizon. Yellow represents species that, by 2050, can be used with some caution depending on where they are planted. These species require surfaces that are slightly protected from the afternoon sun in the summer months, by establishing new zoning or by placing them in partial shade from other plants.

Practically all species, in the distant horizon (2100), will worsen their ability to withstand environmental conditions, and will be located in the orange and red bands. Species in these conditions require irrigation in the face of heat waves and periods of drought. A suitable strategy would be to plant in semi-shaded areas or in the shade of trees or large shrubs and in places where a certain amount of water is stored in the subsoil after rainfall.

3 In order to understand the origins of the ecosystemic connectivity of the municipality, and within the SCN project, in February 2023, Sebastián Pérez and Sara Núñez proceeded to collect a total of 15 sediment samples to be studied from a palynological point of view in the mediaeval necropolis of Los Azogues, Santander. The samples showed relatively homogeneous characteristics throughout the sequence studied. From this analysis, it can be deduced that the site would be composed of a deciduous forest in terms of the tree layer, where species such as oak, willow and hazel have a good presence in the landscape. These species are accompanied by other species typical of deciduous woodland, such as alder, birch and ash, thus demonstrating a relatively humid climate.

The thesis of a humid climate is also supported by the presence of hydro-hygrophilous vegetation, such as different types of ferns. However, the space surrounding the site would have been dominated more by open areas, in which herbaceous vegetation was the most important, with very few shrubs. Specifically, the landscape domain corresponded to grass pastures together with anthropic-nitrophilous communities, which could be evidence that this population would have been linked, among other things, to economic production activities, since these grass pastures would correspond to pastures for livestock use.

TABLE 5.20. *List of species proposed for planting in Santander*

N.°	SPECIES	2050	2100
1	*Quercus robur*		
2	*Quercus pyrenaica*		
3	*Quercus ilex* subsp. Ilex		
4	*Castanea sativa*		
5	*Fagus sylvatica*		
6	*Betula alba /celtiberica*		
7	*Fraxinus excelsior*		
8	*Alnus glutinosa*		
9	*Tilia platyphyllos*		
10	*Tilia cordata*		
11	*Salix alba*		
12	*Salix atrocinerea*		
13	*Ulmus glabra*		
14	*Ulmus minor*		
15	*Juglans regia*		
16	*Acer campestre*		
17	*Acer pseudoplatanus*		
18	*Prunus avium*		
19	*Prunus mahaleb*		
20	*Ilex aquifoliun*		
21	*Laurus nobilis*		
22	*Arbutus unedo*		
23	*Phillyrea latifolia* [Taxon]		
24	*Rhamnus alaternus*		
25	*Pistacia lentiscus*		
26	*Ligustrum vulgare*		
27	*Frangula alnus*		
28	*Coryllus avellana*		
29	*Crataegus monogyna*		
30	*Malus sylvestris*		
31	*Pyrus cordata /pyraster*		
32	*Sorbus aria*		
33	*Sorbus aucuparia*		
34	*Prunus spinosa*		
35	*Berberis vulgaris*		
36	*Cornus sanguinea*		
37	*Euonymus europaeus*		
38	*Sambucus nigra*		
39	*Viburnum lantana*		
40	*Viburnun tinus*		
41	*Rosa canina*		
42	*Rosa semperviren*		

Source: CINCc (UC), 2024, based on a list provided by the Santander City Council.

With global change, **new gardening techniques** also need to be developed, as traditional methods do not always provide adequate adaptation, and care should be taken to create inorganic beds or mulches, so that rainwater is used as much as possible and evaporation from the sun is reduced. For example, using combinations of plantings and the placement of stones with specific terraces for each plant or group of plants, thus capturing rainwater with appropriate treatment of the subsoil. In this sense, rain garden solutions can be an effective measure by encouraging landscape design techniques that maximise water efficiency.

In view of the expected changes in the annual distribution of rainfall and the increase in the number of days with high temperatures and the duration of heat waves, it is essential to **manage water** appropriately. Urban green spaces, both public and private, require adapted management, based on by-laws that are consistent with climate change. In addition to the aforementioned techniques in the use of species adapted to the future climate of Santander and the design of green spaces to reduce water consumption, wherein rainwater storage must be conceived as a priority, it is also key to **control water losses and leaks** in the distribution system. Prioritising efforts on leakage detection and consumption savings will allow better adaptation to periods of drought.

We believe that **community participation** in the development and maintenance of municipal green infrastructure (both public and private spaces) is crucial to obtain maximum benefits. Training programmes and awareness-raising campaigns on drought and water management, as well as the promotion of proper water management and the adoption of sustainable gardening practices, will achieve the resilience objectives of a good citizen-driven ecosystem network.

2. Permeabilising the Soil to Cope with Rain Floods

The climate scenarios show that the total amount of precipitation in the long term will not change significantly. However, the increase in dry periods means that torrential rainfall events in short time periods will increase. Therefore, the municipal drainage network may be compromised and sewage may be discharged to the surface, posing a risk to public health and the environment. Flooding can cause property damage, traffic disruption and safety risks to people.

To cope with pluvial flooding and reduce the impacts of extreme rainfall events in Santander, it is necessary to implement a series of strategies to increase **permeability** and **drainage capacity**.

The improvement and redesign of the municipal **sewerage network** in the areas identified as being at risk involves the enlargement of the sections of the existing collectors, as well as the implementation of a separate rainwater network to manage the flow of rainwater more efficiently and avoid saturation of the sewerage system. Sectors such as the area around the

Town Hall in Calle Jesús de Monasterio, Calle Gerardo de Alvear and Av. de Candina in the industrial estate of the same name, or some sections of Calle Castilla, may require specific studies for the implementation of improvements to the network.

Likewise, **surveillance and control of the rainwater evacuation network** of the various tunnels in the city must be reinforced, as these sections are particularly vulnerable to vehicular collapse due to waterlogging and flooding.

Figure 5.52. *Ponding in the tunnel of Calle Burgos, Santander*
Source: CINCc (UC), june 2023.

Some recurrent areas with flooding events, such as the Santiago Mayor Urbanisation in Nueva Montaña or Joaquín Salas Street near the Mercasantander industrial estate, can be solved with technical solutions aimed at controlling the opening to the sea and the drainage system of the Raos Canal, implementing the evacuation system.

In addition, the **construction of storm tanks** is an effective strategy to reduce the impact of extreme rainfall events. Storm tanks are underground storage structures that temporarily retain excess rainwater and release it in a controlled manner into the drainage network, thus preventing overflows and flooding. The municipality already has this type of infrastructure, but the installation of new tanks at other points of interest cannot be ruled out.

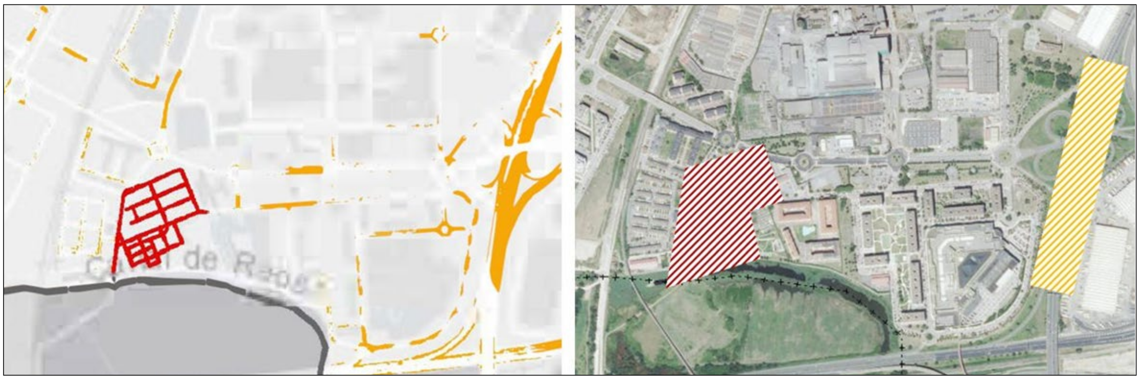


Figure 5.53. *Location of possible areas of ponding (Santiago Mayor - Av. de Parayas).*
Source: CINCc (UC), 2024.

In order to promote the **permeabilisation** of urban areas, one of the main measures is the adoption of Sustainable Urban Drainage Systems **(SUDS)**. These are drainage systems based on techniques capable of capturing and temporarily retaining rainfall, using elements such as permeable pavements or rain gardens, among others. The various SUDS solutions allow water to infiltrate slowly into the subsoil, reducing the volume of surface runoff that reaches the drainage network. It is essential that these measures are integrated into an overall water cycle management strategy, considering both green infrastructure and nature-based solutions. By combining the creation of green corridors and the protection and restoration of water ecosystems (which act as natural buffers against flooding), renaturation projects of impermeable spaces, such as the transformation of paved areas into parks and private areas, will contribute to increase the absorption capacity of the soil and reduce runoff, thus mitigating the risk of flooding.

3. Incorporate Urban Design Solutions to Combat Heat Islands

For the city of Santander to become more resilient to extreme heat and reduce the impacts of urban heat islands, strategies must address both mitigation and adaptation to climate change.

In terms of mitigation strategies, the promotion of sustainable modes of transport such as cycling and clean public transport will contribute to a significant reduction in greenhouse gas emissions, reducing urban warming generated by motorised vehicles. In terms of adaptation, **sustainable urban planning** is needed to encourage the increase of urban vegetation by planting trees and creating **shaded areas** to reduce ambient temperatures. In addition to absorbing carbon dioxide, urban trees have a thermoregulatory capacity and help to improve air quality with consequent positive effects on the health of the population.

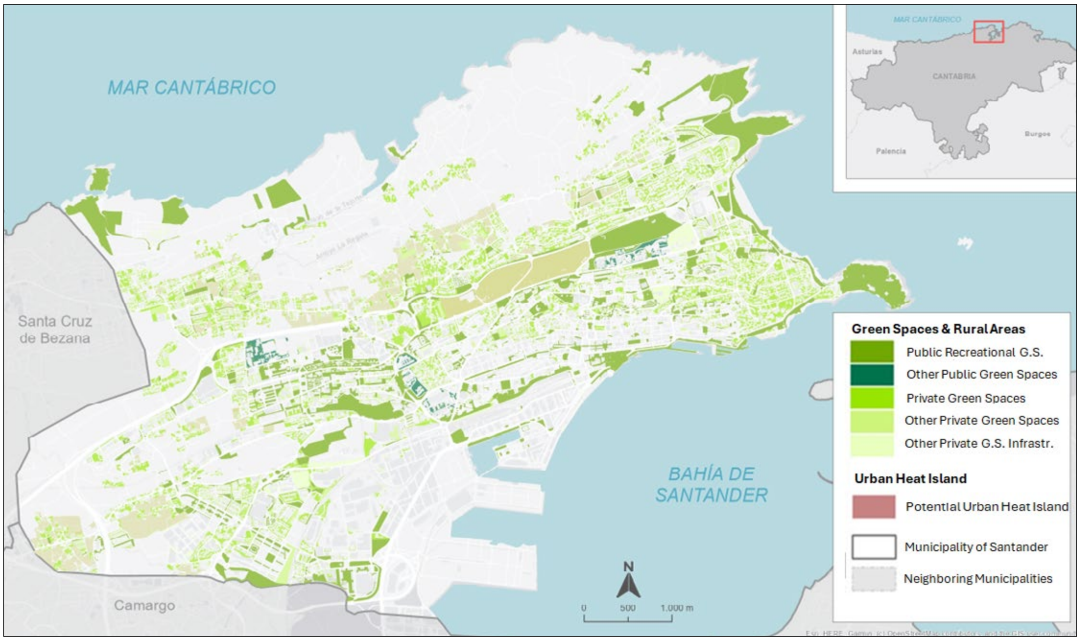


Figure 5.54. *Overlapping urban heat islands and green areas*

Source: CINCc (UC), 2024.

Santander's urban heat islands are determined, at certain times of the year, by the municipality's orographic conditions, the direction and intensity of the wind and the concentration of high temperatures driven by paved surfaces (sectors with low ground permeability, with large asphalted surfaces and paved with low albedo tiles, or sectors with a concentration of activities and buildings). To the south of the natural promontory of Peñacastillo, on both sides of Avenida Primero de Mayo in the residential neighbourhoods of Luis Pombo, Peñacastillo, around Mercasantander or Nueva Montaña, surface temperatures can be notable, as well as in the areas close to the port area, Candina, Parayas and Ciudad del Transportista. In other densely populated neighbourhoods such as El Alisal, La Albericia, around Cuatro Caminos, Calle Alta, Las Estaciones and Castilla-Hermida, or in areas of the city centre, next to the Town Hall or on the southern slopes of Paseo de Canalejas, improving the **thermal insulation of dwellings** with energy-efficient ventilation systems and air-conditioning equipment is recommended. The installation of cool roofs (cool and landscaped roofs), which reflect radiation, helps to reduce the temperature in buildings and reduces the effect of urban heat islands; and these solutions are of particular interest in industrial areas.

Finally, there is considerable room for improvement in public spaces. High-albedo pavements can be used, streets and recreational areas can be designed with materials and colours that reflect sunlight and reduce heat absorption. Also, water fountains that act as natural cooling systems can be incorporated, and shaded areas can be created using urban trees as the main adaptive resource.

4. Readjusting the Coastline to Adapt to Sea Level Rise and its Associated Effects

The **rise in sea level**, in combination with extreme storm events or storm surges, has a special effect on the Santander coastline. This phenomenon has already been recorded, especially on the beaches of the Sardinero, as well as other effects in different vulnerable coastal areas identified through the state project, PIMA Adapta.

Global warming causes thermal expansion of the oceans and melting of ice caps and glaciers, resulting in a progressive net rise in sea level. Changes in the tidal run have caused waves and currents to erode the coastline, while the construction of coastal infrastructure and other developments and anthropogenic activities have altered the natural balance of the coasts, increasing their vulnerability to erosion. To address **shoreline retreat**, adaptation measures are required, such as restoration of coastal habitats, **coastal spatial planning** and land use planning that takes into account the risks associated with climate change and sea level rise.

In the case of the coastal front of the beaches of El Sardinero, the retreat of the coastline could force a **rearrangement of the uses and the current physiognomy** of the environment, putting at risk infrastructures and buildings along the edge of the beaches, such as the promenade and car park on El Camello Beach, the Balneario de la Concha (La Concha Beach), the former Balneario de Pombo (First Beach of El Sardinero), and the buildings known as Cormorán and Parque de Trueba on the Second Beach of El Sardinero. This redevelopment could entail the demolition of the buildings and the extension of the intertidal space, increasing the beach area. The current Mesones Park and its promenade at the foot of the Second Beach of El Sardinero could be altered in its physiognomy, relocating its route and giving up part of its surface area to the sandy stretch. In any case, these interventions will have to be analysed in depth as the uncertainty associated with the wave penetration line resulting from the rise in sea level and the associated extreme events are reduced (figure 5.55).

Figure 5.55. *Exposed areas and possible actions on the waterfront*
Source: CINCc (UC), 2024.

At the end of the promenade at Calle Manuel García Lago, next to the Hotel Chiqui, it is possible to **arrange the coastal space** between the cliff and the viewpoint with a structure of semi-natural pools distributed to reduce wave energy, taking advantage of the experience of projects in this line such as the European LIFE COSTAdapta project, which promotes the design of innovative and progressive systems of tidal pool-reef for the adaptation of the coast.

In the interior of the Bay, the coastline can be affected by the erosive action of waves, with winds from the south-southeast. The alternative of using protection solutions with hard infrastructures must be analysed in detail due to the implications of this type of intervention on the landscape. In the port area, it may be necessary to raise the height of the quays to avoid the penetration of waves in southerly wind storms.

Santander, as a coastal municipality, also requires strategies for the management of its coastal space connected to the ecosystem services offered by green areas. The **blue spaces**, both those associated with inland waters and marine waters, and the transitional spaces of the maritime-terrestrial public domain (estuaries, bays, coastal lagoons, coastal strip, breakwater areas, beaches, marshes, etc.) (hydrodiversity), are areas of unquestionable **heritage value** and a great resource as strategic blue infrastructure for the sustainable development[4] and **resilience** of Santander. In relation to EU community policies, such as blue growth or the blue economy, **incorporating them into current and future plans**, instruments and policies, should be proposed.

The municipality of Santander has several **sectors** in where blue spaces pose particular **potentialities and limitations** in the face of climate change:

1. **Northern cliff strip** with a high degree of naturalness and landscape value connecting with the peri-urban coastal countryside landscapes.
2. **Protected inner beaches,** the most used and valued natural space in the city (walking, playing, bathing, swimming, surfing, etc.), but also with notable threats in the context of current climate change.
3. **An urban seafront** where the natural elements, their components and dynamics have a notable influence on the many and intense uses that are made of this blue space.
4. **Inner rim of the bay and marshes** where industrial activity and other residential and commercial uses are interspersed with natural spaces.

[4] Sustainable development must be supported by promoting public awareness of the risks faced by green areas and the coastline through educational, training and cultural programmes in the framework of SDG 11 (Sustainable Cities and Communities), 13 (Climate Action) and 14 (Marine Environment) and the 2030 Agenda. Programmes such as the 'Sentinels Cantabria' initiative, or 'The Sea Starts Here. Don't throw rubbish into the sewer', an international initiative already present in other Spanish cities, or "Agents of Change: Geography and Education for Sustainability", which promotes sustainability contents among the different educational centres in Cantabria, are some examples of demonstrative actions that focus on the knowledge and conservation of this adaptive resource.

For the conservation and enhancement of the environmental quality and sustainable use of Santander's blue spaces, it will be necessary to develop a comprehensive **land-use planning instrument** for the enhancement of the seafront and to coordinate it with other recent projects such as the 'Plan Bahía', promoting the interconnection with the green ring and facilitating the creation of a 'Santander Blue Belt', with adaptation measures such as the creation of a **drainage and rainwater evacuation** system in the roads near the main beaches, especially flood areas (extendable to the rest of the seafront in the future), reducing spillages and improving water quality.

The **tourism potential** of blue spaces as an economic driver requires an in-depth analysis of the challenges posed by climate change, developing a blue tourism strategy that guarantees resilient use. Examples of this could be the evaluation of the retreat of the beaches of the municipality and their economic impact, or the analysis of the future evolution of the singular surf breaks of interest for surfing (the Vaca Gigante, or the historical breaks of El Sardinero), which could lead to the definition of a Surfing Reserve for Santander as a tourist asset.

ADAPTATION MEASURES 6

Francisco García Sánchez, Cecilia Ribalaygua, Nareme Herrera López, Pablo Fernández de Arroyabe, Domingo Rasilla Álvarez, Carmen Gil de Arriba, Juan J. González Trueba, Sebastián Pérez Díaz, Francisco Conde Oria.

Contributors: Lourdes Galindo Delgado, Mario González Ceballos

Based on the above diagnosis, and with the participation of citizens and the collaboration of experts and people with technical and institutional responsibilities, a set of measures have been designed to enable Santander to achieve its adaptation objectives. These measures are grouped into four fundamental adaptation goals: Resilient City, Biodiversity, Health, and Adapted Society and Economy.

6.1 CRITERIA FOR THE SELECTION OF MEASURES

Given the need to promote adaptation measures that respond to the possible impacts derived from climate variability, and assuming the difficulty of reducing greenhouse gas emissions in the short term, the Adaptation Plan is articulated as the tool for transformation towards adaptation. According to the summary of the AR6 Synthesis Report for policy makers (IPCC, 2022b), this 'transformative' capacity occurs with measures that prioritise equity, social justice, climate justice, rights-based approaches and inclusiveness. It is such measures that lead to more sustainable outcomes, reduce trade-offs and promote climate-resilient development.

At this stage of defining adaptation measures, and in line with the 'Guidelines on Member States' adaptation strategies and plans, the measures of the Santander Adaptation Plan have been defined by following the recommendations set out in its Annex II (Unión Europea, 2023):

- **Just resilience:** The most vulnerable groups in society are often most affected by climate change, so climate change impact and vulnerability assessments must pay attention to the disproportionate consequences for disadvantaged groups of people and geographic areas. To achieve fair resilience, it is essential to avoid unequal burdens and to leave no one behind.

  With this in mind, the Santander Adaptation Plan has identified vulnerable groups at the census section level and defined risk levels for each hazard from different perspectives, gender, age groups, and socio-economic inequality. The analysis of the various sensitivity indicators has made it possible to establish measures focused on generating a more adapted and safer society.

- **Maladaptation:** All adaptation work takes place in a constantly changing context and is associated with a high level of uncertainty. Adaptation is, therefore, a continuous process whose outcomes are difficult to predict. In some cases, adaptation efforts can result in unintended and undesirable negative consequences, referred to as 'maladaptations'. The adaptation measures outlined in this plan have been reviewed and evaluated from a 'maladaptation' perspective, identifying further problems in their implementation. Understanding the causes of vulnerability and the impacts derived from exposure, despite the degree of uncertainty, allows for a high degree of effectiveness of the measures. As a methodological advance, the Santander Adaptation Plan projects risk to the hypothetical conditions of the city for the long-term horizon, so the degree of uncertainty is significantly reduced.
- **Nature-based solutions:** The European Green Deal in general, and EU adaptation and biodiversity policies in particular, call for greater efforts to implement nature-based solutions much faster and on a much larger scale than is currently the case.

  The Adaptation Plan addresses a range of measures focusing on the guidelines set out in the communication: conservation and restoration (including renaturation); sustainable management of green infrastructure; and creation of new ecosystems designed for specific adaptation needs (such as green roofs or hybrid solutions for coastal management).
- **Climatic endurance tests:** Climate resistance testing detects potential risks in a specific area arising from hazards related to climate events. The tests are carried out by collecting and creating information on the effects of climate change (the element to be made resilient) and on the vulnerability of systems and objects to such effects.

  The exhaustive analysis of the threats, exposure and social, economic and environmental sensitivity of Santander guarantees the contribution of basic information that has been contrasted in the different debates developed in the participatory workshops. The exchange of information between the various entities participating in the consultative process and the contributions of different citizen groups have allowed us to assess the climate resilience of the different actions proposed.

The **characteristics of the measures** designed for Santander, in addition to meeting the adaptation criteria mentioned above, are aligned with the different institutional frameworks reviewed in the introductory chapter, and meet the following requirements.

- Measures that can be implemented in the **short and medium terms**, executable in periods not exceeding 10 years. However, some of the measures can be developed in longer periods due to their technical or managerial complexity.

- Focused on **strengthening adaptive capacity**, improving local understanding and preparedness, implementing training capacities, as well as ensuring an effective response to climate change through concrete actions.
- Measures with proven **environmental, economic and social benefits** that outweigh the cost of implementation.
- Measures with **relatively low costs**, although given that their benefits can be significant, they can be implemented assuming a certain degree of uncertainty in effectiveness.
- **Flexible or reversible** measures that do not imply a drastic break with the existing situation and can be improved over time with technological advances or new capabilities.

Taking these aspects into account, measures are contemplated that respond to the different typologies, which can be grouped under the different headings:

- **Soft or adaptive capacity measures:** Strengthen adaptive capacity. They support the improvement of risk management (both with advances in the understanding of the phenomenon, as well as in risk management or training issues).
- **'Green' adaptation measures based on ecosystems and green infrastructure:** Specific actions based on ecosystems and green infrastructure that increase urban resilience.
- **Hard or gray infrastructure measures:** Engineering works that minimise the effects of risk.
- **Hybrid measures or solutions (green + gray):** Combination of engineering works with green measures based on ecosystems or green infrastructure.

Following these criteria, the methodology discussed below has been proposed for the selection and prioritisation of Santander's adaptation measures.

6.2 METHODOLOGY FOR SELECTION AND PRIORITISATION OF MEASURES

In line with the European Union Communication on Adaptation Plans (2023), the following methodology has been structured in two fundamental phases: First, with the definition of adaptation options and the creation of a portfolio of options; and then moving on to the participatory phase of co-assessment and prioritisation of adaptation options.

Adaptation Options

Based on the risk assessment, taking into consideration the hazards, their exposure and the sensitivity associated with them, the process of identifying specific measures to address all of the identified phenomena began. To this end, the drafting team made a long proposal of measures selected from an exhaustive bibliographic review of various Spanish local plans in similar situations and configuration, and a set of international examples of interest to Santander. In addition, the diagnosis of local exposure and vulnerability conditions allowed the identification of concrete measures that at the municipal and neighbourrhood level can reduce the level of risk. In this phase, a total of 558 measures were grouped by the lines of action related to the impacts, according to table 6.1:

TABLE 6.1. *Long list of measures*

LINES OF ACTION	N.° MEASURES	LINES OF ACTION	N.° MEASURES
Human Health	20	Education and Society	64
Natural Heritage and Biodiversity	52	Primary Sector	31
Water and Water Resources	57	Industry	11
City, Urbanism, Building	73	Finance and Insurance	16
Coasts and Marine Environment	19	Social Cohesion	5
Climate and Climate Scenarios	28	Mobility and Transport	66
Energy	55	Cultural Heritage	16
Tourism	6	Transversal; Other	39

Source: CINCc (UC) - FIC, 2024.

With this broad spectrum of adaptation options, an adjusted list of specific measures was defined and evaluated for the specific case of Santander. As with the first long list of options, this group of measures was structured along the following lines of action:

A prioritisation process under expert criteria reduced the number of adaptation measures to a total of 215. This prioritisation, through a quantitative assessment of each measure between 0 and 10 points, was carried out by the drafting team, experts in the scientific field and staff of the technical team of the City Council of Santander. Subsequently, the set of pre-selected measures was contrasted with citizens and risk experts during four participatory workshops where 88 measures were grouped into adaptation goals and objectives. Finally, the set of measures selected and prioritised for Santander was reduced to 85 actions distributed across four major goals and ordered according to the degree of priority given in the participatory process.

TABLE 6.2. *Adjusted list of specific measures*

LINES OF ACTION	N.° MEASURES	LINES OF ACTION	N.° MEASURES
Human Health	14	Education and Society	22
Natural Heritage and Biodiversity	25	Primary Sector	8
Water and Water Resources	26	Industry	5
City, Urbanism, Building	34	Finance and Insurance	6
Coasts and Marine Environment	11	Social Cohesion	2
Climate and Climate Scenarios	16	Mobility and Transport	17
Energy	18	Cultural Heritage	5
Tourism	5	Transversal; Other	1

Source: CINCc (UC) - FIC, 2024.

The four goals that group the set of measures together reflect the principles and strategies defined in the policy framework and cover the broad spectrum of adaptation solutions required: **Biodiversity; Resilient City; Adapted Health;** and **Adapted Society and Economy**. For each goal, a series of adaptation objectives have been established, with the design of a corresponding set of measures.

TABLE 6.3. *Validated List of Goals, Objectives and Measures*

GOALS	N.° OF OBJETCTIVES	N.° OF MEASURES
Biodiversity	3	11
Resilient City	7	31
Health	4	20
Adapted Society and Economy	6	23

Source: CINCc (UC) - FIC, 2024.

The information for the development of a subsequent Action Plan for each of these measures is included in an **individual sheet**. Each sheet includes information on the type of measure, the threats to which it responds, the territorial scope of the action, the mission of each of these measures, the level of priority of the action, including its quantitative assessment and, finally, the follow-up indicators that allow the degree of achievement of the goals to be evaluated.

6.3 GOALS, OBJECTIVES AND MEASURES

The measures designed respond to the adaptation objectives necessary for the fulfillment of the four major goals that lie ahead for Santander to become a resilient city.

BIODIVERSITY

The Biodiversity Goal focuses on fostering a resilient green infrastructure adapted to the future climate, while favouring biodiversity and enhancing ecosystem services. Factors that should encompass several fundamental aspects to ensure its effectiveness and long-term sustainability include the following:

1. **Conservation and Ecological Restoration:** The goal prioritises the conservation of existing natural habitats and the restoration of degraded areas. The goal is not only to protect areas of high biodiversity value but also to connect habitat fragments to form ecological corridors that allow for the movement and adaptation of species in the face of climate change.
2. **Design and Planning of an Integrated Green Infrastructure:** Green infrastructure will contribute to integration with the urban environment, promoting the multifunctionality of spaces. This includes the creation of urban parks, community gardens, and the implementation of green roofs and façades. Green infrastructure should be designed to maximise carbon sequestration, improve stormwater management, and promote ecological connectivity.
3. **Adaptation to Climate Change:** Green infrastructure must be resilient to the impacts of climate change. It is, therefore, necessary to consider future climate change scenarios in the planning and management of these areas, ensuring that they can withstand and recover from extreme events such as floods, heat waves, and droughts. The selection of plant species should be strategic, prioritising those that are native and resilient.
4. **Ecosystem Services Enhancement:** The goal recognises and enhances the ecosystem services that green infrastructure provides, such as climate regulation, biodiversity support, mental and physical health benefits for people.
5. **Community Involvement and Awareness:** Community participation in planning, stewardship, and maintenance of green infrastructure needs to be encouraged.
6. **Monitoring and Evaluation:** A monitoring and evaluation system should be established to measure the effectiveness of implemented actions.

By addressing these aspects, the Biodiversity Target can effectively guide the transition to a resilient and biodiverse city, creating systems that not only support local flora and fauna, but also benefit Santander society and contribute to climate change mitigation and adaptation.

OBJECTIVES

B1 Promote biodiversity and soil quality for greater urban resilience.

B2 Make urban green infrastructure an ally against climate change impacts.

B3 Ensure the participation of society in the management of green infrastructure in the face of climate change.

Objective B.1: **Promoting biodiversity and soil quality for greater urban resilience**

Promoting biodiversity and soil quality in urban areas is essential for building cities that are more resilient to the challenges of climate change and environmental degradation. An effective strategy to achieve this is the renaturation of paved surfaces, transforming them into green areas that increase soil permeability and promote biodiversity. This not only improves water management, preventing urban flooding through the natural absorption and filtration of rainwater, but also contributes to the creation of habitats for various species.

Excessive paving in cities limits the soil's ability to absorb and filter water, exacerbating runoff problems and increasing the risk of flooding. Renaturalising these areas by reintroducing high quality soils and vegetation improves soil infiltration capacity, recharges the subway aquifer, and improves water quality through natural filtration processes.

Urban green areas are vital for biodiversity, providing habitats for insects, birds and small mammals. The selection of native plants in these renaturation projects, with control of invasive species, is key to providing food and shelter for local wildlife, contributing to biodiversity conservation. These areas not only enrich the urban landscape, but also provide essential ecosystem services, such as climate regulation, carbon sequestration and air quality improvement.

Implementing renaturation measures requires careful planning and collaboration between different stakeholders, including the City Council, communities and environmental experts. It is also essential to integrate these green spaces into the urban fabric so that they are accessible to all citizens, thus providing additional social benefits such as recreational and wellness spaces.

Five adaptation measures are included in this objective:

B1.1 Greening paved surfaces

B1.2 Renaturalisation of private areas

B1.3 Control of invasive species

B1.4 Renaturalisation of river corridors

B1.5 Demonstrative actions and promotion of Nature-based solutions

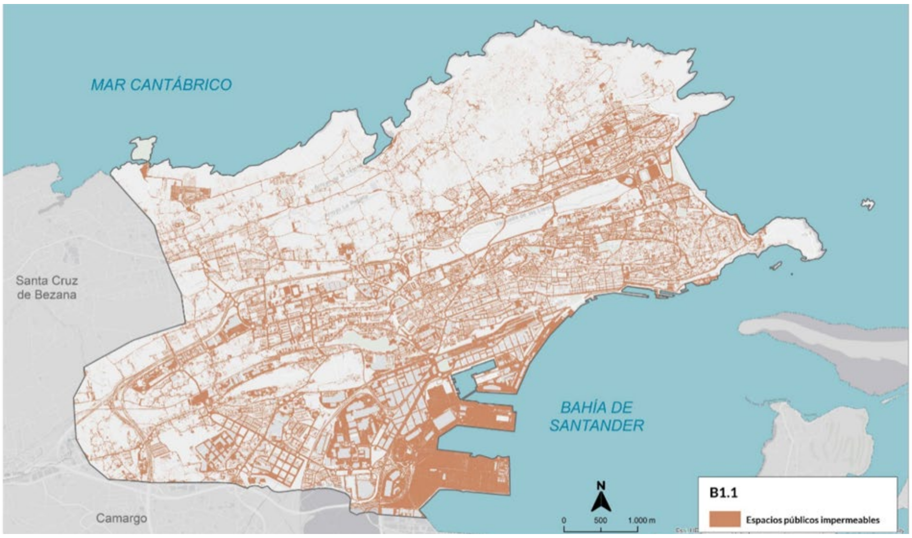
Greening paved surfaces

B1.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, pluvial flooding	Municipal

MISSION OF THIS MEASURE
Renaturalise large paved areas by increasing the permeability of soils with the provision of high quality soils for the promotion of biodiversity.

FIGURE B1.1. Impermeable public spaces



Source: CINCc (UC) - FIC, 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,38

FOR MORE INFORMATION
Reference: Un país para renaturalizarlo. (Equipo EYS Municipales, 2022) More information at: https://www.eysmunicipales.es/articulos/un-pais-para-renaturalizarlo

MONITORING INDICATORS
Percentage of permeable surface area / Municipal surface area Percentage of permeable surface of open spaces / Total surface of open spaces

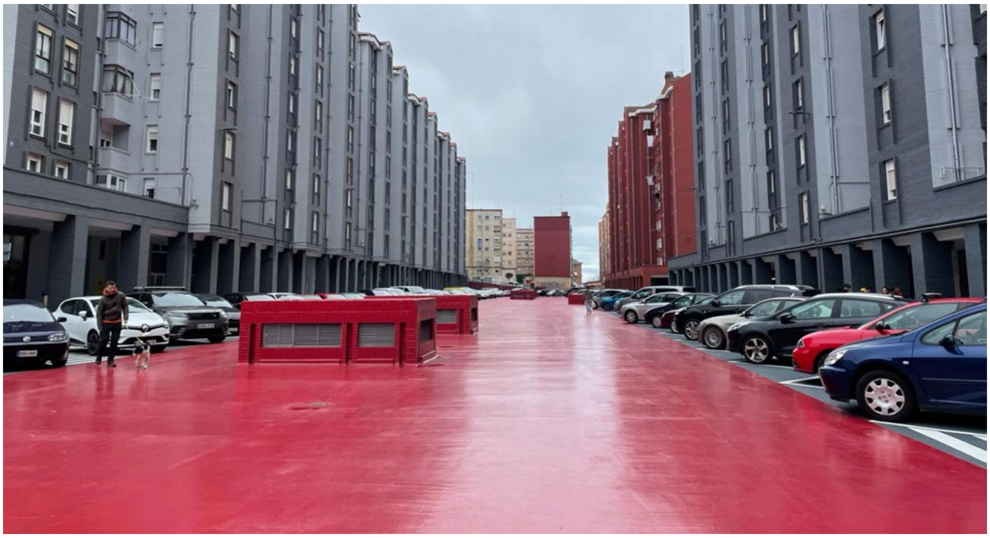
Renaturalisation of private areas

B1.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Nature-based solutions	Heat waves, pluvial flooding	Neighbourhood

MISSION OF THIS MEASURE
Greening the urban environment in the common spaces between blocks and block courtyards.

FIGURE B1.2. Sector with high artificialisation (C/ Blas Cabrera, Santander)



Source: CINCc (UC) - FIC, 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,31

FOR MORE INFORMATION
Reference: Plan municipal del Valle de Egüés. (Ayuntamiento del Valle de Egüés, 2024). More information at: https://www.valledeegues.com/recurso_turistico_cp/sarriguren/

MONITORING INDICATORS
Percentage of surface area of private green areas / Surface area of public open spaces Percentage of green areas in private spaces / Private non-built-up areas

Control of invasive species

B1.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Nature-based solutions	Heat waves, wind / Derived threats - disease vectors	Municipal

MISSION OF THIS MEASURE
Control and eradicate invasive species by generating a comprehensive system of data collection and species evolution.

FIGURE B1.3. Specimen of Plumero, invasive alien species in Santander

Source: CINCc (UC) - FIC, 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,38

FOR MORE INFORMATION
Reference: Proyecto para la eliminación del Plumero de Pampa en la Mancomunidad de Servicios de Uribe Kosta (SOPELA, 2023) More information at: https://sopela.eus/areas-municipales/sostenibilidad/proyecto-para-la-eliminacion-del-plumero-de-pampa-en-la-mancomunidad-de-servicios-de-uribe-kosta/

MONITORING INDICATORS
Percentage of surface area with degraded areas / Municipal surface area Number of invasive alien species per hectare

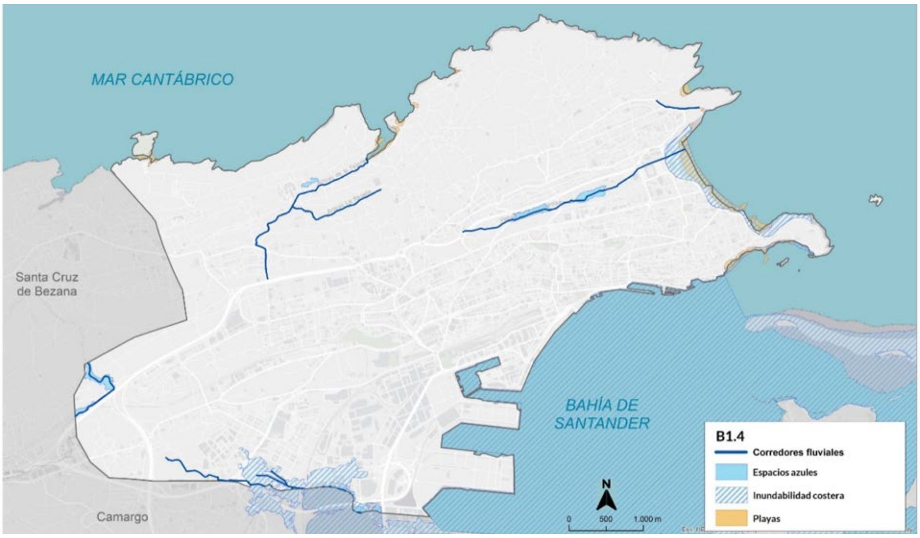
Renaturalisation of river corridors B1.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Nature-based solutions	Heat waves, drought, pluvial flooding	Punctual

MISSION OF THIS MEASURE

Renaturalise river corridors, such as the Arroyo Otero river corridor, removing any barriers to water and biological flow. Increase the renaturation of the municipality's minor streams (Tejona, Regata and Molinucos) and the Raos Canal.

FIGURE B1.4. River corridors, water bodies and areas affected by coastal flooding



Source: CINCc (UC) - FIC, 2024 based on data from PEMUSAN (2016)

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,23

FOR MORE INFORMATION

Reference: Estrategia para la restauración y renaturalización de los ecosistemas fluviales en el Término Municipal de Loja y la reducción del riesgo de inundación del entorno urbano del río Genil a su paso por Loja (Paseo del Genil).
More information at: https://fundacion-biodiversidad.es/.

MONITORING INDICATORS

River corridors and water bodies naturalised, created or restored (No., m^2)
Surface area of Blue Infrastructure / Municipal surface area

Demonstrative actions and promotion of NbS B1.5

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Education	Heat waves, drought, pluvial flooding, coastal flooding, wind	Neighbourhood

MISSION OF THIS MEASURE
Demonstrate actions to increase biodiversity and public green infrastructure for replication in private spaces.

FIGURE B1.5. Subida al Gurugú vertical garden

Source: CINCc (UC) - FIC, 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,85

FOR MORE INFORMATION
Reference: High Line, Nueva York, Estados Unidos. (Friends of the high line, 2024) More information at: https://www.thehighline.org/about/

MONITORING INDICATORS
No. of demonstration actions of NbS solutions No. of communication and awareness-raising projects No. of knowledge transfer activities

Objective B.2: **Making urban green infrastructure an ally in the face of climate change impacts**

Transforming urban green infrastructure into a key ally against climate change impacts is an appropriate strategy to increase urban resilience. This adaptation involves several innovative measures that harmonise urban spaces with the natural environment, fostering a sustainable and resilient coexistence.

Climate change-adapted revegetation is the first step towards this goal with the selection and planting of native and resilient species, capable of surviving and thriving under the new climatic conditions. This practice not only enhances urban biodiversity, providing habitats for a wide range of species, but also improves air quality and provides green spaces for community recreation.

Incorporating nature-based solutions (NBS) for coastal protection is another vital measure, especially in urban areas vulnerable to erosion and sea level rise. Techniques such as shoreline restoration, erosion protection, introduction of native species for wave protection not only protect coastlines from physical impacts, but also support biodiversity and boost the local economy through tourism and fisheries.

New methodologies for adaptive landscaping include designing green spaces that require less maintenance and resources, opting for drought-tolerant plants and efficient irrigation systems that minimise water use. This approach reduces the demand for potable water for irrigation and promotes the sustainable use of water resources.

Water harvesting strategies for urban landscaping, such as rainwater capture and reuse, are essential. These systems not only reduce pressure on municipal water supplies, but also contribute to sustainable stormwater management, reducing runoff and flood risk.

Each of these measures contributes to creating an urban green infrastructure that not only addresses the challenges of climate change, but also promotes a healthier, more biodiverse and pleasant environment for urban living. Objective B.2 consist of the following four adaptation measures:

B2.1 Climate change-adapted revegetation

B2.2 Incorporation of NbS for coastal protection

B2.3 New methodologies for an adapted gardening

B2.4 Water harvesting strategies for urban landscaping

Climate change-adapted revegetation B2.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Nature-based solutions	Heat waves, drought, wind	Municipal

MISSION OF THIS MEASURE
Plant species adapted to climate change from the catalogue validated by the Plan and monitoring of their evolution.

FIGURE B2.1. Climate-adapted planting strategies, Calle Tetuán, Santander

Source: CINCc (UC) - FIC, 2024

PRIORITY LEVEL	**HIGH**	**MEDIUM**	**LOW**	**Value: 9,23**

FOR MORE INFORMATION
Reference: Adapta Biofilia (Diputación de Badajoz, 2024) More information at: https://transicionecologica.dip-badajoz.es/proyecto/adapta-biofilia

MONITORING INDICATORS
Percentage of species adapted to the future climate / Total municipal catalogue of species

Incorporation of NbS for coastal protection

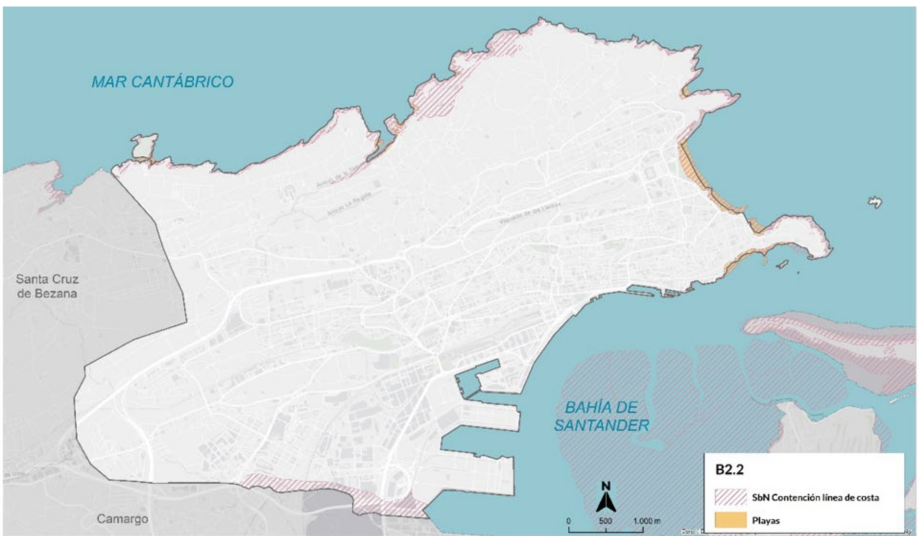
B2.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Nature-based solutions	Coastal flooding	Punctual

MISSION OF THIS MEASURE

Incorporate nature-based solutions for the containment of the coastline, especially beaches, reinforcing dune systems and marine ecosystems, and avoiding intervention through protective infrastructures with impacts on the landscape and coastal heritage.

FIGURE B2.2. Zoning for the implementation of NBS for coastal protection



Source: CINCc (UC) - FIC, 2024 based on data from PEMUSAN 2016

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 9,15

FOR MORE INFORMATION

Reference: Nature-based solutions frente al cambio climático: restauración de dunas y marismas (Uhina, B. 2020)

More information at: https://www.ehu.eus/cdsea/web/wp-content/uploads/2017/03/Articulos_Uhina_bea2020.pdf

MONITORING INDICATORS

Length (m) (km) of urban green infrastructure for coastal protection

New methodologies for an adapted gardening B2.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, drought, wind	Municipal

MISSION OF THIS MEASURE
Adapt current gardening practices to future climatic conditions (maintenance, planting of species.).

FIGURE B2.3. Supervision of new plantations in the framework of the Santander Capital Natural project

Source: SEO/BirdLife, 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,38

FOR MORE INFORMATION
Reference: Nuevos pasos para adaptar la jardinería municipal al cambio climático (Eldiarioex, 2023) More information at: https://www.eldiario.es/extremadura/sociedad/nuevos-adaptar-jardineria-municipalclimatico_1_1720721.html

MONITORING INDICATORS
Annual volume of water reused in municipal irrigation Percentage of adapted species / Total number of species in municipal catalogue

Water harvesting strategies for urban landscaping

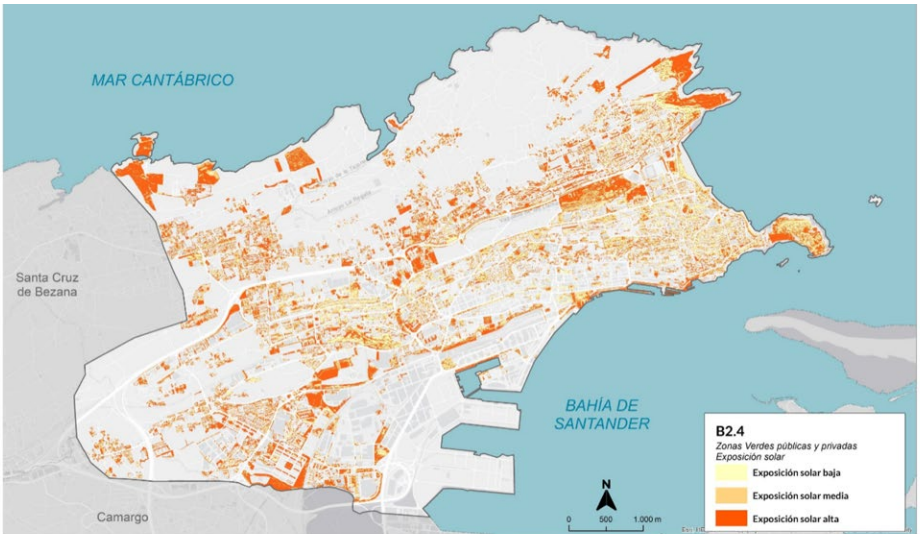
B2.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Nature-based solutions	Pluvial flooding, drought, heat waves	Punctual

MISSION OF THIS MEASURE

New plantings in climate-protected areas, shaded, shaded beds or predominantly inorganic mulches to maximise rainwater harvesting and avoid loss through evapotranspiration.

FIGURE B2.4. Solar exposure of public and private green spaces



Source: CINCc (UC) - FIC, 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,38

FOR MORE INFORMATION

Reference: Las 10 ciudades más sostenibles: Lideres en prácticas de Management del agua. (Tappwater, 2023).
More information at: https://tappwater.co/es/blogs/blog/10-ciudades-mas-sostenibles-gestion-del-agua

MONITORING INDICATORS

Annual volume (m^3) of rainwater collected and stored
Annual volume (m^3) of water reused for municipal irrigation / Annual volume (m^3) municipal irrigation water

Objective B.3: Ensuring society's participation in the management of green infrastructure in the face of climate change

Ensuring the participation of society in the management of green infrastructure effectively addresses the challenges of climate change, especially with regard to the conservation of coastal areas and marine biodiversity, as well as the stewardship of natural areas. This collective participation not only fosters greater environmental awareness and responsibility among citizens, but also ensures that conservation strategies are more inclusive, sustainable and tailored to local needs and values.

The conservation of coastal spaces and the protection of marine biodiversity require a collaborative approach, where local communities, non-governmental organisations, businesses and governments work together to develop and implement management plans that promote the resilience of these ecosystems. The active participation of society can take many forms, from involvement in beach clean-ups and natural shoreline restoration, e.g., coastal oak groves, to involvement in citizen science projects that monitor the health of marine ecosystems. These actions not only contribute to environmental conservation, but also strengthen community ties and promote a sense of ownership and responsibility towards natural resources.

On the other hand, wilderness stewardship involves the management and protection of these areas by the local community, in collaboration with landowners and environmental authorities. This conservation model allows citizens to participate directly in the protection of their environment, adopting sustainable land use practices, habitat restoration and prevention of invasive species. Land stewardship encourages a more decentralised management adapted to the specific characteristics of each natural area, ensuring that conservation measures are effective and supported by the community.

Encouraging citizen participation in the management of green infrastructure and nature conservation is essential to create a more resilient and environmentally engaged society. Through environmental education, volunteerism and community collaboration, effective strategies can be developed to respond to the challenges of climate change, protecting and restoring our valuable ecosystems for future generations.

Two main adaptation measures are defined in Objective B.3:

B3.1 Conservation of coastal areas and marine biodiversity

B3.2 Stewardship of natural areas

Conservation of coastal areas and marine biodiversity

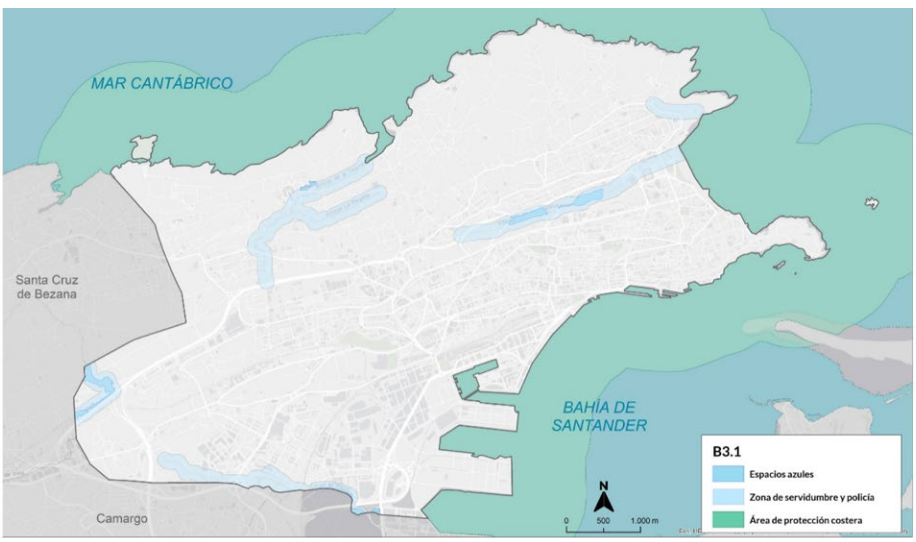
B3.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Nature-based solutions	Coastal flooding, pluvial flooding, heat waves	Punctual

MISSION OF THIS MEASURE

Create a programme for the conservation, environmental quality and sustainable use of blue spaces, as well as programmes to increase and monitor marine biodiversity in the immediate coastal strip in coordination with competent coastal administrations.

FIGURE B3.1. Areas susceptible to conservation of coastal areas



Source: CINCc (UC) - FIC, 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,92

FOR MORE INFORMATION

Reference: Programa LIFE Intemares. (Life Intemares, 2024)
More information at: https://intemares.es/en/

MONITORING INDICATORS

Area (m^2) of coastal space threatened by loss of biodiversity
Area (m^2) with coastal and marine restoration projects
Identification of discharges and effluents (no.) on the coastline

Stewardship of natural areas

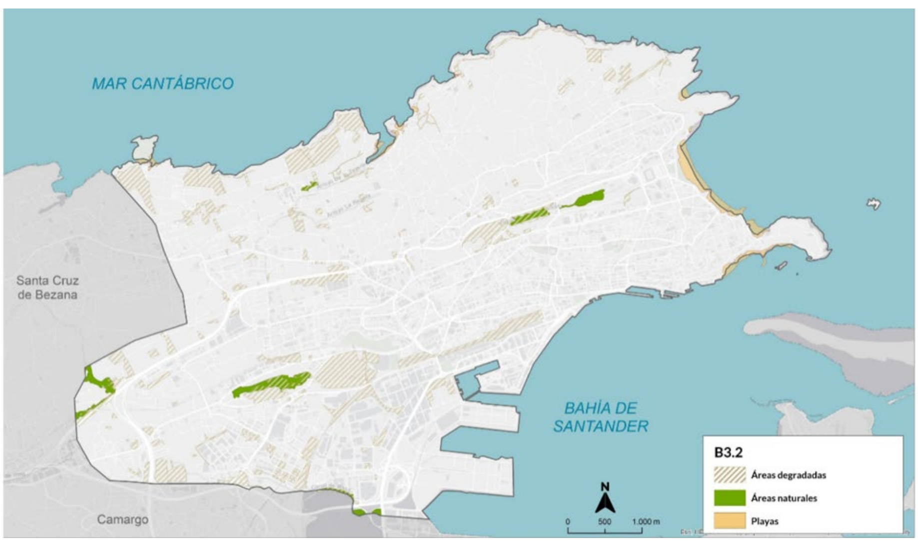
B3.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Coastal flooding, pluvial flooding, heat waves, drought	Municipal

MISSION OF THIS MEASURE

Define a strategy for the stewardship of natural areas with continuous monitoring of their state and evolutionary process.

FIGURE B3.2. Areas likely to be integrated into land stewardship strategies



Source: CINCc (UC) - FIC, 2024 based on data from Santander City Council

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,00

FOR MORE INFORMATION

Reference: Programa de Fomento de la Custodia del Territorio para la Conservación y el Desarrollo Sostenible de los Espacios Naturales Protegidos de Andalucía (Portal ambiental de Andalucía, 2021)
More information at: https://www.juntadeandalucia.es/medioambiente/portal/areas-tematicas/espacios-protegidos/dinamizacion-socioeconomica-espacios-protegidos/programa-fomento-custodia-territorio

MONITORING INDICATORS

Surface area of degraded areas / Surface area of natural areas
No. of natural areas with management and conservation plan (land stewardship)

RESILIENT CITY GOAL

Making cities resilient to climate change involves a multidimensional approach that adapts both the urban fabric and critical infrastructure to future challenges. This goal is achieved through the development and implementation of innovative urban planning tools capable of anticipating climate impacts and designing effective adaptation strategies.

To reduce the impact of extreme temperatures, the development of green infrastructure, such as parks and green roofs, which can provide shaded areas and help reduce the urban heat island effect, should be encouraged. These areas not only improve the quality of life and well-being of citizens, but also become tools for the thermal regulation of cities.

Extreme rainfall events require special attention with improved drainage systems and stormwater management techniques, such as rain gardens and permeable pavements, which allow for the efficient absorption and management of excess water, thus reducing the risk of urban flooding.

In the face of rising sea levels, it is necessary to strengthen coastal management and develop protection zones that can absorb coastal phenomena, protecting critical infrastructure and residential areas close to the coast. This should be complemented by reassessment and, if necessary, relocation of the most vulnerable infrastructures. Early warning protocols and rapid response systems are crucial to minimise damage and ensure public safety in the face of extreme weather events. Warning systems must be accessible and comprehensive, ensuring effective communication and rapid mobilisation of resources and emergency services.

Therefore, it is necessary to implement efficient rainwater harvesting and reuse systems, improve the efficiency of irrigation in urban green spaces, and develop policies that promote responsible water use among citizens. Together, these measures and strategies contribute to building more resilient cities, capable of facing and adapting to the challenges imposed by climate change, ensuring the sustainability, safety and quality of life of their inhabitants.

OBJECTIVES

R1 Developing tools to enable planning for a climate-resilient city

R2 Reducing the impact of extreme temperatures on the urban fabric

R3 Reducing the impact of extreme precipitation on the urban fabric

R4 Reducing the impact of sea level rise on the coastline

R5 Be prepared with protocols for early warning and response to extreme events

R6 Optimising and controlling water resources in a climate change scenario

Objective R.1: **Developing tools to enable planning for climate-resilient city**

Developing adaptation strategies with a multidisciplinary approach involves collaboration between experts in environment, urban planning, agriculture, public health and other relevant areas. This integrated approach ensures that solutions are holistic and address multiple aspects of the climate challenge.

Climate-smart urban planning is a tool for incorporating climate considerations into the design and management of urban spaces. A planning policy that integrates green infrastructure, sustainable public spaces and biodiversity conservation areas into the urban fabric is needed. In addition, urban development practices that minimise environmental impact and promote energy efficiency and rational land use should be adopted.

The Blue Infrastructure Plan focuses on sustainable water management, using natural systems such as wetlands, restored urban rivers and infiltration areas to improve the quality and availability of water resources in urban environments. Within this aspect, coastal spaces should be considered, which in the case of Santander have various strategic functions.

Adaptation Monitoring and Evaluation Protocols are essential to ensure that the measures implemented are effective over time. The protocols allow for monitoring progress, identifying areas for improvement and adjusting strategies as necessary to maintain urban resilience, including control of the energy system, housing conditions or the use and transformation of rural land.

R1.1 Development of adaptation strategies with a multidisciplinary approach

R1.2 Drafting of a climate-adapted urban planning

R1.3 Blue Infrastructure Plan

R1.4 Protocols for Monitoring and Evaluation

R1.5 Adapted electrical system

R1.6 Protected agricultural land

R1.7 Control of unhealthy areas in buildings

Development of adaptation strategies with a multidisciplinary approach

R1.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, coastal flooding, drought, wind	Municipal

MISSION OF THIS MEASURE

Avoid maladaptation by planning effective measures with a multidisciplinary approach, including landscape, socio-economic, environmental, etc., criteria.

FIGURE R1.1. Multidisciplinary teams

Source: Getty Images (CC).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 9,64

FOR MORE INFORMATION

Reference: Mejora de la adaptación intersectorial al cambio climático en el sudeste de Queensland, Australia.
More information at: https://link.springer.com/article/10.1007/s10113-013-0442-6#citeas

MONITORING INDICATORS

No. of sectors benefiting from the adaptation action
GHG reduction value of the adaptation action (mitigation benefits)

Drafting of a climate-adapted urban plan R1.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, coastal flooding, drought, wind	Municipal

MISSION OF THIS MEASURE
Integrate adaptation criteria into urban planning: 1. Future climate scenarios; 2. Delimitation of Urban Adaptation Areas (AAU) and 3. General Systems of Open Spaces as a reserve for adaptation.

FIGURE R1.2. Resilient urban planning

Source: Getty Images (CC).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 9,38

FOR MORE INFORMATION
Reference: Diseño de un escenario estratégico para la región central de Arizona-Phoenix More information at: https://www.sciencedirect.com/science/article/pii/S0169204619309478.

MONITORING INDICATORS
Existence of future climate analysis in urban planning No. of Urban Adaptation Areas identified Surface area (m^2) of the General System of Open Spaces destined to climatic refuges

Blue infrastructure plan

R1.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Pluvial flooding, coastal flooding	Municipal

MISSION OF THIS MEASURE

Create a Blue Infrastructure Master Plan for Santander, with a strategy adapted to climate change.

FIGURE R1.3. Surroundings of El Bocal in Costa Quebrada, Santander

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,23

FOR MORE INFORMATION

Reference: Integración de la infraestructura azul-verde en la Planning urbana en las ciudades de Chennai y Kochi, India.

More information at: https://www.sciencedirect.com/science/article/pii/S0264837722004823

MONITORING INDICATORS

Identification of blue spaces
Area of naturalised water bodies created or restored
No. of blue spaces with ecological functions

Protocols for monitoring and evaluation

R1.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, coastal flooding, drought, wind	Municipal

MISSION OF THIS MEASURE
Create a protocol for monitoring adaptation criteria in public and private works projects, justifying the progress achieved.

FIGURE R1.4. Urban Adaptation Support Tool

Source: Covenant of Mayors

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 9,64

FOR MORE INFORMATION
Reference: Propuesta de metodología para planes de adaptación climática a nivel local (Plataforma de riesgo y adaptación climática territorial (PRACT), 2022) More information at: https://www.adaptacionclimatica.cl/assets/pdf/Metodologia-de-adaptacion.pdf

MONITORING INDICATORS
No. of monitoring protocols by areas or sectors of activity No. of adaptation measures carried out or promoted by actions

Adapted electrical system

R1.5

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves	Municipal

MISSION OF THIS MEASURE
Adapt the load capacity of the municipal electricity system to peak demand due to extreme temperatures.

FIGURE R1.5. Electricity grid

Source: Getty Images (CC).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,00

FOR MORE INFORMATION

Reference: Adaptación del sector eléctrico de California al cambio climático. (Klotz, M., y Schäuble, B. 2011)

More information at: https://link.springer.com/article/10.1007/s10584-011-0242-2

MONITORING INDICATORS

No. of safety and resilience assessments of the municipal electricity system

Time to restore service in the event of grid outage or collapse

Percentage of diversification of supply sources / Degree of external dependence

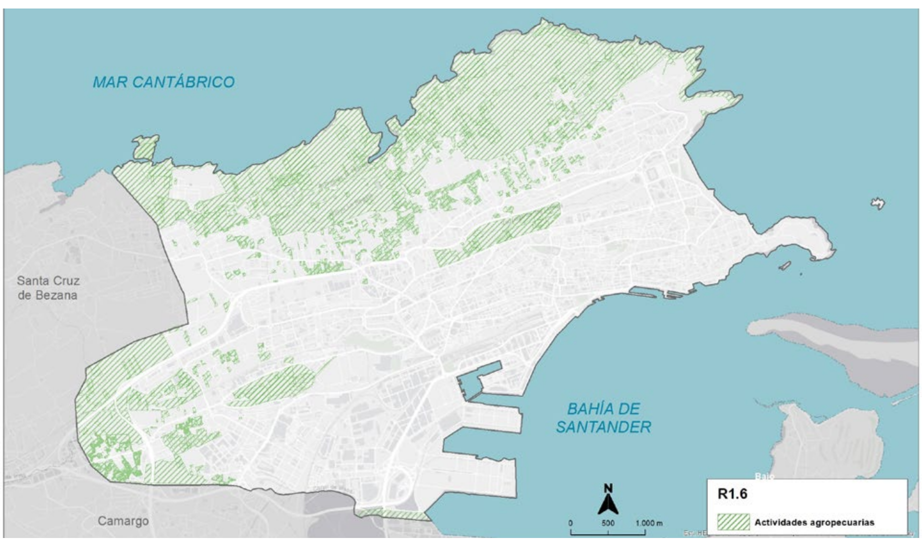
Protected agricultural land

R1.6

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, derivated vectors	Punctual

MISSION OF THIS MEASURE
Protect municipal agricultural land to promote greater food sovereignty.

FIGURE R1.6. Areas used for agricultural activities



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,62

FOR MORE INFORMATION
Reference: Agenda de la alimentación urbana (Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO), 2024) More information at: https://www.fao.org/urban-agriculture/es/

MONITORING INDICATORS
Total annual agricultural area / Municipal area Diversity and typology of organic crops / Total agricultural area Soil organic matter level (Annual values)

Control of unhealthy areas in buildings

R1.7

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Health – derivated vectors	Punctual

MISSION OF THIS MEASURE
Identify unhealthy spaces in old buildings that may have damp, and dingy underfloors.

