KLIMA 2050
BASQUE COUNTRY
ekintzak - acciones

Assessment of vulnerability and risk to climate change in the municipalities of the Basque Country

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Front cover photo credit: José Miguel Llano. This photo shows the impact of the tornado in a beech forest in the Sierra de Entzia mountains (Araba/Álava) in the early hours of the morning on 5 July 2018.

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01

Context and background of the project

In international, regional and local spheres, much of the work done to fight climate change has focused on mitigation, aiming to reduce greenhouse gas emissions (GHG). However, since this type of action, although necessary, is not sufficient to prevent the impact of climate change, there is a need to act by planning possible responses, thus adapting to the situations generated by those impacts.

There is scientific consensus that the effects of climate change are inevitable even if we are able to reduce greenhouse gas emissions to the levels proposed in international protocols. Because of this, in recent years **adaptation policies are receiving important stimulus**, which, **in Europe materialise** in the **EU Strategy on adaptation to climate change** (2013)[1] and its implementing instruments. The aforementioned strategy recognises the need to **stimulate effective regional and local adaptation policies**, for two main reasons:

— Although climate change is a global phenomenon, its impact can affect far smaller territories, with serious economic, environmental and social costs to municipalities, including loss of human life and health issues, damage to homes and infrastructures, loss of business and loss of labour productivity. Vulnerability to and risk of climate change depend on the physical, biological, ecological, economic, social and cultural characteristics of each municipality, therefore public institutions have a crucial role to play in identifying and assessing the risks of climate change. In addition, actions and initiatives for adaptation must be implemented at the local or regional level, since the impacts and vulnerabilities are locally specific (FEMP, 2010)[2].

— Given the current distribution of competencies, regions and municipalities have adaptive capacities in some very relevant aspects, such as territorial planning, city planning, management of infrastructures, health, natural resources, etc.

The Basque Region takes part in several international initiatives where adaptation to climate change is the main focus of the action, such as the *Compact of States and Regions*[3] from the Lima Summit (COP20)[4] and the *RegionsAdapt*[5] initiative in 2015.

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0216:FIN:ES:PDF

[3] http://www.redciudadesclima.es/files/2017-06/vulnerabilidad-cambioclimatico-escalalocal.pdf

[3] https://www.theclimategroup.org/news/compact-states-and-regions-2016-disclosure-report

[4] http://www.cop20lima.org/

[5] http://www.nrg4sd.org/climate-change/regionsadapt/

This commitment at a local scale can also be seen in greater awareness and involvement of Basque municipalities in **other international incentives**, like the *Global Covenant of Mayors for Climate & Energy*[6], the purpose of which, among others, is to prepare for the impacts of climate change.

Additionally, in 2016, in the framework of the 8th European Conference on Sustainable Cities & Towns[7], these commitments were ratified with the signature of the *"Basque Declaration of new pathways for European Cities and Towns to create productive, sustainable and resilient cities"*[8], which recognises the need to transform in order to decarbonise energy systems, create sustainable urban mobility patterns, protect and enhance biodiversity and ecosystem services, reduce the use of greenfield land and natural space, protect water resources and air quality, and adapt to climate change, among other objectives.

Adhesion to this and other similar initiatives and the requirement to monitor compliance with the commitments acquired in time will create a need to include indicators to measure the implementation and execution of the policies adopted by local institutions. In recent years, some of these municipalities have taken steps to diagnose their vulnerability to climate change and to prepare adaptation strategies, as is the case of Vitoria-Gasteiz[9] or, more recently still, Donostia / San Sebastian[10]. At the proposal of the Basque Government, these two municipalities and Bilbao were selected among the best international projects because of their positive capacity for transformation becoming part of the Transformative Actions Program (TAP)[11], organised by ICLEI (Local Governments for Sustainability)[12] and presented in 2015 at the United Nations Climate Change Conference (COP 21) in Paris[13]. This institutional effort is mentioned in the **KLIMA 2050 Strategy of the Basque Country**[14], approved in 2015. Specifically, Goal 3 seeks to increase territorial efficiency and resilience in decades to come. Also, Action 20, established in the aforementioned Goal 3 talks of preparing support tools and methodologies for the municipalities of the Basque Region, such as, for example, comparative vulnerability maps, thus increasing the municipalities' grasp of their exposure, vulnerability, risk, etc. and Action 25 of the same Goal which also includes a thematic cartography of impacts and vulnerability to climate change in the Basque Region.

Previously, **in 2010**, associated with the K-Egokitzen[15] project and the City Planning Manual in the Basque Country for mitigation and adaptation to climate change[16], a comparative analysis was performed at municipal level in the geographic area of the Basque Country, to identify which municipalities were most vulnerable to a series of climate hazards and, in particular, which of these should be analysed in greater detail to define and implement effective response mechanisms and policies. This analysis was carried out based on the **4th IPCC Assessment Report on Impacts, Adaptation and Vulnerability**[17] (AR4), published in 2007, which defined vulnerability as *"a function of the character, magnitude, and frequency of climate variation, to which a system is exposed, its sensitivity, and its capacity to adapt"*.

However, this framework of reference has subsequently been revised, and thus, **in 2014**, the **5th Climate Change**

[6] http://www.globalcovenantofmayors.org/

[7] http://conferences.sustainablecities.eu/basquecountry2016/es/

[8] http://www.sustainablecities.eu/fileadmin/repository/Basque_Declaration/BD_May_Update/Basque-Declaration-SPANISH-www.pdf

[9] http://www.vitoria-gasteiz.org/wb021/http/contenidosEstaticos/adjuntos/es/41/69/44169.pdf

[10] https://www.donostia.eus/info/ciudadano/ma_areas.nsf/vowebContenidosId/NT00000CDA?OpenDocument&idioma=cas&id=A501610418492&cat=Cambio%20Clim%E1tico&subcat=Donostia%20/%20San%20Sebasti%E1n%20se%20adapta%20al%20cambio%20clim%E1tico&doc=D

[11] http://tap-potential.org/

[12] http://www.iclei.org/

[13] http://www.cop21paris.org/

[14] http://www.ingurumena.ejgv.euskadi.eus/contenidos/informacion/klima_2050/es_def/adjuntos/KLIMA2050_es.pdf

[15] http://www.euskadi.eus/web01-a2inguru/es/contenidos/libro/kegokitzen/es_doc/indice.html

[16] http://www.udalsarea21.net/Publicaciones/Ficha.aspx?IdMenu=892e375d-03bd-44a5-a281-f37a7cbf95dc&Cod=e9dcf80c-d20d-4193-9b6a-d494e08fefb8&Idioma=es-ES

[17] https://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html

Report: Impacts, Adaptation, and Vulnerability[18] (AR5) was published, giving greater weight to risk, 'risk' being defined as the interaction of vulnerability, exposure, and hazard, represented as probability of occurrence of hazardous events (hazard factor) or trends multiplied by the impacts if these events or trends occur (exposure and vulnerability factors). Vulnerability, in turn, depends on two main components: on the one hand, sensitivity or susceptibility sensitivity and, on the other, susceptibility to harm and lack of capacity to cope and adapt. From a methodological standpoint, all this is stimulating a new approach and focus on climate change risk and vulnerability analysis.

Also, since the comparative analysis was performed and to date, the values of many indicators on which that study (**UDALPLAN**[19] and **EUSTAT**[20], as sources) was based have changed, and its findings are now outdated. It is also worth mentioning the **increasing availability of information** on climate change to citizens, companies and the public authorities through the **GEOEUSKADI**[21] spatial data portal.

A revision of the **analysis of the main impacts and sectors affected** that cause most concern in the framework of the **KLIMA 2050 Strategy** for inclusion in the new comparative analysis of vulnerability to climate change at the municipal level also seems appropriate. In this regard, as well as the main KLIMA 2050 Strategy, other supporting documents were prepared during the strategic focus process that include a multiple-criteria analysis[22]. Said analysis assesses the relevance of each sector *vis-a-vis* adaptation to climate change.
Among the sectors and impacts included, it is worth mentioning, among others, the impact of heat waves on health; the impact of the variations in rainfall on water resources (both rainfall scarcity and more frequent heavy rainfall causing floods), and the impact of sea level rise on the coastline.

Assuming that different impacts are expected in the municipalities of the Basque Country, it is **extremely important to classify the type of impact and the level of vulnerability of Basque municipalities** to align current plans and activities and propose new ones for the future, thus facilitating a transition toward more resilient municipalities. In fact, among the findings of the first Workshop on the Assessment of the EU's Strategy on Adaptation to Climate Change (Brussels, 2017)[23], were the evident importance of taking a multi-sector approach to adaptation, and the driving role of tools for assessing vulnerability to stimulate more activity in adaptation on different scales.

When it comes to fighting climate change, in recent years, **local governments** have acquired **an increasingly important role**, and it seems that their future involvement will be even more decisive from the point of view of adaptation, as is evident, for example, in the latest **IPCC assessment report**, which classifies **urban areas as priority sectors** for the first time since its creation; from the conclusions of the aforementioned Assessment Workshop on the EU's Strategy on Adaptation to Climate Change; and the progress made in recent years to define international standards (ISO 37120:2014[24] on indicators for urban services and quality of life; ISO 37123[25] on indicators for resilient cities, currently in development, etc.).

Local authorities, which are responsible for public management, must ensure the health and quality of life of the population, reducing losses caused by the adverse effects of climate change and making more efficient use of environmental resources, with a consequential positive impact on the environment (Udalsarea 21, 2011)[26].

[18] https://www.ipcc.ch/report/ar5/wg2/

[19] http://www.euskadi.eus/web01-a2inguru/es/contenidos/informacion/estatistika_ing_200206/es_def/index.shtml

[20] http://www.eustat.eus

[21] http://www.geo.euskadi.eus/s69-15375/es

[22] http://participacion.cantabria.es/documents/10711/34286/Estrategia+Vasca/79ac3177-3d25-4e5b-84e9-7390c7b070a3

[23] https://ec.europa.eu/clima/consultations/evaluation-eus-strategy-adaptation-climate-change_es

[14] http://www.ingurumena.ejgv.euskadi.eus/contenidos/informacion/klima_2050/es_def/adjuntos/KLIMA2050_es.pdf

[24] https://www.iso.org/standard/62436.html

[25] https://www.iso.org/standard/70428.html

[26] http://www.euskadi.eus/gobierno-vasco/-/manual/guia-para-la-elaboracion-de-programas-municipales-de-adaptacion-al-cambio-climatico/

This publication contains the findings of the **"Analysis of impacts and vulnerability of the Basque municipalities to climate change"** project carried out in 2017. **Section 1** describes the **context and background of the project**; **Section 2** describes the **methodology applied** to assess vulnerability and the risk of municipalities in the Basque Country to climate change; **Section 3** contains the **main results** of the vulnerability and risk assessment; **Section 4** contains some **general adaptation measures** for Basque municipalities according to the types of risks analysed; **Section 5** contains a **summary and the important findings** of the project, in general; and **Section 6** includes the **bibliography and references** for more detailed **consultation**.

