score

D1.3 - Map and report of baseline exposure and vulnerability

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V 0.2	Emilio Laíño Rebollido (UCC) Gregorio Iglesias (UCC)	04/04/2023	Second draft after internal contributions
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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Meaning / Full text
CCLL	Coastal City Living Lab
CSI	Coastal Sensitivity Index
DEM	Digital Elevation Model
EBA	Ecosystem-Based Approach
ESL	Extreme Sea Level
GIS	Geographical Information System
LECZ	Low Elevation Coastal Zone
MERIT	Multi-Error-Removed Improved-Terrain
MHW	Mean High Water
MMU	Minimum Mapping Unit
MSL	Mean Sea Level
MSLR	Mean Sea Level Rise
NBS	Nature-Based Solution
RCP	Representative Concentration Pathway
RSLR	Relative Sea Level Rise
SCORE	Smart Control of the Climate Resilience in European Coastal Cities
SLR	Sea Level Rise
SSP	Shared Socioeconomic Pathway
WP	Work Package

BACKGROUND: ABOUT THE SCORE PROJECT

SCORE is a four-year EU-funded project aiming to increase climate resilience in European coastal cities.

The intensification of extreme weather events, coastal erosion and sea-level rise are major challenges to be urgently addressed by European coastal cities. The science behind these disruptive phenomena is complex, and advancing climate resilience requires progress in data acquisition, forecasting, and understanding of the potential risks and impacts for real-scenario interventions. The Ecosystem-Based Approach (EBA) supported by smart technologies has potential to increase climate resilience of European coastal cities; however, it is not yet adequately understood and coordinated at European level.

SCORE outlines a co-creation strategy, developed via a network of 10 coastal city 'living labs' (CCLLs), to rapidly, equitably and sustainably enhance coastal city climate resilience through EBAs and sophisticated digital technologies.

The 10 coastal city living labs involved in the project are: Sligo and Dublin, Ireland; Barcelona/Vilanova i la Geltrú, Benidorm and Basque Country, Spain; Oeiras, Portugal; Massa, Italy; Piran, Slovenia; Gdansk, Poland; Samsun, Turkey.

SCORE will establish an integrated coastal zone management framework for strengthening EBA and smart coastal city policies, creating European leadership in coastal city climate change adaptation in line with The Paris Agreement. It will provide innovative platforms to empower stakeholders' deployment of EBAs to increase climate resilience, business opportunities and financial sustainability of coastal cities.

The SCORE interdisciplinary team consists of 28 organizations encompassing a wide range of skills including environmental science and policy, climate modelling, citizen and social science, data management, coastal management and engineering, security and technological aspects of smart sensing research.

EXECUTIVE SUMMARY

This document is a deliverable of the SCORE project, funded under the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003534.

This document primarily describes the methodology and summarises the results and conclusions of Task 1.3 – Mapping of coastal cities exposure and vulnerability to climate effects and sea level rise. It is part of the work included in WP1, whose final objective is to produce a high-level baseline risk map of extreme climate impacts and sea-level rise based on a semi-quantitative assessment of exposure and vulnerability for the ten CCLLs.

This report is based on the results of the literature review carried out in Task 1.1 – Impacts of extreme climate events and sea level rise on coastal cities: literature review, Task 1.2 –Mapping of past extreme events and identification of key hazards in the coastal cities, and on a participatory process involving the CCLLs, in conjunction with WP2.

Indicators of exposure and vulnerability to sea level rise and extreme climate-related impacts in the CCLLs (including all frontrunners and followers) have been produced and mapped through a high level, semi-quantitative approach to the baseline situation (current climatic conditions).

These vulnerability and exposure indicators relate to the key climate-related hazards identified in *D1.2 – Map and report of key climate change hazards*.

The analysis include the development of indicators of exposure of the physical system, population, land uses, critical infrastructure, critical assets and ecosystems and indicators of adaptive capacity of the CCLLs.

Available European, national and regional hazard datasets are used when local data were limited.

Complementary to the high-level analysis performed, the results are mapped using GIS software.

The results are further analysed in Task 1.4 – Baseline risk analysis and mapping of extreme climate impacts and sea level rise and in WP6 – Strategies to increase the financial resilience of coastal cities.

LINKS WITH OTHER PROJECT ACTIVITIES

Different work packages are being prepared under the umbrella project *Smart Control of the Climate Resilience in European Coastal Cities* (acronym: SCORE) between 2021 and 2025:

- Work Package 1 – Mapping the baseline exposure and risk of extreme climate impacts on coastal cities
- Work Package 2 – Coastal City Living Labs Design, Implementation, and Evaluation
- Work Package 3 – Regional and Local Projections, Analyses, Modelling and Uncertainties
- Work Package 4 – CCLL co-warning and comonitoring
- Work Package 5 – Pre/post-EBA Interventions Evidence Collection and Knowledge Marketplace
- Work Package 6 – Strategies to increase the financial resilience of coastal cities
- Work Package 7 – Socio-economic assessment of adaptation strategies and policy recommendations
- Work Package 8 – Development of integrated early warning support and spatial digital twin solution prototypes
- Work Package 9 – Dissemination, communication, exploitation
- Work Package 10 – Coordination and management

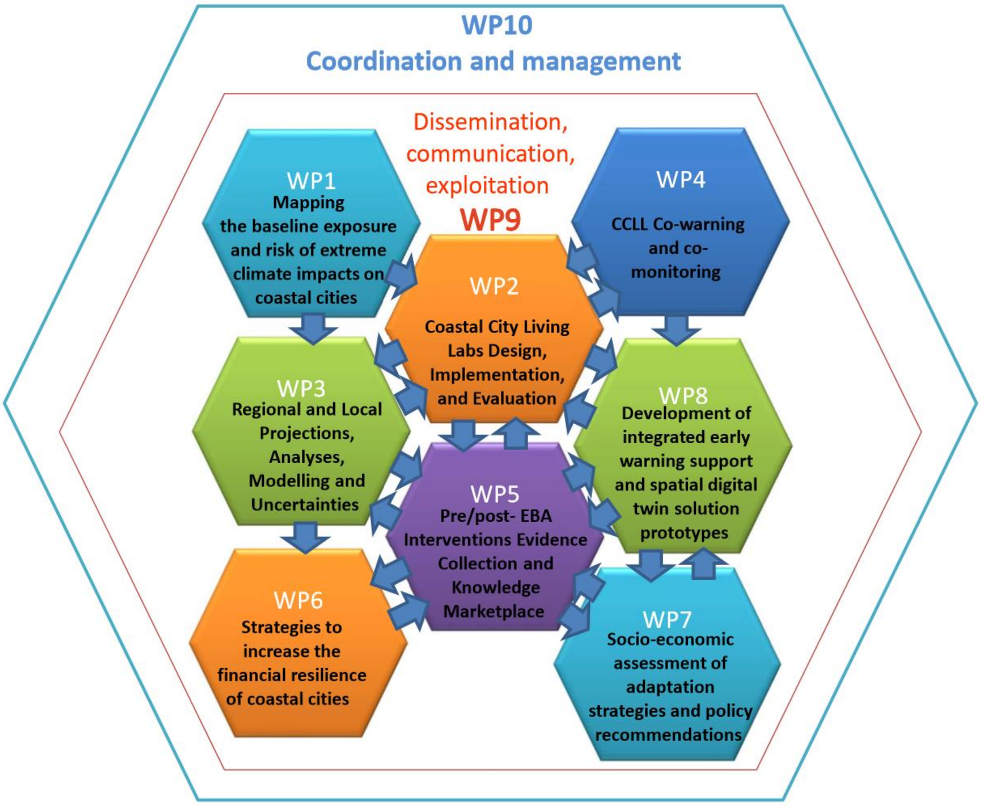

Figure 1: SCORE work packages structure.

In this vein, this report has been prepared as the third of four deliverables of Work Package 1 – Mapping the baseline exposure and risk of extreme climate impacts on coastal cities:

- Deliverable 1.1 – Literature review report
- Deliverable 1.2 – Map and report of key climate-change hazards
- Deliverable 1.3 – Map and report of baseline exposure and vulnerability
- Deliverable 1.4 – Report of baseline risk analysis

The main goal of WP1 is to produce a high-level baseline risk map of extreme climate impacts and sea-level rise based on a semi-quantitative assessment of exposure and vulnerability for the ten CCLLs. The documents *Literature review report* and *Map and report of key climate-change hazards* were completed in December 2021 and June 2022, respectively. While the maps produced in D1.2 are important intermediate steps, it is also necessary to conduct exposure and vulnerability studies. These studies will provide a deeper understanding of how the mapped hazards could impact the population and infrastructure in the affected areas. Therefore, the exposure and vulnerability studies at a high level performed in this document, *Map and report of baseline exposure and vulnerability*, are the next steps forwards.

Regarding the links of this work with the SCORE project, this document is complemented by the data collected from the CCLLs in WP2. The report outcomes directly feed the next WP1 task (Task 1.4 – Baseline risk analysis and mapping of extreme climate impacts and sea level rise) and contribute to the development of certain tasks in WP3, WP5, WP6, WP7 and WP8.

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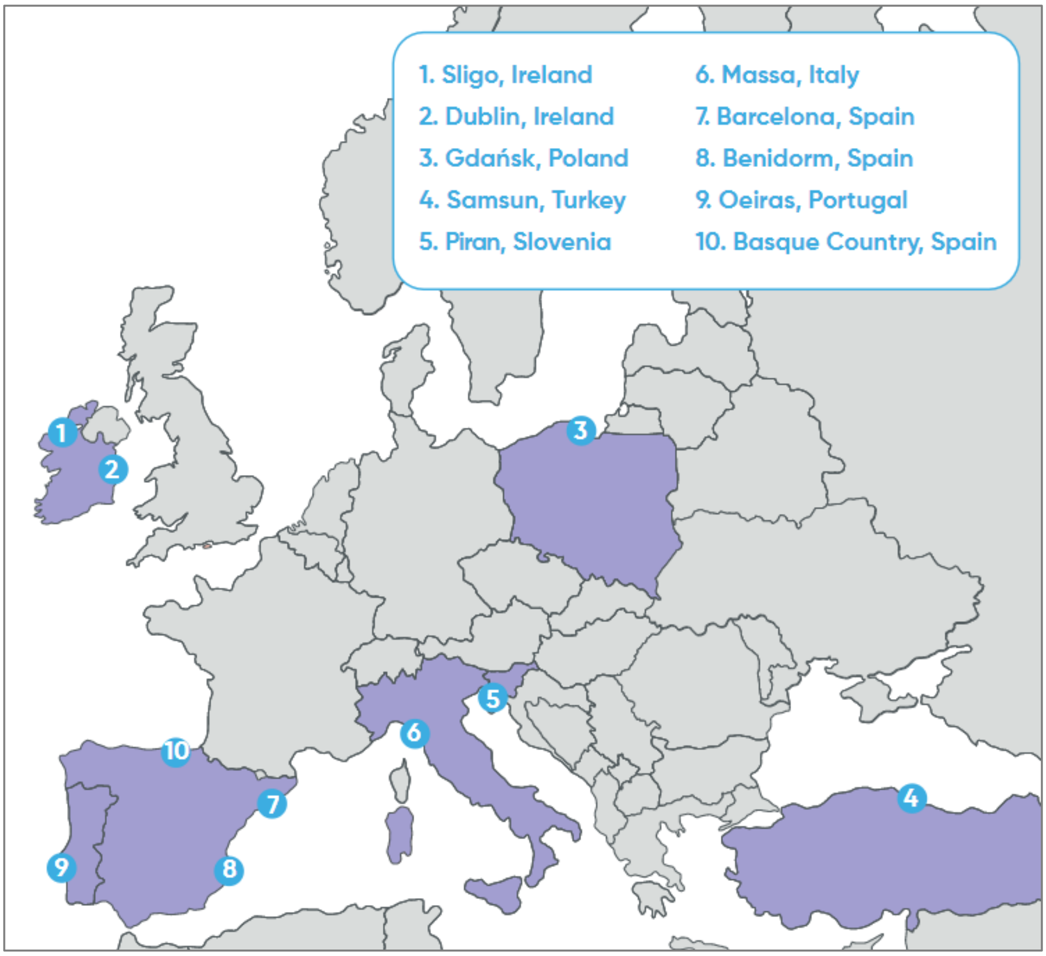
1.INTRODUCTION

In general, the impact of sea level rise and extreme climate-related hazards can result in significant losses on infrastructure, buildings, facilities, services, cultural heritage, industry, agriculture and ecosystems. In particular, interruptions in transportation, power and water supply, medical care and other vital necessities during a disaster can be experienced if critical infrastructure and facilities are damaged.

Death by severe storms and related hazards (e.g., coastal and land flooding, and strong winds) can be caused by drowning associated with the storm surge, falling trees, falls, electrocution, and other trauma. Exposure to extreme hot or cold ambient temperatures could result in heat- or cold-related illness, including heat stroke or hypothermia, as well as exacerbation of respiratory, cardiovascular, and other chronic diseases. Extreme storms landfall can also result in a range of non-fatal injuries, including falls, traffic accidents, blunt trauma, puncture wounds, lacerations, sprains/strains, motor vehicle crashes, animal bites, and electrocution. Elder, low-income, health conditioned, incarcerated, isolated and other minority populations, are more vulnerable to climate-related hazards as they are prone to have difficulties related to evacuation, sheltering, transportation and prevalence of health problems.

According to Adger (2006), "*vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt*". In general, the key parameters of vulnerability are the stresses to which a system is exposed, its sensitivity, and its adaptive capacity or resilience. In this document, the concept of vulnerability is related to a semiquantitative tool for describing states of susceptibility of the CCLLs to the key hazards identified in the previous tasks.

Figure 2: Location of the CCLLs.



Based on the outcome of the previous task, vulnerability and exposure indicators of communities and infrastructure in the CCLLs (both frontrunners and followers) have been developed as part of a high level, semi-quantitative approach to the baseline situation (current climatic conditions) in this report.

These vulnerability and exposure indicators relate to the key climate hazards identified in Task 1.2. The analysis includes the presence of critical infrastructure and public, residential and commercial assets, as well as human and environmental exposure. Available European, national and regional hazard datasets have been used as appropriate when local data were scarce. Complementary to the high-level analysis performed, the results were mapped using GIS software.

2. MATERIALS AND METHODOLOGY

2.1. SEMIQUANTITATIVE ANALYSIS OF EXPOSURE AND VULNERABILITY

There is a number of tools used to assess vulnerability to climate change on coastal areas. The European Environment Agency summarised these on the technical paper *Methods for assessing coastal vulnerability to climate change* (2011) (Ramieri et al., 2011). The most relevant assessment methods include index-based methods, indicator-based approaches, methods based on dynamic computer models and GIS-based Decision Support Systems. Each method has its own strengths and limitations, depending on the different aspects taken into consideration in the assessment, e.g., time scale, spatial scale and resolution, drivers or impacts analysed, assessment targets, availability of data, complexity or desired outputs. Indicators or index-based approaches are useful tools for a baseline assessment and the identification of priority vulnerable areas and systems due to their simplified approach, whereas the methods based on dynamic computer models and GIS-based Decision Support Systems are more appropriate for a more detailed quantitative assessment of costal vulnerability and the related identification of adaptation measures.

Index-based approaches express coastal vulnerability by a one-dimensional, and generally unitless, risk/vulnerability index. This index is calculated through the quantitative or semi-quantitative evaluation and combination of different variables. Conversely, indicator-based approaches express the vulnerability by a set of independent elements that characterise key coastal issues (e.g., coastal drivers, pressures, state, impacts, responses, exposure, sensitivity, risk and damage). These indicators are in some cases combined into a final summary indicator. The latter approach allows the evaluation of different aspects related to coastal vulnerability within a consistent assessment context.

However, in general, the most popular index-based and indicators methodologies do not address all the hazards and impacts identified for the CCLLs, as they are usually developed focusing on part of them or just on some of the parameters of the vulnerability assessment, e.g., coastal flooding and coastal erosion, physical vulnerability or impacts on ecosystems. Notwithstanding, it is of common practice to adapt existing methods to the necessities of a particular assessment.

In our case, the CCLLs face different climate-related hazards and impacts and, furthermore, there is a lack of available data for some of them. Therefore, in this report, a customized semi-quantitative approach based on a combination of popular index-based and indicator methods is utilized. Essentially, the methodology is developed to adapt to the available information through existing indicators. The assessment involves the evaluation of the three fundamental parameters of vulnerability: stresses, sensitivity and resilience. These are identified as key hazards (stresses); physical exposure, socioeconomic activity, social vulnerability and ecosystem vulnerability (sensitivity); and adaptive capacity (resilience) and measured in terms of indicators. Therefore, vulnerability can be expressed as a function of its components according to the equation:

$$Vulnerability = Stresses \times Sensitivity \times Resilience.$$

The list of indicators considered in this report are presented in Table 1. The information sources used to collect these are summarised in the following point.

Table 1: Vulnerability parameters and indicators produced.

Vulnerability parameter	Indicators

Key hazards (stresses)	• Climate-related hazards identified in the report D1.2 – Map and report of key climate-change hazards.
Physical exposure (sensitivity)	• Geographical coverage • CCLL total land area • CCLL coastline length • Rates of sea-level change • Significant wave heights • Tidal ranges • Lithology of the coastline • LECZ area • LECZ area per coastline length • Extent of flood-prone areas • Extent of landslide-prone areas • Extent of forest-fire-prone areas • Extent of strong-wind-prone areas • Exposure to heat waves
Population (sensitivity)	• Census population • Population within the LECZ • Population living in the flood-prone areas • Population living in the landslide-prone areas • Population living in the forest-fire-prone areas • Population living in the strong-wind-prone areas • Population under 5 years old • Population over 80 years old
Land uses within the hazard-prone areas (indicators developed for each key climate-related hazard) (sensitivity)	• Area of residential land use within the hazard-prone areas • Area of industrial/ commercial land use within the hazard-prone areas • Area of agriculture land use within the hazard-prone areas • Area of beaches, dunes, and sand plains (impacts on tourism and service sector) within the hazard-prone areas
Critical infrastructure within the hazard-prone areas (indicators developed for each key climate-related hazard) (sensitivity)	• Area of critical infrastructure (road, railway, port, airport and associated land) within the hazard-prone areas • Presence of railway within the hazard-prone areas • Presence of port or marina within the hazard-prone areas • Presence of airport within the hazard-prone areas
Areas of high ecological value within the hazard-prone areas (indicators developed for each key climate-related hazard) (sensitivity)	• Area of natural vegetation within the hazard-prone areas • Area of wetlands within the hazard-prone areas • Area of water bodies within the hazard-prone areas • Area of beaches, dunes, and sand plains (impacts on ecosystem) within the hazard-prone areas • Area of green urban areas within the hazard-prone areas
Adaptive capacity (resilience)	• Existence of local coastal adaptation planning • National sea level rise preparedness • Spatial scale of SLR projections

The indicators, the way that these have been measured and the thresholds used for the scoring are explained in the following sections. Most of the thresholds are based on proportion out of a total (es. area, population living in an area etc.). In other cases, a more qualitative assessment has been adopted and the thresholds have been adjusted through comparison of the results for the different CCLLs. The calculation of a final score of vulnerability and risk will be accordingly developed in Task 1.4.

2.2. Information sources

The parameters presented in the previous point are part of most of the indexes commonly used in the vulnerability assessment of climate change on coastal cities. Thus, the collection of the existing information regarding these topics will result in a better understanding of the baseline situation and serve as an useful database for further assessments.

In this sense, data for this task have been collected from the responses to WP2 questionnaires, the previous tasks (i.e., the technical reports *D1.1 – Literature Review Report* and *D1.2 – Map and report of key climate-change hazards*) and existing databases.

The information on past extreme events has been analysed in the previous task (Task 1.2 – Mapping of past extreme events and identification of key hazards in the coastal cities), and the results are available in the document D1.2 – Map and report of key climate-change hazards. Moreover, in order to collect the largest amount of available information relating to vulnerability and exposure, a series of questions were sent to the CCLLs as part of WP2 questionnaires. In summary, the questions were designed to provide significant information on the following points.

- Sea level projections
- Cartography
- Land uses, buildings, and infrastructure systems
- Critical assets
- Demography
- Ecosystems and physical systems

The data on Extreme Sea Levels (ESL) include the contributions of local or regional (if local data are not available) Relative Sea Level Rise (RSLR), astronomical tides, storm surge and wave setup. Projections for the SSP1-2.6, SSP2-4.5 and SSP5-8.5 Shared Socioeconomic Pathways (SSP) defined in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (AR6) were also requested.

The land digital cartography and digital bathymetry of the coastal area were requested with a desirable spatial resolution of 1 m, including flood defences and other structures or small topographic features that may have an impact on flood hazards. The CCLLs were invited to include another kind of information which may be useful (e.g., coastal profiles).

Regarding the land uses, information on residential, industrial, commercial, recreational, agricultural, natural protected and natural unprotected areas were requested, as well as the market values of land. In the case of residential use, information on the residential type was requested. Data on buildings include their area, functional characteristic, number of storeys and structural integrity. The infrastructure systems include the electricity grid, water supply, sanitation, transport network, telecommunications, and all other relevant systems in the coastal area which may be exposed to risk. Information regarding the elements of the systems were also requested. For instance, for transport networks, if roads are paved or unpaved; the road section width; the hierarchy or relevance at national, regional or local levels; the railway track gauge; etc.

In the case of critical assets which may be exposed to risk, the CCLLs were guided to complete a table (see the mentioned Appendix), including a variety of data in order to clearly define the asset in terms of vulnerability and exposure.

Furthermore, the CCLLs were asked to populate a table including census data at the lowest level of disaggregation available, including information on financial deprivation, health, family structure, age, house type, occupation, rural and urban, ethnicity and language, insurance, transience, education and gender.

Finally, maps containing information about the coastal ecosystem and physical characteristics of the coastal area, along with details about some coastal variables such as erosion rate, average slope, significant wave height, significant wave period, and tidal range, were also collected. The data collected include, *inter alia:* CCLL's existing datasets, repositories at national, regional and local levels, scientific publications, risk assessments and other technical documents containing relevant information. In the literature review (D1.1), scientific sources including conference proceedings, scientific-technical reports and peer-reviewed scientific journal articles, were reviewed through the Scopus and Web of Science scientific databases for each city. The outputs of this review also complements the results provided in this report.

When local data were scarce, regional-scale studies were also considered. These sources are explained In the following lines, including the EUROSION database, MERIT DEM, WorldPop's population datasets, CORINE Land Cover and Urban Atlas 2012.

The EUROSION (2004).[1] database is a GIS database containing 19 layers of information including administrative and maritime boundaries, coastal elevation and bathymetry, coastline, geology, geomorphology, coastal infrastructure, coastal defence works, erosion trends, land cover, land cover changes since 1975, wave and wind regime, sea level rise, tidal range, river sediment transport, areas of high ecological value, budget invested in coastal defence, and regional exposure to coastal erosion risk.

The Multi-Error-Removed Improved-Terrain Digital Elevation Model (MERIT DEM) is a high accuracy global digital elevation model (DEM) at 3" resolution and ±2 m vertical resolution (Yamazaki et al., 2017). It uses filtered data from other existing spaceborne DEMs (NASA SRTM3 DEM v2.1, JAXA AW3D-30m DEM v1 and Viewfinder Panoramas' DEM) and other complementary datasets, reducing multiple error components. The elevation is represented in meters and referenced to WGS84 and EGM96. The MERIT DEM is both accurate and has wide dissemination rights (MacManus et al., 2021).

WorldPop[2] have produced 100 m resolution gridded population estimates produced using a built settlement growth model and a top-down constrained estimation for most of the countries. In the top-down constrained estimation, Random Forests based modelling is applied to disaggregate population to only those grid cells identified as containing buildings/built settlement. These data have been contrasted and used in the estimation of social vulnerability indicators. WorldPop has been shown to produce accurate disaggregated estimations in many locations and is widely used (MacManus et al., 2021).

The CORINE Land Cover[3] [© European Union, Copernicus Land Monitoring Service 2022, European Environment Agency (EEA)] (CLC) consists of an inventory of land cover of the European Union in 44 classes in a three-level classification by the European Environment Agency. CLC uses Sentinel-2 and Landsat-8 satellite data and a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a minimum width of 100 m for linear phenomena. The thematic accuracy is greater than 85%. CLC data have been applied in a wide variety of cases at different levels of scale from European to sub-national, including the development and monitoring of EU and EEA policies, mapping of the spatial extent of ecosystem types and their services, urban and landscape level assessment and another range

[1] http://www.eurosion.org/
[2] https://www.worldpop.org/
[3] https://land.copernicus.eu/pan-european/corine-land-cover

of applications from forest fires to drought and soil. In some countries, national land cover/uses datasets are available with higher resolution than CLC.

Furthermore, for cities with a population greater than 50,000 inhabitants (e.g., Dublin, Benidorm, Lisbon, Massa, Gdansk and Samsun), Urban Atlas 2012[4] classifies the land cover in 17 urban classes with a MMU of 0.25 ha and 10 Rural Classes with a MMU of 1ha in 2012. It also includes population estimates per Urban Atlas polygons, a street three layer and estimates of building blocks heights in a 10 x 10 grid.

The datasets from Joint Research Centre Data Catalogue have been used to assess land flooding (Dottori et al., 2021). These maps depict flood prone areas in Europe and the World for river flood events of different magnitude (from 1-in-10-year to 1-in-500-year). The maps have been developed using hydrological and hydrodynamic models, driven by the climatological data of the European and Global Flood Awareness Systems (EFAS and GloFAS). All maps are in raster format (GEOTIF) with a grid resolution of 100m (European-scale maps) and 30 arcseconds (global-scale maps).

In Spain, ARPSI are defined as those areas of the territory for which it has been concluded that there is a significant potential risk of flooding or in which the materialization of such risk can be considered probable as a result of the Preliminary Risk Assessment work, carried out within the scope of each river basin district, in compliance with article 5 of Royal Decree 903/2010, of July 9, on the evaluation and management of flood risks, which transposes Directive 2007/60/EC , related to the evaluation and management of flood risks. The delimitation of the ARPSI is carried out on the basis of the preliminary evaluation of the flood risk, which is elaborated from the easily available information, such as registered data and studies of long-term evolution, including the impact of climate change, and taking into account the current circumstances of land occupation, the existence of infrastructures and activities for protection against floods and the information provided by the National System of Cartography of Floodable Zones and by the competent Administrations in the matter.

The European Landslide Susceptibility Map version 2 (ELSUS v2) shows levels of spatial probability of generic landslide occurrence at continental scale in Europe (Günther et al., 2014; Wilde et al., 2018). The map has been produced by regionalizing the study area based on elevation and climatic conditions, followed by spatial multi-criteria evaluation modelling using pan-European slope angle, shallow sub-surface lithology, and land cover spatial datasets as the main landslide conditioning factors. The map has been produced jointly by Bundesanstalt für Geowissenschaften und Rohstoffe (BGR, Hannover, Germany), Istituto di Ricerca per la Protezione Idrogeologica (CNR-IRPI, Perugia, Italy), Institut de Physique du Globe de Strasbourg (CNRS-EOST, Strasbourg, France), and the Joint Research Centre (JRC, Ispra, Italy), as part of the collaborative work of the European Landslide Expert Group and the European Centre on Geomorphological Hazards (CERG) in support of the EU Thematic Strategy for Soil Protection.

The European Climate Assessment & Dataset platform (ECAD) holds information on changes in weather and climate extremes, as well as the daily dataset needed to monitor and analyse these extremes.

Based on the vulnerability studies identified in the literature, indicators of exposure for which data were available are identified in the following points and mapped in some cases.

2.3. Key climate-related hazards

The identification and mapping of the key climate-related hazards were already carried out in the report *D1.2 – Map and report of key climate-change hazards*. These are presented in Results.

[4] https://land.copernicus.eu/local/urban-atlas

2.4. Indicators of physical exposure

2.4.1. Geographical coverage

The definition of the geographical coverage of each CCLL is fundamental, as it will be used throughout the assessment. These have been defined based in existing administrative boundaries, in alignment with previous tasks. The administrative boundaries and corresponding land areas and coastline lengths are summarised in Table 2.

Table 2: Geographical coverage, land area and coastline length of the CCLLs.