FIGURE R1.7. Presence of dampness in buildings

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,15

FOR MORE INFORMATION
Reference: Control de espacios y viviendas en situaciones de insalubridad A(yuntamiento de Terrassa, 2024) More information at: https://www.terrassa.cat/es/control-d-espais-i-habitatges-en-situacio-d-insalubritat

MONITORING INDICATORS
No. of dwellings in unhealthy conditions / Total no. of dwellings in the municipality

Objective R.2: Reducing the impact of extreme temperatures on the urban fabric

To reduce the impact of extreme temperatures on the urban fabric, it is essential to implement measures that promote heat mitigation and improve the thermal comfort of urban spaces. Planting trees in temperature-critical areas is an effective strategy, as trees provide shade and reduce air temperature, helping to create cooler and more pleasant microclimates.

Increasing green roofs and green façades is another key measure. Green roofs and green façades act as natural insulators, reducing heat absorption in buildings and helping to maintain cooler temperatures inside. These infrastructures improve air quality, absorb carbon dioxide and provide habitats for urban biodiversity.

The creation of climate-protected public spaces provides areas for rest and recreation during periods of extreme heat. Public spaces should be designed with shading elements, such as pergolas, canopies or plant structures, as well as with heat-reflecting materials, such as permeable paving and high-albedo surfaces.

Increasing high albedo surfaces, i.e., those that reflect solar radiation, helps to reduce heat absorption in the city and mitigate the urban heat island effect. The use of reflective materials in streets, squares and car parks, as well as the use of cool roofs, helps to achieve these objectives.

Revegetation of roads and footpaths provides multiple benefits, including reducing soil temperature, retaining moisture and improving the urban landscape. Also, the creation of climate-compatible pedestrian routes, connecting green and shaded areas, facilitates sustainable mobility and promotes outdoor physical activity.

Together, these measures not only help to reduce the impact of extreme temperatures on the urban fabric, but also contribute to creating cities that are more sustainable, healthier and more resilient to climate change. Six measures have been selected for Objective R.2:

- **R2.1** Tree planting in temperature-critical areas
- **R2.2** Increase in green roofs and green façades
- **R2.3** Climate-protected public spaces
- **R2.4** Increase of high albedo surfaces
- **R2.5** Revegetation of roads and paths
- **R2.6** Creation of climate-friendly pedestrian routes

Tree planting in temperature critical areas

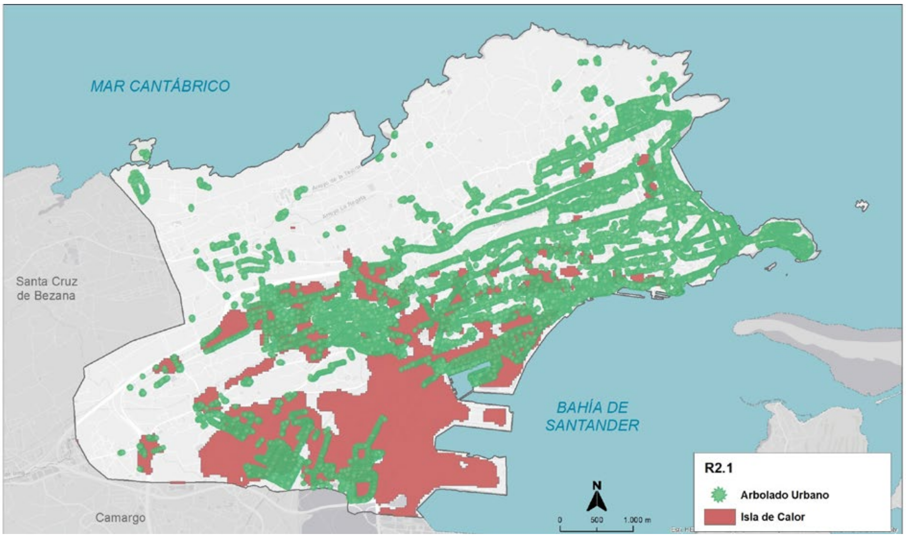
R2.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Nature-based solutions	Heat waves, pluvial flooding	Municipal

MISSION OF THIS MEASURE

Increase the number of trees to obtain increased evapotranspiration and urban coolness in areas identified as potential heat islands.

FIGURE R2.1. Tree planting areas in high surface temperature zones



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,77

FOR MORE INFORMATION

Reference: El papel del paisaje arbóreo para reducir los efectos de las islas de calor urbanas en las ciudades brasileñas de Curitiba y Sao Paulo

More information at: https://link.springer.com/article/10.1007/s00468-021-02230-8

MONITORING INDICATORS

Surface area of new naturalised areas / Areas with potential for high temperatures

No. of trees and shrubs planted in identified high temperature areas

Increase in green roofs and green façades R2.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, pluvial flooding	Punctual

MISSION OF THIS MEASURE
Increase the area of green/cool roofs and green façades with a programme that identifies the most viable buildings and sets short-term targets.

FIGURE R2.2. Green roof located at the building of Physics Institute of Cantabria

Source: University of Cantabria

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,31

FOR MORE INFORMATION
Reference: El edificio residencial 'Agora Garden' (Taiwán) como jardín vertical More information at: https://www.construible.es/2019/03/01/edificio-residencial-agora-garden-eleva-taiwan-jardin-vertical-forma-helicoidal

MONITORING INDICATORS
Area of green - cool roofs / Total area of roofs in heat island zones Area of green façades

Climate-protected public spaces

R2.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, pluvial flooding	Neighbourhood

MISSION OF THIS MEASURE

Incorporate in the design of public spaces areas of protection from rain and sunlight to improve their thermal comfort.

FIGURE R2.3. Science Square

Source: CINCc (UC), 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,08

FOR MORE INFORMATION

Reference: Proyecto de mejora del confort térmico en el casco antiguode Trebujena (Ayuntamiento de Trebujena, 2022)

More information at: Confort Térmico Trebujena. https://contrataciondelestado.es/wps/wcm/connect/b6194d6a-d3fc-497f-a1db-31c1cc959525/DOC20221109082350PROYECTO+DE+OBRAS+QUE+INCLUYE+PPTP+Y+ANEXO+SUBSANACION.pdf?MOD=AJPERES%20

MONITORING INDICATORS

No. of public spaces with weather protection features

No. of infrastructures and equipment for protection from rain and sunshine

Increase of high albedo surfaces

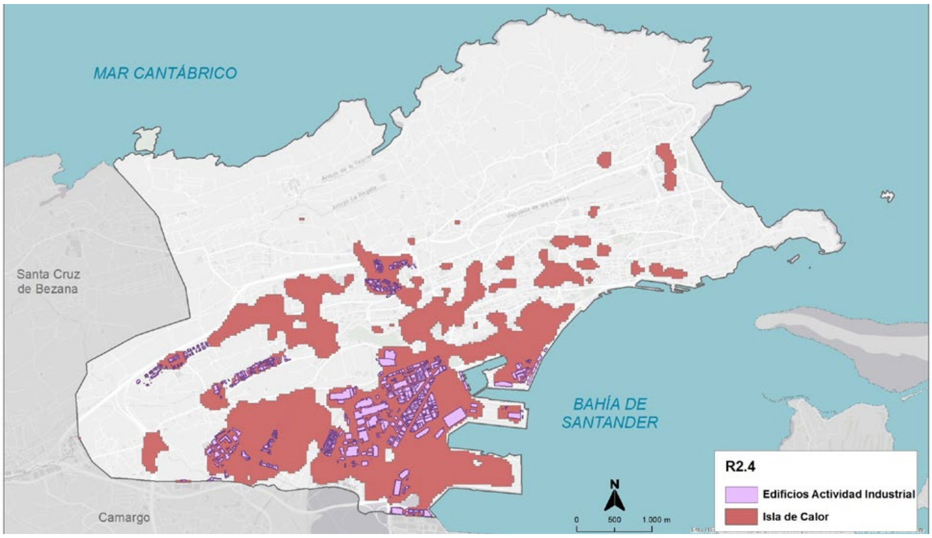
R2.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves	Neighbourhood

MISSION OF THIS MEASURE

Increase high albedo surfaces on pavements and roofs in industrial areas, especially in sectors affected by urban heat islands.

FIGURE R2.4. Industrial areas in high surface temperature sectors



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,00

FOR MORE INFORMATION

Reference: Rendimiento térmico del pavimento y contribución al clima urbano y global (Federal Highway Administration, US Department of Transportation)
More information at: https://www.fhwa.dot.gov/pavement/enstewardship.cfm

MONITORING INDICATORS

Paved area with high albedo / Total paved area
Percentage of high albedo industrial roof surface in heat island areas

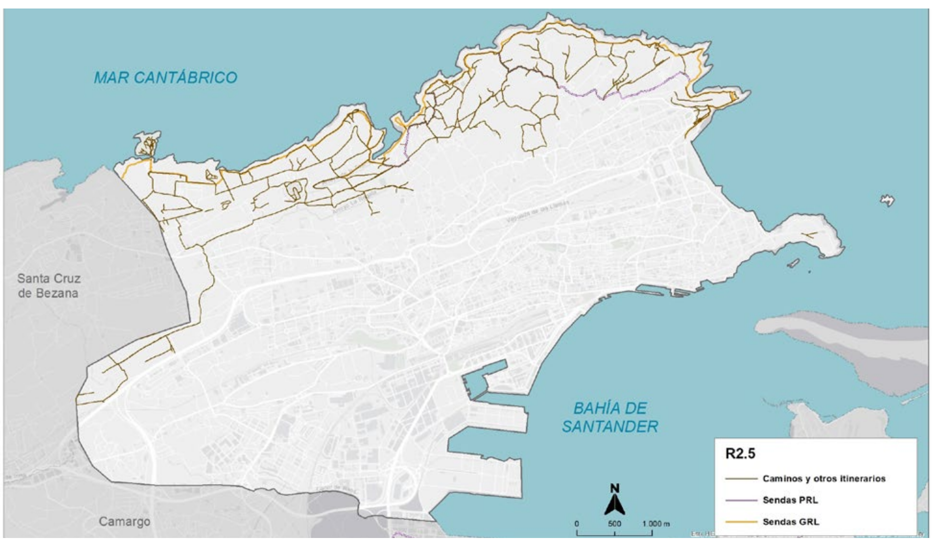
Revegetation of roads and paths R2.5

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, wind	Municipal

MISSION OF THIS MEASURE

Develop revegetation interventions using bushes and native trees on rural roads and paths to create shaded areas and wind protection.

FIGURE R2.5. Rural roads and footpaths with potential for tree planting



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,70

FOR MORE INFORMATION

Reference: Corredor verde Oliver-Valdefierro, Zaragoza
Más información: https://www.zaragoza.es/ciudad/urbanismo/arquitect/valdefierrooliver.htm

MONITORING INDICATORS

Length (m) of revegetated paths or trails
Percentage of the network of paths and trails with tree cover

Creation of climate-friendly pedestrian routes R2.6

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves	Punctual

MISSION OF THIS MEASURE
Link vertical pedestrian routes (ramps and stairs) to shaded rest areas.

FIGURE R2.6. La Teja Park

Source: CINCc (UC), 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,69

FOR MORE INFORMATION

Reference: Buenas Prácticas en Accesibilidad Universal (Junta de Comunidades de Castilla La Mancha, 2012)
More information at: https://www.castillalamancha.es/sites/default/files/documentos/20120511/librobuenaspracticasaccesibilidaduniversal.pdf

MONITORING INDICATORS

Surface area of open spaces with protected areas / Total surface area of open spaces
No. of trees per total length of roads and footpaths in public areas

Objective R.3: Reducing the impact of extreme precipitation events on the urban fabric

Measures that effectively manage excess water and reduce the risk of flooding can be taken to control extreme rainfall in the urban fabric. The implementation of Sustainable Urban Drainage Systems (SUDS) allows the use of natural techniques to manage rainwater, such as permeable green areas, retention ponds and green roofs, allowing water infiltration into the ground and reducing surface runoff.

The implementation of a separate sanitation network is another strategic measure. This network separates stormwater from wastewater, channelling it into sustainable drainage systems rather than mixing it with treated wastewater. Reducing the load on the drainage network and wastewater treatment plants minimises the risk of overflows during heavy rainfall events.

The creation of permeable public and private spaces is a common measure to increase the absorption capacity of the soil and reduce runoff. This is achieved through the use of permeable paving, rain gardens, landscaped areas and permeable green areas that allow rainwater to gradually infiltrate into the ground. The rain garden network consists in the creation of landscaped areas designed to capture and retain rainwater, allowing it to infiltrate into the ground, thereby reducing the risk of flooding. In this sense, capture in water ponds and reservoirs is also an efficient measure. Rain gardens can be located in public spaces as well as on private properties, such as residential gardens and commercial areas, but also along high-capacity roads and high slopes that generate a large volume of water in surface runoff. Adapting street furniture or developing strategies in urban planning are also necessary measures among those selected for Objective R.3.

The selected measures are as follows:

R3.1 SUDS implementation

R3.2 Implementation of a separate sanitation network

R3.3 Permeable public and private spaces

R3.4 Rain garden network

R3.5 Climate-adapted public transport stops

R3.6 Strategies for urban development

R3.7 Implementation of water recharge reserves

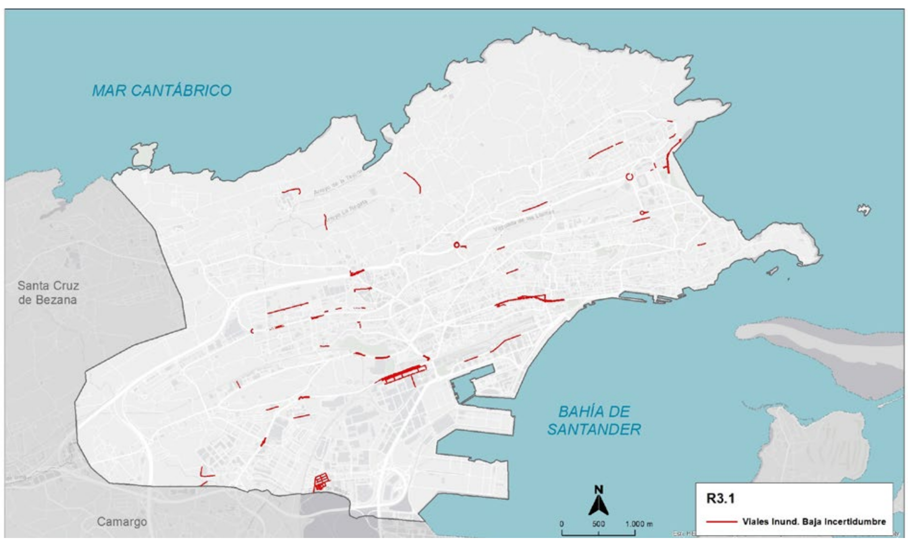
SUDS implementation R3.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, pluvial flooding, drought	Punctual

MISSION OF THIS MEASURE

Implement a network of Sustainable Urban Drainage Systems (SUDS) that contribute to soil permeability, surface runoff management, and improved bathing water quality.

FIGURE R3.1. Low-uncertainty flooded roads



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,69

FOR MORE INFORMATION

Reference: The Circle, solución sostenible frente a inundaciones en Normal (Illinois) (Hoerr Schaudt, 2010)
More information at: https://www.hoerrschaudt.com/project/uptown-normal/?parent=90

MONITORING INDICATORS

No. of Sustainable Urban Drainage Systems implemented
Permeable area promoted by SUDS / Municipal permeable area

Implementation of a separate sanitation network R3.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Pluvial flooding	Municipal

MISSION OF THIS MEASURE

Develop a separate sewerage network and storm tanks for extreme rainfall control.

FIGURE R3.2. Construction of the Sardinero storm water tank

Source: Ayuntamiento de Santander

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,54

FOR MORE INFORMATION

Reference: El camino del agua en el paisaje urbano, Neighbourhood de Bon Pastor, Barcelona
More information at:
https://aus.arquitectes.cat/wp-content/uploads/2014/05/2017_Soto_Perales_SuDSBonPastor_Bcn.pdf

MONITORING INDICATORS

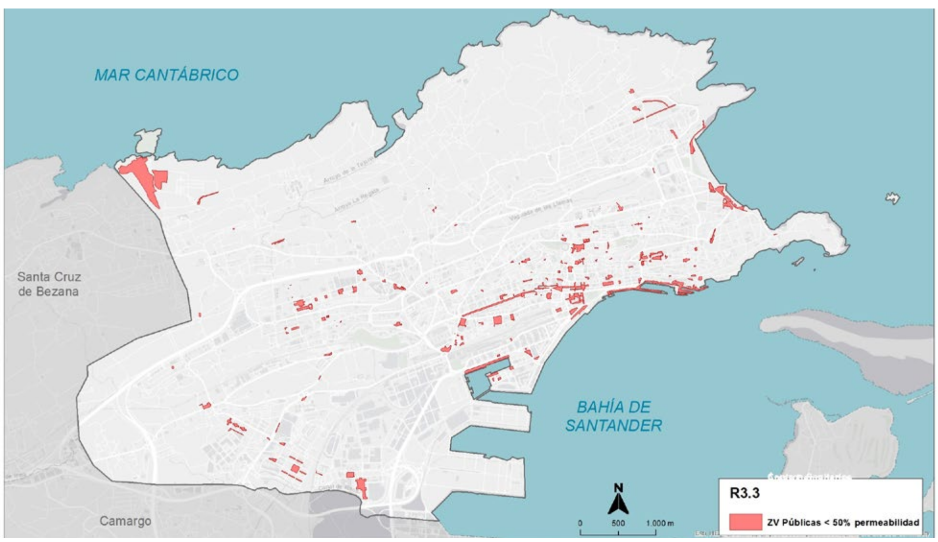
Percentage of the sewerage network of a separate nature with respect to the total
Volume (hm^3) collected by storm tanks

Permeable public and private spaces R3.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, drought	Municipal

MISSION OF THIS MEASURE
Ensure that at least 50% of the surface area of identified public and private open spaces is permeable.

FIGURE R3.3. Public green areas with less than 50% permeable area



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,54

FOR MORE INFORMATION
Reference: Proyecto de ordenación urbana en el Neighbourhood de Vallcarca en Barcelona More information at: https://ciclica.eu/es/projects/proyecto-de-ordenacion-urbana-en-el-barrio-de-vallcarca-en-barcelona/

MONITORING INDICATORS
Percentage of permeable open spaces / Total area of open spaces

Rain garden network

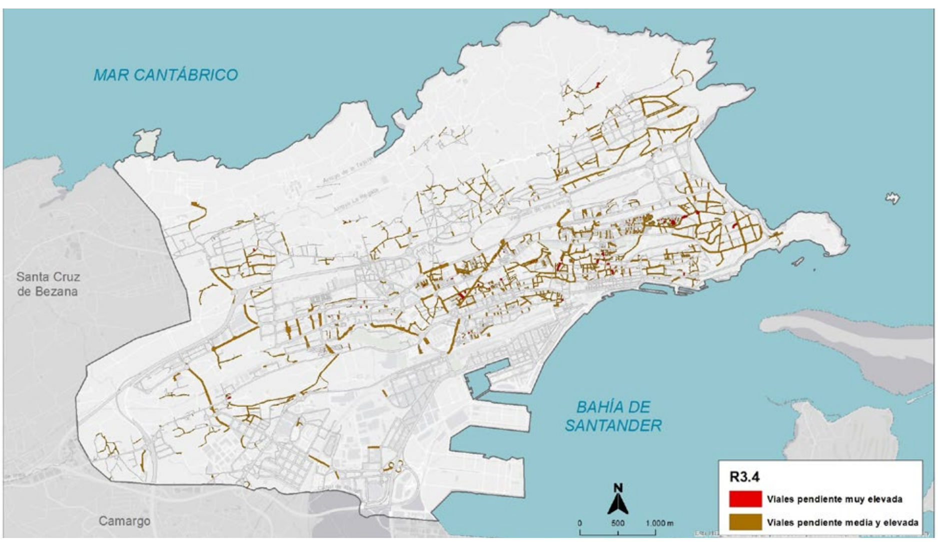
R3.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Nature-based solutions	Pluvial flooding	Punctual

MISSION OF THIS MEASURE

Create a network of Rain Gardens for surface runoff, especially along high-capacity roads and highly impermeable urban sections.

FIGURE R3.4. Roads with high and medium slopes for rain gardens



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,77

FOR MORE INFORMATION

Reference: Jardines de lluvia en Salamanca en el marco del proyecto LIFE Vía de la Plata
More information at: https://www.lifeviadelaplata.com/jardines-de-lluvia/

MONITORING INDICATORS

Installed area of rain gardens
Rain garden catchment area

Climate-adapted public transport stops

R3.5

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, pluvial flooding, wind	Punctual

MISSION OF THIS MEASURE
Adapt the design of bus shelters to wind and precipitation exposure to provide shelter during the winter.

FIGURE R3.5. Bus stop at Plaza de San Martín

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,54

FOR MORE INFORMATION
Reference: Refugios populares adaptados al clima: Evaluación sobre el terreno (University of Technology Sydney (UTS), 2018) More information at: https://www.uts.edu.au/isf/explore-research/projects/climate-adapted-people-shelters#:~:text=The%20Climate%20Adapted%20People%20Shelters%20%28CAPS%29%20project%20has,heat%20and%20extreme%20weather%20events%20in%20Western%20Sydney

MONITORING INDICATORS
No. of bus stops protected from wind and precipitation

Strategies for urban development

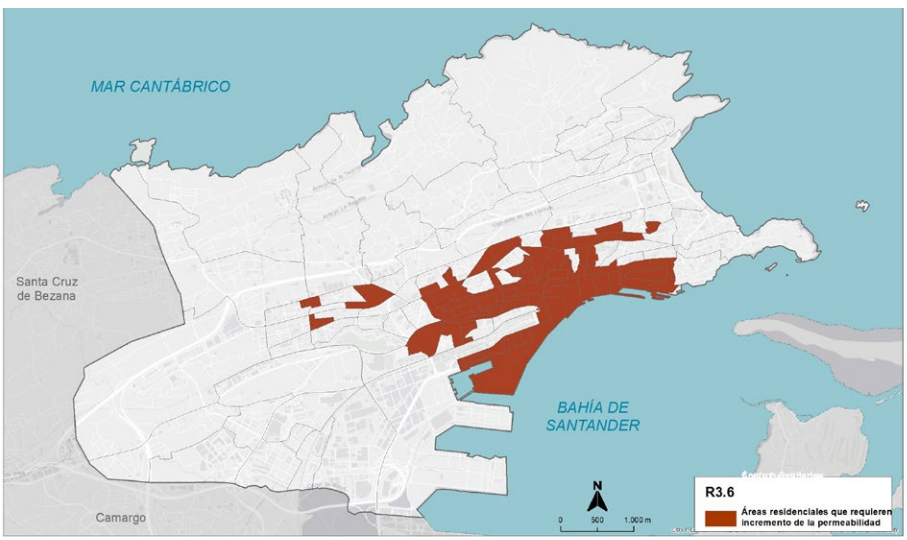
R3.6

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Pluvial flooding	Municipal

MISSION OF THIS MEASURE

Employ land-use transfer strategies to increase the presence of permeable zones in dense areas.

FIGURE R3.6. Census sections with low permeability



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,38

FOR MORE INFORMATION

Reference: Proyecto Madrid-Río (Besomi, A. 2011)
More information at: https://www.archdaily.co/co/02-89344/proyecto-madrid-rio-mrio-arquitectos-asociados-y-west-8

MONITORING INDICATORS

No. of land use transfer projects for retrofitting
Permeable area generated with land-use transfer projects

Implementation of water recharge reserves

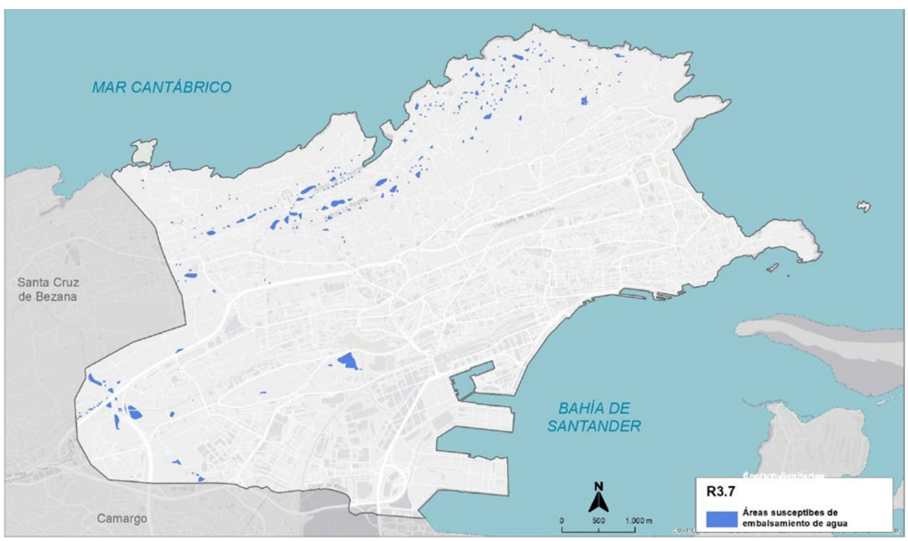
R3.7

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Pluvial flooding	Municipal

MISSION OF THIS MEASURE

Create recharge water reservoirs by protecting sectors prone to flooding identified in the Blue Spots mapping

FIGURE R3.7. Areas susceptible to water impoundment



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 5,92

FOR MORE INFORMATION

Reference: Construcción de balsas para la recarga del acuífero del Baix Camp en el marco del proyecto LIFE REMAR

More information at: https://www.comaigua.cat/-/la-recarga-del-acuifero-del-baix-camp-proyecto-seleccionado-en-la-primera-fase-del-programa-life-2020-de-la-union-europea-

MONITORING INDICATORS

Identified surface area of water recharge reservoirs

Annual volume (hm^3) of abstraction from recharge ponds

Objective R.4: Reducing the impact of sea level rise on the coastline

In order to reduce the impact of sea level rise on the coast, measures must be implemented to protect coastal infrastructure and buildings, as well as to conserve natural ecosystems that act as barriers against erosion and flooding.

Firstly, it is proposed to adapt infrastructures and buildings to sea level rise through the design and development of coastal space. It is sometimes necessary to make the lower floors of existing buildings permeable, to build containment reinforcements, to redesign public space to adapt it to the impact of waves or to relocate critical infrastructures outside risk areas. Risk control measures should be implemented to effectively manage the hazards associated with sea level rise. Safety perimeters can be established in vulnerable coastal areas and surveillance systems can be developed to monitor the behaviour of the sea during coastal storms and extreme weather events.

Coastal sediment conservation is another important strategy to reduce the impact of sea level rise. Coastal sediments act as natural barriers that absorb wave energy and protect the coastline from erosion. Maintaining the integrity of these ecosystems by protecting coastal areas and restoring degraded habitats is essential to preserve their function as buffers against sea level rise.

Proper planning of the coastline will reduce impacts and, in extreme situations, restore the functionality of these sectors in less time. Santander's beaches are particularly prone to impacts from sea level rise. The redesign of the coastline of the Second Beach of El Sardinero may become necessary. Options such as the recession of the promenade and the redesign of the Mesones Park, raising its current height, could guarantee a response to the impact of storms. A very sensitive sector corresponds to the end of the promenade, next to the Hotel Chiqui. In this area, maritime protection structures should be proposed to reduce the energy of the waves by increasing the sheet of water, with solutions similar to the natural pools included in the LIFE COSTAdapta project. This type of solution is being tested on coasts with a rocky substrate such as the one in question.

Three basic measures have been defined for the development of Objective R.4:

R4.1 Infrastructures and buildings adapted to sea level rise
R4.2 Implementation of risk control measures
R4.3 Coastal sediment conservation

Infrastructures and buildings adapted to sea level rise

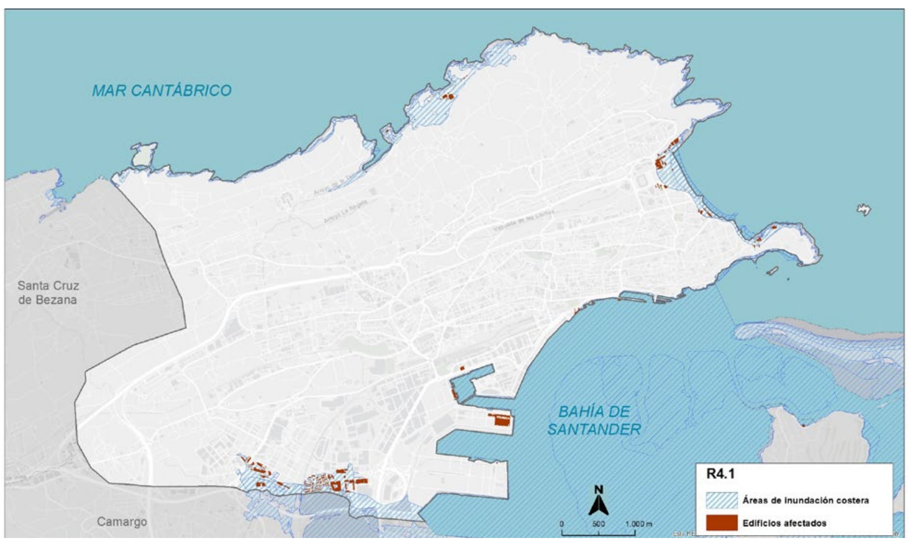
R4.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Coastal flooding	Punctual

MISSION OF THIS MEASURE

Carry out defence and/or relocation works of infrastructures and buildings exposed to sea level rise, sea surges and strong waves in areas at risk.

FIGURE R4.1. Buildings exposed to sea level rise



Source: CINCc (UC) - FIC, 2024 based on data from PEMUSAN 2016

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,31

FOR MORE INFORMATION

Reference: Desarrollar la adaptación costera al cambio climático en la infraestructura de la ciudad de Nueva York: proceso, enfoque, herramientas y estrategias (García et al., 2018).
More information at: https://www.sciencedirect.com/science/article/abs/pii/S0264837717314278

MONITORING INDICATORS

No. of buildings exposed to coastal flooding
Building area exposed to sea level rise

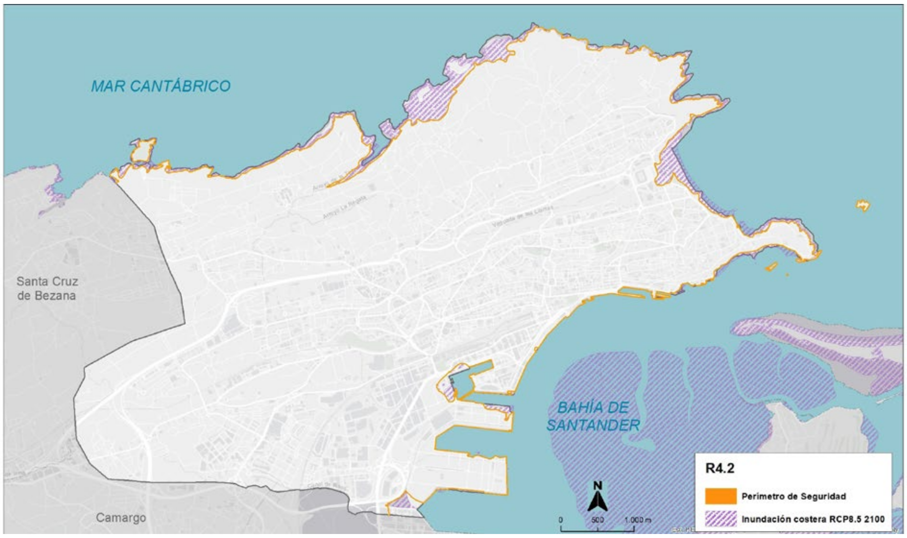
Implementation of risk control measures

R4.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Coastal flooding	Municipal

MISSION OF THIS MEASURE
Establish security perimeters and surveillance measures during coastal storms in at-risk areas.riesgo

FIGURE R4.2. Coastal flooding safety perimeters



Source: *CINCc (UC) - FIC, 2024 based on data from PEMUSAN 2016*

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,00

FOR MORE INFORMATION
Reference: "Sistema de Alerta Temprana de Tsunamis del Pacífico" (PTWS) Estrategia (2022-2030). (Intergovernmental Oceanographic Commission (IOC) of UNESCO, 2012) More information at: https://unesdoc.unesco.org/ark:/48223/pf0000384524

MONITORING INDICATORS
Area included within the security perimeter for extreme coastal events Budget allocated to security and surveillance measures for extreme coastal events

Coastal sediment conservation R4.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Coastal flooding	Punctual

MISSION OF THIS MEASURE

Design comprehensive measures for the conservation of sediments that favour the nourishment of beaches, without affecting their landscape value.

FIGURE R4.3. Sediment displacement on the Magdalena Peninsula, Santander

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,85

FOR MORE INFORMATION

Reference: Restauración de islas barreras para defensa de huracanes y del aumento del nivel del mar en Louisiana.
More information at: https://www.audubon.org/magazine/fall-2017/louisiana-restoring-its-barrier-islands-defend

MONITORING INDICATORS

Volume (m^3) of sediment with coastal protection capacity

Objective R.5: Be prepared with protocols for early warning and response to extreme events

Being prepared with early warning and response protocols for extreme events helps to protect communities and reduce the damage caused by natural disasters. One of the pillars of these protocols is the continuous monitoring of the response to extreme events, which involves closely monitoring the evolution of climatic phenomena such as storms, floods, droughts or other extreme events. This monitoring makes it possible to anticipate potential risks, assess the magnitude of the impact and take preventive measures in a timely manner.

For events such as drought, a well-defined action protocol is necessary. Water conservation measures can be implemented, promoting the efficient use of the resource and establishing restrictions when necessary. Strategies should also be developed to diversify water supply sources, such as investing in rainwater harvesting and storage infrastructure, and promoting treated water reuse practices.

Securing water supply is essential in preparing for extreme weather events. Mechanisms must be put in place to ensure the availability of drinking water even under conditions of scarcity, such as optimising water resource management, and implementing robust and resilient storage and distribution systems.

An additional strategy to prepare for extreme events is the implementation of insurance policies to cover weather-related losses. Insurance can provide financial compensation in case of material losses caused by extreme weather events, helping the municipality to recover more quickly from adverse impacts and reducing its economic vulnerability.

The aim, therefore, is to be prepared with early warning and response protocols for extreme events involving a combination of monitoring, planning, resource management and adaptation measures.

A total of four measures have been prioritised for Objective R.5:

R5.1 Monitoring the response to extreme events
R5.2 Drought action protocol
R5.3 Guaranteed water supply
R5.4 Implementation of insurance policies to cover weather-related losses

Monitoring the response to extreme events R5.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE

Create a tool to monitor the response of urban infrastructure and facilities to extreme events.

FIGURE R5.1. Monitoring tools

Source: Adaptecca (2024)

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,23

FOR MORE INFORMATION

Reference: 2023: Un año récord de eventos climáticos extremos y emisiones de CO_2. (Greenpeace, 2023).
More information at: https://es.greenpeace.org/es/noticias/eventos-climaticos-extremos-en-2023-entre-la-esperanza-y-la-ecoansiedad/

MONITORING INDICATORS

No. of monitoring tools
No. of people assigned to monitoring extreme events

Drought action protocol

R5.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, drought	Municipal

MISSION OF THIS MEASURE

Develop an action protocol for drought events, with actions depending on the degree of intensity (number of days without rainfall and high temperatures) and assessment of irrigation demand.

FIGURE R5.2. Prolonged drought events

Source: Getty Images (CC)

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,00

FOR MORE INFORMATION

Reference: Protocolo de actuación por situación de drought. (Ajuntament de Barcelona, 2023)
More information at: https://ajuntament.barcelona.cat/ecologiaurbana/es/que-hacemos-y-porque/energia-y-cambio-climatico/plan-sequia

MONITORING INDICATORS

No. of protocols for monitoring against drought / Sector of activity

Guaranteed water supply

R5.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, drought	Municipal

MISSION OF THIS MEASURE

Guarantee water supply with a supplementary system in the event of a water cut.

FIGURE R5.3. Pronillo's coat of arms

Source: CINCc (UC), 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,00

FOR MORE INFORMATION

Reference: Management sostenible del agua para la población y el medio ambiente de Nueva York. More information at: https://www.nyc.gov/assets/dep/downloads/pdf/climate-resiliency/one-nyc-one-water.pdf

MONITORING INDICATORS

Volume (hm^3) of water stored in supplemental systems
No. of safety and resilience assessments of the municipal electricity system
Time to restore service in case of grid failure or collapse

Implementation of insurance policies to cover weather-related losses

R5.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Confirm the coverage of municipal insurance policies for risks associated with climate change.

FIGURE R5.4. Insurance policy management

Source: Getty Images (CC).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,15

FOR MORE INFORMATION
Reference: Cobertura de riesgos extraordinarios derivables del cambio climático. (AdapteCCa, 2024). More information at: https://adaptecca.es/casos-practicos/cobertura-de-riesgos-extraordinarios-derivables-del-cambio-climatico

MONITORING INDICATORS
Economic value of policy coverage for climate change-related risks Economic amount supported by policies for climate change impacts

Objective R.6: Optimising and controlling water resources in a climate change scenario

In a climate change scenario, optimising and controlling water resources is essential to ensure the availability of drinking water and to reduce the effects of climate variability. To achieve this, it is necessary to implement measures at the municipal level, as well as in the private sector. Firstly, it is essential to introduce water saving and leakage control elements in the municipal water supply network. It is essential to modernise infrastructure and install technologies that reduce water losses during transport and distribution. In addition, it is important to implement leakage control systems in open spaces, municipal facilities and equipment to avoid waste.

To promote water saving among citizens, communication and awareness-raising campaigns should be carried out. These campaigns can include practical advice on the efficient use of water in the home, the promotion of low consumption technologies and the importance of reducing water waste in everyday activities. In the private sector, regulations need to be developed to promote water efficiency in new construction, including requirements for rainwater harvesting and storage in buildings, as well as the use of water reuse technologies for non-potable uses such as garden irrigation and cleaning of outdoor spaces.

To increase the volume of rainwater storage, priority should be given to the construction of a network of closed tanks connected to the separate rainwater network. These reservoirs can be used to store rainwater and then used for municipal irrigation.

The recharge zones of the Aquifer Subsystem 4A San Román Unit and 4D Santander Unit should be protected to prevent saline intrusion due to sea level rise. The expansion of permeable zones that allow rainwater to infiltrate into the subsoil, thus recharging the underground aquifers and maintaining their adequate quality and quantity, would guarantee the success of this measure.

The optimisation and control of water resources requires the implementation of comprehensive measures at municipal and private level, ranging from the modernisation of infrastructures to the promotion of efficient water use and the protection of natural resources.

Objective R.6 will be achieved through the following four priority measures:

R6.1 Efficient supply network
R6.2 Promotion of water saving
R6.3 Rainwater storage
R6.4 Protection of aquifers

Efficient supply network

R6.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Technification	Drought	Municipal

MISSION OF THIS MEASURE

Introduce saving and leakage control elements in the supply network and in municipal open spaces, facilities and equipment.

FIGURE R6.1. Registration of water distribution network, Santander

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,31

FOR MORE INFORMATION

Reference: Orientaciones y gobernanza en la Management del agua y cambio climático (Gobierno de España)
More information at: https://www.miteco.gob.es/es/agua/temas/sistema-espaniol-gestion-agua.html

MONITORING INDICATORS

No. of leaks identified and repaired
Annual volume (hm^3) of water lost in leaks / Total volume of supply water
Average consumption of water resources (l/inhab/day)

Promotion of water saving

R6.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Education	Drought	Municipal

MISSION OF THIS MEASURE
Promote water saving with communication campaigns to the public

FIGURE R6.2. Water resource losses

Source: Getty Images (CC).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,00

FOR MORE INFORMATION

Reference: Análisis crítico de las campañas de comunicación para fomentar la "cultura del agua" en México (HernándezÁvila, M. and Masso-Delgado, Y., 2016)

More information at: https://www.scielo.org.mx/scielo.php?pid=S0188-252X2016000200223&script=sci_arttext

MONITORING INDICATORS

Water consumption per inhabitant and floating population

No. of public awareness events and outreach materials

Rainwater storage

R6.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, pluvial flooding, drought	Municipal

MISSION OF THIS MEASURE

Increase the volume of rainwater storage with a network of closed tanks connected to the separate network. Encourage its use for municipal irrigation. In the private sector, develop water use regulations, requiring new buildings to collect and store rainwater.

FIGURE R6.3. Pronillo water deposit

Source: Aguas Municipales de Santander (2020)

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,85

FOR MORE INFORMATION

Reference: Depósito regulador de pluviales Joan Miró de Barcelona
Mas información en: https://www.iagua.es/blogs/jordi-oliveras/deposito-regulador-pluviales-joan-miro-barcelona

MONITORING INDICATORS

Stormwater storage capacity (Volume m^3) public and private
Volume (hm^3) of rainwater directly used for municipal irrigation

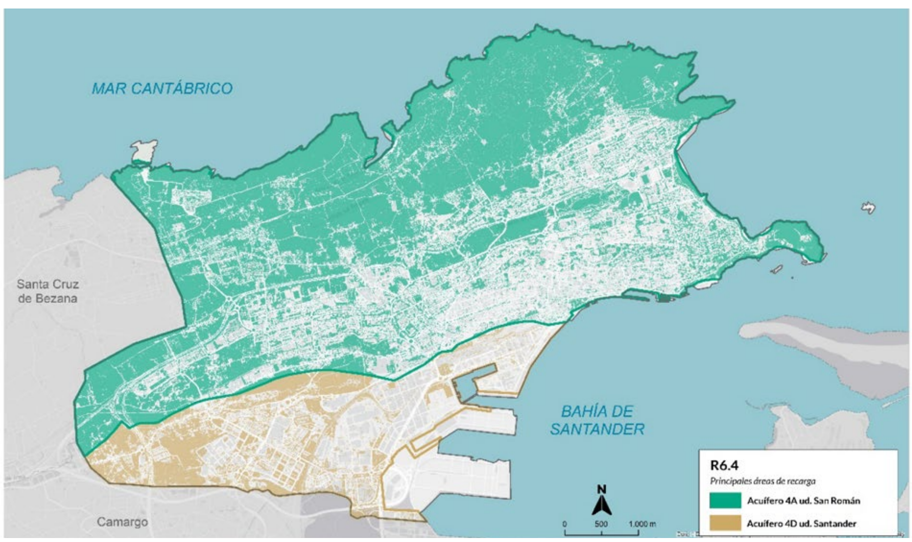
Protection of aquifers

R6.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Pluvial flooding, coastal flooding	Punctual

MISSION OF THIS MEASURE
Protect the recharge zones of the aquifer Subsystem 4A San Román Unit and 4D Santander Unit in order to prevent saline intrusion due to sea level rise with the extension of permeable zones.

FIGURE R6.4. Aquifer recharge areas



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,23

FOR MORE INFORMATION
Reference: Medidas urbanísticas de adaptación al cambio climático en Santa Cruz de Galápagos, Ecuador (Pérez Celaya, N., 2020) More information at: https://repositorio.unican.es/xmlui/handle/10902/21363

MONITORING INDICATORS
Permeable surface of aquifer recharge areas / Surface area of the recharge area

HEALTH GOAL

The Health Goal focuses on improving the resilience of health care services and the epidemiological surveillance system to protect the health of the population in a context of climate change. To achieve this, it is necessary to develop mechanisms to control and monitor climate change and its impact on public health, including the establishment of monitoring systems to identify and predict risks associated with extreme weather events and climate-related diseases.

It is important to have the capacity to respond to extreme weather and its effects on health, including the implementation of mitigation and adaptation measures, as well as the training of medical and emergency personnel to deal with climate-related crises such as heat waves, floods or vector-borne diseases.

An important part of this goal is to reduce the risk to the population most sensitive to extreme temperatures, such as the elderly, young children and people with chronic diseases. The implementation of awareness and prevention programmes favours the identification and protection of vulnerable groups, and the provision of adequate health services during adverse weather events for these sectors of the population. It also seeks to mitigate negative environmental conditions affecting public health, which would address problems such as air pollution, water quality, ecosystem degradation and exposure to toxic substances, which may be aggravated by climate change. Policies and actions should be implemented to reduce these environmental threats and promote healthier and safer environments for the population.

The Health Goal seeks to strengthen the health system's capacity to respond and adapt to climate change by implementing climate monitoring and control measures, preparing for extreme weather events, protecting vulnerable groups and promoting healthy environments. These actions are essential to address public health challenges in an ever-changing climate environment.

OBJECTIVES

SL1 Developing mechanisms for monitoring and tracking climate change impacts on health

SL2 Capacity to respond to extreme weather, minimising its effects on health

SL3 Reduce the risk of the most sensitive population to extreme temperatures

SL4 Reduce the negative environmental factors affecting health

Objective SL.1: Developing mechanisms for monitoring and tracking climate change impacts on health

Developing mechanisms to monitor and track climate change and its impact on health helps to protect the population from emerging environmental challenges. A key strategy is to establish a Biometeorological and Human Health Research Laboratory. This laboratory will study the relationships between atmospheric processes and human health, enabling a deeper understanding of how climate affects human well-being.

It is proposed that a complementary network of air quality and bioaerosol monitoring observatories, equipped with aeroallergen capture stations, would monitor pollutant and nanoparticle emissions at district or census section level, providing detailed air quality data.

Optimisation of the Smart City sensor network is another key measure. This network would allow real-time detection of high temperature hotspots in the city, which would facilitate the implementation of preventive actions to protect the population from the effects of extreme heat, such as heat stroke or dehydration. Sensors that are correctly located and provide reliable data for decision-making should be selected.

To strengthen epidemiological surveillance, systematic surveillance of vectors posing a potential risk to public health is proposed by monitoring the presence and activity of mosquitoes, ticks and other disease-transmitting vectors, which would allow early detection of possible outbreaks and the implementation of appropriate control measures. In addition, it is suggested that a mapping of possible vector nesting sites, such as open water impoundment, be created.

Finally, it is proposed that the impacts of the south wind be assessed on the physical and mental health of the population, which would allow a better understanding of how this climatic phenomenon affects people's well-being in order to develop appropriate adaptation and mitigation strategies. Taken together, these measures would contribute to improving the response capacity of Santander to the public health challenges associated with climate change.

For Objective SL.1 the following six measures have been established:

SL.1.1 Biometeorological and human health research laboratory
SL.1.2 Air quality observatory network
SL.1.3 Climate sensors network
SL.1.4 Surveillance and early warning for health risk vectors
SL.1.5 Mapping hotspots of diseases vectors associated with high temperatures
SL.1.6 Southern wind impact monitoring

Biometeorological and human health research laboratory

SL1.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Technification	Health	Municipal

MISSION OF THIS MEASURE

Develop a Biometeorological and Human Health Research Laboratory to study the relationships between atmospheric processes and human health and well-being.

FIGURE SL1.1. Bio-meteorological monitoring laboratories

Source: Pixabay Creative Commons Zero (CC0).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,69

FOR MORE INFORMATION

Reference: El cambio climático y la Salud en Cuba. (Borroto et al, 2022)

More information at: https://www.paho.org/sites/default/files/2023-05/cambio-climatico-salud-cuba.pdf

MONITORING INDICATORS

No. of persons employed at the Biometeorological-Human Health Research Laboratory

No. of research and studies published by the laboratory

Air quality observatory network

SL1.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Technification	Health	City

MISSION OF THIS MEASURE

Create a complementary network of air quality observatories, bio-aerosol monitoring (with aero-allergen capture stations) to monitor pollutant and nanoparticle emissions at census section scale.

FIGURE SL1.2. Measuring stations

Source: CINCc (UC), 2024, based on CIMA, Gobierno de Cantabria

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,62

FOR MORE INFORMATION

Reference: Red de control y vigilancia de la calidad del aire en Cantabria (Centro de Investigación de Medio Ambiente (CIMA), 2015).
More information at: https://cima.cantabria.es/calidad-del-aire

MONITORING INDICATORS

No. of data collection stations
Daily count of particulate matter concentration below 2.5 microns

Climate sensors network

SL1.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Technification	Health	Municipal

MISSION OF THIS MEASURE

Optimise the Smart City sensor network to detect high temperature hotspots in real time.

FIGURE SL1.3. Smart City Santander Equipment

Source: CINCc (UC), 2024

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,46

FOR MORE INFORMATION

Reference: Red de sensores SmartCity para la vigilancia de la salud en Barcelona
More information at: https://www.barcelona.cat/infobarcelona/ca/tema/smart-city

MONITORING INDICATORS

Number of optimised Smart City sensors
Sensor coverage area

Surveillance and early warning for health risk vectors

SL1.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, health	Municipal

MISSION OF THIS MEASURE

Strengthen epidemiological surveillance with systematic surveillance of vectors posing a potential risk to the population for possible incorporation into an early warning system.

FIGURE SL1.4. Vector-transmitting mosquito

Source: Pixabay, Creative Commons, Zero (CC0).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,46

FOR MORE INFORMATION

Reference: Mosquito Alert, pieza clave de un proyecto reconocido por la Comisión Europea para alertar sobre enfermedades transmitidas por mosquitos (Premio EIC Horizon de Alerta Temprana para epidemias)
More information at Mosquito Alert: https://map.mosquitoalert.com/es

MONITORING INDICATORS

No. of vectors identified
No. of annual vector surveillance campaigns

Mapping hotspots of diseases vectors associated with high temperatures

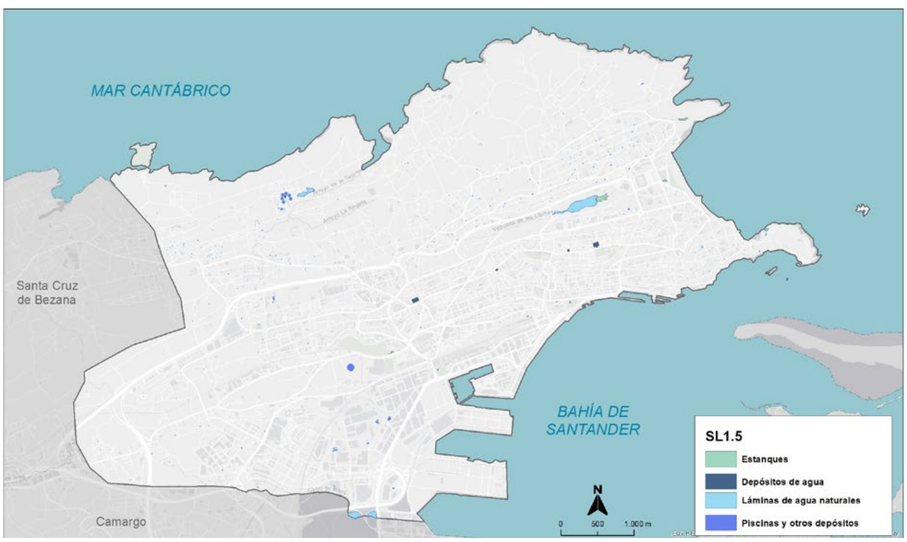
SL1.5

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, health	Municipal

MISSION OF THIS MEASURE

Create a mapping of potential breeding sites for disease vectors associated with high temperatures, especially outdoor water impoundment.

FIGURE SL1.5. Possible sources of disease vectors



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,85

FOR MORE INFORMATION

Reference: El observatorio mundial de la salud. (Organización Mundial de la Salud (OMS), 2024)
More information at: https://www.who.int/data/gho/map-gallery

MONITORING INDICATORS

Surface area of areas identified as sources of disease vectors

Southern wind impact monitoring

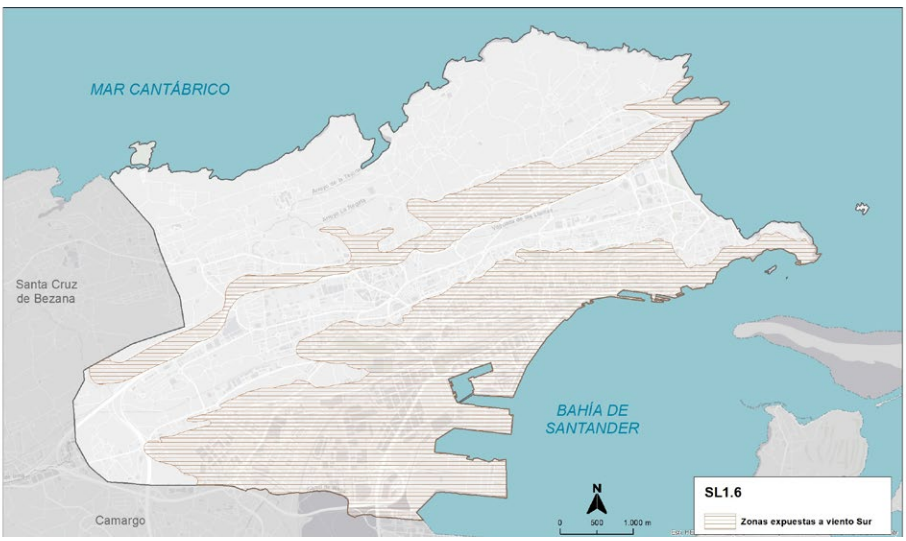
SL1.6

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Education	Heat waves, wind, health	Municipal

MISSION OF THIS MEASURE

Assess the impacts of South wind (by measuring its electrical characteristics) on the physical and mental health of citizens.

FIGURE SL1.6. South wind exposure



Source: CINCc (UC) - FIC, 2024 based on data from PEMUSAN 2016

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,31

FOR MORE INFORMATION

Reference: Evaluación del wind y directrices para ciudades inteligentes. (Actiflow, 2020)
More information at: https://actiflow.com/wind-assessment-and-guidelines-for-smart-cities/#

MONITORING INDICATORS

No. of inhabitants in areas at risk due to wind south
No. of people affected in hospitals depending on the frequency and duration of the events

Objective SL.2: Capacity to respond to extreme weather, minimising its effects on health

To develop mechanisms for monitoring and tracking climate change and its impact on health, a public health early warning system should be established. This system would provide early warning of extreme weather events, such as heat waves, unfavourable air quality conditions or south wind, allowing effective coordination between primary health care services, social and health organisations and civil protection.

A necessary measure is to establish a specific action protocol for heat wave events. This protocol would include a hierarchy of actions depending on the degree of intensity of the heat wave, from surveillance and monitoring of vulnerable people to coordination between health and care agencies to provide medical care and assistance to those in need. The expected increase in this phenomenon makes it necessary to systematise prevention and control programmes, targeting vulnerable groups, especially the elderly.

Another important aspect is to define action protocols for the control of pests and disease vectors associated with heat waves and high temperatures, implementing control and prevention measures, such as the fumigation of areas prone to the proliferation of mosquitoes and ticks, as well as the elimination of insect and rodent breeding sites.

Water storage in fountains and ponds also needs to be properly managed to prevent the proliferation of disease vectors. Plausible measures include the implementation of water filtration and treatment systems, as well as regular maintenance of fountains and ponds to prevent the accumulation of stagnant water, which is an ideal breeding ground for mosquitoes and other disease vectors.

Extreme temperature events, although not specific to the city of Santander, may appear as occasional episodes in which long periods of high temperatures are reached, and should, therefore, be taken into account in the mechanisms for the control and management of social and health emergencies.

Four main adaptation measures have been established for Objective SL2:

SL.2.1 Early warning system for extreme events
SL.2.2 Protocols for heat wave events
SL.2.3 Protocols for heat-related pest control actions
SL.2.4 Management of water storage for vector control

Early warning system for extreme events

SL2.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, wind, drought	Municipal

MISSION OF THIS MEASURE

Establish a public health early warning system for extreme heat events, unfavourable air quality conditions or south wind and facilitate the coordination of primary care services, socio-health entities and civil protection.

FIGURE SL2.1. Mobile early warning systems

Source: Getty Images (CC)

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,62

FOR MORE INFORMATION

Reference: La OMS prepara un sistema de alerta temprana para personas en riesgo de Heat waves (Agencia SINC, 2023)
More information at: https://www.agenciasinc.es/Noticias/La-OMS-prepara-un-sistema-de-alerta-temprana-para-personas-en-riesgo-por-olas-de-calor

MONITORING INDICATORS

No. of people with secured access to the Early Warning System

Protocols for heat wave events

SL2.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves	Municipal

MISSION OF THIS MEASURE

Establish an action protocol for heatwave events through a hierarchy of actions depending on the degree of intensity (monitoring of vulnerable people and coordination between health and care agencies).

FIGURE SL2.2. Sardinero-Santander Health Centre

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,62

FOR MORE INFORMATION

Reference: El Ayuntamiento de Madrid elabora un protocolo de actuación ante olas de calor en la ciudad (Diario de Madrid, 2023)
More information at: https://diario.madrid.es/blog/notas-de-prensa/el-ayuntamiento-de-madrid-elabora-un-protocolo-de-actuacion-ante-olas-de-calor-en-la-ciudad/

MONITORING INDICATORS

No. of official protocols approved for the Management of extreme heat events
No. of health service staff involved in the management of heat waves

Protocols for heat-related pest control actions

SL2.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, drought	Municipal

MISSION OF THIS MEASURE

Define action protocols for the control of pests and disease vectors resulting from heat waves and high temperatures.

FIGURE SL2.3. Pest treatment and control

Source: Getty Images (CC)

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,23

FOR MORE INFORMATION

Reference: Impactos del cambio climático en la incidencia de plagas y enfermedades de los cultivos (CropLife LA, 2023)

More information at: https://www.croplifela.org/es/actualidad/impactos-del-cambio-climatico-en-la-incidencia-de-plagas-y-enfermedades-de-los-cultivos

MONITORING INDICATORS

No. of protocols established for different typologies of heat pests

Management of water storage for vector control SL2.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, drought	Neighbourhood

MISSION OF THIS MEASURE
Manage water storage in fountains and ponds for disease vector control.

FIGURE SL2.4. Vector sources

Source: Nueva España, 2020

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,85

FOR MORE INFORMATION

Reference: Estrategia de Gestión Integrada de Prevención y Control de Dengue para Uruguay. (Pan American Health Organization 2023).
More information at: https://www.paho.org/sites/default/files/2024-12/egi-dengue-uruguay.pdf

MONITORING INDICATORS

Volume (m^3) of water in treated open air sources and storage sites

Objective SL.3: Reduce the risk of the most sensitive population to extreme temperatures

In order to reduce the risk to the population most sensitive to extreme temperatures, measures should be proposed to mitigate the impact of intense heat and ensure a healthier and safer environment in urban settings. A key strategy is to increase urban coolness by creating fountain gardens in areas identified as heat islands. Green spaces not only provide a cooler and more pleasant environment, but also help to reduce the ambient temperature through water evaporation. However, it is important to ensure that these fountains have shut-off or emptying systems to prevent water stagnation and the proliferation of disease vectors such as mosquitoes.

In addition, establishing a network of park-and-ride facilities and limiting vehicle access to areas identified as urban heat islands during periods of intense heat can significantly contribute to reducing ambient temperatures and improving air quality.

Preventive care controls for older people in their own homes should be designed into action plans related to the impact of heat and epidemic situations, including the installation of air conditioning systems, regular visits by medical or care staff, and the promotion of self-care measures. Developing preventive outreach programmes targeting vulnerable people is another useful measure to avoid risky situations during heat waves. These programmes can include information on the importance of staying hydrated, avoiding direct exposure to the sun during the hottest hours, and engaging in moderate physical activity. Finally, it is necessary to encourage the development of studies on vulnerable groups that define the risk associated with the absence of thermal comfort, taking into account their health profiles, comorbidities and socio-economic situations, as well as their workplace.

A total of six measures have been designed for Objective SL.3:

SL.3.1 Creation of green areas and fountains in urban heat islands
SL.3.2 Reduction of road traffic in urban heat islands
SL.3.3 Preventive control of heat island impact on elderly people
SL.3.4 Information programmes on heat wave prevention
SL.3.5 Occupational heat risk mapping
SL.3.6 Studies on heat vulnerable groups

Creation of green areas and fountains in urban heat islands

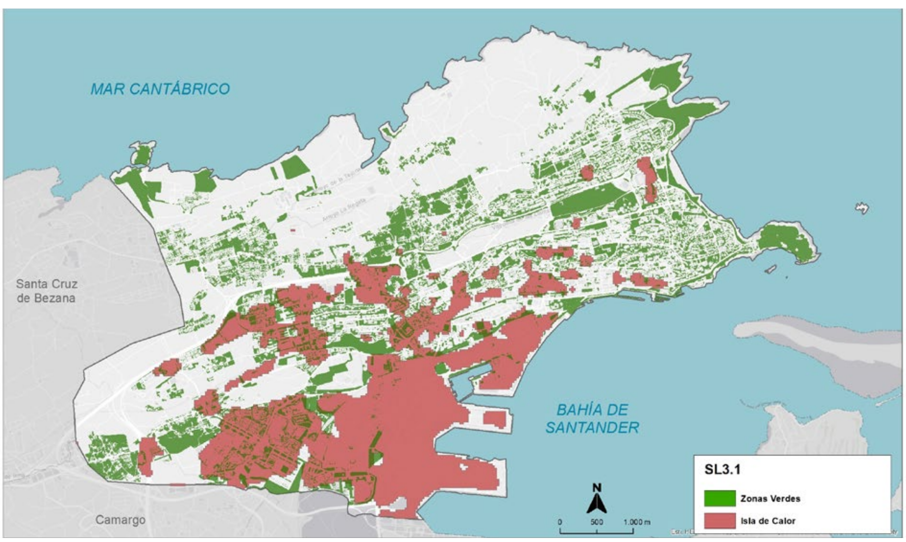
SL3.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, drought	Neighbourhood

MISSION OF THIS MEASURE

Increase urban coolness with fountain gardens in areas identified as heat islands. These fountains should have closing or emptying systems to avoid water stagnation and the proliferation of disease vectors.

FIGURE SL3.1. Areas of environmental improvement in urban heat island sectors



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,46

FOR MORE INFORMATION

Reference: Reducir los efectos de las islas de calor urbanas es el objetivo de los ganadores de Climathon 2023. (ORM, 2024)

More information at: https://www.orm.es/noticias-2024/reducir-los-efectos-de-las-islas-de-calor-urbanas-es-el-objetivo-de-los-ganadoras-de-climathon-2023/

MONITORING INDICATORS

Hourly temperature and humidity data collection in urban heat island areas

Naturalised area with green and blue infrastructure in urban heat island areas

Reduction of road traffic in urban heat islands

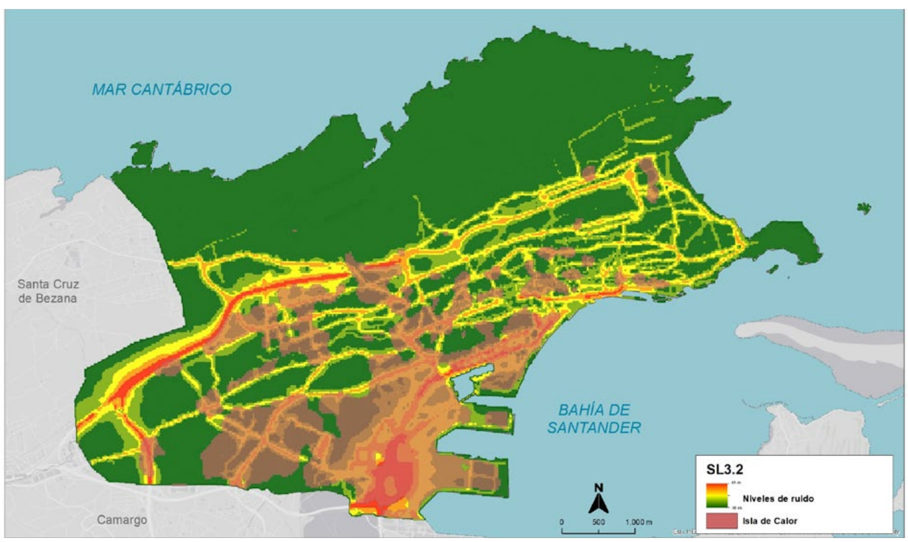
SL3.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves	Neighbourhood

MISSION OF THIS MEASURE

Establish a network of park-and-ride car areas and limit vehicle access to areas identified as urban heat islands at least during periods of intense heat.