02

Methodology applied to assess the vulnerability and risk of climate change to Basque Country municipalities

The methodology used to assess the vulnerability of the Basque Country municipalities to the risks of climate change is based on a **combination of qualitative, statistical and spatial analysis methods** taking the most recent **international estimates and projects** as a starting point for assessing vulnerability and risk at the local and regional level. Among these international references where greater understanding is being generated to carry out this type of analysis, it is worth mentioning **European research projects** *Reconciling Adaptation, Mitigation and*

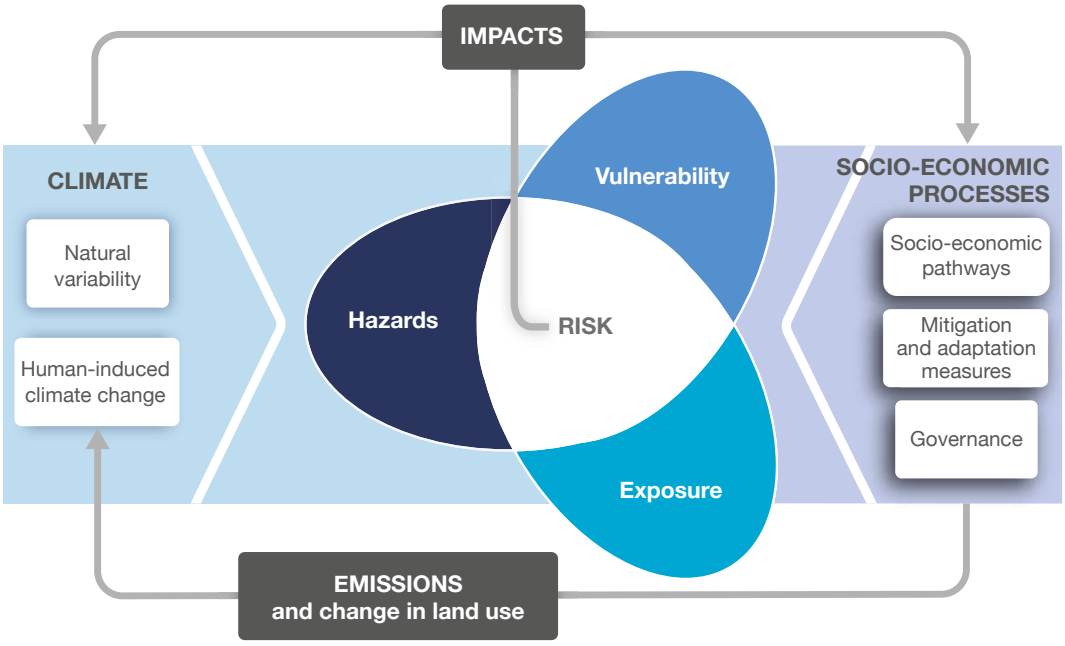

Figure 1. Conceptual framework of reference for the methodology to assess vulnerability and risk of climate change to municipalities in the Basque Country. IPCC (2014).

Sustainable Development for cities (FP7 **RAMSES**, 2012-2017)[27] and the Climate Resilient Cities and Infrastructures project (H2020 **RESIN**, 2015-2018)[28].

The assessment methodology for Basque Country municipalities, like those of the two mentioned reference European projects, is aligned with the new conceptual framework established in the **Fifth IPCC Report on Impacts, Adaptation and Vulnerability** (IPCC, 2014). As mentioned earlier, this framework is based on a concept of risk associated to climate change, which is illustrated graphically in Figure 1.

The main difference with respect to the Fourth IPCC Report (2007), which was applicable when making previous comparative analyses of municipalities in the Basque Country (2010), lies in that **vulnerability is analysed with variables associated with sensitivity and adaptive capacity**. Therefore, exposure is no longer a component of vulnerability, but is now another component of risk. In other words, in the context of climate change, risk is defined as a combination of **hazard, exposure and vulnerability**. And it tends to be expressed as a function of the likelihood of occurrence of a certain event (or sequence of events), multiplied by its adverse consequences. Two of the three

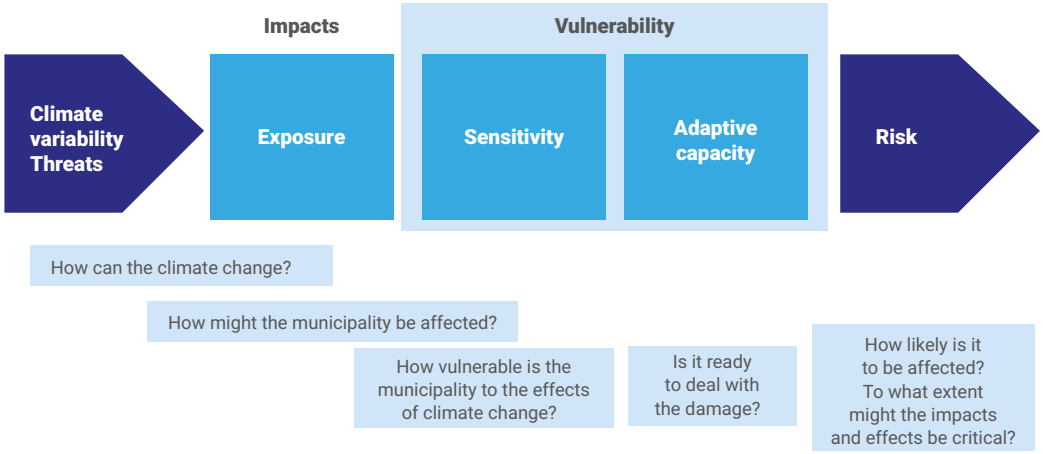

Figure 2. Sequencing analysis of the effects of climate change at the local scale. Source: Tecnalia (2017).

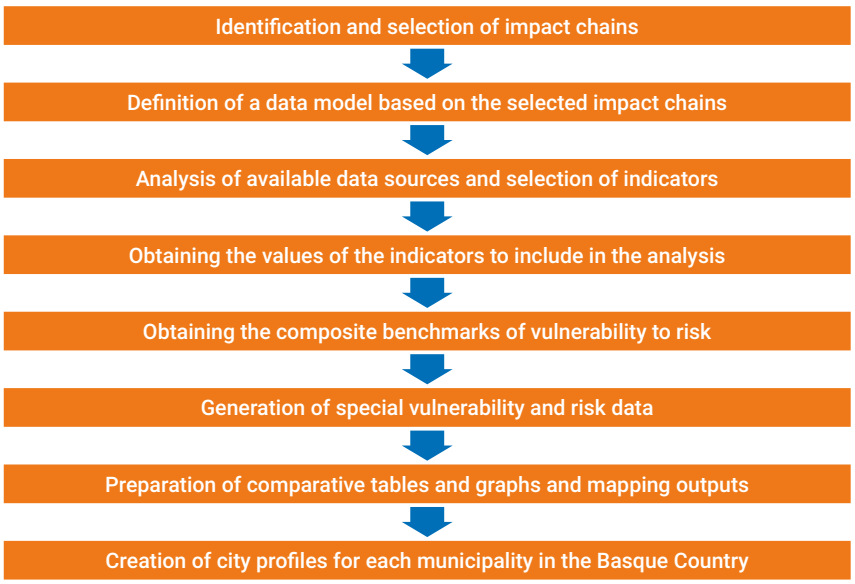

Figure 3. Sequence of the methodology applied to assess vulnerability of and risk of climate change to municipalities in the Basque Country. Tecnalia (2017).

[27] http://www.ramses-cities.eu/home/

[28] http://www.resin-cities.eu/home/

components of risk –exposure and vulnerability– contribute to generating its consequences, while likelihood is determined by the hazard. See Figure 2.

The glossary included in the IPCC report provides the definitions of the terms also used in this publication.

The Figure 3 sample summarises a **sequential view of the steps** that includes the methodology applied to assess vulnerability and the risk of climate change. The following subsections give more details about each of these steps.

2.1 Identification and selection of impact chains

The final aim of this step is to **identify and select a limited number of priority impact chains upon which to delimit and focus** the assessment of vulnerability and risk of climate change to municipalities in the Basque Country as practically and efficiently as possible. Using impact chains, it is possible to obtain the **cause-effect relationship between a particular (existing or future) climate hazard and a specific sector, area or recipient**. By way of example, the hazard "Rising temperatures and heat waves" can be considered impact chains on the "Health" sector, and the hazard "Increased droughts" on the "Agricultural" sector.

In this regard, to be able to prioritise the impact chains that are most interesting from the point of view of a vulnerability and risk assessment, it was important to have **relative information about the current and future climate context of the Basque Country** in advance, and to know the main **hazards and climate impacts** forecast for **some sectors or specific areas** of our autonomous region.

2.1.1 The climate context of the Basque Region

Based on existing studies available in the Basque Region, some historical regional trends and future projections regarding variables like temperature, rainfall and sea level rise have been identified. The main data used were those provided by the project **Preparation of high resolution regional climate change scenarios for the Basque Country**[29], including the Klimatek 2016 call, from which climate forecasts were obtained for different time horizons (2011-2040, 2041-2070 and 2071-2100). The information contained in the **Climate Change Strategy of the Basque Country to 2050 (KLIMA 2050)** and in other earlier studies (**e.g. ERORTEK K-Egokitzen project**) has also been taken into consideration.

The following is a summary to the main changes foreseen in the Basque Country for the different time horizons.

Sea level rise

According to the work of Chust et al. (2010)[30] the sea level is expected to rise by between 29 and 49 cm in the Bay of Biskay by the end of the 21st century.

Subsequent studies estimate similar or higher values. For example, Slangen et al. (2011)[31] estimate a rise of 47 ±16 cm under the RCP 4.5 scenario and 64 ±22 cm under the RCP 8.5 scenario for the 2081-2100 period. Vousdoukas et al. (JRC, 2017)[32] foresee a rise of 53 cm under the RCP 4.5 scenario and 80 cm under the RCP 8.5 scenario for 2100.

Rainfall

The aforementioned Klimatek 2016 project establishes that, by the end of the century, average annual rainfall may decrease by around 15%, the effect of which will be more pronounced in the south and south-east of the Basque Country (Figure 4).

[29] http://www.lhobe.eus/Publicaciones/Ficha.aspx?IdMenu=750e07f4-11a4-40da-840c-0590b91bc032&Cod=a7c9bcd2-1bd0-4198-a05d-5549aaef6e81&Idioma=es-ES

[30] Regional scenarios of sea level rise and impacts on Basque (Bay of Biscay) coastal habitats, throughout the 21st century. Estuarine, Coastal and Shelf Science.

[31] https://link.springer.com/article/10.1007%2Fs00382-011-1057-6

[32] https://ec.europa.eu/jrc/en/publication/extreme-sea-levels-rise-along-europe-s-coasts

Although these data are associated with significant uncertainty, a reduction in days with low, moderate and heavy rain is foreseen (r1, r10 and r20) while in contrast, an increase of intensity the days with rainfall (sdii) and a slight increase in the daily maximum (rx1day) is also foreseen (Figure 5). The maximum length of dry spells (CDD) may increase in the future.

Temperature

Temperatures are expected to rise, varying between 1.5ºC and 5ºC depending on the scenario and model. This increase in the maximum temperature will be more pronounced in the south and south-east of the Basque Country (Figure 6).

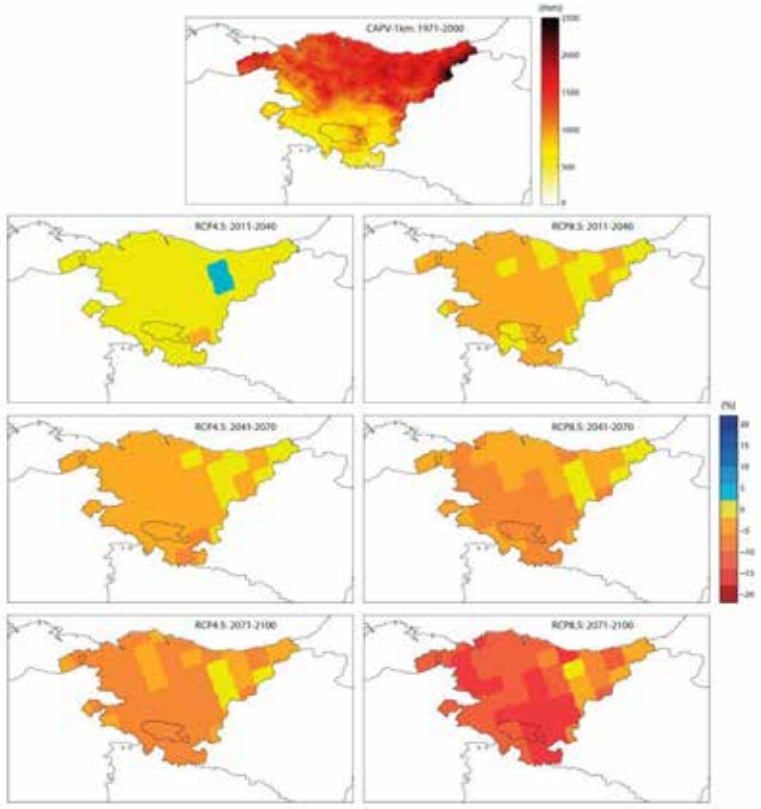

Figure 4. Deltas for annual rainfall: projections of the RCM of Euro-CORDEX under the RCP 4.5 (left) and RCP 8.5 (right) scenario for the three future periods (2011-2040, 2041-2070 and 2071-2100). NOTE: In this case, projected rainfall is represented as a percentage increment (+) or reduction (-) with respect to historic rainfall.
Source: NEIKER-Tecnalia, Klimatek 2016.