CCLL	Geographical coverage	Land area (km^2)	Coastline length (km)*	*Source
Sligo	County Sligo	1,837	211	Neilson and Costello (1999).
Dublin	Great Dublin area (counties of Dublin, Kildare, Meath and Wicklow)	6,986	318	Neilson and Costello (1999).
Vilanova i la Geltrú	Vilanova i la Geltrú municipality	34.0	15.4	Measured from GIS model.
Benidorm	Benidorm municipality	38.5	16.7	Measured from GIS model.
Oarsoaldea	Municipalities of Errenteria, Lezo, Oiartzun and Pasaia	111.9	19.8	Measured from GIS model.
Oeiras	Oeiras municipality	45.9	13.2	Measured from GIS model.
Massa	Massa municipality	94.1	9.5	Measured from GIS model.
Piran	Piran municipality	44.6	20.4	Measured from GIS model.
Gdansk	City of Gdansk	262	33.9	Measured from GIS model.
Samsun	Samsun province	9,579	235	Measured from GIS model.

2.4.2. Rates of sea-level changes, wave regimes and tidal ranges

The publication *Detecting changes in european shoreline evolution trends using Markov Chains and the Eurosion database* summarises the information on regional rates of sea-level changes, mean significant wave heights and tidal ranges contained in the Eurosion database (Le Cozannet et al., 2020). These results, obtained by means of hydrodynamic models and the interpolation of tide gauge records in 2004, are depicted in Figure 3. The coarse resolution of the results is not sufficient for the identification of local particularities in the CCLLs. Nevertheless, the information provided by this dataset allows to understand the regional context of the CCLLs in terms of these three parameters, which are key for the high-level assessment of coastal erosion and coastal flooding. In the case of Piran, data from the adjacent Italian area in the northern Adriatic Sea have been used. The measurement of these indicators has been omitted for Samsun CCLL , as it has the status of Fellow and no data were available for this city.

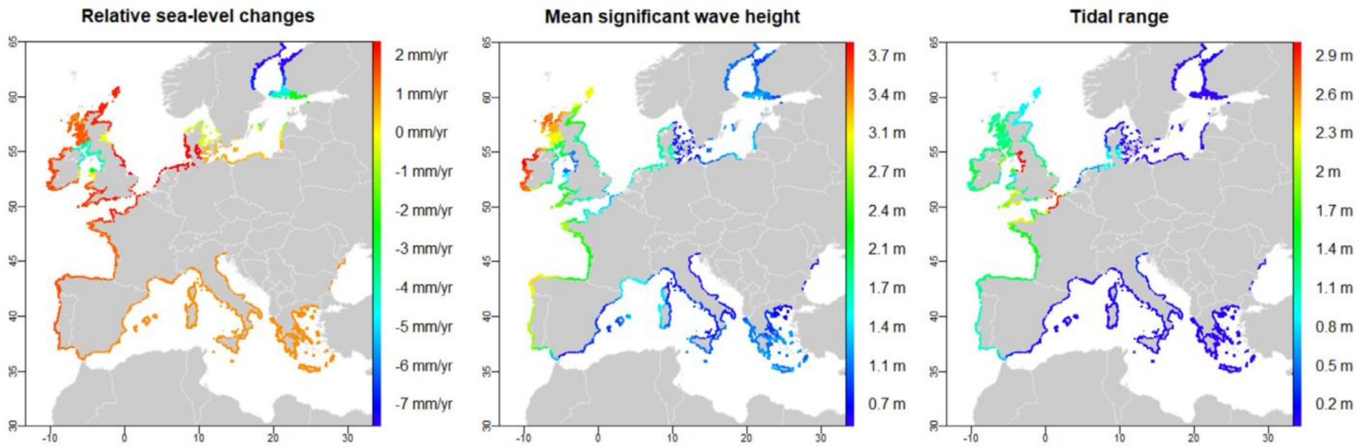


Figure 3: Relative sea-level change, mean significant wave height, and tidal range along the coastline of Europe. Source: Eurosion and Le Cozannet et al. (2020).

Thresholds for the previous parameters have been calculated and summarised in Table 3 by comparison of the results for each CCLL, available in the section Physical exposure.

Table 3: Thresholds for the indicators "Relative sea-level changes (mm/year)", "Mean significant wave height (m)" and "tidal range (m)".

Relative sea-level changes (mm/year)	Mean significant wave height (m)	Tidal range (m)	Scoring
<0.5	<1.5	<0.5	Low exposure
Between 0.5-1.0	Between 1.5-2.5	Between 0.5-1.0	Medium exposure
>1.0	>2.5	>1.0	High exposure

2.4.3. Lithology of the coastline

Based in the data from Günther et al. (2014) and Wilde et al. (2018), the lithology of the coastline of the CCLLs where coastal erosion was identified as a key hazard has been deduced. In a simplified approach, the predominant lithotype has been characterised in each CCLL.

Mainly four mechanisms trigger coastal erosion: hydraulic action, abrasion, attrition and corrosion. However, the strength of the waves breaking along the coastline can be considered the main source of coastal erosion. Hence, the resistance to coastal erosion largely depends on the hardness of the coastal lithotype. The hardness of the lithotypes identified have been classified into soft, medium and hard and, consequently, values of low, medium and high resistance to coastal erosion have been attributed.

Table 4: Thresholds for the indicators "Lithotype hardness".

Lithotype	Lithotype hardness	Resistance to coastal erosion	Scoring
Sandstone and conglomerates (Sligo CCLL)	Hard	High	Low exposure
Limestone and shale (Dublin CCLL)	Medium	Medium	Medium exposure
Limestones, marlstones and marls (Benidorm CCLL) Gravels (Massa CCLL)	Soft	Low	High exposure

Although limestone obtains a hardness of 3-4 on the Mohs scale, marls are softer (2-3 on Mohs scale) and the lithology of Benidorm CCLL has been considered highly exposed to coastal erosion according to this indicator. Limestone and shale have a punctuation of 3-4 in the Mohs scale and their resistance to coastal erosion has been considered as medium. In the case of Sligo CCLL, the hardness of sandstone is between 6-7 on the Mohs scale, whereas the hardness of conglomerates depends on the clast composition and strength of cement.

2.4.4. Low-elevation coastal zone (LECZ)

Low-elevation coastal zone (LECZ) is defined as a contiguous area near the coast and less than 10 m above mean sea level. It is a critical area due to its proximity to sea and consequent exposure to climate-related hazards, and for being usually densely populated and economically developed. LECZ areas have been calculated for each CCLL using the MERIT DEM and mapped in GIS. The LECZ areas are compared to the total CCLL area and expressed as an offset of the coastline. In addition, maps representing the LECZ are presented in Appendix – maps. The thresholds are summarised in Table 5 and the numerical results and scores are shown in Table 25.

Table 5: Thresholds for the indicators "LECZ area (%)" and "LECZ / Coastline length (ha/km)"

LECZ area (%)	LECZ / Coastline (ha/km)	Scoring
<10	>50	Low exposure
Between 10-25	Between 50-150	Medium exposure
>25	>150	High exposure

2.4.5. Extent of flood-prone areas

The extents of the flood-prone areas for the 100-year return period have been calculated for the CCLLs using the dataset from Dottori et al. (2021). For the cities where this source presented no data (cities where the width of their rivers is lower than 100 m), namely Vilanova i la Geltrú and Oeiras, local studies have been used.

Areas of historical flooding events provided by Vilanova i la Geltrú CCLL partners were used for this city in the absence of data from the European dataset.

In the case of Oeiras CCLL, the main source used to assess this indicator showed no data. However, thanks to the information provided by the CCLL partners, a particular vulnerability assessment is developed in the section Additional results.

The thresholds for this parameter have been adjusted according to the results. These are presented in Table 6.

Table 6: Thresholds for the indicator "Extent of flood-prone areas (%)".

Extent of flood-prone areas (%)	Scoring
<5	Low exposure
Between 5-10	Medium exposure
>10	High exposure

2.4.6. Extent of landslide-prone areas

Landslides have been identified as a key climate-related hazard in Oarsoaldea and Massa. In the case of Oarsoaldea CCLL, the extent of the landslide-prone areas has been estimated using the data from Günther et al. (2014) and Wilde et al. (2018) for the susceptibility levels of 4 and 5. In the case of Massa CCLL, regional data were available, as explained in D1.2. Thus, the landslide hazard information corresponds to the maps from "Plan on landslide and geomorphological risk" (PAI) at 1/10,000 scale for the susceptibility levels of "high" and "very high". As the number of study cases have not been considered enough for the production of thresholds based in the comparison between them, an intermediate scenario of medium exposure has been considered for all the areas.

Table 7: Thresholds for the indicator "Extent of landslide-prone areas (%)".

Extent of landslide-prone areas (%)	Scoring
-	Medium exposure

2.4.7. Extent of forest-fire-prone areas

The areas affected by past forest fires were identified in Task 1.2 and reported in D1.2. These areas have been measured and defined as areas of medium exposure, in the absence of more data (Table 8).

Table 8: Thresholds for the indicator "Extent of forest-fire-prone areas (%)".

Extent of forest-fire-prone areas (%)	Scoring
-	Medium exposure

2.4.8. Extent of strong-wind-prone areas

Vilanova i la Geltrú is the only CCLL where strong winds are considered as a key climate-related hazard. The strong-wind-prone areas have been estimated from the past extreme events database generated in Task 1.2 for Vilanova i la Geltrú CCLL, including the storm events, as they are usually accompanied by strong winds. A score between Low-Medium-High hazard was assigned to the areas elaborated by the CCLL partners according to their descriptions, as shown in Table 9. The areas associated to the events SW1, SW2 and ST2 were given a score of high, due to their high intensity and sea-proximity. The storm event "ST1" was scored as of medium hazard because, although it is not recorded as a strong wind event, it has the longest duration of all the events and occurred along the coastal façade. Part of the original area of this event was overlapping the high-hazard areas, being consequently clipped and conservatively maintaining the high-hazard areas. Finally, the area associated to the event SW3 was characterised as a low-hazard area, due it is defined as a secondary area, less affected. In the absence of more cases to compare, exposure has been considered as medium for these areas, as shown in Table 10.

Table 9: Past extreme strong wind events and high-level hazard categorisation in Vilanova i la Geltrú CCLL.

Extreme event ID	Extreme event type	Short description	Date	Duration	Hazard scoring
ST1	Storm	Accumulated rainfall of up to 787.7 litres per square meter.	20/01/2020	3 days	Medium
SW1	Strong winds	Column of air in rapid descent that after impacting the surface extends in all directions.	12/08/2019	1 day	High
SW2	Strong winds	Column of air in rapid descent that after impacting the surface extends in all directions.	12/08/2019	1 day	High
SW3	Strong winds	Secondary area, less affected.	12/08/2019	1 day	Low
ST2	Storm	Tornado.	23/11/2021	2 days	High

Table 10: Thresholds for the indicator "Extent of strong-wind-prone areas (%)".

Extent of strong-wind-prone areas (%)	Scoring
-	Medium exposure

2.4.9. Exposure to heat waves

Heat waves are a key hazard in Vilanova i la Geltrú CCLL. In Spain, the national meteorology agency (AEMET) defines heat wave as an episode of at least three consecutive days, in which at least 10% of the stations considered record maximums above the 95% percentile of their daily maximum temperature series for the months of July and August of the period 1971-2000. This definition is based in the measures of temperature from a series of weather stations distributed across the national territory. In the particular case of Vilanova, the methodology described by AEMET is applied with data from the weather station located in the airport of Barcelona, the closest locality to Vilanova i la Geltrú (distance of less than 30 km) with accessible and representative data.

Data on daily maximum temperatures have been collected from the European Climate Assessment & Dataset platform (ECAD) for the period (1971-2022) (Klein Tank et al., 2002). In particular, data have been retrieved from the weather station located in the airport of Barcelona (BARCELONA/AEROPUERTO weather station). The threshold temperature obtained (95% percentile of the period 1917-2000) was 30.6 °C, the same published by AEMET for the region (Figure 4).

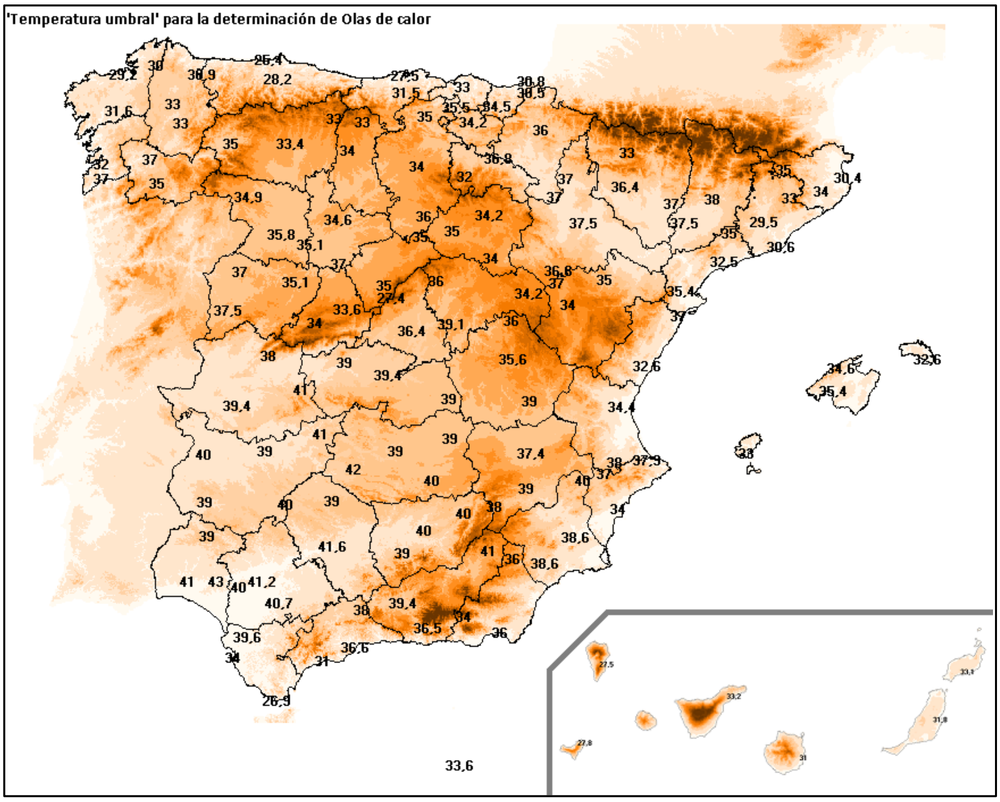
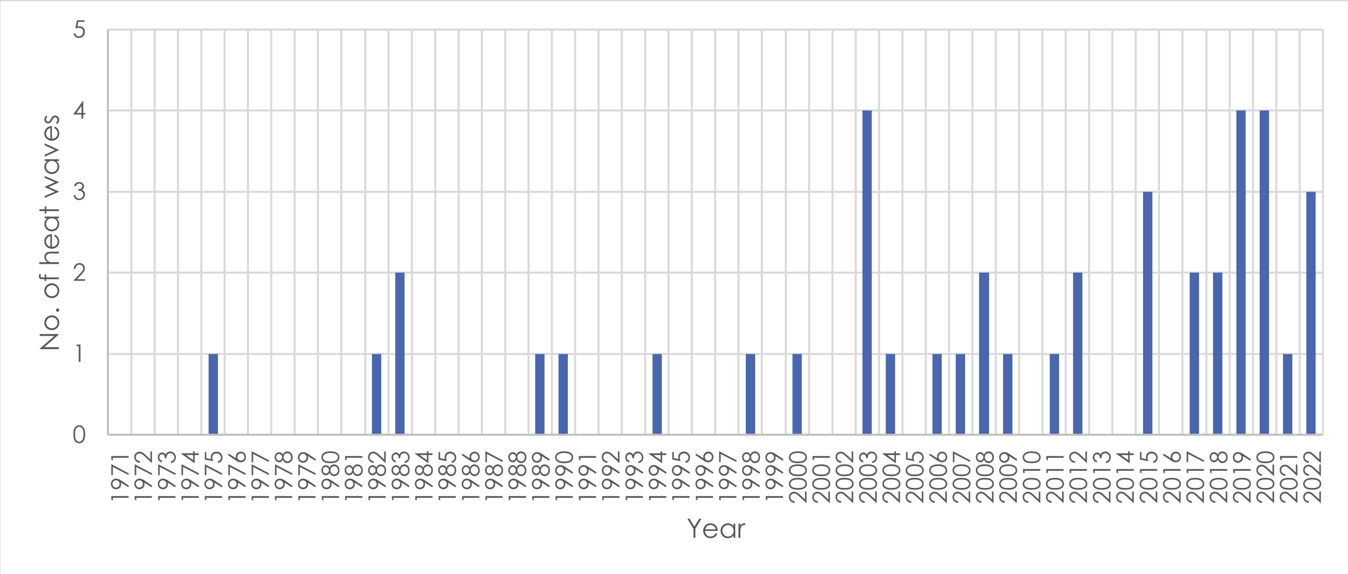


Figure 4: Threshold temperatures for the determination of heat waves in Spain. Source: AEMET.

In total, 41 heat waves have occurred in Vilanova i la Geltrú since 1971, with a cumulative duration of 272 days. The number of heat waves per year and the accumulated heat wave duration in days per year have been represented in Figure 5. With 4 heat waves adding up to 60 days of heat wave, 2003 can be considered the hottest year in the series. There is a visible growing tendency when the reference period (1971-2000) is compared to the following years (2001-2022) in both cases. Furthermore, 16 heat waves have consecutively occurred in the last 6 years (2017-2022), accumulating up to 90 days of heat wave. Or, equivalently, between 1971-2022, 39.02% of the heat waves occurred in the last 6 years (11.76% of total interval length), accumulating 33.09% of the total days of heat wave.

Based on these results, the exposure to heat waves in Vilanova i la Geltrú has been considered as high.



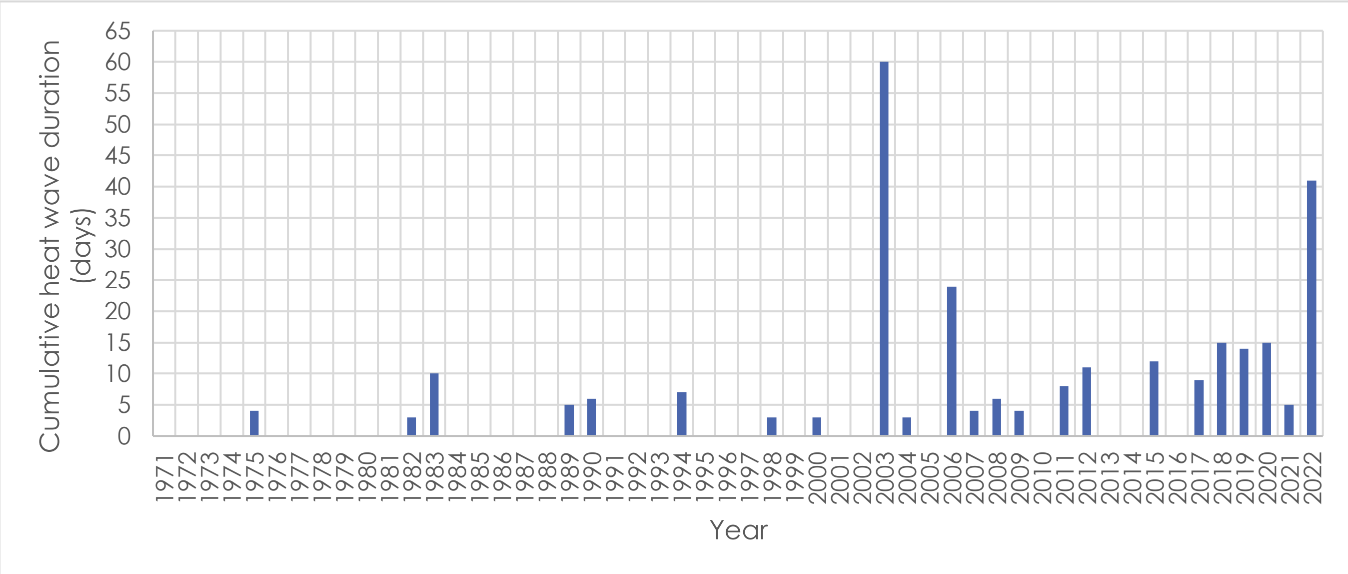


Figure 5: Yearly distribution of heat waves (top) and cumulative duration of the heat waves per year (down) in Vilanova i la Geltrú CCLL.

2.5. Indicators of population exposure

2.5.1. Total population

The spatial distribution of population on the CCLLs in 2020 have been derived from WorldPop's datasets. In particular, datasets of 100 m resolution gridded population estimates were downloaded for each country. The total population of each CCLL were estimated in the GIS model using this dataset. The results are presented in Table 11, which also shows the total population according to an official statistics institution. In general, the estimates are close to the official data, with the exception of Benidorm.

Table 11: Official and estimated population of the CCLLs.

CCLL	Estimated population (2020)	Official population*	*Census year	*Source
Sligo	77,024	69,819	2022	Central Statistics Office of Ireland
Dublin	2,197,152	2,073,459	2022	Central Statistics Office of Ireland

Vilanova i la Geltrú	73,751	67,733	2020	Statistics Institute of Catalonia
Benidorm	106,893	70,450	2020	National Statistics Institute of Spain
Oarsoaldea	70,474	71,987	2020	National Statistics Institute of Spain
Oeiras	181,367	177,991	2020	National Statistics Institute of Portugal
Massa	68,757	66,423	2022	National Statistics Institute of Italy
Piran	19,824	18,080	2020	Statistical office of the Republic of Slovenia
Gdansk	459,674	465,475	2020	Statistics Poland
Samsun	1,324,256	1,356,079	2020	Turkish Statistical Institute

2.5.2. Population living in the LECZ

Having validated the methodology to estimate population by contrasting the estimated and official total population, the population living within the LECZ has been estimated for each CCLL using the datasets form WordPop. The thresholds (see Table 12) have been adjusted through comparison of the results, which are presented and scored in Table 26.

Table 12: Thresholds for the indicator "LECZ population (%)".

LECZ population (%)	Scoring
<10	Low exposure
Between 10-25	Medium exposure
>25	High exposure

2.5.3. Population living in the flood-prone areas

In the same manner, the population living in the flood-prone areas has been estimated for the CCLLs of Sligo, Dublin, Vilanova i la Geltrú, Oarsoaldea, Gdansk and Samsun using the data from WorldPop.

Table 13: Thresholds for the indicator "Flood-prone areas population (%)".

Flood-prone areas population (%)	Scoring
<5	Low exposure
Between 5-10	Medium exposure
>10	High exposure

2.5.4. Population living in the landslide-prone areas

The population living in the landslide-prone areas has been estimated for the CCLLs of Oarsoaldea and Massa using the data from WorldPop. As there are no sufficient cases for comparing the results, an intermediate exposure of medium has been assigned to the values obtained.

Table 14: Thresholds for the indicator "Landslide-prone areas population (%)".

Landslide-prone areas population (%)	Scoring

-	Medium exposure

2.5.5. Population living in the forest-fire-prone areas

The population living in the forest-fire-prone areas has been estimated for Vilanova i la Geltrú CCLL using the data from WorldPop. As this indicator is only measured in Vilanova i la Geltrú CCLL, the totality of the population living with these areas will be considered at medium exposure at an intermediate scenario.

Table 15: Thresholds for the indicator "Forest-fire-prone areas population (%)".

Forest-fire-prone areas population	Scoring
-	Medium exposure

2.5.6. Population living in the strong-wind-prone areas

The population living in the strong-wind-prone areas has been estimated for Vilanova i la Geltrú CCLL using the data from WorldPop. As this indicator is only measured in Vilanova i la Geltrú CCLL, the totality of the population living with these areas will be considered at medium exposure at an intermediate scenario.

Table 16: Thresholds for the indicator "LECZ population (%)".

Strong-wind-prone areas population (%)	Scoring
-	Medium exposure

2.5.7. Most vulnerable population according to age

Based on statistics from WorldPop.org, the population under 5 years old or over 80 years have been measured for each CCLL. This groups represent a vulnerable sector due to their difficulties on evacuation, sheltering and transportation during a disaster and the prevalence of health problems. The thresholds are presented in Table 17, based in the results obtained. These results and the scoring are summarized in Table 26 .

Table 17: Thresholds for the indicator "Most vulnerable population (age) (2020) (%)".

Percentage of population under 5 years old or over 80 years old	Scoring
<9	Low exposure
Between 9-11	Medium exposure
>11	High exposure

2.6. Land cover and land uses

A number of indicators have been considered under this category. The different classes included in the CORINE and Urban Atlas datasets are simplified in a few classes. The extension of these land cover/uses classes within the different-prone areas are then measured in the GIS model for each CCLL. More information on the different land classes considered in CORINE Land Cover is shown in Figure 6.

2.6.1. Socioeconomic activity

The indicator "Area of residential land use (%)" includes the different densities of urban fabric. All the industrial, commercial, mine, dump and construction sites areas are computed under "Area of category industrial/commercial land use (%). The indicator "Area of agricultural land use (%)" represents all kind of agricultural areas (e.g., arable lands, permanent crops, pastures and other heterogeneous agricultural areas). The indicator "Area of beaches, dunes and sandplains (%)" is considered alone as these areas are both important assets for the tourism and service sector and areas of high ecological value. All the indicators are expressed as a percentage of the hazard-prone area, not over the total CCLL area.

Table 18: Thresholds for the indicators “Area of residential land use (%)”, “Area of industrial/ commercial land use (%)”, “Area of agricultural land use (%)” and “Area of beaches, dunes, and sand plains (%)”.

Area of residential land use (%)	Area of industrial/ commercial land use (%)	Area of agricultural land use (%)	Area of beaches, dunes, and sand plains (%)	Scoring
<10	<5	<20	<5	Low exposure
Between 10-25	Between 5-10	Between 20-40	Between 5-10	Medium exposure
>25	>10	>40	>10	High exposure

2.6.2. Critical infrastructure

Regarding the transportation network, the indicator “Area of critical infrastructure (%)” measures the portion of land covered by roads, railways, airports and ports and associated land within a given hazard-prone area. Moreover, the presence of railways, port or airport within the different hazard-prone areas has been assessed in a No-Yes scale.

Table 19: Thresholds for the indicators “Area of critical infrastructure (%)”, “Presence of railway”, “Presence of port” and “Presence of airport”.

Area of critical infrastructure (%)	Presence of railway	Presence of port	Presence of airport	Scoring
<5	No	No	No	Low exposure
Between 5-10	-	-	-	Medium exposure
>10	Yes	Yes	Yes	High exposure

2.6.3. Areas of high ecological value

The categories of green urban areas, natural vegetation zones, wetlands and water bodies are considered in the indicator “Areas of high ecological value (%)” and include, *inter alia*, urban parks, sport and leisure facilities and other green urban areas, forests and shrub and/or other herbaceous vegetation areas, all kind of inland and coastal wetlands and water bodies.

Table 20: Thresholds for the indicators “Areas of high ecological value (%)”.

Areas of high ecological value (%)	Scoring
<10	Low exposure
Between 10-25	Medium exposure
>25	High exposure

Figure 6: CORINE Land Cover classes. Source: Copernicus Global Land Service.

2.7. Adaptive capacity

2.7.1. Local coastal adaptation planning

The Coastal Adaptation Plan is a technical analysis of the exposure to the cities to current or expected effects of climate change and a pathway to adapt to these. It is a key tool for coastal adaptation and its availability or not is crucial for the adaptive capacity of coastal cities (see Table 21).

Table 21: Thresholds for the indicator "Local coastal adaptation planning".

Existence of local coastal adaptation plan	Scoring
Yes	High adaptive capacity
No	Low adaptive capacity

2.7.2. National sea-level rise preparedness

National documents are an important reference when local coastal adaptation planning is not available. McEvoy et al. (2021) measured the preparedness to sea-level rise on national coastal adaptation planning based on the opinion of a group of experts. In the article, the level of preparedness is measured in a scale ranging between (Not well; Reasonably well; Well/very well). In this report, scores of (low adaptive capacity; medium adaptive capacity; high adaptive capacity) are respectively assigned (Table 22).

Table 22: Thresholds for the indicator "National sea level rise preparedness". Source: McEvoy et al. (2021).

National sea level rise preparedness	Scoring
Well/very well – Reasonably well	High adaptive capacity
Reasonably well	Medium adaptive capacity
Not well	Low adaptive capacity
-	Low adaptive capacity

2.7.3. Scale of sea-level rise scenarios

Planning for sea-level rise is a critical step to adapt to its impacts. Some fundamental aspects for SLR planning are the spatial scale of the SLR projections, the SLR scenarios (e.g., RCP or SSP scenarios), the time horizons and corresponding levels of SLR and the uncertainty in the projections. In addition, in some cases a high-end sea level rise is considered in SLR planning.