FIGURE SL3.2. Areas of high vehicle concentration in urban heat islands



Source: CINCc (UC) - FIC, 2024 based on data from MER 2016

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,15

FOR MORE INFORMATION

Reference: Planificación para la reducción de la isla de calor en Valencia
More information at: https://www.valencia.es/documents/20142/424002/Estrategia%2520Valencia%25202020.pdf/45a6bf21-6304-7509-c717-ea0e105de538

MONITORING INDICATORS

No. of vehicle traffic management protocols in periods of intense heat (vehicles/hour)
No. of park-and-ride car areas
Proportion of use of combustion vehicles and non-polluting and non-heat emitting vehicles
Length (m) (km) of roads incorporated into the control network for extreme events

Preventive control of heat island impact on elderly people

SL3.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, health	Neighbourhood

MISSION OF THIS MEASURE

Design preventive care checks for the elderly in their own homes in action plans relating to the impact of heat and epidemic situations.

FIGURE SL3.3. Care for the elderly

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,15

FOR MORE INFORMATION

Reference: Plan Nacional de Actuaciones Preventivas de los Efectos del Exceso de Temperaturas sobre la Salud. (Ministerio de Sanidad, 2022)

More information at: https://www.sanidad.gob.es/areas/sanidadAmbiental/riesgosAmbientales/calorExtremo/publicaciones/planesAnteriores/docs/PlanNacionalExcesoTemperaturas_2022.pdf

MONITORING INDICATORS

No. of hospitalisations of elderly people in periods of extreme heat

Information programmes on heat wave prevention

SL3.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Education	Heat waves, health	Municipal

MISSION OF THIS MEASURE

Develop preventive health education programmes aimed at vulnerable people in order to avoid risk situations in the event of heat waves (physical exercise, dehydration, etc.).

FIGURE SL3.4. Prevention outreach programmes

Source: Ministerio de Derechos Sociales y Agenda 2030.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,08

FOR MORE INFORMATION

Reference: Protocolo general de actuación en el ámbito educativo andaluz no universitario ante Heat waves o altas temperaturas excepcionales. (Junta de Andalucía, 2023).

More information at: https://www.juntadeandalucia.es/educacion/portals/delegate/content/a9cb922b-91ab-4cd3-8d82-ac3c6a96518a/Protocolo%20ola%20calor%20y%20altas%20temperaturas%202023

MONITORING INDICATORS

No. of programmes disseminating information on preventive activities against Heat waves

Occupational heat risk mapping

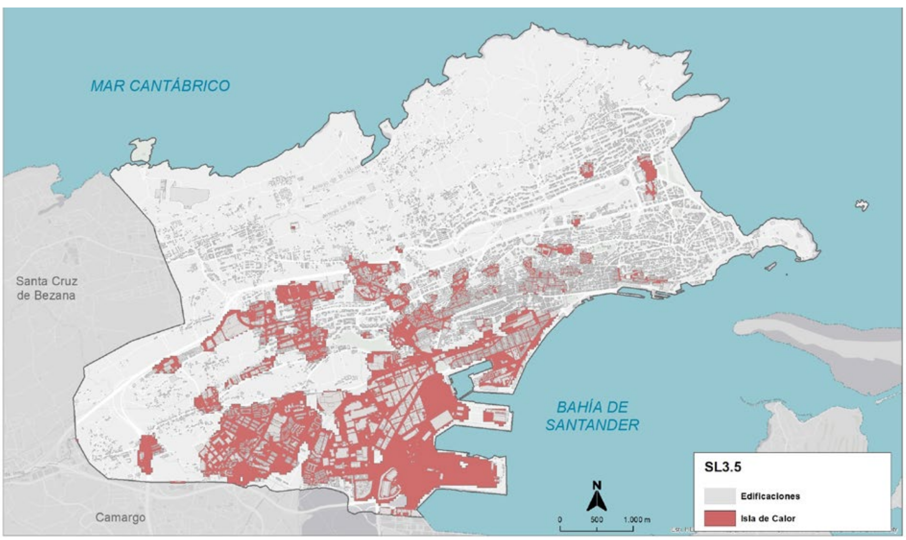
SL3.5

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves	Municipal

MISSION OF THIS MEASURE

Ensure occupational health by identifying areas and workplaces subject to increased heat stress, enabling more frequent rotations.

FIGURE SL3.5. Built-up areas in urban heat island sectors



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,85

FOR MORE INFORMATION

Reference: Rastreador de calor y salud. (CDC, 2024)
More information at: https://ephtracking.cdc.gov/Applications/heatTracker/

MONITORING INDICATORS

No. of people and workplaces in heat stress conditions
No. of hospitalisations per year due to extreme heat wave effects

Studies on heat vulnerable groups

SL3.6

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Policies	Health	Municipal

MISSION OF THIS MEASURE

Encourage the development of studies on vulnerable groups that define the risk associated with the absence of thermal comfort, taking into account their health profiles, co-morbidities and socio-economic situations.

FIGURE SL3.6. Thermal comfort in public spaces

Source: Getty Images (CC).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,85

FOR MORE INFORMATION

Reference: El calor extremo no afecta a todos por igual: deja más muertes en barrios con menos recursos. (Zafra, J.L. 2020)

More information at: https://valenciaplaza.com/calor-extremo-puede-acelerar-deterioro-cognitivo-poblacionesvulnerables

MONITORING INDICATORS

No. of people identified as being vulnerable to heat

Objective SL.4: Reduce the negative environmental factors affecting health

Objective SL.4 focuses on reducing the negative environmental factors that affect health, for which it is effective to carry out an exhaustive analysis of mortality and morbidity in the population associated with climatic conditions, providing key information to develop effective strategies to help mitigate and reduce the adverse effects on health.

With regard to noise pollution, it is necessary to implement measures to reduce its impact through the use of low-noise gardening machinery and the creation of green barriers in sectors with high noise exposure. Noise pollution not only affects people's hearing health, but can also have negative repercussions on mental health, sleep and general quality of life, as well as on biodiversity.

Blue infrastructures, such as natural and artificial bodies of water, can be harnessed as therapeutic spaces to promote well-being and health. Thalassotherapies, which involve the therapeutic use of seawater and its derivatives, are an example of how these infrastructures can be used to promote health. Santander, as a historic spa town, has important resources in this area that should be used efficiently, especially in view of the increase in global temperatures.

It is also necessary to resize the urban sanitation sections to avoid the accumulation of stagnant water that encourages the development of pathogens and favours the appearance of outbreaks of water-related diseases. One possible measure involves improving rainwater and wastewater management, ensuring adequate drainage and preventing contamination of drinking water sources.

So in order to reduce the negative environmental determinants affecting health, it is necessary to carry out detailed analyses of risk factors and to develop targeted and effective interventions. Developing measures to reduce noise pollution is also suggested, take advantage of blue infrastructures to promote well-being, along with improving water management and urban sanitation to prevent water-related diseases.

The main measures proposed for Objective SL.4 are the following:

SL.4.1 Studies on mortality and morbidity associated with climatic conditions
SL.4.2 Reduction of noise pollution in gardening
SL.4.3 Blue infrastructure as a therapeutic and wellness space
SL.4.4 Resizing of urban sanitation infrastructures

Studies on mortality and morbidity associated with climatic conditions

SL4.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Education	Health	Municipal

MISSION OF THIS MEASURE

Analyse and study mortality and morbidity in the population associated with climatic conditions in order to mitigate and reduce their effects.

FIGURE SL4.1. Health and Climate Studies

Source: Getty Images (CC).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,00

FOR MORE INFORMATION

Reference: El cambio climático está detrás de casi el 40% de las muertes por calor. (National Geographic, 2024)

More information at: https://www.nationalgeographic.com.es/ciencia/el-cambio-climatico-esta-detras-de-casi-el-40-de-las-muertes-por-calor-_16979

MONITORING INDICATORS

No. of deaths associated with climatic processes

No. of pathologies influenced by climatic conditions

Reduction of noise pollution in gardening

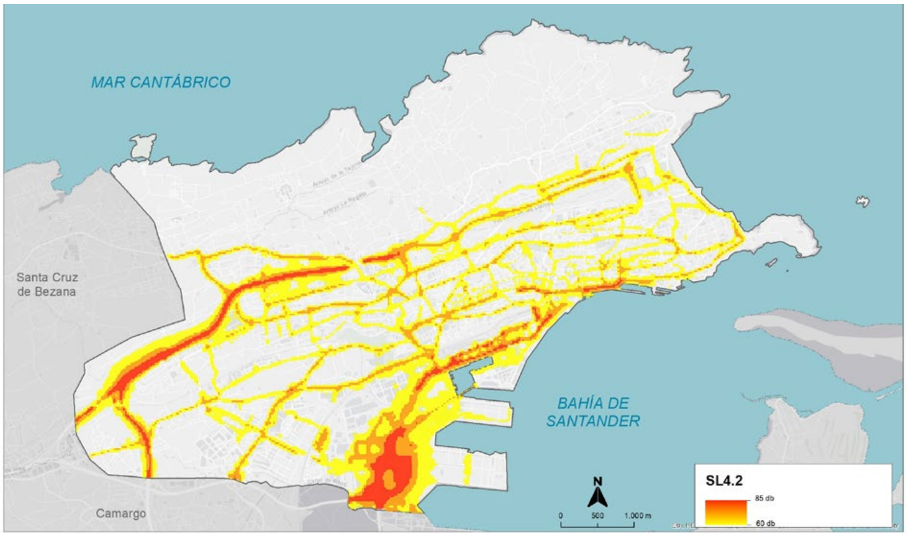
SL4.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, health	Municipal

MISSION OF THIS MEASURE

Reduce noise pollution through the use of low-noise gardening machinery and green screening in areas of high noise exposure due to their impact on health and biodiversity.

FIGURE SL4.2. Noise pollution areas



Source: CINCc (UC) - FIC, 2024 based on data from MER 2016

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,69

FOR MORE INFORMATION

Reference: Guía técnica para la gestión del ruido ambiental en las administraciones locales (Diputación Foral de Bizkaia).

More information at: https://www.bizkaia.eus/home2/archivos/DPTO9/Temas/Pdf/RUIDO/RUIDO%20DEF/3C%20GUIA%20TECNICA%20RUIDO%20AMBIENTAL%20AYUNTAMIENTOS_DFB.pdf?hash=1fa615ea97ca2134b5d9943ccb4bf075&idioma=EU

MONITORING INDICATORS

Budget for low-noise gardening equipment

No. of low noise impact gardening equipment / Total no. of equipment

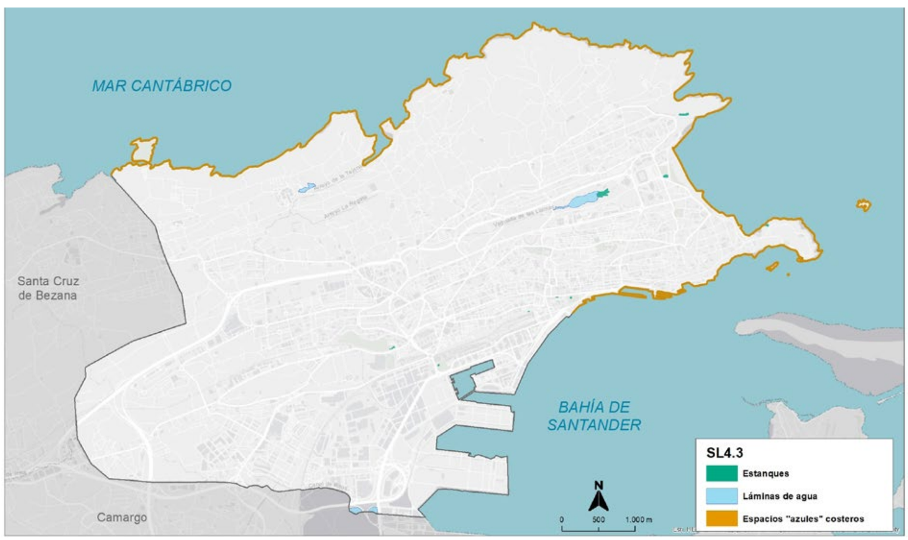
Blue infrastructure as a therapeutic and wellness space

SL4.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Health	Municipal

MISSION OF THIS MEASURE
Use blue infrastructures as therapeutic, healing and wellness areas (promotion of thalassotherapy).

FIGURE SL4.3. Blue infraestructures



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,31

FOR MORE INFORMATION
Reference: Infraestructura Verde-Azul de Bizkaia (Diputación de Bizkaia, 2023) More information at: https://www.bizkaia.eus/es/cambio-climatico/infraestructura-verde-azul

MONITORING INDICATORS
Area (m^2) blue infrastructure identified as therapeutic spaces / Blue Infraestructure surface

Resizing of urban sanitation infrastructures

SL4.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Constructive	Heat waves, pluvial flooding, drought	Neighbourhood

MISSION OF THIS MEASURE

Resize urban sanitation sections to avoid stagnant water that can support the growth of pathogens and outbreaks of water-associated diseases.

FIGURE SL4.4. Works to improve the sewerage network

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,92

FOR MORE INFORMATION

Reference: Vietnam invierte 4.300 millones de euros en 38 nuevas plantas de tratamiento de aguas residuales en Hanói. (iAgua, 2023)

More information at: https://www.iagua.es/noticias/saneamiento/13/06/03/vietnam-invertira-4300-millones-de-euros-en-38-nuevas-plantas-de-tratamiento-de-aguas-residuales-e

MONITORING INDICATORS

Length (m) (km) of strategic sanitation network resized for extreme events

ADAPTED SOCIETY AND ECONOMY GOAL

The Adapted Economy and Society Goal seeks to increase the adaptive capacity of the socio-economic fabric in the face of climate change, ensuring public awareness and monitoring of impacts in order to be prepared for, and respond effectively to extreme events. To achieve this, it is necessary to develop comprehensive actions that address both awareness, preparedness and adaptation of various sectors of society.

First, public awareness of climate change and its impacts must be ensured by conducting public awareness and education campaigns on risks and necessary adaptation measures. In addition, information and communication programmes should be developed to promote understanding of the implications of climate change and encourage public participation in adaptation. Citizens should be prepared to respond to extreme events through the implementation of emergency plans and action protocols.

These plans should include prevention, early warning, evacuation and crisis management measures, involving different actors and sectors of society in their implementation. Updating the Municipal Emergency Plan to new climate scenarios could be a decisive tool. Monitoring and assessing the effect of climate change and its impacts are equally important to better understand emerging trends and risks.

Fostering a business fabric that is prepared and adapted to climate change supports economic resilience and sustainability by promoting business strategies that integrate climate considerations, and by encouraging innovation and investment in sustainable technologies and practices. Finally, promoting sustainable and climate resilient tourism is key to protecting natural resources and promoting sustainable economic development in the city of Santander. The promotion of responsible tourism practices, the diversification of tourism products and services, and the creation of climate change resilient destinations are some of the possible strategies to achieve this goal.

OBJECTIVES

SE1 Be prepared to respond to extreme events.

SE2 Monitor and assess the climate change impacts on Santander

SE3 Understanding the implications of climate change and promoting citizen participation in adaptation

SE4 Reduce social vulnerability to climate change

SE5 Promote a business fabric that is prepared and adapted to climate change

SE6 Promoting sustainable and climate change adapted tourism

Objective SE.1: **Be prepared to respond to extreme events**

Objective SE.1 focuses on how society should be prepared to respond to extreme events by protecting the population and minimising the adverse impacts that may arise from severe weather events. To achieve this, coordinated and planned actions are required to address different aspects of emergency management.

First, the Municipal Emergency Plan needs to be adapted to take into account expected climate variability. The document needs to be reviewed and updated to include specific response measures for extreme rainfall, heat waves and extreme wind. It is necessary to define the appropriate emergency services and establish clear protocols of action for each type of extreme event. The municipality must assume the need to invest financial resources in the development of a new document and provide the necessary corrective measures to ensure that the community security and care services are well prepared for possible extreme events.

Identifying weather shelters among open spaces and facilities is another good measure. Shelters would provide a safe place for the population in case of extreme events. In addition, providing a list of health care facilities for vulnerable people would ensure that those in need of medical care can access it quickly during emergencies. Adequate mapping of safe and accessible facilities in extreme situations should be developed and disseminated to extreme weather response services and the public.

Creating an early warning system through mobile phone applications is also an effective tool for informing the public about extreme weather events. These applications can provide the population with instant alerts and safety advice.

Establishing security capacities at events, celebrations or spaces with a high concentration of people will guarantee an effective response to extreme events, limiting the number of people allowed in a given area to avoid risky situations during weather emergencies.

Four adaptation measures are included in Objective SE.1:

SE.1.1 Adapting the municipal emergency plan to future climate risks
SE.1.2 Climate shelter mapping
SE.1.3 Mobile application for early warning system
SE.1.4 Safety capacity at public events

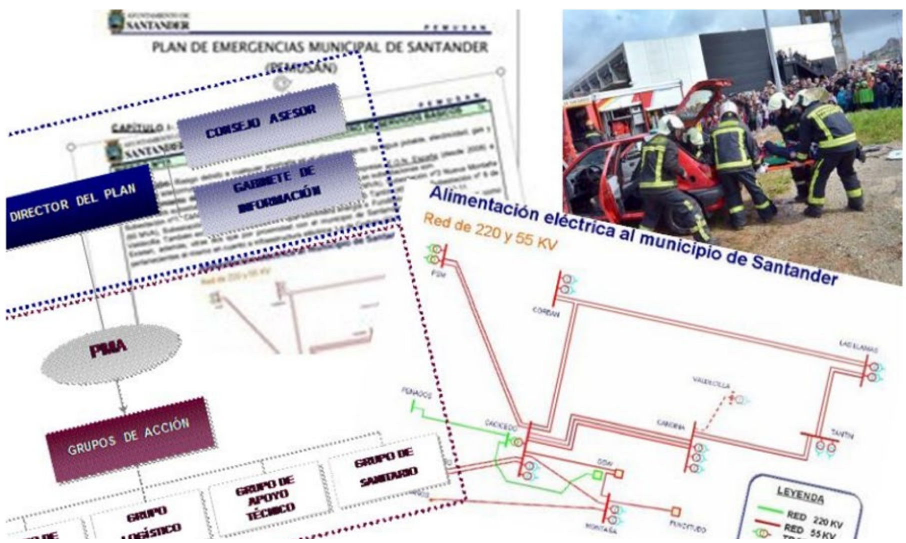
Adapting the municipal emergency plan to future climate risks

SE1.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Adapt the Municipal Emergency Plan considering the expected climatic variability, defining the appropriate emergency services in case of extreme rainfall, heat waves and extreme wind.

FIGURE SE1.1. Municipal Emergency Plan



Source: CINCc (UC), 2024, from Fire Department, Santander City Council.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 9,46

FOR MORE INFORMATION
Reference: Planes de Emergencias Municipal de Santander (PEMUSAN) More information at: https://www.santander.es/ciudad/plan-emergencias

MONITORING INDICATORS
No. of contingency plans according to sectors adjusted to expected climate variability

Climate shelter mapping

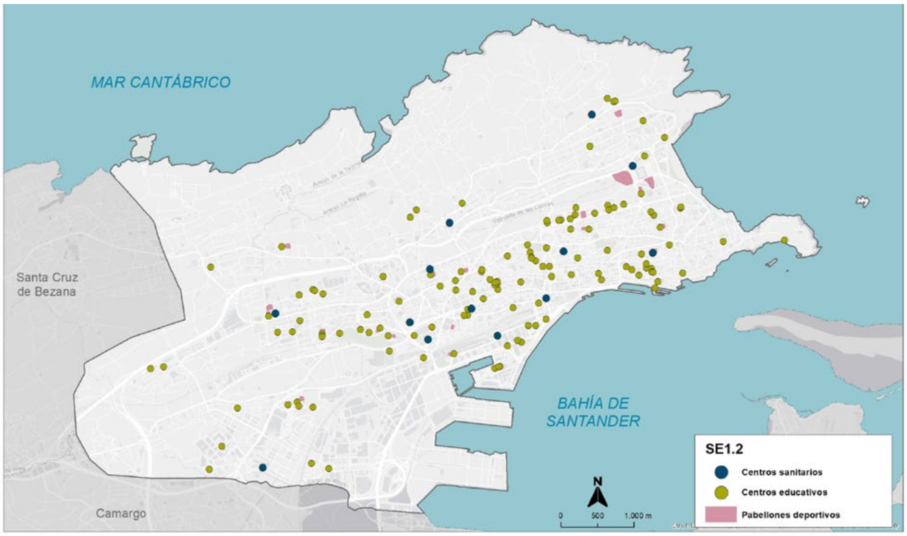
SE1.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Neighbourhood

MISSION OF THIS MEASURE

Identify weather shelters among the open spaces and facilities, providing a list of assistance centres for vulnerable people in case of extreme events for the information of citizens and visitors.

FIGURE SE1.2. Potential climate refuges



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,77

FOR MORE INFORMATION

Reference: 155 refugios climáticos repartidos por toda la ciudad para hacer frente al calor (Ayuntamiento de Barcelona, 2021).
More information at: https://www.barcelona.cat/infobarcelona/es/tema/emergencia-climatica/mas-de-160-refugiosclimaticos-repartidos-por-toda-la-ciudad-para-hacer-frente-al-calor-4_1083949.html

MONITORING INDICATORS

No. of climatic shelters
Total capacity of climatic shelters
Population coverage within 300 m and urban area of climate shelters

Mobile application for early warning system

SE1.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Technification	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Create an early warning system through mobile phone applications (SmartCity or other) related to extreme weather events.

FIGURE SE1.3. Civil protection alert notification

Source: CINC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,15

FOR MORE INFORMATION
Reference: Sistema de alerta integral para la adaptación al cambio climático (LIFE BAETULO, 2022) More information at: https://adaptecca.es/sites/default/files/documentos/230220_aq_laymansreport_baetulo_es.pdf

MONITORING INDICATORS
No. of people registered in the early warning system mobile application

Safety capacity at public events

SE1.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding coastal flooding, wind, drought	Punctual

MISSION OF THIS MEASURE

Establish safety capacities for events, celebrations or spaces with a high concentration of people in order to guarantee the response to extreme events.

FIGURE SE1.4. Mass crowds

Source: CINC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,22

FOR MORE INFORMATION

Reference: La gira de Taylor Swift en Brasil, empañada por dos muertes, varios atracos y una peligrosa ola de calor. (El Mundo, 2023)

More information at: https://www.elmundo.es/cultura/musica/2023/11/21/655c52fdfdddf fd9398b459e.html

MONITORING INDICATORS

No. of annual events with concentrations above the municipal response capacity

Record of exceedance of established levels

No. of events cancelled or modified by extreme weather conditions

Objective SE.2: **Monitor and assess the climate change impacts on Santander**

Several measures are proposed to effectively monitor climate change and assess its impact on the city and its environment. To do this, firstly, it is necessary to develop a framework of monitoring indicators and target parameters for monitoring climate change impacts. Indicators could cover aspects such as changes in temperatures, precipitation levels, air quality, sea level, among others. These parameters would allow for systematic monitoring of climate change and evaluation of the effectiveness of implemented adaptation measures. This Adaptation Plan provides a set of indicators as a starting point for the development of an effective and adaptive monitoring tool.

Encouraging cooperation between cities through participation in networks such as the Cities for Climate Network or similar would be beneficial. Such collaborations allow for the exchange of experiences and best practices on climate change adaptation, as well as learning from strategies implemented by other cities facing similar challenges.

Creating an internal municipal body in charge of managing adaptation measures is strategic to effectively coordinate and manage climate change actions. This body would be responsible for designing and implementing adaptation policies and programmes, as well as monitoring and evaluating their impact.

It is also important to inventory potential impacts on the municipality's cultural heritage due to extreme weather events, which implies identifying cultural assets vulnerable to the effects of climate change, such as floods, coastal erosion or storms, and developing protection and conservation strategies to mitigate their deterioration.

Ensuring the monitoring and assessment of the effect of climate change therefore requires the implementation of comprehensive measures that address both climate monitoring and the assessment of its impact on the city and its heritage. By adopting a systematic and collaborative approach, the city of Santander will be better prepared to face the challenges of climate change and protect its natural and cultural environment.

For Objective SE.2, the following adaptation measures have been established:

SE.2.1 Climate impact and adaptation monitoring Indicators
SE.2.2 Exchange of experiences with other cities
SE.2.3 Municipal authority for climate adaptation
SE.2.4 Assessment of climate impacts on cultural heritage

Climate impact and adaptation monitoring indicators

SE2.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE

Develop a framework of monitoring indicators and target parameters for monitoring climate change impacts and progress on adaptation.

FIGURE SE2.1. Data collection of indicators

Source: CINCc (UC), 2024.

PRIORITY LEVEL	**HIGH**	**MEDIUM**	**LOW**	**Value: 8,85**

FOR MORE INFORMATION

Reference: Sistema de Información de la Agenda de Transparencia de acciones climáticas a nivel subnacional (SIAT-Subnacional). (Gobierno de México. 2020).
More information at: https://siatsubnacional.semarnat.gob.mx

MONITORING INDICATORS

No. of extreme weather events per year
No. of climate events exceeding expected thresholds
No. of adaptation measures implemented

Exchange of experiences with other cities SE2.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Education	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Encourage cooperation between cities by exchanging adaptation experiences (Cities for Climate Network, etc.).

FIGURE SE2.2. International and European institutions, associations and organisations

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,77

FOR MORE INFORMATION
Reference: (Red Española de Ciudades por el Clima y FEMP, 2024) More information at: https://redciudadesclima.es/jornadas

MONITORING INDICATORS
No. of climate adaptation experience exchange programmes participated in No. of adaptation projects developed in coordination with other cities and regions No. of events - congresses for the exchange of experiences held Funds in European programmes with an impact on urban adaptation

Municipal authority for climate adaptation

SE2.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Create an internal municipal body responsible for the management of adaptation measures.

FIGURE SE2.3. Santander City Council

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,85

Note: LOW is highlighted in yellow.

FOR MORE INFORMATION

Reference: Comisión municipal de Medioambiente para la elaboración del Plan Municipal contra el Cambio climático de Córdoba. (Ayuntamiento de Córdoba, 2023)

More information at: https://www.cordoba.es/servicios/medio-ambiente/temas/cambio-climatico/plan-municipal-contra-cambio-climatico

MONITORING INDICATORS

No. of people involved in the development of the municipal body for adaptation

No. of adaptation measures managed by the municipal adaptation body annually

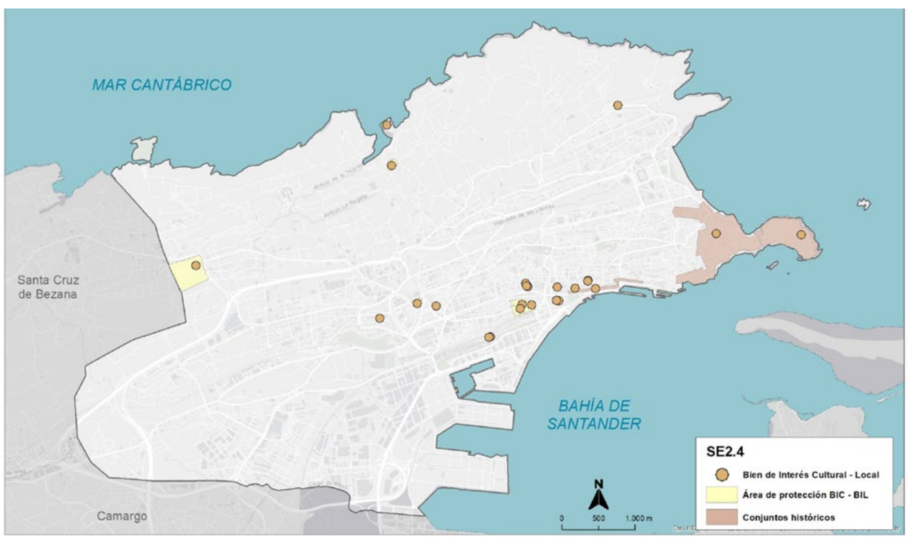
Assessment of climate impacts on cultural heritage

SE2.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Inventory the possible effects of extreme weather events on the cultural heritage of the municipality.

FIGURE SE2.4. Potential BICs and exposed historic sites



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,46

FOR MORE INFORMATION
Reference: Los expertos dicen que hay que vigilar el cambio climático para la conservación de Altamira. (LA INFORMACIÓN, 2018). More information at: https://www.lainformacion.com/mundo/los-expertos-dicen-que-hay-que-vigilar-el-cambio-climatico-para-la-conservacion-de-altamira_wuvw2naozsxkomeok3un06/

MONITORING INDICATORS
No. of heritage elements exposed to extreme climatic phenomena No. of impacts suffered due to exposure to extreme events of the inventoried assets

Objective SE.3: Understanding the implications of climate change and promoting citizen participation in adaptation

To understand the implications of climate change and encourage citizen participation in adaptation, it is important to implement various educational and awareness-raising strategies that inform and empower the population.

A first step is to carry out awareness-raising campaigns on climate change and its effects. These campaigns can use various media, such as visual information on the Santander city bus network, social networks and posters in public spaces, to convey clear and accessible information about the impacts of climate change on the city and the daily lives of its inhabitants.

It is necessary to develop a training plan on the effects of climate change aimed at different groups in society, including students, professionals and citizens in general. This training plan can include lectures, workshops and courses that address topics such as the science of climate change, exposure to climate hazards, associated risks and vulnerabilities, and necessary adaptation measures.

It is also important to articulate a technical training and awareness-raising plan specifically targeted at municipal workers, who play a key role in the implementation of adaptation and mitigation measures in the city. This training can include technical aspects related to environmental management and public policy design, as well as awareness raising on the importance of climate change and the need to act proactively.

To facilitate access to information on climate change and adaptation measures, it is necessary to set up an information point on the municipal website. This information point can provide resources such as documents, guides, links to relevant websites and updates on progress in implementing adaptation measures in the city. Complementing this information with physical signage in public places helps to reach those who cannot access information online. Thus, understanding the implications of climate change and encouraging citizen participation in adaptation requires a combination of education, awareness raising and access to information strategies.

The following adaptation measures have been identified for Objective SE.3:

SE.3.1 Information campaigns on climate change and its effects
SE.3.2 Training plan on the effects of climate change
SE.3.3 Web-based information point on climate change

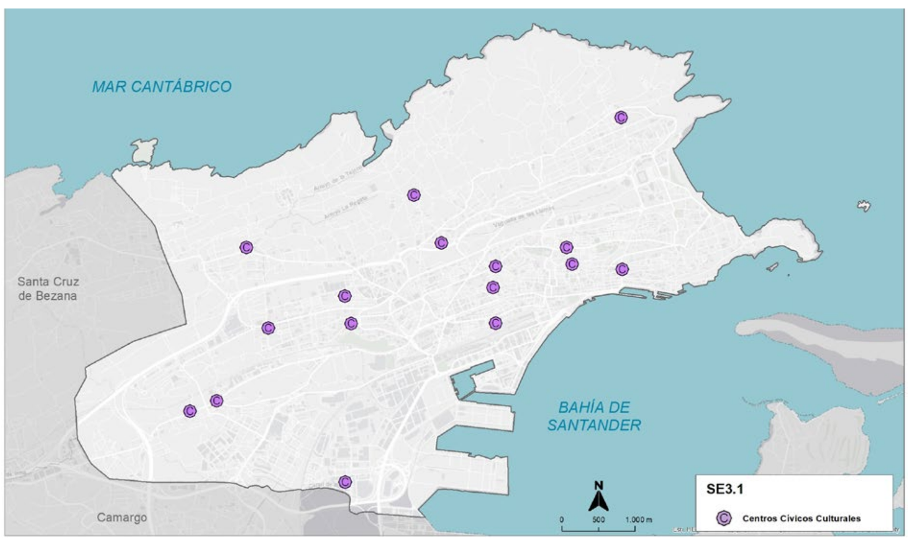
Information campaigns on climate change and its effects

SE3.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Education	Heat waves, pluvial flooding, coastal flooding, wind, drought	Neighbourhood

MISSION OF THIS MEASURE
Develop public information campaigns on climate change and its effects.

FIGURE SE3.1. Potential information points: Civic centres



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,38

FOR MORE INFORMATION
Reference: Campañas sobre cambio climático. (Manos Unidas, 2024) More information at: https://www.manosunidas.org/observatorio/cambio-climatico/campanas-cambio-climatico

MONITORING INDICATORS
No. of outreach campaigns No. of outreach and awareness-raising materials

Training plan on the effects of climate change

SE3.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Education	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Articulate a technical training and awareness-raising plan for municipal workers

FIGURE SE3.2. Actions of the Santander City Council Fire Service

Source: Bomberos Ayuntamiento de Santander.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,46

FOR MORE INFORMATION
Reference: Climate change education (UNESCO, 2023) More information at: https://www.unesco.org/en/climate-change/education

MONITORING INDICATORS
No. of training activities for staff in technical areas of the administration No. of people benefiting from the transfer of knowledge on adaptation

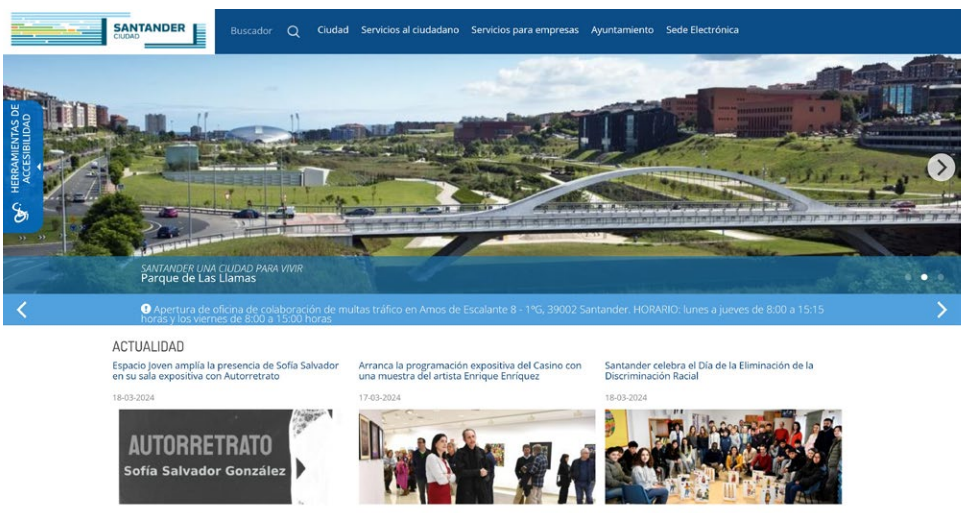
Web-based information point on climate change

SE3.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Technification	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Enable an information point on climate change, mitigation and adaptation measures and monitoring of the progress made on the municipal website, complementary to the information on physical signage.

FIGURE SE3.3. Santander City Council website



Source: Ayuntamiento de Santander, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,62

FOR MORE INFORMATION
Reference: ¿Qué me ofrece AdapteCCA? (AdapteCCA, 2024) More information at: https://adaptecca.es/

MONITORING INDICATORS
No. of visits to the climate change web section Average time spent browsing the climate change sections of the website

Objective SE.4: **Reduce social vulnerability to climate change**

In order to reduce social vulnerability to climate change, specific measures are required to address the needs of the most affected communities. An effective strategy involves implementing programmes and policies that provide direct support to vulnerable people.

A subsidy programme for the rehabilitation of vulnerable housing is essential. This programme can provide funds to improve the energy efficiency of housing and strengthen its resilience to the impacts of climate change, such as flooding or extreme temperatures. Prioritising these grants for the homes of people with the greatest identified climate vulnerability will ensure that those most at risk receive the support they need to protect themselves. Policies to renovate the building stock should continue, not only for their effect on mitigation, but also to ensure their adaptation to future climate and its impacts.

Establishing a registry of climate-vulnerable people will identify and provide targeted assistance to those most in need. This registry can include information on the elderly, persons with disabilities, low-income families and other vulnerable populations. A dedicated municipal unit can manage this registry, ensuring the collection of relevant information, timely assistance and dissemination of information on protection and adaptation measures.

Complementarily, it is proposed to create a network of climate-adapted urban gardens as well, which can contribute to reducing social vulnerability to climate change. The gardens can be designed to withstand extreme weather conditions and provide fresh and healthy food to local communities. In addition, promoting intergenerational activities in these gardens fosters collaboration and mutual support between different age groups, thus strengthening the social fabric and community resilience.

Reducing social vulnerability to climate change requires implementing measures that address the specific needs of the most affected communities, including subsidy programmes for housing rehabilitation, establishment of registers of vulnerable people, and creation of resilient community spaces, such as climate-smart urban gardens.

Adaptation measures under Objective SE.4 are presented below:

SE.4.1 Subsidy programme for the rehabilitation of vulnerable housing
SE.4.2 List of climate-vulnerable people
SE.4.3 Network of climate-adapted vegetable gardens

Subsidy programme for the rehabilitation of vulnerable housing

SE4.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Prioritise subsidies for the rehabilitation of housing of people with identified climate vulnerability

FIGURE SE4.1. Neighbourhood of El Cabildo, Santander

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,77

FOR MORE INFORMATION

Reference: Estrategia de Rehabilitación Energética de Edificios – (Ayuntamiento de Madrid, 2023)
More information at: https://transforma.madrid.es/rehabilitacion/

MONITORING INDICATORS

Assessment of the energy performance of buildings
No. of rehabilitated dwellings
Percentage of dwellings with vulnerable people rehabilitated / Total number of vulnerable dwellings
Public funds earmarked for climate retrofitting

List of climate-vulnerable people

SE4.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Ensure the registration, assistance and information of people vulnerable to climate change through a specific municipal unit.

FIGURE SE4.2. Vulnerable groups

Source: Getty Images (CC).

PRIORITY LEVEL	**HIGH**	**MEDIUM**	**LOW**	**Value: 7,08**

FOR MORE INFORMATION
Reference: Cambio climático y salud en la ciudad de Barcelona. (Agencia de salud pública de Barcelona, 2023) More information at: https://www.aspb.cat/noticia/canvi-climatic-salut-barcelona/

MONITORING INDICATORS
Total no. of people vulnerable to climate change identified annually Percentage of elderly people living alone and receiving care from social services Percentage of people receiving support for electricity supply

Network of climate-adapted vegetable gardens SE4.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, health	Neighbourhood

MISSION OF THIS MEASURE

Create a network of climate-protected urban gardens designed to promote intergenerational activities.

FIGURE SE4.3. Urban gardens, Santander

Source: Ayuntamiento de Santander

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,08

FOR MORE INFORMATION

Reference: Lanzamos 'Semillas por el clima', un proyecto agroecológico en los centros educativos de la sierra de Madrid (La Troje – Asociación, 2022)
More information at: https://www.latroje.org/lanzamos-semillas-por-el-clima-un-proyecto-agroecologico-en-los-centros-educativos-de-la-sierra-de-madrid/

MONITORING INDICATORS

No. of people participating in the cultivation of municipal urban allotments
Total area of urban allotments / Total municipal urban population
Volume (kg) of food produced in the urban gardens / Participating people

Objective SE.5: Promote a business fabric that is prepared and adapted to climate change

In order to promote a business fabric that is prepared and adapted to climate change, various strategies focused on sustainable management and public-private partnerships should be promoted.

A first effective measure is to stimulate sustainable business management through initiatives such as certification and training programmes, as they can provide companies with the necessary tools to implement more sustainable practices in their operations, from reducing carbon emissions to the efficient management of natural resources. In addition, fostering public-private collaboration based on Corporate Social Responsibility (CSR) can help drive urban adaptation actions. This collaboration can be translated into joint projects to improve green infrastructure, promote sustainable mobility and develop innovative solutions to adapt to the impacts of climate change in Santander's urban environment.

Another important aspect is to require objective justification of the climate change benefits of eligible actions in various economic sectors. This ensures that public and private investments are directed towards projects that effectively contribute to the adaptation and mitigation of the effects of climate change.

Given the importance of the hospitality sector in the city of Santander, it is proposed to raise awareness among the population and train food handlers on conservation and the cold chain in the event of extreme heat events. Adequate training in this aspect guarantees correct food safety in adverse weather conditions, taking into consideration that there is no long-term experience in extreme heat conditions.

Fostering a business fabric that is prepared and adapted to climate change requires a combination of measures that promote sustainable management, public-private partnerships and public awareness. By promoting concrete actions in these areas, business resilience can be strengthened and contribute to building a more sustainable economy that is more resilient to the effects of climate change.

The three priority actions under Objective SE.5 are presented below:

SE.5.1 Sustainable business management incentives
SE.5.2 Incorporation of adaptation criteria in the adjudication of grants
SE.5.3 Training and awareness-raising on food preservation in extreme heat events

Sustainable business management incentives SE5.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Stimulate sustainable business management through certification and training programmes and publicprivate partnerships based on Corporate Social Responsibility aimed at promoting urban adaptation actions.

FIGURE SE5.1. Business management

Source: Getty Images (CC)

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,00

FOR MORE INFORMATION
Reference: Hacia la responsabilidad social como estrategia de sostenibilidad en la gestión empresarial. (Bom-Camargo, Y. I. 2021) More information at: https://dialnet.unirioja.es/servlet/articulo?codigo=7927655

MONITORING INDICATORS
No. of companies with recognised environmental certifications / No. of companies in the municipality No. of public-private partnership agreements aimed at urban adaptation

Incorporation of adaptation criteria in the adjudication of grants

SE5.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE

Require objective justification of the benefits provided in the fight against climate change in the eligible actions in the productive, industrial, commercial, building, tourism, etc. sectors.

FIGURE SE5.2. Control of Grants for Adaptation

Source: Getty Images (CC)

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,46

FOR MORE INFORMATION

Reference: Convocatoria de ayudas para la elaboración/actualización de los planes de acción para el clima y la energía sostenible (PACES) de los municipios de la Comunidad Valenciana. (Generalitat Valenciana, 2024)
More information at: https://www.gva.es/es/inicio/procedimientos?id_proc=G23320

MONITORING INDICATORS

Percentage of eligible actions with environmental benefits
Volume (Tn) of CO_2 emissions avoided from the agreed adaptation measuresas

Training and awareness-raising on food preservation in extreme heat events

SE5.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Education	Heat waves, health	Municipal

MISSION OF THIS MEASURE

Raise public awareness and train food handlers on conservation and cold chain in the event of extreme heat events.

FIGURE SE5.3. Food handling

Source: Pixabay, Creative Commons, Zero (CC0).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,54

FOR MORE INFORMATION

Reference: Guía Didáctica de adaptación al calor (Gobierno de España, 2020)
More information at: https://www.miteco.gob.es/content/dam/miteco/es/ceneam/recursos/materiales/guiaaclimatarnos_tcm30-540408.pdf

MONITORING INDICATORS

No. of people in the catering sector with food handling certification
No. of training and capacity building activities for professionals in the sector

Objective SE.6: **Promoting sustainable and climate change adapted tourism**

In order to promote sustainable tourism adapted to climate change, it is necessary to promote actions that promote resilience and sustainability in the tourism sector. A first action is to study the carrying capacity of certain tourism spaces and infrastructures, considering the visitor population in the face of extreme weather events. Measures of this kind make it possible to properly manage the flow of visitors and guarantee the safety and well-being of those who visit these destinations, especially in situations of climatic risk.

Developing tourism deseasonalisation campaigns to reduce pressure on destinations in times of high demand or attracting funding for projects to adapt the tourism sector to climate change can include the implementation of resilient infrastructure, the promotion of sustainable practices and the training of tourism staff in climate risk management and adaptation measures.

Implementing measures to control tourist housing in saturated areas would guarantee adequate management of real social vulnerability, which would mean establishing regulations and controls to ensure balanced and sustainable tourism development, avoiding the overexploitation of resources and the saturation of infrastructures.

Integrating risks and adaptation measures in the strategic plans dedicated to tourism in the municipality ensures effective management of climate change impacts on the sector (Ley et al., 2024). Measuring tourism indicators related to sustainability and resilience allows assessing progress and adjusting strategies as needed. Finally, stimulating the adaptation of the tourism sector in the renovation of its building stock, considering the global rise in temperatures, is key to ensure the comfort and safety of tourists in a context of climate change.

The following adaptation measures have been identified for Objective SE.6:

SE.6.1 Studies of the carrying capacity of tourist sites in the face of extreme events
SE.6.2 Tourist attraction campaigns adapted to the new climatic conditions
SE.6.3 Rising finance for the adaptation of the tourism sector
SE.6.4 Calculation of actual vulnerability in tourist residential areas
SE.6.5 Integration climate adaptation in tourism plans
SE.6.6 Stimulating the renovation of the building stock in the tourism sector

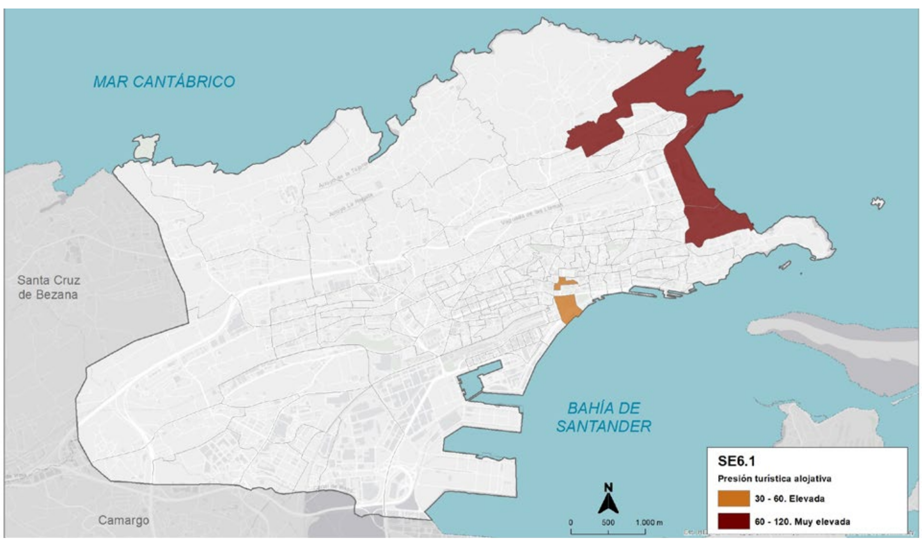
Studies of the carrying capacity of tourist sites in the face of extreme events

SE6.1

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, coastal flooding, wind, drought	Neighbourhood

MISSION OF THIS MEASURE
Study the carrying capacity of certain areas and infrastructures with a high influx of tourists, considering the visiting population in the face of extreme events.

FIGURE SE6.1. Census sections with high tourist function rate



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,44

FOR MORE INFORMATION
Reference: Estudio sobre la capacidad de carga turística en Lanzarote. (Cabildo de Lanzarote, 2024) More information at: https://www.cabildodelanzarote.com/documents/35307/0/Capacidad+de+Carga+Lanzarote.pdf/b956ae9b-bcbe-f3b2-2fb6-51b25f5fa56d?t=1684154327999

MONITORING INDICATORS
No. of hotel tourist establishments / Unbuilt-up area of the census section No. of tourist beds / Population of the census section

Tourism attraction campaigns adapted to the new climatic conditions

SE6.2

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Develop campaigns to attract visitors in the low season, encouraging the deseasonalisation of tourism in appropriate weather conditions.

FIGURE SE6.2. The main tourist attraction, El Sardinero

Source: CINCc (UC), 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,11

FOR MORE INFORMATION
Reference: El impacto del cambio climático en el turismo en España: análisis y perspectivas. (Heymann, D.A. 2024) More information at: https://www.caixabankresearch.com/es/analisis-sectorial/turismo/impacto-del-cambio-climatico-turismo-espana-analisis-y-perspectivas

MONITORING INDICATORS
No. of tourism promotion campaigns No. of tourism events in low season

Raising finance for the adaptation of the tourism sector

SE6.3

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Attract funding for projects to adapt the tourism sector to climate change.

FIGURE SE6.3. Tourism and Economy

Source: Getty Images (CC).

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 8,11

FOR MORE INFORMATION
Reference: Guía para inversiones adaptadas al cambio climático para un turismo sustentable y resiliente. (ADAPTUR, 2021). More information at: https://www.unwto.org/es/covid-19-oneplanet-iniciativas-recuperacion-responsable/guia-para-inversiones-adaptadas-al-cambio-climatico

MONITORING INDICATORS
Funds earmarked for projects to adapt the tourism sector to climate change

Calculation of actual vulnerability in tourist residential areas

SE6.4

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE

Implement measures to control tourist housing in saturated areas to ensure that real social vulnerability is calculated.

FIGURE SE6.4. Extra - hotel accommodation

Source: CINCc (UC), 2024

PRIORITY LEVEL	HIGH	**MEDIUM**	LOW	Value: 7,89

FOR MORE INFORMATION

Reference: Análisis preliminar de la vulnerabilidad de la costa de Andalucía a la potencial subida del nivel del mar asociado al Cambio Climático. (Consejería de Medio Ambiente/Junta de Andalucía, 2011)
More information at: https://www.juntadeandalucia.es/medioambiente/portal/documents/20151/522644/vulnerabilidad_costas.pdf/a71d25a3-3b00-d755-4246-e2724b2b3df9?t=1402329434000

MONITORING INDICATORS

Ratio of tourists over resident population
No. of extra - hotel dwellings / No. of dwellings per census section

Integrating climate adaptation into tourism plans

SE6.5

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Planning	Heat waves, pluvial flooding, coastal flooding, wind, drought	Municipal

MISSION OF THIS MEASURE
Integrate risks and adaptation measures into the strategic plans dedicated to tourism in the municipality, incorporating the measurement of tourism indicators.

FIGURE SE6.5. Tourism Action Plan

Source: Turismo, Santander. Ayuntamiento de Santander, 2023.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 7,23

FOR MORE INFORMATION
Reference: Marco de Sendai para la Reducción del Riesgo de Desastres 2015-2030. (Naciones Unidas para la Reducción del Riesgo de Desastres (UNISDR), 2015). More information at: https://rua.ua.es/dspace/bitstream/10045/59231/3/2016_Olcina_Vera_AnGeogrUnivComplut.pdf

MONITORING INDICATORS
No. of plans for tourism with climate adaptation criteria Intensity of tourist use per hectare in vulnerable or exposed areas No. of redefined tourism itineraries with future climate adaptation criteria

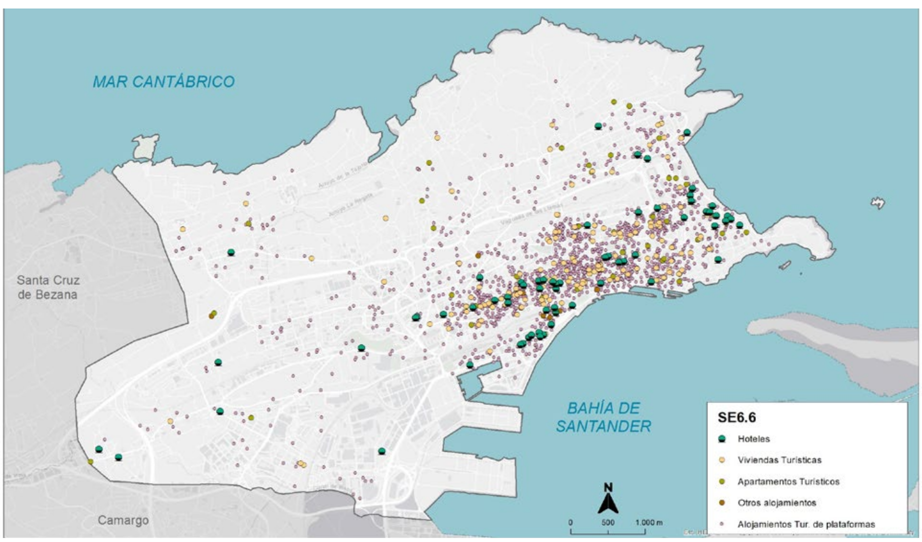
Stimulating the renovation of the building stock in the tourism sector

SE6.6

TYPE OF MEASURE	THREATS	TERRITORIAL REACH
Management	Heat waves, pluvial flooding	Municipal

MISSION OF THIS MEASURE
Stimulate the adaptation of the tourism sector in the renovation of its building stock, taking into account the global increase in temperatures.

FIGURE SE6.6. Location of the tourist accommodation building stock



Source: CINCc (UC) - FIC, 2024.

PRIORITY LEVEL	HIGH	MEDIUM	LOW	Value: 6,38

FOR MORE INFORMATION
Reference: Impactos, vulnerabilidad y adaptación al cambio climático en el sector turístico. (Gómez, M., 2016). More information at: https://www.miteco.gob.es/content/dam/miteco/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/impactosvulnerabilidadyadaptacionalcambioclimaticoenelsectorturistico_tcm30-178443.pdf

MONITORING INDICATORS
Energy efficiency in the tourism sector No. of tourist buildings renovated and adapted to new climatic conditions

MONITORING INDICATORS 7

Nareme Herrera López, Laura Asensio Martínez, Francisco García Sánchez

This document establishes a set of indicators that serve as a basis for monitoring the Adaptation Plan and is based on two basic elements:

- The set of indicators defined by the Fundación Biodiversidad for the framework of the city renaturation programme, whose purpose is to facilitate the monitoring of project progress and the evaluation of the results of the projects, as well as to establish the basis of a medium and long-term management framework to evaluate the progress of the municipality in its urban renaturation process. Several indicators of the Guide for the Measurement and Monitoring of Indicators in urban renaturation projects managed by the Fundación Biodiversidad have been incorporated as part of the Action A2 Climate Change Adaptation Plan.
- The definition of specific monitoring indicators for each of the proposed measures, guaranteeing the evaluation of the achievements obtained in terms of urban adaptation.

A Climate Change Adaptation Measures Indicator Monitoring Plan is essential to evaluate the effectiveness of the implemented actions and to adjust them as necessary. Although an Indicator Monitoring Plan is not the subject of development in this document, it has been considered advisable to establish a first list of monitoring and evaluation indicators. In a further specific development of the Indicator Monitoring Plan, the tool should contain the following components:

- The goals and targets encompassing the adaptation measures defined in this Plan provide a framework for selecting the indicators and for assessing progress towards these goals over time.
- Complementary to the indicators defined for each of the measures in this Adaptation Plan, new relevant indicators should be added to monitor the progress of the adaptation measures. Indicators should be specific, measurable, relevant, achievable and timely. They may include indicators of exposure, vulnerability, impact and adaptive capacity, among others.
- Baselines should be established as far as possible for each indicator to provide a reference point for assessing progress and determining the impact of actions.
- It is desirable to establish clear mechanisms for collecting the necessary data for the selected indicators, such as collecting existing data, implementing new monitoring systems and collaborating with different actors to obtain the required information.
- The plan should specify the frequency with which data will be collected and analysed, as well as responsibilities for monitoring each indicator. Individuals or enti-

ties responsible for collecting, analysing and reporting data should be designated. It is estimated that an annual assessment may be necessary for most indicators, although longer timeframes may be set for some indicators.

Finally, the plan should include provisions for regular reporting on the analysis and progress of the Adaptation Plan with the preparation of internal reports for decision makers, as well as communication of the results to different stakeholders, including the general public and other relevant actors.

BASELINE SENSITIVITY INDICATORS

The average municipal value (baseline) of the sensitivity indicators is presented below:

TABLE 7.1. *Base value Sensitivity Indicators (Municipal mean value)*

SENSITIVITY INDICATORS (MUNICIPALITY AVERAGE)		SENSITIVITY INDICATORS (BASELINE)
SE1-1:	Percentage of population with income per consumption unit below 60% of the national median	18.70%
SE2-1:	No. of dwellings <45m^2 /No. of total low-income dwellings (between 20-40% of the population with incomes > 60% of the national median)	470 / 0.51%
SE2-2:	Percentage of one-bedroom in low-income dwellings	0.16%
SE2-3:	No. of dwellings without collective or private heating/No. of dwellings	13,515 / 14.70%
SE3-1:	Unemployed population / Active population	5.80%
SE4-1:	Gini index	31,006
SE5-1:	Illiterate, uneducated or with first degree / Population > 15 years of age (%)	12.95%
SE6-1:	Percentage of population residing outside the optimal service areas of public health facilities.	2.06%
SE6-2:	Percentage of surface area outside the optimal service areas of public health centres.	42.00%
SE7-1:	No. Inhabitants / km	4,792
SE8-1:	Population aged >65 years/ Total Population (%)	25.73%
SE8-2:	Population aged <5 years/ Total Population (%)	3.89%
SE9-1:	Percentage of employed in dependent sectors/ Total Employed Population	1.21%
SE10-1:	Percentage of Women	53.95%

[.../...]

Continuación **TABLE 7.1**

SENSITIVITY INDICATORS (MUNICIPALITY AVERAGE)		SENSITIVITY INDICATORS (BASELINE)
M1-1:	Percentage of dwellings in pre-1940 buildings / total number of dwellings	12.63%
M2-1:	% of dwellings with deficient construction quality / Total No. of dwellings	15.90%
M3-1:	% dwellings in a dilapidated, bad or deficient state / Total number of dwellings	8.30%
M4-1:	No. dwellings / ha	25.75
A1-1:	Built-up volume / municipal area	1,267
A1-2:	% Impermeable urban area / Municipal area	62.26%
A2-1:	Estimated % pop affected by noise > 65 dB (FB indicator CBA-004)	22.16%
A2-2:	Level of Air Pollution from Vehicular Traffic	
A3-1:	Tourist Function Rate (bedplaces per 100 inhabitants)	4.85
A3-2:	Socio-environmental Pressure Index in tourist areas (Mobile)	
A3-3:	Tourist Function Fee for unregulated accommodation (Airbnb)	
A4-1:	Surface m^2 of green areas (recreational + public spaces) per inhabitant (Recreational spaces: green areas and pedestrian areas for recreation)	21.97
A5-1:	% Surface area of degraded areas	7.49%
A6-1:	Estimated population outside the optimal level of waste management coverage	0.,20%
A7-1:	% of Buildings without energy certification or with category below class E	86.23%
A8-1:	% Population >400m of public green area (or recreation space) of 0.5Ha of minimum area (CBS-002 of the FB)	3.47%
A9-1:	% Estimated population without private green spaces	53.85%

Fuente: CINCc (UC) – FIC, 2024.