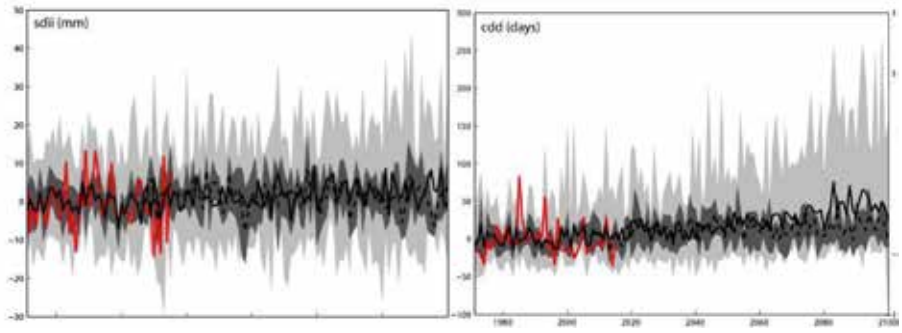

Figure 5. Graph of rainfall intensity (mm). Red line: average of observations; discontinuous black line: average forecasts for RCP 4.5; continuous black line: average projections for RCP 8.5: dark grey shading: dispersion of the RCP 4.5 scenario; light grey shading; dispersion of the RCP 8.5 scenario. Source: NEIKER-Tecnalia, Klimatek 2016.

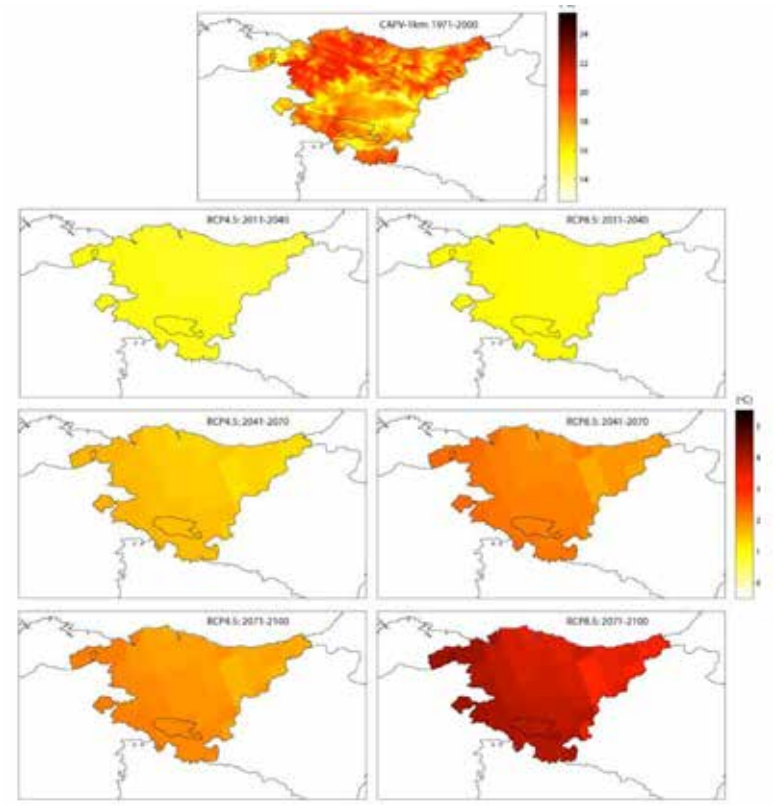

Figure 6. Deltas for maximum temperature: EURO-CORDEX projections under the RCP 4.5 scenario (left) and RCP 8.5 scenario (right) for the three future periods (2011-2040, 2041-2070 and 2071-2100). NOTE: In this case, projected temperatures are represented as a an increment of degrees Celsius (+) with respect to historic temperature. Source: NEIKER-Tecnalia, Klimatek 2016.

The indicators associated with days on which temperatures are low will tend to decrease, while indicators related to high temperatures will tend to rose. It is expected there will be an increase in "su" indicators (number of days with a maximum temperature greater than 25ºC), "su35" (number of days with a maximum temperature greater than 35ºC), and "tr" (number of days with a minimum temperature above 20ºC), associated with hot days and nights, and heat waves (Figure 7).

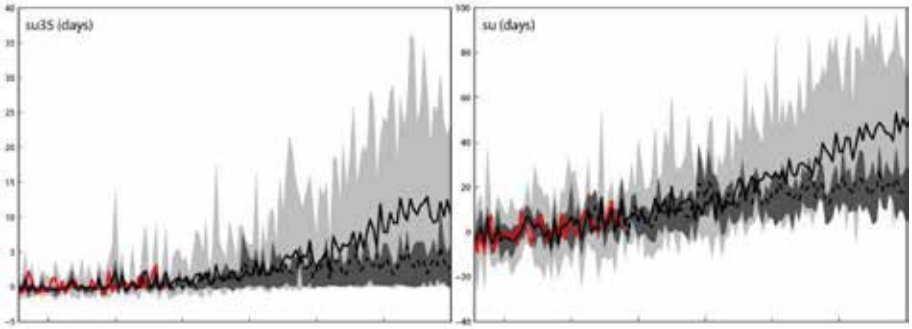

Figure 7. Graph of su indicators (number of days with a maximum temperature greater than 25ºC) and su35 (number of days with a maximum temperature greater than 35 ºC); discontinuous black line: average projections for RCP 4.5; continuous black line: average projections for RCP 8.5; dark grey shading; dispersion of RCP 4.5 scenario; light grey shading; dispersion of the RCP 8.5 scenario. Source: NEIKER-Tecnalia, Klimatek 2016.

2.1.2 Main hazards and climate impacts on sectors of the Basque Country

The following is a summary of the main climate hazards that may have a particular impact on some sectors or areas of our region, the main sources of information of which are the **Climate Change Strategy Focus of the Basque Country** (2013) and the **KLIMA Strategy 2050** (2015).

Urban environment

The urban environment will be affected by extreme temperature changes, intense precipitations, sea level rise and extreme waves. Other non-climate-related aspects must also be added to these climate factors such as city format, structure and functions, land-use changes, sanitation system, social and demographic changes, etc. In terms of future impacts, increased flooding, landslides and subsidence are expected as a result of a more intense urban heat island effect and drought periods. With respect to flooding, significant increases are foreseen in maximum flood flows, together with a larger flooded area and higher speed flow and current due to more intense rainfall.

Primary sector

In the farming sector, climate change is expected to increase yields of certain crops (winter wheat, vine). Even so, thermal stress will also have negative effects on aspects such as, for example, crops and woodland, and increased pests and diseases, and the appearance of invasive species are more likely. As well as these impacts, there will be more fires and soil erosion. In the livestock sector, an increase in the appearance of parasite diseases is expected, which together with thermal stress will damage livestock productivity.

Biodiversity

The ecological niche of oak, beech and Monterey Pine (*Pinus radiata*) is expected to have almost completely disappeared, with progressive northward displacement by the end of the century. Mountains in the Atlantic area will be affected, particularly over 900 m, due to the temperature increase (particularly beech trees and mountain zones). Ecosystems in the Mediterranean area will be affected by increased droughts and water shortages.

Health

The impacts expected due to climate change in the health area are related to the increased temperature, poorer air quality and increased floods and earth landslides.
All this will cause higher morbidity-mortality, more disease (respiratory, skin, diseases transmitted by vectors, etc.) and a worsening of human comfort. Specifically, the impact of heat waves on heat is one of the most serious problems for coming decades at the global level. In this regard, the Basque Country is no exception and, according to the conclusions of the Klimatek project *"Prevention of the health effects of heat waves in a context of climate change"*[33] (2017), if greenhouse gas emissions continue to increase without adopting mitigation measures, our main cities will have to cope with more heat waves, which may cause an increase in mortality due to this phenomenon.

Lineal infrastructures

Linear infrastructures suffer from greater material fatigue and the expected increase in floods and landslides may reduce road safety.

Energy and industry

Scant rainfall may affect hydroelectricity production.
An increase in extreme events may impact the exposed infrastructures, transport and distribution networks, leading to damage.

[33] http://www.lhobe.eus/Eventos/ficha.aspx?IdMenu=74e0675a-2235-4892-af39-e5bf7072bc20&Cod=854&Idioma=es-ES

2.1.3 Selection of impact chains

Taking into account the information about the climate context of the Basque Country and possible impacts on some of its main sectors, where particular attention must be given to those caused by heat waves, river flooding, sea level rise and increase in extreme waves, the vulnerability and risk assessment of the municipalities in the Basque Country considers *"Impact of heat waves on human health"*, *"Impact of river floods on urban areas"*, *"Impact of floods caused by sea level rise on urban areas"*, and *"Impact of increased periods of drought periods on economic activities, particularly on farming"*.

Impact of heat waves on human health

Exposure to heat in a specific territory is determined by exterior heat and interior heat which, in turn, is strongly influenced by the configuration of the territory itself, where the urban fabric is an essential element. Outdoor heat is the main aspect on which climate change has a particular impact. In the exposed population, with very different conditions of sensitivity to heat, temperature increase causes loss of comfort in the best of cases, when it does not cause a marked decrease in labour productivity and even a greater risk of morbidity and mortality for people.

Impact of river floods on the urban area

Climate change is expected to exacerbate natural hazards. One example is the growing risk of flooding. These climate factors, together with non-climate-related factors such as social and economic development of municipalities, topography, drainage systems, permeability, the constructed environment, etc., increases the likelihood of damage caused by flooding. Economic loss caused by flooding has become particularly important at the global level.

Impact of flooding caused by sea level rise in the urban area

Like river flooding, the economic losses that can be caused by floods caused by sea level rise in the urban area and the increase in extreme waves in built-up areas may become very significant due to the concentration of infrastructures close to the coastline.

Impact of increased periods of drought periods on economic activities, particularly on farming

As well as an expected increase in heavy rain, it is important to identify the duration of periods without rain that may be of concern to local economic activities that seem to be particularly vulnerable to climate change, such as primary sector activities.

2.2 Definition of a data model based on the selected impact chains

Given the selected impact chains, types of data which, in the geographic context of the Basque Country may be most suitable for characterising the different factors intrinsic to each, have been found, selected and identified. To do this, recently revised **scientific-technical documentation** in the framework of the EU RAMSES project has been taken into account, as well as **data models used in other projects** that assess vulnerability and risk of climate change, which also follow the focus described in the Fifth IPCC Report on Impacts, Adaptation and Vulnerability (AR5, 2014).

Among the data models analysed, it is worth mentioning:

— The European Project FP7 *Reconciling Adaptation, Mitigation and Sustainable Development for cities* (RAMSES, 2012-2017);

— The European Project H2020 *Climate Resilient Cities and Infrastructures* (RESIN, 2015-2018), in which the city of Bilbao is one of the study cases;

— Planning for increased temperatures caused by the climate in the Metropolitan Area of San Salvador (CDKN, 2016)[34];

— The Vulnerability Analysis of Climate Change in the city of Madrid (2015)[35];

— Donostia / San Sebastián Plan for adaptation to climate change (Donostia / San Sebastián City Hall, 2017)[36]; and

— UNE-ISO 37120:2015 Standard: Sustainable development in cities. Urban services and quality of life indicators[37].