In this work, the previous information has been synthetised in to five indicators. These correspond to cataloguing existing projections within four groups and their scale, as presented in Table 23. Due to the disparities in the measurement of SLR projections between the different countries, the projections are not scored.

Table 23: Thresholds for the indicators "MSL rise scenarios scale".

Indicator	Scoring	Notes
MSL rise scenario midterm (optimistic)	Measured but not scored	Include MSLR projections up to the 2050 horizon for optimistic scenarios (e.g., RCP2.6, RCP4.5 or SSP126)
MSL rise scenario midterm (pessimistic)	Measured but not scored	Include MSLR projections up to the 2050 horizon for pessimistic scenarios (e.g., RCP8.5 or SSP585)
MSL rise scenario end-century (optimistic)	Measured but not scored	Include MSLR projections between 2050-2100 horizon for optimistic scenarios (e.g., RCP2.6, RCP4.5 or SSP126)
MSL rise scenario end-century (pessimistic)	Measured but not scored	Include MSLR projections between 2050-2100 horizon for pessimistic scenarios (e.g., RCP8.5, SSP585, or high-end)
MSL rise scenario scale	• National: low adaptive capacity • Regional: medium adaptive capacity • Local: high adaptive capacity	-

2.8. Summary of indicators and thresholds

A summary of all the indicators scored and their thresholds used in this report is presented in Table 24.

Table 24: Indicator-based methodology for estimating the exposure and vulnerability of the CCLLs.

Indicator	Low exposure	Medium exposure	High exposure
Relative sea-level changes (mm/year)	The rate of relative sea-level change is lower than 0.5 mm/year	The rate of relative sea-level change is lower than 0.5 mm/year and greater than 1 mm/year	The rate of relative sea-level change is greater than 1 mm/year
Mean significant wave height (m)	The mean significant wave height is lower than 1.5 m	The mean significant wave height is lower than 1.5 m and greater than 2.5 m	The mean significant wave height is greater than 2.5 m
Tidal range (m)	The tidal range is lower than 0.5 m	The tidal range is lower than 0.5 m and greater than 1 m	The tidal range is greater than 1 m
Lithotype hardness	The hardness of the lithotype of the coastal area is defined as hard	The hardness of the lithotype of the coastal area is defined as medium	The hardness of the lithotype of the coastal area is defined as soft
LECZ area (%)	Less than 10% of the CCLL area lies on the LECZ	Between 10% to 25% of the CCLL area lies on the LECZ	More than 25% of the CCLL area lies on the LECZ
LECZ area per coastline length (m^2/km)	< 50	Between 50 to 150	> 150
Extent of flood-prone areas (%)	Less than 5% of the CCLL area lies on the flood-prone areas	Between 5% to 10% of the CCLL area lies on the flood-prone areas	More than 10% of the CCLL area lies on the flood-prone areas
Extent of landslide-prone areas (%)	-	A value of medium exposure has been assigned in the absence of more data	-
Extent of forest-fire-prone areas (%)	-	A value of medium exposure has been assigned in the absence of more data	-
Extent of landslide-prone areas (%)	-	A value of medium exposure has been assigned in the absence of more data	-
Exposure to heat waves	-	-	A value of high exposure has been assigned in Vilanova i la Geltrú CCLL according to the analysis performed
LECZ population (%)	Less than 10% of CCLL population live in the LECZ	Between 10% to 25% of CCLL population live in the LECZ	More than 25% of CCLL population live in the LECZ
Flood-prone areas population (%)	Less than 5% of CCLL population live in the flood-prone areas	Between 5% to 10% of CCLL population live in the flood-prone areas	More than 10% of CCLL population live in the flood-prone areas
Landslide-prone areas population (%)	-	A value of medium exposure has been assigned in the absence of more data	-

Forest-fire-prone areas population (%)	-	A value of medium exposure has been assigned in the absence of more data	-
Strong-wind-prone areas population (%)	-	A value of medium exposure has been assigned in the absence of more data	-
Most vulnerable population (age) (2020)	Less than 9% of CCLL population is under 5 years old or over 80 years old	Between 9% to 11% of CCLL population is under 5 years old or over 80 years old	More than 11% of CCLL population is under 5 years old or over 80 years old
Area of residential land use (%) (all hazard-prone areas)	Less than 10% of the land cover within the hazard-prone area is occupied by urban areas	Between 10% to 25% of the land cover within the hazard-prone area is occupied by urban areas	More than 25% of the land cover within the hazard-prone area is occupied by urban areas
Area of industrial/ commercial land use (%) (all hazard-prone areas)	Less than 5% of the land cover within the hazard-prone area is occupied by industrial or commercial areas	Between 5% to 10% of the land cover within the hazard-prone area is occupied by industrial or commercial areas	More than 10% of the land cover within the hazard-prone area is occupied by industrial or commercial areas
Area of agriculture land use (%) (all hazard-prone areas)	Less than 20% of the land cover within the hazard-prone area is occupied by agriculture areas	Between 20% to 40% of the land cover within the hazard-prone area is occupied by agriculture areas	More than 40% of the land cover within the hazard-prone area is occupied by agriculture areas
Area of beaches, dunes, and sand plains (%) (all hazard-prone areas)	Less than 5% of the land cover within the hazard-prone area is occupied by beaches, dunes or sand plains	Between 5% to 10% of the land cover within the hazard-prone area is occupied by beaches, dunes or sand plains	More than 10% of the land cover within the hazard-prone area is occupied by beaches, dunes or sand plains
Area of critical infrastructure (%) (all hazard-prone areas)	Less than 5% of the land cover within the hazard-prone area is occupied by roads, railways, ports or airports or associated land	Between 5% to 10% of the land cover within the hazard-prone area is occupied by roads, railways, ports or airports or associated land	More than 10% of the land cover within the hazard-prone area is occupied by roads, railways, ports or airports or associated land
Presence of railway (all hazard-prone areas)	There is not presence of railway or associated land within the hazard-prone area	-	There is presence of railway or associated land within the hazard-prone area
Presence of port (all hazard-prone areas)	There is not presence of port or marina or associated land within the hazard-prone area	-	There is presence of port or marina or associated land within the hazard-prone area
Presence of airport (all hazard-prone areas)	There is not presence of airport or associated land within the hazard-prone area	-	There is presence of airport or associated land within the hazard-prone area

Areas of high ecological value (%) (all hazard-prone areas)	Less than 10% of the land cover within the hazard-prone area is occupied by high ecological value areas	Between 10% to 25% of the land cover within the hazard-prone area is occupied by high ecological value areas	More than 25% of the land cover within the hazard-prone area is occupied by high ecological value areas
Local coastal adaptation planning	Yes	-	No
National sea level rise preparedness	Well/very well	Reasonably well	Not well
MSL rise projections spatial scale	Local	Regional	National

2.9. Limitations of the methodology

It must be considered that the assessment performed in this report for the ten CCLLs is characterised for being a high-level indicator-based approach. In some cases, global datasets have been used for the development of the indicators. In these cases, the spatial resolution and the uncertainty of the global datasets can be coarse for the CCLLs with reduced geographical coverage (i.e., Vilanova i la Geltrú, Benidorm and Massa CCLLs).

The geographical resolution of land cover data varies between the Corine Land Cover and Urban Atlas datasets. In particular, the precision of the measurement of the areas associated to the different land covers analysed may vary between the CCLLs according to the dataset utilised.

3. RESULTS

3.1. Key climate-related hazards

The identification and mapping of the key climate-related hazards was already carried out in the report *D1.2 – Map and report of key climate-change hazards*. These are summarised in Figure 7. Storms, coastal and land flooding, and coastal erosion are the main hazards identifies in the Irish cities of Sligo and Dublin. Coastal flooding has been found to be the most important hazard in Piran. Similarly, coastal flooding and, in addition, land flooding have been identified as the most serious climate-related perils in Gdansk and Oeiras. In Samsun, in addition to coastal and land flooding, coastal erosion completes the list of key hazards. Coastal erosion and flooding are the most relevant hazards found in Massa. Finally, storms are a common hazard in the three Spanish coastal cities. Furthermore, Oarsoaldea is critically affected by coastal and land flooding and coastal erosion; Benidorm by coastal erosion and coastal flooding; and Vilanova i la Geltrú by land flooding, heat waves, strong winds and forest fires.

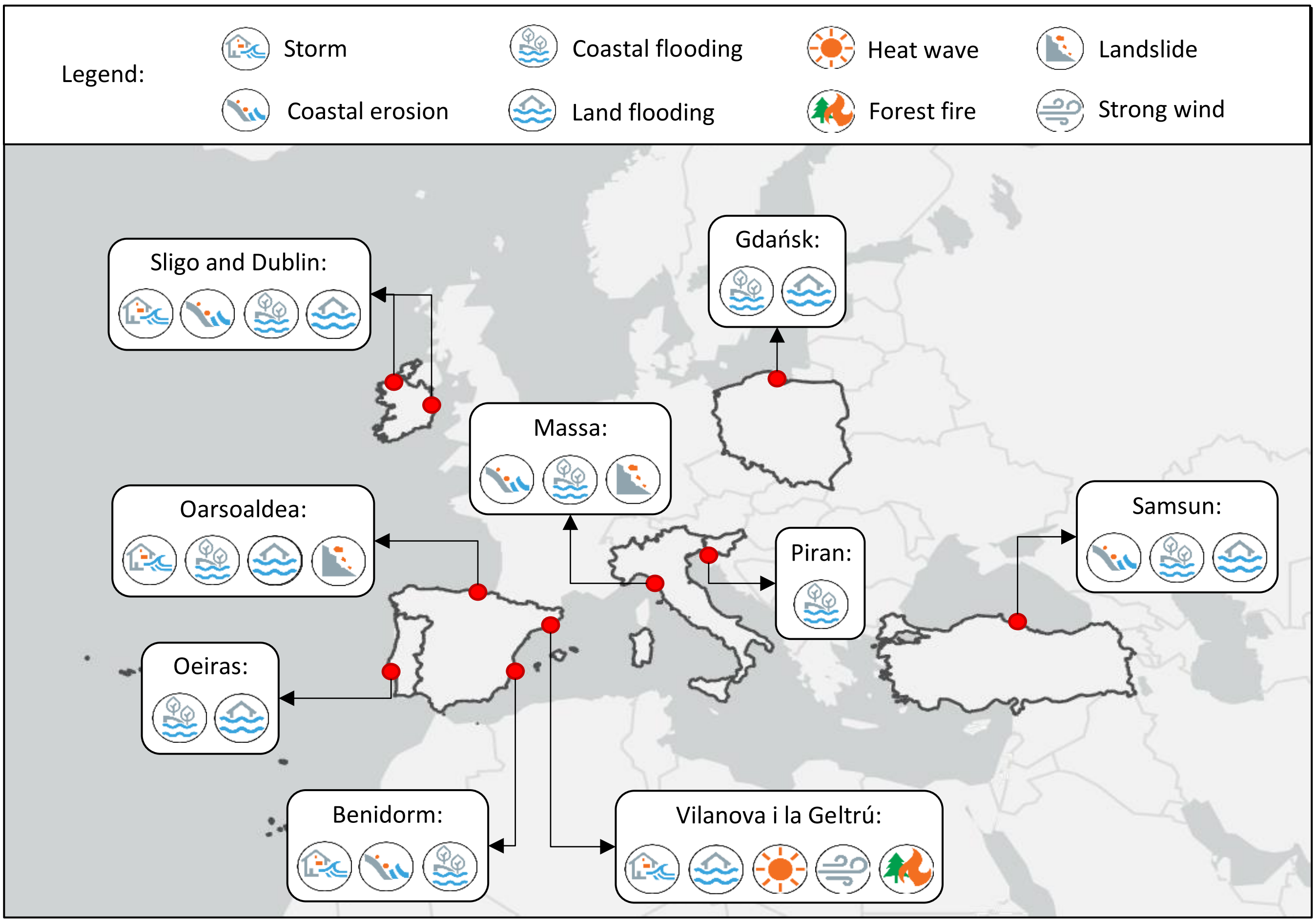


Figure 7: Schematic representation of the key climate-related hazards identified in the ten coastal cities studied.

3.2. Physical exposure

With regard to the indicator "Relative sea-level changes (mm/year)", Sligo CCLL and Oeiras CCLL scored with high exposure. The exposure score for the CCLLs located in the Mediterraneum Sea (Vilanova i la Geltrú, Benidorm, Massa and Piran) is of medium. Lastly, the exposure to sea-level rise is the lowest for Dublin and Gdansk CCLLs.

The results for the indicator "Mean significant wave height (m)" are practically the same as for the previous indicator, with the exception of the CCLLs located in the Mediterranean Sea and Oarsoaldea CCLL, where the exposure is of a lower degree compared to the previous case.

The exposure for the indicator "Tidal range (m)" is high in the CCLLs of Sligo, Oarsoaldea and Oeiras; medium in Dublin CCLL; and low in the rest of the CCLLs assessed.

The hardness of the lithotypes has been measured for four CCLLs. Benidorm CCLL presents the softer lithotype (high exposure), Dublin and Massa CCLLs are characterised by a medium hardness (medium exposure) and the lithotype of Sligo CCLL is the hardest (low exposure).

Gdansk CCLL outstand for having the most extensive LECZ compared to its total area, occupying almost half of the territory (46.7%). Piran CCLL presents also a large LECZ, which covers almost a third of the total municipality area (30.7%). The size of the LECZ is relatively small for Oeiras, Oarsoaldea, Dublin, Benidorm, Sligo and Vilanova i la Geltrú CCLLs, ranking lowest for Oeiras (0.4%), and increasing respectively for the rest (1.1%, 1.7%, 4.1%, 4.6% and 5.5%). Finally, Massa and Samsun are in a middle range, with relative areas of LECZ of 18.8% and 10.1%, respectively.

In the case of the parameter defined as LECZ area per coastline length, Samsun ranks the highest with 410 ha/km, followed by Gdansk (361 ha/km) and Massa (181 ha/km). Again, Oeiras ranks the lowest with 1.1 ha/km, and the values remain low but increasing for Oarsoaldea, Benidorm, Vilanova i la Geltrú, Dublin and Sligo (6.3 ha/km, 9.5 ha/km, 12.1 ha/km, 36.7 ha/km and 39.9 ha/km, respectively). Piran is in a middle range with a value of 67.1 ha/km.

Considering the proportion between LECZ and total area less than a tenth (<10%) as low exposure, between a tenth and a quarter (>10% and <25%) as medium exposure, and greater than a quarter (>25%) as high exposure, the results have been respectively coloured in green, yellow and red in Table 25. Similarly, the relationship between LECZ area and coastline length is scored as low exposure (green) when the result is lower than 50 ha/km, medium exposure (yellow) when the value is between 50 ha/km and 150 ha/km, and high exposure (red) when it is greater than 150 ha/km.

The scores for the indicator "Extent of flood-prone areas (%)" are of high exposure in Gdansk CCLL, of medium score in Massa CCLL and of low score in the other cases.

The indicators of "Extent of landslide-prone areas (%)", "Extent of forest-fire-prone areas (%)" and "Extent of strong-wind-prone areas (%)" have been measured as of medium exposure, as previously explained.

As it was explained in the section Exposure to heat waves, the exposure to the heat-wave hazard is high in Vilanova i la Geltrú CCLL.

Table 25: Physical exposure – scoring.

Indicator	Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Oarsoaldea	Threshold
Geographical coverage	County Sligo	Great Dublin area (counties of Dublin, Kildare, Meath and Wicklow)	Vilanova i la Geltrú municipality	Benidorm municipality	Municipalities of Errenteria, Lezo, Oiartzun and Pasaia	
Coastline length (km)	211	318	15.4	16.7	19.8	
Total area (km2)	1837	6986	34	38.5	111.9	

Relative sea-level changes (mm/year)	1.5	0	1	1	1.5	(0.5; 1.0)
Mean significant wave height (m)	3.7	1.4	0.7	0.7	2.4	(1.5; 2.5)
Tidal range (m)	1.1	0.8	0.2	0.2	1.4	(0.5; 1.0)
Lithotype hardness	Hard	Medium	-	Soft	-	(Hard; medium; soft)
LECZ (ha)	8410	11673	186	159	126	
LECZ area (%)	4.6	1.7	5.5	4.1	1.1	(10; 25)
LECZ / Coastline (ha/km)	39.9	36.7	12.1	9.5	6.3	(50; 150)
Extent of flood-prone area (%)	0.16	1.4	1.5	0.9	0.3	(5; 10)
Extent of the landslide-prone areas (%)	-	-	-	-	56.3	-
Extent of the forest-fire-prone areas (%)	-	14.0	-	-	-	-
Extent of the strong-wind-prone areas (%)	-	-	17.4	-	-	-
Exposure to heat waves	-	-	High	-	-	-

Indicator	Oeiras	Massa	Piran	Gdansk	Samsun	Threshold
Geographical coverage	Oeiras municipality	Massa municipality	Piran municipality	City of Gdansk	Samsun province	
Coastline length (km)	13.2	9.5	20.4	33.9	235	
Total area (km2)	45.9	94.1	44.6	262	9579	
Relative sea-level changes (mm/year)	1.5	1	1	0.5	-	(0.5; 1.0)
Mean significant	2.7	0.7	0.7	1.4	-	(1.5; 2.5)

wave height (m)						
Tidal range (m)	1.1	0.2	0.2	0.2	-	(0.5; 1.0)
Lithotype hardness	-	Medium	-	-	-	(Hard; medium; soft)
LECZ (ha)	17	1769	1368	12237	96362	
LECZ area (%)	0.4	18.8	30.7	46.7	10.1	(10; 25)
LECZ / Coastline (ha/km)	1.3	186.2	67.1	361.0	410.0	(50; 150)
Extent of flood-prone area (%)	0.2	7.6	-	26.0	7.6	(5; 10)
Extent of the landslide-prone areas (%)	-	27.0	-	-	-	-
Extent of the forest-fire-prone areas (%)	-	-	-	-	-	-
Extent of the strong-wind-prone areas (%)	-	-	-	-	-	-
Exposure to heat waves	-	-	-	-	-	-

3.3. Population exposure

Six indicators have been evaluated using a methodology similar to that described earlier for assessing population exposure. The level of population exposure within the LECZ (Low Elevation Coastal Zone) is classified as low if it accounts for less than 10% of the total CCLL (Coastal Cities with Large Population) population, medium if it ranges between 10% and 25%, and high if it exceeds 25%. In the case of the indicator including the percentage of population under 5 years old and over 80 years old for the total CCLL population, the thresholds are 9% and 11%.

The CCLLs with the lowest population within the LECZ are Oeiras, Benidorm, Dublin and Vilanova i la Geltrú (1.2%, 5.5%, 8.4% and 9.3%, respectively). Sligo and Samsun CCLLs show intermediate values of 10.7% and 18.2%, respectively. Oarsoaldea, Massa, Piran and Gdansk CCLLs accumulate the largest values of population within the LECZ (27.8%, 34.1%, 34.3% and 36.8%, respectively).

The results for the indicator "Flood-prone areas population (%)" are generally of low exposure (Sligo, Dublin, Vilanova i la Geltrú and Oarsoaldea CCLLs). Samsun CCLL scored with medium exposure and Gdansk CCLL with high exposure.

The measures for the indicators referring to the population living in the areas prone to landslides (Oarsoaldea and Massa CCLLs), forest fires (Vilanova i la Geltrú CCLL) and strong winds (Vilanova i la Geltrú CCLL) were assigned a score of medium exposure due to the lack of more data for comparison.

In terms of the indicator "Most vulnerable population (age) (2020) (%)", only Gdansk and Samsun score with low exposure (8.91% and 8.38%), whereas Dublin (9.79%), Oeiras (10.04), Sligo (10.29%) and Vilanova i la Geltrú (10.77) score with medium exposure, and Massa (13.02%), Benidorm (11.2%), Oarsoaldea (11.02%) and Piran (11.01%) score with high exposure.

Table 26: Population exposure – scoring.

Indicator	Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Oarsoaldea	Threshold	Notes
Official population (2020)	69819*	2073459*	67,733	70,450	71,987	-	*Data from 2022 census
Population estimate (2020)	77,024	2,197,152	73,751	106,893	70,474	-	
LECZ population (2020)	7,450	173,924	6,321	3,854	20,018	-	
LECZ population (%)	10.7	8.4	9.3	5.5	27.8	(10; 25)	
Flood-prone areas population (%)	0.9	2.7	3.4	-	0.4	(5; 10)	
Landslide-prone areas population (%)	-	-	-	-	5.7	-	Intermediate value assigned
Forest-fire-prone areas population (%)	-	-	0.1	-	-	-	Intermediate value assigned
Strong-wind-prone areas population (%)	-	-	24.6	-	-	-	Intermediate value assigned
Population under 5 years old (2020) (%)	6.61	6.6	4.5	3.92	4.59	-	
Population over 80 years old (2020) (%)	3.68	3.19	6.27	7.28	6.43	-	
Most vulnerable population (age) (2020) (%)	10.29	9.79	10.77	11.2	11.02	(9; 11)	
Indicator	**Oeiras**	**Massa**	**Piran**	**Gdansk**	**Samsun**	**Threshold**	**Notes**
Official population (2020)	177,991	66423*	18,080	465,475	1,356,079	-	*Data from 2022 census
Population estimates (2020)	181,367	68,757	19,824	459,674	1,324,256	-	

LECZ population (2020)	2,155	22,641	6,201	171,254	247138	-	
LECZ population (%)	1.2	34.1	34.3	36.8	18.2	(10; 25)	
Flood-prone areas population (%)		-	-	16.5	7.4	(5; 10)	
Landslide-prone areas population (%)	-	6.0	-	-	-	-	Intermediate value assigned
Forest-fire-prone areas population (%)	-	-	-	-	-	-	
Strong-wind-prone areas population (%)	-	-	-	-	-	-	
Population under 5 years old (2020) (%)	4.27	3.81	5.33	5.05	6.25	-	
Population over 80 years old (2020) (%)	5.77	9.21	5.68	3.86	2.13	-	
Most vulnerable population (age) (2020) (%)	10.04	13.02	11.01	8.91	8.38	(9; 11)	

3.4. Land cover and land uses exposure

3.4.1. Socioeconomic activity

Four indicators of socioeconomic activity are measured and scored in Table 27. These are the areas of residential land use, industrial or commercial land use, agriculture land use, and beaches, dunes or sandplains. All the areas are measured within the corresponding hazard-prone area and are expressed as a portion of these areas, in percentage. A score of low (green-coloured cells), medium (yellow-coloured cells) or high (red-coloured cells) exposure is assigned to the areas according to the thresholds expressed in brackets.

3.4.1.1. Socioeconomic activity in the LECZ

Benidorm CCLL concentrates the largest percentage of urban fabric along its LECZ (62.8%). Vilanova i la Geltrú (47.5%) and Massa (34.8%) CCLLs have also big shares of this land use. Conversely, the portion of land used for residential use is much less in Samsun (2.3%) and Sligo (3.3%) CCLLs, where most of the land is used for agriculture (72.1% and 60.5%, respectively). Something similar occurs in Dublin, where the area of agriculture land use has been estimated of 43.6% and the area of residential land use, of 15.6%. Oeiras, Massa and Gdansk CCLLs accumulate the largest proportions of industrial or commercial land uses, with values of 18.6%, 13.5% and 14.4%, respectively. Finally, Benidorm shows the largest relative area of beaches, dunes or sandplains (24.1%), by a large difference compared to the other cities.

Table 27: Scoring of the exposure of the socioeconomic activity – LECZ.

Indicator	Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Oarsoaldea	Threshold	Notes

Area of residential land use within the LECZ (%)	3.3	15.6	47.5	62.8	21.7	(10;25)	Mainly residential use
Area of industrial/ commercial land use within the LECZ (%)	1.3	6.1	5.5	2.7	0.2	(5;10)	Includes industrial, commercial, public, military and private units uses. Impacts on economy
Area of agriculture land use within the LECZ (%)	60.5	43.6	31.3	0.0	0.2	(20;40)	
Area of beaches, dunes, and sand plains within the LECZ (%)	6.5	1.3	0.0	24.1	0.0	(5;10)	Impacts on tourism and service sector

Indicator	Oeiras*	Massa	Piran	Gdansk	Samsun	Threshold	Notes
Area of residential land use within the LECZ (%)	24.8	34.8	7.7	8.0	2.3	(10;25)	Mainly residential use
Area of industrial/ commercial land use within the LECZ (%)	18.6	13.5	0.0	14.4	1.1	(5;10)	Includes industrial, commercial, public, military and private units uses. Impacts on economy
Area of agriculture land use within the LECZ (%)	4.4	3.4	36.4	35.4	72.1	(20;40)	
Area of beaches, dunes, and sand plains within the LECZ (%)	0.9	2.0	0.0	1.3	2.7	(5;10)	Impacts on tourism and service sector

* Areas for the 100-year return period coastal flooding event in the case of Oeiras.

3.4.1.2. Socioeconomic activity in the flood-prone areas

The Spanish CCLLs of Vilanova i la Geltrú and Oarsoaldea concentrate the largest percentage of urban fabric along their flood-prone areas (45.8% and 39.0%, respectively), resulting in high exposure. The rest of CCLLs shown results of low exposure for this indicator.

Again, the CCLLs of Vilanova i la Geltrú and Oarsoaldea, and now also Gdansk CCLL, registered high-exposure portions of land intended to industrial and commercial uses within the flood-prone areas (10.7%, 21.0% and 11.2%, respectively), whereas the exposure was scored as low in the other CCLLs.

Agricultural land is highly exposed in most of the cities assessed. These cities include the CCLLs of Sligo, Dublin, Gdansk and Samsun. Vilanova i la Geltrú scored medium exposure for this indicator and Oarsoaldea CCLL, low exposure.

Lastly, the sandy areas are lowly exposed in all the cases.

Table 28: Scoring of the exposure of the socioeconomic activity – flood-prone areas.

Indicator	Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Oarsoaldea	Threshold	Notes
Area of residential land use within the flood-prone areas (%)	4.7	5.6	45.8	-	39.0	(10;25)	Mainly residential use
Area of industrial/ commercial land use within the flood-prone areas (%)	0.7	2.9	10.7	-	21.0	(5;10)	Includes industrial, commercial, public, military and private units uses. Impacts on economy
Area of agriculture land use within the flood-prone areas (%)	42.7	69.3	39.4	-	0	(20;40)	
Area of beaches, dunes, and sand plains within the flood-prone areas (%)	4.7	0	0	-	0	(5;10)	Impacts on tourism and service sector
Indicator	**Oeiras**	**Massa**	**Piran**	**Gdansk**	**Samsun**	**Threshold**	**Notes**
Area of residential land use within the flood-prone areas (%)	*	-	-	4.4	1.3	(10;25)	Mainly residential use
Area of industrial/ commercial land use within the flood-prone areas (%)	*	-	-	11.2	0.2	(5;10)	Includes industrial, commercial, public, military and private units uses. Impacts on economy
Area of agriculture land use within the flood-prone areas (%)	*	-	-	52.8	60.1	(20;40)	
Area of beaches, dunes, and sand plains within the flood-prone areas (%)	*	-	-	1.5	2.8	(5;10)	Impacts on tourism and service sector

* Flood-prone areas are particularly assessed in the section Additional results in the case of Oeiras CCLL.

3.4.1.3. Socioeconomic activity in the landslide-prone areas

The landslide hazard has low impact in the areas related to socioeconomic activity. As it will be reported in the section Ecosystems exposure in the landslide-prone areas, landslide-prone areas are mostly covered by natural vegetation.

Table 29: Scoring of the exposure of the socioeconomic activity – landslide-prone areas.

Indicator	Oarsoaldea	Massa	Threshold	Notes

Area of residential land use within the LECZ within the landslide-prone areas (%)	0.6	2.3	(10;25)	Mainly residential use
Area of industrial/ commercial land use within the landslide-prone areas (%)	0.7	2.3	(5;10)	Includes industrial, commercial, public, military and private units uses. Impacts on economy
Area of agriculture land use within the landslide-prone areas (%)	7.5	6.3	(20;40)	
Area of beaches, dunes, and sand plains within the landslide-prone areas (%)	0.0	4.1	(5;10)	Impacts on tourism and service sector

3.4.1.4. Socioeconomic activity in the forest-fire-prone areas

In terms of socioeconomic activity, forest fires only expose agricultural land in Vilanova i la Geltrú CCLL, with a medium value.