SPECIFIC INDICATORS FOR ADAPTATION MEASURES

BIODIVERSITY GOAL
B1. Promote Biodiversity and soil quality for increased urban resilience
Percentage of permeable surface area / Municipal surface area
Percentage of permeable surface of open spaces / Total surface of open spaces
Percentage of surface area of private green areas / Surface area of public open spaces
Percentage of green areas in private spaces / Private non-built-up areas
Percentage of surface area with degraded areas / Municipal surface area
Number of invasive alien species per hectare
River corridors and water bodies naturalised, created or restored (No., m^2)
Surface area of Blue Infrastructure / Municipal surface area
No. of demonstration actions of NBS solutions
No. of communication and awareness-raising projects
No. of knowledge transfer activities
B2. Making urban green infrastructure an ally in the face of climate change impacts
Percentage of species adapted to the future climate / Total municipal catalogue of species
Length (m) (km) of urban green infrastructure for coastal protection
Annual volume of water reused in municipal irrigation
Percentage of adapted species / Total number of species in municipal catalogue
Annual volume (m^3) of rainwater collected and stored
Annual volume (m^3) of water reused for municipal irrigation / Annual volume (m^3) municipal irrigation water
B3. Ensure the participation of society in the management of green infrastructure in the face of climate change
Area (m^2) of coastal space threatened by loss of biodiversity
Area (m^2) with coastal and marine restoration projects
Identification of discharges and effluents (no.) on the coastline
Surface area of degraded areas / Surface area of natural areas
No. of natural areas with management and conservation plan (land stewardship)

RESILIENT CITY GOAL
R1. Develop tools to enable planning for a climate resilient city
No. of sectors benefiting from the adaptation action
GHG reduction value of the adaptation action (mitigation benefits)
Existence of future climate analysis in urban planning
No. of Urban Adaptation Areas identified
Surface area (m^2) of the General System of Open Spaces destined to climatic refuges
Identification of blue spaces
Area of naturalised water bodies created or restored
No. of blue spaces with ecological functions

No. of monitoring protocols by areas or sectors of activity
No. of adaptation measures carried out or promoted by actions
No. of safety and resilience assessments of the municipal electricity system
Time to restore service in the event of grid outage or collapse
Percentage of diversification of supply sources / Degree of external dependence
Total annual agricultural area / Municipal area
Diversity and typology of organic crops / Total agricultural area
Soil organic matter level (Annual values)
No. of dwellings in unhealthy conditions / Total no. of dwellings in the municipality
R2. Reducing the impact of extreme temperatures on the urban fabric
Surface area of new naturalised areas / Areas with potential for high temperatures
No. of trees and shrubs planted in identified high temperature areas
Area of green - cool roofs / Total area of roofs in heat island zones
Area of green façades
No. of public spaces with weather protection features
No. of infrastructures and equipment for protection from rain and sunshine
Paved area with high albedo / Total paved area
Percentage of high albedo industrial roof surface in heat island areas
Length (m) of revegetated paths or trails
Percentage of the network of paths and trails with tree cover
Surface area of open spaces with protected areas / Total surface area of open spaces
No. of trees per total length of roads and footpaths in public areas
R3. Reducing the impact of extreme precipitation events on the urban fabric
No. of Sustainable Urban Drainage Systems implemented
Permeable area promoted by SUDS / Municipal permeable area
Percentage of the sewerage network of a separate nature with respect to the total
Volume (hm^3) collected by storm tanks
Percentage of permeable open spaces / Total area of open spaces
Installed area of rain gardens
Rain garden catchment area
No. of bus stops protected from wind and precipitation
No. of land use transfer projects for retrofitting
Permeable area generated with land-use transfer projects
Identified surface area of water recharge reservoirs
Annual volume (hm^3) of abstraction from recharge ponds
R4. Reducing the impact of sea level rise on the coastline
No. of buildings exposed to coastal flooding
Building area exposed to sea level rise
Area included within the security perimeter for extreme coastal events
Budget allocated to security and surveillance measures for extreme coastal events
Volume (m^3) of sediment with coastal protection capacity

R5. Be prepared with protocols for early warning and response to extreme events
No. of monitoring tools
No. of people assigned to monitoring extreme events
No. of protocols for monitoring against drought / Sector of activity
Volume (hm^3) of water stored in supplemental systems
No. of safety and resilience assessments of the municipal electricity system
Time to restore service in case of grid failure or collapse
Economic value of policy coverage for climate change-related risks
Economic amount supported by policies for climate change impacts
R6. Optimize and control water resources in a climate change scenario
No. of leaks identified and repaired
Annual volume (hm^3) of water lost in leaks / Total volume of supply water
Average consumption of water resources (l/inhab/day)
Water consumption per inhabitant and floating population
No. of public awareness events and outreach materials
Stormwater storage capacity (Volume m^3) public and private
Volume (hm^3) of rainwater directly used for municipal irrigation
Permeable surface of aquifer recharge areas / Surface area of the recharge area
HEALTH GOAL
SL1. Developing mechanisms for monitoring and tracking climate change impacts on health
No. of persons employed at the Biometeorological-Human Health Research Laboratory
No. of research and studies published by the laboratory
No. of data collection stations
Daily count of particulate matter concentration below 2.5 microns
Number of optimised Smart City sensors
Sensor coverage area
No. of vectors identified
No. of annual vector surveillance campaigns
Surface area of areas identified as sources of disease vectors
No. of inhabitants in areas at risk due to wind south
No. of people affected in hospitals depending on the frequency and duration of the events
SL2. Capacity to respond to extreme weather, minimising its effects on health
No. of people with secured access to the Early Warning System
No. of official protocols approved for the Management of extreme heat events
No. of health service staff involved in the management of heat waves
No. of protocols established for different typologies of heat pests
Volume (m^3) of water in treated open air sources and storage sites

SL3. Reduce the risk of the most sensitive population to extreme temperatures
Hourly temperature and humidity data collection in urban heat island areas
Naturalised area with green and blue infrastructure in urban heat island areas
No. of vehicle traffic management protocols in periods of intense heat (vehicles/hour)
No. of park-and-ride car areas
Proportion of use of combustion vehicles and non-polluting and non-heat emitting vehicles
Length (m) (km) of roads incorporated into the control network for extreme events
No. of hospitalisations of elderly people in periods of extreme heat
No. of programmes disseminating information on preventive activities against Heat waves
No. of people and workplaces in heat stress conditions
No. of hospitalisations per year due to extreme heat wave effects
No. of people identified as being vulnerable to heat
SL4. Reduce the negative environmental factors affecting health
No. of deaths associated with climatic processes
No. of pathologies influenced by climatic conditions
Budget for low-noise gardening equipment
No. of low noise impact gardening equipment / Total no. of equipment
Area (m^2) blue infrastructure identified as therapeutic spaces / Blue Infraestructure surface
Length (m) (km) of strategic sanitation network resized for extreme events
ADAPTED SOCIETY AND ECONOMY GOAL
SE1. Be prepared to respond to extreme events
No. of contingency plans according to sectors adjusted to expected climate variability
No. of climatic shelters
Total capacity of climatic shelters
Population coverage within 300 m and urban area of climate shelters
No. of people registered in the early warning system mobile application
No. of annual events with concentrations above the municipal response capacity
Record of exceedance of established levels
No. of events cancelled or modified by extreme weather conditions
SE2. Monitor and assess the climate change impacts on Santander
No. of extreme weather events per year
No. of climate events exceeding expected thresholds
No. of adaptation measures implemented
No. of climate adaptation experience exchange programmes participated in
No. of adaptation projects developed in coordination with other cities and regions
No. of events - congresses for the exchange of experiences held
Funds in European programmes with an impact on urban adaptation
No. of people involved in the development of the municipal body for adaptation
No. of adaptation measures managed by the municipal adaptation body annually
No. of heritage elements exposed to extreme climatic phenomena
No. of impacts suffered due to exposure to extreme events of the inventoried assets

SE3. Understanding the implications of climate change and promoting citizen participation in adaptation
No. of outreach campaigns
No. of outreach and awareness-raising materials
No. of training activities for staff in technical areas of the administration
No. of people benefiting from the transfer of knowledge on adaptation
No. of visits to the climate change web section
Average time spent browsing the climate change sections of the website
SE4. Reduce social vulnerability to climate change
Assessment of the energy performance of buildings
No. of rehabilitated dwellings
Percentage of dwellings with vulnerable people rehabilitated / Total number of vulnerable dwellings
Public funds earmarked for climate retrofitting
Total no. of people vulnerable to climate change identified annually
Percentage of elderly people living alone and receiving care from social services
Percentage of people receiving support for electricity supply
No. of people participating in the cultivation of municipal urban allotments
Total area of urban allotments / Total municipal urban population
Volume (kg) of food produced in the urban gardens / Participating people
SE5. Promote a business fabric that is prepared and adapted to climate change
No. of companies with recognised environmental certifications / No. of companies in the municipality
No. of public-private partnership agreements aimed at urban adaptation
Percentage of eligible actions with environmental benefits
Volume (Tn) of CO2 emissions avoided from the agreed adaptation measuresas
No. of people in the catering sector with food handling certification
No. of training and capacity building activities for professionals in the sector
SE6. Promoting sustainable and climate change adapted tourism
No. of hotel tourist establishments / Unbuilt-up area of the census section
No. of tourist beds / Population of the census section
No. of tourism promotion campaigns
No. of tourism events in low season
Funds earmarked for projects to adapt the tourism sector to climate change
Ratio of tourists over resident population
No. of extra - hotel dwellings / No. of dwellings per census section
No. of plans for tourism with climate adaptation criteria
Intensity of tourist use per hectare in vulnerable or exposed areas
No. of redefined tourism itineraries with future climate adaptation criteria
Energy efficiency in the tourism sector
No. of tourist buildings renovated and adapted to new climatic conditions
No. of cancelled or modified events due to extreme climate conditions

PARTICIPATION PLAN 8

Cecilia Ribalaygua, Francisco García Sánchez, Nareme Herrera López

8.1 OBJECTIVE OF THE PARTICIPATION PLAN

The main objective of this section is to compile the actions carried out to develop the Santander Climate Change Adaptation Plan, involving local stakeholders and citizens in the decision-making process and in the identification of measures to address the impacts of climate change. To encourage citizen participation, various activities such as workshops, roundtables, surveys and public meetings have been developed to gather information, opinions and concerns of residents, businesses, organisations and other key stakeholders in the Santander area.

In addition, the participation plan seeks to promote awareness and education on climate change and its consequences, as well as on available adaptation strategies. To this end, the dissemination of the results of the studies carried out on the specific climate risks faced by Santander has been combined with public workshops in which contributions have been gathered from both citizens and different key actors in local risks. These sessions have also sought to encourage the collaboration of these entities in identifying solutions and in providing relevant, up-to-date and highly useful information to ensure the effectiveness of the Adaptation Plan.

8.2 PHASES OF THE PARTICIPATORY PROCESS

The process of citizen participation in the elaboration of the Santander Climate Change Adaptation Plan is organised in several key phases, designed to ensure the effective collaboration of all sectors of society in the identification and prioritisation of adaptation measures:

The first phase, 'Planning the Work to Co-create the Plan', focused on sharing the Project Approach, identifying local priorities and the risk perception of the different actors involved. This initial phase sought to establish a solid basis for working together, starting with the presentation of the objective and scope of the plan. In addition, workshops and interviews were conducted with a wide range of stakeholders, such as representatives of the municipal administration, emergency services, local businesses, biodiversity experts and other relevant entities, in order to gather valuable information on climate risks and the specific adaptation needs of the city.

In the second phase, 'Analysis and Identification of the Risk Index', different actions were carried out to ensure an adequate analysis of the information collected and to identify the main climate risks faced by Santander. To this end, consultations and surveys were carried out with local experts and citizens, including the Second Technical Workshop of local actors, in which valuable contributions were made to complete the validation of the risk analysis. This phase made it possible to establish the climate risk indices that served as a basis for the subsequent definition and prioritisation of adaptation measures.

Finally, in the third phase, 'Definition and Prioritisation of Adaptation Measures', citizens were involved in the technical consultation on possible adaptation measures and in the identification of those considered most relevant and urgent. Citizen workshops were carried out, promoting at the same time the awareness and participation of children and young people. In a final phase, web-based surveys were carried out to ensure broad and diverse participation in decision-making on the future.

The main actions that took place in each of the above phases are detailed below:

8.2.1. Phase 1: Approach to the work of co-creating an adaptation plan

Three types of actions have been carried out in this phase:

Public presentation of the Plan

The project was publicly presented in September 2022 in the Sustainability Room Forum of the 2022 edition of Greencities by the Mayoress of Santander. A few months later, a more extensive presentation was made in Santander, presenting the planned calendar of actions, including the participation programme for the Climate Change Adaptation Plan.

In the public presentation of the project, special emphasis was placed on the importance of public participation in the process: 'Social participation is key to achieving the objectives of "Santander Capital Natural", which is why the entire population of the city has been integrated into the proposal so that they can take ownership of the actions undertaken, through participation in decision-making or volunteering'.

At the same event, the channels for participation and access to the information, coordinated through the website and specifically for dissemination of participatory events, were also announced. Likewise, the approximate calendar of participation in the Adaptation Plan was also made public.

Risk perception initial technical workshop

In December 2022, the first technical workshop was held with a broad representation of local actors and institutions related to the affected sectors. It was a comprehensive session, combining the presentation of the project objectives with technical work in groups to identify the main local hazards, prioritisation of vulnerability factors and localisation of the main exposed sites. The session concluded with a wide range of quantitative and qualitative results.

From this event, which created a collaborative environment between participants and plan drafters, the basis for further technical consultations was established.

Figure 8.1. *Workshop I with the presence of Councillor Margarita Rojo*
Source: CINCc (UC), 2022.

Bilateral technical consultations with key entities

During the months of January to June 2023, bilateral collaboration work was carried out with entities who could provide relevant information for the Plan. During this period, the drafting team met with the following institutions, gathering very relevant contributions for the study, as well as databases, cartography, previous studies and all kinds of essential information for the development of the work. The meetings included the following:

- Those responsible for Smart City, for the collection of climatic data and the influx of people in tourist areas.

- Those responsible for the Santander Fire Department, for the identification of risk areas, potential solutions, as well as the supply and verification of important databases of outings for their geolocation.
- Aqualia, for the identification of potential improvement works and the request for information from cartographic databases.
- Municipal Tourism Office and Department of Tourism, for the collection of data and the interpretation of the potentials and weaknesses found in the local tourism sector with respect to climate change.
- AEMET, for the provision of relevant climatic information for the study.
- Head of the Parks and Gardens Department of the City Council, for the identification and characterisation of municipal green areas, as well as the main management problems.
- Those responsible for the Department of the Environment and the Urban Planning Department. Responsible for the Department of the Environment and the Municipal Urban Planning Department, to provide basic municipal information and coordination with the rest of the entities.
- Municipal Register Office, to update the socio-economic databases used in the study, as well as the supply of a large part of them, complementary to the interviews and requests held with the office of the National Statistics Institute.
- Drafting team of recent urban planning documents (Santander Hábitat Futuro) for an updated database of some of the physical and social features of the city. Based on meetings held with those responsible for the analysis criteria, previous work was interpreted and updated, giving continuity to the studies whenever possible.
- Those responsible for other ongoing research projects on local and regional urban adaptation, with the aim of coordinating methodologies and integrating their proposals into the adaptation measures.

8.2.2. Phase 2: Analysis and identification of the risk index

Three types of actions have been carried out in this phase:

Realisation of the Second Technical Workshop

The second technical workshop, ‘Climate Change Risk Analysis in Santander’, took place on 27 June 2023, with 26 active participants. This second technical workshop was attended by the same people and institutions as the initial workshop. It was a 5-hour technical session where the methodology applied to obtain the risk index and the main results obtained so far were reviewed. The contributions of the participants were key to complete the study and ensure a correct identification of vulnerability in Santander to Climate Change. With the contributions from this workshop duly incorporated into the study, the results were validated and the next phase of identification of adaptation measures was carried out.

Figure 8.2. *Photographs from the second technical workshop, preliminary results*
Source:: CINCc (UC), 2023.

Consultation with experts

In the process of selection and weighting of sensitivity factors (social, material and environmental), a process of consultation and prioritisation by experts was followed. In this sense, the methodology involved the collaboration of 5 technicians with expert criteria to identify the weight of different aspects in the sensitivity. These weightings were subsequently validated in the second technical workshop held the validation of the risk index.

Dissemination actions and participation of children and young people

To complete the diagnosis, different dissemination actions were also carried out in which the fundamental ideas of the project were transmitted, requesting the map location of the places identified as most affected by climate change. The aim was not only to gather valuable information for the diagnosis, but also to contribute to the education and awareness of the general public and participating children on the subject.

FigurE 8.3. *Participation in the European Researchers' Night 2023 activities*
Source: CINCc (UC), 2023.

Some of these actions have had an informative and recreational component, such as participation in events like 'European Researchers' Night' (29 September 2023), where people were able to experience and learn first-hand about the benefits of renaturalisation through experiments in order to subsequently provide naturalisation solutions on a giant map of Santander.

Other actions have been developed within the 'Geografícate' programme of the University of Cantabria in different educational centres in Cantabria. The sessions included information and awareness-raising on climate change, followed by the involvement of secondary and high school students in identifying areas for improvement in the city and providing adaptation solutions. These events were held in the schools themselves during the 2022-23 and 2023-24 school years.

8.2.3. Phase 3: Definition and prioritisation of adaptation measures

In the last phase of the participation process, the following activities were carried out:

Technical consultations on measures and prioritisation of experts

Based on the previous scientific work, in which the adaptation needs of Santander were identified, specific technical consultations were carried out to define measures. These consultations included a survey of experts to identify local adapted species, with the aim of prioritising their planting. Experts from the Royal Botanical Garden of Madrid and other specialists in Forestry Engineering and Palynology were involved, given the importance of green infrastructure within the Plan.

In addition, various consultations were held with the municipal technical teams of Parks and Gardens, the Department of the Environment and the Urban Planning Department of Santander City Council. Given the importance of risk management, several meetings were held with the Chief of the Santander Fire Brigade, which resulted in high quality primary information for decision-making.

However, the globality of the measures were also subject to participatory analysis with expert criteria and municipal technical managers. In total, a group of 15 experts and technical managers collaborated in the prioritisation of the initial proposed measures, both through voting and qualitative comments to qualify and, in some cases, group measures. With these contributions, a list of 88 adaptation measures was consolidated, which were taken forward for consultation in the citizens' workshops.

Citizen workshops (co-design of climate change adaptation measures in Santander)

Once the measures had been identified by the research team, and after prioritisation in the previous action, the content of the measures, grouped into adaptation objectives and targets, was put out for public consultation in the last week of November 2023. In the workshops, presentation tasks were carried out, both of the expected reality in Santander in terms of climate risks and of the possible adaptation strategies.

The workshops were held in different cultural centres in the most affected neighbourhoods, as well as in different academic environments, with school children, university students and people from to the senior programme. During the sessions, numerous contributions were made on the measures, helping to define and prioritise them. The final result was 85 adaptation measures.

Awareness-raising, and child and youth participation

The prioritisation of the 85 measures also allowed for awareness-raising in schools, where the Plan continues to be disseminated and participants are asked to collaborate with new contributions. These sessions follow a similar format to the citizens' workshops: a first part of presentation; a second part of work in small groups to prioritise the measures of a specific goal; and a final part of sharing the results where there is an opportunity to include nuances, improvements and possible locations or agents involved for the proposed measures. In these sessions, the scores given for prioritisation by the participants are noted down.

Figure 8.4. *Participatory workshops IES Alberto Pico, Santander.*
Source: CINCc (UC), 2023.

Validation through web surveys

In the last step of the Participation Plan consists in publishing the results of the Adaptation Plan in an informative format accessible to all citizens. In this last step of the process, both the Risk results and Santander's Adaptation goals, Objectives and Measures are presented. In this format, the participation of citizens is sought in the identification of priorities, as well as in raising awareness and improving knowledge about the problem.

8.3 AGENTS INVOLVED

In the early stages of the process, participation focused on the people in charge of municipal technical offices and different local agents with responsibilities associated with risk in Santander, as well as the economic and social areas most vulnerable to climate change. These agents, together with experts in climate research and its repercussions, have been the main groups participating in the initial part of the process. Their contributions have made it possible to focus the study from its first steps towards Santander's real priorities, as well as to strengthen a collaborative relationship and enrich the process.

In the phase related to the identification and prioritisation of measures, participation has been open and focused mainly on citizens. Participation in these processes have made it possible to raise public awareness of the issue and to learn about the risks facing Santander in the future.

8.4

RESULTS OF PARTICIPATORY WORKSHOPS

This section includes the results and content of the main participatory actions carried out, as well as the participating agents, the dynamics followed and their contributions.

8.4.1. Participatory Technical Workshop I: Perception of Climate Change Risk in Santander

On the perception of climatic hazards in Santander

The first questionnaire of this consultation process consisted of evaluating a long list of plausible hydrometeorological hazards (direct and derived) for the municipality with the final objective of prioritising the importance of each one specifically for Santander. First, the level of importance of each hazard was scored based on two basic criteria; the frequency with which the hazard occurs and the magnitude of the hazard in terms of intensity. The results of this public consultation are presented in Table 8.1 The process was repeated twice, first for direct hazards and in a second process for derived hazards.

TABLE 8.1. *Intensity and frequency of the direct hazards considered*

CRITERION 1: INTENSITY OR MAGNITUDE OF THREAT				
CLIMATE THREAT	LOW (1)	MEDIUM (2)	HIGH (3)	TOTAL SCORE
Pluvial flooding	1	12	8	49
Coastal flooding	1	7	13	54
Sea level rise	3	5	13	52
Peri-urban fires	8	7	3	31
Gales - extreme wind	8	7	3	31
Heat saves	8	7	3	31
Tropical / torrid nights	8	7	3	31
Drought	7	4	9	42

[.../...]

Continuation **TABLE 8.1**

CRITERION 2: FREQUENCY OR RECURRENCE OF THE THREAT				
CLIMATE THREAT	LOW (1)	MEDIUM (2)	HIGH (3)	TOTAL SCORE
Pluvial flooding	5	12	4	41
Coastal flooding	2	9	9	47
Sea level rise	7	7	7	42
Peri-urban fires	9	4	3	29
Gales - extreme wind	4	9	3	46
Heat waves	4	10	3	39
Tropical / torrid nights	7	1	3	29
Drought	6	5	3	37

Fuente: CINCc (UC) - FIC, 2024.

If we take the range of possible values for each criterion, from 0 to 63 points, we observe that none of the hazards reaches 'low' scores or below its third quantile (below 21), so that, a priori, none of the hazards analysed in the workshop can be considered irrelevant for the municipality.

More than 50% of the respondents (high confidence) agree that coastal flooding and sea level rise are the hazards with the greatest magnitude or intensity for the municipality compared to the rest of the hazards, while the perception of their recurrence becomes less cohesive, i.e., there is the same number of responses in each of the levels of relevance of the frequency criterion (low or medium confidence).

Regarding rainfall floods, more than 50% of those surveyed believe that both their intensity and recurrence have a medium level of importance (high confidence), compared to the rest of the hazards. In the case of windstorms accompanied by extreme winds, there is greater variability in the responses obtained. Nearly 80% of those surveyed considered them to be of medium or high importance for the municipality, both in terms of magnitude and recurrence, with an overall score higher than even pluvial floods. With respect to slow-onset hazards, such as droughts, the results show a level of confidence that is sometimes very low, mainly due to the fact that this type of hazard is generally perceived as more complex. However, droughts, heat waves and increased tropical nights generally achieve medium scores.

In last place, peri-urban fires affecting green areas of the municipality and peri-urban vegetation fires reach the lowest percentage of valuation of approximately 9% with respect to the total.

With respect to the incidence of derived climatic threats, the aggregate assessment of all respondents (a total of 21) indicates a higher relevance for the increase of invasive species together with an increase of vectors of new diseases, with a final score of 23% and 22%, respectively, followed by a proliferation of allergenic pollens and insect pests, both with a final score of approximately 19% and, in last place, an increase in the incidence of Saharan dust, with almost 17% of the final score. As was the case in the assessment of direct threats, none of these derived climatic hazards has "low" scores overall, with the average level being the one usually indicated by the respondents.

TABLE 8.2. *Intensity and frequency of the derived hazards considered.*

CRITERION 1: INTENSITY OR MAGNITUDE OF THREAT				
DERIVED CLIMATE THREATS	LOW (1)	MEDIUM (2)	HIGH (3)	TOTAL SCORE
Elevated levels of allergenic pollens	7	12	8	37
Saharan dust intrusion	8	7	13	32
Appearance of new disease vectors	5	10	6	43
Peri-urban fires	4	10	5	39
Gales - extreme wind	2	13	6	46
CRITERION 2: FREQUENCY OR RECURRENCE OF THE THREAT				
Elevated levels of allergenic pollens	7	10	4	39
Saharan dust intrusion	8	7	4	34
Appearance of new disease vectors	4	11	6	44
Peri-urban fires	6	8	5	37
Gales - extreme wind	4	10	7	45

Source: CINCc (UC) - FIC, 2024.

On the perception of vulnerability

The following results were obtained from the sum of the 20 contributions identified, where the variables studied were valued between 0-1 and 3, so that the maximum values will be 60 and minimum values between 0 and 20.

In questionnaire No.1, the participants evaluated the changes observed in five climatic hazards in Santander. Thus, we see in Figure 8.5 the data shows heat waves to be the prioritised hazard where these changes have been most perceived by the participants, especially in variables related to the increase in intensity, frequency and extremes.

On the other hand, all the participants observe notable changes in the prioritised hazards, the only one that does not seem to be as relevant for them being the geographical alteration of sea rise.

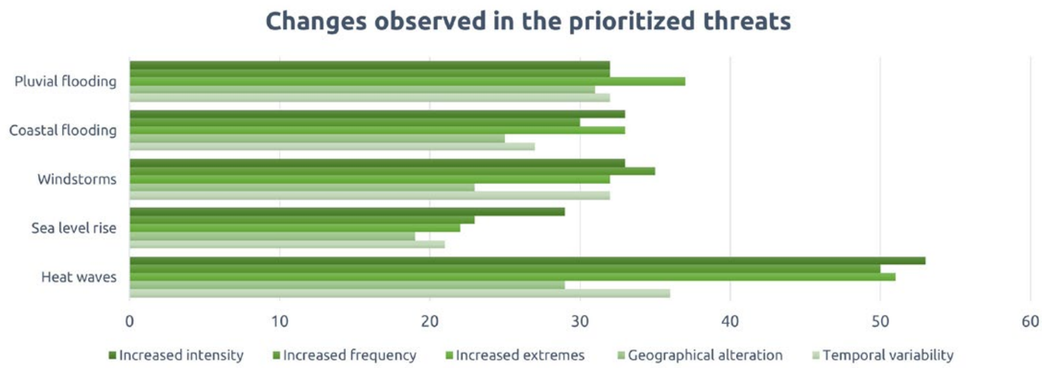


Figure 8.5. *Perceived Changes in Direct Threats*
Source: CINCc (UC) - FIC, 2024.

Questionnaire No. 2 consisted of the identification of different elements exposed to the prioritised hazards in Santander, for which five elements were chosen: population, housing, critical infrastructure, environment and economy.

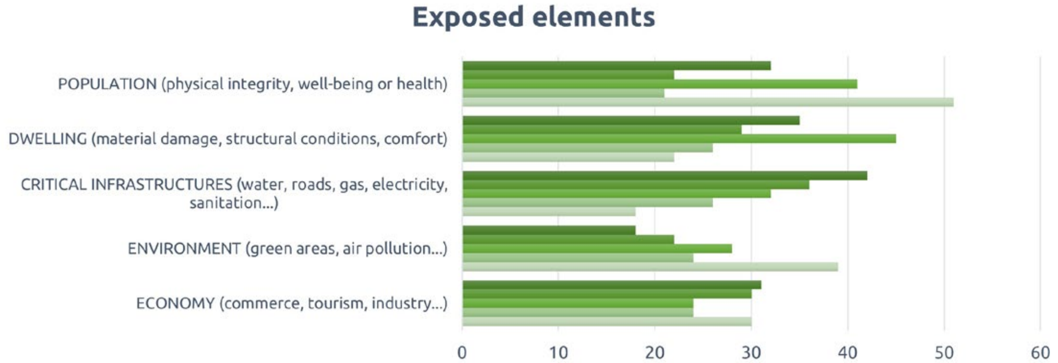


Figure 8.6. *Elements exposed to Direct Threats*
Source: CINCc (UC) - FIC, 2024.

In this case, the participants consider that the population, housing and critical infrastructures are the elements with the greatest exposure to the hazards described, highlighting in particular the effects of heat waves (threat 5) on the population, followed by the exposure of housing to windstorms.

For the participants, the exposure of the environment to pluvial floods and the exposure of critical infrastructures to heat waves were of a lower level.

On the other hand, questionnaire No. 3 analyses the relevance of different factors of sensitivity to climate change in Santander and the prioritised hazards: socio-economic sensitivity, material sensitivity and environmental sensitivity.

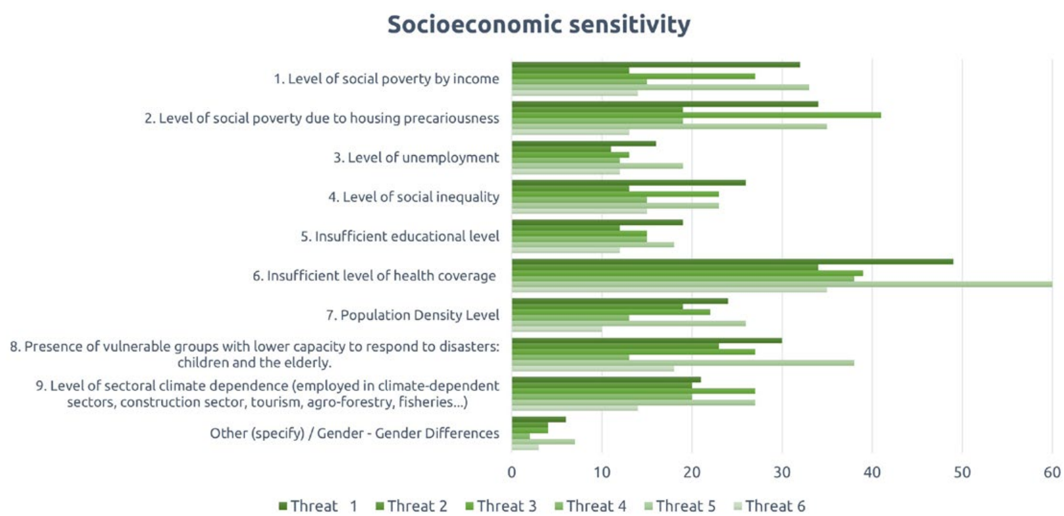


Figure 8.7. *Assessment of socio-economic sensitivity factors to Direct Threats*
Source: CINCc (UC) - FIC, 2024.

For socio-economic sensitivity, the factors related to insufficient health coverage are the most relevant of all those analysed, especially when affected by heat wave threats, thus being a very relevant problem for the respondents, while the unemployment variable and the educational level obtain the lowest values as they are considered to be not very relevant and where the different prioritised threats are not considered significant factors.

With regard to material sensitivity, we observe that none of the factors analysed is very relevant, although it is true that there seems to be a continuity in the relevance of different hazards prioritised over the different factors analysed. In this sense, pluvial floods and windstorms are the two hazards that obtain the highest values as precursors of material sensitivity in the four variables studied.

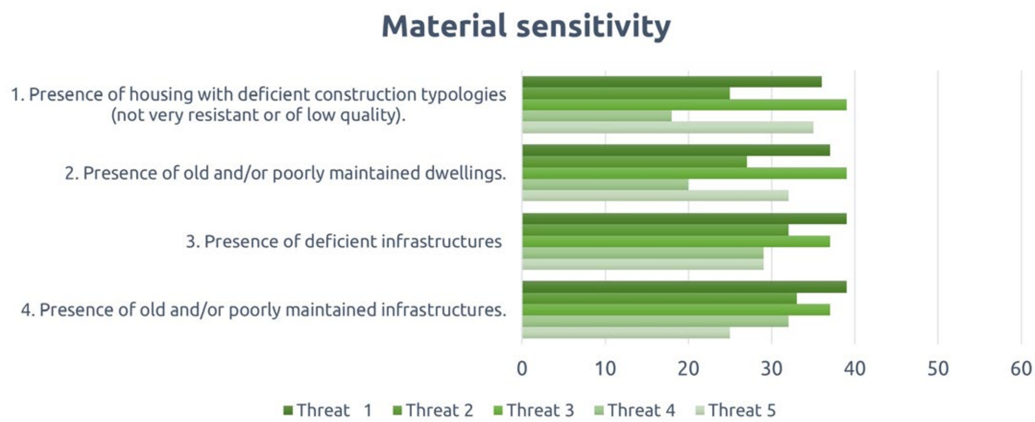


Figure 8.8. *Assessment of material sensitivity factors to Direct Threats*

Source: CINCc (UC) - FIC, 2024.

On the other hand, as we can see in Figure 8.9, environmental sensitivity is, like material sensitivity, considered a factor of little relevance for the participants, with rain flooding and heat waves as the only threats for some of the variables described.

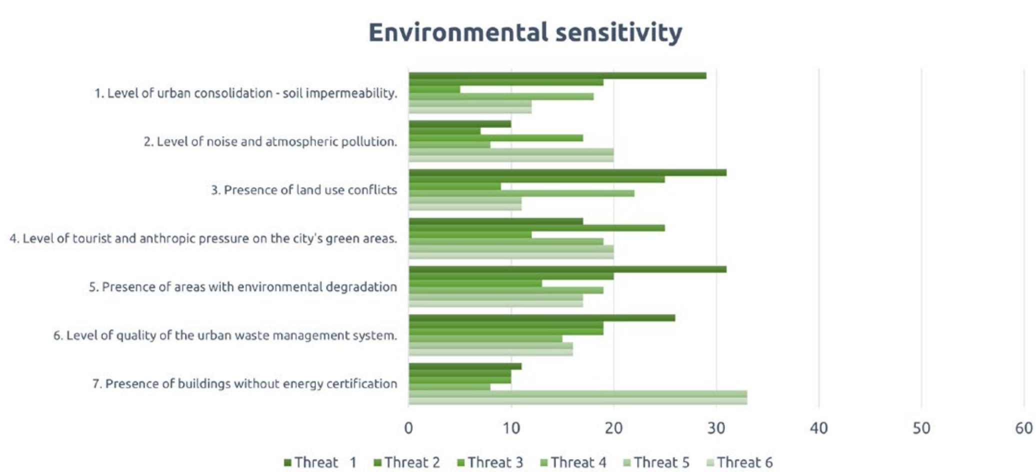


Figure 8.9. *Assessment of environmental sensitivity factors to Direct Threats*

Source: CINCc (UC) - FIC, 2024.

Finally, in questionnaire No. 4, the participants assessed how different factors can help to adapt, reduce or eliminate potential damages derived from the prioritised hazards, for which six blocks were established that group together different capabilities in the face of climate change.

The following factors were analysed for the capacity to anticipate and prevent damage from extreme events:

A.1 Availability of effective early warning systems, hazard monitoring and control systems capable of predicting adverse phenomena and providing adequate warning.

A.2 Knowledge of the population on what to do in case of emergency (level of social training on risk).

A.3 Existence of legislative regulation and urban planning in terms of risk.

In this block, the participants agree that all the factors described above are important for dealing with all the threats.

The following factors were considered for local intervention and response capacity:

B.1 Availability of civil protection services in the event of disastrous events (1st response of security and citizen protection resources).

B.2 Existence of evacuation and relocation centres for affected people.

B.3 Availability of local medical health care resources in the event of disastrous events in terms of the number of people potentially affected.

In general, they were not considered to have a very significant importance, with the exception of factor B.1, the most relevant factor in relation to the different prioritised hazards, and factor B.3 with hazard 5 (heat waves).

The following factors were considered in terms of resilience to disastrous events (institutional and economic approach):

C.1 Availability of mechanisms and resources for early recovery from damage-existence of an insurance system, flexibility of affected companies, efficiency of housing reconstruction companies, etc.

C.2 Existence of public economic resources for intermediate investment in material damage recovery work.

C.3 Existence of private economic resources for intermediate investment in material damage recovery work.

C.4 Institutional capacity to promote and finance disaster recovery projects and adaptation measures with local implementation.

In this case, all the factors were considered important against the prioritised hazards, but it is observed that in hazards 4 and 5 (sea level rise and heat waves) the factors were less important against resilience after disastrous events with an institutional and economic approach.

On the other hand, two factors were considered for their ability to withstand a potentially disastrous even:

D.1 Having adequate infrastructures (sewage networks, roads, dikes, etc.) to contain climatic hazardas or reduce potential damage.

D.2 Having critical buildings and equipment whose construction typology is efficient to withstand climate hazards or significantly reduce potential damage.

Finally, with regard to ecosystemic buffers against potentially disastrous events (systemic approach), two factors were analysed:

E.1 Open spaces and green infrastructure capable of buffering damage from extreme weather events.

E.2 Degree of green coverage in the municipality to reduce or prevent climate damage.

The results obtained in this workshop were transferred to the subsequent multi-criteria analysis for the selection of vulnerability factors. Likewise, as mentioned above, the results referred to the selection of hazards were integrated into the analysis of the present and future climate.

8.4.2. Participatory Technical Workshop II: Climate Change Risk Analysis in Santander: Presentation of Preliminary Results

After the intervention of the speakers, the last block consisted of the contribution of the different attendees on doubts, considerations, as well as contributions to take into account in the modification of some variables or for the validation of the same.

In addition, an online and collaborative resource, Mymaps, was opened for attendees to post comments on a mapping established by the FIC and the UC with layers of information related to climate hazards, as well as locate areas where they perceived or had witnessed problems of the same nature.

The following My Maps web link was used for participation: https://www.google.com/maps/d/u/0/edit?mid=1MrgOUs6Y35hXPq9KAOLJOUTsCXc7xXo&ll=43.46658008636385%2C-3.86348592455598&z=12

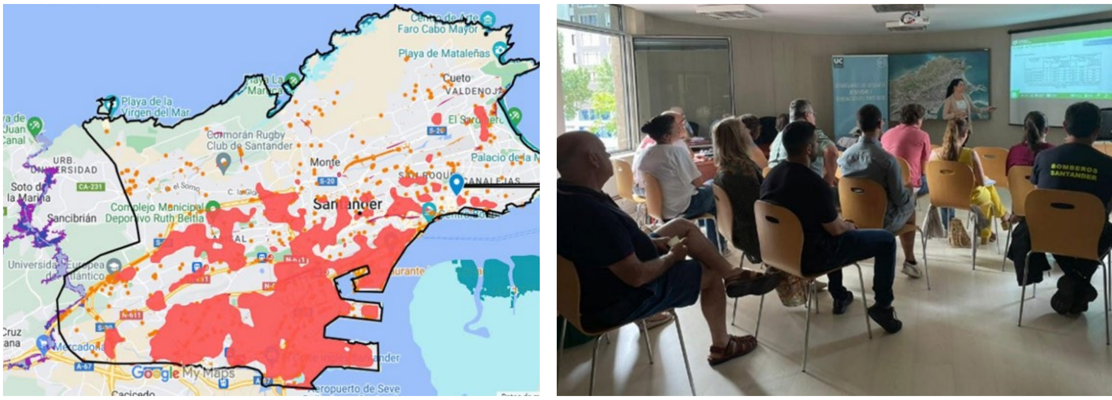


Figure 8.10. *Photographs from the second technical workshop, preliminary results*
Source: CINCc (UC), 2023.

The results of the workshop made it possible to ratify and qualify the preliminary results of the Climate Change Adaptation Plan and, more specifically, the Climate Change Scenario analysis for Santander (2050-2100), the hazard analysis and the vulnerability analysis.

8.4.3. Citizen Workshops: Co-Design of climate change adaptation measures in Santander

Once the presentation was finished, through collaborative activities, the participants began to evaluate and prioritise the different goals and objectives of the Adaptation Plan, assessing the aspects of the Plan that seemed the most and least relevant to them.

Figure 8.11. *Development of Participatory Workshops in civic centers*
Source: CINCc (UC), 2023.

In groups of 2-3 people and in a brainstorming format, different groups were formed to evaluate and discuss the specific measures for each of the goals, to finally indicate which of them was of the highest priority for each of the specific objectives described, as per their perception and knowledge, justifying and debating with the rest of the attendees.

The attendees validated the grouping of the measures into 4 goals: Resilient City, Biodiversity, Health, and Adapted Society and Economy, which in turn have specific objectives:

GOAL 1: RESILIENT CITY

To achieve an urban fabric and critical infrastructures adapted to the future climate

- R1. Develop tools to enable planning for a climate resilient city
- R2. Reducing the impact of extreme temperatures on the urban fabric
- R3. Reducing the impact of extreme precipitation events on the urban fabric
- R4. Reducing the impact of sea level rise on the coastline
- R5. Be prepared with early warning and response protocols for extreme events
- R6. Optimize and control water resources in a climate change scenario

GOAL 2: BIODIVERSITY

Promote a resilient green infrastructure adapted to the future climate, favoring biodiversity and enhancing the ecosystem services it offers

- B1. Promote Biodiversity and soil quality for increased urban resilience
- B2. Making urban green infrastructure an ally in the face of climate change impacts
- B3. Ensure the participation of society in the management of green infrastructure in the face of climate change

GOAL 3: HEALTH

Improve the resilience of health care services and the epidemiological surveillance system to ensure the health of the population in the future context

- SL1. Develop mechanisms to control and monitor climate change and its impact on health
- SL2. Develop the capacity to act in the face of extreme weather, minimising its effects on the health of the population
- SL3. Reduce the risk of the most sensitive population to extreme temperatures
- SL4. Reduce the negative environmental factors that affect health

GOAL 4: ADAPTED SOCIETY AND ECONOMY

Increase the adaptive capacity of the socio-economic fabric, ensuring public awareness of climate change and monitoring of impacts

- SE1. Be prepared to respond to extreme events
- SE2. Monitor and assess the effect of climate change and its impacts on Santander
- SE3. Understand the implications of climate change and encourage citizen participation in adaptation
- SE4. Reduce social vulnerability to climate change
- SE5. Promote a business fabric that is prepared and adapted to climate change
- SE6. Promote sustainable tourism adapted to climate change

Figure 8.12. *Structure of pre-selected goals and objectives*
Source: CINCc (UC), 2024.

The main measures that obtained the highest scores were the following:

Goal 1. Resilient City

- Avoid maladaptation, planning with a multidisciplinary approach and effective measures that include landscape, socio-economic, environmental, etc., criteria.
- Integrate adaptation criteria in urban planning: 1. future climate scenarios; 2. delimitation of Urban Adaptation Areas (AAU) and 3. general systems of open spaces as a reserve for adaptation.
- Create a protocol for monitoring adaptation criteria in public and private works projects, justifying the progress achieved.

Goal 2. Biodiversity

- Renaturalise large paved surfaces by increasing the permeability of soils with the contribution of high quality soils for the promotion of biodiversity.
- Greening common spaces between blocks and block courtyards in the urban environment.
- Control and eradicate invasive species by generating an exhaustive system of data collection and species evolution.

Goal 3. Health

- Develop a Biometeorological and Human Health Research Laboratory to study the relationships between atmospheric processes, and human health and well-being.
- Create a complementary network of air quality observatories, and bio-aerosol control (with aero-allergen capture stations) for monitoring pollutant emissions and nanoparticles at census section scale.
- Optimise the Smart City sensor network to enable real-time detection of high temperature hotspots.

Goal 4. Adapted Society and Economy

- Adapt the Municipal Emergency Plan considering the expected climate variability, defining the appropriate emergency services in the event of extreme rainfall, heat waves and extreme wind.
- Identify weather shelters among open spaces and facilities, providing a list of assistance centres for vulnerable people in case of extreme events.
- Create an early warning system through cellphone applications (SmartCity or others) related to extreme weather events.
- Establish security capacity at events, celebrations or spaces with a high concentration of people, in order to guarantee response to extreme events.

The contributions made in the workshops have contributed to the adjustment of the content of the measures, finally reduced to 85 actions, incorporating the nuances, corrections and contributions of the workshops held. This consolidation of the results have made it possible to face a final phase of validation of the Plan.

8.4.3. Conclusions of the Participation Plan

The participation process as a whole has allowed the co-design of this Adaptation Plan, both with local experts and key actors, as well as with the citizenry as a whole. The participatory process has been present throughout the development of the Plan. From the beginning, it has laid the foundations of what was necessary to study to make a good Adaptation Plan for Santander, until the end of the process where citizens have intervened to define and prioritise the appropriate adaptation measures.

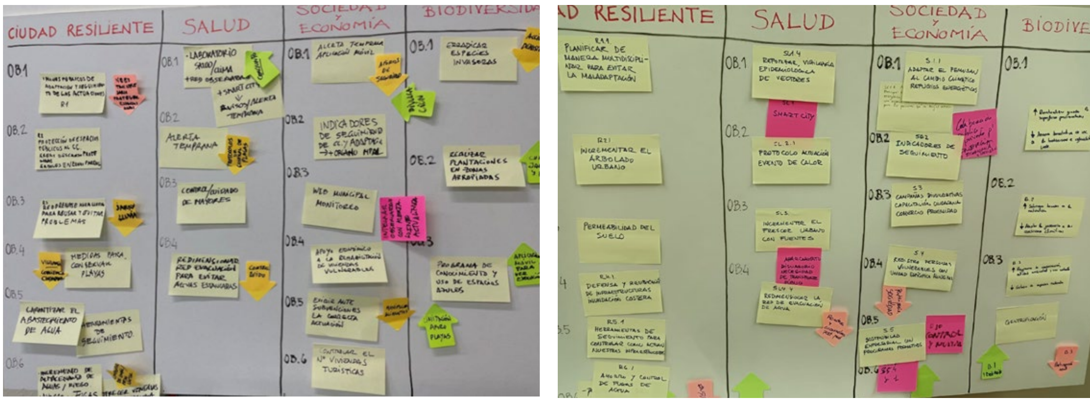


Figure 8.13. *Panel discussion of the second cycle of citizen workshops*

Source: CINCc (UC), 2024.

From the participatory processes followed for the preparation of the Plan, the following contributions stand out:

- The identification of **climate hazards**, based on the survey conducted in the initial face-to-face Workshop 1.
- The assessment of **vulnerability** and **sensitivity** by the key actors and technicians of Workshop 1, which has made it possible to assign weights to the different factors, based on knowledge of the local social, economic and material reality.
- Create an **early warning system** through cell phone applications (SmartCity or others) related to extreme weather events.
- Refinement and **validation of the risk index** and the values used to quantify vulnerability through the contributions made by the city's social actors in Technical Workshop 2.
- **The assessment and prioritisation of the 85 adaptation** measures by the public, based on Workshops 3 to 6 held in the Civic Centres and the University. The contributions made have allowed the nuance and grouping of some of the measures, as well as the reconsideration of some of those initially listed among the 88 priorities.

The consolidation of a list of sufficiently contrasted measures allows for a final phase of dissemination and publication of the results. This last phase consists in the dissemination of the information generated to the affected entities and experts who have participated in the process, as well as the dissemination to the public through the project's website and the organisation of scientific dissemination events by the University of Cantabria.

RISK CARTOGRAPHY

EXPOSURE MAPS
E.01: Location of roadways susceptible to flooding
E.02: Combined exposure index to coastal flooding projected to 2100 (RCP 8.5, Tr100 years)
E.03: Location of buildings exposed to coastal flooding with scenario projected to 2100 (RCP 8.5, Tr 100 years):
E.04: Calculation of Land Surface Temperature (LST) for day 01 / 07 / 2022.
E.05: Percentage of the resident population exposed to potential Diurnal Urban Heat Islands (DHI)
E.06: Estimated percentage of resident population exposed per parcel to potential Diurnal Urban Heat Islands
E.07: Detail of road sections, railroad lines, and natural cover exposed to fluvial flooding events.
E.08: Location of buildings exposed to north wind and Gallego (Galernas) atmospheric events.
E.09: Location of buildings exposed to south wind atmospheric events

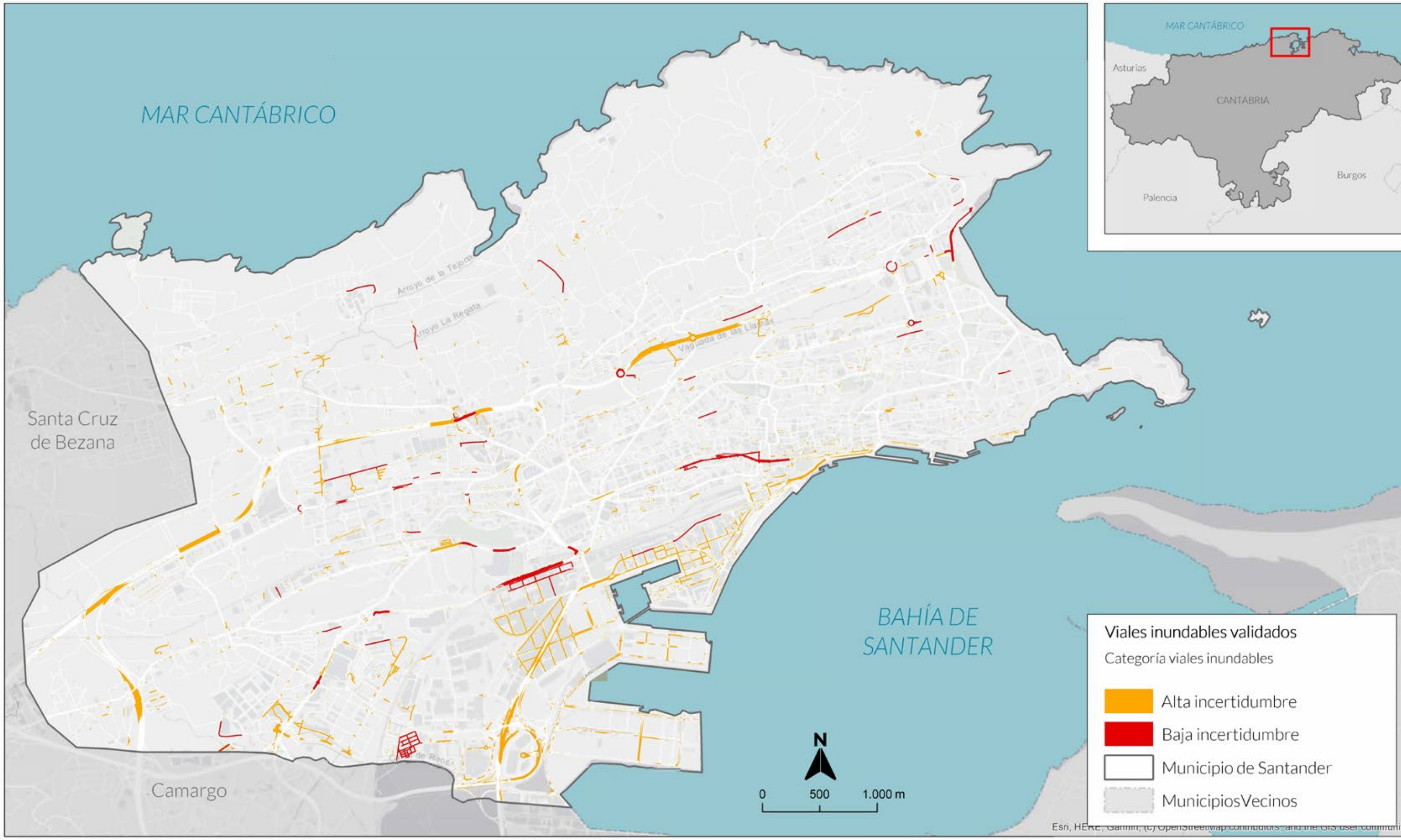
VULNERABILITY: SOCIOECONOMIC SENSITIVITY
SE/1-1: Percentage of population with income per consumption unit below the national average in Santander.
SE/2-1: Percentage of precarious housing due to lack of space (<45m^2)
SE/2-2: Percentage of precarious housing due to lack of space (1 bedroom)
SE/2-3: Percentage of precarious housing due to lack of collective or public heating
SE/3-1: Percentage of unemployed population in relation to the active population by census section
SE/4-1: Gini index by census section
SE/5-1: Percentage of illiterate population, without studies or with first degree / population> 15 years old by census section
SE/6-1: Percentage of population residing outside of optimal service areas of public health centers
SE/6-2: Percentage of area outside the optimal service areas of public health centers by census section
SE/7-1: Inhabitant density (inhab/km2) by census section
SE/8-1: Percentage of elderly population aged 65 years or older by census section
SE/8-2: Percentage of population aged 5 years or younger by census section in the municipality of Santander
SE/9-1: Percentage of population employed in climate-dependent sectors / total employed population by census section (Coastal I. - SNM)

VULNERABILITY: SOCIOECONOMIC SENSITIVITY
SE/9-2: Percentage of population employed in climate-dependent sectors / total employed population by census section (Extreme rainfall)
SE/9-3: Percentage of population employed in climate-dependent sectors as a proportion of the total employed population by census section (Extreme wind - TCA)
SE/9-4: Percentage of population employed in climate-dependent sectors /employed population by census section (Drought)
SE/9-5: Percentage of population employed in climate-dependent sectors / total employed population by census section (Heat waves)
SE/10-1: Percentage of women by census section

VULNERABILITY: MATERIAL SENSITIVITY
M1-1: Percentage of dwellings in pre-1940 buildings / total dwellings by census section
M2-1: Percentage of dwellings in buildings constructed in the year 1940 or earlier by census section
M3-1: Percentage of dwellings in substandard state of maintenance
M4-1: Density of dwellings per hectare by census section

VULNERABILITY: ENVIRONMENTAL SENSITIVITY
A1-1: Built-up volume (m^3) per total area (m^2) by census section in the municipality of Santander.
A2-1: Percentage of impervious urban land per census section in the municipality of Sanatnder
A2-2: Percentage of population affected by noise => 65dB by census section
A3-1: Tourist Function Rate per census section
A3-2: Socio-environmental pressure index taking into account the areas of touristic affluence
A3-3: Tourist Function Rate of non-regulated accommodation by census section
A4-1: Deficit of m^2 of green and recreational areas per inhabitant with respect ot the optimum of $20m^2$/ inhabitant
A5-1: Percentage of degraded area by census section
A6-1: Percentage of population outside optimal municipal waste management coverage by census section
A7-1: Percentage of buildings without energy certification or with energy certification below class ''E''.
A8-1: Percentage of population more than 400 m from a public green or recreational area with a surface area => 0.5 ha.
A9-1: Percentage of population per census section without private green spaces

RISK INDICES
Ri.01: Normalised Index of Extreme Rainfall Risk by census section
Ri.02: Normalised River Flood Risk Index by census section
Ri.03: Normalised index of risk due to potential Diurnal Heat Islands by census section
Ri.04: Normalised Risk Index for Hot Nights by census section
Ri.05: Normalised Heatwave Risk Index by census section
Ri.06: Standardised index of risk due to meteorological drought by census section
Ri.07: Standardised wind gust risk index by census section
Ri.08: Standardised index of risk due to coastal flooding events by census section



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

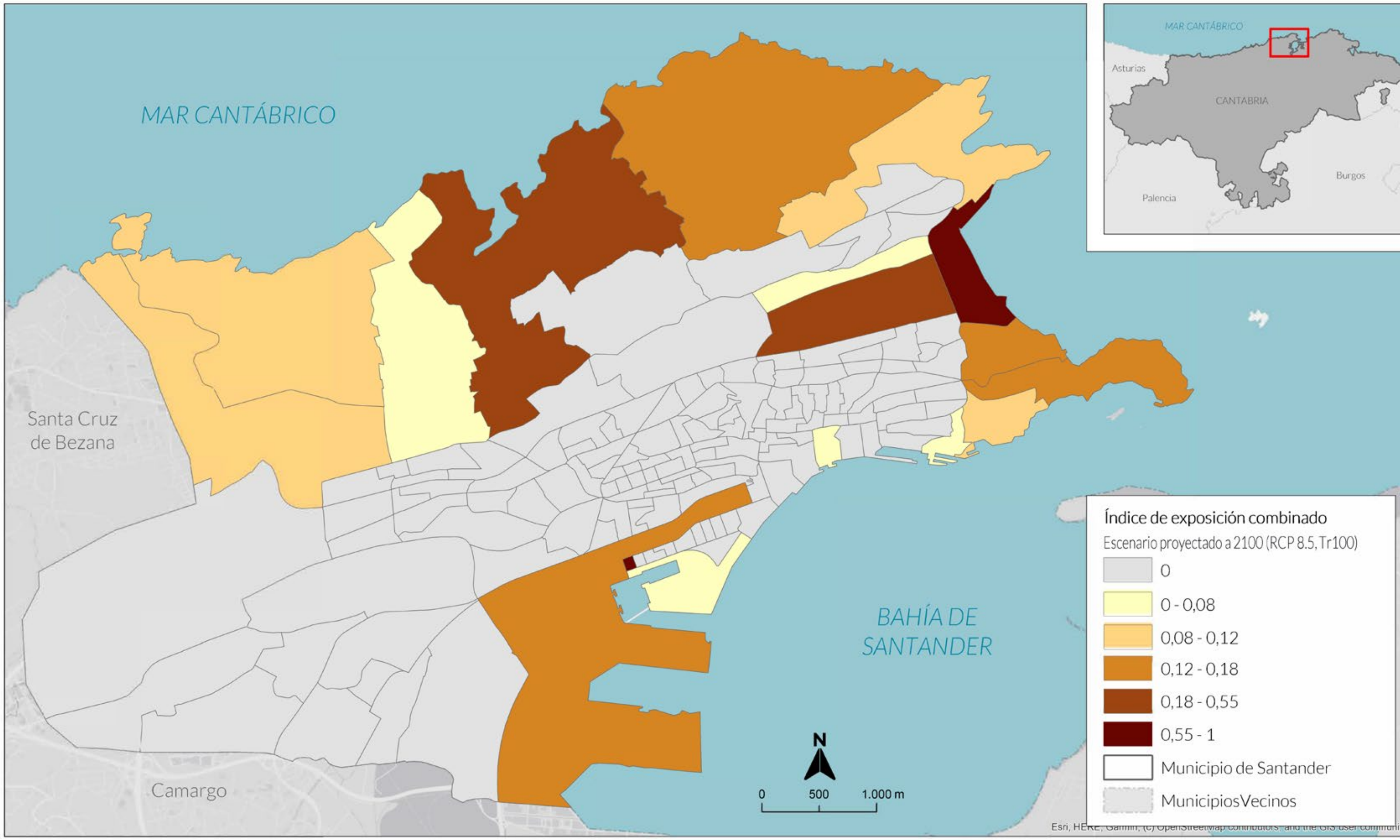
Mapa:
E.01:Ubicación de viales susceptibles de encharcamientos

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:

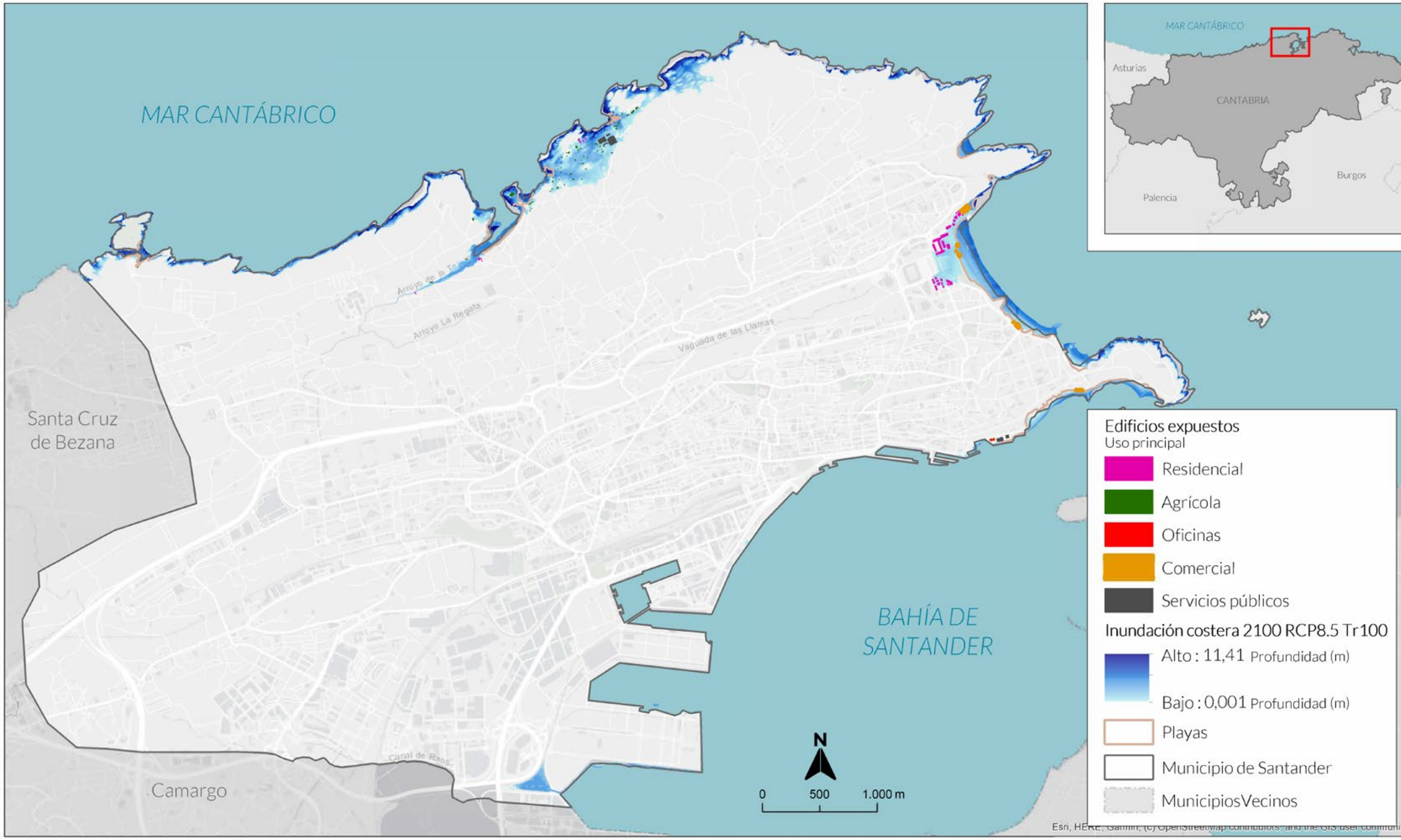


Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
E.02: Índice de exposición combinado frente a inundación costera proyectado a 2100 (RCP 8.5, Tr100 años)

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

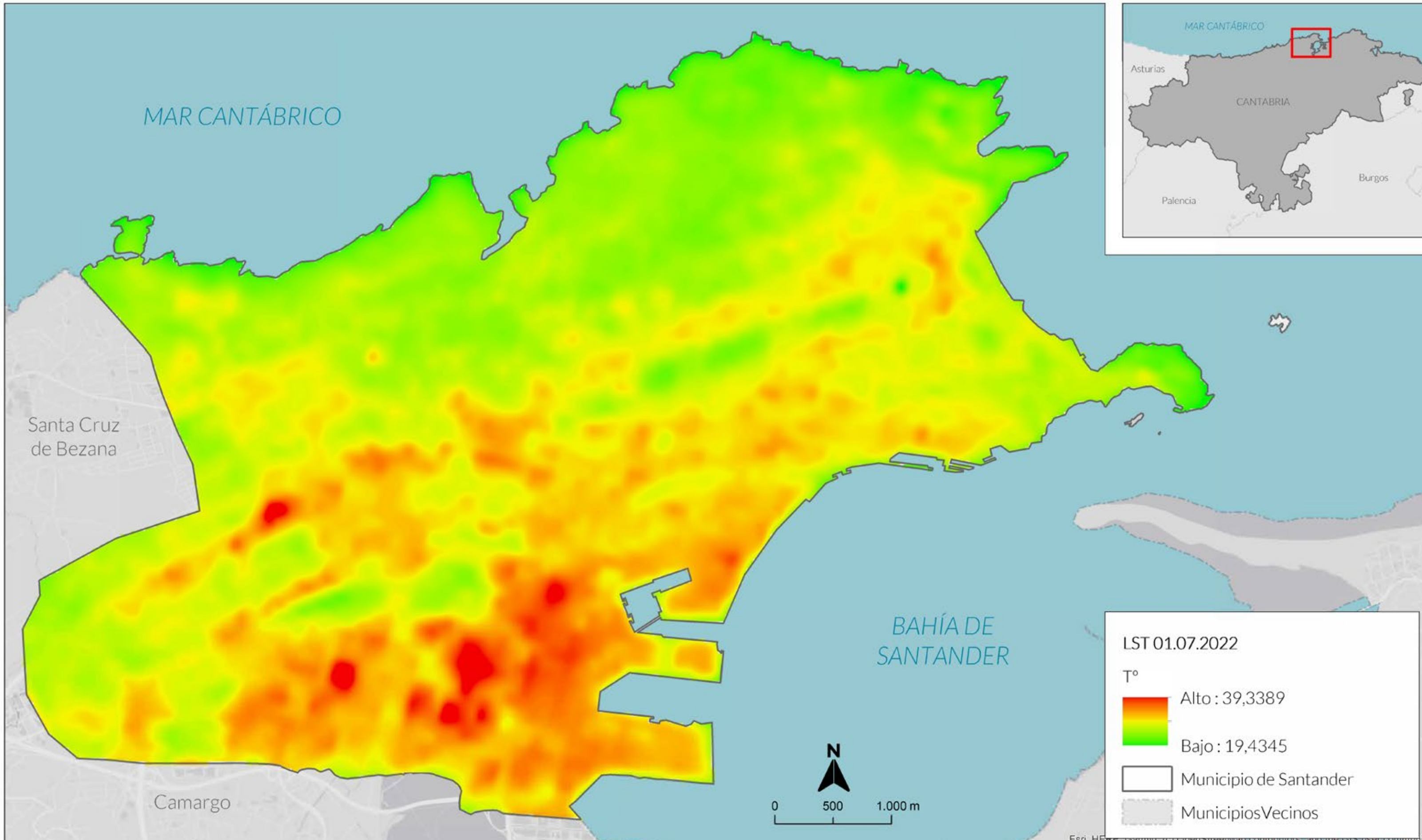
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
E.03: Ubicación de edificios expuestos a inundación costera con escenario proyectado a 2100 (RCP 8.5, Tr 100 años)

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU

Autoría:
Universidad de Cantabria
fic
SANTANDER CAPITAL NATURAL



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

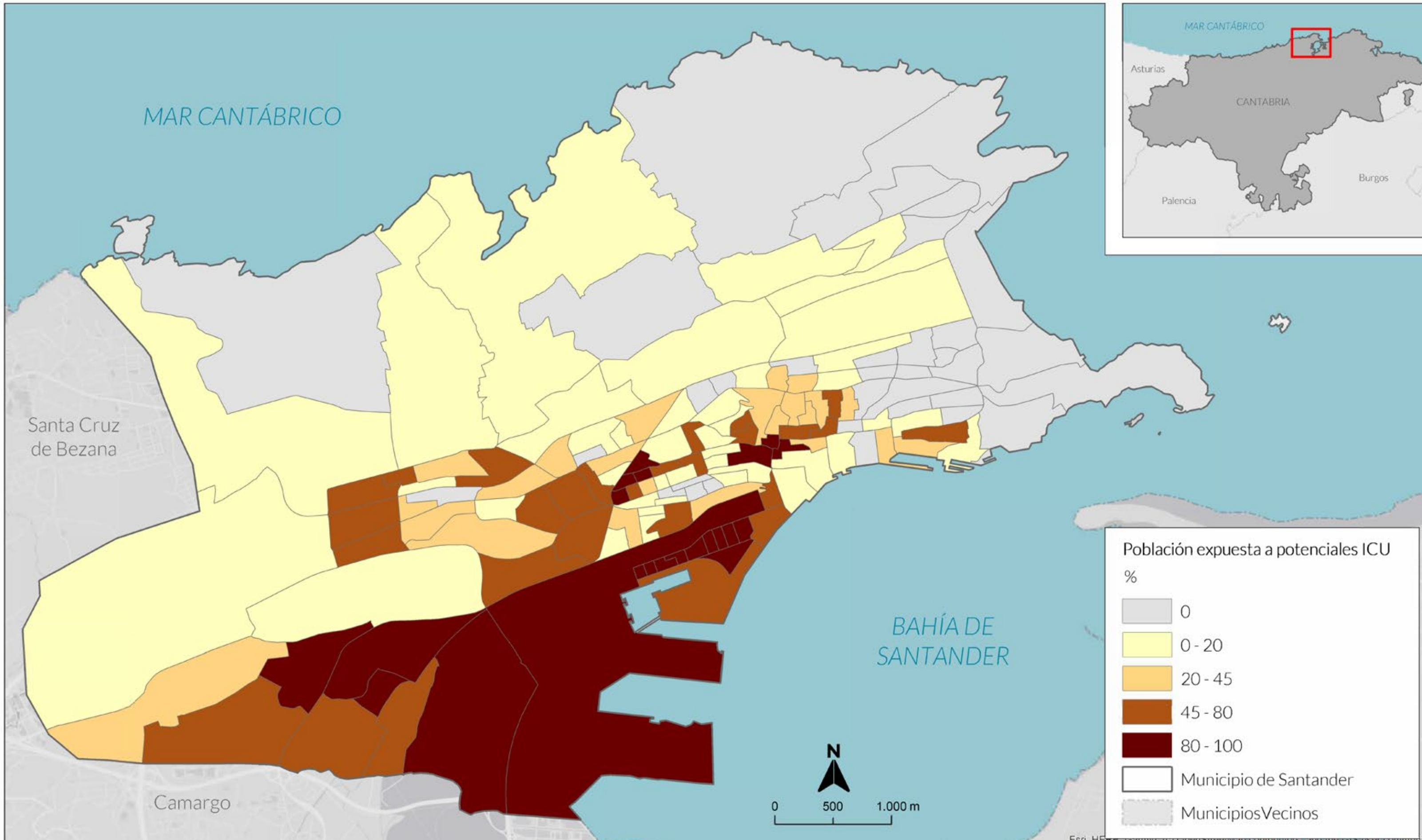
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
E.04: Cálculo de Temperatura Superficial Terrestre (LST) para el día 01/07/2022 en Santander