The data structures found in the above sources of reference have been compared with the most recent version of the **Local Sustainability Indicators System 21 of Udalsarea**[38], finding close correlation between the relevant benchmarks for assessment of municipal vulnerability, related impact chains, and Udalsarea 21 indicators. One example of this are the indicators regarding the block of Environmental Aspects, such as Territory and Planning, Land and Water; the indicators from the Social Aspects block, such as Health, Well-being and social inclusion, Housing, Education and Demographics; the indicators from the Economic Aspects block, such as Job Market and Economic Development; and the indicators from the Governance block, such as Awareness raising and communication or Coordination.

The idea has not been to have an endless list of possible types of data, but to obtain those which, essentially and to the extent that there are suitable data of acceptable quality, **best characterise** the different components of vulnerability and the risk of each of the selected impact chains, in other words, **hazard, exposure, sensitivity and response/adaptive capacity**.

Table 1 is a schematic representation of the types of data that appear most frequently in the above mentioned models. The table is organised so that the types of data considered of interest to the different impact chains correspond with the **themed blocks and areas defined for the Local Sustainability Indicators System of Udalsarea 21**. Within each themed area, the types of data related to each of the four impact chains in question have been included. As can be seen, some of these are specific to one impact chain while others, in contrast, are shared by more than one, a phenomenon that tends to occur more frequently with economic and governance data than with social, environmental and territorial considerations.

[34] https://cdkn.org/project/planificacion-en-torno-incrementos-de-temperatura-provocados-por-el-clima-en-el-area-metropolitana-de-san-salvador/?loclang=es_es

[35] http://www.madrid.es/UnidadesDescentralizadas/Sostenibilidad/EspeInf/EnergiayCC/04CambioClimatico/4b2Vulnera/Ficheros/InfVulneraCC2015VerWeb.pdf.

[36] https://www.donostia.eus/info/ciudadano/ma_areas.nsf/vowebContenidosId/NT00000CDA?OpenDocument&idioma=cas&id=a501610418492&cat=Cambio%20Clim%E1tico&subcat=Donostia%20/%20San%20Sebasti%E1n%20se%20adapta%20al%20cambio%20clim%E1tico&doc=D

[37] http://www.aenor.es/aenor/normas/normas/fichanorma.asp?tipo=N&codigo=N0054983

[38] http://www.udalsarea21.net/Publicaciones/Ficha.aspx?IdMenu=892e375d-03bd-44a5-a281-f37a7cbf95dc&Cod=64d398ef-ab0d-4ce4-9b98-ef4f08c74538&Idioma=es-ES

SISL US21 Blocks	Themed areas SISL US21	Heat waves, potential effect on human health	River floods on the urban area	Floods caused by sea level rise in the urban area	Drought on economic activities, with special interest in farming
Environmental and territorial aspects	Territorial and planning	Land use; Free urban spaces; Building	Land use; Building and infrastructures; Free urban spaces; Hydrology; Hydrogeology	Land use; Building and infrastructures; Free urban spaces	Land use
	Biodiversity and natural environment	Investments in environmental projects	Investments in environmental projects	Investments in environmental projects	Special protected areas; Sustainable farming and livestock activities; Productivity; Risk of fire
	Mobility and transport	Fleet of vehicles			
	Floors		Contaminated land	Contaminated land	
	Water				Water consumption; Irrigated agriculture
	Climate change and global impact	Urban climate map; Indicators of maximum temperatures, minimum temperatures and daytime temperature gradient	Map of danger of river flooding according to different recurrence intervals and scenarios; Maximum precipitation indicators	Maps of danger of sea level rise according to different recurrence intervals and scenarios.	Drought indicators
Social aspects	Health	Air quality; Healthcare and accessibility; Mortality; Diseases			
	Well-being and social inclusion	Personal income; Social protection; Inequality and poverty	Personal income	Personal income	
	Housing	Tenure/ ownership; Equipment	Tenure/ ownership; Empty home; Not main home	Tenure/ ownership; Empty home; Not main home	
	Education	School Agenda 21; Level of education and skills	School Agenda 21; Level of education and skills	School Agenda 21; Level of education and skills	School Agenda 21; Level of education and skills
	Demographics	Population; Dependency; Age; Family unit			

SISL US21 Blocks	Themed areas SISL US21	Heat waves, potential effect on human health	River floods on the urban area	Floods caused by sea level rise in the urban area	Drought on economic activities, with special interest in farming
Economic aspects	Job market	Job			Type of activity; Jobs
	Economic development	GDP; Municipal income; Level of indebtedness	GDP; Municipal income; Level of indebtedness; Economic losses	GDP; Municipal income; Level of indebtedness; Economic losses	Type of company; Gross added value; GDP; Municipal income; Level of indebtedness; Economic losses
Governance	Environmental management of the municipal authority	Adaptation plans	Adaptation plans	Adaptation plans	Environmental management instruments; Adaptation plans
	Awareness raising and communication	Educational activities; Raising environmental awareness	Educational activities; Raising environmental awareness	Educational activities; Raising environmental awareness	Educational activities; Raising environmental awareness
	Citizen participation	Agenda local 21; Associationism	Agenda local 21; Associationism	Agenda local 21; Associationism	Agenda local 21; Associationism
	Coordination	Intra-municipal and supra-municipal coordination; Risk management; Alert systems	Intra-municipal and supra-municipal coordination; Risk management; Alert systems	Intra-municipal and supra-municipal coordination; Risk management; Alert systems	Intra-municipal and supra-municipal coordination; Risk management; Alert systems

Table 1. Data model for assessment of the vulnerability and risk of Basque municipalities to climate change considering the selected impact chains.

2.3 Analysis of available data sources and selection of indicators

Once having selected the most appropriate impact chains and data for characterisation, the availability of information at the municipal level for the entire Basque Country was analysed. This has been done using **existing public data sources**, since they provide the most up-to-date information and are of interest according to the data models proposed.

Among the most important of these data sources are the **GEOEUSKADI**, **EUSTAT**, and **UDALPLAN** platforms which also provide information to the Local Sustainability Indicators System 21 of Udalsarea. To calculate the different **impact chain hazard and exposure indicators**, the chosen source of information are the **high resolution indicators of the Basque Country for climate change scenarios in the 21st century**[39] (periods 2011-2040 and 2071-2100, under scenarios RCP 4.5 and RCP 8.5). In the specific case of data about scenarios regarding sea level rise, data has been taken from the study by Vousdoukas et al. published in 2017 by the European Commission through the *Joint Research Centre* (JRC) *"Extreme sea levels on the rise along Europe's coasts"* in which an increase of 18 and 22 cm for 2050, and an elevation of 53 and 80 cm for 2100, according to the RCP 4.5 and RCP 8.5 scenarios are estimated, respectively.

[39] http://www.ingurumena.ejgv.euskadi.eus/r49-11293/es/contenidos/ds_informes_estudios/escenarios_cclimatico/es_def/index.shtml

It is important to stress that, given **that the unit of territorial analysis** over which the vulnerability assessment and risk **is the municipality**, the data compiled has been, above all, of a supra-munipal scope and almost always with coverage for all the municipalities in the Basque Country.

Given that the intention is to be able to characterise the different components of vulnerability and the risk for each impact chain, the identification and compilation of data has been carried out **seeking direct or indirect relations** if subjected to some type of subsequent transformation — **with possible indicators of hazard, exposure, sensitivity or adaptive capacity**. Ultimately, the intention is to have data for the greatest possible number of components of vulnerability and risk in all the selected impact chains.

Once the search for data of interest is complete, the **structure of a database of indicators** has been defined, which are considered adequate and representative to carry out the evaluation of vulnerability and the risk of the different impact chains. To select these indicators, quality, coverage and availability criteria were taken into account for a sufficient set of municipalities, the date of the most recent update, etc.

The structure of the database of input indicators for the vulnerability analysis and the risk of climate change in municipalities follows a **similar scheme** to that proposed in the **Local Sustainability Indicators System of Udalsarea 21**, and includes the following **descriptive information** for each of the indicators (the coding used in the database in brackets):

— Impact chain corresponding to the indicator,

— Unique identification code of the indicator.

— Type of hazard or climate chain to which it is related:
  - Heat wave (HW).
  - River flooding (FLF).
  - Flood caused by rising sea levels (FLS).
  - Drought (DR).

— Risk component that includes:
  - Hazard or Danger (HZ).
  - Exposure (EX).
  - Vulnerability (VU).

— Extent of the vulnerability, if applicable:
  - Sensitivity (SE).
  - Adaptive capacity (AC).

— Domain or recipient of the impact chain:
  - Population or human capital (HC).
  - Urban environment (BE).
  - Economic activities (EA).

— Name of indicator.

— Definition and explanation of the indicator and its component parameters.

— Units of measurement of the indicator (p.e., %, m^2/hab., hab./ha, etc.).

— Method and form of calculating the indicator based on its corresponding parameters.

— Types of additional processes necessary to obtain the indicator (i.e spatial analysis to adapt it to the municipal scale, other numerical processes...).

— Type of source of the indicator (supra-municipal, local, state...).

— Source from which the data is obtained (GEOEUSKADI, UDALPLAN, EUSTAT, etc.).

— Year when the data source consulted was last updated.

— Year or range of years for which the values of the indicator are obtained.

A simple classification has been used as **criteria** for determining when **an indicator can be for sensitivity or adaptive capacity**, which characterise, respectively, the degree of intrinsic fragility or recovery of a municipality: if the vulnerability increases with the value of the indicator, this is considered a sensitivity indicator; while in contrast, if vulnerability is reduced, then this is considered to be an indicator of response capacity/adaptive capacity.

As can be observed in Figure 8, in total, a database with 30 indicators has been generated for the impact chain of heat waves on human health; 24 indicators for the impact chain of river floods on the urban environment; 19 indicators for the impact chain of floods due to sea level rise on the urban environment; and 16 indicators for the impact chain of longer periods of drought on economic activities, with special interest in the farming sector.

IMPACT CHAINS	INDICATORS				
	Hazard	Exposure	Sensitivity	Adaptive capacity	TOTAL
Impact of heat waves on human health	3	1	10	16	30
River floods on the urban area	1	8	7	8	24
Floods caused by sea level rise in the urban area	0	8	3	8	19
Increased impact of drought on economic activities, particularly on agriculture	1	2	9	4	16

Figure 8. Number and type of indicators included in the analysis of vulnerability and risk for the impact chain.

The complete list of indicators, their definition, origin and characteristics can be consulted in the city profiles.

2.4 Obtaining the values of the indicators to include in the analysis

The purpose of this phase is to compile, prepare and generate the values of the **previously selected indicators for each municipality**, so that these input data can be used to assess vulnerability and risk from climate change for the different impact chains.

An important aspect to highlight is that it has been chosen to use **public** data from official sources (preferably autonomous regional data), which are as **recent** as possible, which have been **updated** to date periodically and which have **total coverage** for all 251 municipalities of the Basque Country.

Another important point in this section is that **most of the indicators**, particularly those originating in sources like **GEOEUSKADI**, **UDALPLAN** and the **high resolution climate scenarios** of the Basque Country, have been subjected to **numerous spatial analytical processes** to adapt them to the unit of analysis subject to this project, the municipality. This has therefore generated **new data, created specifically for this project**. Only the indicators of a more social or economic nature, taken primarily from **EUSTAT** and already aggregated at a municipal level, needed considerably simpler processing, it being sufficient to compile, file and organise them within the structure defined for the vulnerability and risk database.

It is also important to remember that some of these indicators (**all those corresponding to the risk hazard component and many of those for exposure**) are **variables**, in other words, their values change according to the time horizon and the climate scenario considered, which multiplies the number of space-time analyses carried out in this study. This has made it possible to approach the problem of climate change from different perspectives (impact chains), all of interest to the CAPV, and also according to possible future scenarios in each of them (see cells shaded in blue in Figure 9).