Table 30: Scoring of the exposure of the socioeconomic activity – forest-fire-prone areas.

Indicator	Vilanova i la Geltrú	Threshold	Notes
Area of residential land use within the forest-fire-prone areas (%)	0.0	(10;25)	Mainly residential use
Area of industrial/ commercial land use within the forest-fire-prone areas (%)	0.0	(5;10)	Includes industrial, commercial, public, military and private units uses. Impacts on economy
Area of agriculture land use within the forest-fire-prone areas (%)	8.4	(20;40)	
Area of beaches, dunes, and sand plains within the forest-fire-prone areas (%)	0.0	(5;10)	Impacts on tourism and service sector

3.4.1.5. Socioeconomic activity in the strong-wind-prone areas

Most of the strong-wind-prone areas cover urban fabric in Vilanova i la Geltrú CCLL (51.5%), resulting in high exposure. Also, agricultural areas are at medium exposure for this indicator, with a relative area of 30.6%. The rest of the land uses in this section presented low exposure.

Table 31: Scoring of the exposure of the socioeconomic activity – strong-wind-prone areas.

Indicator	Vilanova i la Geltrú	Threshold	Notes
Area of residential land use within the strong-wind-prone areas (%)	51.5	(10;25)	Mainly residential use
Area of industrial/ commercial land use within the strong-wind-prone areas (%)	0.7	(5;10)	Includes industrial, commercial, public, military and private units uses. Impacts on economy
Area of agriculture land use within the strong-wind-prone areas (%)	30.6	(20;40)	

Area of beaches, dunes, and sand plains within the strong-wind-prone areas (%)	0.0	(5;10)	Impacts on tourism and service sector

3.4.2. Critical infrastructure

Four indicators have been developed, measured, and scored for the estimation of the exposure of roads, railways, ports and airports with their associated land areas. The area of these four infrastructures is measured within the different hazard-prone areas, and values of low, medium, and high exposure are assigned as in the previous point. Then, it is observed if areas associated to railway, port or airport infrastructure are present in these areas, and a binary score of low exposure (green cells) or high exposure (red cells) is assigned in the negative or affirmative case, respectively.

3.4.2.1. Critical infrastructure in the LECZ

Oarsoaldea is by far the CCLL where most presence of critical infrastructure is measured within the LECZ (64.9%), mostly corresponding to its port area. Vilanova i la Geltrú CCLL occupied the second place in this respect, with 13.2% of land area intended for any of these four infrastructures. All the CCLLs, with the exception of Benidorm and Piran, have presence of railway within the LECZ; only Massa CCLL does not account for some area of harbour or marina; and airport areas are included within the LECZ of Sligo, Piran and Samsun CCLLs.

Table 32: Scoring of the exposure of the critical infrastructure – LECZ.

Indicator	Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Oarsoaldea	Threshold	Notes
Area of critical infrastructure within the LECZ (%)	1.1	2.6	13.2	0.4	64.9	(5;10)	Includes road, railway, port and airport
Presence of railway within the LECZ	Yes	Yes	Yes	No	Yes	(No; Yes)	Railway and/or associated area
Presence of port within the LECZ	Yes	Yes	Yes	Yes	Yes	(No; Yes)	Port and/or associated area within
Presence of airport within the LECZ	Yes	No	No	No	No	(No; Yes)	Airport and/or associated area
Indicator	**Oeiras***	**Massa**	**Piran**	**Gdansk**	**Samsun**	**Threshold**	**Notes**
Area of critical infrastructure within the LECZ (%)	7.2	0.2	5.3	5.3	0.7	(5;10)	Includes road, railway, port and airport
Presence of railway within the LECZ	Yes	Yes	No	Yes	Yes	(No; Yes)	Railway and/or associated area
Presence of port within the LECZ	Yes	No	Yes	Yes	Yes	(No; Yes)	Port and/or associated area within
Presence of airport within the LECZ	No	No	Yes	No	Yes	(No; Yes)	Airport and/or associated area

* Areas for the 100-year return period coastal flooding event in the case of Oeiras.

3.4.2.2. Critical infrastructure in the flood-prone areas

Relatively large areas of land associated to transportation infrastructure are potentially affected by floods in Sligo and Oarsoaldea CCLLs (17.3% and 14.5%, respectively), including the presence of railway infrastructure in the case of Sligo CCLL. Although the other CCLLs assessed present lower values of exposure (medium exposure in Dublin, Vilanova i la Geltrú and Gdansk CCLLs and low exposure in Samsun CCLL), the exposed areas include the presence of railway and port infrastructure. Moreover, in the case of Dublin CCLL, part of the airport area lies within the flood-prone area.

Table 33: Scoring of the exposure of the critical infrastructure – flood-prone areas.

Indicator	Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Oarsoaldea	Threshold	Notes
Area of critical infrastructure within the flood-prone areas (%)	17.3	2.5	4.1	-	14.5	(5;10)	Includes road, railway, port and airport
Presence of railway within the flood-prone areas	Yes	Yes	Yes	-	No	(No; Yes)	Railway and/or associated area
Presence of port within the flood-prone areas	No	Yes	Yes	-	No	(No; Yes)	Port and/or associated area within
Presence of airport within the flood-prone areas	No	Yes	No	-	No	(No; Yes)	Airport and/or associated area
Indicator	**Oeiras***	**Massa**	**Piran**	**Gdansk**	**Samsun**	**Threshold**	**Notes**
Area of critical infrastructure within the flood-prone areas (%)		-	-	6.1	0.1	(5;10)	Includes road, railway, port and airport
Presence of railway within the flood-prone areas		-	-	Yes	Yes	(No; Yes)	Railway and/or associated area
Presence of port within the flood-prone areas		-	-	Yes	Yes	(No; Yes)	Port and/or associated area
Presence of airport within the flood-prone areas		-	-	No	No	(No; Yes)	Airport and/or associated area

3.4.2.3. Critical infrastructure in the landslide-prone areas

The areas exposed to the landslide hazard in Oarsoaldea and Massa CCLLs are low. However, they affect the railway in both cities and the port in Oarsoaldea.

Table 34: Scoring of the exposure of the critical infrastructure – landslide-prone areas.

Indicator	Oarsoaldea	Massa	Threshold	Notes
Area of critical infrastructure within the landslide-prone areas (%)	0.1	2.0	(5;10)	Includes road, railway, port and airport

Presence of railway within the landslide-prone areas	Yes	Yes	(No; Yes)	Railway and/or associated area
Presence of port within the landslide-prone areas	Yes	No	(No; Yes)	Port and/or associated area within
Presence of airport within the landslide-prone areas	No	No	(No; Yes)	Airport and/or associated area

3.4.2.4. Critical infrastructure in the forest-fire-prone areas

The results show that no areas (or at least a low value) of critical infrastructure are within the areas of past forest fires in Vilanova i la Geltrú CCLL.

Table 35: Scoring of the exposure of the critical infrastructure – forest-fire-prone areas.

Indicator	Vilanova i la Geltrú	Threshold	Notes
Area of critical infrastructure within the forest-fire-prone areas (%)	0	(5;10)	Includes road, railway, port and airport
Presence of railway within the forest-fire-prone areas	No	(No; Yes)	Railway and/or associated area
Presence of port within the forest-fire-prone areas	No	(No; Yes)	Port and/or associated area within
Presence of airport within the forest-fire-prone areas	No	(No; Yes)	Airport and/or associated area

3.4.2.5. Critical infrastructure in the strong-wind-prone areas

The areas of past strong winds cover a low area of critical infrastructure in Vilanova i la Geltrú CCLL (4.7%), although these affect the railway and port.

Table 36: Scoring of the exposure of the critical infrastructure – strong-wind-prone areas.

Indicator	Vilanova i la Geltrú	Threshold	Notes
Area of critical infrastructure within the strong-wind-prone areas (%)	4.7	(5;10)	Includes road, railway, port and airport
Presence of railway within the strong-wind-prone areas	Yes	(No; Yes)	Railway and/or associated area
Presence of port within the strong-wind-prone areas	Yes	(No; Yes)	Port and/or associated area within
Presence of airport within the strong-wind-prone areas	No	(No; Yes)	Airport and/or associated area

3.4.3. Ecosystems exposure

The areas of green urban spaces, beaches, dunes and sandplains, natural vegetation, wetlands, and water bodies have been considered of high ecological value due to their capacity to host ecosystems. These areas have been measured, combined and scored under a global indicator.

3.4.3.1. Ecosystems exposure in the LECZ

Piran CCLL accumulates the largest area in this regard, with more than a half of its LECZ total area (50.5%), mainly composed by wetlands. Oeiras, Sligo, Gdansk, Massa, Benidorm and Dublin CCLLs have also important relative areas of high ecological value (37.9%, 33.6%, 33.2%, 32.5%, 30.1% and 26.4%, respectively), whereas Vilanova i la Geltrú CCLL only presents a 2.4%.

Table 37: Scoring of the exposure of the ecosystems – LECZ.

Indicator	Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Oarsoaldea	Threshold	Notes
Areas of high ecological value within the LECZ (%)	33.6	26.4	2.4	30.1	13.0	(10;25)	Includes green urban areas, beaches, dunes and sandplains, natural vegetation, wetlands and water bodies
Indicator	**Oeiras***	**Massa**	**Piran**	**Gdansk**	**Samsun**	**Threshold**	**Notes**
Areas of high ecological value within the LECZ (%)	37.9	32.5	50.5	33.2	23.4	(10;25)	Includes green urban areas, beaches, dunes and sand plains, natural vegetation, wetlands and water bodies

* Areas for the 100-year return period coastal flooding event in the case of Oeiras.

3.4.3.2. Ecosystems exposure in the flood-prone areas

The exposure to land flooding is high in Samsun CCLL (37.4%), medium in Sligo, Dublin, Oarsoaldea and Gdansk CCLLs (17.3%, 19.6%, 18.6% and 18.6%, respectively) and low in Vilanova i la Geltrú CCLL, with no (or very low) affectation.

Table 38: Scoring of the exposure of the ecosystems – flood-prone areas.

Indicator	Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Oarsoaldea	Threshold	Notes
Areas of high ecological value within the flood-prone areas (%)	17.3	19.6	0	-	18.6	(10;25)	Includes green urban areas, beaches, dunes and sandplains, natural vegetation, wetlands and water bodies
Indicator	**Oeiras**	**Massa**	**Piran**	**Gdansk**	**Samsun**	**Threshold**	**Notes**
Areas of high ecological value within the flood-prone areas (%)		-	-	18.6	37.4	(10;25)	Includes green urban areas, beaches, dunes and sand plains, natural vegetation, wetlands and water bodies

3.4.3.3. Ecosystems exposure in the landslide-prone areas

As mentioned before, the landslide-prone areas mostly affect areas of high-ecological value, covering 89.7% and 86.5% of these areas in Oarsoaldea and Massa CCLLs, respectively.

Table 39: Scoring of the exposure of the ecosystems – landslide-prone areas.

Indicator	Oarsoaldea	Massa	Threshold	Notes

Areas of high ecological value within the landslide-prone areas (%)	89.7	86.5	(10;25)	Includes green urban areas, beaches, dunes and sandplains, natural vegetation, wetlands and water bodies

3.4.3.4. Ecosystems exposure in the forest-fire-prone areas

In Vilanova i la Geltrú, the exposure of the areas categorised as having high-ecological value is medium for the hazard of forest fires. Note that in the past, this area could be larger, which reduced due to the loss of forest cover from the fires and consequent changes in the land uses.

Table 40: Scoring of the exposure of the ecosystems – forest-fire-prone areas.

Indicator	Vilanova i la Geltrú	Threshold	Notes
Areas of high ecological value within the forest-fire-prone areas (%)	11.0	(10;25)	Includes green urban areas, beaches, dunes and sandplains, natural vegetation, wetlands and water bodies

3.4.3.5. Ecosystems exposure in the strong-wind-prone areas

A medium value of land having high-ecological value corresponds to the areas affected by past strong winds in Vilanova i la Geltrú (10.3%).

Table 41: Scoring of the exposure of the ecosystems – strong-wind-prone areas.

Indicator	Vilanova i la Geltrú	Threshold	Notes
Areas of high ecological value within the strong-wind-prone areas (%)	10.3	(10;25)	Includes green urban areas, beaches, dunes and sandplains, natural vegetation, wetlands and water bodies

3.5. Adaptive capacity

Lastly, the adaptive capacity is measured in terms of three indicators: (I) existence or non-existence of coastal adaptation planning at the local level, (ii) sea level rise preparedness at the national level, and (iii) whether the level of application of the SLR projections for the CCLL are national, regional, or local. In this sense, there are local coastal adaption plans for only half of the CCLLs (Dublin, Vilanova i la Geltrú, Benidorm, Oeiras and Gdansk), scored with "Yes" (green-coloured cells in Table 42) and "No" (red-coloured cells) in the rest of cases. The national SLR preparedness was measured in McEvoy et al. (2021) based in the opinion of a group of experts in the field. In the case of Slovenia, no data were available and a conservative score of *low adaptive capacity* was assigned, and Italy is not well prepared in general (red-coloured cells). Ireland, Portugal and Poland are reasonably well prepared (yellow-coloured cells). In the case of Spain, the expertise was equally split between *Well/very well* and *Reasonably well*, thus a score of *high adaptive capacity* was assigned (green-coloured cells). Finally, Benidorm is the only region benefited from SLR projections under the national scale, particularly, at regional scale, and a medium score is accordingly assigned.

Table 42: Adaptive capacity – scoring.

Indicator	Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Oarsoaldea	Threshold	Notes

Local coastal adaptation planning	No	Yes	Yes	Yes	No	(Yes; No)	
National sea level rise preparedness	Reasonably well	Reasonably well	Well/very well – Reasonably well	Well/very well – Reasonably well	Well/very well – Reasonably well		Source: McEvoy et al. (2021)
MSL rise scenario midterm (optimistic)	-	-	0.13	0.1457	0.13	-	
MSL rise scenario midterm (pessimistic)	-	-	0.17	0.1564	0.17	-	
MSL rise scenario end-century (optimistic)	-	0.5	0.38	0.4245	0.38	-	
MSL rise scenario end-century (pessimistic)	0.81	1	0.68	0.572	0.68	-	
MSL rise scenario scale	National	National	National	Regional	National	(Local; Regional; National)	CCLL responses and McEvoy et al. (2021)

Indicator	Oeiras	Massa	Piran	Gdansk	Samsun	Threshold	Notes
Local coastal adaptation planning	Yes	No	No	Yes	No	(Yes; No)	
National sea level rise preparedness	Reasonably well	Not well	Not well	Reasonably well	Not well		Source: McEvoy et al. (2021)
MSL rise scenario midterm (optimistic)	-	-	-	-	-	-	
MSL rise scenario midterm (pessimistic)	-	-	-	-	-	-	
MSL rise scenario end-century (optimistic)	0.5	0.35	-	-	-	-	
MSL rise scenario end-	1.5	1	-	0.6	-	-	

century (pessimistic)							
MSL rise scenario scale	National	National	National	National	National	(Local; National)	CCLL responses and McEvoy et al. (2021)

3.6. Additional results

In the case of Benidorm, Oarsoaldea and Oeiras CCLLs, some additional indicators could be developed thanks to the availability of more data. These additional results are summarised in the following subsections.

3.7. Benidorm CCLL

Benidorm CCLL provided information regarding the location of natural protected areas and seabed morphology (see Figure 8). It can be observed that the seabed is mainly composed by unconsolidated very fine-grained sediments, which are mostly sand. In addition, the seabed is also a natural protected area. For these reasons, it can be confirmed that the vulnerability of Benidorm to coastal erosion is high.

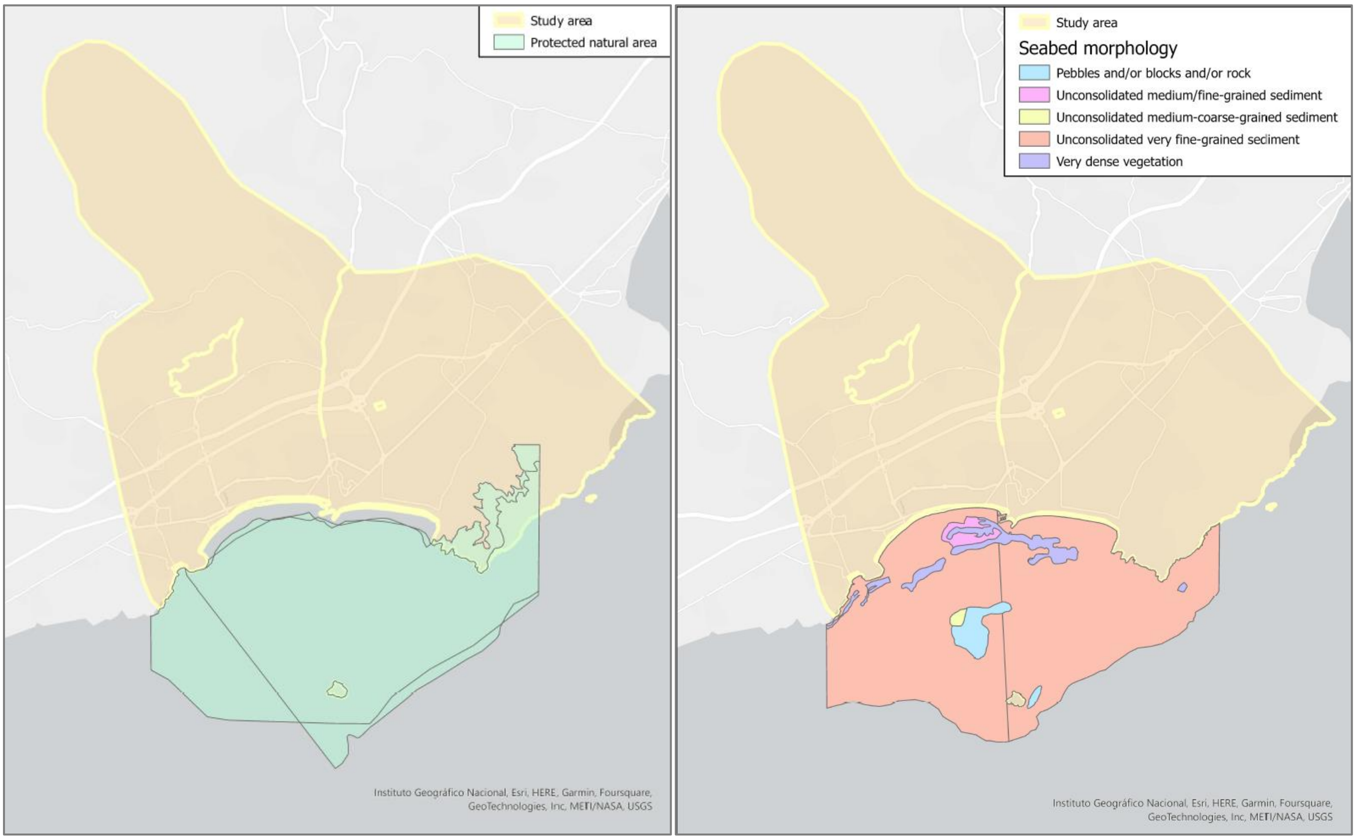


Figure 8: Benidorm CCLL – protected natural areas (left) and seabed morphology (right).

3.8. Oarsoaldea CCLL

The lithology of the coastal area of Oarsoaldea is mainly composed sandstone flysch from the Eocene of the Higer-Getaria formation. This formation alternates thick layers of quartzose sandstones (80-90% quartz grains with carbonate cement) and thin layers of clayey or marlaceous lutites. In the intertidal area of the Oiartzun River there are surface alluvial deposits, overlaying the flysch.

In particular, the soil within the LECZ is mostly characterised by sandstone and, therefore, it can be considered as "non likely erodible". This information can be used as an indicator of the exposure to coastal erosion, showing that in this sense the exposure of this CCLL is at least not high.

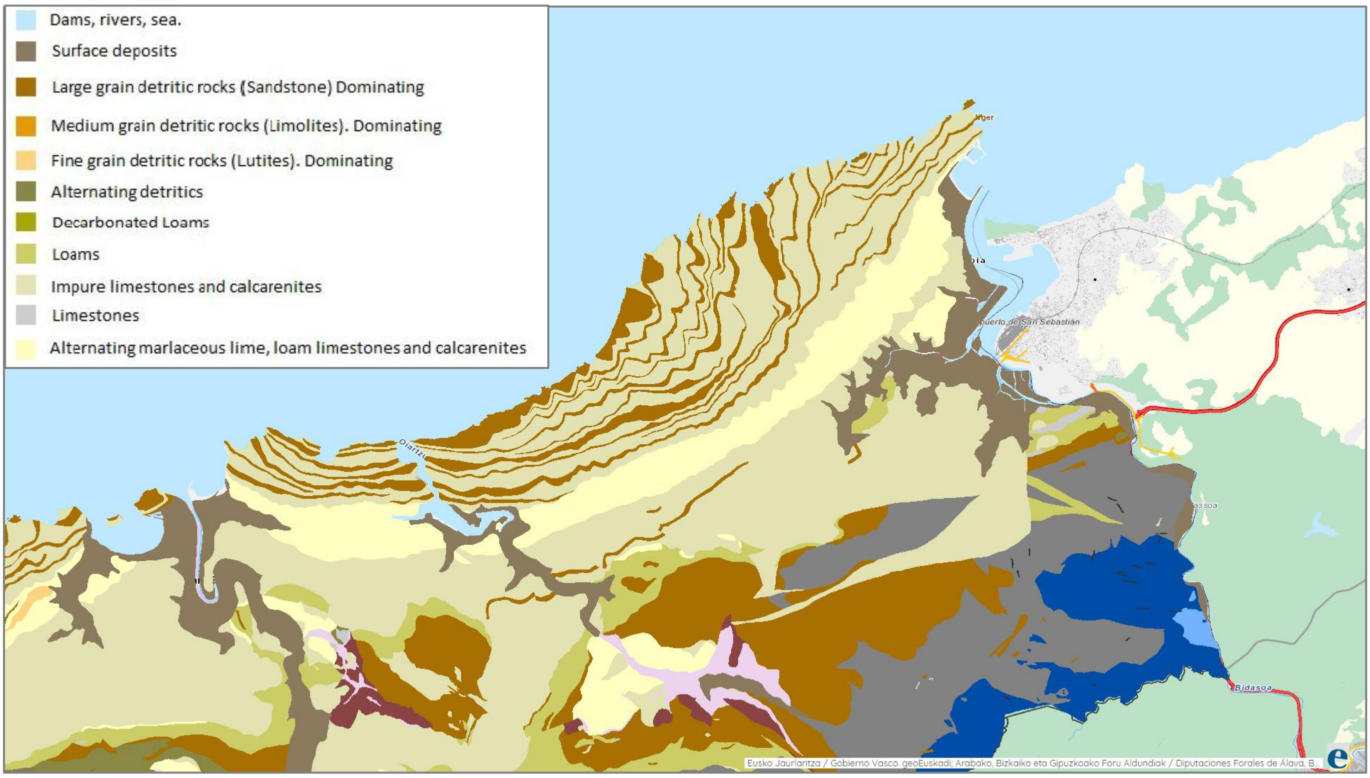


Figure 9: Lithology of Oarsoaldea shire. Source: GeoEuskadi web-viewer.

3.9. Oeiras CCLL

In the case of this CCLL, there is a number of results concerning climate change vulnerability available. The document *Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan (PMAACO), 2020* assesses and quantifies the impact of climate change on overtopping (SWAN and SWASH models) and coastal flooding (binary response model) and the morphological response of beaches (equilibrium profile model) according to two scenarios of mean sea level rise (+0.5 m and +1.5 m). The main results of the study are summarised in the following lines.

The coastline of Oeiras is essentially cliff and rocky or artificial, with small beaches, part of which can be used for bathing. The coastal strip is home to the urban fabric and relevant infrastructure, such as road networks, ports, defence equipment and basic sanitation infrastructure, which increases exposure to oceanographic forcing, evaluated in terms of overtopping, coastal flooding and variation in the morphodynamics of the beaches. These phenomena were evaluated in two MSLR scenarios in the time horizon of 2100, considering extreme events with return periods of 50 and 100 years.

Regarding the beaches, these occupy around 30% of the length of the coastline. Of a total of 12 beaches, five are considered urban bathing beaches with intensive use. As in most of the coastline of Oeiras, the coastline is associated with rigid structures, and the response capacity of this to changes in forcing is very limited.

The beaches of Oeiras have a relatively simple geomorphological configuration, with a sedimentary prism based on a rocky substrate, modelled on a single berm that articulates with a beach face. The beach face borders the rocky platform at -2 m elevation, and has slopes between 0.06 in Praia Velha, and 0.13 in the western section of Santo Amaro beach. The berm has a variable width between 20 and 70 m, and crest at an approximate height of 2 m.

The results of the study show that the rise in mean sea level could lead to a general reduction in the usable area of beaches in both modelled scenarios (see Table 43). In the scenario of +0.5 m MSLR, there is a reduction in width that varies between 16% and 40%, and on bathing beaches the magnitude of this reduction is 24% on average, with a maximum on Caxias beach (31 %). For the worst scenario (+1.5 m MSLR), the estimated reduction is greater than 80% on some beaches, with emphasis on Caxias beach, whose width will be reduced to 4 m, and on the western section of Dafundo beach, which is completely inundated. In this scenario, the only beach where a reduction of less than 50% is expected corresponds to the western sector of Santo Amaro beach. In both scenarios, the largest percentage of reductions are observed in the east sector of the municipality, but, in absolute terms, they occur in Praia Velha, Praia da Torre and Santo Amaro (west sector), with losses of 36 m, 32 m and 29 m. m (+1.5 m MSLR scenario), respectively.

Table 43: Variation of the width of the beach berm for two scenarios of sea level rise in Oeiras. Adapted from: Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan (PMAACO), 2020.

Beach	Reference beach width (m)	Loss in +0.5 m MSLR scenario (%)	Loss in +1.5 m MSLR scenario (%)
Torre	60	21	54
Santo Amaro - West	70	16	41
Santo Amaro - East	32	24	62
Paco de Arcos	40	21	55
Praia Velha	60	23	61
Caxias	22	31	82
S. Bruno de Caxias - West	32	27	70
S. Bruno de Caxias - East	31	27	71
Cruz Quebrada	32	31	82
Dafundo - West	20	40	100
Dafundo - East	35	28	72
Alges	25	34	90

Under current climatic conditions, coastal flooding mostly affects consolidated urban and residential green spaces (Table 44 and Figure 10). Also worth mentioning are the defence equipment and port areas, which, in this municipality, are located mainly on the coastline. In terms of flooded area, in the 50-year return period scenario, an area of 7 ha is potentially flooded, increasing to 10 ha in the 100-year return period scenario.

Table 44: Distribution of land cover/uses within Oeiras CCLL coastal flood-prone areas. Adapted from: Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan (PMAACO), 2020.