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

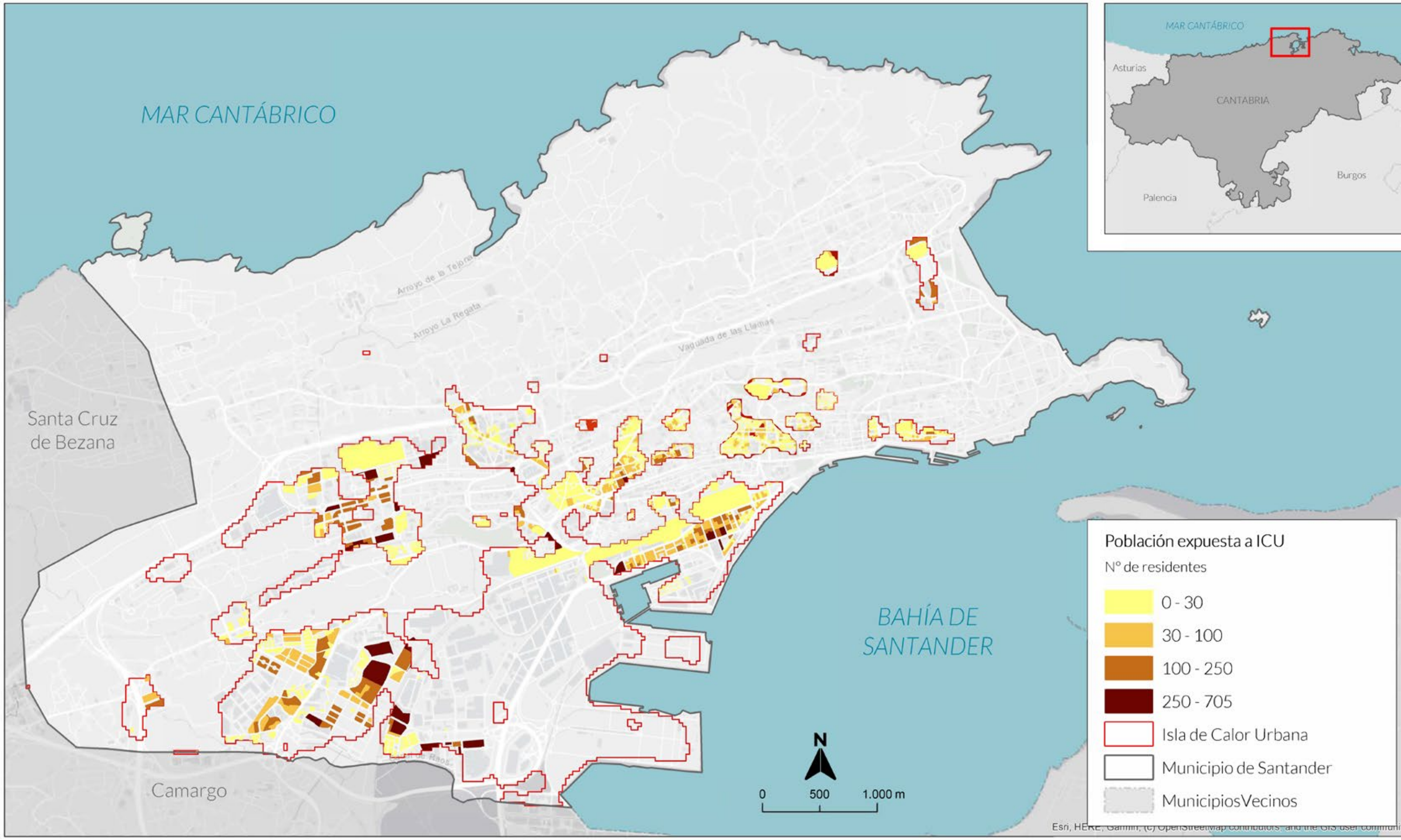
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
E.05: Porcentaje de población residente expuesta frente a potenciales Islas de Calor Urbana Diurnas

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

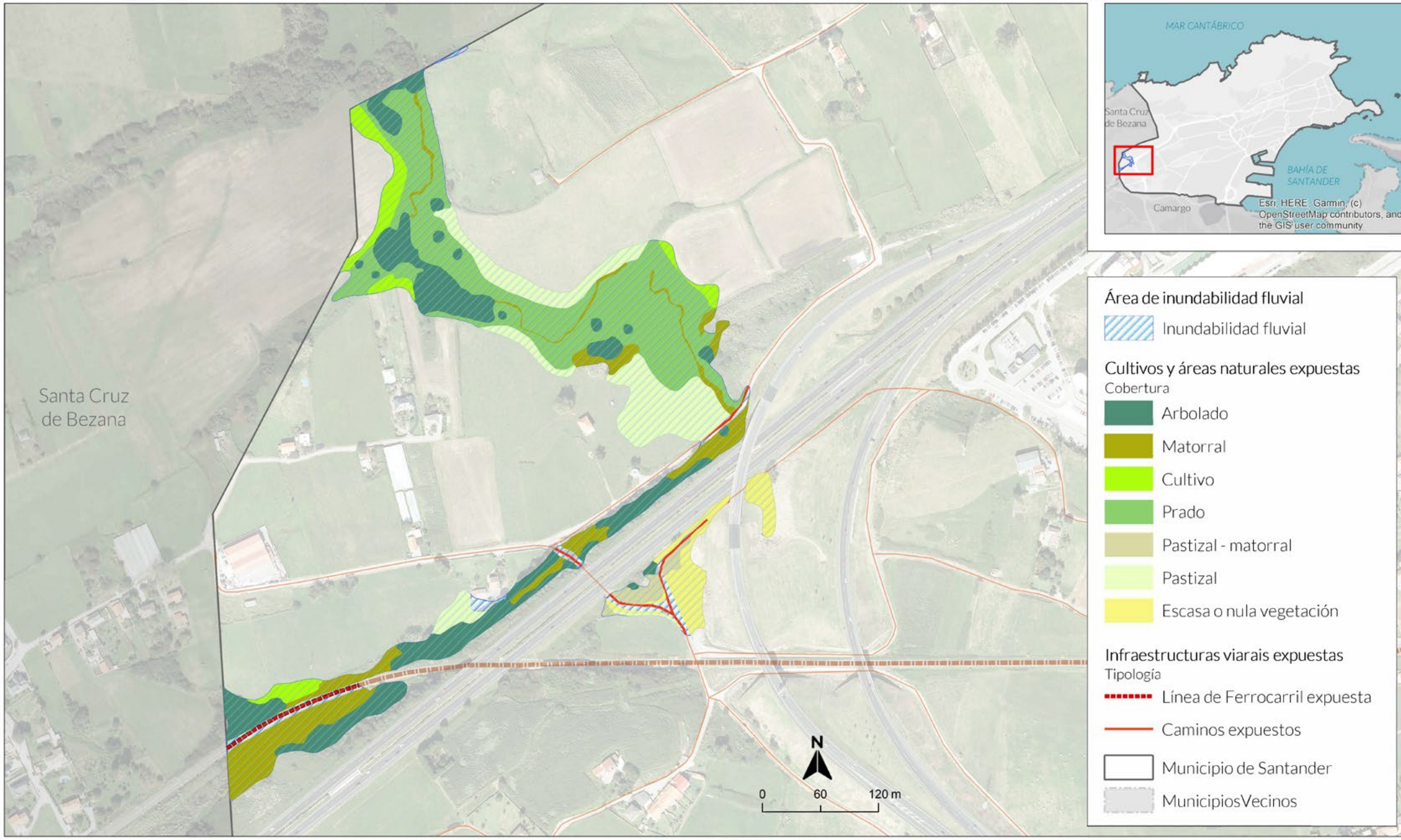
Mapa:
E.06: Población residente estimada expuesta por parcela frente a potenciales Islas de Calor Urbana Diurna

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

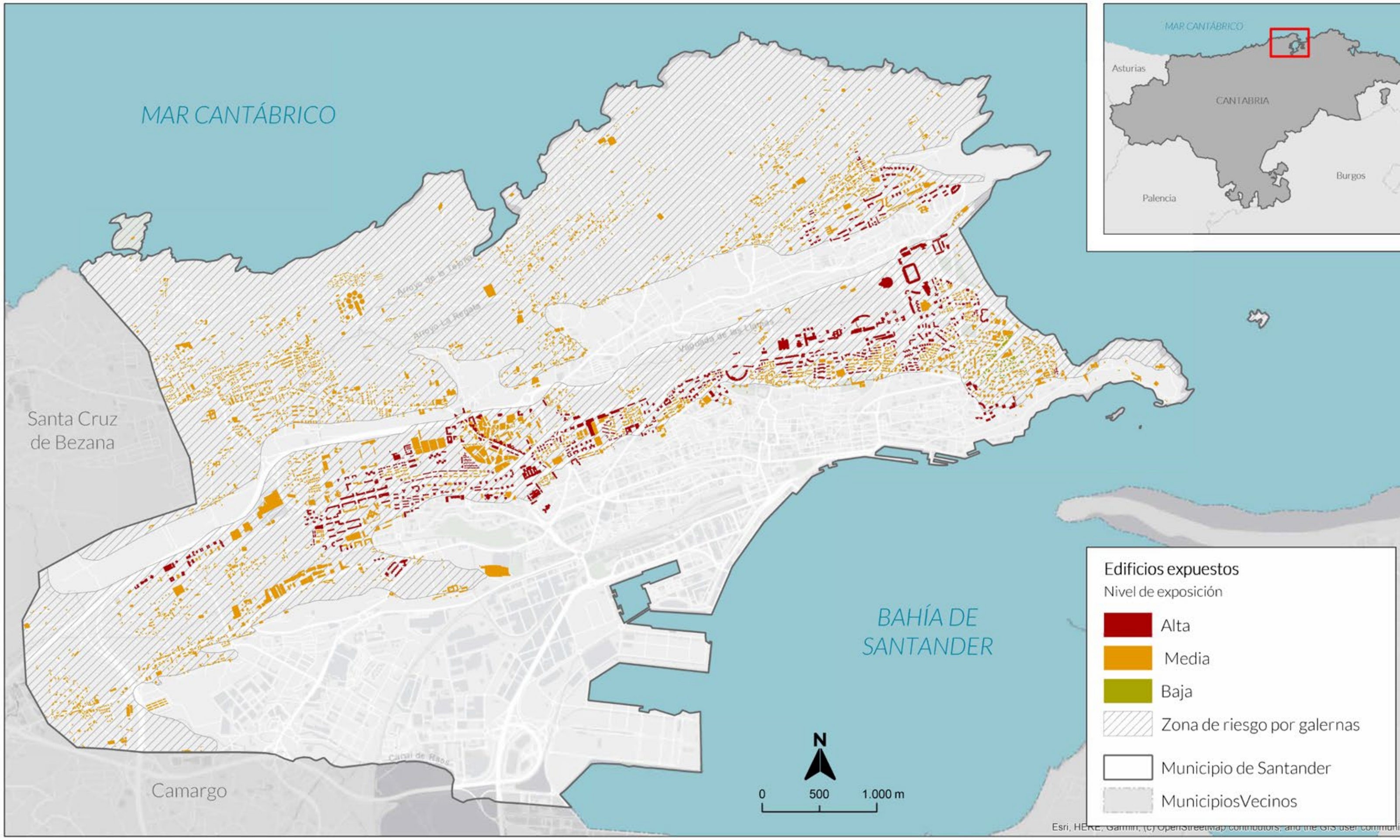
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
E.07: Detalle de tramos de caminos, líneas de ferrocarril y coberturas naturales expuestas a eventos de inundación fluvial

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea
NextGenerationEU

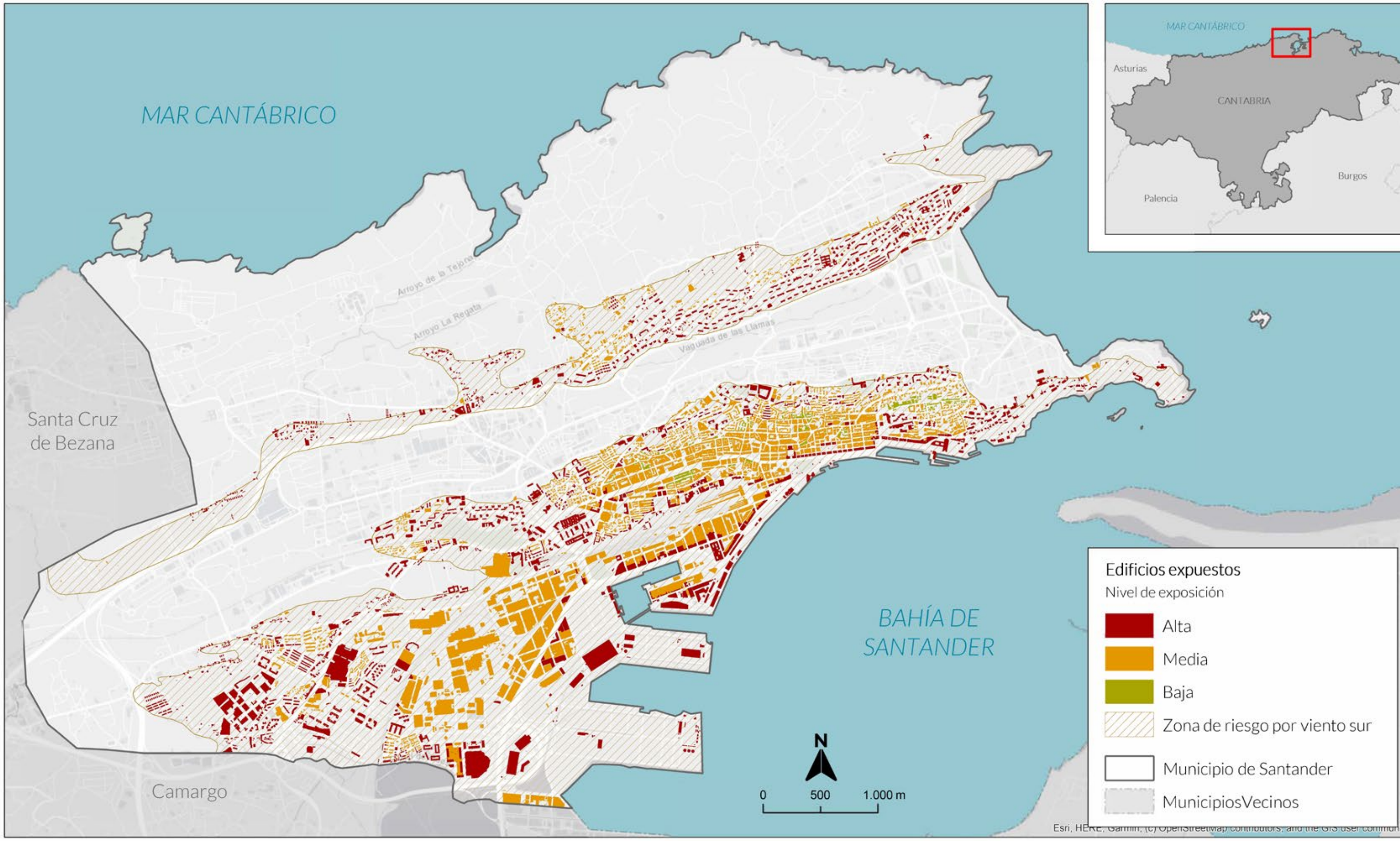
Autoría:
Universidad de Cantabria
fic
SANTANDER CAPITAL NATURAL



Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
E.08: Ubicación de edificios expuestos a eventos atmosféricos de viento de componente norte y gallego (galernas)

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU
Autoría:
UC Universidad de Cantabria



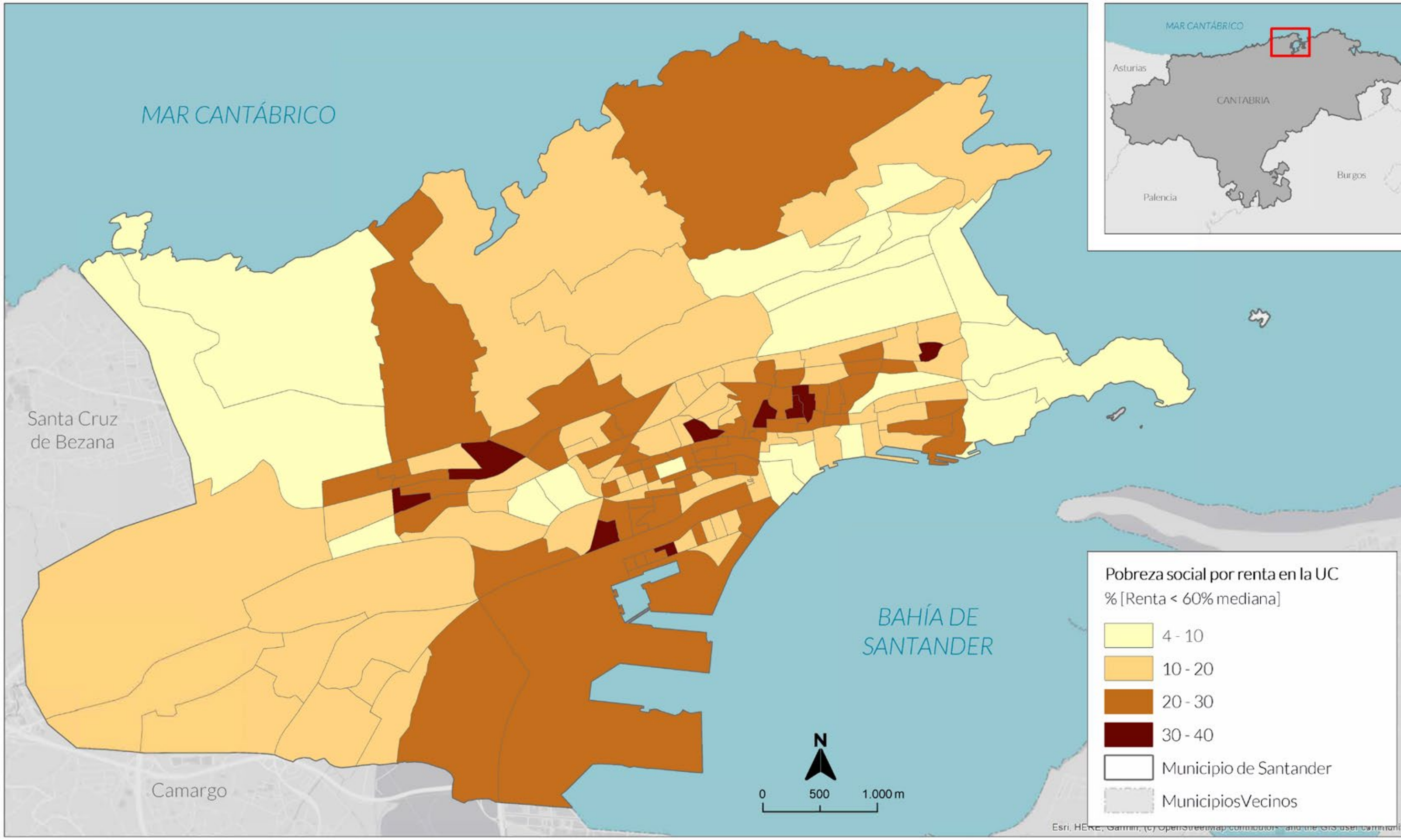
Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
E.09: Ubicación de edificios expuestos a eventos atmosféricos de viento de componente sur

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea
NextGenerationEU
Autoría:
Universidad de Cantabria
SANTANDER CAPITAL NATURAL

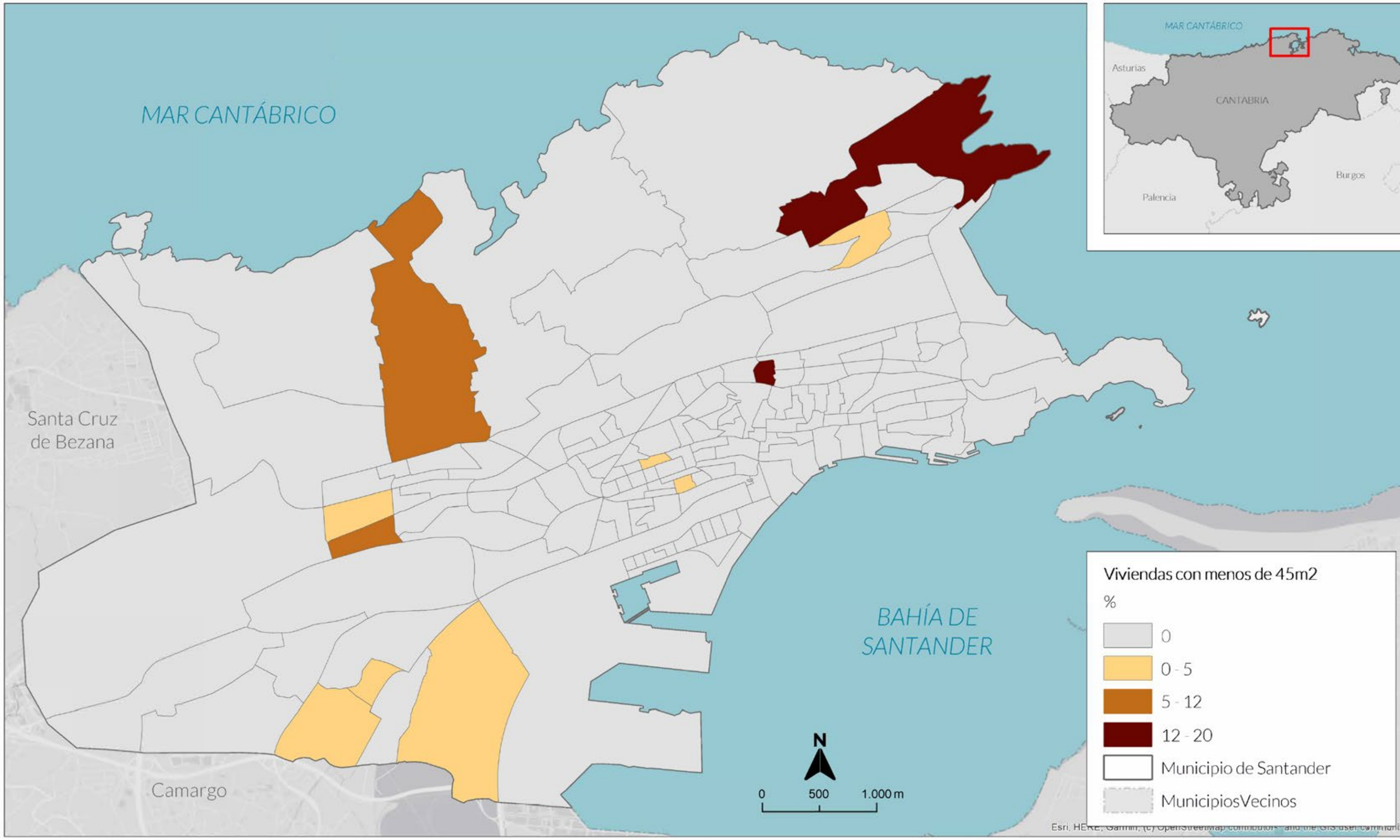


Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
SE/1-1: Porcentaje de población con ingresos por unidad de consumo por debajo del 60% de la mediana a nivel nacional en Santander

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

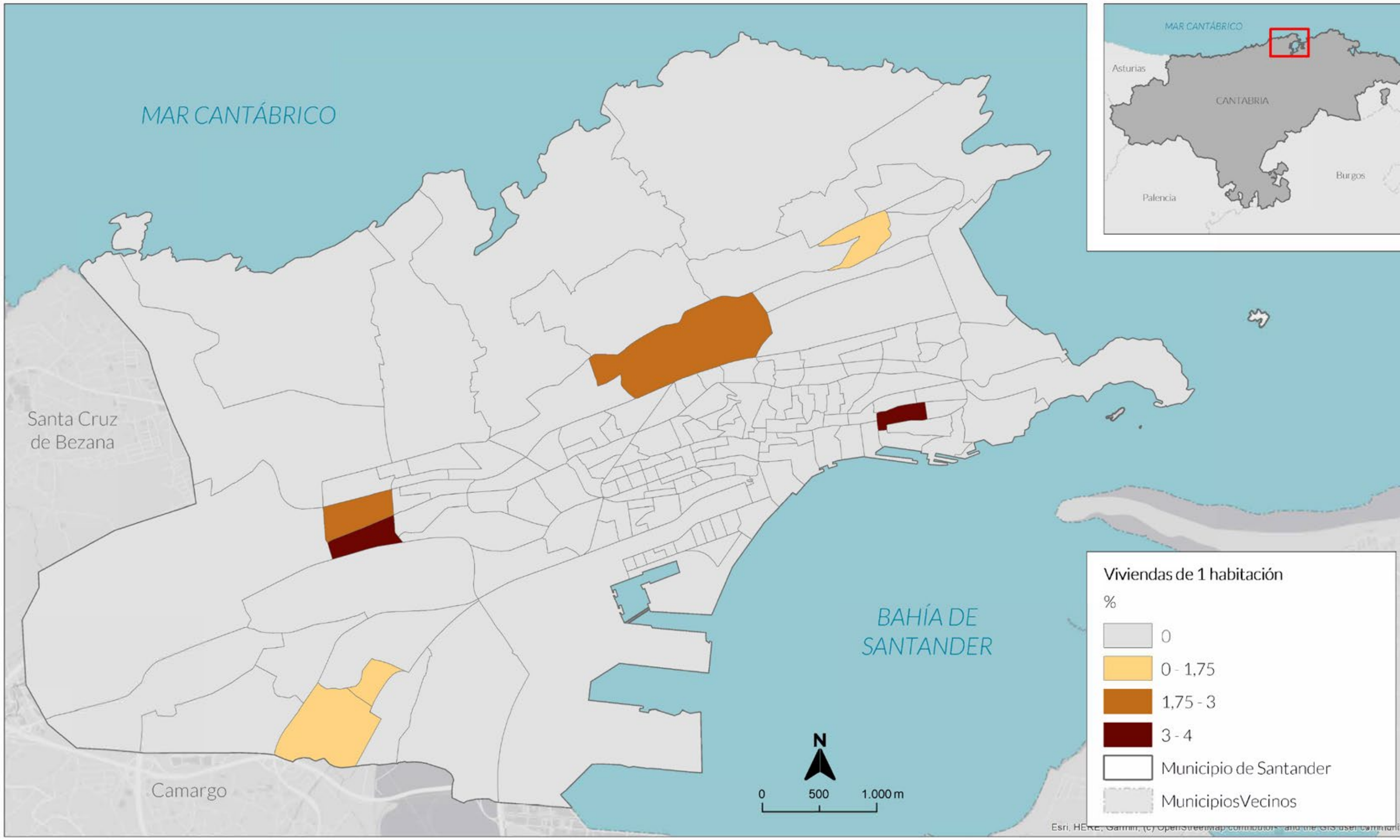
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
SE/2-1: Porcentaje de viviendas precarias por faltas de espacio (<45m2) en el municipio de Santander

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

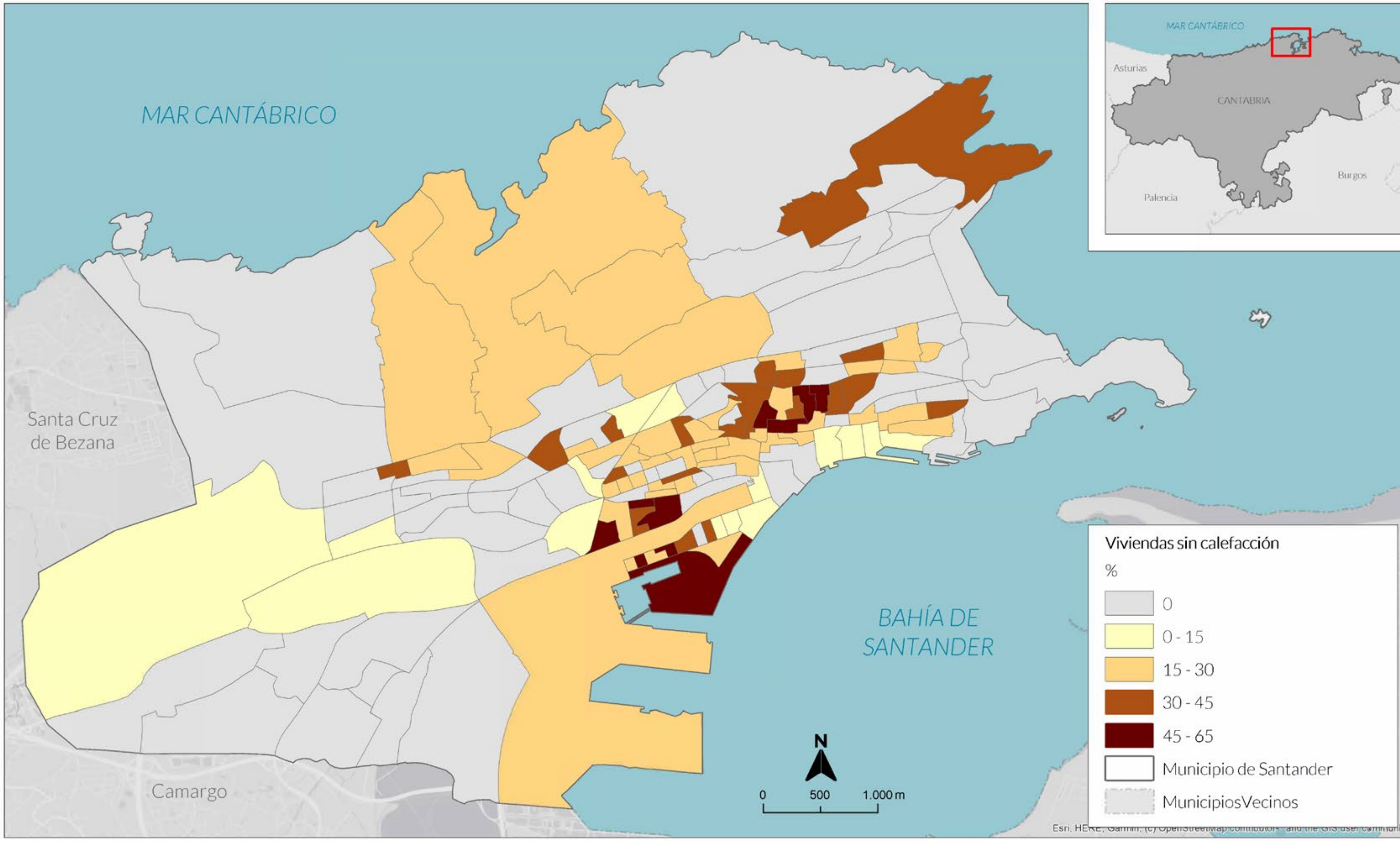
Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
SE/2-2: Porcentaje de viviendas precarias por faltas de espacio (1 habitación) en el municipio de Santander

Fecha:
Abril 2024

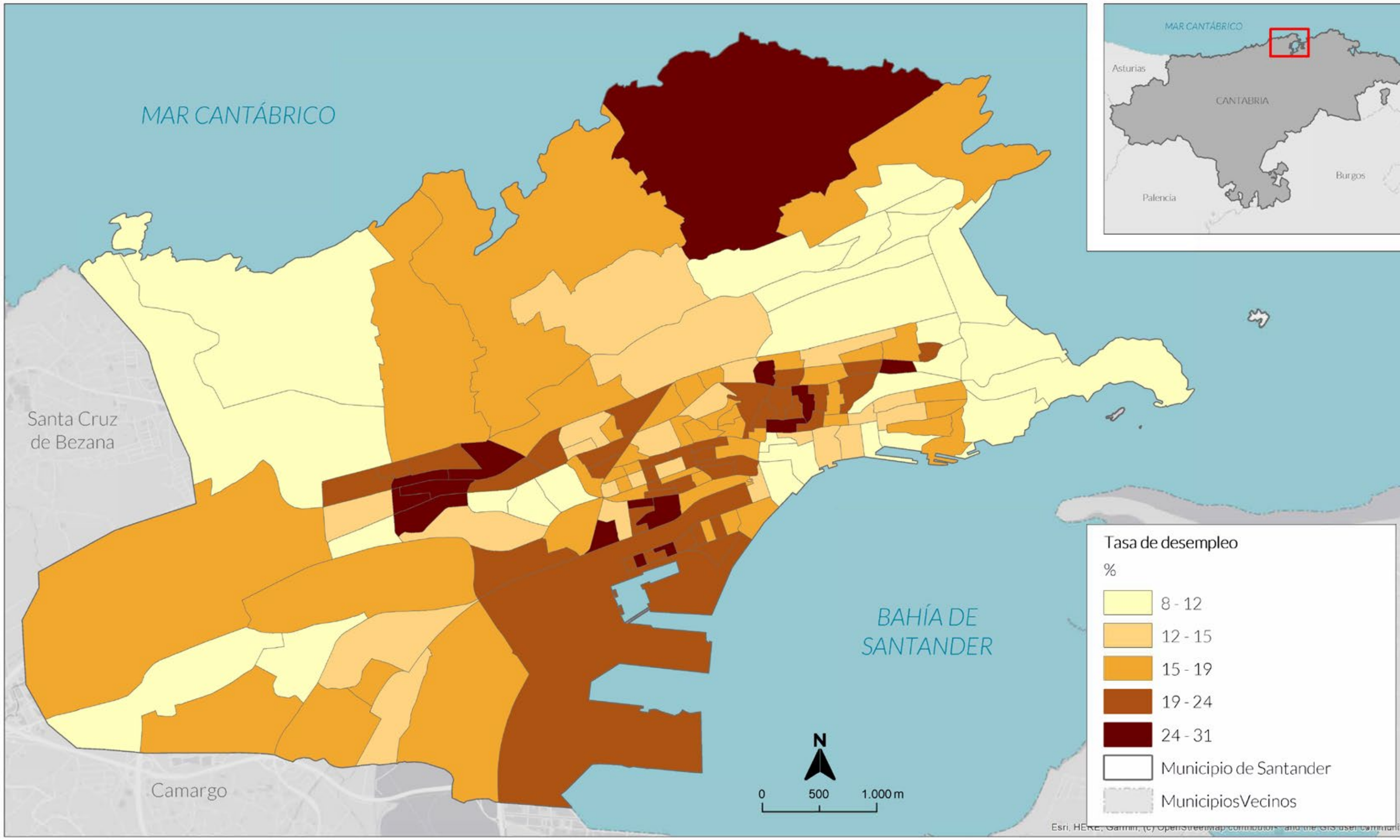
Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU
Autoría:
UC Universidad de Cantabria
fic
SANTANDER CAPITAL NATURAL



Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
SE/2-3: Porcentaje de viviendas precarias por faltas de calefacción colectiva o pública en el municipio de Santander

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea
NextGenerationEU
Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
SE/3-1: Porcentaje de población parada respecto a la población activa por secciones censales en el municipio de Santander

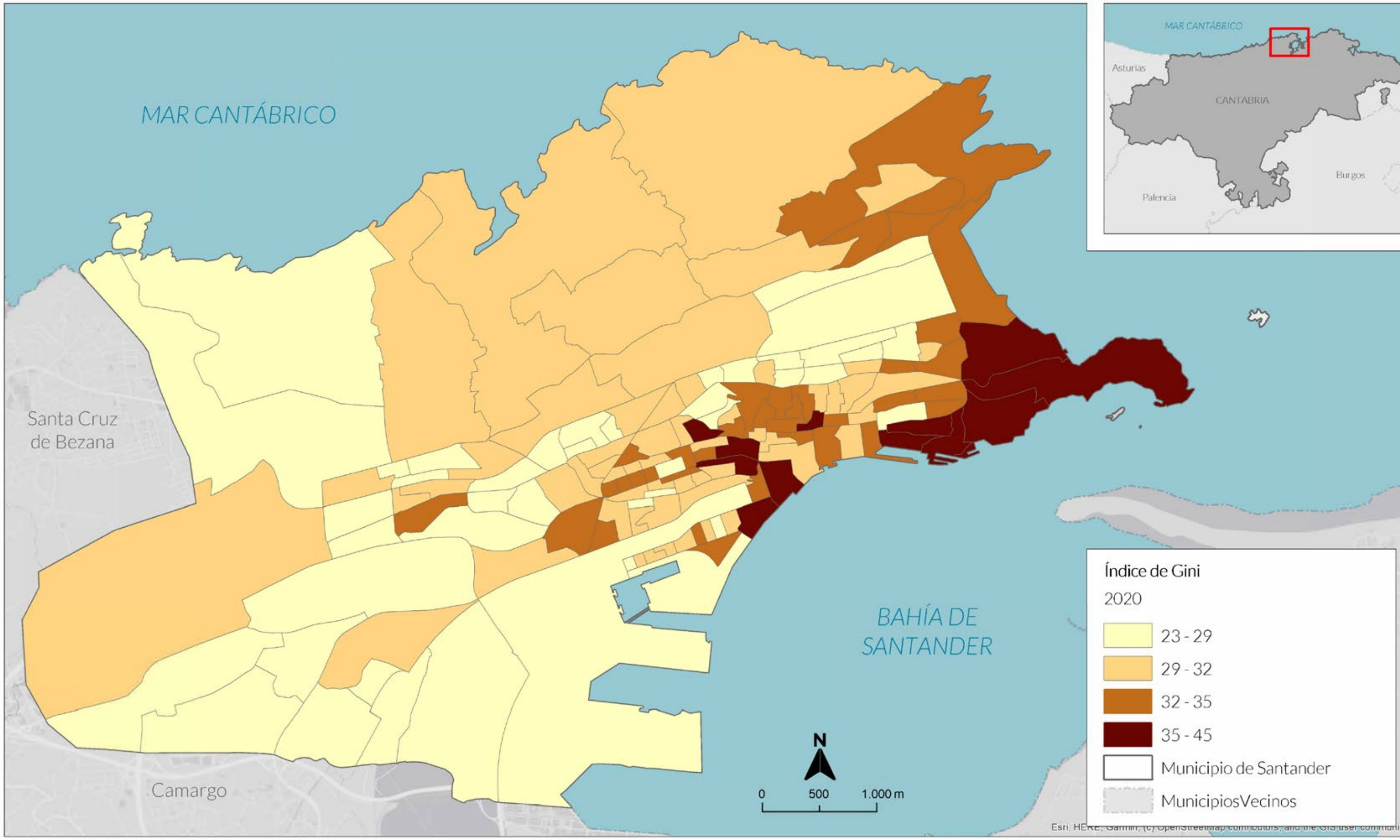
Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:

Universidad de Cantabria

SANTANDER CAPITAL NATURAL

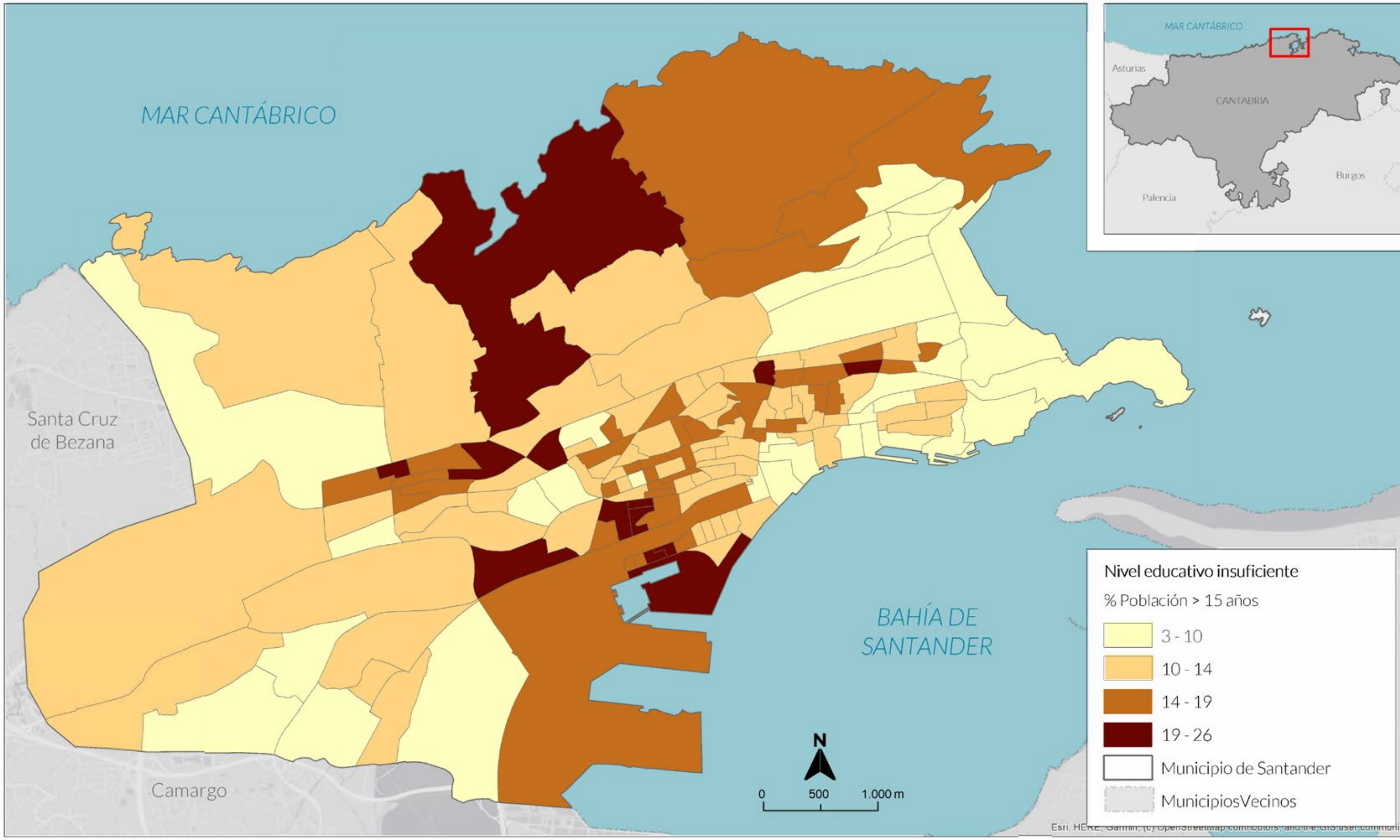


Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
SE/4-1: Índice de Gini por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

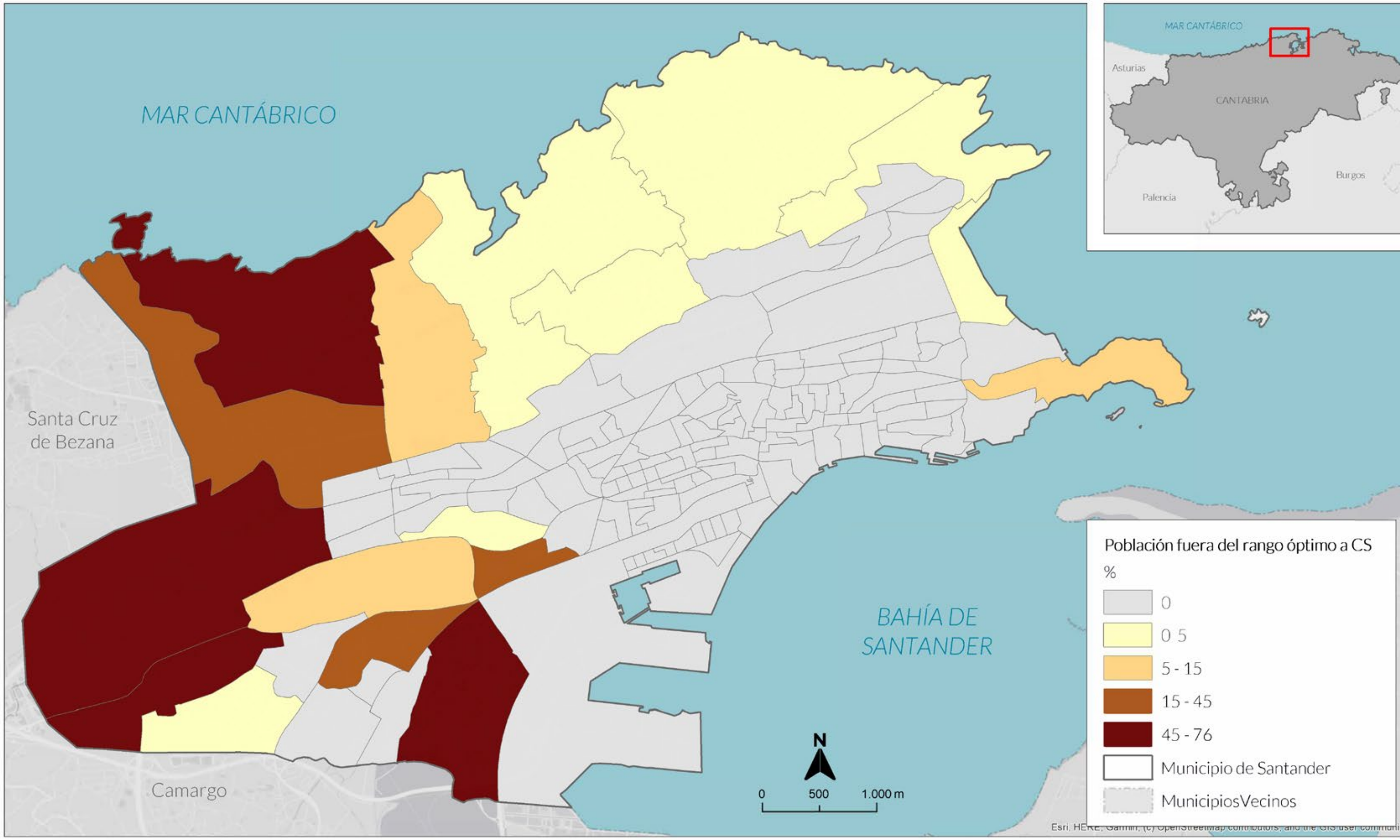
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
SE/5-1: Porcentaje de población analfabeta, sin estudios o con primer grado / población > 15 años por sección censal

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

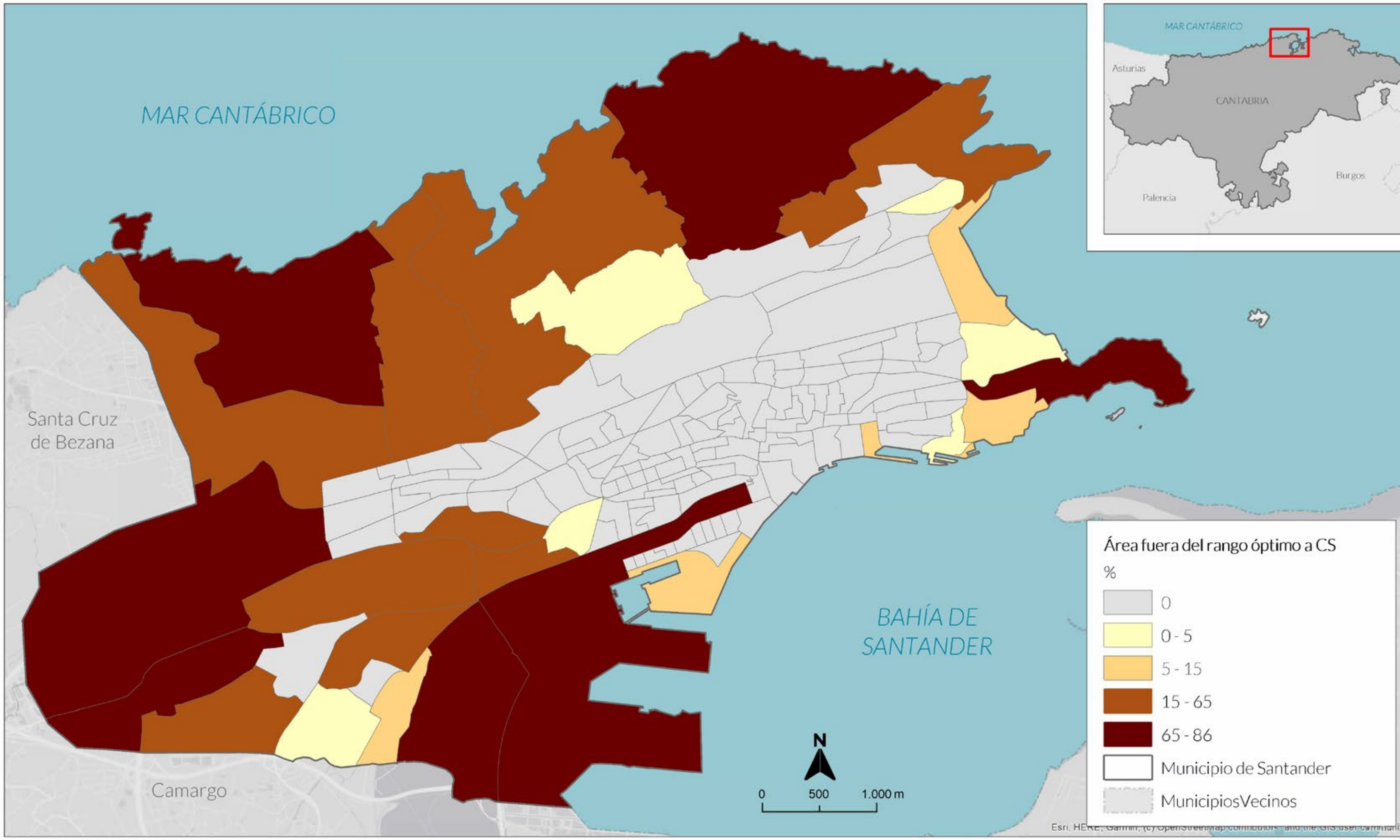
Fecha:
Abril 2024

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
SE/6-1: Porcentaje de población que reside fuera de las áreas óptimas de servicio de los centros de salud pública

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

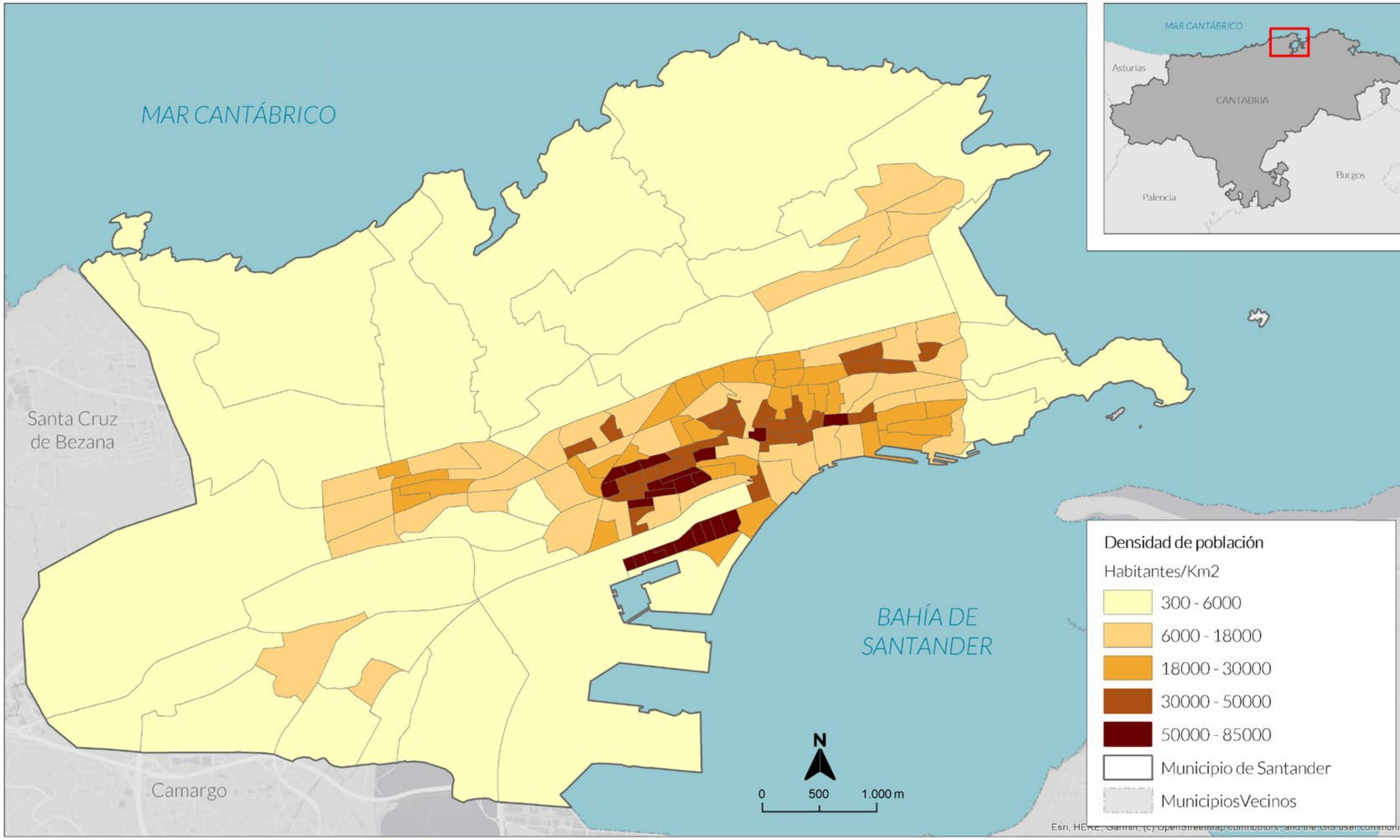
Mapa:
SE/6-2: Porcentaje de superficie fuera de las áreas óptimas de servicios de los centros de salud pública por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

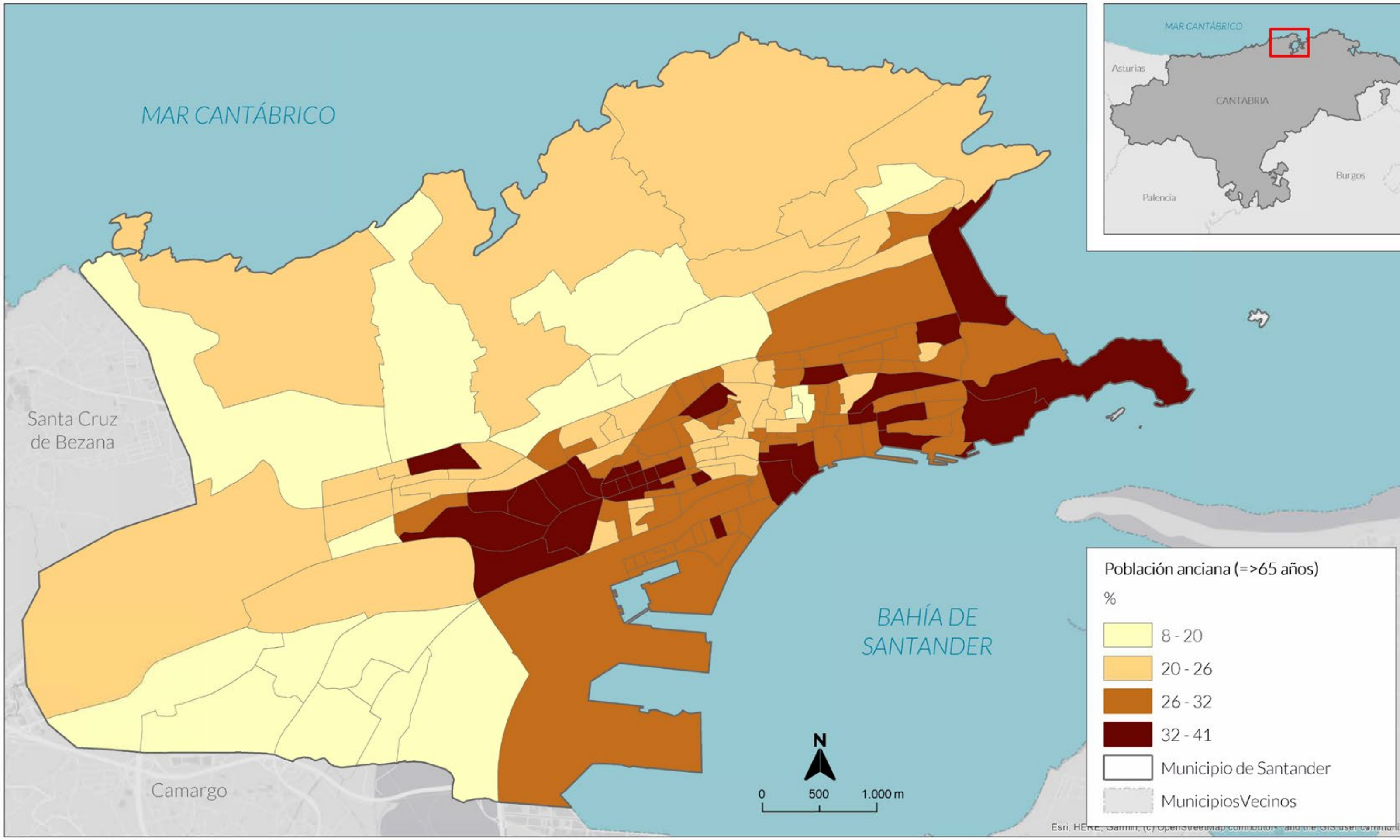
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
SE/7-1: Densidad de habitantes (hab /km2) por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU

Autoría:
UC Universidad de Cantabria
fic
SANTANDER CAPITAL NATURAL



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

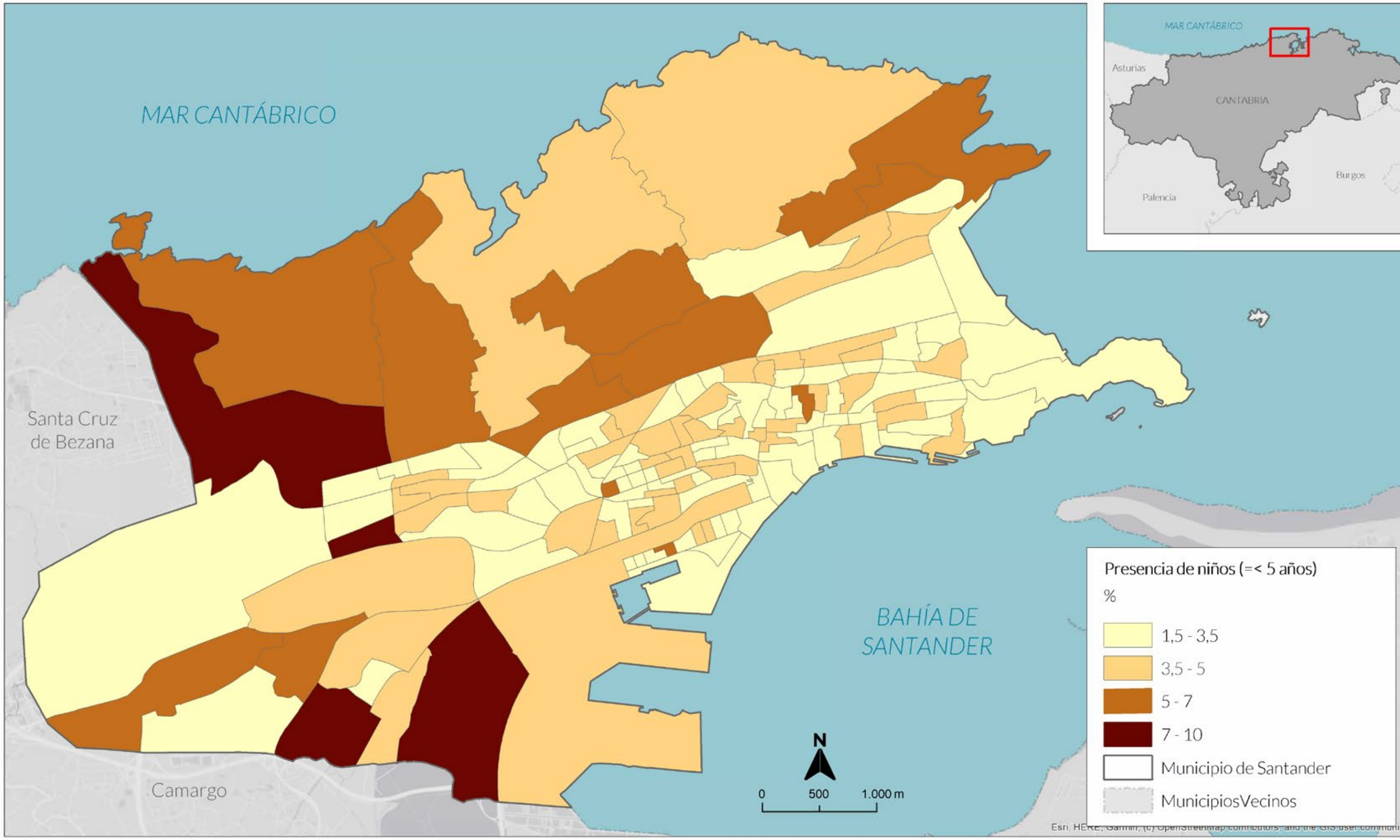
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
SE/8-1: Porcentaje de población anciana de igual o mayor a 65 años por secciones censales en el municipio de Santander