IMPACT CHAINS	Reference (1971-2000)	Reference (2016)	Years 2011-2040		Year 2050		Years 2071-2100		Year 2100	
			RC 4.5	RCP 8.5	RC 4.5	RCP 8.5	RC 4.5	RCP 8.5	RC 4.5	RCP 8.5
Impact of heat waves on human health	■		■	■			■	■		
River floods on the urban area	■		■	■			■	■		
Floods caused by sea level rise in the urban area		■			■	■			■	■
Increased impact of drought on economic activities, particularly on agriculture	■		■	■			■	■		

Figure 9. Climate scenarios considered (in blue) in the vulnerability and risk assessment of municipalities in the Basque Country to climate change according to impact chains.

2.5 Obtaining composite vulnerability and risk indices

Once the databases were structured and completed with the indicator values, these were subjected to a series of **statistical processes and tests** (normalisation, standardisation and rescaling) using R. data software analysis. The analysis carried out with this software was performed **independently and sequentially for each impact** chain that forms part of the vulnerability and risk assessment, and considering each of their respective five possible scenarios.

This series of statistical processes have been performed **to make it possible to aggregate the values** of the standardised sensitivity and adaptive capacity indicators to generate their respective composite sensitivity and adaptive capacity indicators and then, by aggregating these, to obtain the composite vulnerability indicator of each municipality. In turn, this vulnerability index has been aggregated to the indicators composed of hazard and exposure, ultimately obtaining the risk indicator for each municipality in the Basque Country, which is also specific to each impact chain and scenario analysed.

Composite sensitivity and adaptive capacity indexes have been obtained by assigning **different weights** to their respective individual indicators. These weights have been analysed, dynamically, **using statistical methods** (mainly analysis of the main components and factor analysis). With these, **redundancy is eliminated** in the information associated with each indicator and indicators are not given relative importance. Thus, indicators containing redundant information are assigned a lower weight than those whose individual explanatory load is greater, which are given greater weight, thus endeavouring not to give undue importance to more closely interrelated indicators. Otherwise expressed, this does not necessarily mean that indicators which are given greater weight from a statistical point of view are more important than those given less weight, rather that the information contributed is more specific and is less distributed than that of other indicators which are more closely interrelated.

Once having generated the weights, the final step was to **aggregate the different indicators in the different composite indices for each impact chain considered**, in other words, to calculate exposure, sensitivity, response and adaptation capability, vulnerability and risk indices for each municipality in the Basque Country. Weighted **geometric aggregation (multiplicative aggregation)** was used rather than weighted arithmetic aggregation (additive aggregation).

Finally, specific composite **indices were obtained for each municipality in the Basque Country and for each of impact chain and scenario analysed**. This enables a comparison between municipalities in the Basque Country, identifying which are most vulnerable and at greatest risk for each impact chain, contributing additional information to propose local activities to reduce vulnerability and risk to climate change.

The extent of the vulnerability and risk can be assessed by measures of position such as quartiles, deciles, percentiles, etc. For example, if selecting municipalities with a decile equal to or greater than 7 (in other words equivalent to or higher than the 60th percentile) we are considering the 40% of municipalities in the Basque Country at greatest risk for a specific impact chain.

It is worth mentioning that, although the risk score of each municipality increases in all future cases, it can be seem that for some of them the relative measures of position (the deciles, for example), may be lower with respect to a specific relevant period. This behaviour, apparently although not anomalous, is because the magnitude of the change in risk is not the same in all municipalities. Whilst in some, this magnitude barely changes and, therefore, its relative position may be lower, in other municipalities it changes significantly, increasing this relative position
.

2.6 Generation of spacial vulnerability and risk data

Having obtained the values of composite vulnerability scores of all the municipalities in the Basque Country, the corresponding **spacial data (SIG layers)** have been generated for publication in the GEOEUSKADI viewer, in the ENVIRONMENT layer, and in the INGURUMENA WMS service.

A specific SIG layer has been created for each of impact chain and time scenario analysed that contains the numeric values of all composite indices: sensitivity (SE), adaptive capacity (AC), vulnerability (VU), hazard (HZ), exposure (EX) and risk (RK). The values of these variables have been represented for the current climate and for two future climate scenarios, according to the RCP 4.5 and 8.5 scenarios. Standardised indicators (on a scale of 1 to 2) and deciles have been published in the SIG layers, using normalised indicators for visual representation.

2.7 Creation of city profiles for each municipality in the Basque Country

To give **each municipality in the Basque Country the personalised local indicators used in the vulnerability and risk assessment and the aggregated indices obtained** these data have been transferred to a set of individual city profiles for each of the 251 municipalities, two summary sheets have been created in Excel format, one in Spanish and the other in Euskera.

It is worth mentioning that these profiles contain a **section to be completed by the municipalities themselves**, enabling them to include and report their own vision, knowledge and experience from a local perspective, adding to the project outcomes with respect to possible hazards, the most vulnerable **sectors** and **municipal policies** either current or planned, regarding adaptation to climate change. Identifying the local measures, plans and policies that are already helping to mitigate the risks of climate change, or which may help to do so in the near

future, also known as **adaptation assets**, is extremely important in order to harness the opportunities they present, as well as being a starting point for addressing other adaptation strategies.

The city profile consists of the following pages and tabs:

Home

A home page containing hyperlinks that gives quick access to the other parts of the city profile. See Figure 10.

Introduction

Page describing general aspects of the assessment of vulnerability and risk from climate change of municipalities in the Basque Country, and the structure of the city profile with municipal data.

Summary

Table summarising vulnerability and risk from climate change of the municipality, for which, vis-a-vis each impact chain analysed, there is a graphic representation of the normalised values of vulnerability and risk indices for the relevant period.

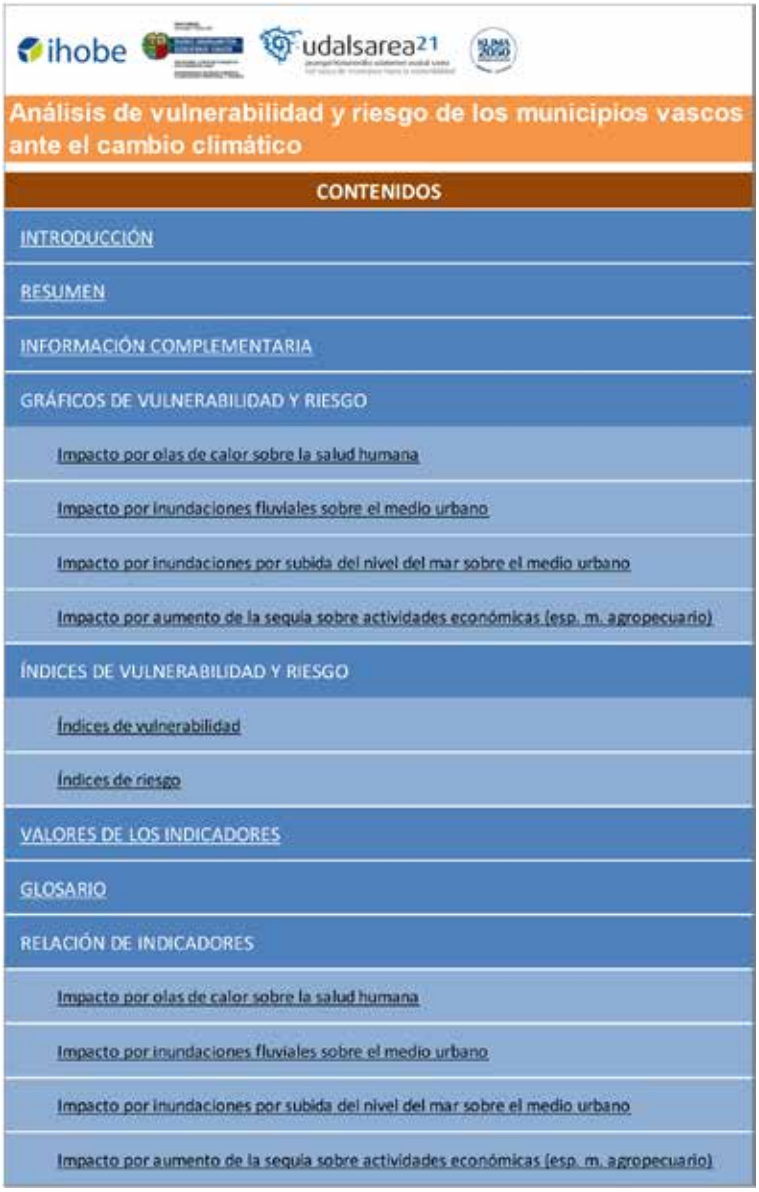

Figure 10. *HOME* tab of the summarised city profile containing data from the assessment of vulnerability and risk from climate change of municipalities in the Basque Country.

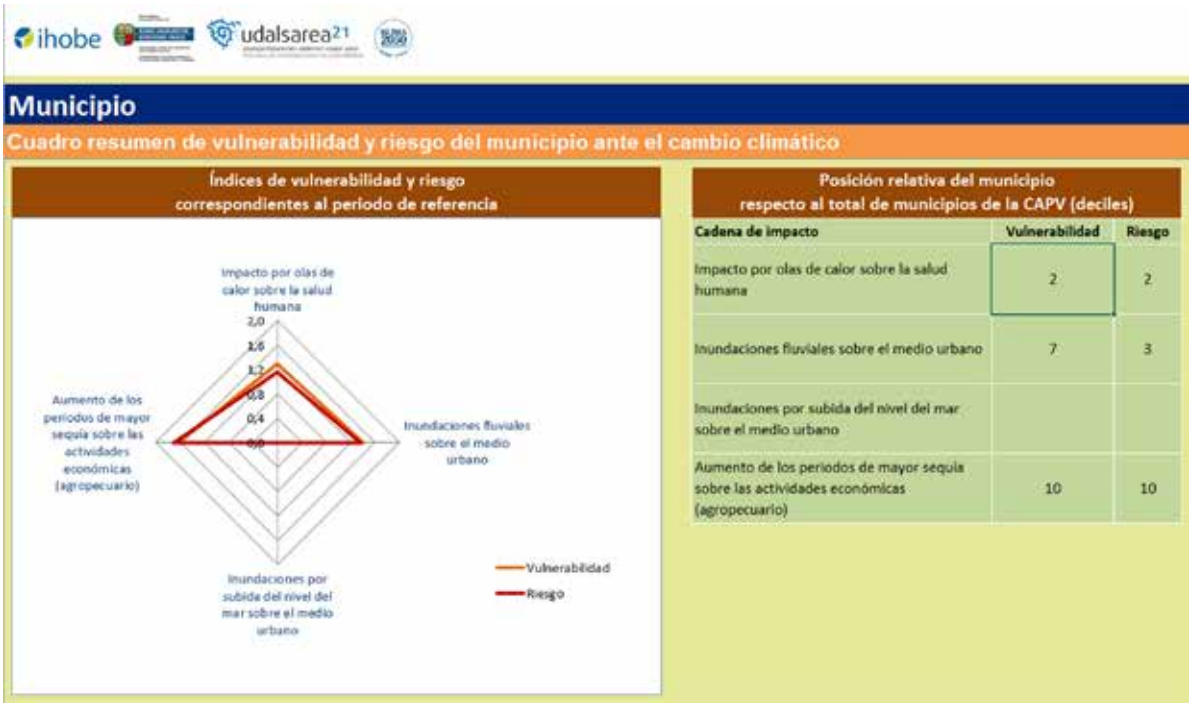

Figure 11. Sample table summarising vulnerability and relative risks of a municipality in the Basque Country included in the city profile.

The relative position (in deciles) of the municipality with respect to the group of municipalities in the Basque Country that represent a risk for a certain impact chain is also shown. The Glossary Page contains additional information about the decile as a statistical measure. See example in Figure 11.

Additional_information

A series of sections is included where municipalities can add updated information with respect to general data about the municipality, about aspects related to known and perceived current and future climate hazards for their territory, areas or sectors that may suffer greater impacts, and possible local policies or action being carried out or foreseen which are related to adaptation to climate change.