Land cover	Flooded area for the 50-year return period scenario (ha)	%	Flooded area for the 100-year return period scenario (ha)	%

Port area	0.60	8.44	0.74	7.19
Culture assets	0.00	0.00	0.00	0.00
Defence assets	0.47	6.61	0.61	5.93
Education assets	0.12	1.69	0.13	1.26
Leisure assets	0.00	0.00	0.00	0.00
Health assets	0.00	0.00	0.00	0.00
Water treatment assets	0.00	0.00	0.00	0.00
Sport assets	0.08	1.13	0.12	1.17
Urban green areas	2.23	31.36	2.99	29.06
Natural vegetation	0.51	7.17	0.70	6.80
Industrial/Commercial	0.18	2.53	1.30	12.63
No vegetation zones	0.14	1.97	0.22	2.14
Beaches, dunes, and sand plains	0.06	0.84	0.09	0.87
Agriculture	0.37	5.20	0.45	4.37
Transportation network	0.37	5.20	0.52	5.05
Urban	1.98	27.85	2.42	23.52
Bare rock	0.00	0.00	0.00	0.00
Total	7.11	100.00	10.29	100.00

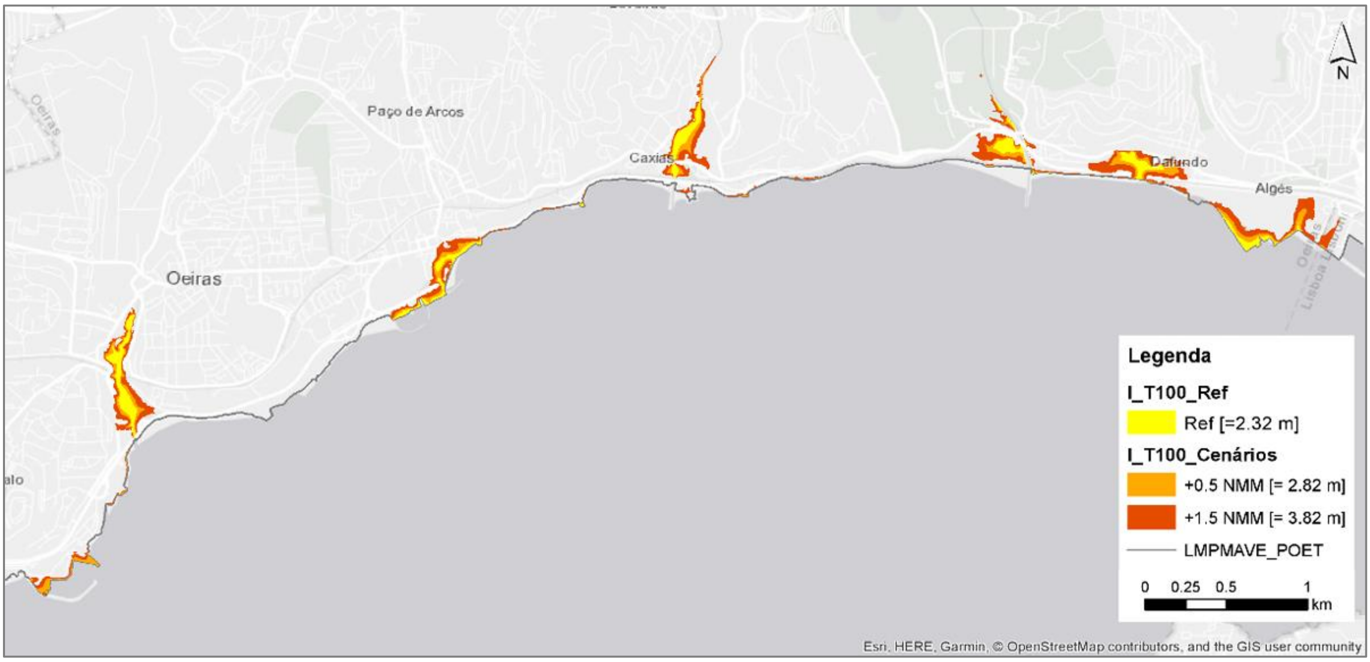


Figure 10: Coastal-flood-prone areas for the 100-year return period in Oeiras under current climatic conditions (yellow), +0.5 m MSLR (orange) and +1.5 m MSLR (red) scenarios. Source: Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan (PMAACO), 2020

The effects of climate change on the coastal zone are transversal to the various sectors considered in the Plan. For each sector, the main impacts were identified, and vulnerability assessed, in the present and future scenarios. The results regarding exposure under the current climatic conditions are summarised in Table 45.

Table 45: Exposure to coastal erosion and coastal flooding in Oeiras CCLL. Adapted from: Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan (PMAACO), 2020.

Sector	Hazard	Exposure
Oeiras coastline	Coastal erosion	Low
Beach	Coastal erosion	Low
Beach	Coastal flooding	High
Coastal aquifers	Seawater intrusion	Medium
Hydrographical network	Coastal flooding	Medium
Residential buildings	Coastal flooding	Low
Critical assets	Coastal flooding	Low
Critical infrastructure	Coastal flooding	High
Cultural heritage	Coastal flooding	Medium
Tourism	Coastal flooding	High

Regarding the land flooding hazard, the documents “Hydrological and Hydraulic Study of the Oeiras Watersheds for the elaboration of a map of areas subject to flooding in accordance with Decree-Law No. 115/2010” assesses the current and future vulnerability in terms of floods and inundations for the Jamor river basin, consisted of the delimitation of floodable areas and their corresponding maximum flood depths and the respective associated hazard, for different return periods. The different time scenarios are based in the projections of climate scenarios in the short (2011-2040), medium (2041-2070) and long term (2071-2100) and the results for the Jamor River were extrapolated for the remaining river basins.

In this context, floodplain areas associated with return periods of 20, 50, 100 and 500 years, which resulted from the elaboration of this study, were calculated assigning a degree of danger that worsens according to the recurrence of the flood (e.g., the return period of 20 years has associated a higher level of danger than the return period of 50 years). After attributing the levels of danger to each floodable area, corresponding to each return period, the information was aggregated into a global index related to the topic in question. The result of this extrapolation to the present, considering the current climatic conditions, is shown in Figure 11.

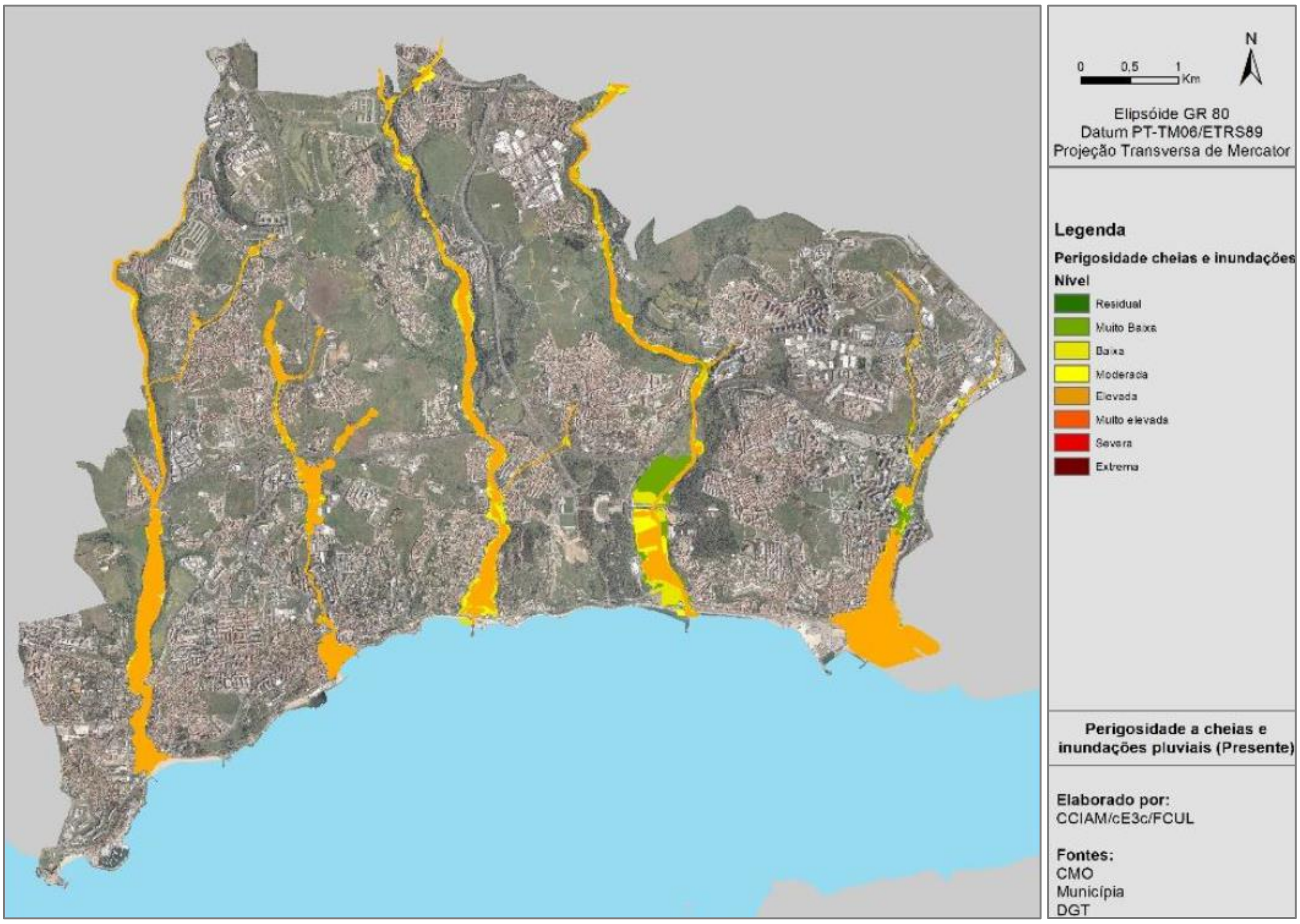


Figure 11: Extrapolated land flooding hazard in Oeiras in the present. Source: Hydrological and Hydraulic Study of the Oeiras Watersheds for the elaboration of a map of areas subject to flooding in accordance with Decree-Law No. 115/2010.

From this cartography, it is possible to verify that the municipality of Oeiras currently reaches a high level of danger to floods, with special relevance to the areas further downstream of the water lines. These areas are especially sensitive because they are areas with high urban density (e.g., downtown Algés, Paço de Arcos).

The vulnerability to this hazard is assessed in the document *Municipal plan for adaptation to climate change in Oeiras*, whose main results are summarised for each parish hereafter and in form of a matrix in Table 46.

Table 46: Exposure to land flooding in Oeiras CCLL. Adapted from: Municipal plan for adaptation to climate change in Oeiras.

Area (Parish)	Transportation network	Agriculture	Economic activity	Tourism	Critical assets
Algés, Linda-a-Velha e Cruz Quebrada-Dafundo	High	Low	High	High	High
Carnaxide e Queijas	Medium	Low	High	Medium	Medium
Barcarena	High	High	Medium	Medium	Medium
Porto Salvo	High	Low	Medium	Low	Low
Oeiras e São Julião da Barra, Paço de Arcos e Caxias	High	Low	Low	Medium	Low

In the case of agriculture, floods can cause partial or total losses in plant production, either by root asphyxiation in situations of prolonged flooding, or by dragging the soil, parts or the entire plant. Of the areas under study, only the Pedreira Italiana garden is at a sufficiently small distance from a stream (Ribeira de Barcarena) to be at risk of flooding. Almost the entire garden area is in a zone of moderate to very high danger at the beginning of the century, being therefore quite vulnerable to floods.

With regard to the transport sector and communication routes, the vulnerability of the transport infrastructure network to floods is high for all the parishes with exception of Carnaxide e Queijas, where is estimated as medium. In general, the North-South orientation of the numerous rivers existing in Oeiras, and their related floodplains expose the transportation network as these could generate generalised traffic constraints, especially at the intermodal station (including railway) in downtown Algés.

The parishes of Barcarena and Porto Salvo stand out for having an area of green spaces greater than the area occupied by the urban fabric, according to the Urban Atlas classification (Table 47). Within these spaces, associations of herbaceous vegetation stand out, scattered throughout the Municipality, with greater emphasis in the parishes of Barcarena, and in the Union of parishes of Carnaxide and Queijas.

Table 47: Green areas in Oeiras CCLL. Adapted from: Municipal plan for adaptation to climate change in Oeiras.

Area (Parish)	Green areas (%)	Urban (%)	Road (%)	Total (%)	Exposure
Algés, Linda-a-Velha e Cruz Quebrada-Dafundo	32.6	52.3	15.1	100	Low
Carnaxide e Queijas	40.1	49.3	10.6	100	Medium
Barcarena	55.4	35	9.6	100	High
Porto Salvo	49.2	41.3	9.5	100	High
Oeiras e São Julião da Barra, Paço de Arcos e Caxias	32.1	52	15.9	100	Medium

Finally, some indicators of social vulnerability for the entire municipality are presented. These have not been scored due to a lack of equivalent data for the rest of the CCLLs for contrast and adjustment.

Table 48: Social exposure indicator for Oeiras CCLL population.

Indicator	Value	Percentage of total
Total population (2021)	171767	100
Population under 14 years old	24318	14.2
Population over 65 years old	41299	24.0
Population with no educational background	20628	12.0
Population with tertiary education	56825	33.1
Female population	92089	53.6
Lone-parent families (2011)	10252	6.0

Population with income under 5000 euro/year	7346	4.3
Occupied population (2011)	76717	44.7
Intransient population (2011)	116479	67.8
Population density (inhabitant/km^2)	3734	-
Average number of floors per building (2011)	3	-
1-person households	-	30.2
5-or-more-persons household	-	5.2

4.CONCLUSIONS

The main outcomes of a high-level characterisation of exposure and vulnerability to climate effects and sea level rise for the ten CCLLs are summarised in this report. Specifically, exposure and vulnerability indicators have been developed, measured and score, and maps for some of them have been also produced and presented in Appendix – maps.

The outputs have been produced bespoke for each city, regardless of the Frontrunner or Fellow status, although the results may be limited by the availability of the information and the resolution of the datasets used. Table 49 and Table 50 present a summary of the maps produced in this task.

Moreover, it has been analysed how exposed are the CCLLs at high level, observing than the concerns vary between them. This constitutes an important milestone for the completion of the baseline risk analysis and mapping of extreme climate impacts and sea level rise in WP1, which will be carried out in Task 1.4 – Baseline risk analysis and mapping of extreme climate impacts and sea level rise.

The indicators developed in this report will be used to assess the risk that the different key climate-related identified in the report D1.2 produces in the CCLLs.

5. REFERENCES

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268–281. https://doi.org/https://doi.org/10.1016/j.gloenvcha.2006.02.006

Dottori, F., Alfieri, L., Bianchi, A., Skoien, J., & Salamon, P. (2021). *River flood hazard maps for Europe and the Mediterranean Basin region*.

Günther, A., Van Den Eeckhaut, M., Malet, J.-P., Reichenbach, P., & Hervás, J. (2014). Climate-physiographically differentiated Pan-European landslide susceptibility assessment using spatial multi-criteria evaluation and transnational landslide information. *Geomorphology*, *224*, 69–85. https://doi.org/https://doi.org/10.1016/j.geomorph.2014.07.011

Klein Tank, A. M. G., Wijngaard, J. B., Können, G. P., Böhm, R., Demarée, G., Gocheva, A., Mileta, M., Pashiardis, S., Hejkrlik, L., Kern-Hansen, C., Heino, R., Bessemoulin, P., Müller-Westermeier, G., Tzanakou, M., Szalai, S., Pálsdóttir, T., Fitzgerald, D., Rubin, S., Capaldo, M., … Petrovic, P. (2002). Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. *International Journal of Climatology*, *22*(12), 1441–1453. https://doi.org/https://doi.org/10.1002/joc.773

Le Cozannet, G., Oliveros, C., Brivois, O., Giremus, A., Garcin, M., & Lavigne, F. (2020). Detecting Changes in European Shoreline Evolution Trends Using Markov Chains and the Eurosion Database. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.00326

MacManus, K., Balk, D., Engin, H., McGranahan, G., & Inman, R. (2021). Estimating population and urban areas at risk of coastal hazards, 1990–2015: how data choices matter. *Earth System Science Data*, *13*(12), 5747–5801. https://doi.org/10.5194/essd-13-5747-2021

McEvoy, S., Haasnoot, M., & Biesbroek, R. (2021). How are European countries planning for sea level rise? *Ocean & Coastal Management*, *203*, 105512. https://doi.org/https://doi.org/10.1016/j.ocecoaman.2020.105512

Neilson, B., & Costello, M. J. (1999). The Relative Lengths of Seashore Substrata Around the Coastline of Ireland as Determined by Digital Methods in a Geographical Information System. *Estuarine, Coastal and Shelf Science*, *49*(4), 501–508. https://doi.org/https://doi.org/10.1006/ecss.1999.0507

Ramieri, E., Hartley, A. J., Barbanti, A., Santos, F. D., Laihonen, P., Natasha, & Marinova. (2011). *Methods for assessing coastal vulnerability to climate change ETC CCA*.

Wilde, M., Günther, A., Reichenbach, P., Malet, J.-P., & Hervás, J. (2018). Pan-European landslide susceptibility mapping: ELSUS Version 2. *Journal of Maps*, *14*(2), 97–104. https://doi.org/10.1080/17445647.2018.1432511

Yamazaki, D., Ikeshima, D., Tawatari, R., Yamaguchi, T., O'Loughlin, F., Neal, J. C., Sampson, C. C., Kanae, S., & Bates, P. D. (2017). A high-accuracy map of global terrain elevations. *Geophysical Research Letters*, *44*(11), 5844–5853. https://doi.org/https://doi.org/10.1002/2017GL072874

APPENDIX – MAPS

Table 49: Summary of maps produced and data sources– Part I.

CCLL	Land cover (LC)	LECZ	LECZ	Land flooding	Land flooding LC
Sligo	CLC 2018 v.2020_20u1	MERIT DEM	CLC 2018 v.2020_20u1; MERIT DEM	Dottori et al. (2021)	CLC; Dottori et al. (2021)
Dublin	Urban Atlas 2012	MERIT DEM	Urban Atlas 2012; MERIT DEM	Dottori et al. (2021)	Urban Atlas 2012; Dottori et al. (2021)
Vilanova i la Geltrú	CLC 2018 v.2020_20u1	MERIT DEM	CLC 2018 v.2020_20u1; MERIT DEM	CCLL partners	CLC 2018 v.2020_20u1; CCLL partners
Benidorm	Urban Atlas 2012	MERIT DEM	Urban Atlas 2012; MERIT DEM	-	-
Oarsoaldea	CLC 2018 v.2020_20u1	MERIT DEM	CLC 2018 v.2020_20u1; MERIT DEM	Dottori et al. (2021)	CLC 2018 v.2020_20u1; Dottori et al. (2021)
Oeiras	-	-	-	-	-
Massa	Urban Atlas 2012	MERIT DEM	Urban Atlas 2012; MERIT DEM	-	-
Piran	CLC 2018 v.2020_20u1	MERIT DEM	CLC 2018 v.2020_20u1; MERIT DEM	-	-
Gdansk	Urban Atlas 2012	MERIT DEM	Urban Atlas 2012; MERIT DEM	Dottori et al. (2021)	Urban Atlas 2012; Dottori et al. (2021)
Samsun	Urban Atlas 2012; CLC 2018 v.2020_20u1	MERIT DEM	Urban Atlas 2012; CLC 2018 v.2020_20u1; MERIT DEM	Dottori et al. (2021)	Urban Atlas 2012; Dottori et al. (2021)

Table 50: Summary of maps produced and data sources – Part II.

CCLL	Landslide	Landslide LC	Forest fire	Forest fire LC	Strong winds	Strong winds LC
Vilanova i la Geltrú	-	-	CCLL partners	CLC 2018 v.2020_20u1; CCLL partners	CCLL partners	CLC 2018 v.2020_20u1; CCLL partners
Oarsoaldea	ELSUS v2	CLC 2018 v.2020_20u1; ELSUS v2	-	-	-	-
Massa	PGRA Tuscany	CLC 2018 v.2020_20u1; PGRA Tuscany	-	-	-	-

5.1. Sligo

Figure 12: Sligo CCLL – LECZ.

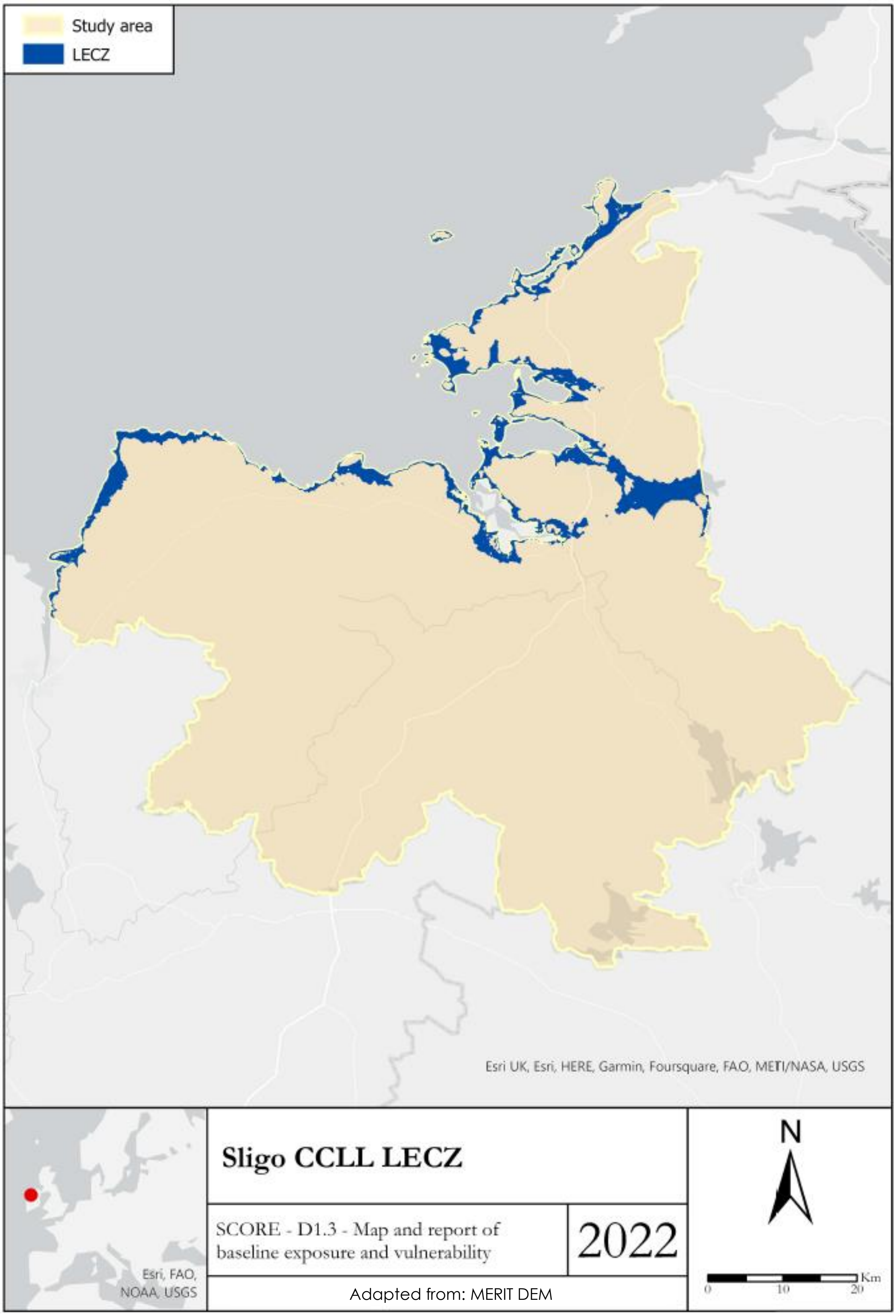


Figure 13: Sligo CCLL – land cover.

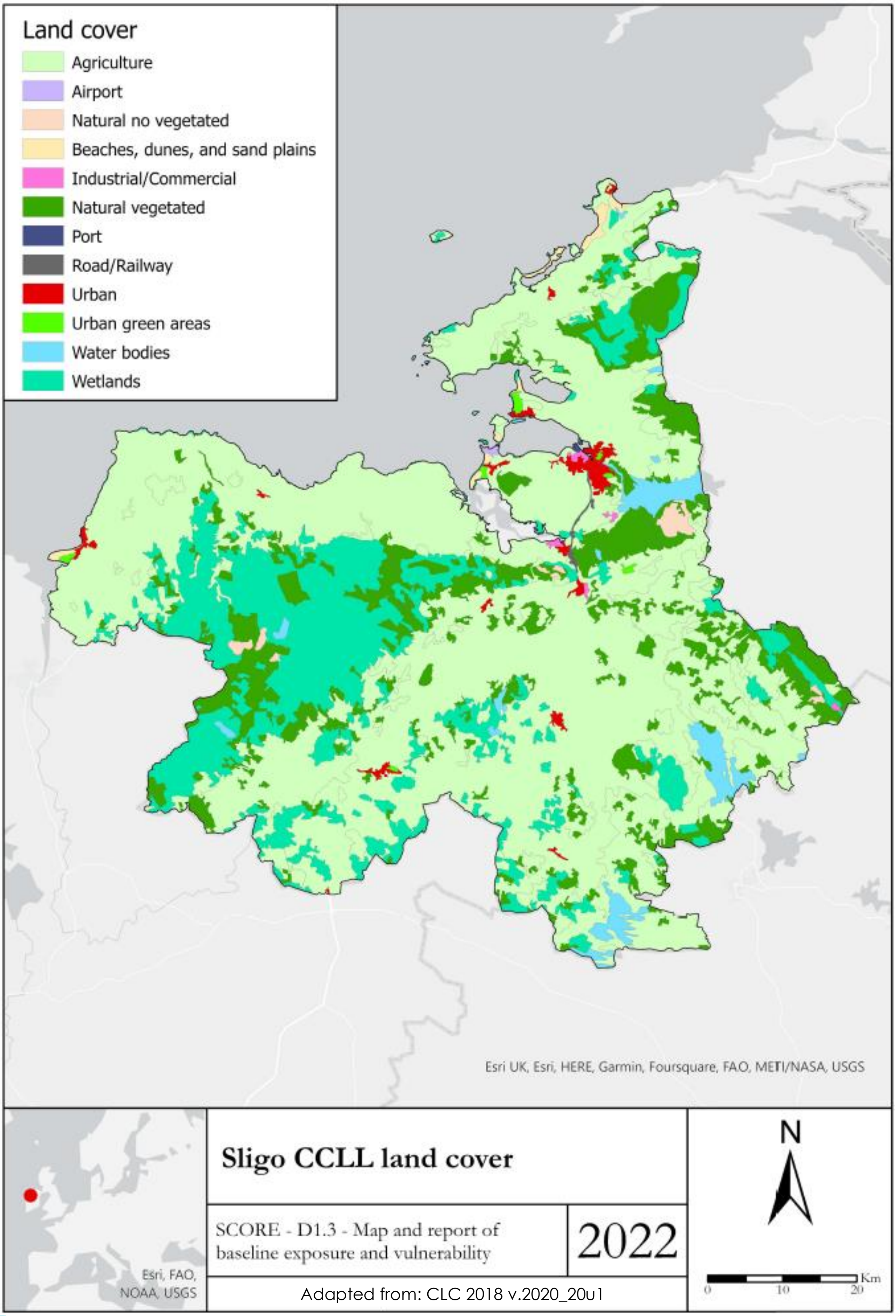


Figure 14: Sligo CCLL – LECZ land cover.

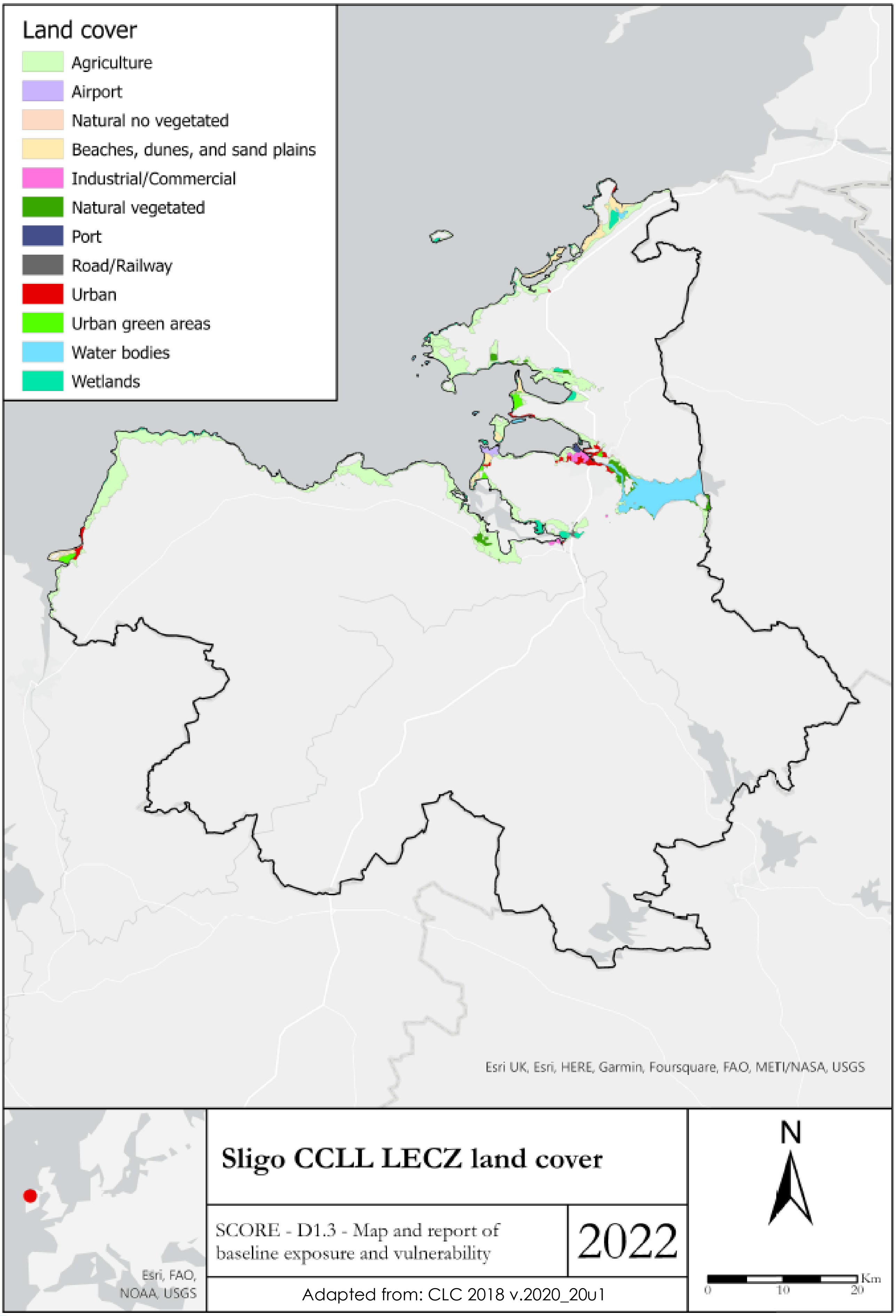


Figure 15: Sligo CCLL – flood-prone areas.