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

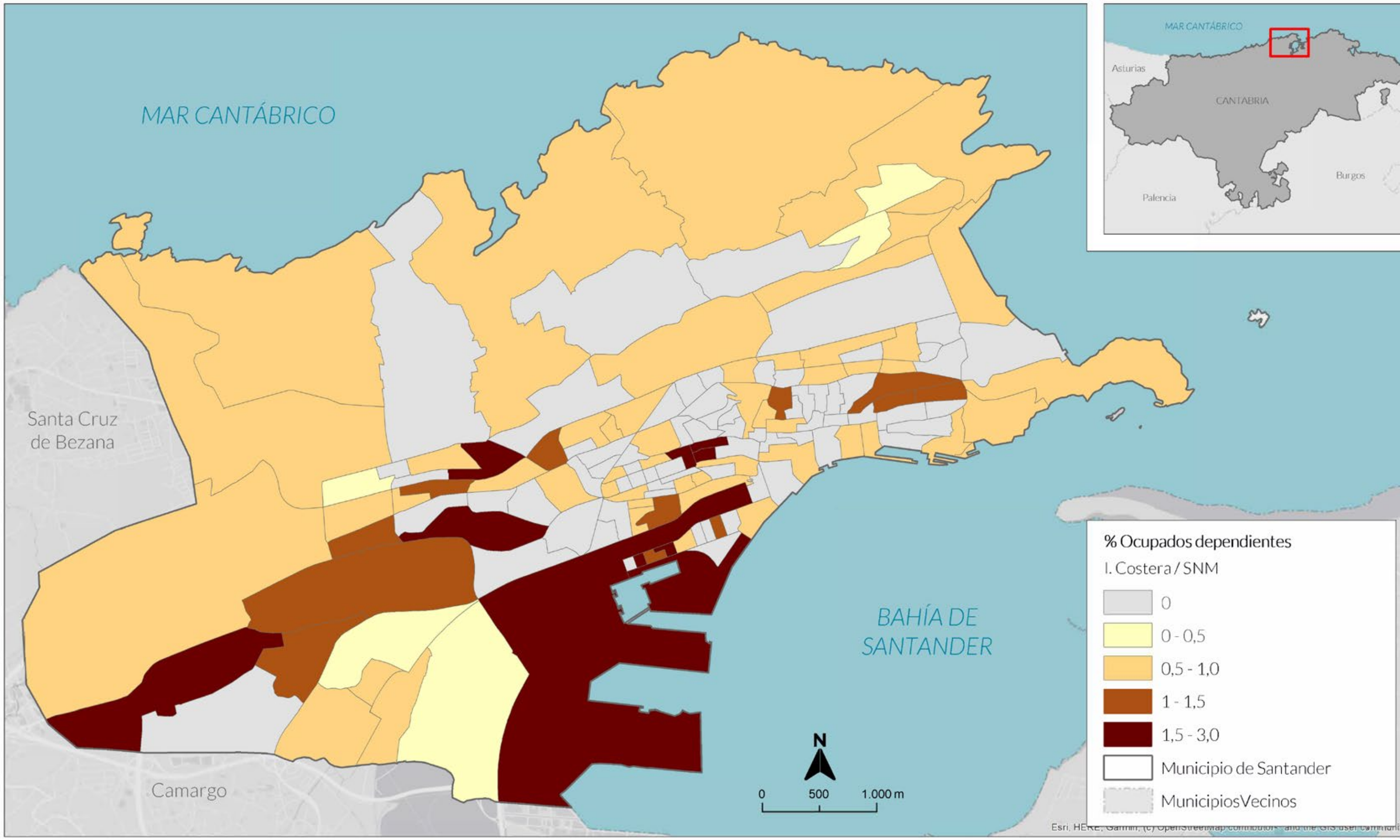
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
SE/8-2: Porcentaje de población con edad igual o menor a 5 años por secciones censales en el municipio de Santander

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

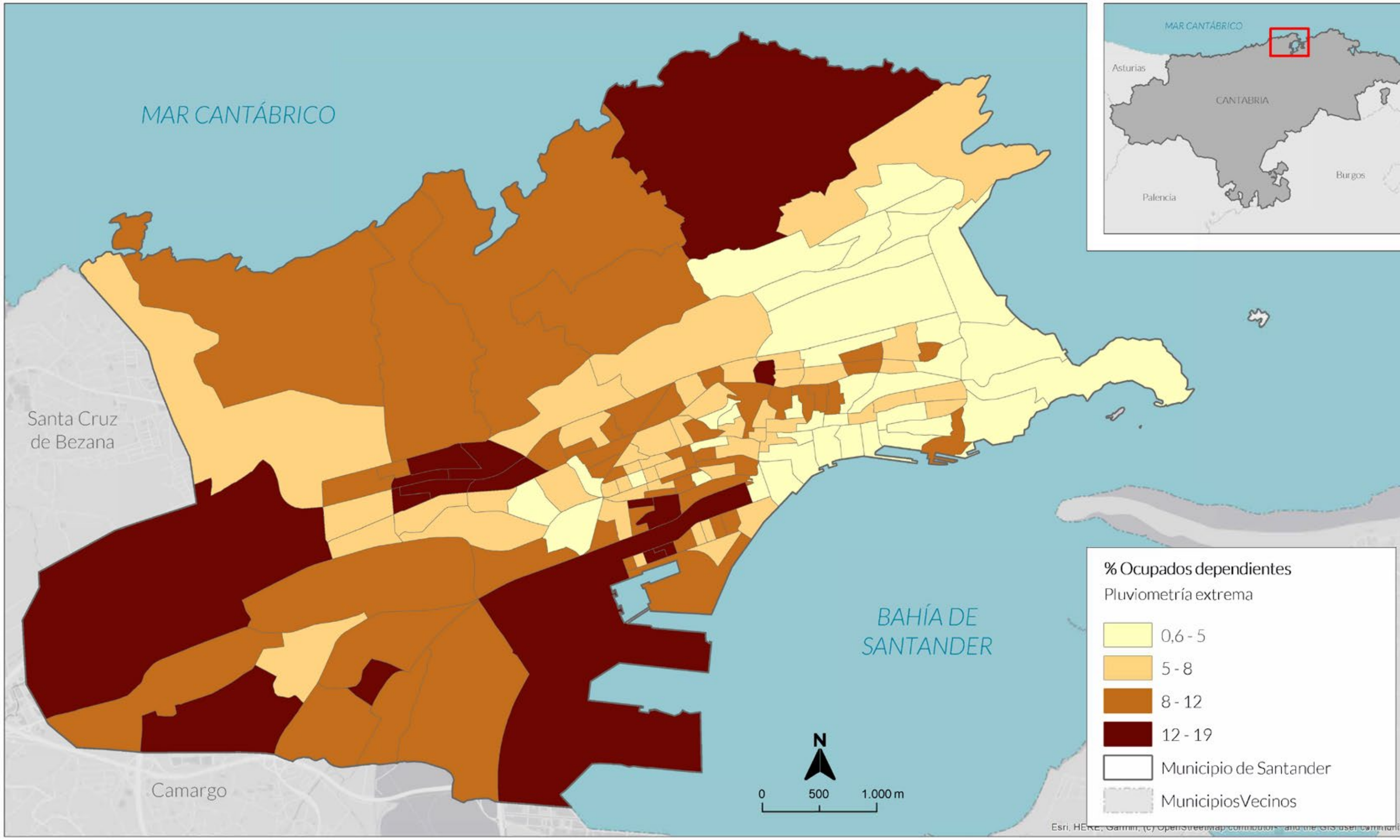
Mapa:
SE/9-1: Porcentaje de población ocupada en sectores dependientes del clima respecto a la población total ocupada por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

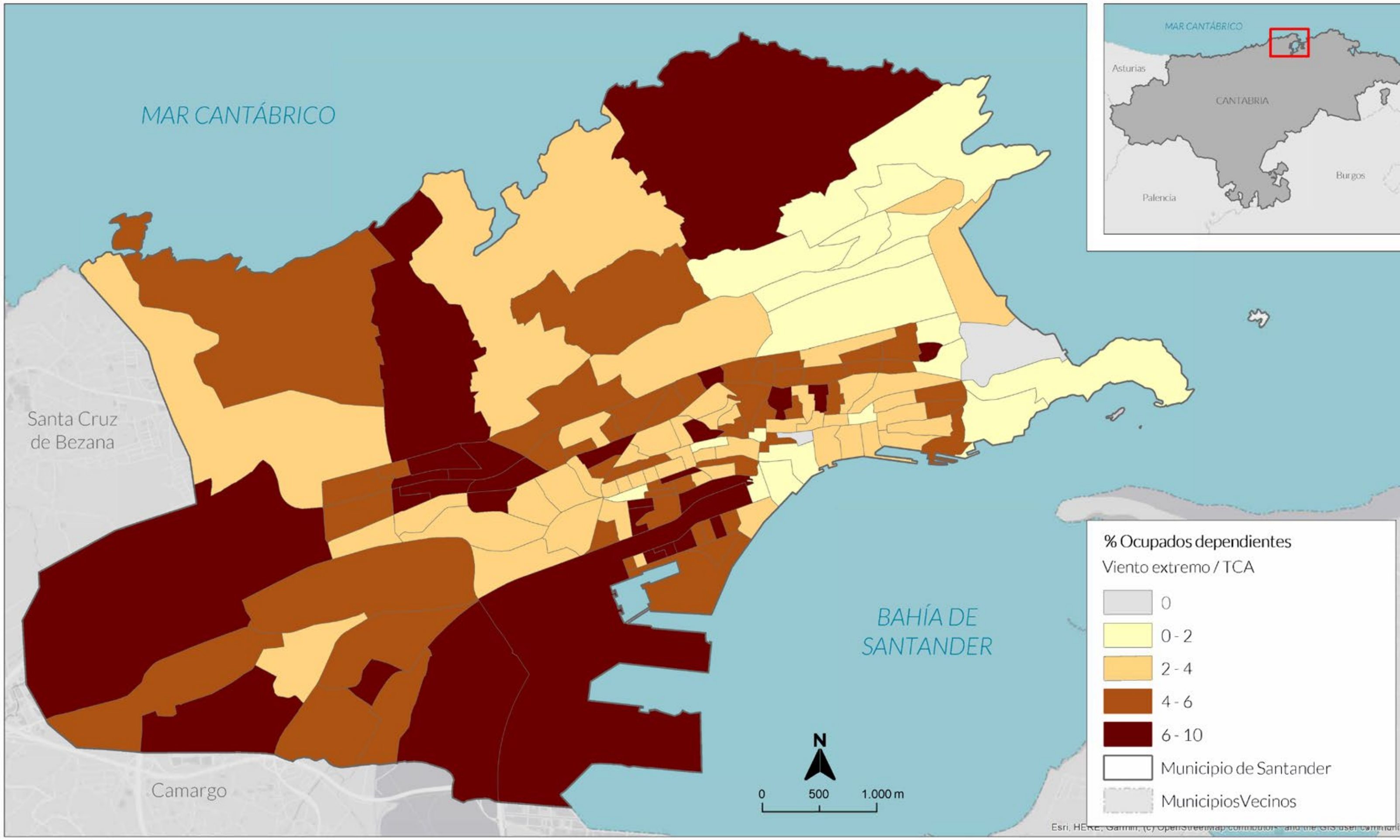
Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
SE/9-2: Porcentaje de población ocupada en sectores dependientes del clima respecto a la población total ocupada por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU
Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

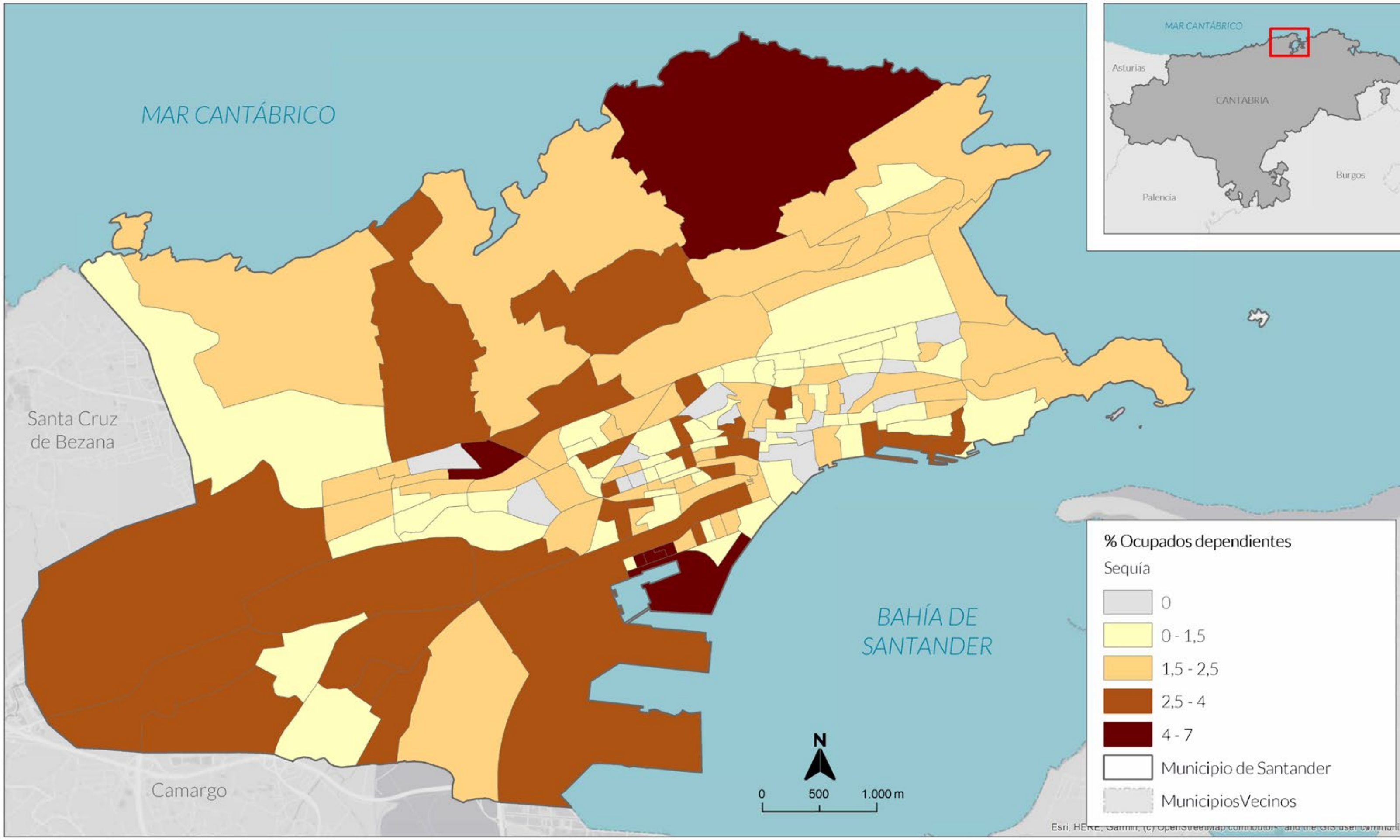
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
SE/9-3: Porcentaje de población ocupada en sectores dependientes del clima respecto a la población total ocupada por sección censal

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

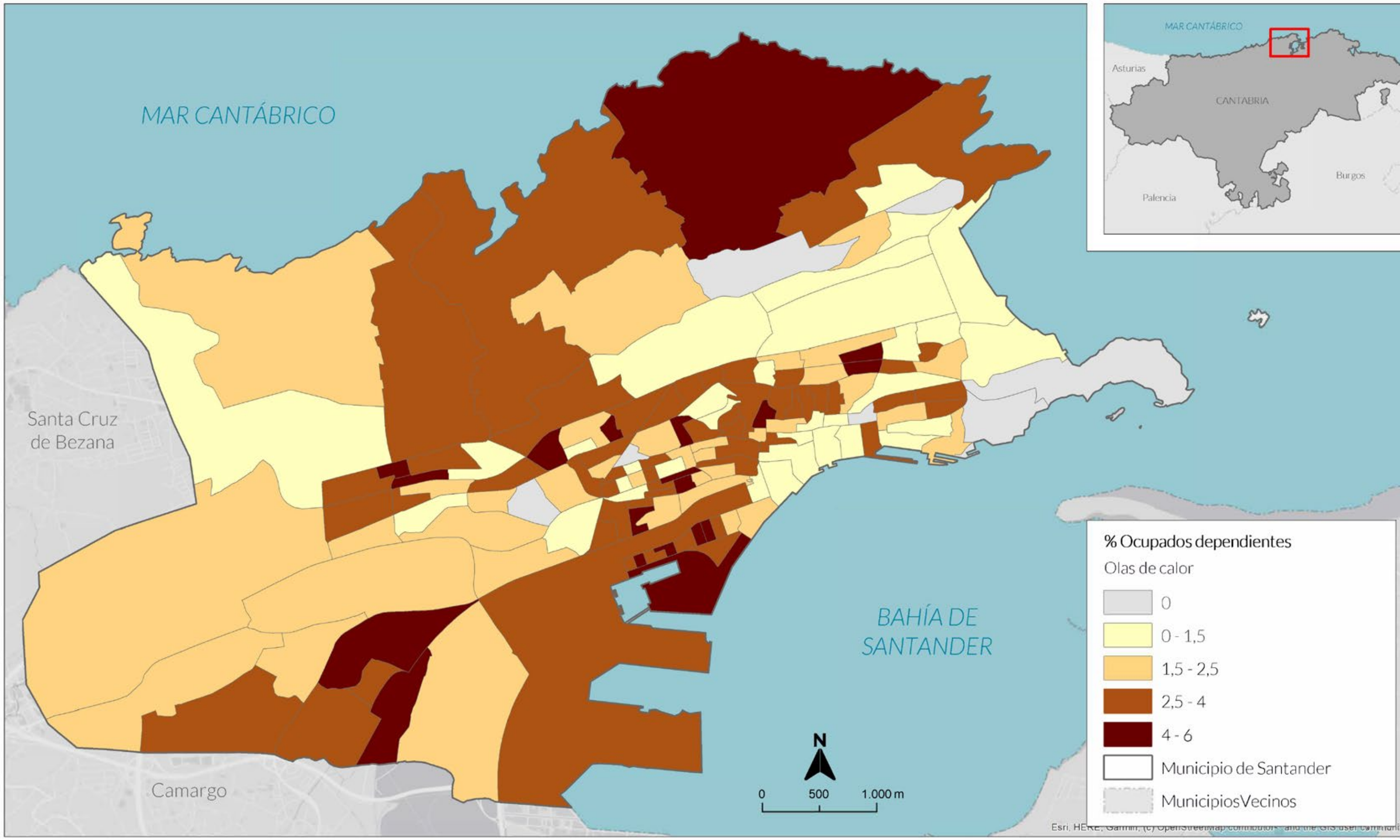
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
SE/9-4: Porcentaje de población ocupada en sectores dependientes del clima respecto a la población total ocupada por sección censal

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

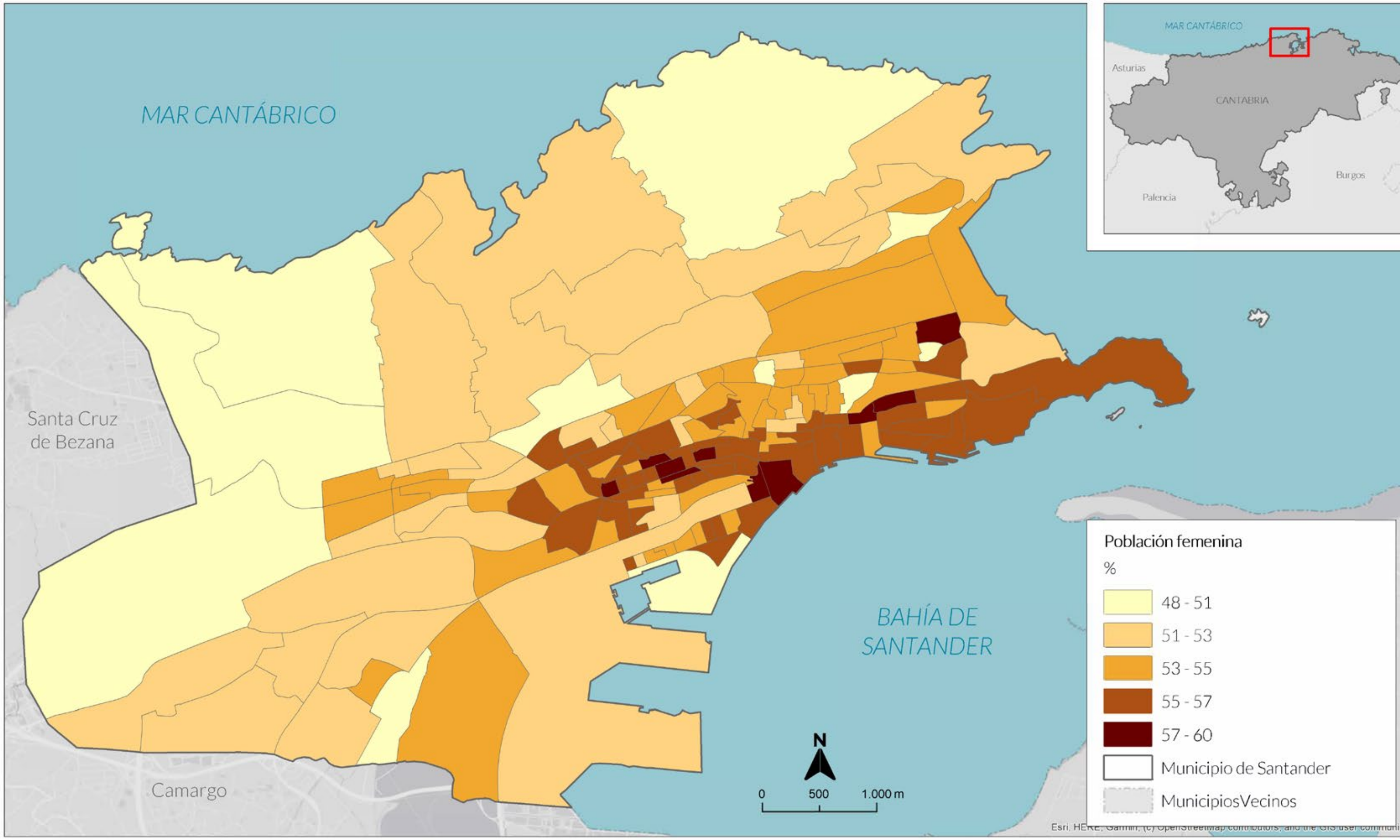
Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
SE/9-5: Porcentaje de población ocupada en sectores dependientes del clima respecto a la población total ocupada por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea
NextGenerationEU
Autoría:
Universidad de Cantabria



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

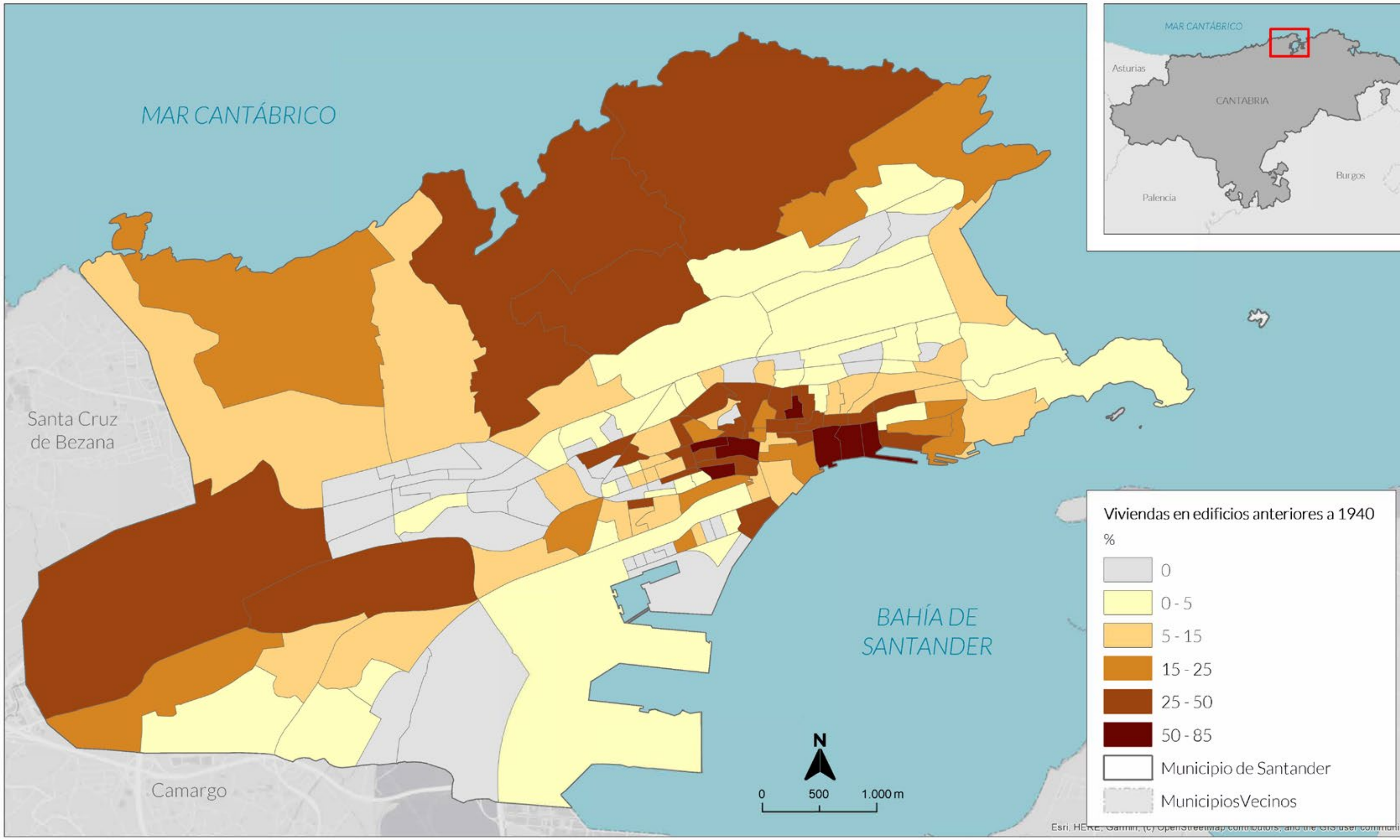
Acción:
A2: Plan de Adaptación Urbana con Escenarios Climáticos

Mapa:
SE/10-1: Porcentaje de mujeres por sección censal

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

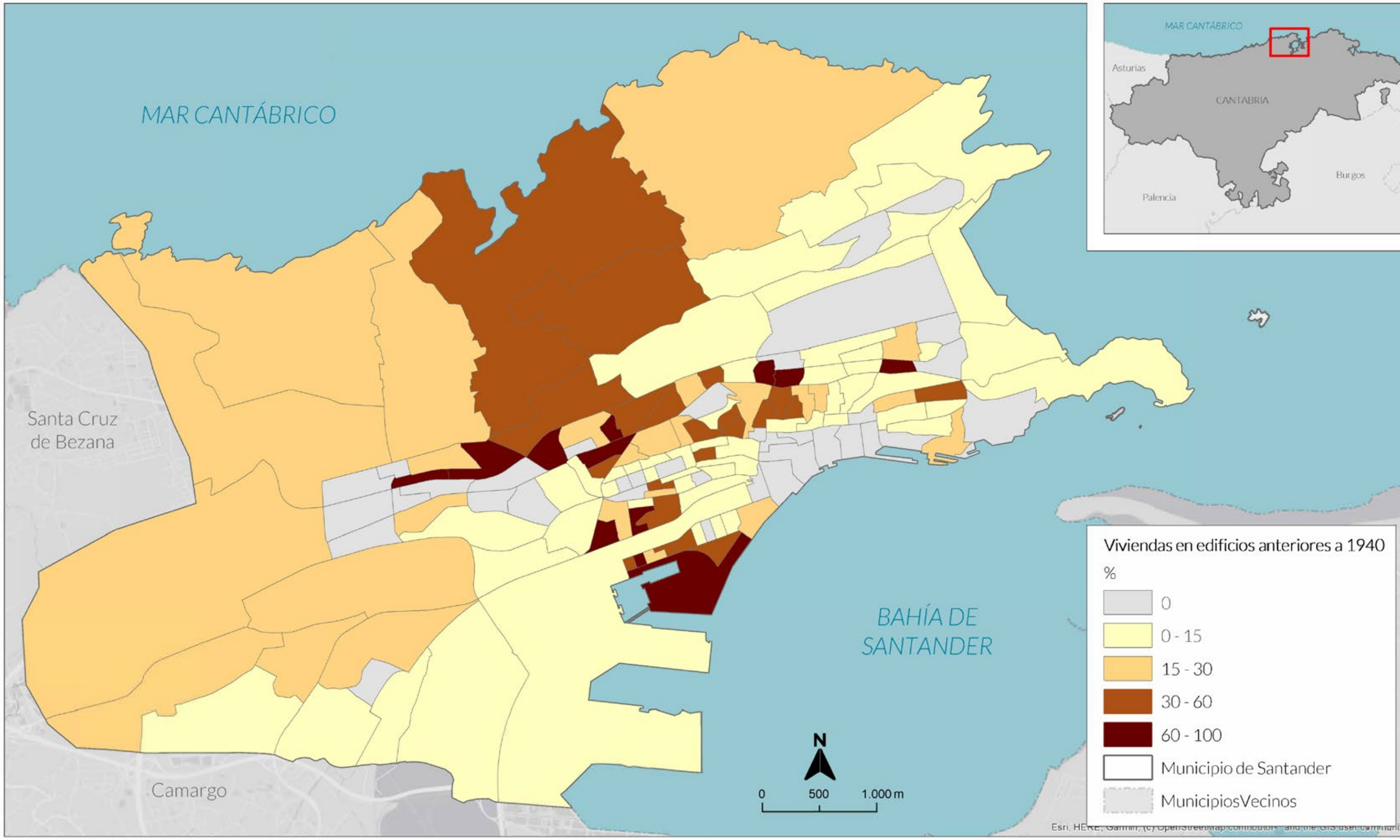
Mapa:
M1-1: Porcentaje de viviendas en edificios anteriores a 1940 / total de viviendas por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

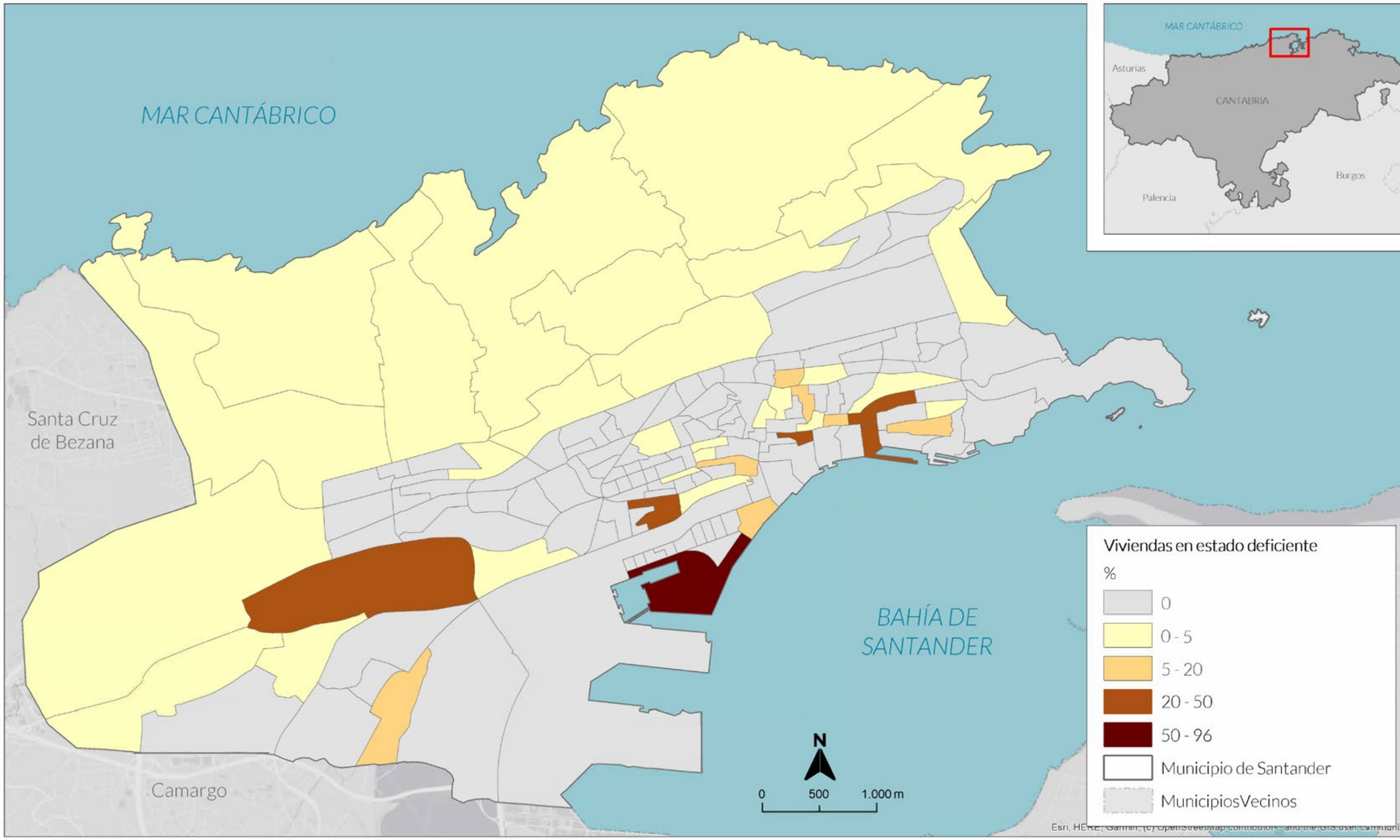
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
M2-1: Porcentaje de viviendas en edificios construidos en el año 1940 o anteriores por sección censal

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:

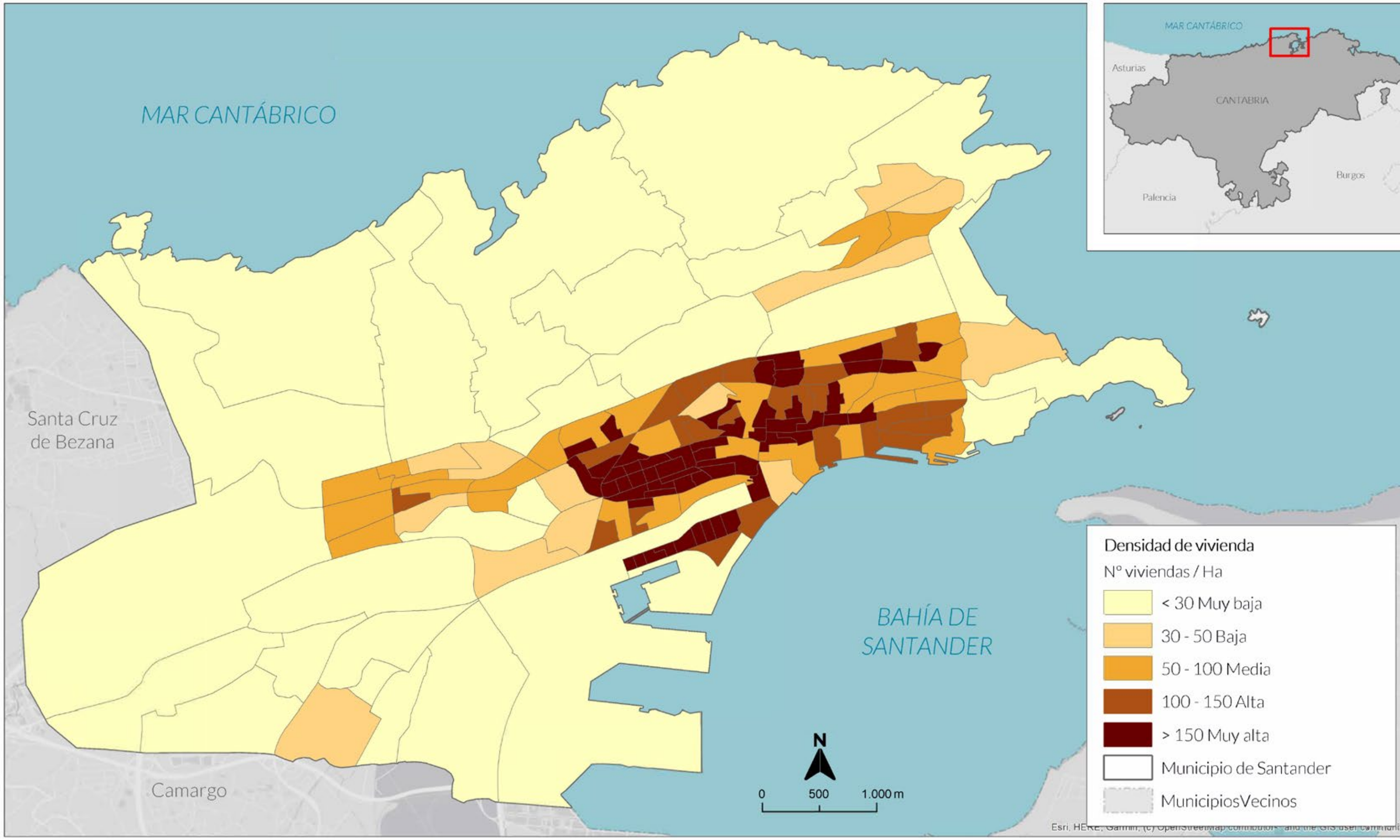


Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
M3-1: Porcentaje de viviendas con estado de mantenimiento deficitario

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU

Autoría:



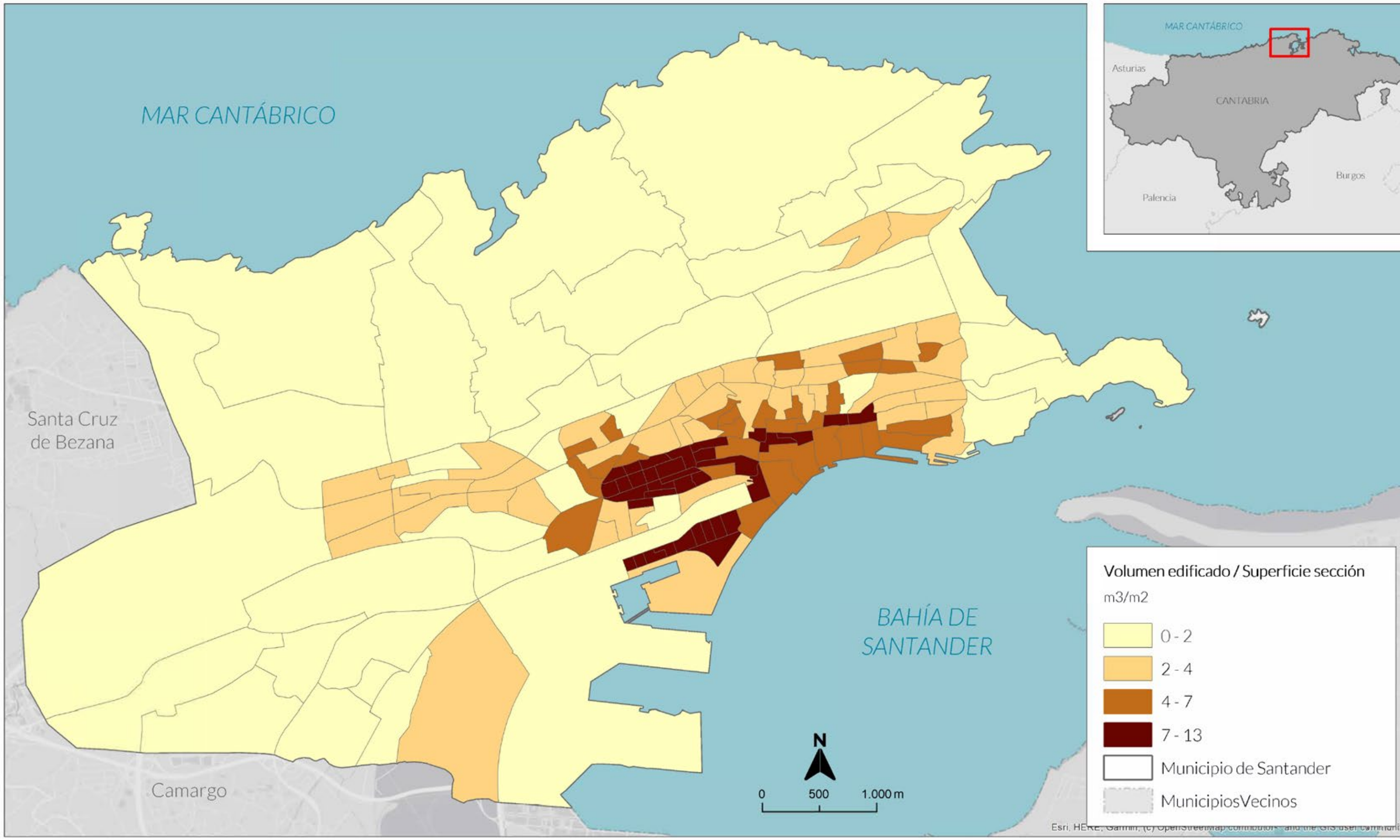
Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
M4-1: Densidad de vivienda por hectárea por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

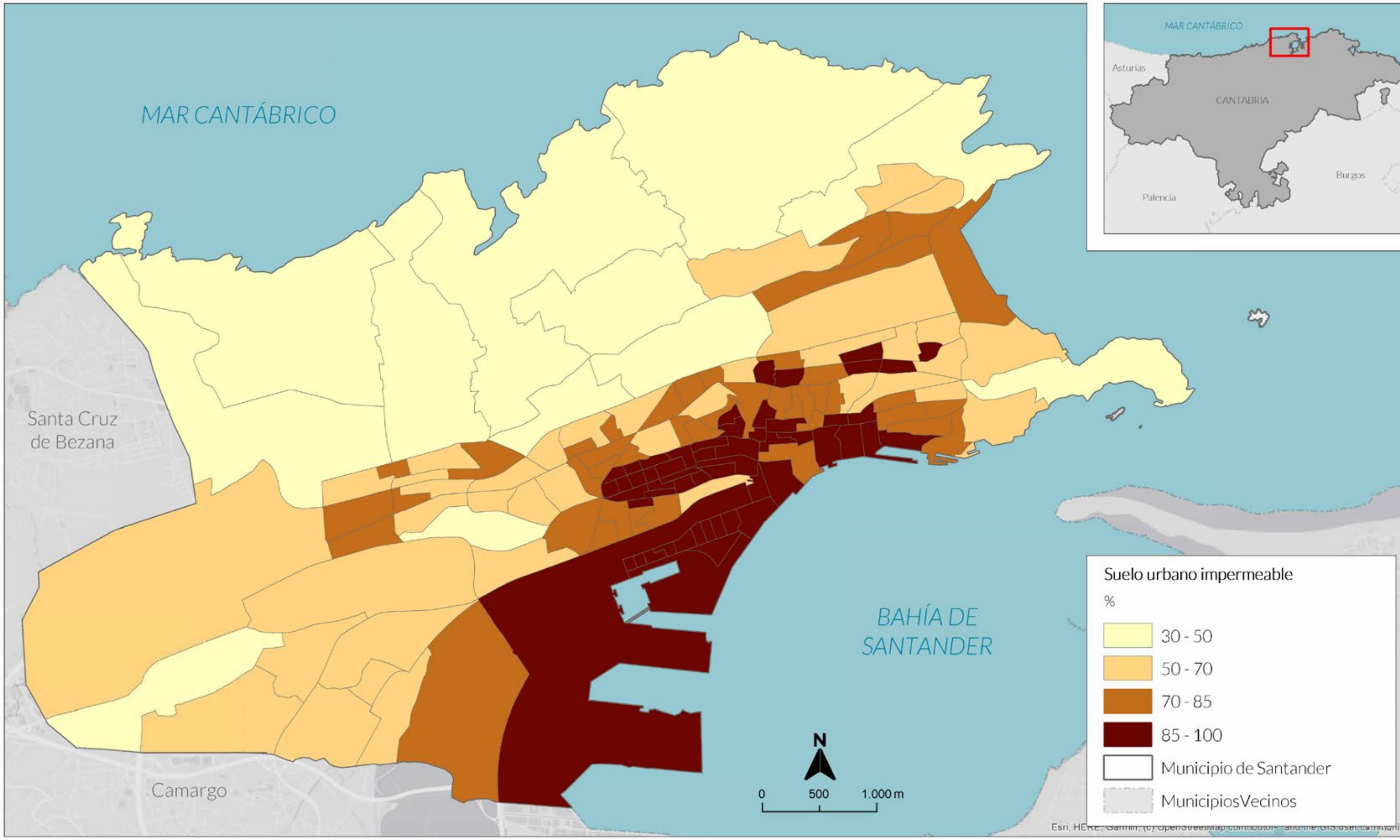
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
A1-1: Volumen edificado (m3) ponderado por la superficie total (m2) por sección censal del municipio de Santander

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

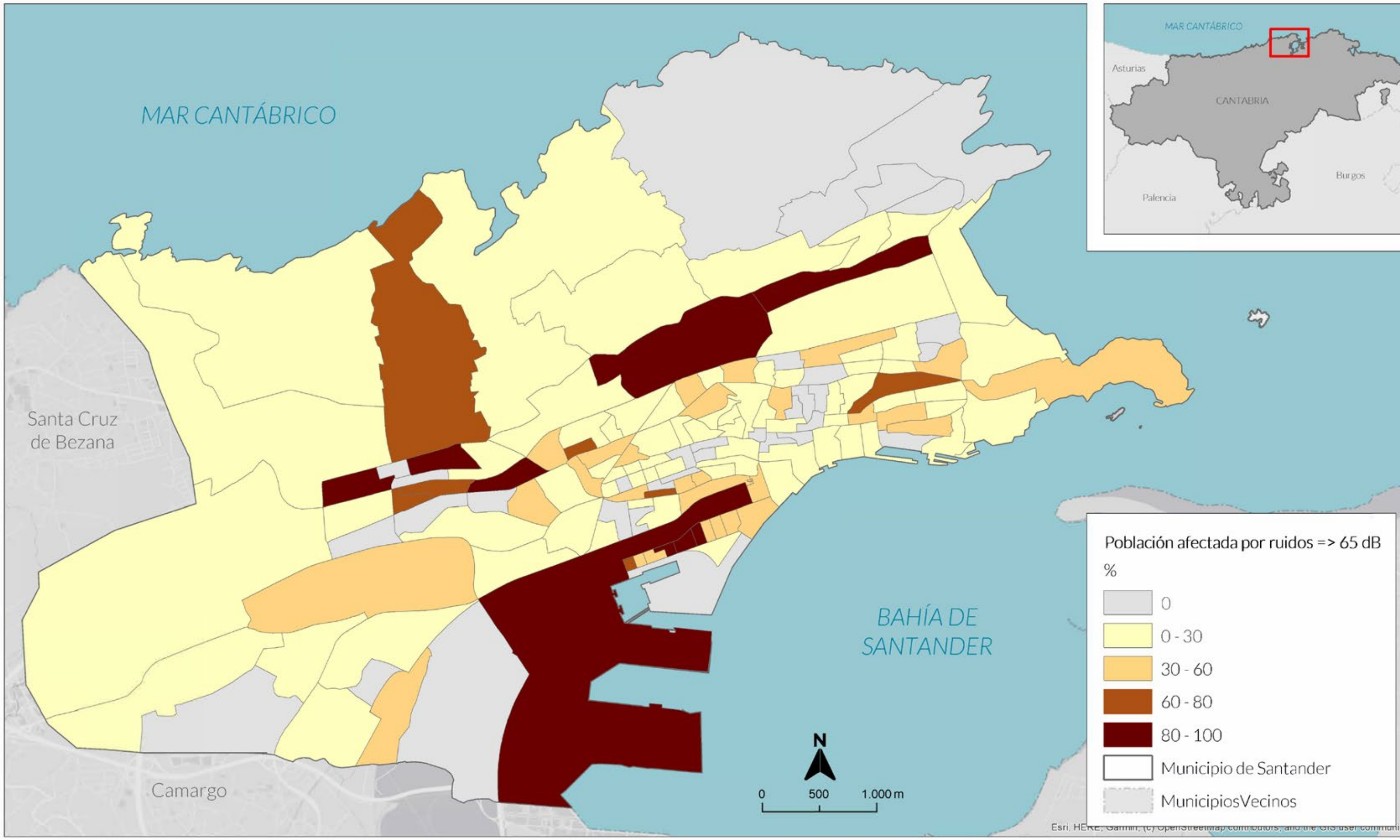
Mapa:
A1-2: Porcentaje de suelo urbano impermeable por sección censales en el municipio de Santander

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

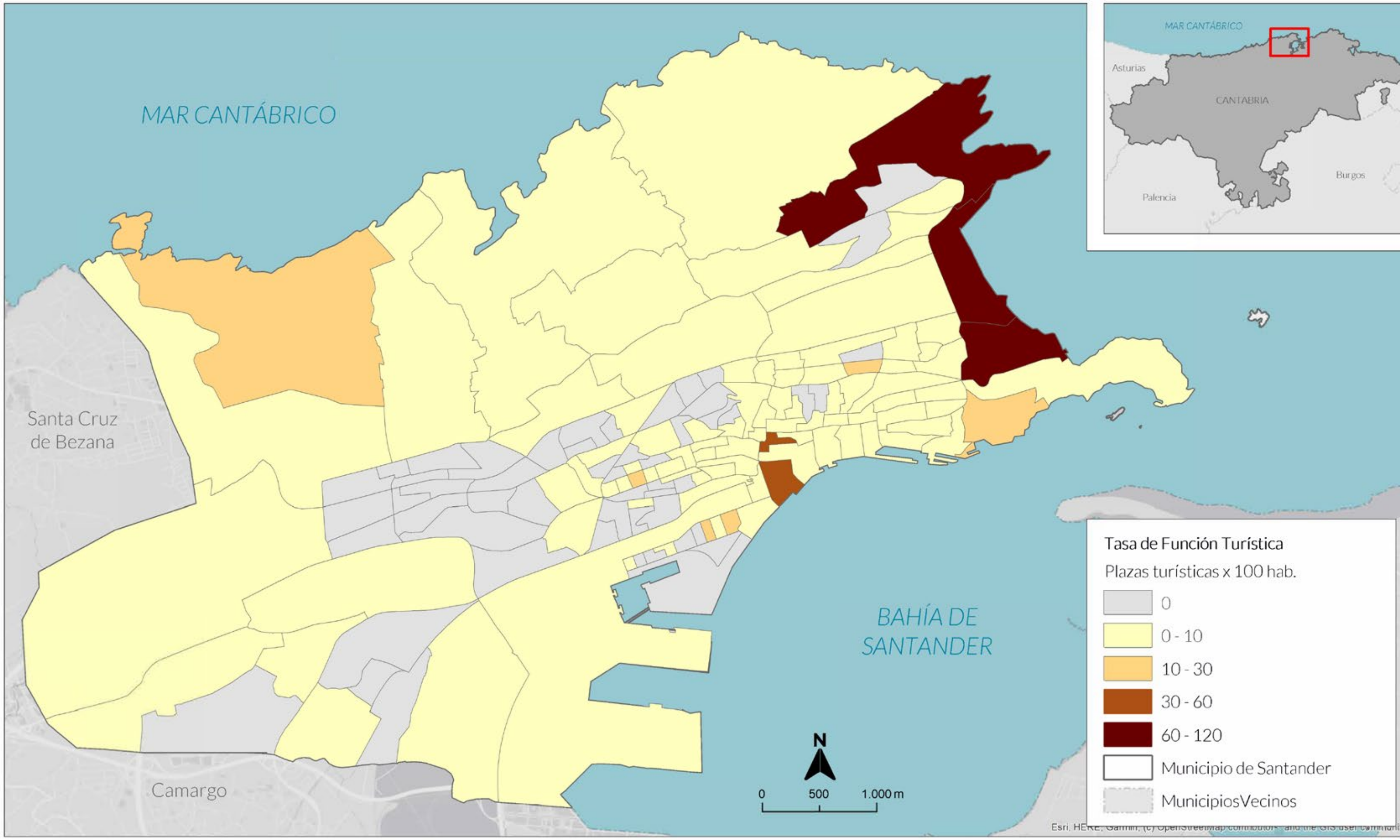
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
A2-2: Porcentaje de población afectada por ruidos => 65 dB por sección censal

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

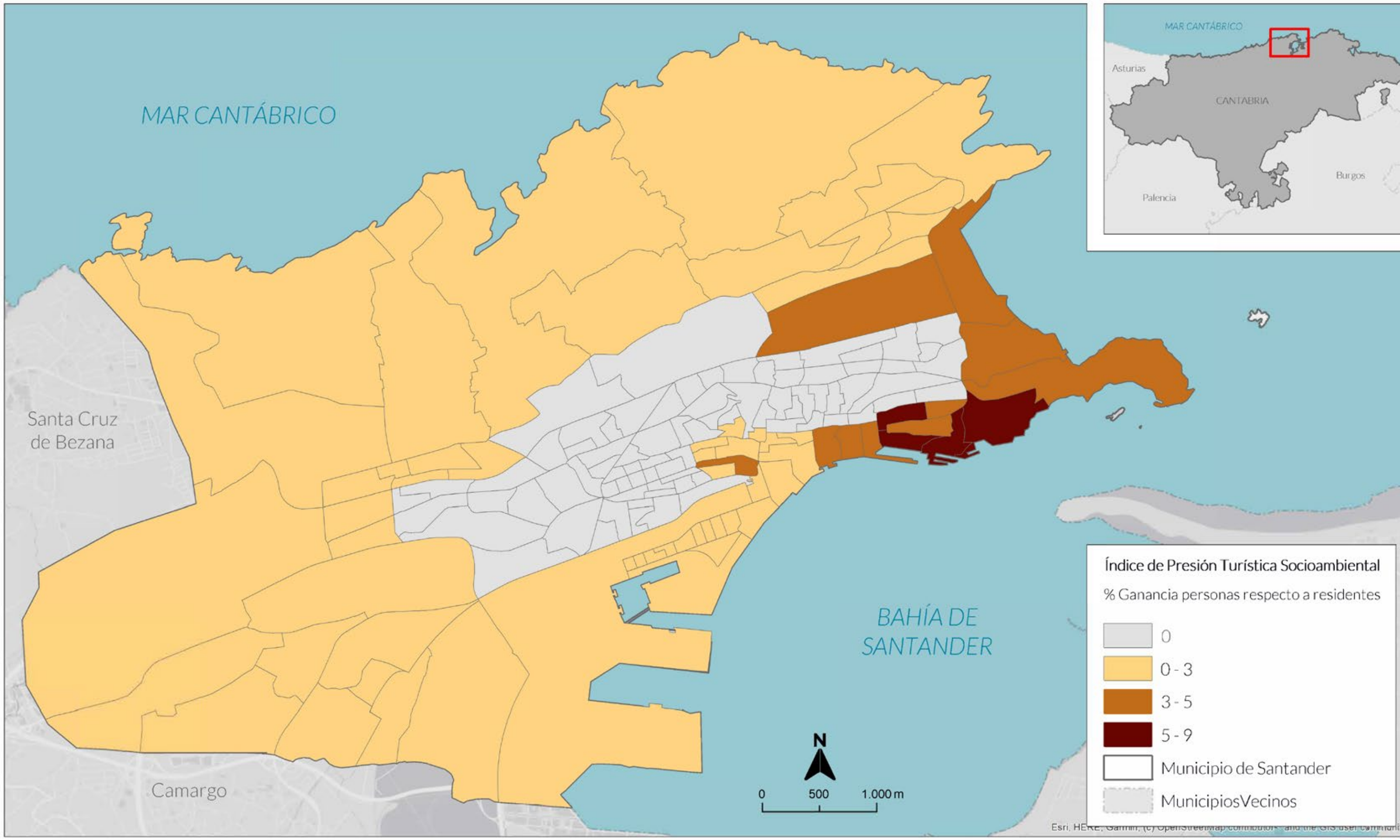
Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
A3-1: Tasa de Función Turística por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea
NextGenerationEU
Autoría:
Universidad de Cantabria



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

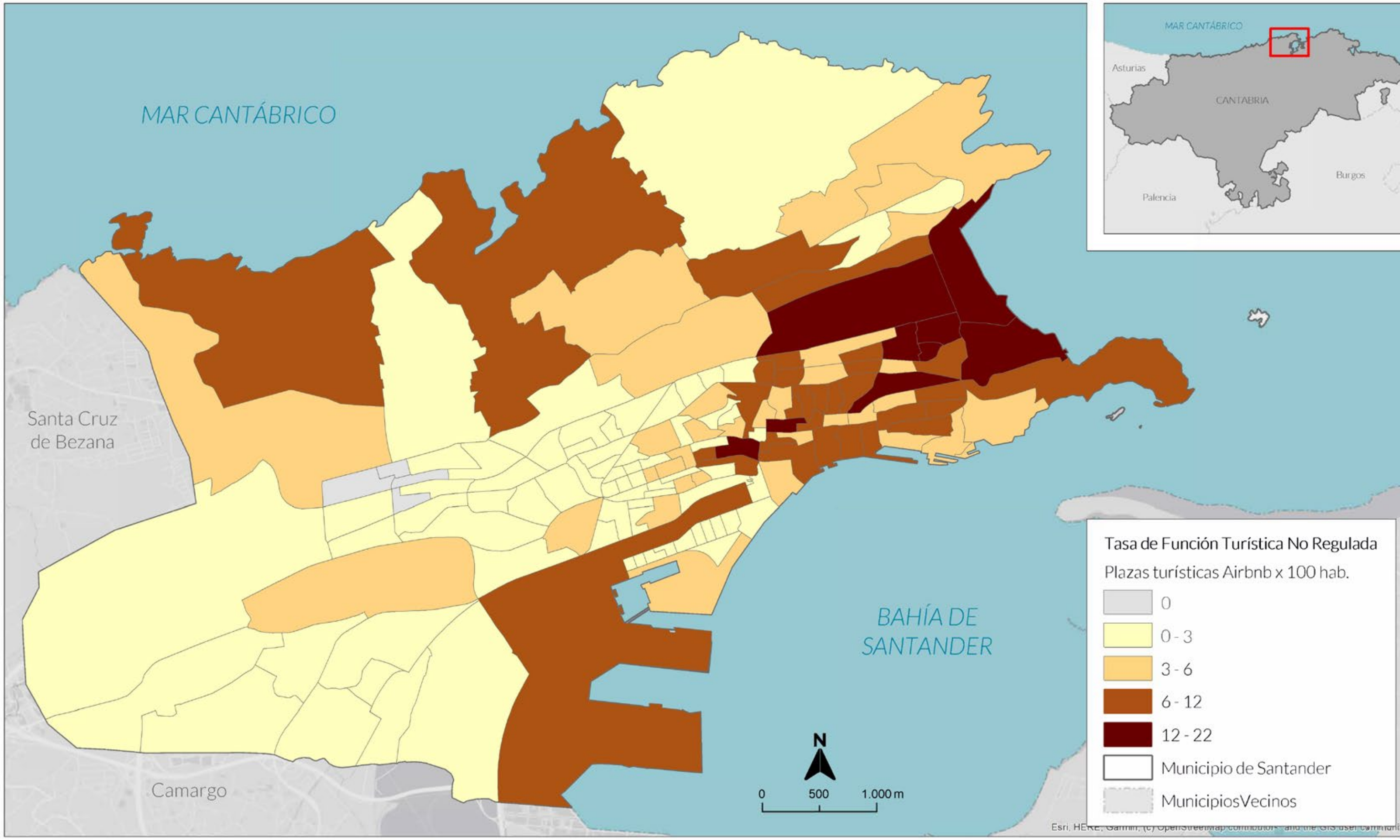
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
A3-2: Índice de presión socioambiental teniendo en cuenta las zonas de afluencia turística

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

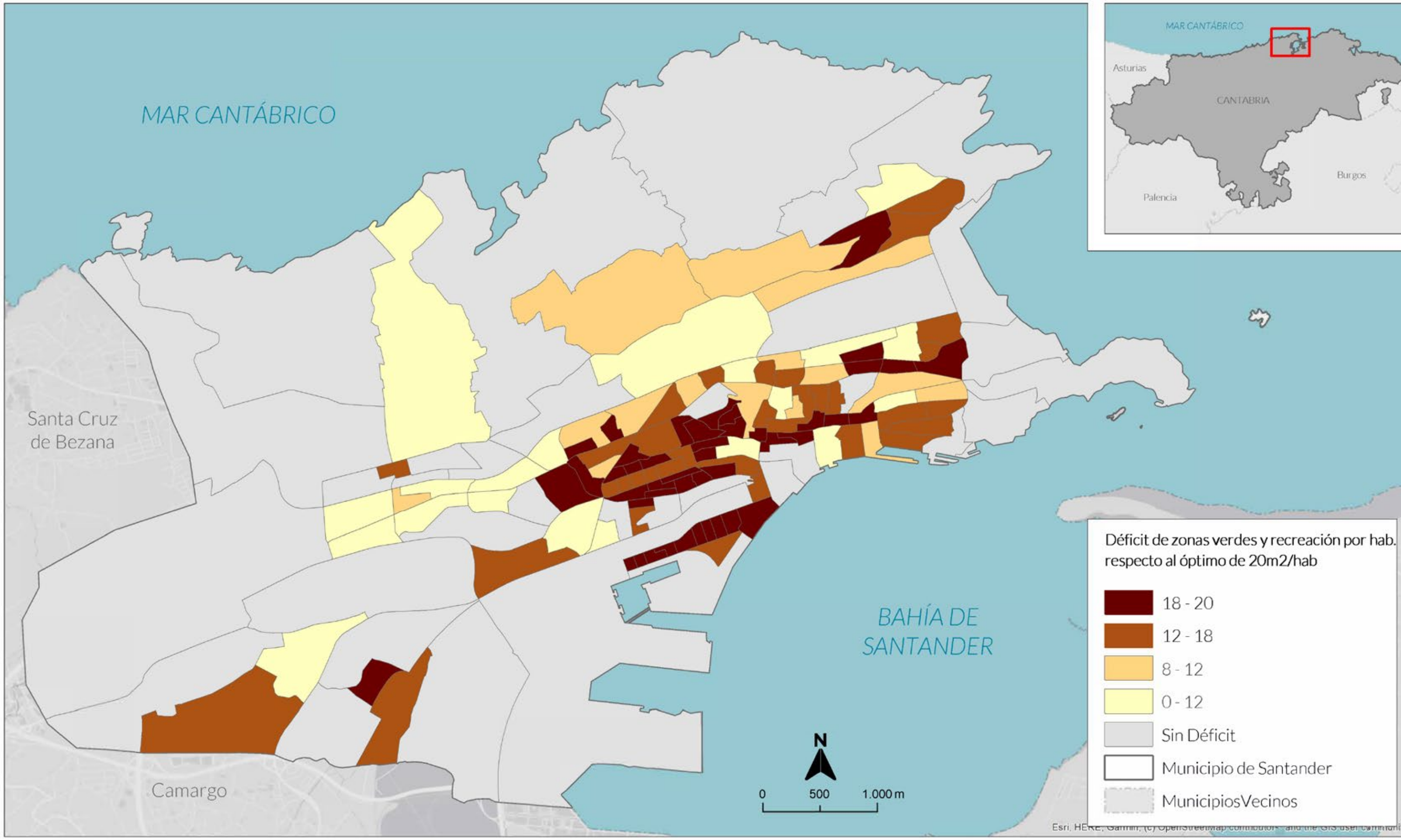
Mapa:
A3-3: Tasa de Función Turística de alojamientos no reglados por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