Heat_wave_graphs, Urban_river-graphs, Urban_coast_graphs and Economy_drought_graphs

Graphs are shown with the vulnerability index (top of page) and risk index (bottom of the page) for each of the four impact chains analysed. If the profile does not have any of these four tabs, this means that, according to currently available data, no risk has been identified for the municipality regarding the impact chain in question.

The municipality's vulnerability index for the relevant period compared to that of the district to which it belongs and that of the Basque Country (percentile 50 in both cases). The contributions of indicators used (in percentage terms) to determine the indices composed of sensitivity and adaptive capacity also shown. These contributions are a function of the values of indicators presented by the city or town itself and the relative weight assigned to the indicator, obtained using statistical techniques.

The index of the risk components (vulnerability, hazard and exposure) is shown in the risk section of the municipality according to different periods and climate scenarios. A territorial comparison of the municipality's risk indices and those of the district to which it belongs and the Basque Country is also shown according to different periods and climate scenarios. See example in Figure 12.

Vulnerability_index

The normalised values of the indices comprising sensitivity, adaptive capacity and vulnerability of the municipality, the district to which it belongs and the Basque Country are shown. Values are distributed by impact chains, periods and climate scenarios.

Figure 12. Sample graphic data showing the vulnerability and relative risks of a municipality in the Basque Country for a specific impact chain included in the city profile.

The relative position (in deciles) of the municipality with respect to the group of municipalities in the Basque Country that represent a risk for a certain impact chain is also shown. Additional information is provided on the Glossary page.

Risk_indices

Normalised values of the indices comprising sensitivity, adaptive capacity and risk of the municipality, the district to which it belongs and the Basque Country are shown. Values are distributed by impact chains, periods and climate scenarios.

The relative position (in deciles) of the municipality with respect to the group of municipalities in the Basque Country that represent a risk for a certain impact chain is also shown. Additional information is provided in the Glossary tab.

Indicator_values

The values, without normalisation, of the hazard, exposure, sensitivity and adaptive capacity indicators of the municipality used to obtain vulnerability and risk indicators are shown. Values are distributed by impact chains, periods and climate scenarios.

Glossary

Glossary of the main terms and definitions used in the project.

Health_waves_indicators, Urban_river_indicators, Urban_coast_indicators and Economy_drought_indicators

A description of each of the hazard, exposure, sensitivity and adaptive capacity indicators included in the vulnerability and risk assessment of the Basque Country according to these four impact chains, is shown, regardless of whether the municipality is ultimately at risk to all of these.

03

Analysis of the results of the vulnerability and risks assessment of basque municipalities to climate change

This section contains a summary of the main outcomes of the vulnerability and risk assessment of the municipalities in the Basque Country regarding climate change for each impact chain analysed.

3.1 Impact of heat waves on human health

Given that the population of each city and town receives possible impacts from increased extreme temperatures and the number or duration of heat waves, this has been considered a decisive factor of exposure to current and future climate hazards. Because of this, **100% of the municipalities of the Basque Country** are affected by this type of risk to some extent. Therefore, vulnerability and risk have been assessed for a group of hazard, exposure, sensitivity and adaptive capacity indicators previously been selected for this impact chain for all 251 municipalities in the Basque Country.

The following figure shows the distribution of the risk indices of *"Heat waves, potential effect on health"* for the relevant 1971-2000 period, 2011-2040 period and 2071-2100 period under the RCP 8.5 scenario.

In this project, an **upward trend in all future scenarios** has been identified. Therefore, **in the 2011-2040 period**, in both the RCP 4.5 and RCP 8.5 scenarios, there would be a greater risk for municipalities in the Basque Country of between 7 and 12% with respect to the risk of the relevant 1971-2000 period. In contrast, in the **2071-2100 period** this increase would be more pronounced, **between 16 and 25%** in the RCP 4.5 scenario and between **21 and 35%** in the RCP 8.5 scenario.

3.2 Impact of river floods on the urban area

There is currently **no modelling for the Basque Country of impacts due to river flooding that considers heavy rain in the future and recent improvement actions** (widening river courses, bridges, rainwater collectors, etc.). Because of this, and following the principle of prudence, the extension of the **current flood area has been used for an avenue of a 500-year recurrence period** (flooding cartography prepared by URA and available in the public GeoEuskadi portal) as a first approximation of the size of the **future flood area with a 100-year recurrence period**. This reveals that **204 of the 251 municipalities**

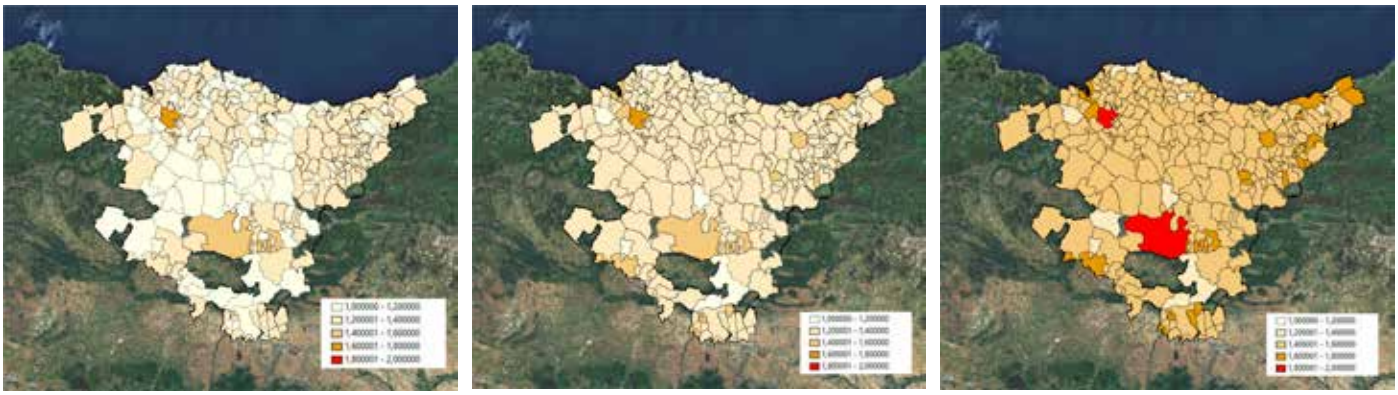

Figure 13. The following figure shows the distribution of the risk indices of "Heat waves, potential effect on health" for the relevant 1971-2000 period, 2011-2040 period and 2071-2100 period under the RCP 8.5 scenario.

in the Basque Country (81%) are exposed to this hazard to some extent. Like the previous impact chain, the vulnerability and risk of these municipalities has been assessed based on the corresponding group of previously selected hazard, exposure, sensitivity and adaptive capacity indicators.

The following figure shows the distribution of the risk indices for *"River flooding on the urban environment"* for the relevant 1971-2000 period, 2011-2040 period and 2071-2100 period under the RCP 8.5 scenario.

Regarding the evolution of the risk, **a general upward trend** has been identified **in all future scenarios contemplated**. However, and without forgetting the greater uncertainty in future rainfall forecasts, this positive trend is not distributed equally among all municipalities. The RV100YEAR climate index (mean maximum rainfall for a 100-year recurrence period), used as a hazard indicator in this project determines the risk values obtained. Therefore, it can be seen that **in the 2011-2040 period**, in the RCP 4.5 scenario, the variation of the risk with respect to the relevant period 1971-2000 is **between -1 and +4%**, very similar to that in the RCP 8.5 scenario, with values **between -2 and +4%**. This variability is even more pronounced in the 2071-2100 period, with ranges that vary **between -1 and +8 %** for the RCP 4.5 scenario and **between 0 and +10 %** for the RCP 8.5 scenario.

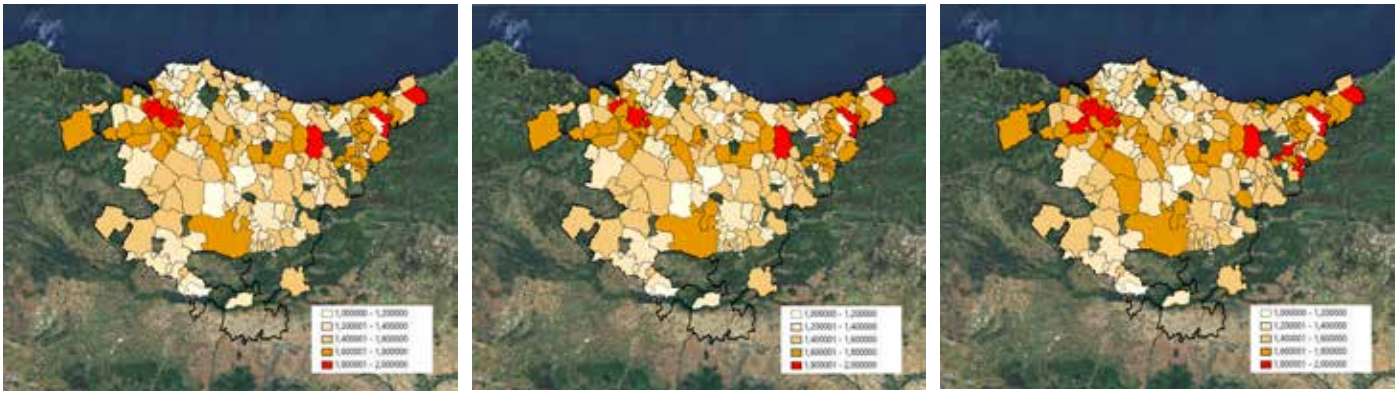

Figure 14. Risk indices of "River flooding on the urban environment" for the relevant 1971-2000 period, 2011-2040 period and 2071-2100 period under the RCP 8.5 scenario.

3.3 Impact of flooding caused by sea level rise in the urban area

According to the projections, data and methodology used in this project, **58 of the 251 municipalities in the Basque Country (23 %)** are exposed to this hazard to some extent. As mentioned in the above impact chains, for municipalities, vulnerability and risk have been assessed based on the corresponding group of previously selected hazard, exposure, sensitivity and adaptive capacity indicators, largely analogous with the composite indicators used for the river flooding of the urban environment impact chain.

The following figure (shows the distribution of risk indices for the impact chain *"Floods caused by rising sea levels in the urban area"*, currently (2016), 2050 and 2100, under the RCP 8.5 scenario.

Regarding the evolution of the risk, a general **upward trend has been identified in all future scenarios contemplated**. Thus, it can be observed that, in 2050, in the RCP 4.5 scenario, the variation in risk with respect to the benchmark year 2016 is **between 0 and 8%**, while in the RCP 8.5 scenario it is **between 0 and 21%**. This variability is even more pronounced **in the year 2100**, particularly in the worst case scenario, with ranges varying **between 0 and 9%** for the RCP 4.5 scenario and **between 0 and 35%** for the RCP 8.5 scenario.

3.4 Impact of increased drought on economic activities (particularly farming)

Given that generally, land not classified for building and particularly, farmland for economic activities, are at risk of impacts due to increased periods of drought, both have been considered decisive factors in terms of exposure to this type of climate hazard. Because of this, **100% of the municipalities in the Basque Country** are affected to some extent by this type of risk. Therefore, for the group of 251 municipalities in the Basque Country, their vulnerability and risk have been assessed based on a group of previously selected hazard, exposure, sensitivity and adaptive capacity indicators for this impact chain.

The Figure 16 shows the distribution of the risk indices of *"Impact of increased periods of drought on economic activities, particularly on farming"* for the relevant 1971-2000 period, 2011-2040 period and 2071-2100 period under the RCP 8.5 scenario.