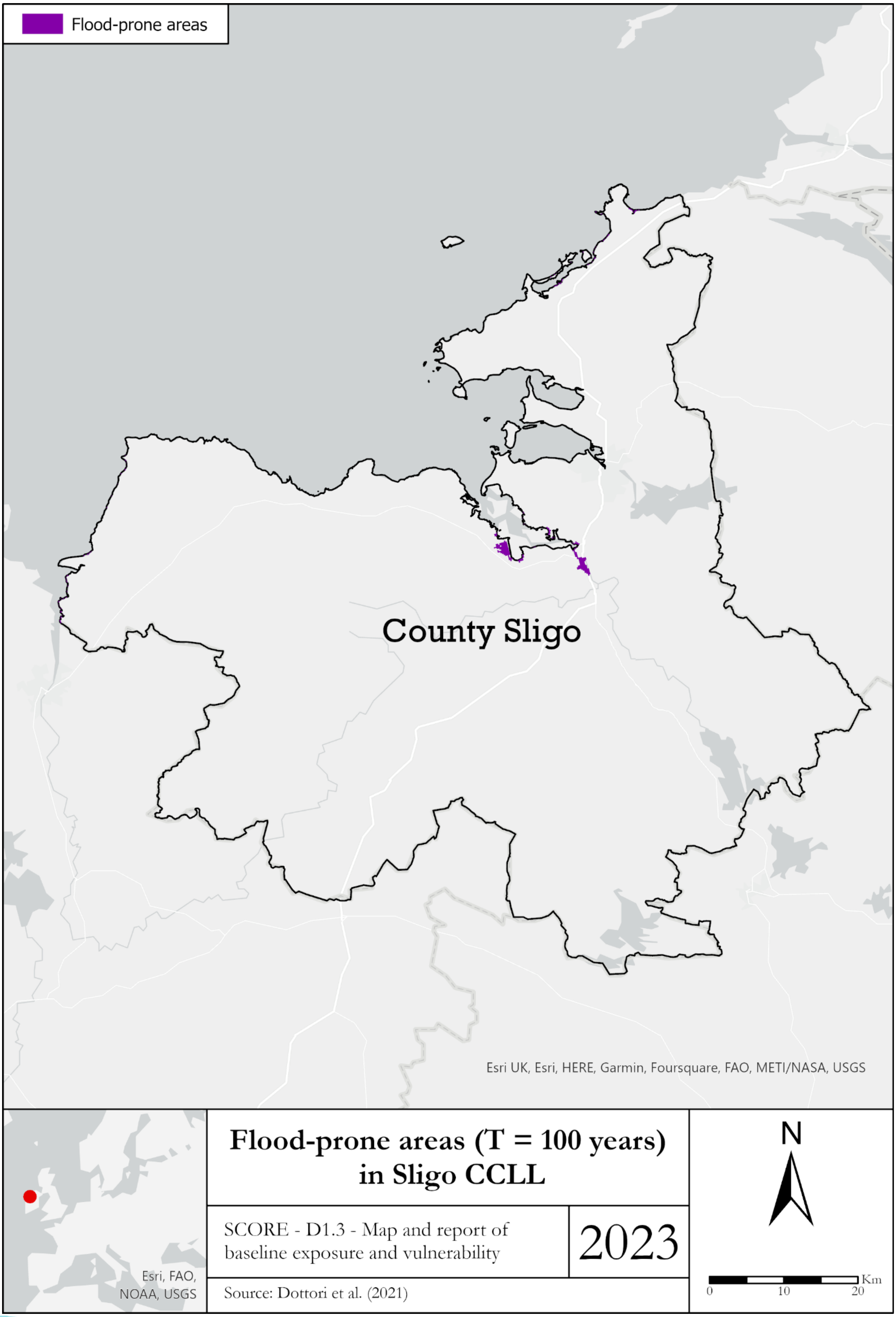
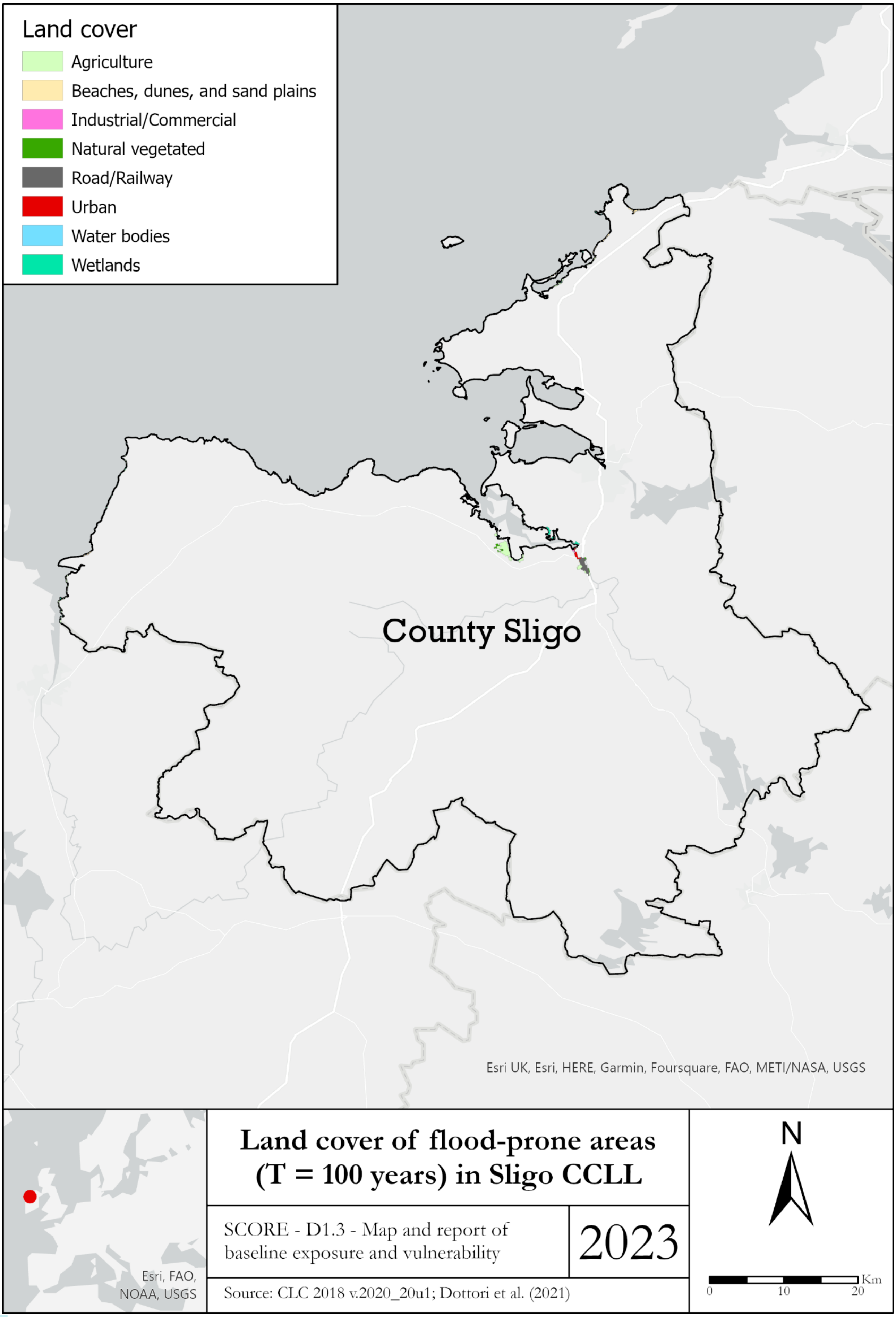


Figure 16: Sligo CCLL – land cover of flood-prone areas.



5.2. Dublin

Figure 17: Dublin CCLL – LECZ.

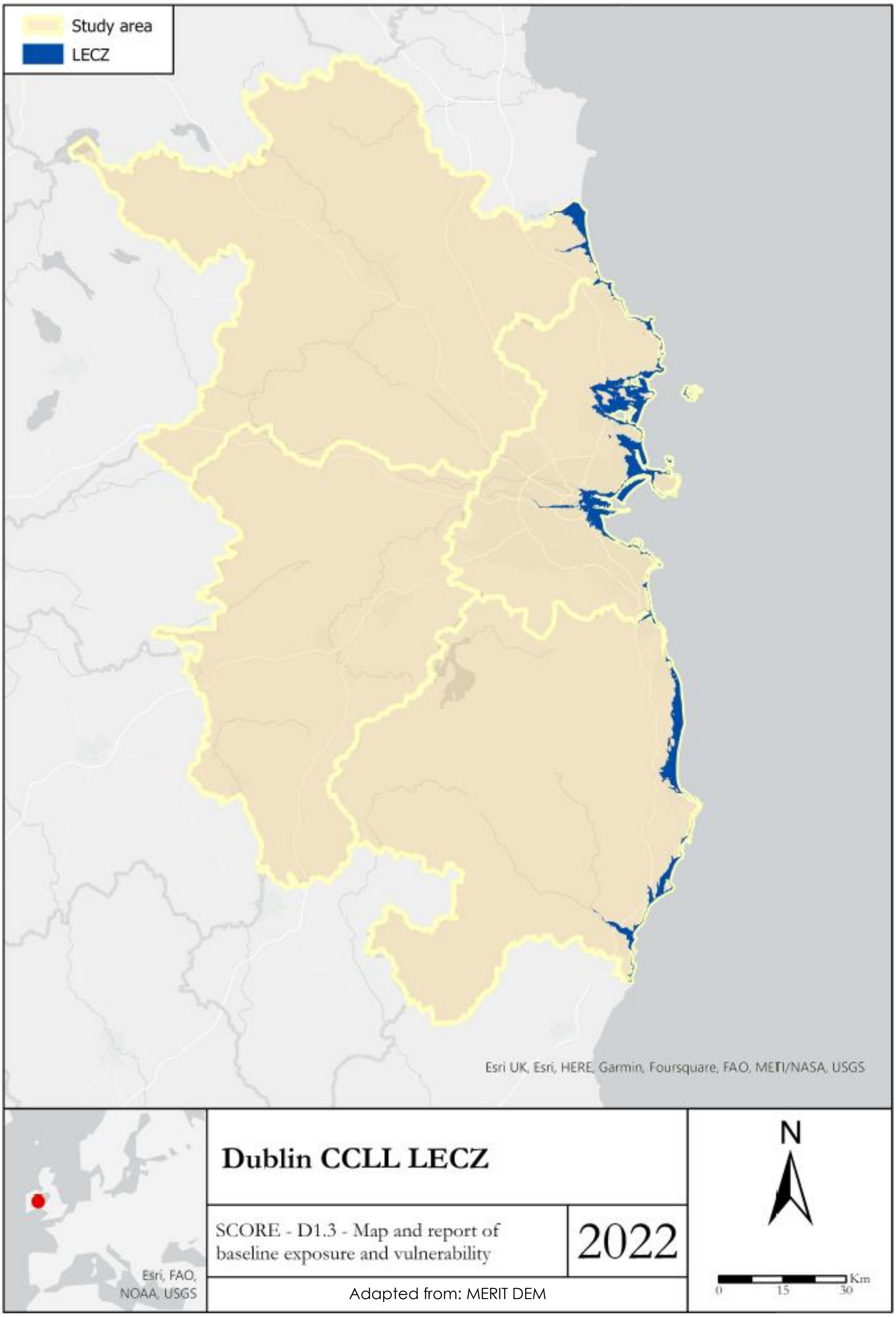


Figure 18: Dublin CCLL – land cover.

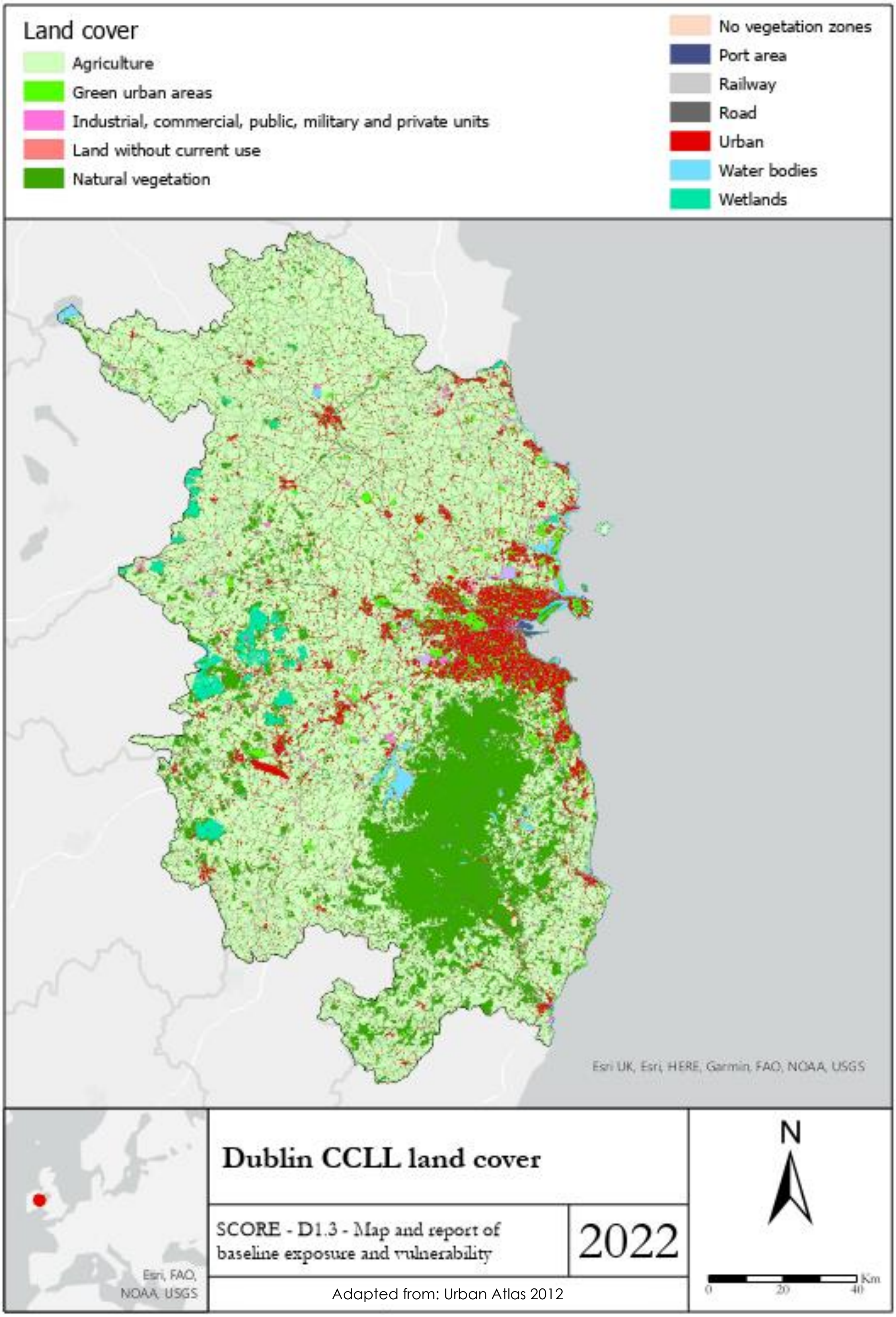


Figure 19: Dublin CCLL – LECZ land cover.

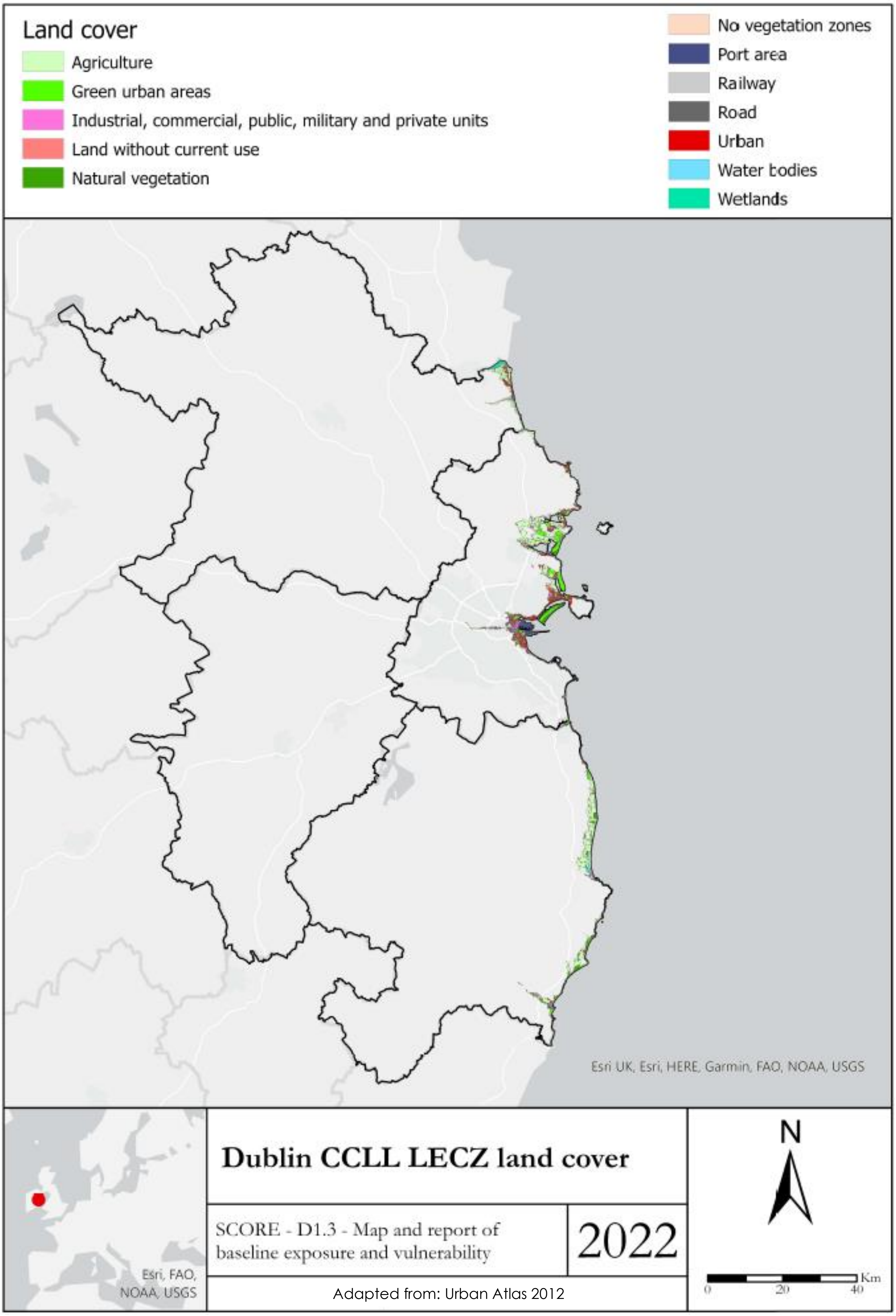


Figure 20: Dublin CCLL – flood-prone areas.

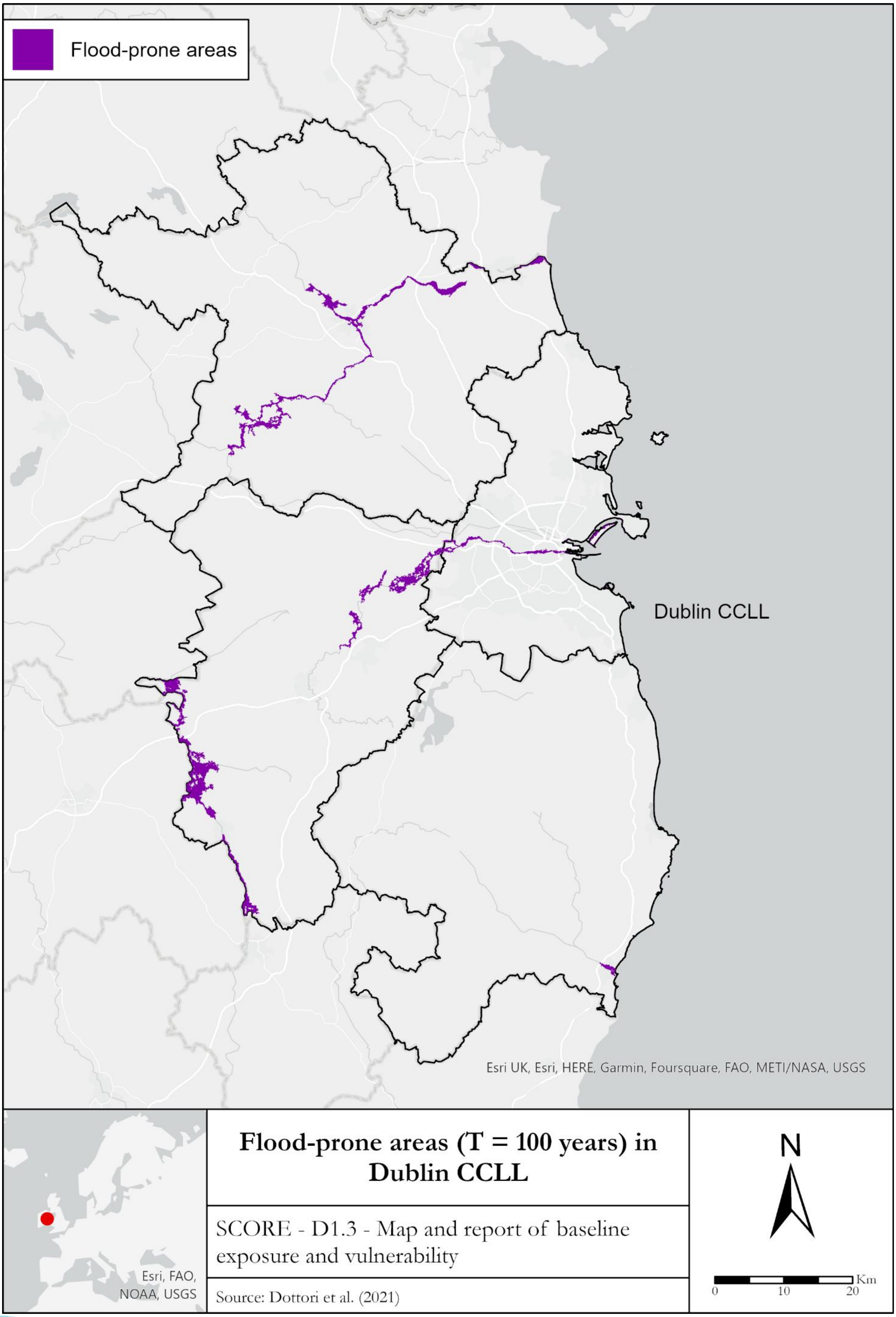


Figure 21: Dublin CCLL – land cover of flood-prone areas (County Meath)

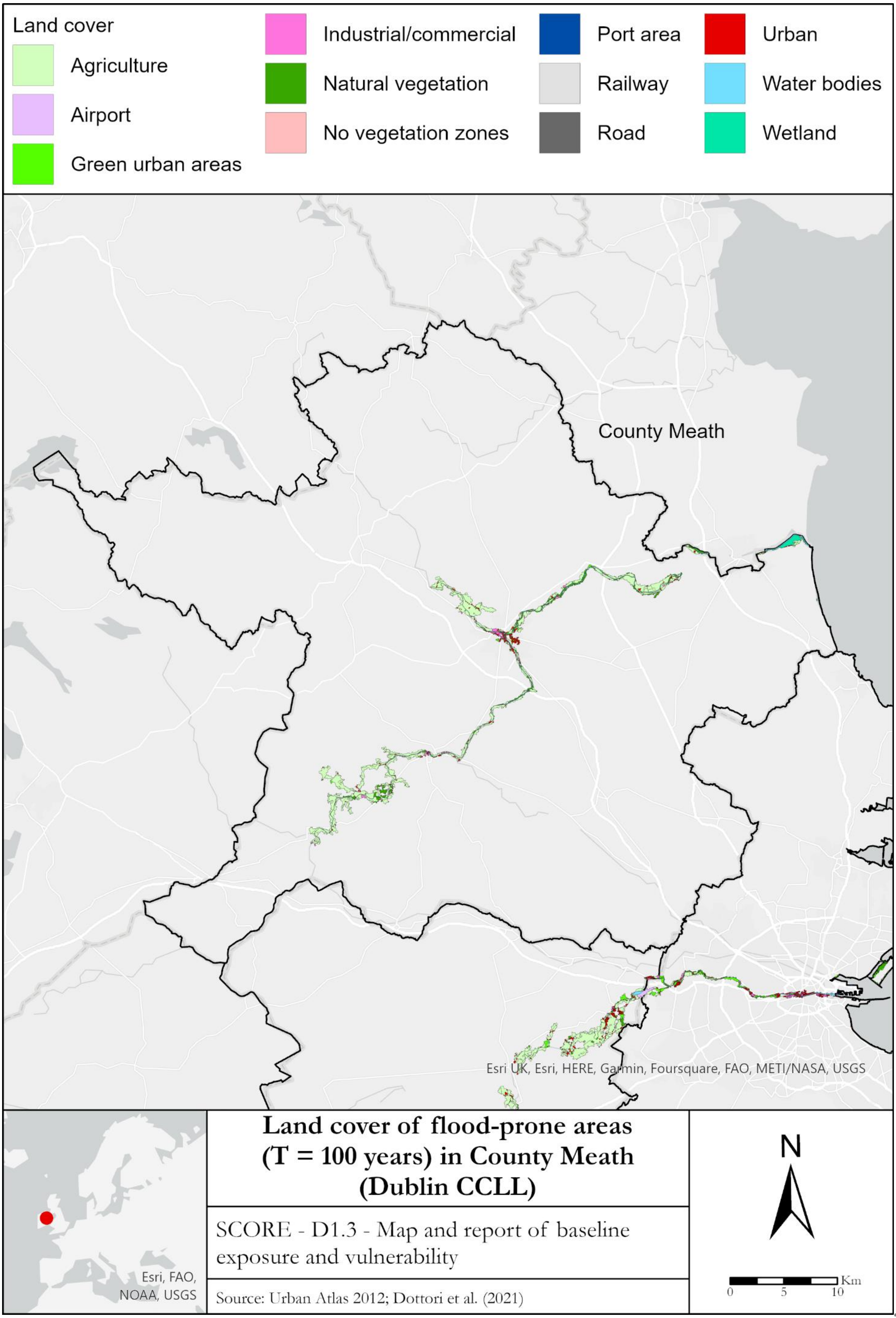


Figure 22: Dublin CCLL – land cover of flood-prone areas (County Dublin and County Kildare)