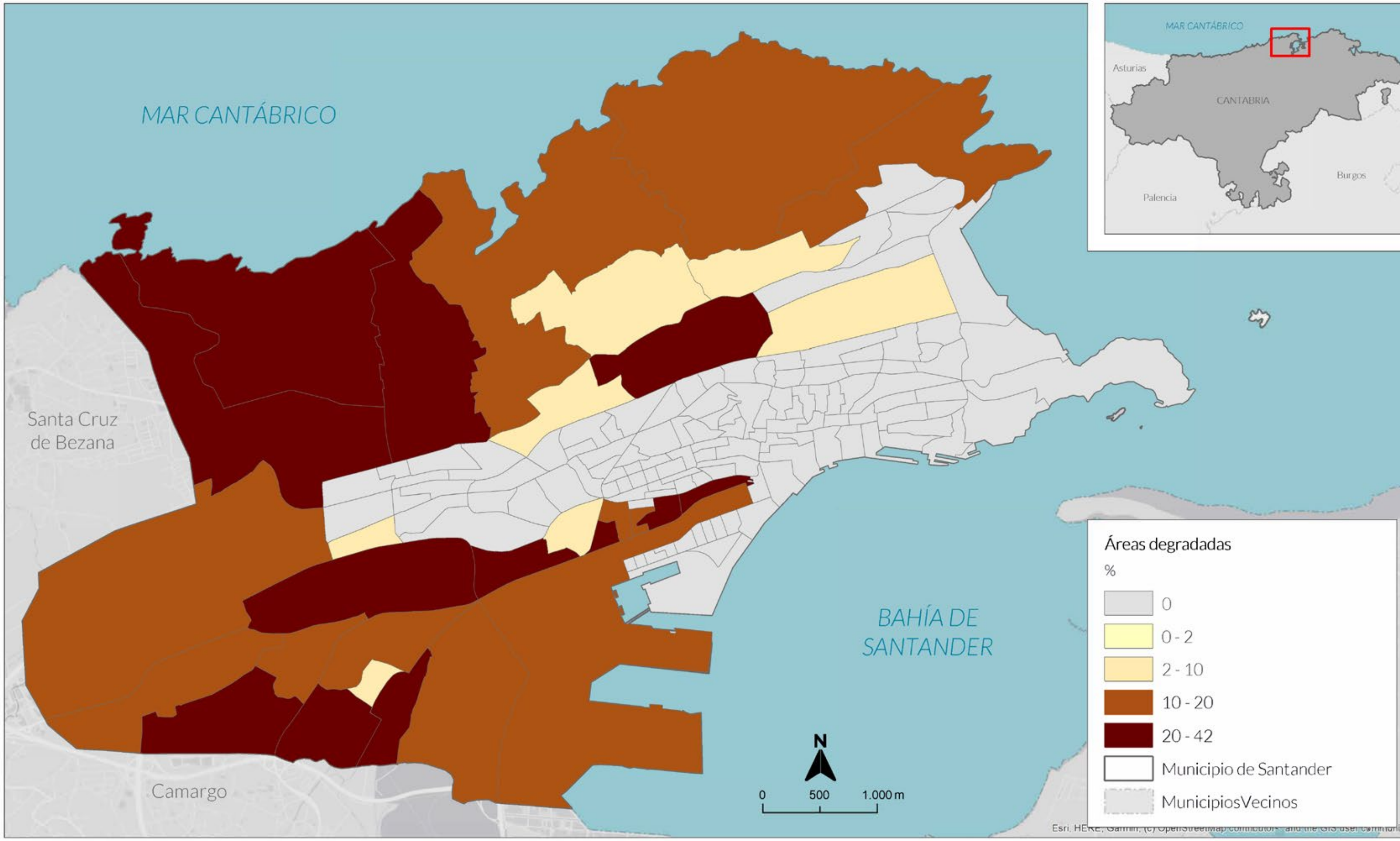
Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
A4-1: Déficit de m2 de zonas verdes y de recreación por habitante respecto al óptimo de 20m2/hab por sección censal

Fecha:
Abril 2024

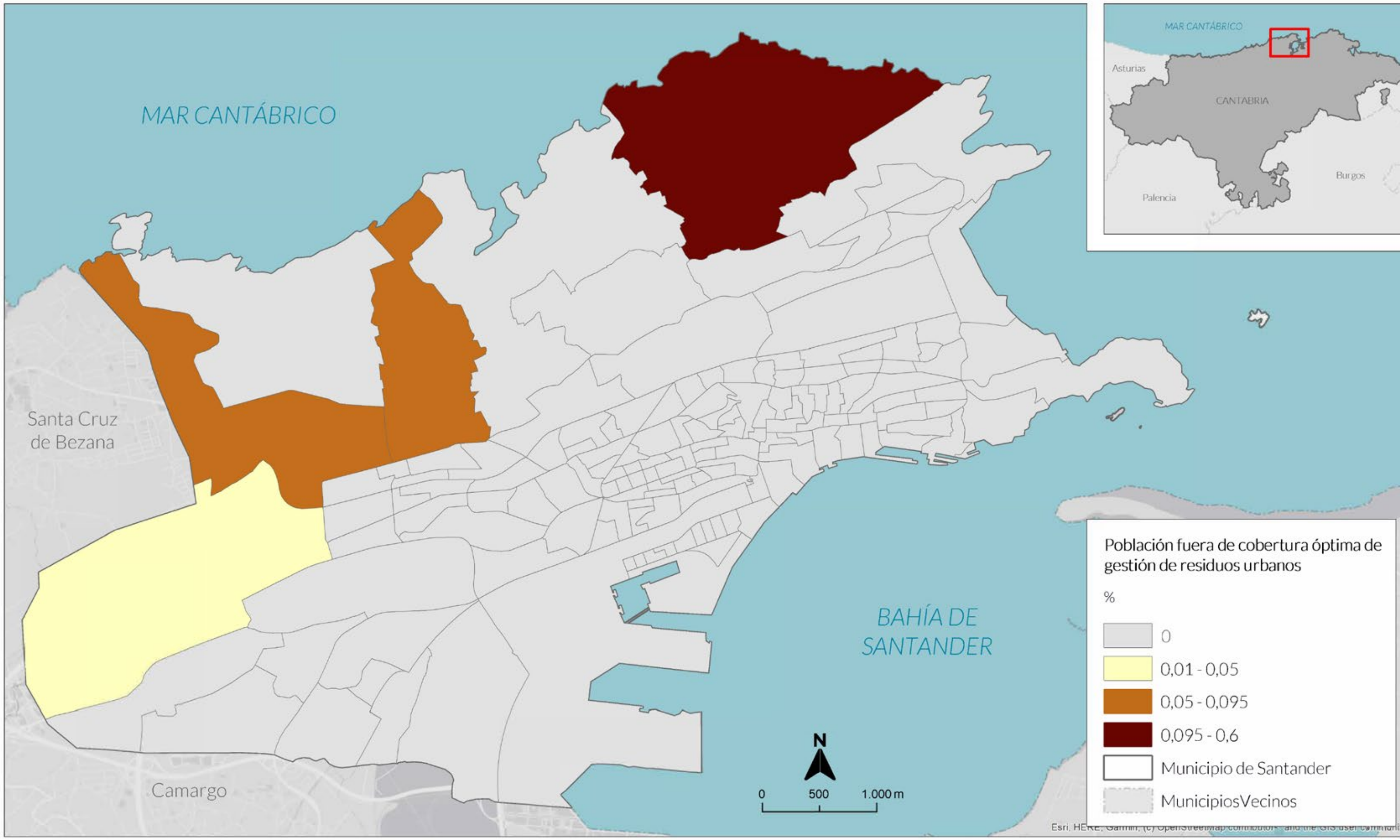
Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos
Mapa:
A5-1: Porcentaje de superficie degradada por sección censal

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea
NextGenerationEU
Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

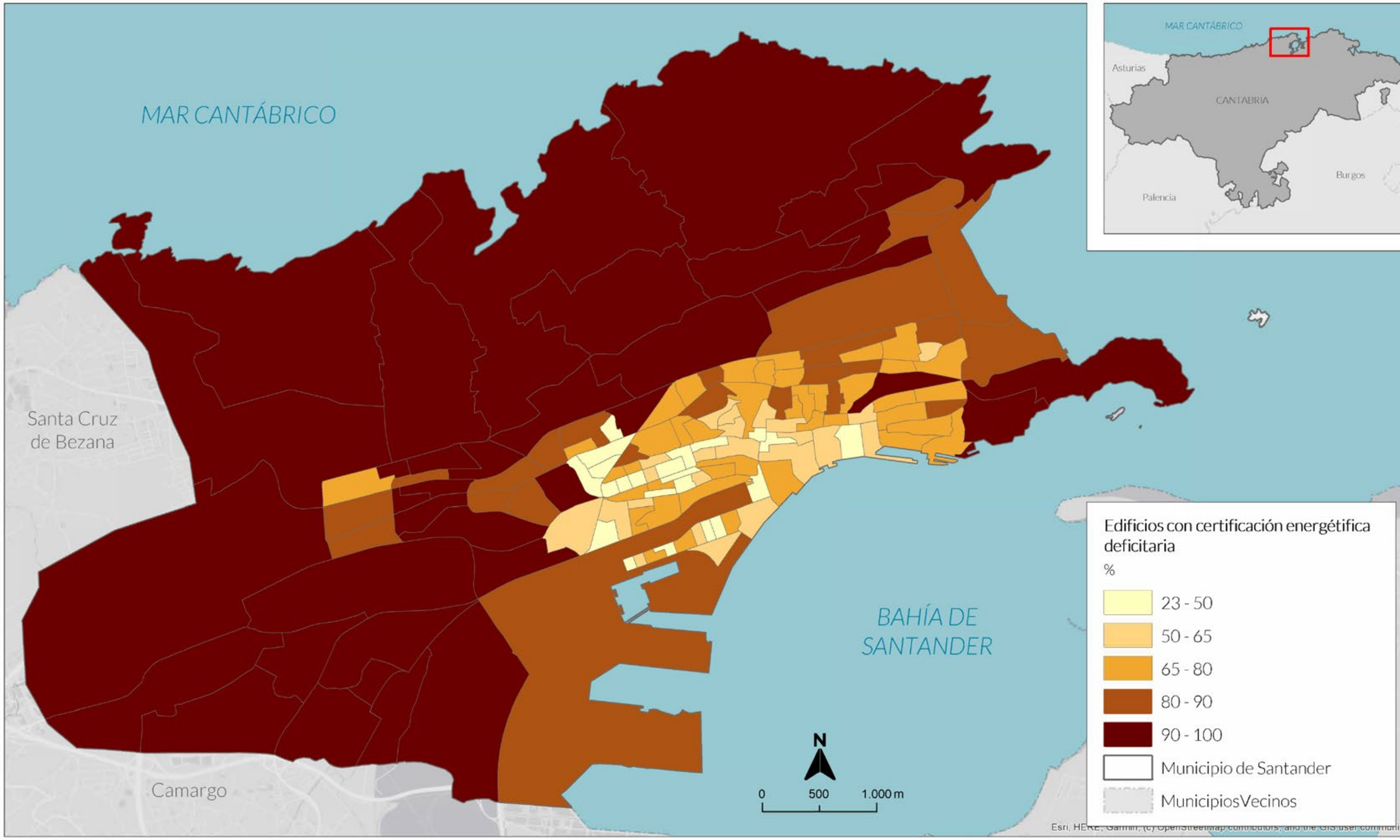
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
A6-1: Porcentaje de población fuera de cobertura óptima de gestión de residuos urbanos por sección censal

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



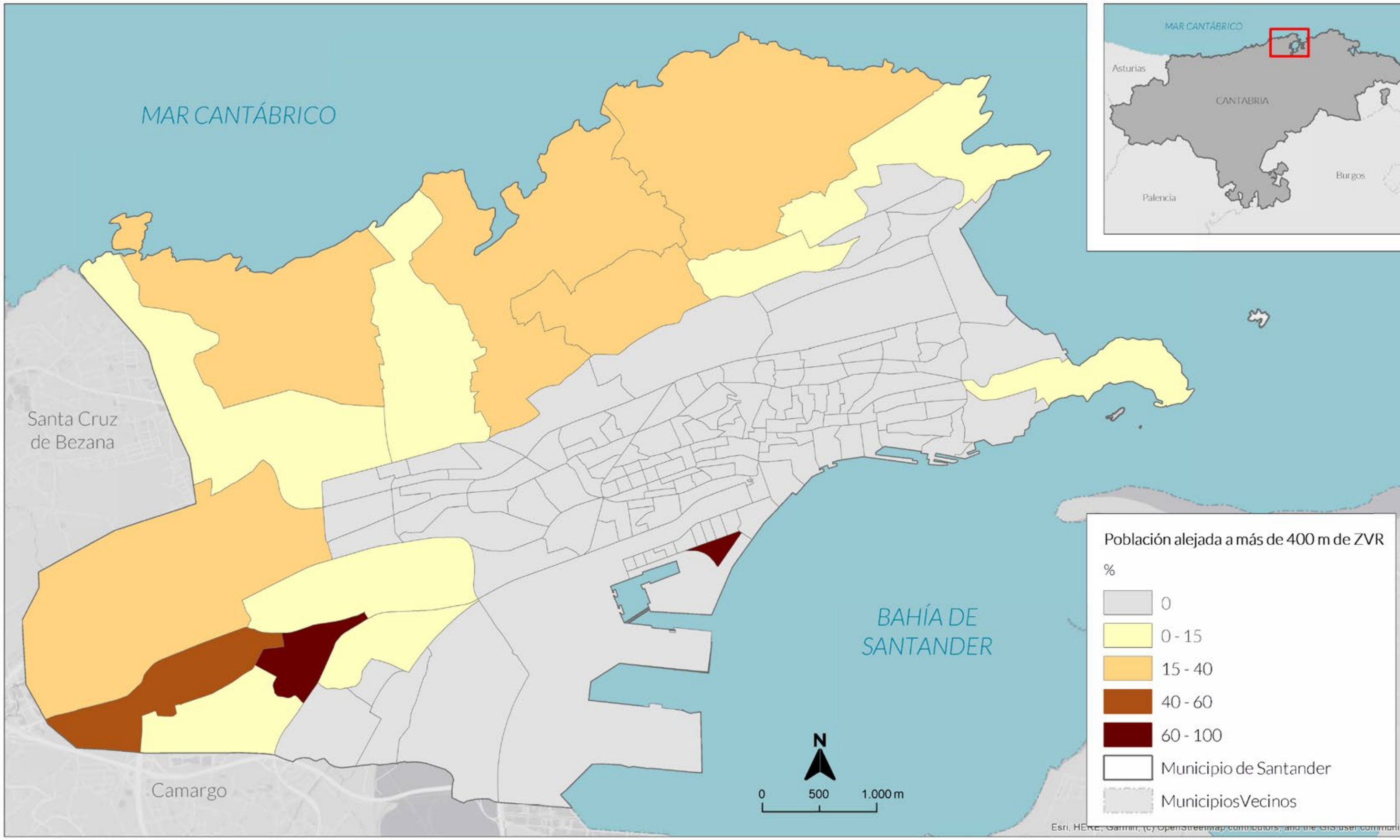
Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
A7-1: Porcentaje de edificios sin certificación energética o con certificación energética inferior a la clase "E"

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU
Autoría:



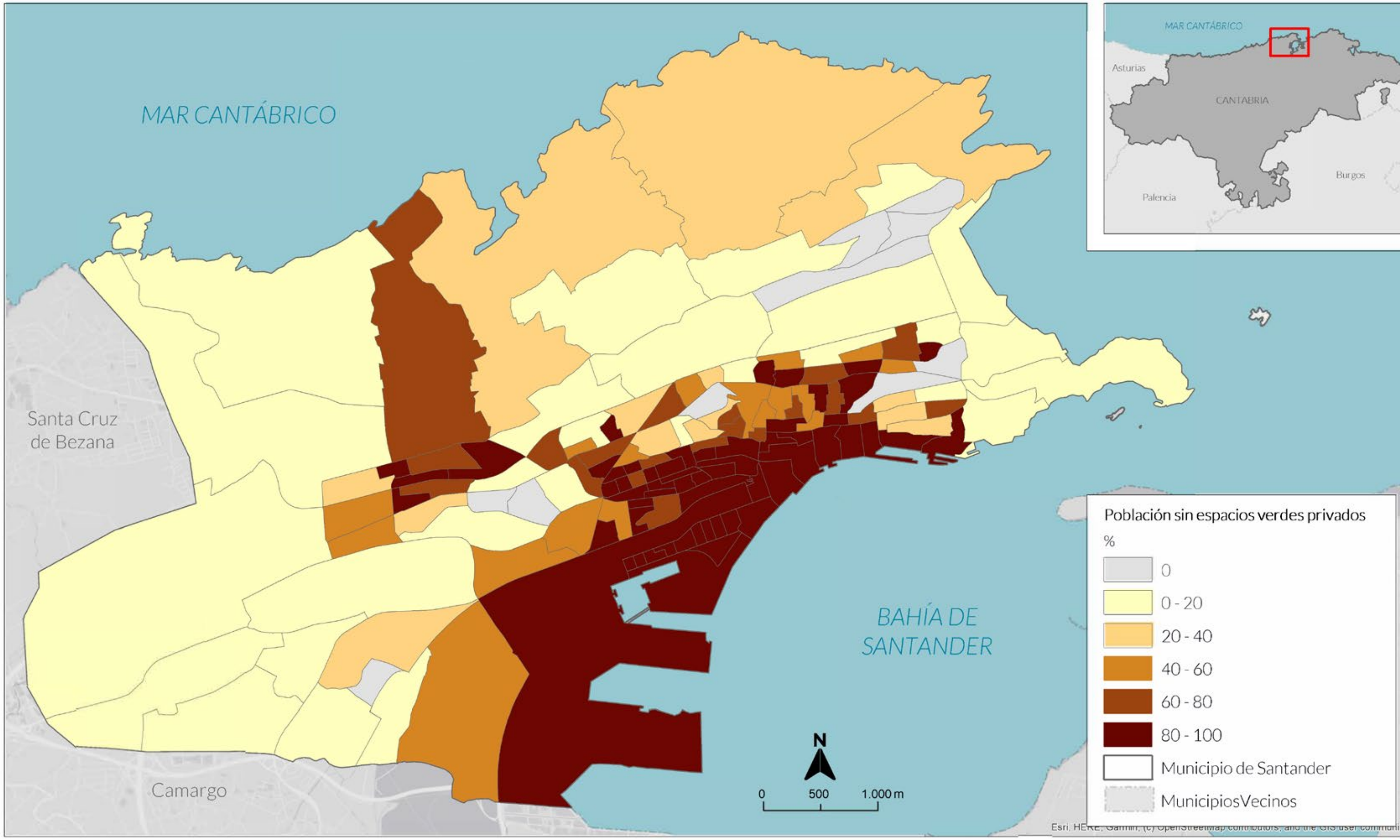
Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
A8-1: Porcentaje de población a más de 400 m de un área verde pública o de recreación con una superficie => 0,5 Ha

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU
Universidad de Cantabria
SANTANDER CAPITAL NATURAL



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

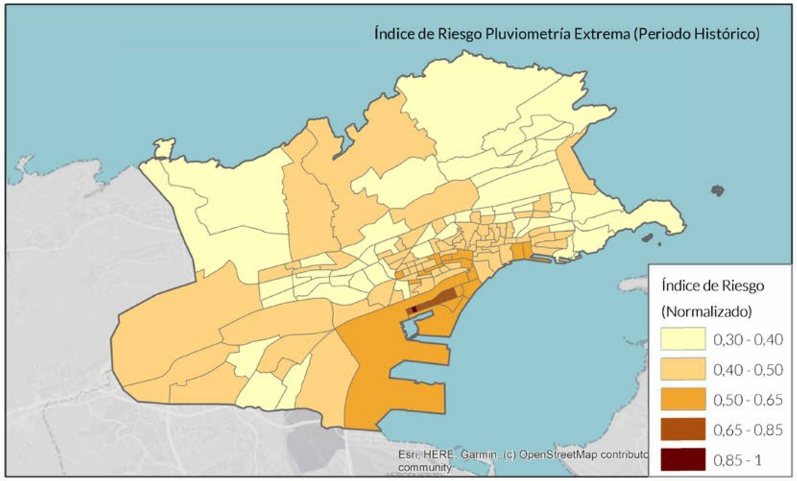
Mapa:
A9-1: Porcentaje de población por sección censal sin espacios verdes privados

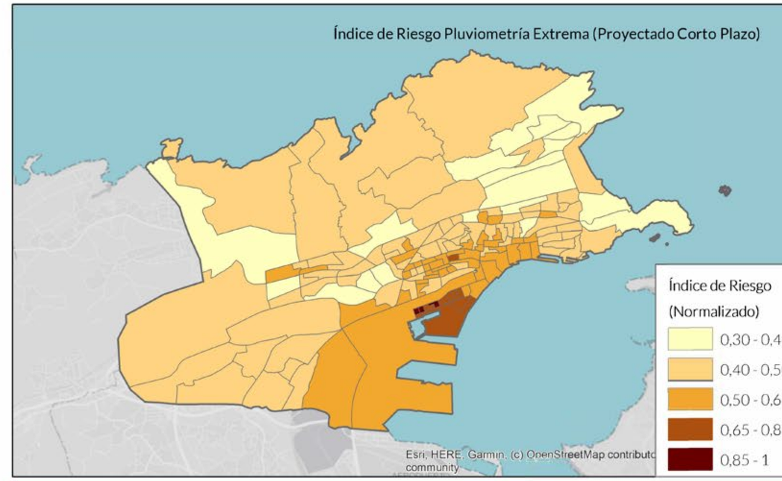
Fecha:
Abril 2024

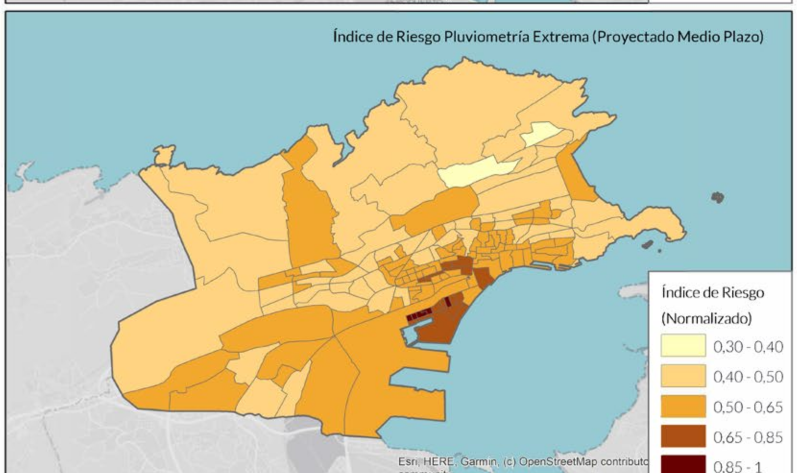
Plan de Recuperación, Transformación y Resiliencia

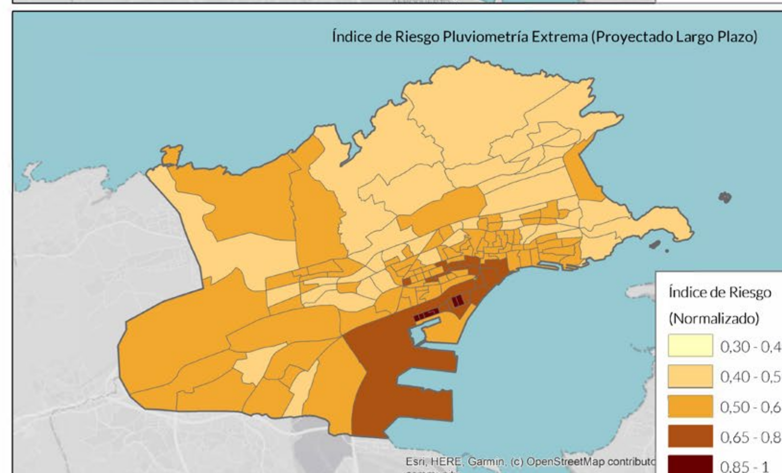
Financiado por la Unión Europea
NextGenerationEU

Autoría:









Proyecto:
SANTANDER CAPITAL NATURAL

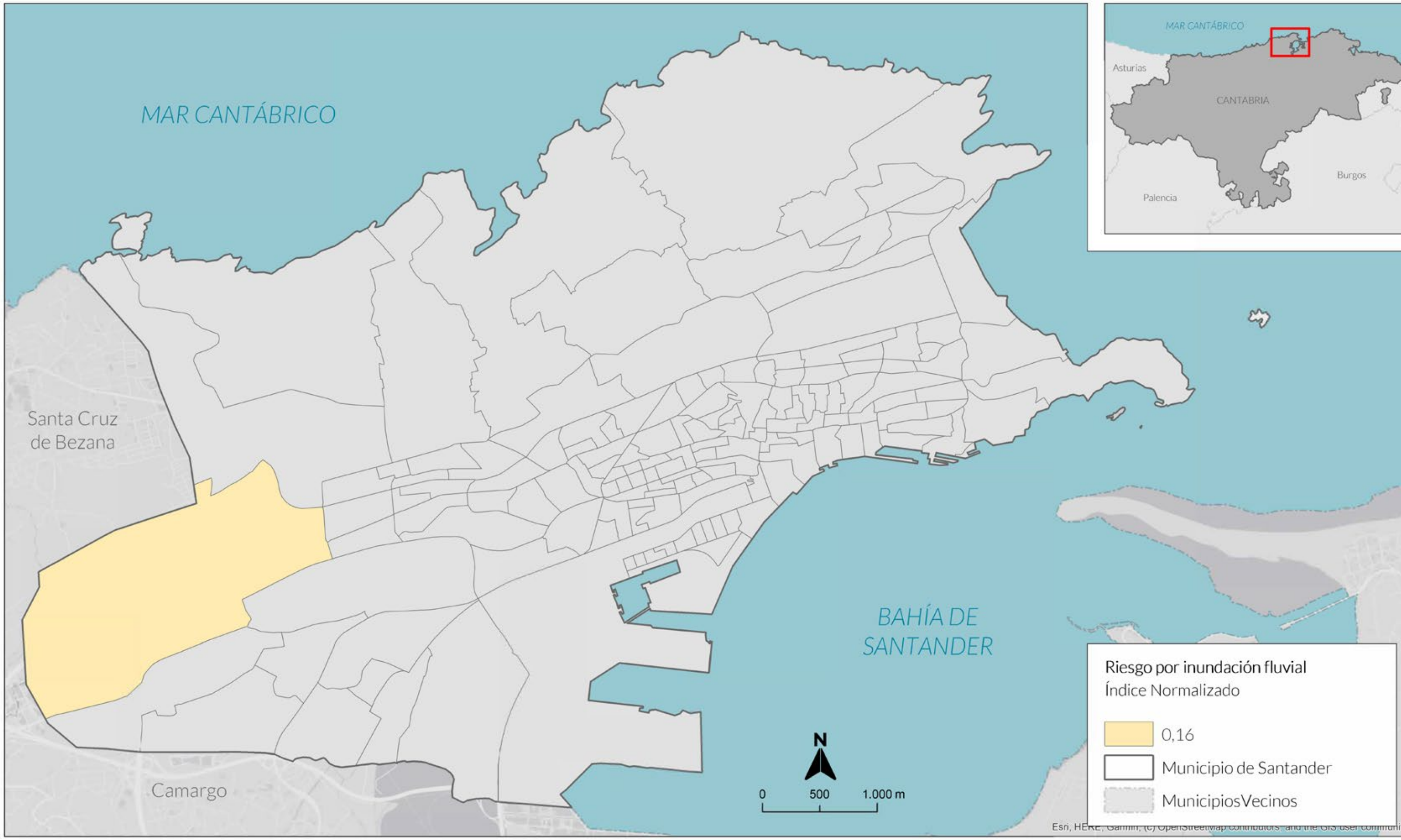
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
Ri.01: Índice normalizado de riesgo por pluviometría extrema por sección censal en el municipio de Santander

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU

Autoría:
UC Universidad de Cantabria
fic
SANTANDER CAPITAL NATURAL



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

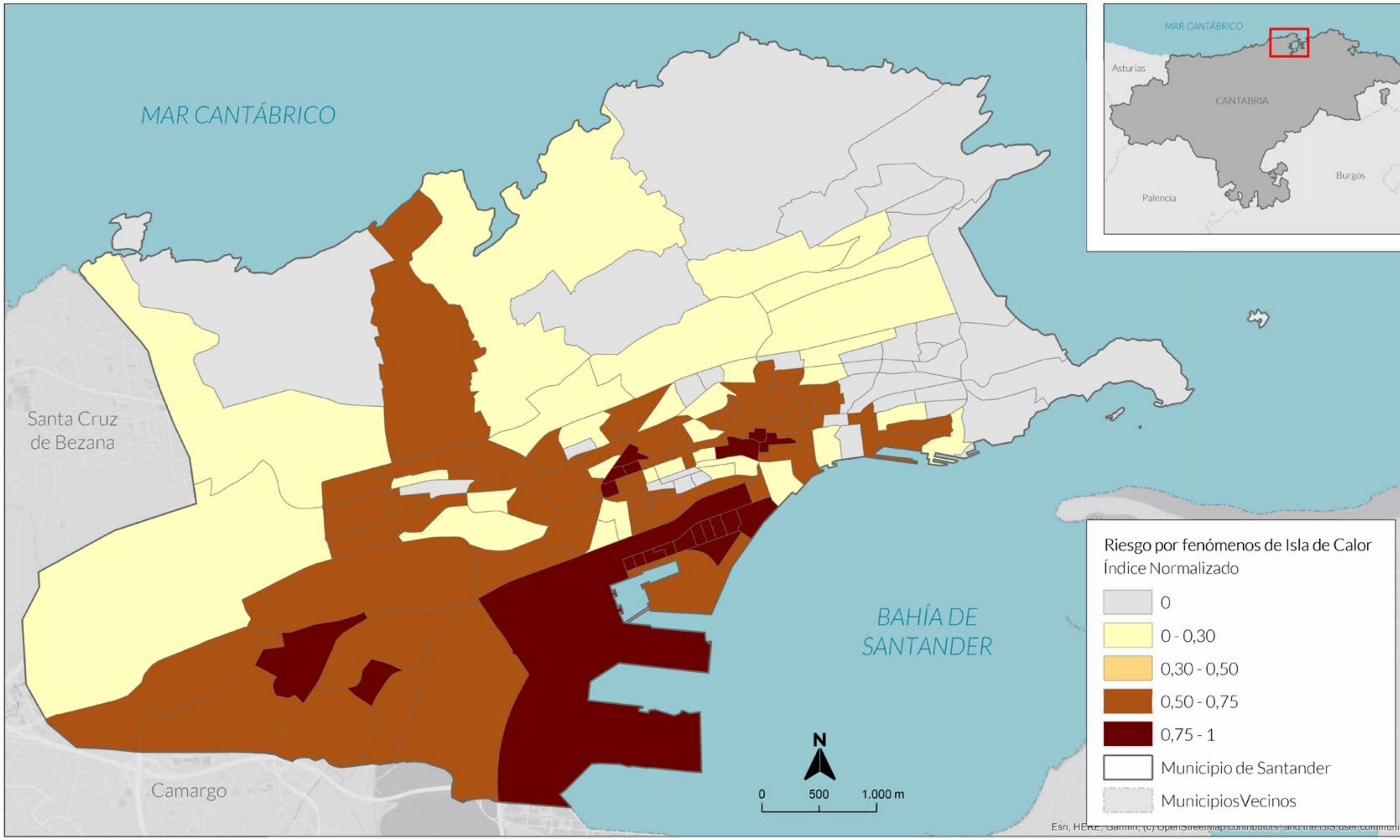
Mapa:
Ri.02: Índice normalizado de riesgo por inundación fluvial por secciones censales en el municipio de Santander

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

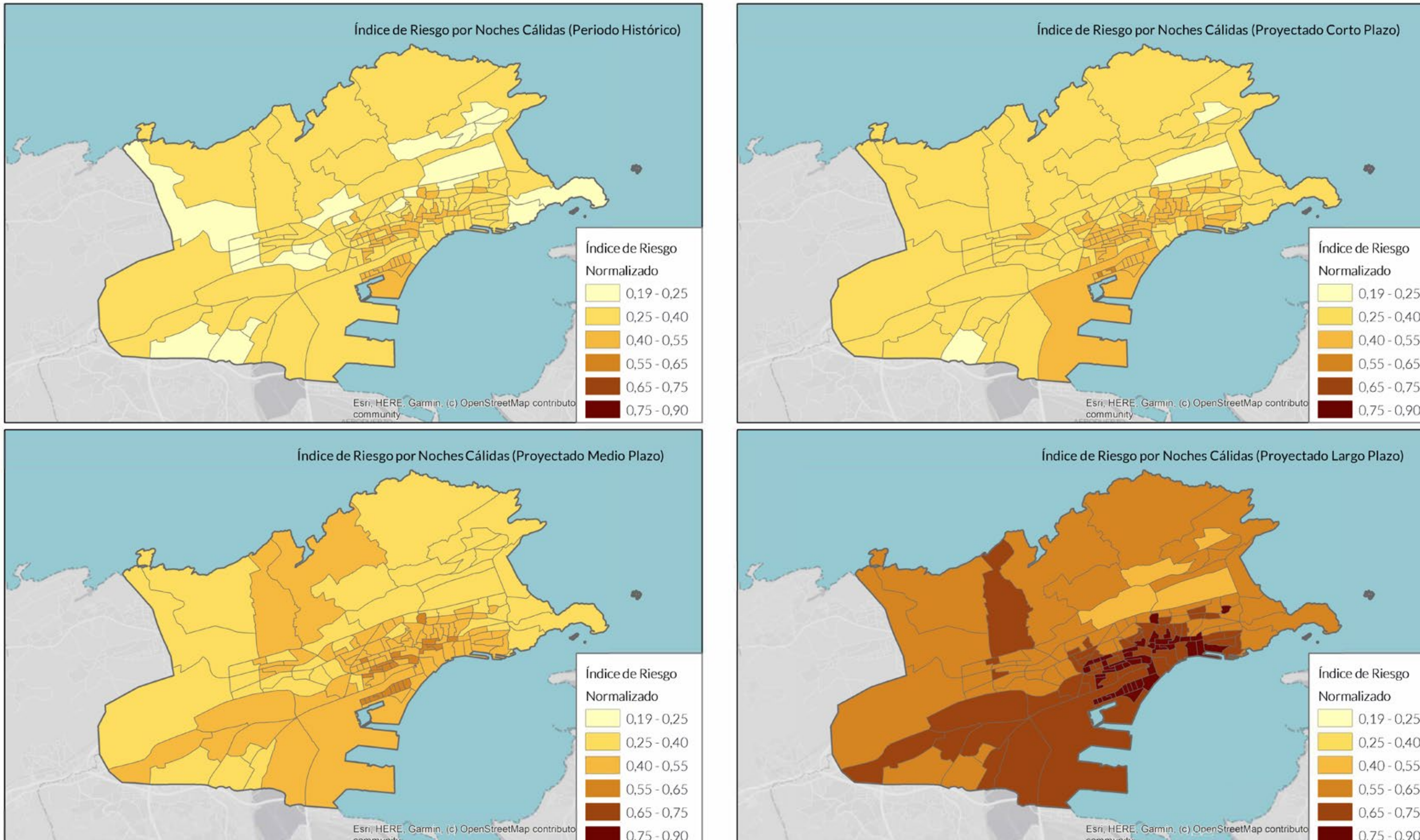
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
Ri.03: Índice normalizado de riesgo por potenciales Islas de Calor Diurna por secciones censales en el municipio de Santander

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

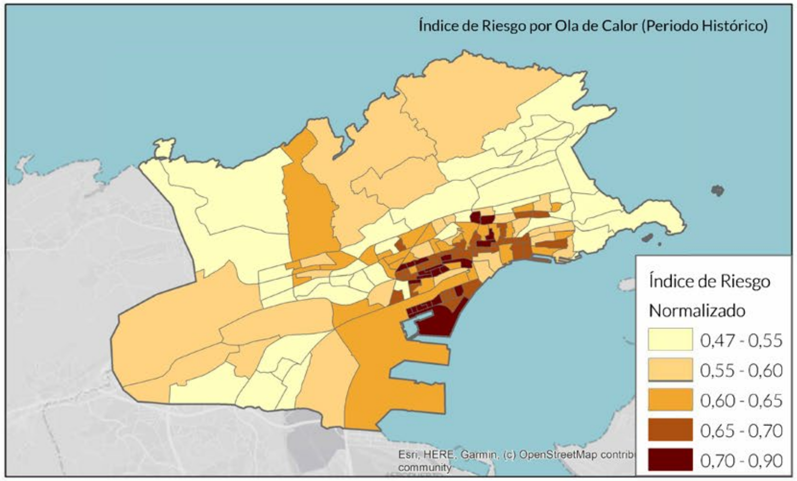
Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

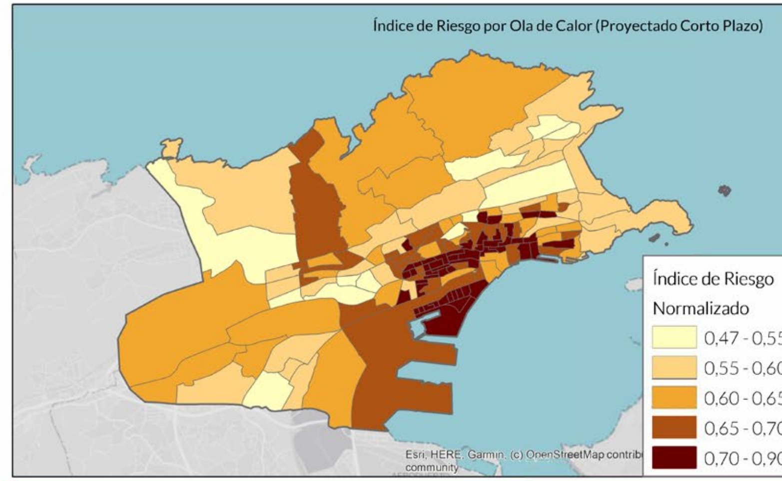
Mapa:
Ri.04: Índice normalizado de riesgo por noches cálidas por secciones censales en el municipio de Santander

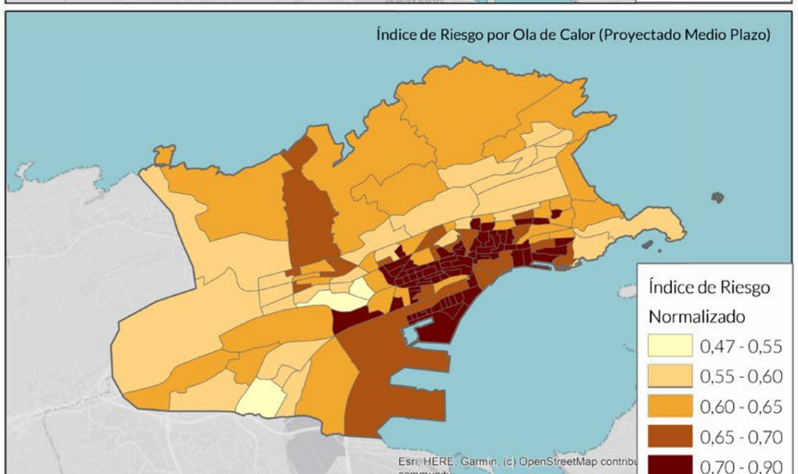
Plan de Recuperación, Transformación y Resiliencia

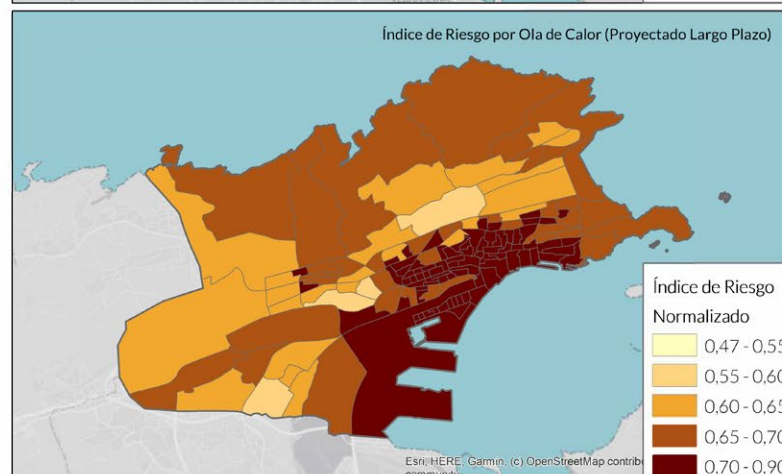
Financiado por la Unión Europea
NextGenerationEU

Autoría:









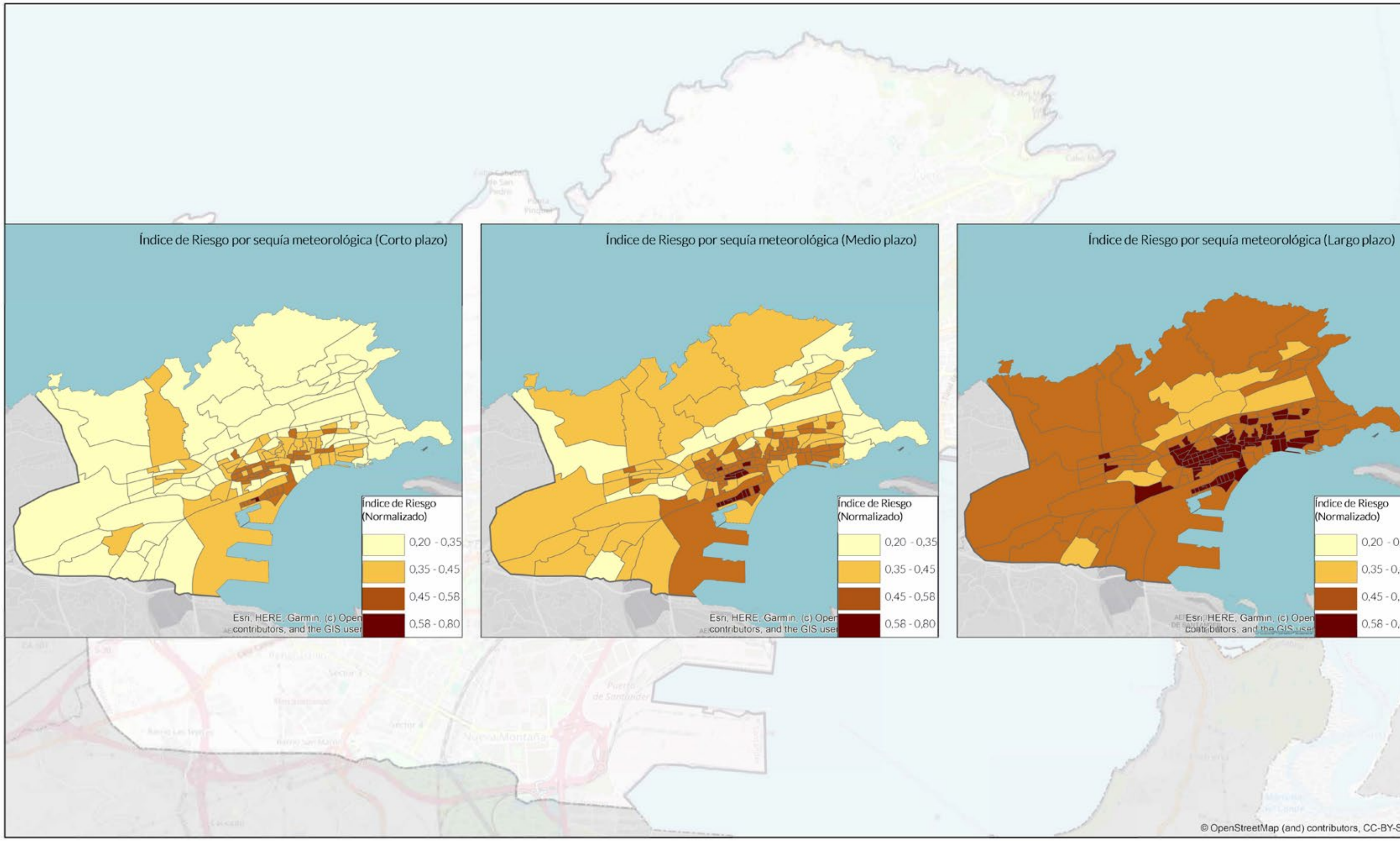
Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
Ri.05: Índice normalizado de riesgo por olas de calor por secciones censales en el municipio de Santander

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

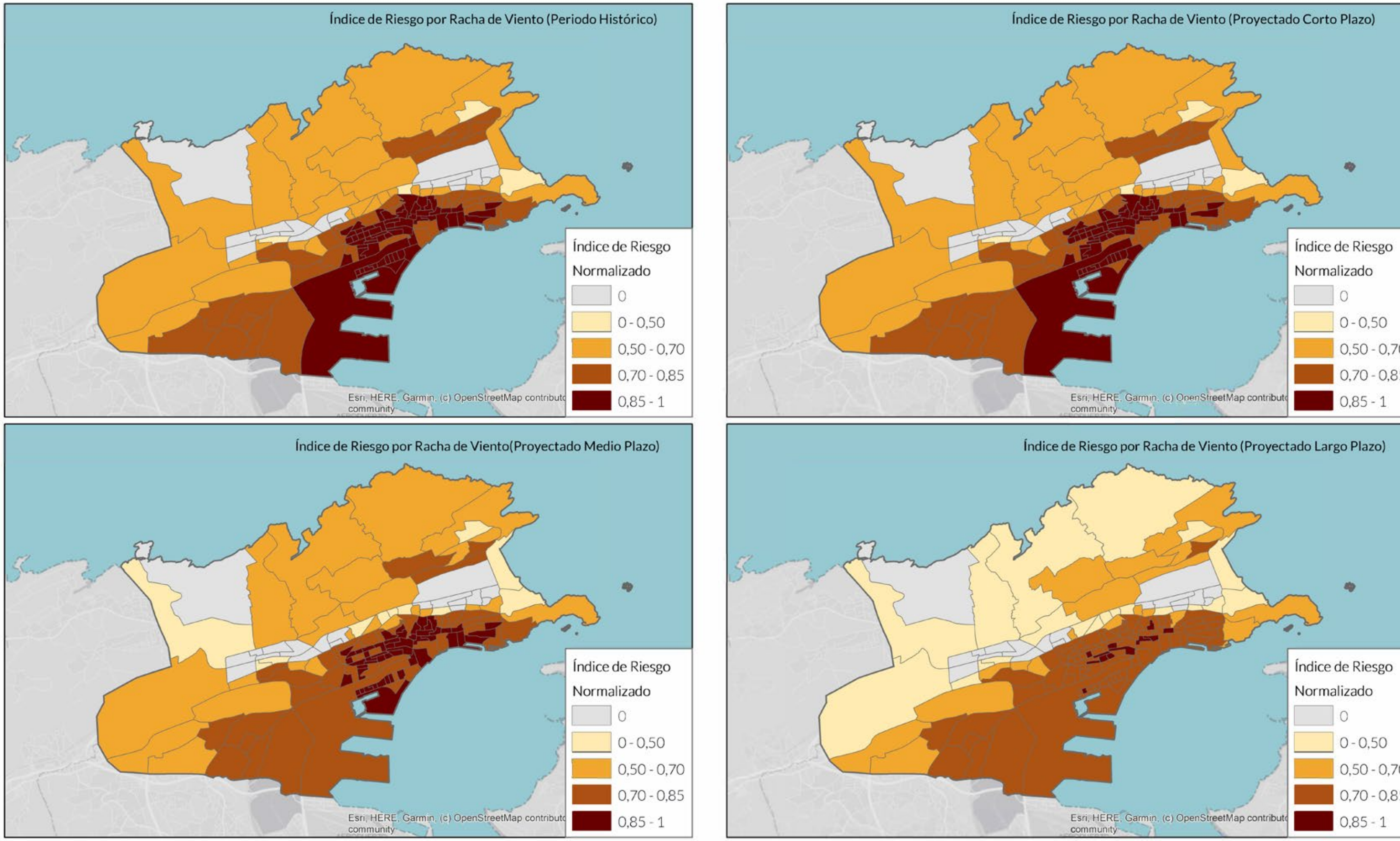
Mapa:
Ri.06: Índice normalizado de riesgo por sequía meteorológica por secciones censales en el municipio de Santander

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU

Autoría:



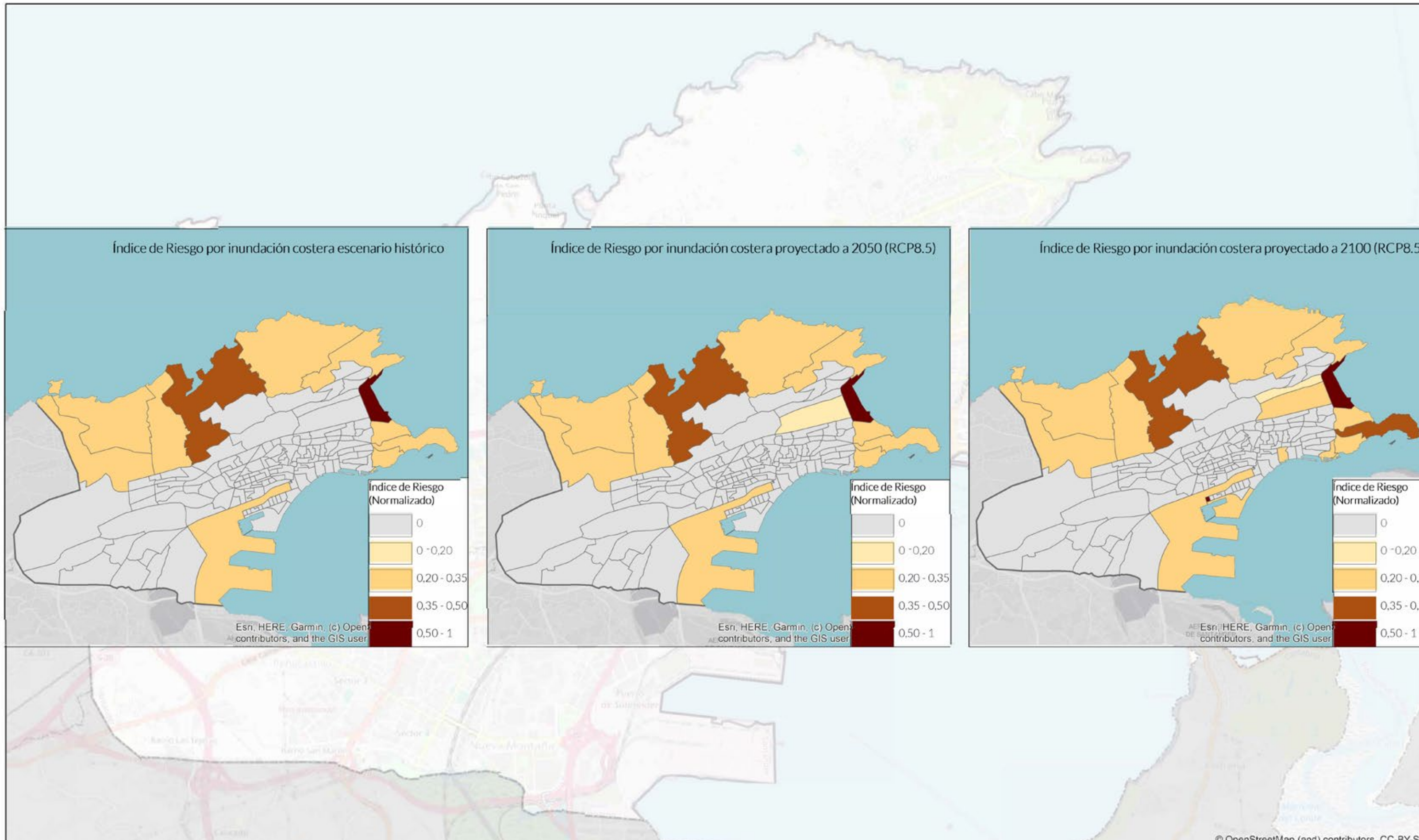
Proyecto:
SANTANDER CAPITAL NATURAL

Fecha:
Abril 2024

Acción:
A2: **Plan de Adaptación Urbana** con Escenarios Climáticos

Mapa:
Ri.07: Índice normalizado de riesgo por rachas máximas de viento por secciones censales en el municipio de Santander

Autoría:



Proyecto:
SANTANDER CAPITAL NATURAL

Acción:
A2: **Plan de Adaptación** Urbana con Escenarios Climáticos

Mapa:
Ri.08: Índice normalizado de riesgo por eventos de inundación costera por secciones censales en el municipio de Santander

Fecha:
Abril 2024

Plan de Recuperación, Transformación y Resiliencia

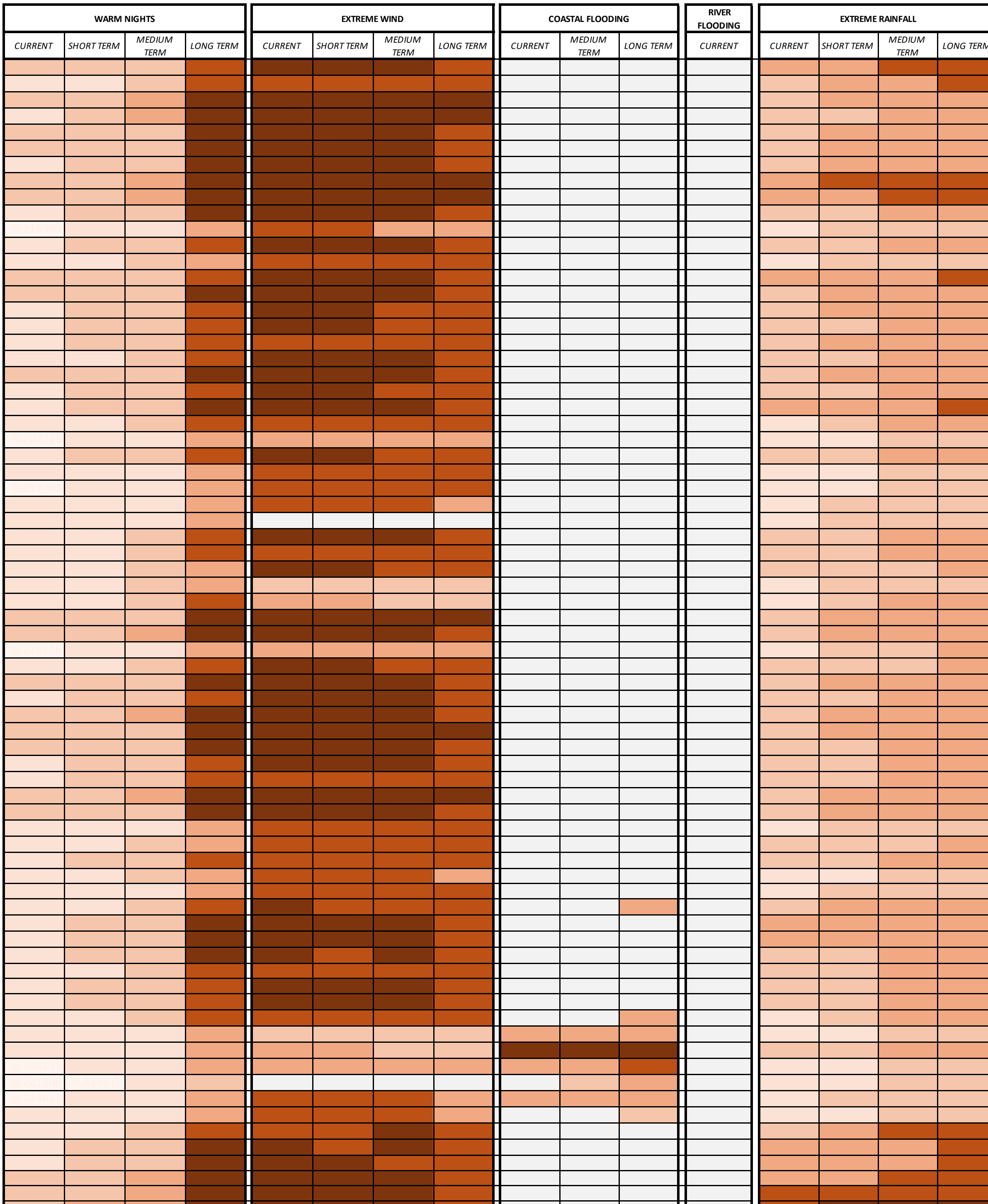
Financiado por la Unión Europea NextGenerationEU

Autoría:

RISK LEVELS

FOR EACH CENSUS SECTION

NEIGHBORHOOD	*CENSUS SECTION*	HEAT ISLAND	HEAT WAVES				DROUGHT		
		UHI	*CURRENT*	*SHORT TERM*	*MEDIUM TERM*	*LONG TERM*	*SHORT TERM*	*MEDIUM TERM*	*LONG TERM*
Centro	3907501001								
Centro	3907501002								
Centro	3907501003								
Centro	3907501004								
Centro	3907501005								
Vía Cornella	3907501006								
Centro	3907501007								
Centro	3907501008								
Calle Alta - Cabildo	3907501009								
Calle Alta - Cabildo	3907501010								
Vía Cornella	3907502001								
La Tierruca	3907502002								
La Tierruca	3907502003								
San Fernando	3907502004								
San Fernando	3907502005								
San Fernando	3907502006								
La Tierruca	3907502007								
Ciudad Jardín - Cuatro Caminos	3907502008								
Ciudad Jardín - Cuatro Caminos	3907502009								
San Fernando	3907502010								
San Fernando	3907502011								
San Fernando	3907502012								
Ciudad Jardín - Cuatro Caminos	3907502013								
Cazoña / Ciudad Jardín Cuatro Caminos	3907502014								
San Fernando	3907502015								
Ciudad Jardín - Cuatro Caminos	3907502016								
Cazoña	3907502017								
Cazoña	3907502018								
Cazoña	3907502019								
Vía Cornella	3907502020								
Vía Cornella	3907502021								
La Tierruca	3907502022								
Cazoña	3907502023								
Cazoña	3907502024								
San Fernando	3907502025								
San Fernando	3907502026								
Cazoña	3907502027								
Vía Cornella	3907503001								
Vía Cornella	3907503002								
Prado - San Roque	3907503003								
Centro	3907503004								
Prado - San Roque	3907503005								
Centro	3907503006								
Prado - San Roque	3907503007								
Prado - San Roque	3907503008								
Puerto Chico	3907503009								
Puerto Chico	3907503010								
Menéndez Pelayo	3907503011								
Tetuán	3907503012								
Prado - San Roque	3907503013								
Prado - San Roque	3907503014								
Tetuán	3907503015								
Puerto Chico	3907504001								
Puerto Chico	3907504002								
Puerto Chico	3907504003								
Tetuán	3907504004								
Tetuán	3907504005								
Tetuán	3907504006								
Tetuán	3907504007								
Tetuán	3907504008								
Sardinero	3907504009								
Las Llamas - Sardinero	3907504010								
Sardinero	3907504011								
Las Llamas - Sardinero	3907504012								
Sardinero	3907504013								
Las Llamas - Sardinero / S20 - La Torre	3907504014								
Centro / Estaciones - Catedral	3907505001								
Estaciones - Catedral	3907505002								
Estaciones - Catedral / Castilla - Hermida - Pesquero	3907505003								
Estaciones - Catedral	3907505004								
Castilla - Hermida - Pesquero	3907505005								
Castilla - Hermida - Pesquero	3907505006								


WARM NIGHTS
CURRENT
SHORT TERM
MEDIUM TERM
LONG TERM
EXTREME WIND
CURRENT
SHORT TERM
MEDIUM TERM
LONG TERM
COASTAL FLOODING
CURRENT
MEDIUM TERM
LONG TERM
RIVER FLOODING
CURRENT
EXTREME RAINFALL
CURRENT
SHORT TERM
MEDIUM TERM
LONG TERM

NEIGHBORHOOD	*CENSUS SECTION*	HEAT ISLAND	HEAT WAVES				DROUGHT		
		UHI	*CURRENT*	*SHORT TERM*	*MEDIUM TERM*	*LONG TERM*	*SHORT TERM*	*MEDIUM TERM*	*LONG TERM*
Castilla - Hermida - Pesquero	*3907505007*								
Castilla - Hermida - Pesquero	*3907505008*								
Castilla - Hermida - Pesquero	*3907505009*								
Estaciones - Catedral	*3907505010*								
Castilla - Hermida - Pesquero	*3907505011*								
Castilla - Hermida - Pesquero	*3907505012*								
Castilla - Hermida - Pesquero / Estaciones - Catedral	*3907505013*								
Castilla - Hermida - Pesquero	*3907505014*								
Castilla - Hermida - Pesquero	*3907505015*								
San Fernando	*3907506001*								
Calle Alta - Cabildo	*3907506002*								
San Fernando	*3907506003*								
Calle Alta - Cabildo	*3907506004*								
San Fernando	*3907506005*								
Calle Alta - valdecilla	*3907506006*								
Calle Alta - valdecilla	*3907506007*								
Calle Alta - valdecilla	*3907506008*								
Calle Alta - valdecilla	*3907506009*								
Campogiro - Cajo / Calle Alta - Valdecilla	*3907506010*								
Campogiro - Cajo	*3907506011*								
Calle Alta - valdecilla	*3907506012*								
Calle Alta - Cabildo	*3907506013*								
Calle Alta - valdecilla	*3907506014*								
San Francisco - Pronillo	*3907507001*								
San Francisco - Pronillo	*3907507002*								
San Francisco - Pronillo	*3907507003*								
San Francisco - Pronillo	*3907507004*								
General Dávila - Los Castros	*3907507005*								
General Dávila - Los Castros	*3907507006*								
General Dávila - Los Castros	*3907507007*								
Los Castros - Fernando de Los Ríos	*3907507008*								
Los Castros - Fernando de Los Ríos	*3907507009*								
Los Castros - Fernando de Los Ríos	*3907507010*								
Los Castros - Fernando de Los Ríos	*3907507011*								
Los Castros - Fernando de Los Ríos	*3907507012*								
Los Castros - Los Pinares - V. Del Camino	*3907507013*								
Los Castros - Los Pinares - V. Del Camino	*3907507014*								
Los Castros - Los Pinares - V. Del Camino	*3907507015*								
Los Castros - Los Pinares - V. Del Camino	*3907507016*								
Menéndez Pelayo	*3907507017*								
Los Castros - Los Pinares - V. Del Camino	*3907507018*								
Los Castros - Los Pinares - V. Del Camino	*3907507019*								
La Albericia / Monte	*3907507020*								
Monte / Las Llamas - Sardinero	*3907507021*								
General Dávila - Los Castros	*3907507022*								
San Francisco - Pronillo	*3907507023*								
Peñacastillo - Hermanos Calderón	*3907508001*								
Campogiro - Cajo	*3907508002*								
Camarreal - Ojaiz	*3907508003*								
Camarreal - Ojaiz / El Alisal	*3907508004*								
La Albericia	*3907508005*								
Cazoña	*3907508006*								
San Román de la Llanilla	*3907508007*								
Monte	*3907508008*								
La Albericia / Monte	*3907508009*								
S20 - La Torre / Valdenoja	*3907508010*								
Cueto	*3907508011*								
Cueto	*3907508012*								
Cazoña	*3907508013*								
Cazoña	*3907508014*								
La Albericia / Cazoña	*3907508015*								
Valdenoja	*3907508016*								
Peñacastillo - Hermanos Calderón	*3907508017*								
El Alisal	*3907508018*								
Valdenoja	*3907508019*								
Peñacastillo - Hermanos Calderón	*3907508020*								
Peñacastillo - Hermanos Calderón	*3907508021*								
Valdenoja	*3907508022*								
El Alisal	*3907508023*								
San Román de la Llanilla	*3907508024*								
Peñacastillo - Hermanos Calderón	*3907508025*								
Nueva Montaña	*3907508026*								
Cueto	*3907508027*								
El Alisal	*3907508028*								
Peñacastillo - Hermanos Calderón	*3907508029*								

WARM NIGHTS				EXTREME WIND				COASTAL FLOODING			RIVER FLOODING	EXTREME RAINFALL			
CURRENT	SHORT TERM	MEDIUM TERM	LONG TERM	CURRENT	SHORT TERM	MEDIUM TERM	LONG TERM	CURRENT	MEDIUM TERM	LONG TERM	CURRENT	CURRENT	SHORT TERM	MEDIUM TERM	LONG TERM

ANNEX: PALYNOLOGICAL STUDY

Sebastián Pérez Díaz, Sara Núñez de la Fuente

Palynological report on 15 sediment samples from the archaeological site of Los Azogues, Santander (Cantabria).