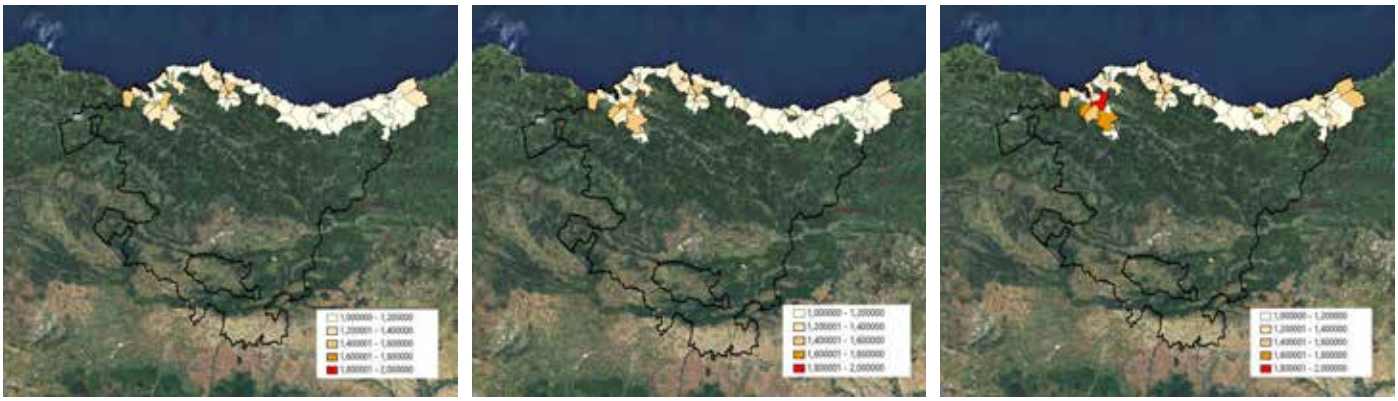

Figure 15. Risk indices for the impact chain "Floods caused by rising sea levels in the urban area", currently (2019), 2050, 2100, under the RCP 8.5 scenario.

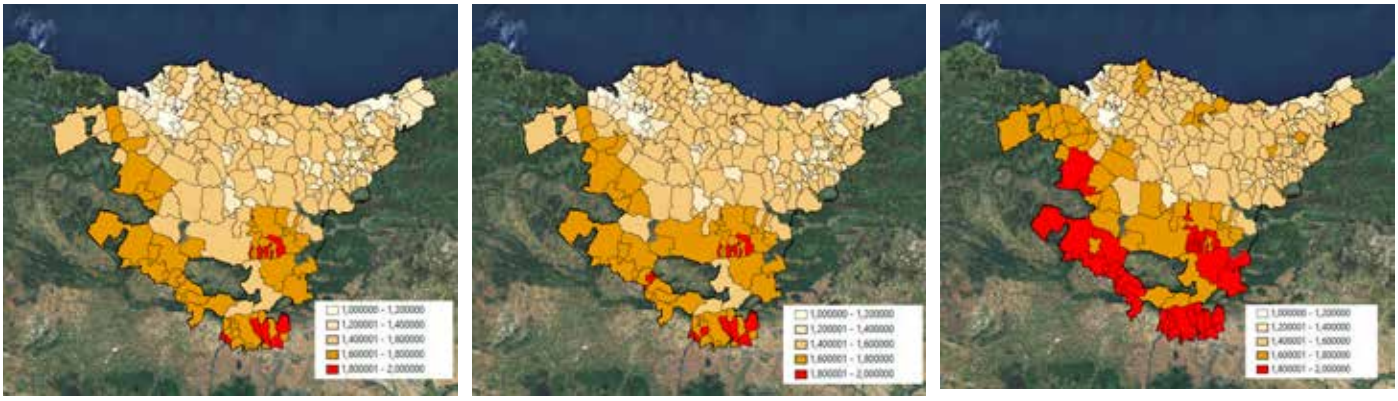

Figure 16. Risk indices of "Impact of increased periods of drought on economic activities, particularly on farming"[40] for the relevant 1971-2000 period, 2011-2040 period and 2071-2100 period under the RCP 8.5 scenario.

Regarding the evolution of the risk, in general, an **upward trend in all future scenarios contemplated has been identified**. Therefore, in the **2011-2040 period**, and according to the RCP 4.5 scenario, there will be an increased risk municipalities in the Basque Country of between 1 and 3% with respect to the relevant period 1971-2000. According to the RCP 8.5 scenario, this increased risk is situated between the values of 0 and 3%. In contrast, in the 2071-2100 period the increase would be more pronounced, **between 2 and 6 %** in the RCP 4.5 scenario and **between 4 and 11 %** in the RCP 8.5 scenario.

[40] Due to limited space, in the GeoEuskadi viewer it has been renamed "effect of drought on the agribusiness sector".

04

General adaptation measures by impact chains, types and sectors

The following is a **set of general measures** to be considered by the municipalities of the Basque Country, **aligned with the results of the vulnerability and risk assessment**. This battery of possible measures is not intended to replace the preparation of a municipal adaptation plan per se, but rather to propose and provide municipalities with the selection of types of measures which can be taken into consideration according to their particular specific risks.

The measures **are classified by impact chain** and accordingly, the measures proposed are classified by **sectors and types**. The following documents have been used to prepare the list of measures:

- Workbook no. 12 of Udalsarea 21 *"Guidelines for preparing municipal programmes for adaptation to climate change"*,
- Methodological Guide *"Measures for mitigation and adaptation to climate change in urban planning"*[41] by the FEMP (2015),
- Climate Change Strategy of the Basque Country KLIMA 2050 for *"Identification of best practices of adaptation to climate change in municipalities and preparation of dissemination materials"*,
- *"Nature-based solutions for local climate adaptation in the Basque Country"* by the Government of the Autonomous Region of the Basque Country. Methodological guide to identification and mapping. Donostia / San Sebastián case study, Klimatek 2016 project[42], and
- Donostia / San Sebastián Plan for adaptation to climate change.

4.1 Types of measures according to typologies and sectors

Each measure proposed is classified by type and the sector to which it applies. Thus, measures according to their **typology** may be:

- Structural.
- Technological.
- Nature-based solutions (NBS).
- Awareness-raising and training measures.

[41] http://www.gea21.com/_media/publicaciones/guia_femp_medidas_ccc_planeamiento_urbano.pdf

[42] http://www.udalsarea21.net/Publicaciones/Ficha.aspx?IdMenu=892e375d-03bd-44a5-a281-f37a7cbf95dc&Cod=adbf2e51-3d8c-4879-ab8d-9a7ab8d48e45&Idioma=es-ES

— Generation of knowledge and support for decision making.
— Financing, grants and tax incentives.
— Plans and programmes, laws, governance and management.
— Preventive.
— Alert systems.

Regarding the sectors to which these may apply, these are classified as follows:

— NATURAL MEDIA-Water resources.
— NATURAL MEDIA-Land and coastal ecosystems.
— NATURAL MEDIA-Land.
— URBAN MEDIA AND INFRASTRUCTURES-Critical infrastructures.
— URBAN MEDIA AND INFRASTRUCTURES-Lineal transport infrastructures.
— URBAN MEDIA AND INFRASTRUCTURES-Territorial and urban planning.
— URBAN MEDIA AND INFRASTRUCTURES-Urban media.
— URBAN MEDIA AND INFRASTRUCTURES-Buildings.
— ACTIVITY-Farming, forestry, livestock and fishing.
— ACTIVITY-Industry.
— ACTIVITY-Tourism.
— ACTIVITY-Finances-Insurance.
— HEALTH AND CIVIL PROTECTION-Health.
— HEALTH AND CIVIL PROTECTION-Civil protection and emergencies.
— OTHERS-Other sectors not considered or cross-cutting actions.

4.2 List of general adaptation measures for municipalities

Table 1 lists the general measures proposed for municipalities, indicating to which impact chain or chains each responds, their type and the main sector to which they apply.

Measurements	Impact of heat waves on human health	Impact of river floods on the urban area	Impact of flooding caused by sea level rise in the urban area	Impact of increased drought on economic activities	Sector	Typology
01. Increase green and permeable area of plazas, spaces and public buildings of the city or town	x	x			URBAN MEDIA AND INFRASTRUCTURES-Territorial and urban planning	NBS
02. Upgrades to improve energy efficiency of public buildings	x				URBAN MEDIA AND INFRASTRUCTURES-Buildings	Structural
03. Create a local ecological connectivity network to maintain biodiversity in the urban ecosystem	x	x	x	x	NATURAL MEDIA - Land and coastal ecosystems	NBS
04. Foster regreening of rooftops and balconies of buildings, and of common spaces and city block courtyards	x				URBAN MEDIA AND INFRASTRUCTURES-Buildings	NBS

Measurements	Impact of heat waves on human health	Impact of river floods on the urban area	Impact of flooding caused by sea level rise in the urban area	Impact of increased drought on economic activities	Sector	Typology
05. Draft a preventive action protocol for heat waves involving agents from municipalities that include early alerts, advice and recommendations for the vulnerable population.	x				HEALTH AND CIVIL PROTECTION-Health	Alert systems
06. Identify, adapt and maintain cool urban areas as a resource for the vulnerable population during heat waves (plazas and shady walks, fountains, etc.)	x				HEALTH AND CIVIL PROTECTION-Health	NBS
07. Foster knowledge and raise public awareness of the possible effects of climate change on the municipality	x	x	x	x	OTHERS-Other sectors not considered or cross-cutting actions.	Awareness-raising and training measures
08. Analyse existing water resources and demand under future climate conditions (anticipate the need to increase storage capacity in good time)	x				NATURAL MEDIA - Water resources	Generation of knowledge and support for decision making
09. Regularly update emergency civil protection plans, incorporating the climate risks foreseen	x	x	x	x	HEALTH AND CIVIL PROTECTION-Civil protection and emergencies	Preventive
10. Draft action protocols with citizen participation involving residents who may be habitually affected by specific impacts	x	x	x		HEALTH AND CIVIL PROTECTION-Civil protection and emergencies	Preventive
11. Create a list of elderly care homes, infant schools and other places inhabited by vulnerable people	x				HEALTH AND CIVIL PROTECTION-Health	Awareness-raising and training measures
12. Install shallow urban pools fed by rainwater to counteract the “heat island” effect	x				URBAN MEDIA AND INFRASTRUCTURES - Urban media	Structural
13. Equip the homes of vulnerable people with measures that help to improve comfort and thermal control in homes during heat waves: thermometers, fans, awnings...	x				URBAN MEDIA AND INFRASTRUCTURES - Buildings	Preventive
14. Renaturalization of river courses and areas exposed and vulnerable to river flooding		x			NATURAL MEDIA- Water resources	NBS

Measurements	Impact of heat waves on human health	Impact of river floods on the urban area	Impact of flooding caused by sea level rise in the urban area	Impact of increased drought on economic activities	Sector	Typology
15. Implement Sustainable Urban Drainage Systems (UDS)		x			NATURAL MEDIA-Water resources	Structural
16. Ensure that municipal new building and planning regulations consider the increased risk of flooding (coastal and river) and the greater risk of drought		x	x		URBAN MEDIA AND INFRASTRUCTURES-Buildings	Plans and programmes, laws, governance and management
17. Restrict construction of new buildings in flood zones (even those where there is currently no risk of flooding)		x	x		URBAN MEDIA AND INFRASTRUCTURES-Territorial and urban planning	Plans and programmes, laws, governance and management
18. Review insurance policies purchased by the city council to ensure coverage of risks associated with climate change		x	x		ACTIVITY-Finances-Insurance	Plans and programmes, laws, governance and management
19. Coordinate with competent public management agents and/or intervention in areas exposed to flooding		x			URBAN MEDIA AND INFRASTRUCTURES-Territorial and urban planning	Plans and programmes, laws, governance and management
20. Analyse the capacity of the municipal sewage system under climate change scenarios		x			NATURAL MEDIA-Water resources	Structural
21. Install “rain gardens”. Rain gardens consists of depression areas with specific vegetation (long root autochthonous plants and herbs) to absorb rainwater, which will fill during rainy periods and filter into the soil instead of entering the system		x			NATURAL MEDIA - Water resources	NBS
22. Change location of busy centres exposed to flooding		x	x		URBAN MEDIA AND INFRASTRUCTURES-Territorial and urban planning	Preventive
23. Build storm tanks to increase rainwater run off capacity, reducing flooding risk		x			URBAN MEDIA AND INFRASTRUCTURES-Urban media	Structural