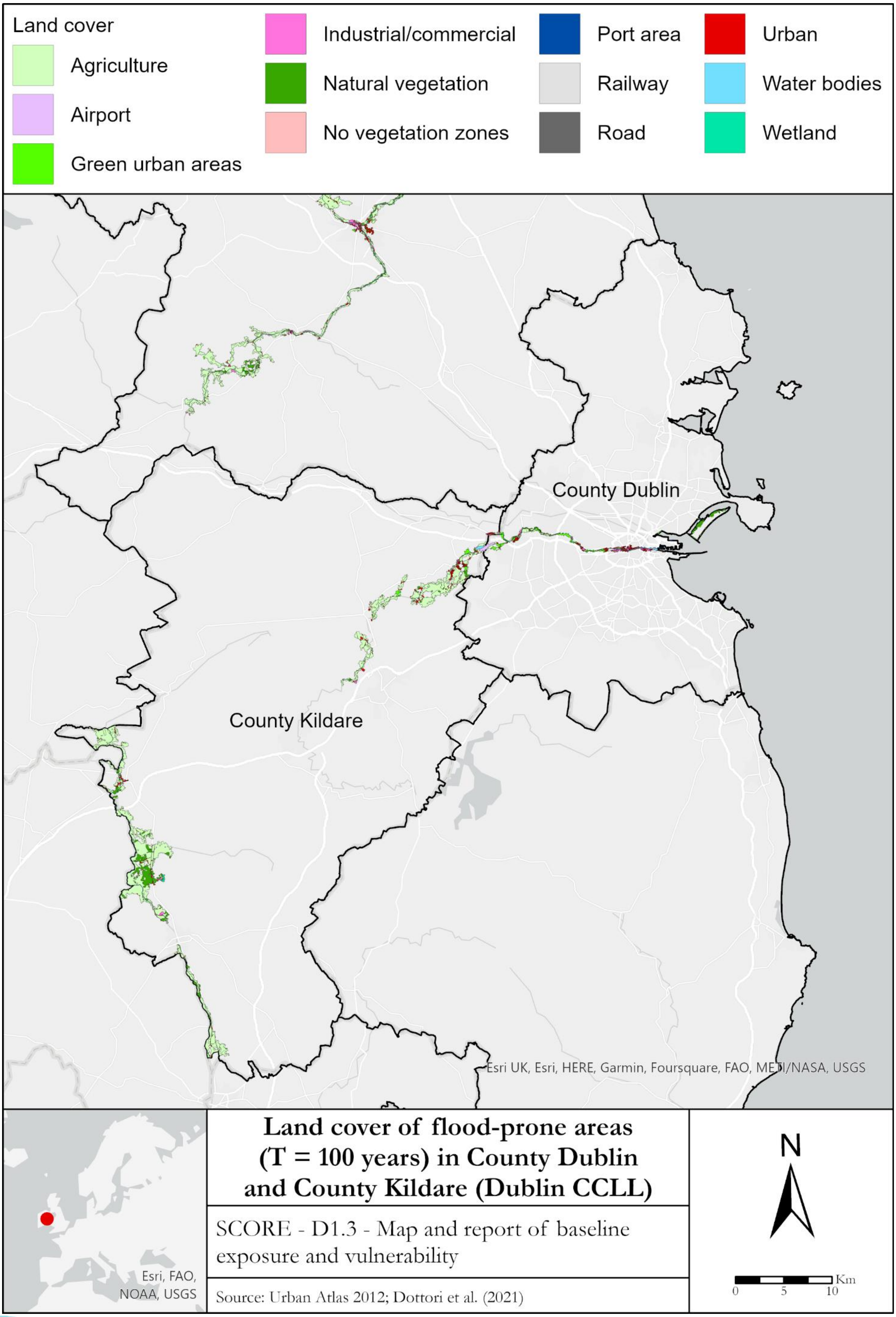
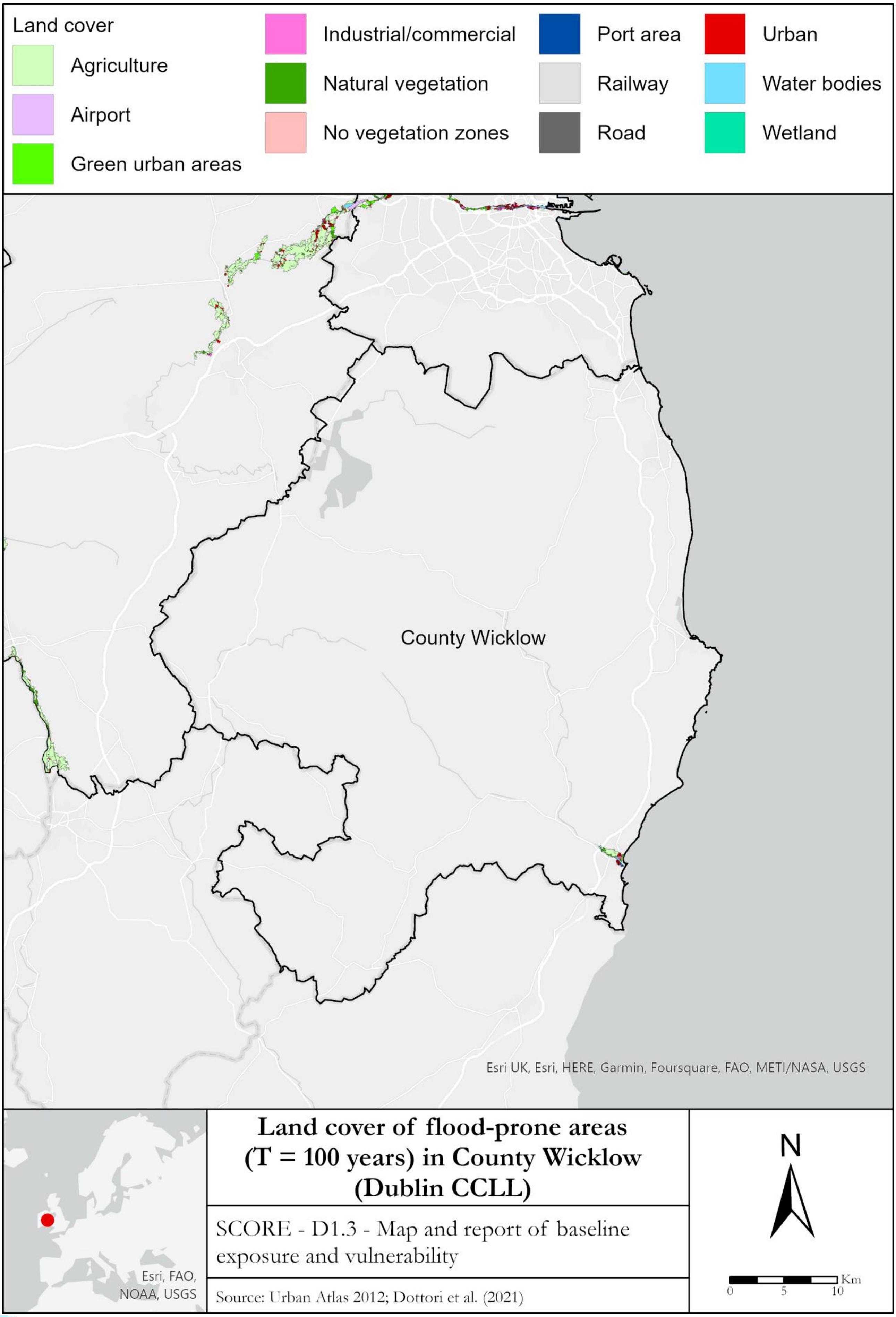


Figure 23: Dublin CCLL – land cover of flood-prone areas (County Wicklow)



5.3. Vilanova i la Geltrú

Figure 24: Vilanova i la Geltrú CCLL – LECZ.

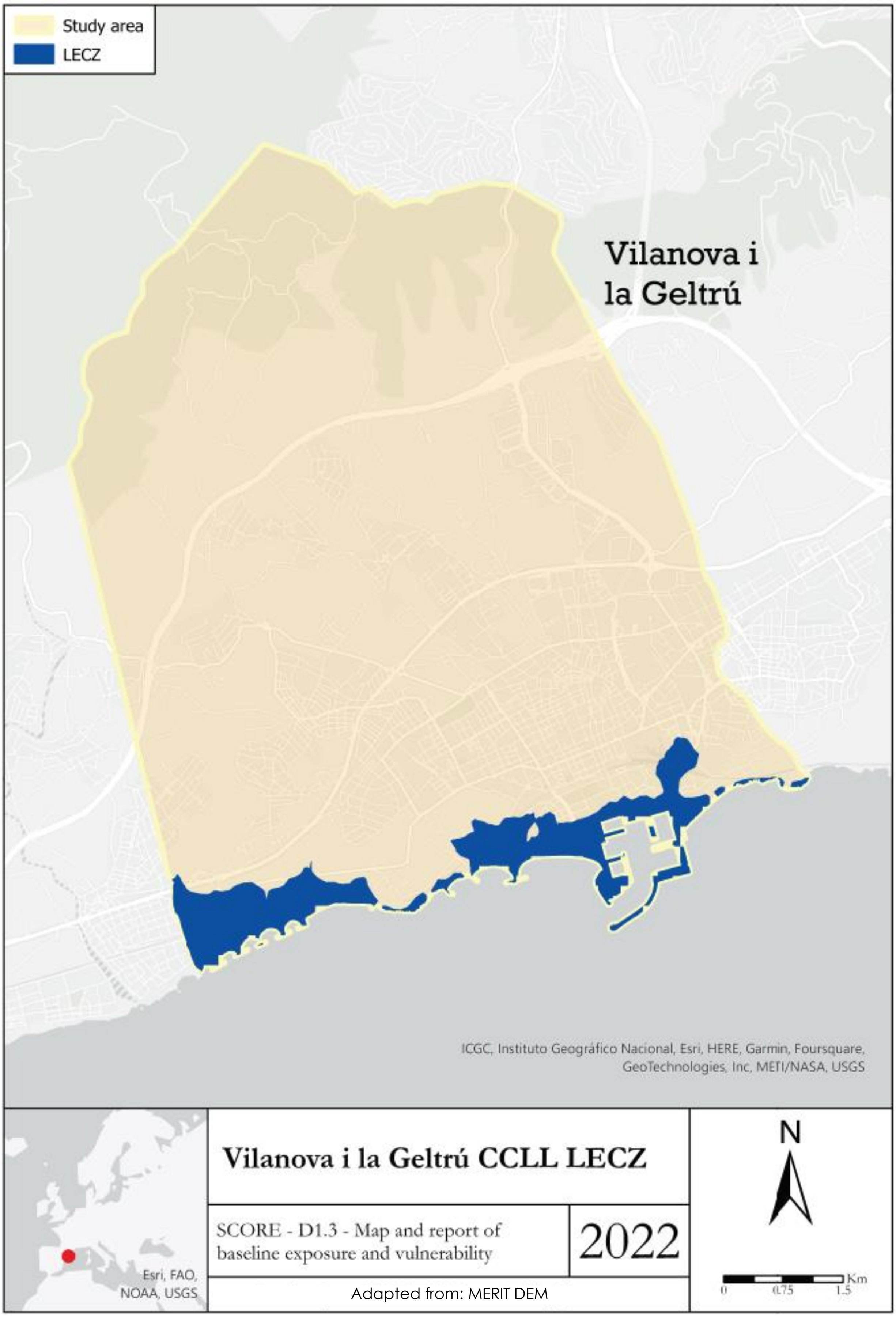


Figure 25: Vilanova i la Geltrú CCLL – land cover.

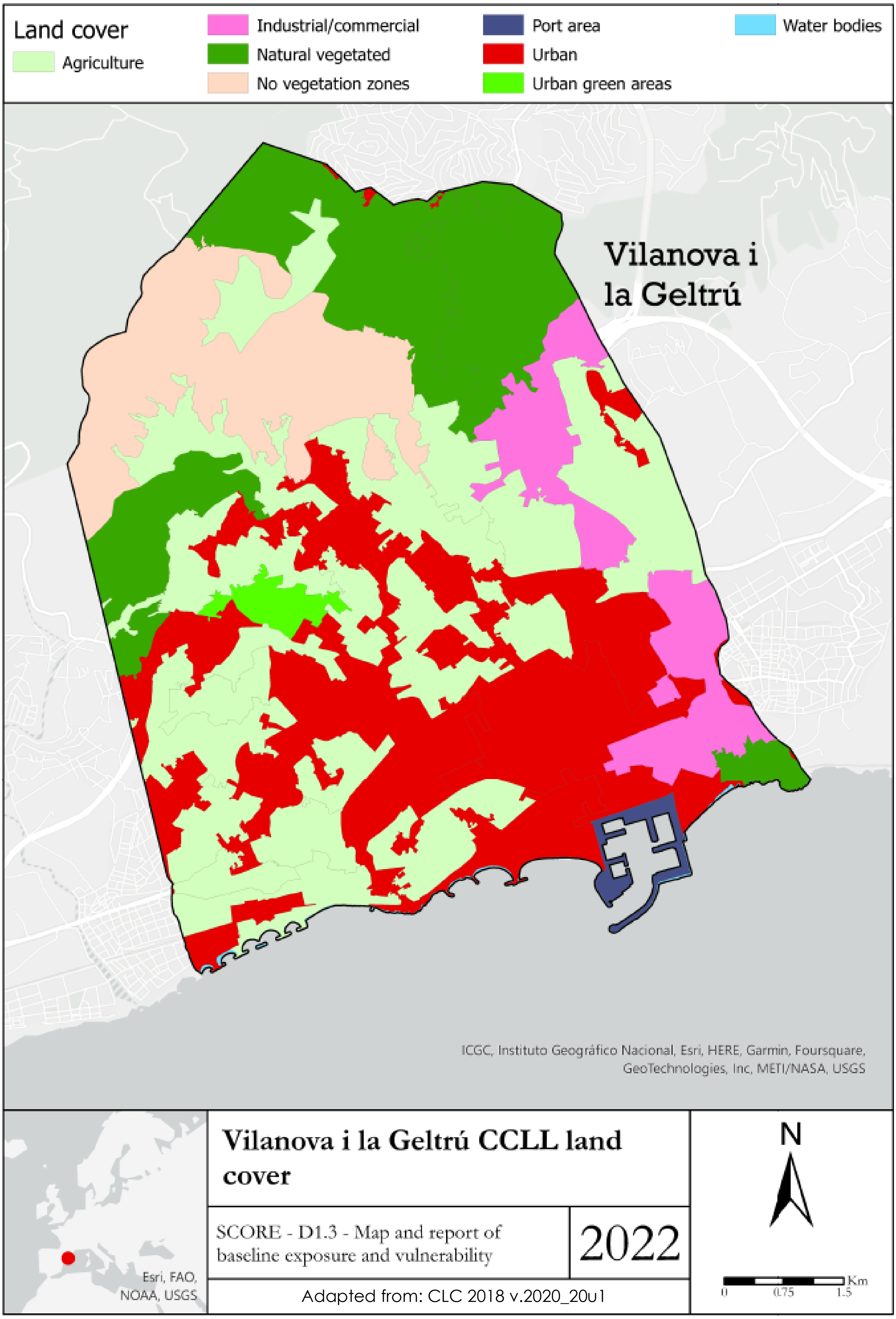


Figure 26: Vilanova i la Geltrú CCLL – LECZ land cover.

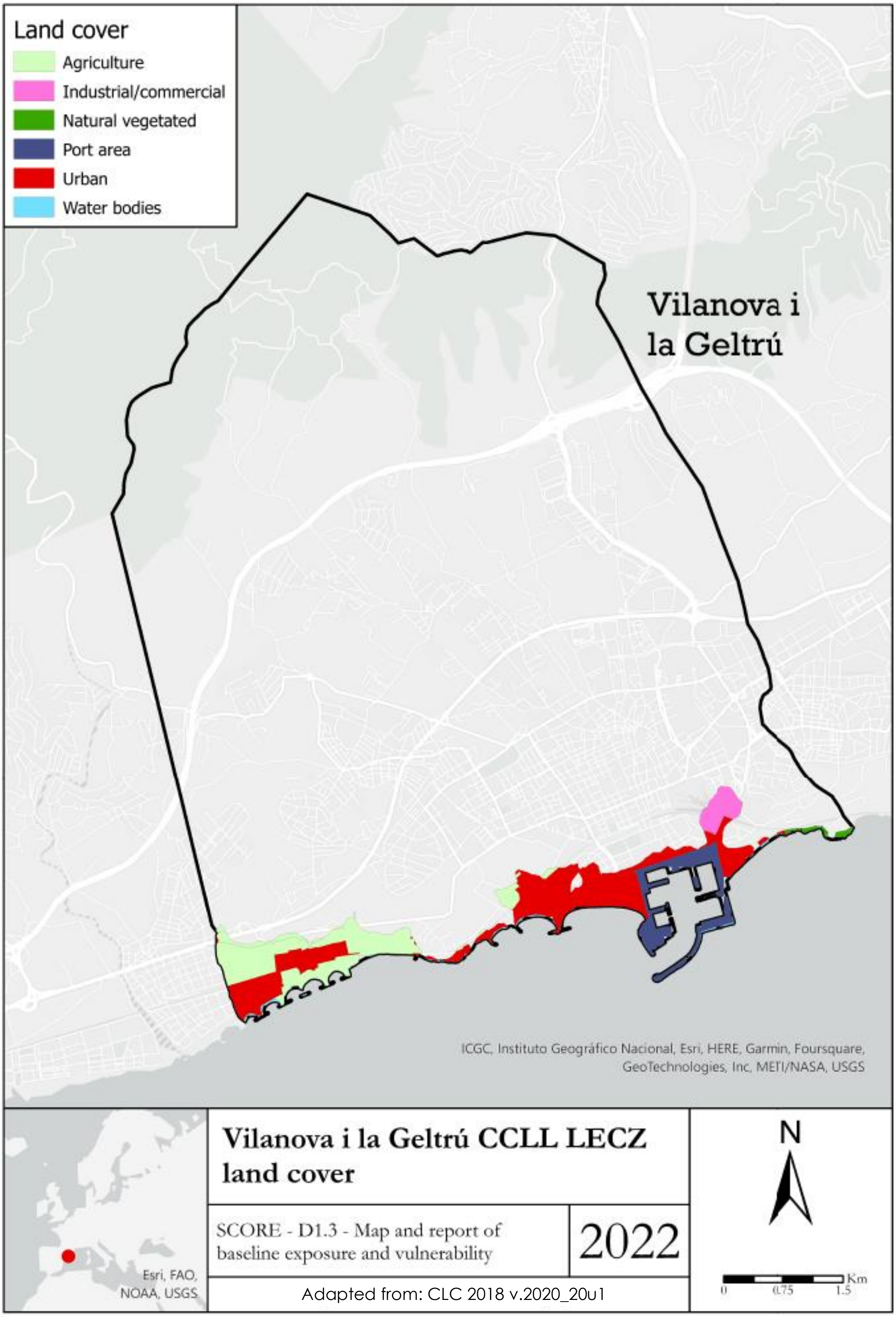


Figure 27: Vilanova i la Geltrú CCLL – flood-prone areas (areas of periodic flooding)

Figure 28: Vilanova i la Geltrú CCLL – land cover of flood-prone areas (areas of periodic flooding)