A.1 INTRODUCTION

The reconstruction of past societies, through their material remains, requires collaboration between different disciplines, both in the field of social sciences and the so-called earth sciences, in order to explain the mechanisms of change and evolution of these societies. In this multidisciplinary context, the study of botanical remains recovered from archaeological sites helps to characterise, from a social and economic point of view, the human groups that inhabited them.

Palaeobotany is essential for explaining the relationship between humans and the environment, attempting to provide an explanatory framework for questions such as forest dynamics, climate evolution, the possibilities for plant life, anthropisation of the environment (deforestation), the existence of detectable economic activities that leave their mark on the landscape, land use, etc.

This report presents the results of the analysis of 15 sediment samples from the archaeological site of Los Azogues (Santander, Cantabria). This analysis is particularly interesting given the location and use of the deposit. The site is located on one of the outer walls of the Cathedral of Santander, and corresponds to a medieval necropolis with a chronology that extends from the 12th to the 15th century.

This report has been prepared by Dr. Sara Nuñez-de-la-Fuente, a professional archaeologist specialising in archaeoaplinology, and Dr. Sebastián Pérez-Díaz, from the Department of Geography, Urban and Regional Planning at the University of Cantabria (Santander).

A.2

MATERIAL AND METHODS

Sampling

In February 2023, a total of 15 sediment samples were collected for palynological study (Table A1). All of them were taken following the standardised method in archaeological palynology, minimising the risk of contamination of the sample with pollens from the current pollen rain.

More in detail, in the case of Los Azogues archaeologycal site, there was an open and continuous stratigraphic profile more than 4 metres deep, so it was decided to take a vertical sample on the stratigraphic profile itself (figures A1 and A2). Sampling was always carried out by levels or stratigraphic units (SUs), previously defined by the archaeologist responsible for the excavation, in order to cover the widest possible temporal and cultural interval.

Once the sampling area was decided, the first step was to clean the stratigraphic profile chosen to remove current pollen contamination; this should always be carried out from top to bottom. After this, approximately 20 grams of sediment were placed in individual zip-lock bags, suitably labelled, and the material used was cleaned with distilled water between samples.

Sampling was carried out starting from the oldest sample (the deepest) to the most recent (the shallowest), i.e. always from the bottom upwards, in order to avoid the risk of contamination by falling sediment. In general, we have opted for a sampling resolution of approximately 10 cm intervals between each sample, depending, of course, on the strength of each stratigraphic unit considered. In fact, in some of them, precisely to avoid the risk of contamination due to the presence of landslides, stone blocks, roots, burrows, etc., a different sampling interval has been used. In some cases, several samples were taken from the SU unit to study the potential variability along the same SU.

Chemical treatment of palynological samples

The chemical treatment used basically follows the so-called classical method (Girard and Renault-Miskovsky, 1969; Goeury and Beaulieu, 1979; Faegry and Iversen, 1989; Burjachs, 1990; Moore et al., 1991; Burjachs et al., 2003; López-Sáez et al., 2003). This method consists in that, after washing the sediment, it is subjected to different chemical attacks with acids and bases (hydrochloric acid, sodium hydroxide, potassium hydroxide), whose objective is to successively eliminate carbonates, organic matter and silicates, in such a way that at the end of the process only the sporo-pollinic content remains. The latter is concentrated by means of a dense liquor, in this case Thoulet's liquor (Goeury and Beaulieu, 1979), which makes it possible to separate the pollen and non-pollen microfossils from the rest by densimetric differences.

The final portion of the sediment is preserved in glycerine gelatine for subsequent mounting and reading under an optical microscope. In a more detailed way, the chemical treatment followed can be summarised in the following stages:

1. After separating the sediment in beakers (approximately 30 grams per sample), distilled water was poured in and sieved if necessary. As a control element, a Lycopodium tablet was added, an exogenous element usually used to estimate pollen concentration (Stockmarr, 1971). Hydrochloric acid (HCl) is then added to remove carbonates and break up the Lycopodium tablets. When this has occurred, the HCl is neutralised by successive washes with distilled water and centrifugation (5 minutes at 2500 revolutions per minute or rpm).
2. Once the HCl has been neutralised, sodium hydroxide (NaOH) diluted to 20 % is added to act on the silicates. To achieve this, each sample is placed in a container with hot water for 20 minutes. The NaOH is then neutralised by successive washes with distilled water and centrifugation (5 minutes at 2500 rpm).
3. Finally comes the most delicate phase of the chemical treatment of the samples, since the aim is to definitively separate the pollen content from the rest of the sediment by densimetric difference (Girard and Renault-Miskovsky, 1969; Goeury and Beaulieu, 1979). To do this, after pouring a drop of HCl on each sample, a dense pollen concentration liquor called Thoulet's liquor (made from potassium iodide, cadmium iodide and distilled water) is added at density 2. After shaking for a variable time, usually about 50 minutes in a mechanical shaker or just 8 seconds in an ultrasonic cell disintegrator (Sonifer 450 CE ultrasonic disintegrator with threaded micro-tip), this liquor is filtered through glass fibre filters, in which the pollen content of the sample remains, according to the density mentioned above. After a further attack of HCl to remove the carbonates from the filter or hydrofluoric acid in the case of using glass fibre filters and its corresponding neutralisation, the sample is ready to be observed under the microscope.
4. All samples analysed in this work have been preserved in eppendorf tubes in gelatinised glycerine. In no case were they stained because of the obvious possibility that staining could mask the ornamentation of certain pollen types (Franco-Múgica et al., 1997).

Microscopic identification

The preparation of the samples for observation under the optical microscope was carried out using 76 x 26 mm slides, 1 mm thick, on which 24 x 60 mm coverslips were placed, finally sealing them with hystolaque to avoid losing the sample and to fix it and make it easier to read. Identification was carried out by optical microscopy (Nikon microscope - 40x and 100x objectives).

Pollen microfossils

Pollen identification is possible thanks to the fact that one of the grain walls (sporodermis) is made up of a very resistant substance called sporopolenin, which allows it to be preserved over time, as well as resisting the chemical process to which the samples are subjected. The structure and chemical composition of the sporodermis of the spores of ferns and other pteridophytes is similar to that of pollens, which is why they can also be preserved and studied. The main diagnostic characters of pollens are the following:

- Number of grains. Pollen within the anther are bound together 4 by 4, in the form of tetrads, but when released from the anther, most are dispersed individually (monads). More rarely, they may occur in groups of 2 (dyads), 4 (tetrads) or >4 grains (polyads).
- Exine ornamentation and structure. The exine is the outermost layer of the sporodermis, itself made up of different layers, the outermost of which (ectexine) may be smooth (without ornamentation), baculate (presence of elements more than one micron and taller than wide), echinate (pointed elements more than 3 microns), etc.
- Distribution and shape of the apertures. The apertures are areas where the exine becomes thinner and may even disappear, favouring the exit of the pollen tube through which fertilisation of the ovocell occurs. They characterise the pollen grain according to their number, shape and distribution. There is a specific denomination for these types of characters according to the number of apertures, with some species lacking them and others with more than half a hundred (0: inarpetuate; 1: mono-, 2: di-, 3: tri-, 4: tetra-, 5: penta-, 6: hexa-, >6: poly-). Depending on the shape of these openings, pollen grains are classified as colpate (opening twice as long as wide), porate (opening as long as wide) and colporate, a mixture of both. The distribution of the apertures is also a defining element, whether they are located in the equatorial zone, distributed over the entire surface or restricted to the poles (in the equatorial zone: zonate; over the entire surface: panto-).
- Shape and size of the pollen or spore. Since the shape and size of the pollen grain may vary after the pollen has left the flower as a result of exposure to environmental conditions and sedimentation, these characteristics are taken into account as a guide rather than a determining factor.

Reference collections were used to identify pollen morphotypes. In addition, a variety of literature on the morphometric characteristics of palynomorphs has been used (Moore and Webb, 1978; Bonnefille and Riollet 1980; Moore et al., 1991; Blackmore et al., 1992; Reille, 1992, 1995).

Non Pollen Palynomorphs

A very important advance related to palaeoenvironmental studies, which has been developed since the mid 1970s, is the study of what have been called non-pollen palynomorphs (NPPs). This is a set of elements found in the palynological residue, consisting of both organic and mineral matter, including algal spores, cyanobacteria, fungal spores and thallus remains, fungal fruiting bodies, fragments of bryophytes or pteridophytes, animal microfossils, microfossils of unknown biological nature, etc. (López-Sáez et al., 1998, 2000; van Geel, 2001; Galop and López-Sáez, 2002).

The study of non-pollen palynomorphs does not involve additional chemical preparations and treatments, but the same as those used in traditional palynological analyses (van Geel, 2001). It is therefore an important and indispensable source of additional information on palaeoecological and palaeoenvironmental aspects that are difficult to detect with traditional pollen analyses based exclusively on the study of pollen.

In the palynological protocol, non-pollen palynomorphs can effectively contribute to understanding aspects such as the degree of water pollution, the temporal evolution of trophism, the selective use of fire, the natural or anthropic origin of fires, the relationship between periods of dryness and humidity, the level of water circulation, the variation in the water table, the degree of erosion, and even the level of anthropisation of a site in the sense of being able to quantify the degree of occupation, etc.

For the identification of these NPPs, abundant literature references have been used (van Geel, 1978; Pals et al., 1980; van Geel et al., 1981, 1983, 1983, 1989, 2003; Bakker and van Smeerdijk, 1982; Pantaleón et al., 1996; López-Sáez et al., 1998, 2000). The MNPs identified have been named according to the typology established for each of them by the school of Dr. B. van Geel of the University of Amsterdam (The Netherlands), although in most cases it is possible to identify them at a generic or specific level.

Processing and representation of palynological data

When considering whether a pollen sample is representative for the interpretation of a palaeopalynological analysis, two concepts must be taken into account: pollen sum and taxonomic diversity. In this work, it is accepted that a sample is representative of the surrounding vegetation when (López-Sáez et al., 2003):

- The pollen base sum counts 200 pollen grains, discounting hydrohydrophilic taxa, non-pollen microfossils, Aster type, Cardueae and Cichorioideae.
- At least 20 different taxa are present in the pollen base sum.
- The percentage of indeterminable pollens does not exceed 50% of the pollen base sum.

The last step followed in the pollen analysis was the elaboration of a graph showing the development of the different pollen and non-pollen types along the sequence. The data processing and graphical representation was carried out with the help of the TILIA and TGview programs (Grimm, 1992, 2004), together with the image processing program Inkscape (free software) for the improvement of the figures. For the elaboration of the pollen diagram, as already mentioned, hydro-hydrophilic taxa, non-pollen microfossils and Aster, Cardueae and Cichorioideae have been excluded from the base sum, since they are usually over-represented due to their zoophilic character (Bottema, 1975; López Sáez et al., 1998, 2000, 2003). The relative percentage of these excluded palynomorphs has been calculated with respect to the total sum (figure A3).

A.3 RESULTS AND DISCUSSION

The first comment concerns the state of preservation of the sporopollen remains. In general, the plant microfragments were in a fairly poor state of preservation, which made it very difficult to assign them to pollen types. As far as the representativeness of the samples is concerned, 9 of them were either sterile or not statistically representative (as they did not contain the minimum number of pollens mentiones avobe). Only 6 samples out of the total have reached the minimum threshold mentioned above (more than 200 pollen grains, discounting hydro-hygrophilic taxa, non-pollen microfossils, type Aster, Cardueae and Cichorioideae, a minimum of 20 different taxa and with an adequate taxonomic variety, and indeterminable values lower than 3%).

With regard to the composition of the plant cover in the area around Los Azogues (figure A3), tree pollen values range from 40.8-46.6%. At the local scale, the most representative taxa are deciduous; Among them are deciduous *Quercus* (*Quercus robur, Quercus pirenaica* or *Quercus faginea, 5.7*-10.8%), hazelnut trees (*Corylus,* 1.9-9.4%), birch trees (*Betula, 5.7%*) and lime trees (*Tilia*), showing the existence of small patches of mixed deciduous forests in the area, well adapted to an Atlantic climate dominated by humidity. In relation to these same environmental conditions, some taxa typical of riparian environments are documented, such as willows (*Salix,* 5.7-11.3%), alders (*Alnus,* maximum values of 7.7%), ashes (*Fraxinus,* maximum values of 7.5%) and elms (*Ulmus*), although taking into account local topographic and environmental factors, they could well be related to stable running water courses, or to the aforementioned mixed deciduous forests. The 16th century historian Juan de Castañeda described the area around the city of Santander in 1592 as follows: "it has many mountains, mainly of oaks, holm oaks, chestnuts and beches". In the same way, the description of this landscape is repeated, in this case referring to the region of Las Asturias de Santillana, which is said to be "all full of large forests and populated with many forests and groves of large and infinite chestnut, walnut and oak tres" (Díez-Herrera, 1987).

Other morphotypes identified are *Pinus sp,* with maximum values of 9.3%. However, due to their high pollen production and wide geographical dispersion (due to their anemophilous pollination), their local landscape representation was residual. Studies of current pollen rainfall have shown that only when values of more than 60% are documented can we consider the existence of pine forests on a local scale (López-Sáez et at., 2013). In this case, we must assume the presence of pine forests on a regional scale, possibly in the nearby mountainous areas, where different palaeobotanical studies have documented the presence of these pine forests in the Asón area (Pérez-Díaz et al. 2016a), as the closest reference, but not in percentages (< 20%) that make us think of extensive pine forests, but rather in a landscape that would have a band of pine forests not too extensive above the deciduous forest. We also find in this location of Los Collados del Asón a landscape very similar to that of Los Azogues for the same chronology, with a composition of deciduous woodland ranging between 35.5% and 58%, formed mainly by hazel and oak trees, and accompanied by lime trees, elms and willows.

In the Cantabrian region, the existence of pine forests has been extensively documented in practically all the sites and peat bogs that have been studied over time. However, the presence of these pines, more extensive during the Pleistocene, was reduced with the arrival of the Holocene, which would have been a period of general climatic improvement. The warmer conditions of this climatic period would have led to the retreat of the pine forests and the development of deciduous formations (oak and beech forests), as has been described in regional pollen records from the eastern Cantabrian section, such as the Zalama, Los Tornos and Culazón peat bogs (Peñalba, 1989; López-Sáez et al, 2013; Pérez-Díaz et al., 2016b), in Lago de Ajo in the central part of the Cantabrian Mountains (Allen et al., 1996), or in the Alto de la Espina peat bog in Asturias (López-Merino et al., 2011).

Other interesting tree components are chestnut trees (*Castanea*), identified with maximum values of 7.5%. The presence of chestnut (*Castanea sativa Mill*) in SW Europe is still under debate, as many authors only consider the presence of this species in these territories as a consequence of its intensive cultivation since Roman times (Scarascia-Mugnozza et al. 2000, Conedera et al., 2004; Krebs et al., 2004). However, the palaeobotanical record documents it in SW Europe from the Pliocene and Lower Pleistocene (Huntley and Birks, 1983). In the Iberian Peninsula it has been identified in the fossil record at least since the Lower Pleistocene (Can Guardiola, Atapuerca), as well as in the Middle Pleistocene (Lezetxiki, Atapuerca, Torralba, Ambrona, Pinedo Formation, Bolomor), possibly in relation to glacial refuges. The autochthonous character of the chestnut tree for the Iberian Peninsula has been proposed from different scientific fields (García Antón et al., 1990; Morla Juaristi, 1996), and palaeobotanical data support this hypothesis (Carrión et al., 2003; Gómez-Orellana et al., 2007; Muñoz-Sobrino et al., 2004; Postigo-Mijarra et al., 2008, 2010, López-Sáez et al., 2017). In the context of the northern Iberian Peninsula, the presence of chestnut has been documented in the archaeological site of Laminak II from ca. 12500 cal BP (Uzquiano, 1994), in the Gesaleta peat bog from ca. 10000 cal BP (Ruiz-Alonso et al., 2019), in the Arbarrain peat bog since ca. 8000 cal BP (Pérez-Díaz et al., 2018), in Atxuri since ca. 4500 cal BP (Pérez-Díaz et al., 2015), to give just a few examples. Therefore, their presence in this context is not strange. In any case, its scarce representation does not seem to derive from cultivation processes, but rather from wild species.

Another interesting morphotype is the yew (*Taxus*), which is infrequent in palynological records due to conservation problems and poor dispersal (Cortés et al., 2000) and which in this case has been identified in samples from stratigraphic units 15 and 16 (figure A3). In addition, its pollen grain has a low sporopollenin content, so that its susceptibility to oxidation is high (Havinga 1964, 1967), which means that its pollen representation is generally low. In this case, its low values (no more than 3%) are sufficient to indicate the existence of an isolated stand in the vicinity of the settlement. The presence of yew has been documented in the Cantabrian region in different sites and peat bogs since prehistoric times, with the presence of charred wood in the case of the caves of El Mirón (Zapata 2012), Mazaculos II (Uzquiano 1992, 1995) and the site of Peña Oviedo (Díez-Castillo, 1996, 2008), and through pollen analysis in the peat bog of Cueto de la Avellanosa (Núñez de-la-Fuente, 2018). Yew wood is known for its high value, as it is strong, dense and of very good quality. This has conditioned its use in the past for numerous activities, including the manufacture of weapons, documented at least since Palaeolithic times (Oakley et al., 1977; Thieme and Veil, 1985). Also made of yew wood were the bow and axe handle carried by Ötzi, "the Iceman", located in 1991 due to melting glaciers in the Alps (ca. 5300 cal BP), on the border between Italy and Austria (Spindler, 1994). Bows and spears made of yew wood were also known during the Middle Ages. In 1396 there is a reference in which Martin, crossbowman to the King of Navarre Charles III the Noble, was sent to the mountains of Burunda and Amescua to cut yew trees to make crossbow bows (Schwendtner, 2010). The excessive use of this tree for the manufacture of weapons led to the appearance of medieval legislation protecting the yew, even dating back to the early Middle Ages in several European countries. In Spain, the ancient Soria and Segovia charters protected the yew and holly, despite their use as fodder, allowing only those branches that could be cut by hand and not with an axe or knife to be used (Ruiz-Alonso, 2014). Yew has also been used historically as a construction element due to its robustness and durability, as fodder for animals and even, in sites related to animal housing, it seems that yew was used as an "insecticide", due to its known antibacterial and antimicrobial properties (Daniewski et al., 1998; Erdemoglu and Sener, 2001).

Something similar can be said about the presence in stratigraphic unit 7 (inhum. 81) of *Olea europaea,* although with very low values (0-1.9%). In this case, it could well be the wild species, associated with sclerophyllous formations of Cantabrian holm oak (together with strawberry tree, which has also been identified), or some occasional olive groves, although at the present stage of our knowledge it is not possible to provide more information in this respect.

Shrubs have a very low representation (maximum of 9.5%), with some taxa typical of Atlantic landscapes such as heaths (*Calluna vulgaris, Erica* type), gorse (*Genista/Ulex*) and others from drier and warmer environments, such as strawberry trees (*Arbutus*) or junipers (*Juniperus* type), the latter perhaps adapted to sclerophyllous formations of the Cantabrian holm oak forest type.

The herbaceous component is very important (values between 44.6 and 59.2%), indicating the dominance of open spaces composed of grass meadows (*Poaceae,* 15.4-26.4%), together with anthropic-nitrophilic and anthropozoogenic inspired communities (*Aster* type, Cardueae, Cichorioideae, Chenopodiaceae, *Urtica dioica* type, *Plantago lanceolata*) indicating a very important degree of anthropisation of the space (figure A4). The values of Cichorioideae (Compositae), usually over-represented in archaeological contexts due to their zoophilic pollination, stand out among them, reaching maximum values of 36.5%. No cultivated species, usually cereals, have been detected; however, the high values reached by the Fabaceae (9.2%) suggest some type of crop related to leguminous plants.

Other taxa identified are Brassicaceae and Ranunculaceae, with maximum values of 11 and 5.6%, respectively. As for the hydro-hydrophilic plants, both *Filicales monolete* and *trilete* are found with high values (42.8 and 11.2%, respectively) and the presence of *Polypodium vulgare* (1.9-24.9%) and Cyperaceae (0.6-11%), which are common species in humid contexts, is also noteworthy.

Finally, the non-pollen palynomorphs are varied. The presence of *Glomus cf. fasciculatum* and *Pseudoschizaea circula,* both indicators of the concurrence of anthropisation processes by sediment removal, should be highlighted, although in both cases their values are not too high (maximums of 7.7 and 4.4%, respectively).

From a palaeoclimatic point of view, the chronological period in which the samples analysed (12th-15th centuries) fall into two different phases. The first lasts until ca. 1350 cal AD (Medieval Warm Period), characterised in south-western Europe by rising temperatures and precipitation. This phenomenon is evident in some deposits, although somewhat distant from the area around Santander, such as the case of the Prados de Randulanda peat bog (Álava), where the high resolution of its analysis allows us to identify this phase (Pérez-Díaz, 2012). In the case of the Azogues archaeological site, the presence of sclerophyllous vegetation may be evidence of this time.

After this last anomaly of an arid and warm medieval character, a new and rapid climatic change occurs, of a cold character, but in this case towards more humid conditions (Mayewski et al., 2004), which gives rise to what is known as the Little Ice Age. Its onset, according to authors, could be established between 1300 and 1400 cal AD (Desprat et al., 2003; Mayewski et al., 2004; Mann, 2007; Jalut et al., 2009), extending until the middle of the 19th century cal AD (ca. 1850 cal AD), with an initial drier phase until 1550 cal AD, and another wetter phase that lasts until the present day (Bradley and Jones, 1993).

Throughout the Little Ice Age, however, at least four moments are documented that represent temperature minima, related, among other factors, to the decrease in solar activity (Grove, 2001; González-Rouco et al., 2003; Steinhilber et al., 2009). These are the so-called Wolf (ca. 1280-1350 cal AD), Spörer (ca. 1460-1550 cal AD), Maunder (ca. 1645-1715 cal AD) and Dalton (ca. 1790-1820 cal AD) minima; of which the most pronounced would be the Maunder minimum. The coolest phase is between 1570-1730 cal

AD, and also another in the 19th century cal AD (Bradley and Jones, 1993), which will be mentioned later.

In the case of the Los Azogues archaeological site, due to the low resolution of the palynological study so far, this phase could not be identified. However, this phase is documented in other sites such as the aforementioned Prados de Randulanda peat bog, where from ca. 1320 cal AD, the palaeoclimatic reconstruction shows a prolonged thermal decline, accompanied by an irregular rainfall regime (Pérez-Díaz, 2012).

A.4 CONCLUSIONS

The palynological study of the medieval necropolis of Los Azogues shows relatively homogeneous characteristics throughout the sequence studied. From this analysis it can be deduced that the site would be composed at the landscape level by a deciduous forest in terms of the tree layer, where species such as oak, willow and hazel have a good presence in the landscape. These species are accompanied by other species typical of deciduous woodland, such as alder, birch and ash, thus demonstrating a relatively humid climate. Pine woods, although also represented in the landscape at this time, and given their relatively low percentage (maximum of 9.3%), would be found in more distant places, and possibly on a regional rather than local scale, or isolated pine trees in the surrounding area, without in any way constituting dominant formations in the vicinity of the Los Azogues site.

The above data regarding a humid climate are supported by the presence of hydro-hydrophilic vegetation, such as different types of ferns. However, the area surrounding the site would have been dominated more by open areas, in which herbaceous vegetation was the most important, with very few shrubs. Specifically, the landscape was dominated by grass pastures together with anthropic-nitrophilous communities, which could be evidence that this population would have been linked, among other things, to economic production activities, as these grass pastures would correspond to pastures for livestock use.

TABLE A.1. *Origin and representativeness of the samples studied at the archaeological site of Los Azogues (Santander, Cantabria).*

SAMPLES	STRATIGRAPHIC UNITS (SU)	PRESENCE OF POLLENS
15	UE-4-TOP	No
14	UE-4-BASE	No
13	UE-4	No
12	UE-13	No
11	UE-5	No
10	UE-6	No
9	UE-7-TOP	Yes
8	UE 7. INHUM 82	Yes
7	UE 7. INHUM 81	Yes
6	UE-7-BASE	No
5	UE-11	Yes
4	UE-15	Yes
3	UE-16	Yes
2	UE 19-TOP	No
1	UE 19-BASE	No

Figure A.1. *Location of samples from EU 4 at the archaeological site of Los Azogues (Santander, Cantabria)*

Figure A.2. *Location of samples in the stratigraphic profile of the Los Azogues archaeological site (Santander, Cantabria)*

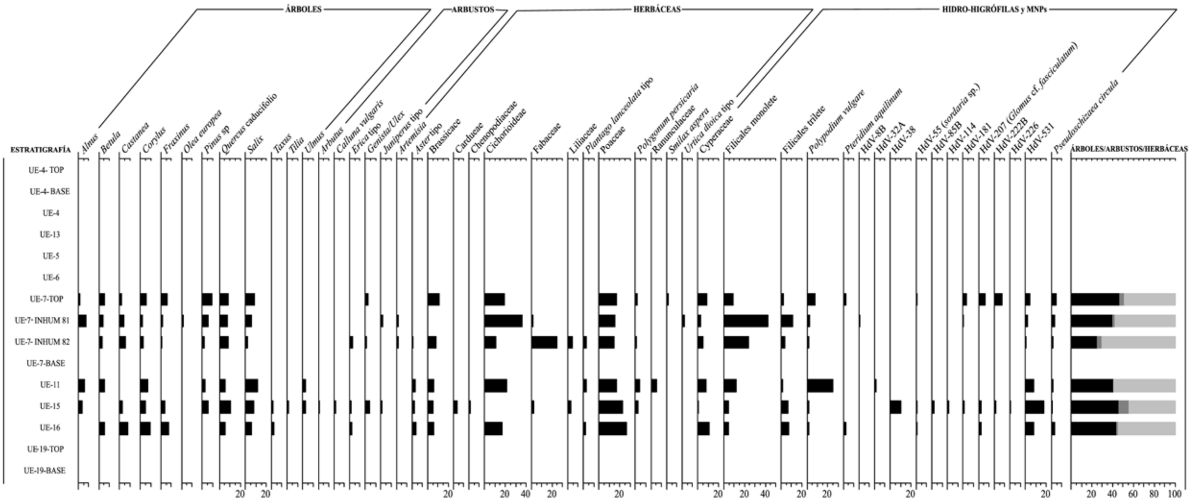


Figure A.3. *Palynological histogram of the archaeological site of Los Azogues (Santander, Cantabria)*

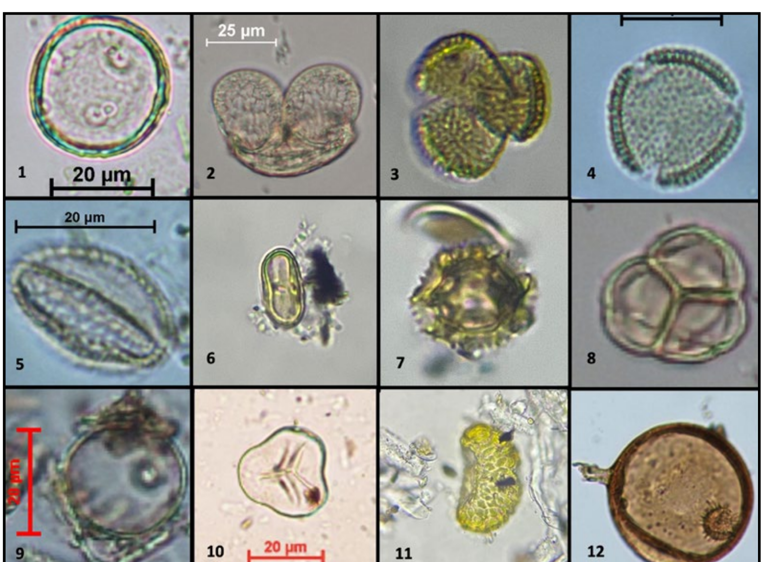


Figure A.4. *Image representing some of the pollen morphotypes identified in the archaeological site of Los Azogues (Santander, Cantabria). 1. Plantago lanceolata, 2. Pinus sp., 3. Brassicaceae, 4. Olea europea, 5. Salix, 6. Fabaceae, 7. Cichorioideae, 8. Erica tipo, 9. Poaceae, 10. Filical trilete, 11. Polypodium vulgare, 12. Glomus cf. fasciculatum.*

LIST OF FIGURES AND TABLES

LIST OF FIGURES

LIST OF TABLES

REFERENCES

ADAPTECCA, 2022. Escenarios de Cambio Climático. https://escenarios.adaptecca.es/#&model=EURO-CORDEX-EQM-verage&variable=tasmax&scenario=rcp85&temporalFilter=year&layers=AREAS&period=MEDIUM_FUTURE&anomaly=RAW_VALUE

AEMET, 2023. Registros meteorológicos históricos de Santander. Agencia Estatal de Meteorología.

AIREF, 2023. Opinión Sobre la Sostenibilidad de las Administraciones Públicas a Largo Plazo: La Incidencia de la Demografía. La Autoridad Independiente de Responsabilidad Fiscal, (AIReF). https://www.airef.es/wp-content/uploads/2023/03/OPINI%C3%93N-SOSTENIBILIDAD/AIReF-2023_Opinion-sostenibilidad-de-las-AAPP-largo-plazo.pdf

Allen, J.R.M.; Huntley, B.; Watts, W.A. 1996. The vegetation and climate of north-west Iberia over the last 14.000 yr. Journal of Quaternary Sciences, 11, 125-147.

Ayuntamiento de Santander, 2016. Plan de Emergencias Municipal 2016. Cuerpo municipal de Bomberos de Santander. Ayuntamiento de Santander.

Bakker, M., van Smeerdijk, D.G. 1982. A palaeoecological study of a Late Holocene section from “Het Ilperveld”, Western Netherlands. Review of Palaeobotany and Palynology, 36: 95-163.

Banco Mundial, 2011. Guide to Climate Change Adaptation in Cities. Accesible en https://openknowledge.worldbank.org/bitstream/handle/10986/27396/653590WP0v200B0Urban0Handbook0Final.pdf?sequence=1

Benestad RE., 2010. Downscaling precipitation extremes. Theor Appl Climatol, 100: 1–21. https://doi.org/10.1007/s00704-009-0158-1

Bentsen, M., Oliviè, D., Seland, Ø., Toniazzo, T.; Gjermundsen, A., Graff, L. S., Debernard, J. B., Gupta, A. K., He, Y., Kirkevåg, A., Schwinger, J., Tjiputra, J., Aas, K. S., Bethke, I., Fan, Y., Griesfeller, J., Grini, A., Guo, C., Ilicak, M., Karset, I. H. L., Landgren, O. A., Liakka, J., Moseid, K. O., Nummelin, A., Spensberger, C., Tang, H., Zhang, Z., Heinze, C., Iversen, T., Schulz, M., 2019. NCC NorESM2-MM model output prepared for CMIP6 ScenarioMIP.. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.608

Bi, D., Dix, M., Marsland, S., O’Farrell, S., Sullivan, A., Bodman, R., Law, R., Harman, I., Srbinovsky, J., Rashid, H. A., Dobrohotoff, P., Mackallah, C., Yan, H., Hirst, A., Savita, A., Dias, F.B., Woodhouse, M., Fiedler, R., Heerdege, A., 2020. ConFiguretion and spin-up of ACCESS-CM2, the new generation Australian Community Climate and Earth System Simulator Coupled Model. Journal of Southern Hemisphere Earth Systems Science 70, 225-251. https://doi.org/10.1071/ES19040

Blackmore, S., Le Thomas, A., Nilsson, S., Punt, W. 1992. Pollen and spores. Terminology, Universidad de Utrecht, Utrecht.

Bonnefille, R., Riollet, G. 1980. Pollens des savanes d´Afrique orientale, CNRS, Paris.

Bottema, S. 1975. The interpretation of pollen spectra from prehistoric settlements (with special attention to liguliflorae). Palaeohistoria, 17: 17-35.

Bradley, R.S., Jones, P.D. 1993. Little Ice Age summer temperature variations: their nature and relevance to recent global warming trends. The Holocene, 3 (4): 367-376.

Burjachs, F. 1990. Palinologia dels dòlmens de l’Alt Empordà i dels dipòsits quaternaris de la cova de l’Arbreda (Serinyà, Pla de l’Estany) i del Pla de l’Estany (Olot, Garrotxa). Evolució del paisatge vegetal i del clima des de fa més de 140.000 anys al N.E. de la Península Ibèrica. Tesis Doctoral. Publicaciones de la Universitat Autònoma de Barcelona, Bellaterra.

Burjachs, F., López-Sáez, J.A., Iriarte, M.J. 2003. Metodología Arqueopalinológica. En: Buxó, R., Piqué, R. (eds.), La recogida de muestras en Arqueobotánica: objetivos y propuestas metodológicas. La gestión de los recursos vegetales y la transformación del paleopaisaje en el Mediterráneo occidental, pp. 11-18. Museu d'Arqueologia de Catalunya, Barcelona.

Carmona, R., Díaz, J., Mirón, I.J., Ortiz, C., Luna, M.Y., Linares, C., 2016. Mortality attributable to extreme temperatures in Spain: A comparative analysis by city. Environment International, 91, 22-28. https://doi.org/10.1016/j.envint.2016.02.018

Carrión, J. S., Sánchez-Gómez, P., Mota, J. F., Yll, R., Chaín, C. 2003. Holocene vegetation dynamics, fire and grazing in the Sierra de Gádor, southern Spain. The Holocene, 13(6), 839-849.

Catastro, 2023. Dirección General de Catastro (Cartografía Catastral INSPIRE).

Climate Adapt, 2023. Planning for Adaptation to Climate Change - Guidelines for Municipalities https://climate-adapt.eea.europa.eu/en/metadata/guidances/planning-for-adaptation-to-climate-change-guidelines-for-municipalities

Conedera, M., Krebs, P., Tinner, W., Pradella, M., Torriani, D. 2004. The cultivation of Castanea sativa (Mill.) in Europe, from its origin to its diffusion on a continental scale. Vegetation history and archaeobotany, 13, 161-179.

Comisión Europea, 2013. Estrategia de adaptación al cambio climático de la UE. Bruselas, 16.4.2013 COM(2013) 216 final. Accesible en: http://ec.europa.eu/transparency/regdoc/rep/1/2013/ES/1-2013-216-ES-F1-1.Pdf

Comisión Europea, 2021. Pacto Verde Europeo. Consecución de nuestros objetivos. Luxemburgo, Oficina de Publicaciones de la UE. https://ec.europa.eu/commission/presscorner/api/files/attachment/869813/EGD_brochure_ES.pdf

CORDEX, 2023. EURO-CORDEX - Coordinated Downscaling Experiment - European Domain. https://www.euro-cordex.net/

Cortés, S., Vasco, F., Blanco, E. 2000. El libro del tejo (Taxus baccata L.). 336 pp. ARBA, Madrid

Costa-Tenorio, M; Morla-Juaristi, C; Sainz-Ollero, H. (Eds.). (2005): Los bosques ibéricos. Una interpretación geobotánica. Editorial Planeta, Barcelona.

Daniewski, W.M.; Gumulka, M.; Anczewski, W.; Masnyk, M.; Bloszyk, E.; Gupta, K. K. 1998. Why the yew tree (Taxus baccata) is not attacked by insects. Phytochemistry, 49 (5). Pp: 1279-1282.

Desprat S., Sanchez-Goni M.F., Loutre M.F. 2003. Revealing climatic variability of the last three millennia in northwestern Iberia using pollen influx data. Earth and Planetary Science Letters: 213, 63-78.

Diez-Castillo, A. 1996. Una cabaña neolítica en los Picos de Europa. I Congrés de Neolitic a la Península Ibérica. Rubricatum, I (1), 349-355.

Diez-Castillo, A. 2008. Las excavaciones en la zona arqueológica de la Peña Oviedo. Las campañas de 2000 a 2003. Actuaciones arqueológicas en Cantabria, 2000-2003. Consejería de Cultura, Educación y Deporte, 101-106.

Díez-Herrera, C. 1987. Cantabria en la Edad Media, evolución socioeconómica. (La formación de la sociedad feudal en Cantabria: la organización del territorio en los siglos IX al XIV). Tesis Doctoral, Universidad de Cantabria.

Dodman, D., B. Hayward, M. Pelling, V. Castan Broto, W. Chow, E. Chu, R. Dawson, L. Khirfan, T. McPhearson, A. Prakash,Y. Zheng, and G. Ziervogel, 2022. Cities, Settlements and Key Infrastructure. En IPCC (2022). Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897 - 2930. https://doi.org/10.1017/9781009325844.029

EC-Earth Consortium (EC-Earth), 2019. EC-Earth-Consortium EC-Earth3-Veg model output prepared for CMIP6 Scenario MIP. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.727

EEA, 2021. Vector-borne diseases. https://www.eea.europa.eu/data-and-maps/indicators/vector-borne-diseases-2/assessment

Erdemoglu, N.; Sener, B. 2001. Antimicrobial activity of the heartwood of Taxus baccata. Fitoterapia, 72 (1). Pp: 59-61.

Eyring, V., Bony, S., Meehl, G.A., Senior, C.A., Stevens, B., Stouffer, R.J., Taylor, K.E., 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, Geosci. Model Dev. 9: 1937-1958. https://doi.org/10.5194/gmd-9-1937-2016

Faegri, K., Iversen, J. 1989. Text-book of pollen analysis. 4 th. Edn. John Wiley & Sons, Chichester.

Franco-Múgica, F., García-Antón, M., Sainz-Ollero, H. 1997. Impacto antrópico y dinámica de la vegetación durante los últimos 2000 años BP en la vertiente septentrional de la Sierra de Gredos: Navarredonda (Ávila, España). Revue de Paléobiologie, 16 (1): 29-45.

Füssel, H.M., Klein, R.J., 2006. Climate change vulnerability assessments: An evolution of conceptual thinking. Climate Change, 75, 301-329. http://dx.doi.org/10.1007/s10584-006-0329-3

Galop, D., López-Sáez, J.A. 2002. Histoire agraire et paléoenvironnement: les apports de la palynologie et des microfossiles non-polliniques. Trabalhos de Antropologia e Etnologia, 42 (1-2): 161-164.

García, F., 2019. Planeamiento urbanístico y cambio climático: la infraestructura verde como estrategia de adaptación = Urban planning and climate change: green infrastructure as an adaptation strategy. CIUR, 122. https://doi.org/10.20868/ciur.2019.122.3870

García, F., Solecki, W.D., Ribalaygua, C., 2018. Climate change adaptation in Europe and the United States: A comparative approach to urban green spaces in Bilbao and New York City. Land Use Policy, 79, 164-173. https://doi.org/10.1016/j.landusepol.2018.08.010

García-Antón, M.; Morla-Juaristi, C., Sainz-Ollero, H. 1990. Consideraciones sobre la presencia de algunos vegetales relictos terciarios durante el Cuaternario en la Península Ibérica. Boletín de la Real Sociedad Española de Historia Natural (Sec.Biol.), 86 (1-4): 95-105.

Gettelman, A., Mills, M.J., Kinnison, D. E., Garcia, R. R., Smith, A. K., Marsh, D. R., Tilmes, S., Vitt, F., Bardee, C.G., Mclnerny, J., Liu, H.-L., Solomon, S.C., Polvani, L.M., Emmons, L.K., Lamarque, J.-F., Richter, J.H., Clanville, A.S., Neale, R.B., Simpson, I.R, DuVivier, A.K., Hodzic, A., Randel, W.J., 2019. The whole atmosphere community climate model version 6 (WACCM6). Journal of Geophysical Research: Atmospheres, 124. https://doi.org/10.1029/2019JD030943

Girard, M., Renault-Miskovsky, J. 1969. Nouvelles techniques de préparation en palynologie appliquées à trois sédiments du Quaternaire final de l´Abri Cornille (Istres, Bouches du Rhône). Bulletin de l´Association Française pour l´Etude du Quaternaire, 1969 (4): 275-284.

GIZ, 2016. Climate and Environmental Report 2016. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://www.giz.de/en/downloads/GIZ_ClimateEnvironment_2016_EN_180718.pdf

Gobierno de Cantabria, 2018. Estrategia de Acción frente al Cambio Climático de Cantabria 2018 – 2030. https://www.cambioclimaticocantabria.es/documents/3528731/3528777/Estrategia+Cambio+Clim%C3%A1tico+2018-2030.pdf/5c61b11b-af55-97bc-58bd-ae68979089ab

Gobierno de España, 2020a. Plan Nacional de Adaptación al Cambio Climático (PNACC) 2021-2030. https://www.miteco.gob.es/content/dam/miteco/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/pnacc-2021-2030_tcm30-512163.pdf

Gobierno de España, 2020b. Estrategia Española de Economía Circular, España Circular 2030. https://www.miteco.gob.es/content/dam/miteco/es/calidad-y-evaluacion-ambiental/temas/economia-circular/espanacircular2030_def1_tcm30-509532_mod_tcm30-509532.pdf

Gobierno de España, 2021a. Ley 7/2021, de 20 de mayo, de cambio climático y transición energética. https://www.boe.es/eli/es/l/2021/05/20/7

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

Goeury, C., Beaulieu, J.L. 1979. Á propos de la concentration du pollen à l`aide de la li-queur de Thoulet dans le sédiments minéraux. Pollen and Spores, 21: 239-251.

Gómez-Orellana, L., Ramil-Rego, P., Sobrino, C. M. 2007. The Würm in NW Iberia, a pollen record from area Longa (Galicia). Quaternary Research, 67(3), 438-452.

González-Rouco, F., Von Storch, H., Zorita, E. 2003. Deep soil temperature as proxy for surface air-temperature in a coupled model simulation of the last thousand years. Geophysical Research Letters, 30 (21), 2116.

Good, P., Sellar, A., Tang, Y., Rumbold, S., Ellis, R., Kelley, D., Kuhlbrodt, T., 2019. MOHC UKESM1.0-LL model output prepared for CMIP6 ScenarioMIP ssp245. 1. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.6339

Grimm, E.C. 1992. Tilia, version 2, Springfield. IL 62703. USA. Illinois State Musseum. Research and Collection Center.

Grimm, E.C. 2004. TGView. Illinois State Museum, Springfield.

Grove, A.T. 2001. The "Little Ice Age" and its geomorphological consequences in Mediterranean Europe. Climatic Change, 18: 121-136.

Gutiérrez, J.M., Herrera, S., San Martín, D., Sordo, C., Rodríguez, J.J., Frochoso, M., Ancell, R., Fernández, J., Cofiño, A.S., Pons, M.R. & Rodríguez, M.A. (2010). Escenarios Regionales Probabilísticos de Cambio Climático en Cantabria: Termopluviometría. Universidad de Cantabria, Consejería de Medio Ambiente, Gobierno de Cantabria.

Havinga, A. J. 1964. Investigation into the differential corrosion susceptibility of pollen and spores. Pollen et spores, 4, 621-635.

Havinga, A. J. 1967. Palynology and pollen preservation. Review of Palaeobotany and Palynology, 2 (1-4), 81-98.

Hayes, M., Svoboda, M., Wall, N., Widhalm, M., 2011. The Lincoln Declaration on Drought Indices: Universal Meteorological Drought Index Recommended. Drought Mitigation Center Faculty Publications. 14. http://digitalcommons.unl.edu/droughtfacpub/14

Huntley, B., Birks, H.J.B. 1983. An atlas of past and present pollen maps for Europe: 0-13000 years ago (BP), Cambridge University Press, Cambridge.

IGN, 2022. Base Topográfica Nacional. Instituto Geográfico Nacional.

IH Cantabria - UC, 2014. Cambio Climático en la Costa Española. Ministerio de Agricultura, Alimentación y Medioambiente. https://www.miteco.gob.es/content/dam/miteco/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/2014%20INFORME%20C3E%20final_tcm30-178459.pdf

INE, 2023. Censo de Población y Vivienda. Instituto Nacional de Estadística.

IPCC, 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

IPCC, 2022a. Annex II: Glossary [Möller, V., R. van Diemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (eds.)]. En: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897–2930, https://doi.org/10.1017/9781009325844.029.

IPCC, 2022b. Summary for Policymakers. In: Climate Change 2021: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Jalut, G., Dedoubat, J. J., Fontugne, M., Otto, T. 2009. Holocene circum-Mediterranean vegetation changes: Climate forcing and human impact. Quaternary International, 200 (1-2): 4-18.

Krebs, P., Conedera, M., Pradella, M., Torriani, D., Felber, M., Tinner, W. 2004. Quaternary refugia of the sweet chestnut (Castanea sativa Mill.): an extended palynological approach. Vegetation history and Archaeobotany, 13, 145-160.

Ley, P., de Castro, Ó., García, F., 2024. Mass tourism urban destinations and climate change in small islands: resilience to extreme rainfall in the Canary Islands. Environ Dev Sustain 26, 10765–10785. https://doi.org/10.1007/s10668-023-03406-7

López-Merino, L.; Martínez-Cortizas, A.; López-Sáez, J.A. 2011. Human induced changes on wetlands: a study case from NW Iberia. Quaternary Science Reviews, 30, 2745- 2754.

López-Merino, L., López-Sáez, J.A. 2009. Dialéctica entre el ser humano y el haya durante el holoceno en el sistema ibérico septentrional. Cuadernos de la Sociedad Española de Ciencias Forestales 30: 43-48.

López-Sáez, J.A., van Geel, B., Farbos-Texier, S., Diot, M.F. 1998. Remarques paléoécologiques à propos de quelques palynomorphes non-polliniques provenant de sédiments quaternaires en France. Revue de Paléobiologie, 17 (2): 445-459.

López-Sáez, J.A., van Geel, B., Martín-Sánchez, M. 2000. Aplicación de los microfósiles no polínicos en Palinología Arqueológica. En: Oliveira Jorge, V. (ed.), Contributos das Ciências e das Technologias para a Arqueologia da Península Ibérica, Actas 3° Congresso de Arqueología Peninsular, vol. IX. Adecap, Oporto, pp. 11-20.

López-Sáez, J.A., López-García, P., Burjachs, F. 2003. Arqueopalinología: Síntesis crítica. Polen, 12: 5-35.

López-Sáez, J.A., Sánchez-Mata, D., Alba-Sánchez, F., Abel-Schaad, D., Gavilán, R.G., Pérez-Díaz, S. 2013. Discrimination of Scots pine forests in the Iberian Central System (Pinus sylvestris var. iberica) by means of pollen analysis. Phytosociologial considerations. Lazaroa, 34, 191-208.

López-Sáez, J. A., Abel-Schaad, D., Iriarte, E., Alba-Sánchez, F., Pérez-Díaz, S., Guerra-Doce, E., Abarquero-Moras, F. J. 2017. Una perspectiva paleoambiental de la explotación de la sal en las Lagunas de Villafáfila (Tierra de Campos, Zamora).

Mann, M.E. 2007. Climate over the past two millennia. Annual Review of Earth Planetary Sciences, 35:111-136.

Martínez-Atienza, F., Morla-Juaristi, C. 1992. Aproximación a la paleocorología de Fagus en la Península Ibérica a través de datos paleopolínicos. Inv. Agr. Sist. Rec. For. Fuera de Serie 1(2): 3-12.

Magri, D., Vendramin, G.G., Comps, B., Dupanloup, I., Geburek, T., Gomory, D., Latalowa, M., Litt, T., Paule, L., Roure, J.M., Tantau, I., Van Der Knaap, W.O., Petit, R.J., De Beaulieu, J.L. 2006. A new scenario for the Quaternary history of European beech populations: palaeobotanical evidence and genetic consequences. New Phytol. 171(1): 199–221.

Mayewski, P.A., Rohling, E.E., Stager, J.C., Karlen W., Maasch K.A.; Meeker, L.D.; Meyerson, E.A., Gasse, F., Van Kreveld, S., Holmgren, K. 2004. Holocene climate variability. Quaternary Research, 62: 243-255.

Ministerio de Sanidad, 2023. MOMO Plan de acciones preventivas contra los efectos de las temperaturas excesivas. https://momo.isciii.es/panel_momo/

MITECO, 2005. Inventario Nacional de Hábitats Terrestres. https://www.miteco.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/informacion-disponible/atlas_manual_habitats_espanioles.html

MITECO, 2015. Guía para la elaboración de Planes Locales de Adaptación al Cambio Climático. Ministerio de Agricultura, Alimentación y Medio Ambiente. Disponible en: https://www.miteco.gob.es/es/cambio-climatico/publicaciones/publicaciones/guia_local_para_adaptacion_cambio_climatico_en_municipios_espanoles_tcm30-178446.pdf

MITECO, 2020. Sistema Nacional de Cartografía de Zonas Inundables. https://www.miteco.gob.es/es/agua/temas/gestion-de-los-riesgos-de-inundacion/snczi.html

MITECO, 2022. Cambio Climático: Impactos, Adaptación y Vulnerabilidad (Guía Resumida del Sexto Informe de Evaluación del IPCC, Grupo II. Disponible en: https://www.miteco.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/ipcc-guia-resumida-gt2-imp-adap-vuln-ar6_tcm30-548667.pdf

Monjo, R.; Caselles, V.; Chust, G., 2014: Probabilistic correction of RCM precipitation in the Basque Country (Northern Spain). Theoretical and Applied Climatology, 117: 317-329. https://doi.org/10.1007/s00704-013-1008-8

Moore, P.D., Webb, J. A. 1978. An illustrated guide to pollen analysis, Hodder and Stoughton, Londres.

Moore, P.D., Webb, J.A., Collinson, M.E. 1991. Pollen analysis. 2nd edition. Blackwell Scientific Publications, London.

Muñoz-Sobrino, C., Ramil-Rego, P., Gómez-Orellana, L. 2004. Vegetation of the Lago de Sanabria area (NW Iberia) since the end of the Pleistocene: a palaeoecological reconstruction on the basis of two new pollen sequences. Vegetation History and Archaeobotany, 13, 1-22.

Naciones Unidas, 2010. Cómo desarrollar ciudades más resilientes. Un Manual para líderes de los gobiernos locales. http://www.unisdr.org/files/26462_manualparalideresdelosgobiernosloca.pdf

Núñez de-la-Fuente, S. (2018). Dinámicas socio-ecológicas, resiliencia y vulnerabilidad en un paisaje atlántico montañoso: la Región Cantábrica durante el Holoceno. Tesis Doctoral. Universidad de Cantabria

Oakley, K.P.; Andrews, P.; Keeley, L.H.; Clark, J. D. 1977. A reappraisal of the Clacton Spearpoint– Proceding of the Prehistoric Society 43. Pp: 13-30.

OPS, OMS, 2019. Agenda de Salud Sostenible para las Américas 2018-2030. Organización Panamericana de Salud. Organización Mundial de la Salud.

Pals, J.P., van Geel, B., Delfos, A. 1980. Palaeoecological studies in the Klokkeweel bog near Hoogkarspel (Prov. of Noord-Holland). Review of Palaeobotany and Palynology, 30: 371-418.

Pantaleón-Cano, L., Pérez-Obiol, R., Yll, E.I., Roure, J.M. 1996. Significado de Pseudoschizaea en secuencias sedimentarias de la vertiente mediterránea de la Península Ibérica e islas Baleares. En: Ruiz-Zapata, M.B. & cols. (eds.), Estudios Palinológicos, XI Simposio de palinología (A.P.L.E.), pp. 101-105. Universidad de Alcalá de Henares, Alcalá de Henares.

Peñalba, M.C. 1989. Dynamique de végétation tardiglaciaire et Holocène du centre-nord de l´Espagne d´après l´analyse pollinique. Ph.D. thesis, Universidad d´Aix, 165 pp.

Peñalba, M.C., Arnold, M., Duplesy, J.C., de Beaulieu, J. L. 1997. Termination of the Last Glaciation in the Iberian Peninsula inferred from pollen sequence of Quintanar de la Sierra. Quaternary Reseach, 48, 205-214.

Pérez-Díaz, S. 2012. El paisaje vegetal durante la Prehistoria Reciente en la vertiente mediterránea de Euskal Herria. Tesis Doctoral. Universidad del País Vasco.

Pérez-Díaz, S., López-Sáez, J. A., Galop, D. 2015. Vegetation dynamics and human activi-ty in the Western Pyrenean Region during the Holocene. Quaternary International, 364, 65-77.

Pérez-Díaz, S., Núñez de-la-Fuente, S., Frochoso, M., González-Pellejero, R., López-Sáez, J. A. 2016a. Seis mil años de gestión y dinámica antrópica en el entorno del Parque Natural de los Collados del Asón (Cordillera Cantábrica Oriental).

Pérez-Díaz, S.; López-Sáez, J.A.; Pontevedra-Pombal, X.; Souto-Souto, M.; Galop, D. 2016b. 8000 years of vegetation history in the northern Iberian Peninsula inferred from the palaeoenvironmental study of Zalama ombrotrophic bog (Basque-Cantabrian Mountains, Spain). Boreas.

Pérez-Díaz, S., López-Sáez, J. A., de-la-Fuente, S. N., Ruiz-Alonso, M. 2018. Early farmers, megalithic builders and the shaping of the cultural landscapes during the Holocene in Northern Iberian mountains. A palaeoenvironmental perspective. Journal of Archaeological Science: Reports, 18, 463-474.

PIMA Adapta Costas, 2020. Conocimiento y acción frente a los riesgos derivados del cambio climático. Oficina Española de Cambio Climático. Ministerio para la Transición Ecológica y el Reto Demográfico, Madrid.

PLATERCANT, 2018. Plan Territorial de Emergencias de Protección Civil de la Comunidad Autónoma de Cantabria. Gobierno de Cantabria.

PNOA, 2017. Cobertura y Usos del Suelo (SIOSE).

Postigo-Mijarra, J. M., Gómez-Manzaneque, F., Morla, C. 2008. Survival and long-term maintenance of tertiary trees in the Iberian Peninsula during the Pleistocene: first record of Aesculus L. (Hippocastanaceae) in Spain. Vegetation History and Archaeobotany, 17, 351-364.

Postigo-Mijarra, J. M., Morla, C., Barrón, E., Morales-Molino, C., García, S. 2010. Patterns of extinction and persistence of Arctotertiary flora in Iberia during the Quaternary. Review of Palaeobotany and Palynology, 162(3), 416-426.

Reille, M. 1992. Pollen et Spores d'Europe et d'Afrique du Nord. Laboratoire de Botanique Historique et Palynologie, Marseille.

Reille, M. 1995. Pollen et Spores d'Europe et d'Afrique du Nord. Supplement 1. Laboratoire de Botanique Historique et Palynologie, Marseille.

Ribalaygua, J., Torres, L., Pórtoles, J., Monjó, R., Gaitán., E, Pino., M.R., 2013. Description and validation of a two-step analogue/regression downscaling method. Theoretical and Applied Climatology 114: 253-269. https://doi.org/10.1007/s00704-013-0836-x.

Rubiales, J.M., García-Amorena, I., Hernández, L., Génova, M., Martínez, F. Gómez-Manzaneque, F., Morla, C. 2010. Late Quaternary dynamics of pinewoods in the Iberian Mountains. Review of Palaeobotany and Palynology, 162 (3): 476-491.

Ruiz-Alonso, M. 2014. Evolución y explotación de los recursos vegetales desde el Tardiglaciar en la vertiente mediterránea del País Vasco: datos antracológicos. Servicio Editorial de la Universidad del País Vasco/Euskal Herriko Unibertsitatearen Argitalpen Zerbitzua.

Ruiz-Alonso, M., Pérez-Díaz, S., López-Sáez, J.A. 2019. From glacial refugia to the current landscape configuration: permanence, expansion and forest management of Fagus sylvatica L. in the Western Pyrenean Region (Northern Iberian Peninsula). Vegetation, History and Archaeobotany, 28. 481-496.

Scarascia-Mugnozza, G., Oswald, H., Piussi, P., Radoglou, K. 2000. Forests of the Mediterranean region: gaps in knowledge and research needs. Forest Ecology and management, 132 (1), 97-109.

Schwendtner, O. 2010. Supervivencia y crisis del tejo (Taxus baccata L.) en el área cantábrica. En II Jornades sobre el teix a la Mediterrànea occidental. Pp: 35-40. Delegació de la Garrotxa de la Institució Catalana d´Historia Natural i Fundación d´Estudis Superiors d´Olot. Olot.

Seferian R., 2019. CNRM-CERFACS CNRM-ESM2-1 model output prepared for CMIP6 AerChemMIP hist-1950HC. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.4041

Spindler, K. 1994. The Man in the Ice– Crown Trade Paperbacks. New York.

Steinhilber, F., Beer, J., Fröhlich, C. 2009. Total solar irradiance during the Holocene. Geophysical Research Letters, Vol. 36, L19704, doi: 10.1029/2009GL040142.

Stockmarr, J. 1971. Tablets with spores used in absolute pollen analysis. Pollen et Spores, 13 (4): 615-621.

Swart N. C., Cole J. N. S., Kharin V. V., Lazare M., Scinocca J. F., Gillett N. P., Anstey J., Arora V., Christian J. R., Hanna S., Jiao Y., Lee W. G., Majaess F., Saenko O. A., Seiler C., Seinen C., Shao A., Sigmond M., Solheim L., von Salzen K., Yang D., Winter B., 2019. The Canadian earth system model version 5 (CanESM5. 0.3). Geoscientific Model Development, 12(11), 4823-4873. https://doi.org/10.5194/gmd-12-4823-2019

Taylor, K., Stouffer, R., Meehl, G., 2012. An Overview of CMIP5 and the Experiment Design. Bulletin of the American Meteorological Society, 93(4): 485–498. https://doi.org/10.1175/BAMS-D-11-00094.1

Thieme, H.; Veil, S. 1985. Neue untersuchunen zum eemzeitlichen Elefanten-Jagdplatz Lehringen– Die Kunde 36. Pp: 11-58.

Unión Europea, 2023. Comunicación de la Unión Europea sobre Planes de Adaptación. https://eur-lex.europa.eu/legal-content/ES/TXT/PDF/?uri=CELEX:52023XC0727(01)

Uzquiano, P. 1992. The late glacial/postglacial transition in the Cantabrian Cordillera (Asturias and Cantabria, Spain) based on charcoal analysis. Palaios, 540-547.

Uzquiano, P. 1994. Estudio antracológico de Laminak II (Berrietua, Bizkaia). Kobie (Serie Paleoantropología), 21: 167-172.

Uzquiano, P. 1995. L'évolution de la végétation à l'Holocène initial dans le nord de l'Espagne à partir de l'étude anthracologique de trois sites archéologiques [Early Holocene vegetation evolution in northern Spain from the study of charcoals in three archaeological localities.]. Quaternaire, 6, 77-83.

van Geel, B. 1978. A palaeoecological study of Holocene peat bog sections in Germany and the Netherlands, based on the analysis of pollen, spores and macro- and microscopic remains of fungi, algae, cormophytes and animals. Review of Palaeobotany and Palynology, 25: 1-120.

van Geel, B. 2001. Non-pollen palynomorphs. En: Smol, J.P., Birks, H.J.B., Last, W.M. (eds.), Tracking environmental change using lake sediments. Volume 3: Terrestrial, Algal, and Siliceous Indicators, pp. 99-119. Kluwer Academic Publishers, Dordrecht.

van Geel, B., Bohncke, S.J.P., Dee, H. 1981. A palaeoecological study of an Upper Late Glacial and Holocene sequence from 'De Borchert', The Netherlands. Review of Palaeobotany and Palynology, 31: 367-448.

van Geel, B., Hallewas, D.P., Pals, J.P. 1983. A Late Holocene deposit under the Westfriese Zeedijk near Enkhuizen (Prov. of N-Holland, The Netherlands): palaeoecological and archaeological aspects. Review of Palaeobotany and Palynology, 38: 269-335.

van Geel, B., Coope, G.R., Hammen, T. van der. 1989. Palaeoecology and stratigraphy of the Late-glacial type section al Usselo (The Netherlands). Review of Palaeobotany and Palynology, 60: 25-129.

van Geel, B., Buurman, J., Brinkkemper, O., Schelvis, J., Aptroot, A., van Reenen, G., Hakbijl, T. 2003. Environmental reconstruction of a Roman Period settlement site in Uitgeest (The Netherlands), with special reference to coprophilous fungi. Journal of Archaeological Science, 30: 873-883.

Von Storch, J.-S., Putrasahan, D., Lohmann, K., Gutjahr, O., Jungclaus, J., Bittner, M., Haak, H., Wieners, K.-H., Giorgetta, M., Reick, C., Esch, M., Gayler, V.,; de Vrese, P., Raddatz, T., Mauritsen, T., Behrens, J., Brovkin, V., Claussen, M., Crueger, T., Fast, T., Fiedler, S., Hagemann, S., Hohenegger, C., Jahns, T., Kloster, S., Kinne, S., Lasslop, G., Kornblueh, L., Marotzke, J., Matei, D., Meraner, K., Mikolajewicz, U., Modali, K., Müller, W., Nabel, J., Notz, D., Peters, K., Pincus, R., Pohlmann, H., Pongratz, J., Rast, S., Schmidt, H., Schnur, R., Schulzweida, U., Six, K., Stevens, B., Voigt, A., Roeckner, E., 2017. MPI-M MPIESM1.2-HR model output prepared for CMIP6 HighResMIP.. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.762.

Wu, T., Lu, Y., Fang, Y., Xin, X., Li, L., Li, W., Jie, W., Zhang, J., Liu, Y., Zhang, L., Zhang F., Zhang, Y., Wu, F., Li, J., Chu, M., Wang, Z., Shi, X., Liu, X., Wei, M., Huang, A., Zhang Y., Liu, X., 2019. The Beijing Climate Center Climate System Model (BCC-CSM): the main progress from CMIP5 to CMIP6 , Geosci. Model Dev. 12, 1573–1600. https://doi.org/10.5194/gmd-12-1573-2019

Yukimoto, S., Koshiro, T., Kawai, H., Oshima, N., Yoshida, K., Urakawa, S.; Tsujino, H., Deushi, M., Tanaka, T., Hosaka, M., Yoshimura, H., Shindo, E., Mizuta, R., Ishii ,M., Obata, A., Adachi, Y., 2019. MRI MRI-ESM2.0 model output prepared for CMIP6 CMIP. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.621.

Zapata, L. 2012. Holocene wood charcoal from El Mirón cave. Vegetation and wood use. In: González Morales, M. y Straus G, L. (eds.) El Mirón Cave, Cantabrian Spain. The site and its Holocene archaeological record. University of New Mexico Press, Albuquerque, 174- 196.

The Santander Climate Change Adaptation Plan is a strategic document, based on the scientific analysis of the present and future social, environmental and climate reality of the municipality. The aim is to provide measures to help build its resilience. The document has been prepared by an interdisciplinary team from the **Department of Geography**, **Urban and Regional Planning** of the **University of Cantabria** and the **Climate Research Foundation**. The study identifies the future risk of the municipality by analysing its exposure to coastal and pluvial floods, as well as the impacts of rising temperatures, future droughts and heatwaves, modelling the region's social, economic and environmental vulnerability to these hazards. This research has led to the development of 51 thematic maps quantifying various levels of hazard, exposure, sensitivity and risk for the different municipality zones. In response to the findings of previous studies, the document lays out a strategic proposal for adaptation and identifies 85 adaptation measures. These are presented in four adaptation goals– Biodiversity; Resilient City; Health; Society and Economy Adapted– with different adaptation objectives for each of them. Their achievement will allow Santander to become a more resilient and less vulnerable city.