Measurements	Impact of heat waves on human health	Impact of river floods on the urban area	Impact of flooding caused by sea level rise in the urban area	Impact of increased drought on economic activities	Sector	Typology
24. Establish infrastructure inspection and maintenance procedures for the municipality where exposed to rising sea levels and/or extreme waves			x		URBAN MEDIA AND INFRASTRUCTURES-Urban media	Plans and programmes, laws, governance and management
25. Study the effect of waves and rising sea levels on currents and municipal beaches			x		NATURAL MEDIA-Land and coastal ecosystems	Generation of knowledge and support for decision making
26. Avoid the advancing of the coastline through adaptation actions of different natures (Dune restoration and beach regeneration, marshes and wetlands, etc.)			x		NATURAL MEDIA-Land and coastal ecosystems	NBS
27. Build dikes to reduce the risk of events related to rising sea levels			x		URBAN MEDIA AND INFRASTRUCTURES-Urban media	Structural
28. Adapt sewage systems to the possibility of suffering events and floods particularly in places where rivers empty into the sea			x		URBAN MEDIA AND INFRASTRUCTURES-Critical infrastructures	Structural
29. Monitor and stabilise the coast by means of depositing sedimentary material. This measure must be carried out in coordination with other municipalities and city councils			x		NATURAL MEDIA-Land and coastal ecosystems	Preventive
30. Implement forest fire early warning systems				x	HEALTH AND CIVIL PROTECTION-Civil protection and emergencies	Alert systems
31. Considering using alternative tree and plant species in parks and green zones, selecting more drought-resistant varieties				x	NATURAL MEDIA-Land and coastal ecosystems	NBS
32. Facilitate adaptation of the primary sector (farming and fishing) to new climate conditions (to address the negative impacts of climate change and maximise opportunities derived from the global change to be maximised)				x	ACTIVITY-Farming, forestry, livestock and fishing	Generation of knowledge and support for decision making

Measurements	Impact of heat waves on human health	Impact of river floods on the urban area	Impact of flooding caused by sea level rise in the urban area	Impact of increased drought on economic activities	Sector	Typology
33. Explore new markets and new opportunities derived from the global change				x	OTHERS-Other sectors not considered or cross-cutting actions.	Generation of knowledge and support for decision making
34. Allocate areas at high risk of flooding to less sensitive uses such as parks and sports areas		x	x		URBAN MEDIA AND INFRASTRUCTURES-Territorial and urban planning	Preventive
35. Use regulatory measures in the land-use process to avoid building critical facilities (hospitals, fire and police stations, waste processing plants...) in areas at risk, particularly at risk of flood or fire	x	x	x		URBAN MEDIA AND INFRASTRUCTURES-Territorial and urban planning	Preventive
36. Avoid building underground car parks in flood zones		x	x		URBAN MEDIA AND INFRASTRUCTURES-Territorial and urban planning	Preventive

Table 2. General adaptation measures for municipalities according to the impact chains, typologies and sectors of application.

05

Summary, general conclusions and potential use of the project results

A summary and general conclusions regarding the project objectives, scope and outcomes, along with their potential, are set out below.

The main objective of the project was **to assess the vulnerability and risks of Basque municipalities in terms of climate change**. Knowledge about **which municipalities and to what extent** can be affected by the main current and future climate threats is of great interest and helps with the implementation of effective response mechanisms and policies at different scales.

A series of **more specific tasks** was therefore carried out and which are summarised below:

— Review of the methodological approach and data model of the previous vulnerability assessment of municipalities of the BAC, conducted in 2010 in a very different context to the current one: driving the adaptation policies in Europe (European Climate Change Adaptation Strategy (2013) and "Mayors Adapt" initiative (2014), for example); Basque municipalities signing up to other international initiatives ("Compact of Mayors", for example); conceptual framework proposed in the IPCC Fifth Assessment Report on Impacts, Adaptation and Vulnerability (2014); publication of the Basque Climate Change Strategy – KLIMA 2050 (2015); opportunity to incorporate new or more recent public data sources at local and regional scale (Geoeuskadi, Udalplan, Eustat, etc.).

— Review of the problem trees or diagrams, the main climate threats and the possibly most impacted sectors or spheres that are identified in the KLIMA 2050 Strategy. The latter provided the basis, in turn, for approach of the risk and vulnerability assessment, which prioritised those impact chains deemed most relevant for BAC municipalities overall:

  a. Impact of heat waves on human health.

  b. Impact of river flooding on the urban environment.

  c. Impact of flooding due to rising sea levels on the urban environment.

  d. And impact of an increase in droughts on economic activities (particularly agriculture).

— Preparing, using spatial analysis techniques, municipal indicator databases aimed at the selected impact chains.

— Conducting a quantitative assessment of the vulnerability and risk relating to Basque municipalities, based on statistical techniques and indicators, for each impact chain selected and from a perspective of multiple climate scenarios (reference and future periods).

— Generating a broad collection of geographical data, tables, graphs and cartographic output in order to facilitate the interpretation and comparison of the results obtained in the vulnerability and risk assessment for the BAC overall.

— Preparing summary datasheets, for each BAC municipality, which include the data from the risk and vulnerability assessment, and compares them to the supramunicipal district in question and the data for the Autonomous Community.

— Proposal of general adaptation measures for the municipalities according to their types of risks, likewise identifying the type of measure and the sector to which it applies.

It should be noted that it is not simply an assessment of the vulnerability and risk from the qualitative point of view, but rather that the methodology used for BAC municipalities overall is based on the use of a **combined set of qualitative, statistical and spatial analysis methods** whose benchmark are **recent international approaches** to assess vulnerability and risk **at regional and local level**.

This risk and vulnerability assessment was conducted using a **battery of municipal indicators expressly generated for this project** and whose definition was aligned, as far as possible, with other existing indicator systems and, in particular, with the **Local Sustainability Indicators System of the Basque Autonomous Community (2017)**.

The results obtained allow a **comparative between municipalities** to be performed and the more important climate change vulnerabilities and risks to be identified according to the selected **impact chains** and future **climate scenarios**.

An aspect that is also important to prepare the indicator database is the decision to use public data from **official sources** (preferably at autonomic level), that are **as recent as possible**, that have been **regularly updated** and that provide **total coverage for the 251 Basque municipalities overall**.

Even though it was initially the purpose of the project, it was considered of special interest for the results obtained for each of municipalities of the BAC, particularly those represented in tables and graphs, **to be grouped** in supramunicipal territorial unites, specifically **in supramunicipal districts**, so that aspects, such as whether all the municipalities of a supramunicipal district follow the same pattern for a specific risk or, on the other hand, there are obvious differences between them, can be interpreted more easily. It is particularly noteworthy that the results can also be displayed and analysed from a cartographic perspective, which facilitates **their understanding in a territorial context** and their comparison between municipalities.

Furthermore, as a new aspect of this project with respect to other similar ones conducted so far, not only nationally, but also internationally, it should be noted that the **risk assessment** of the different impact chains was conducted **from a multiple scenario perspective**. Thus, the results of the risk assessment according to each impact chain has allowed **the differences between the indexe**s of the different municipalities, on the basis of a specific timeline and scenario, to be detected, and, in particular, **the possible trend or evolution** and the degree of intensity of change in the values of those indexes **overtime** to be shown, jointly taking into account different timelines and scenarios.

The methodological resources and the results of this study can allow better informed **urban and territorial decisions** to be made, in order to anticipate the possible impacts of climate change, along with acting proactively to increase the efficiency and resilience of the territory, as envisaged by Goal 3 of the KLIMA 2050 Strategy.

From the perspective of territorial planning, the project results will allow the **risk and vulnerability territorial patterns to be identified**, highlighting crucial spheres or points between different climate threats, from a multiscale perspective, at the level of the BAC as a whole, the provinces and the different functional areas. This identification of critical zones or points could be used as baseline information and with framework potential to establish territorial planning and guidance **requirements** regarding the need for **detailed or specific studies** on threats, vulnerability and risks at critical zones or points of our territory, taking into account the climate information available. The results could likewise facilitate decision making about priority **investments and/or areas of actions** regarding adaptation.

For example, the **Partial Territorial Plans** (PTP) could incorporate the individualised information of the datasheets generated in this study for the municipalities in that area in their territorial planning impact documents summarising the main determinations affect each municipality of the functional area. Thus, there would be an overview of the status of the functional area regarding climate change

vulnerability and risks. Consequently, territorial intervention and planning decisions could be made from an adaptive management perspective. Depending on the specific situation of each functional area, as applicable, asking those municipalities with greater vulnerability and risk to conduct specific studies for those more significant risks or, should that not happen, to provide the reasoned justification could be assessed.

Like at the level of territorial planning, the climate change vulnerability and risk indexes could be incorporated along with other **monitoring and follow-up indicators** (Annex 12.2. Urban Development and Territorial Sustainability Indicators of the review of the Spatial Development Guidelines of the Basque Country) in order to enrich the urban and territorial planning comparisons in the framework of the monitoring reports of the PTP and Sector Territorial Plans (PTS).

At local level, the identification of priority intervention areas in the Progress Reports of the General Urban Development Plans (PGOU), along with the accompanying strategic environmental reports and, to a lesser or greater extent, the decision-making in the **structural or general urban planning** processes are some of the potential uses of the project outcomes. The approach of the Manual of Urban Planning of the Basque Country for Climate Change Mitigation and Adaptation is a suitable framework for integrate the analysis as it exhaustively sets out which approach and scope may have the climate change component on different scales and instruments, associated to threats such as the one analysed in this study and where special mention should be made of flooding and extreme temperatures /urban heat island.

At local level, it is also clear that municipalities have an important adaptive capacity by means of particularly relevant local policies, such as, in addition to urban planning, the supply of drinking water, sanitation networks and waste water treatment, management of roads and public spaces, environmental protection and public health. From this perspective, the results of this risk and vulnerability assessment have become a tool for **self-diagnosis at municipal level**, identifying policies where it is necessary to consider climate change adaptation by making use of the information available through specific studies.

In this context, global data on risks and **adaptation needs worldwide** may be baseline information for:

— The possible preparation of autonomous **adaptation plans**, by establishing a common approach that allows concepts and indicators to possibly be included in the **monitoring** of the adaptation plans to be harmonised and compared.

— Reviewing and updating existing climate change plans.

— Their consideration in sustainability plans and processes or **Local Agendas 21** by integrating climate change risk and vulnerability component, associated with tools to manage and monitor sustainability policies, such as eMugui in the Basque Country.

— Their consideration in key local sectoral plans and policies to address the effects of climate change, such as **risk management** in the **emergency plans**, or other municipal plans such as those of public health, to help to update them by incorporating climate aspects.

— Compliance and monitoring of **international commitments** such as the Global Covenant of Mayors for Climate and Energy.

— Identifying impact chains that require **specific studies** in our municipality (thermal maps, flooding, etc.) for their use in urban development plans, urban regeneration plans, investment projects, etc.

— Identifying **supramunicipal action** and cooperation opportunities to work together in order to reduce the impact associated to impact chains that affect supramunicipal areas such as river basins or coasts.

Finally, the potential use should be noted both in the research and academic sphere, and by **private stakeholders**, by making decisions on preparing studies, adopting investment criteria, etc.

06

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Annex I

Glossary of terms related to vulnerability and risk of climate change

The glossary included in the Fifth Report of the IPCC on Impacts, Adaptation and Vulnerability (IPCC, 2014) provides the definitions of the concepts used in this publication:

Risk

The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.

Hazard

The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.

Exposure

The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Sensitivity

The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise).

Adaptive capacity

The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

The purpose of the study carried out in the Basque Country is to assess risk and vulnerability to climate change as a combination of factors that form part of these elements, in other words, exposure, sensitivity response and adaptive capacity.

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