Figure 29: Vilanova i la Geltrú CCLL – areas of past forest fires

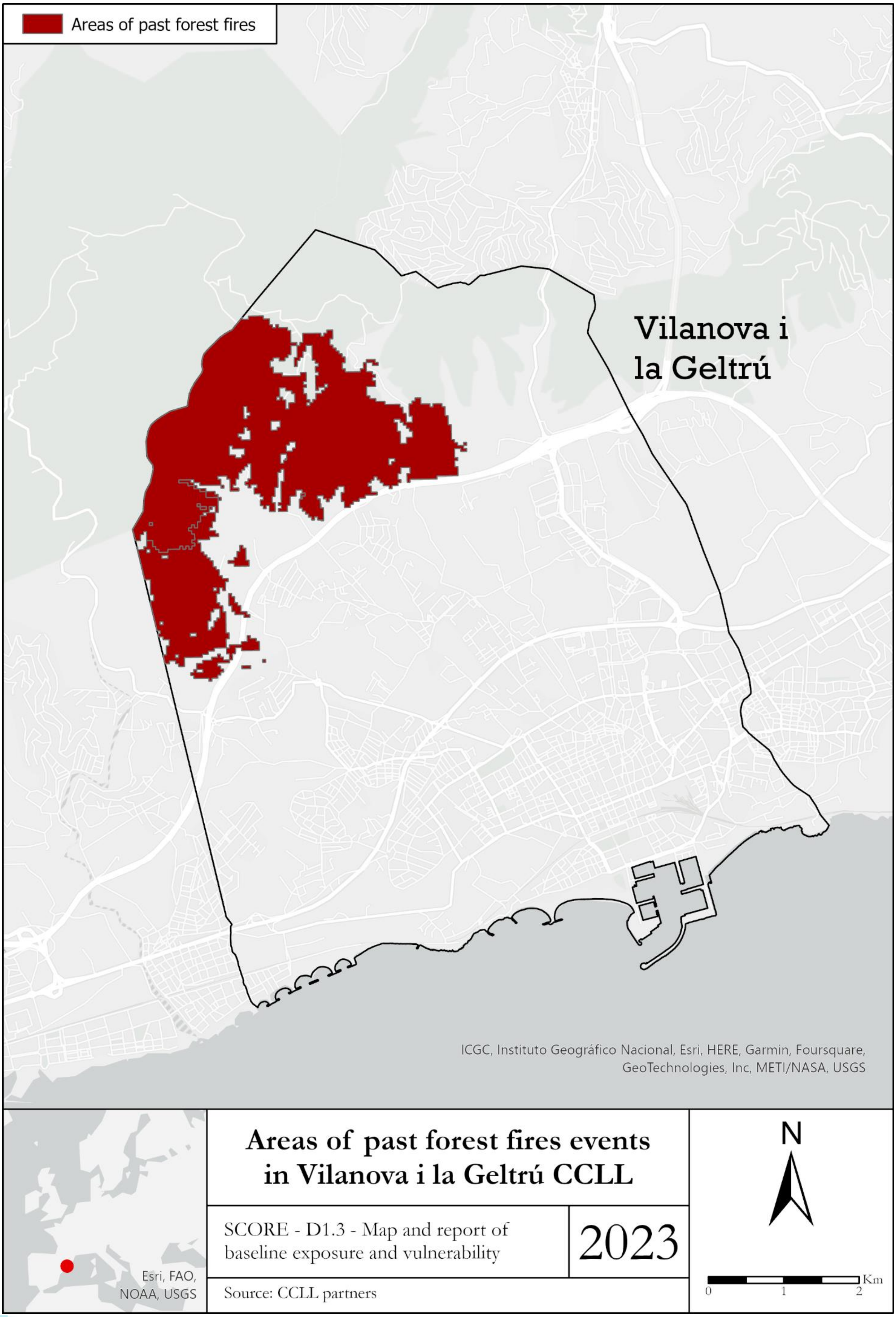


Figure 30: Vilanova i la Geltrú CCLL – land cover of areas of past forest fires

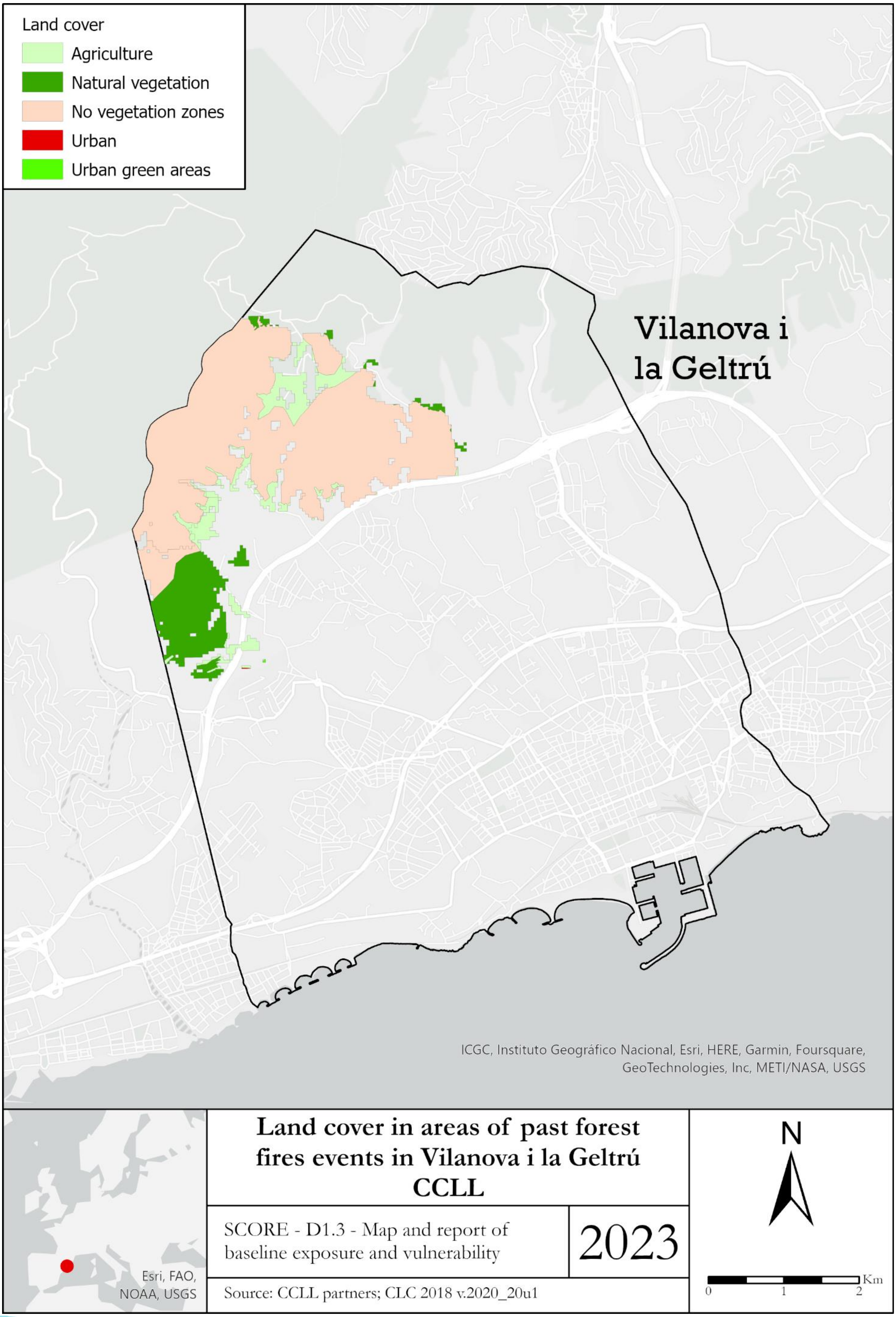


Figure 31: Vilanova i la Geltrú CCLL – areas of past events of strong winds

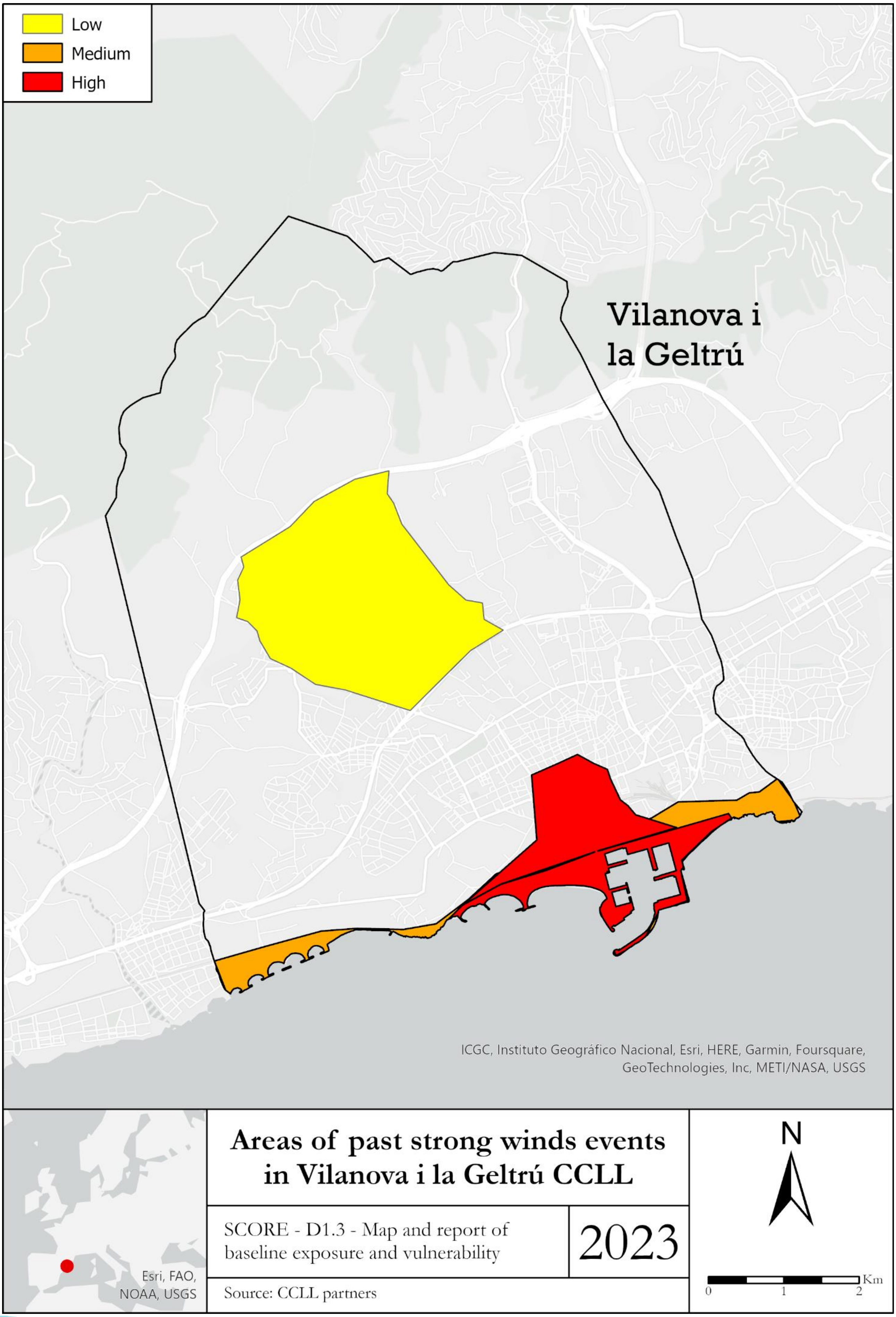
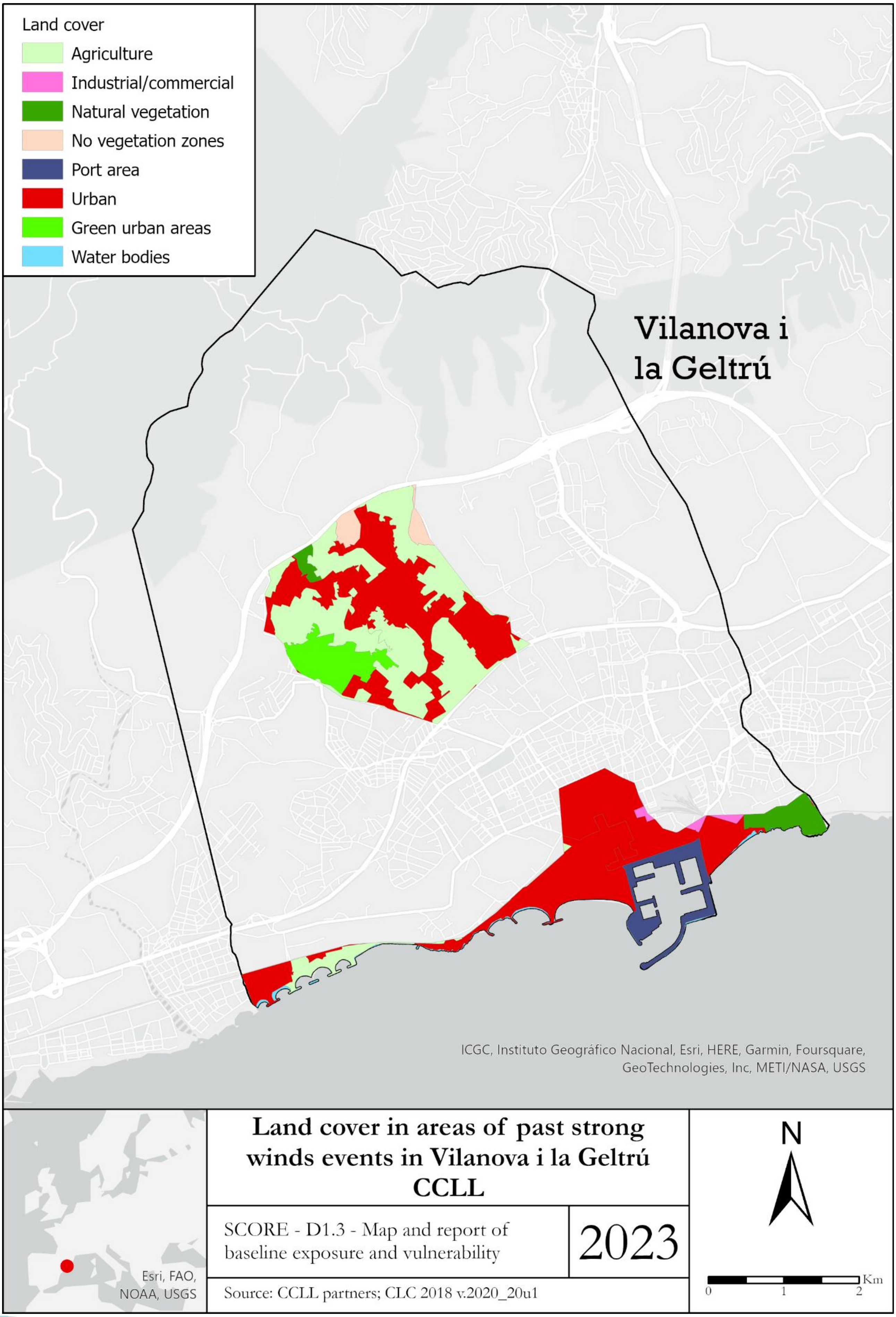


Figure 32: Vilanova i la Geltrú CCLL – land cover of areas of past events of strong winds



5.4. Benidorm

Figure 33: Benidorm CCLL – LECZ.

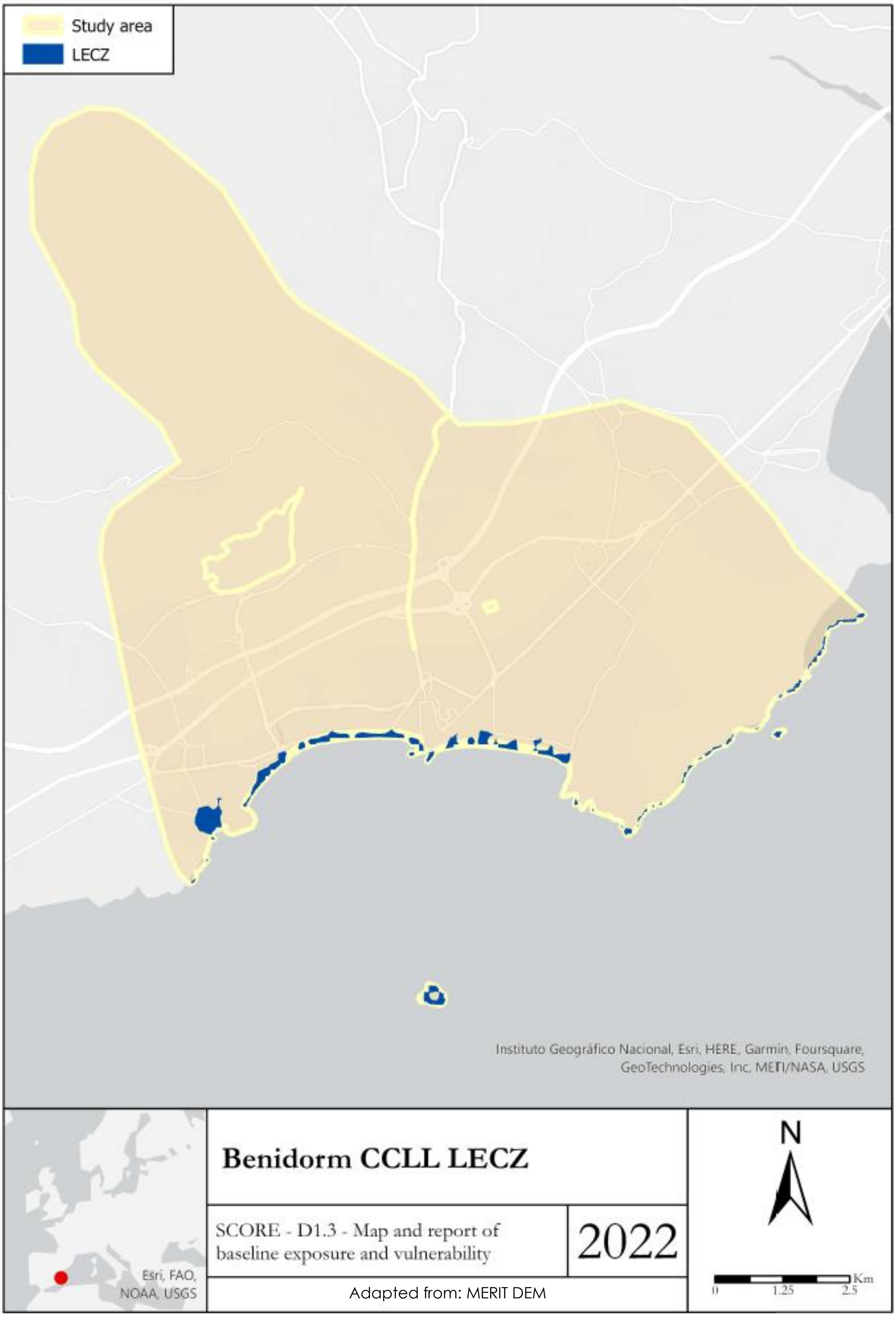


Figure 34: Benidorm CCLL – land cover.

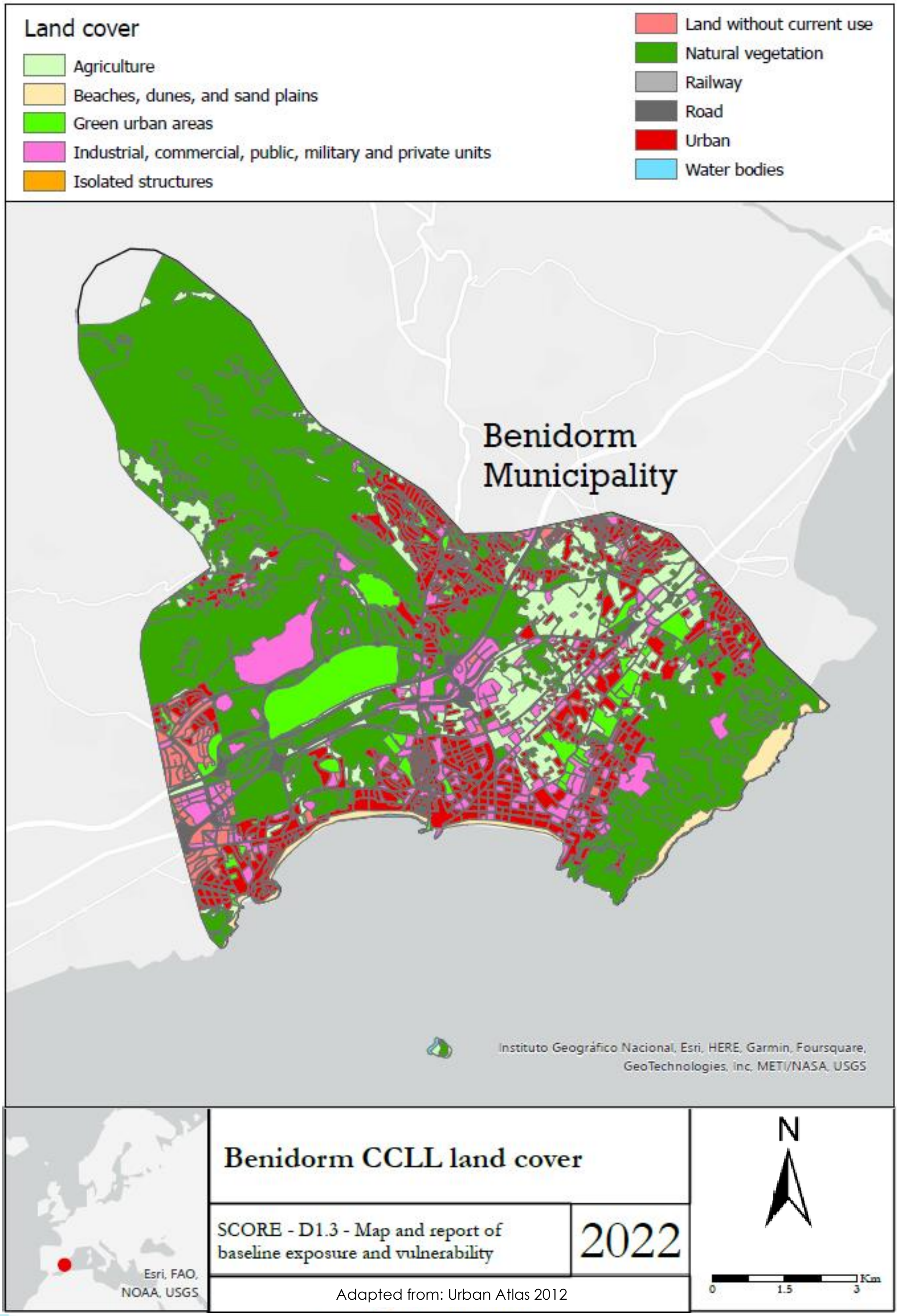
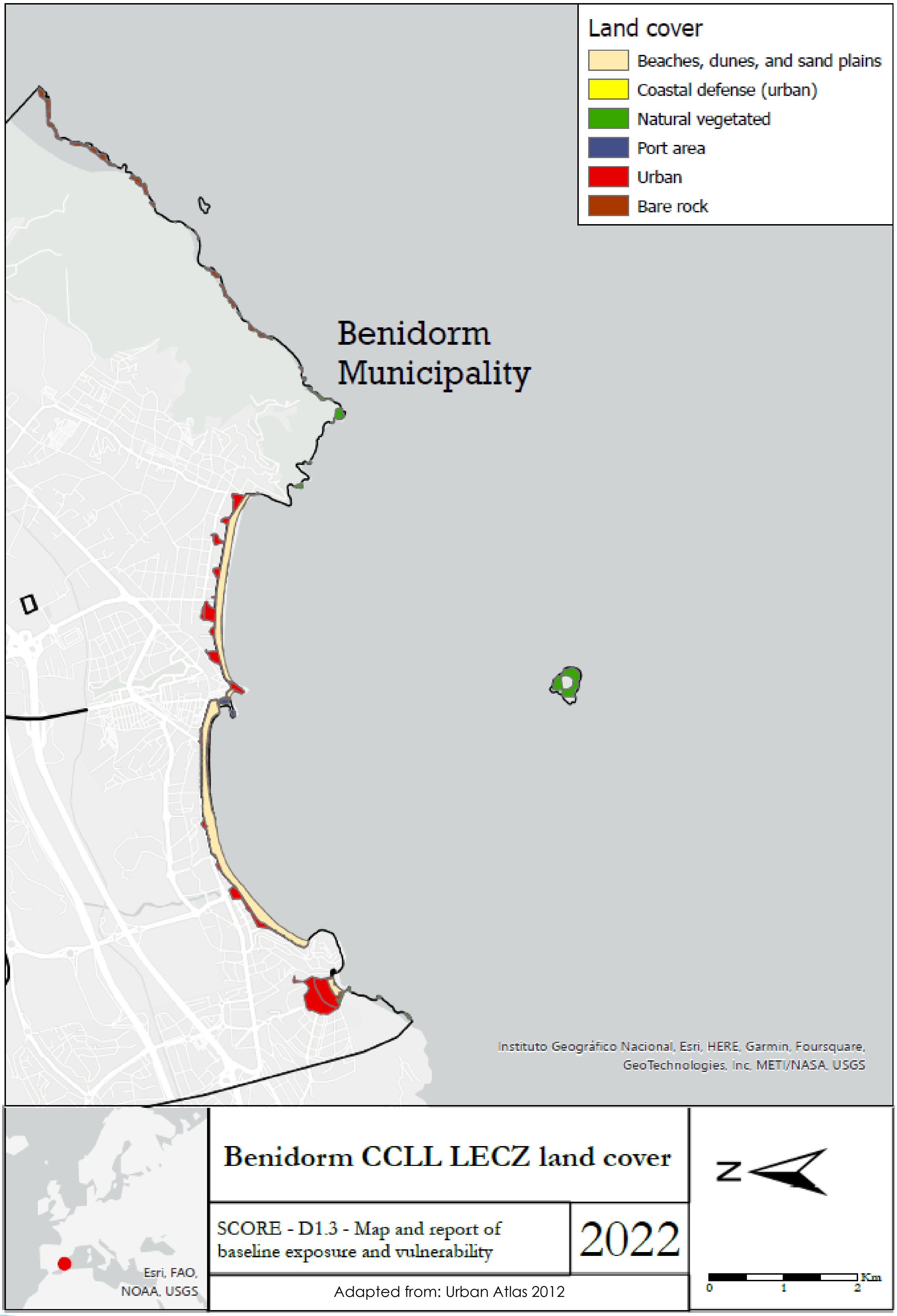


Figure 35: Benidorm CCLL – LECZ land cover.



5.5. Oarsoaldea

Figure 36: Oarsoaldea – LECZ.

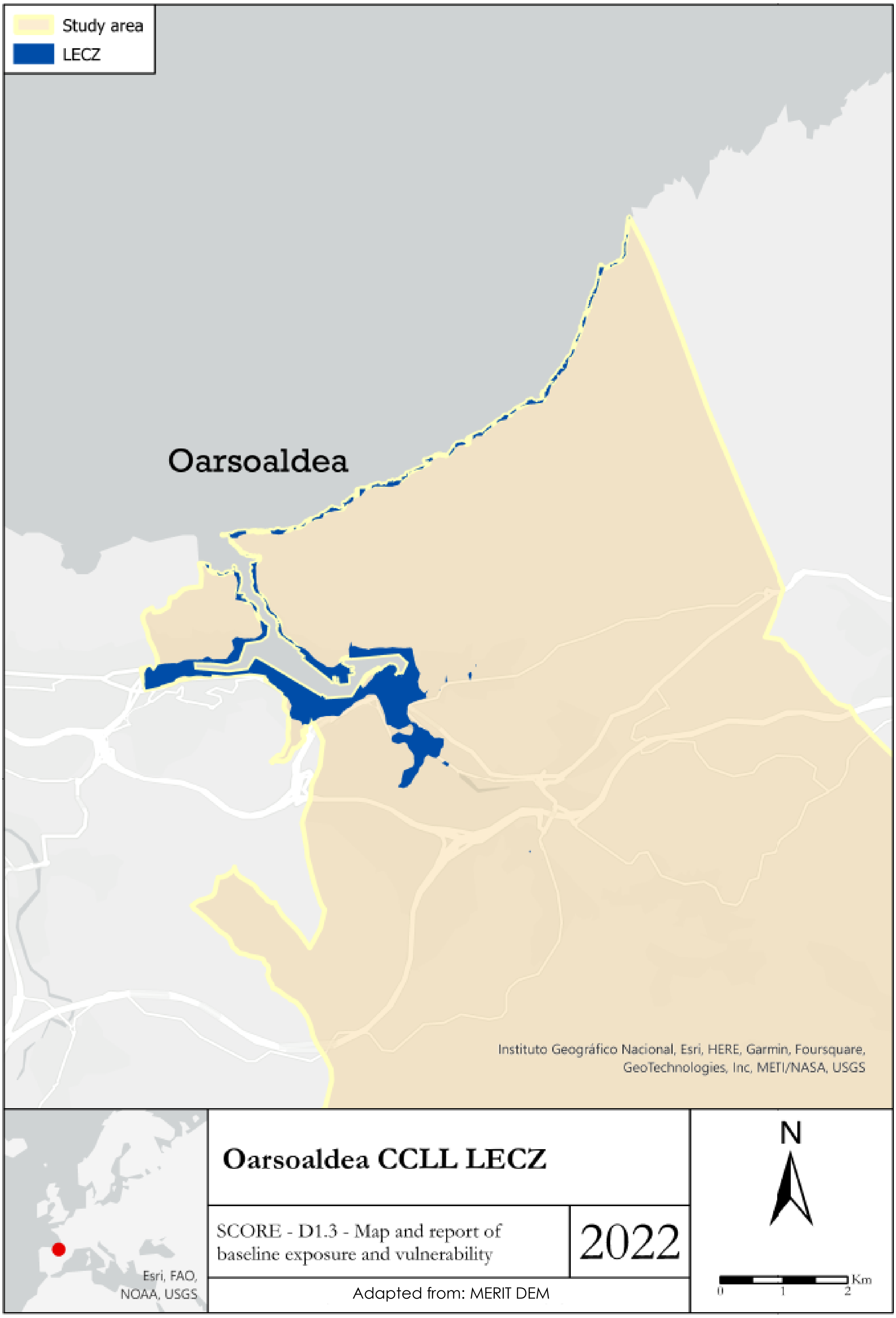


Figure 37: Oarsoaldea – land cover.

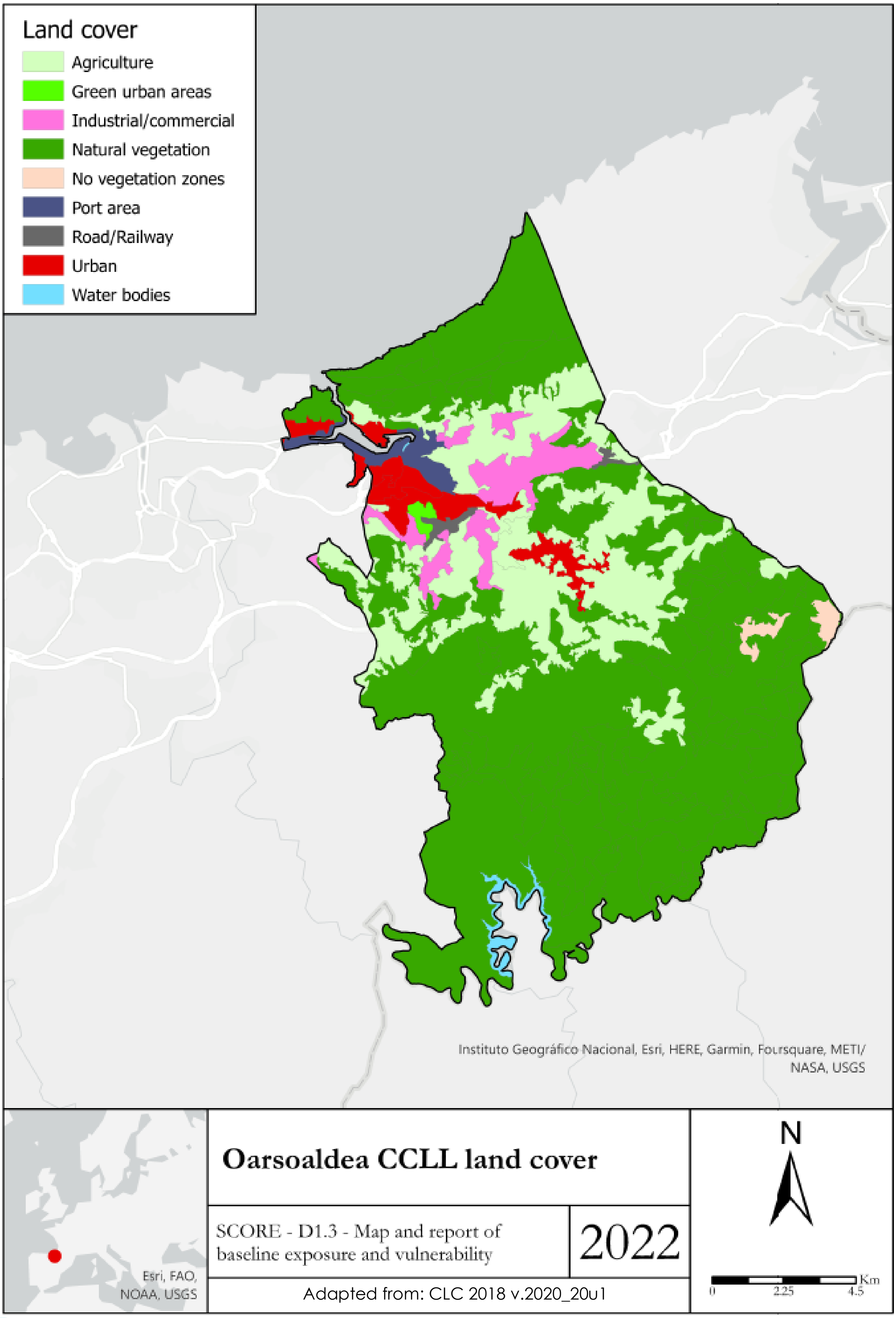


Figure 38: Oarsoaldea – LECZ land cover.

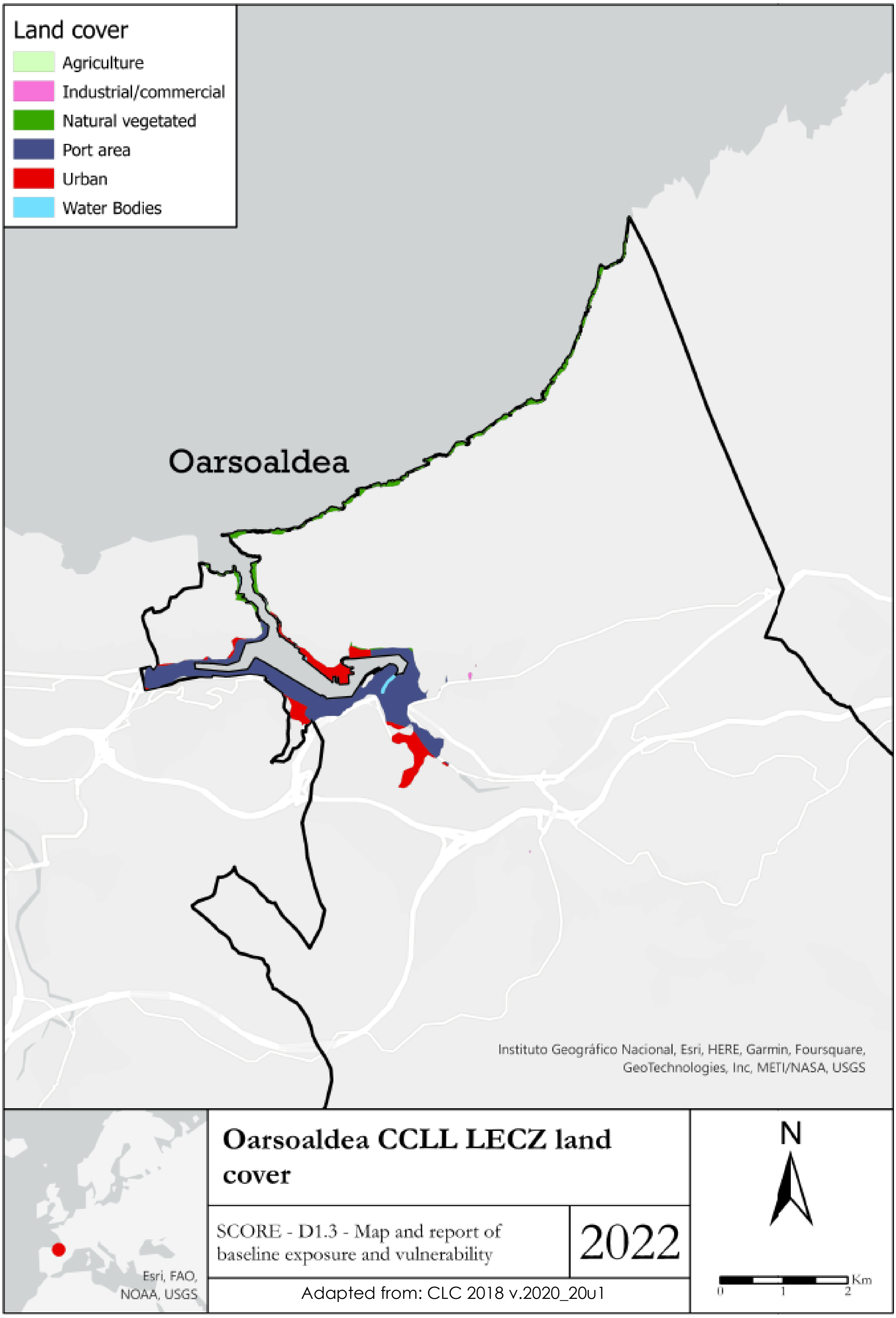


Figure 39: Oarsoaldea – flood-prone areas.

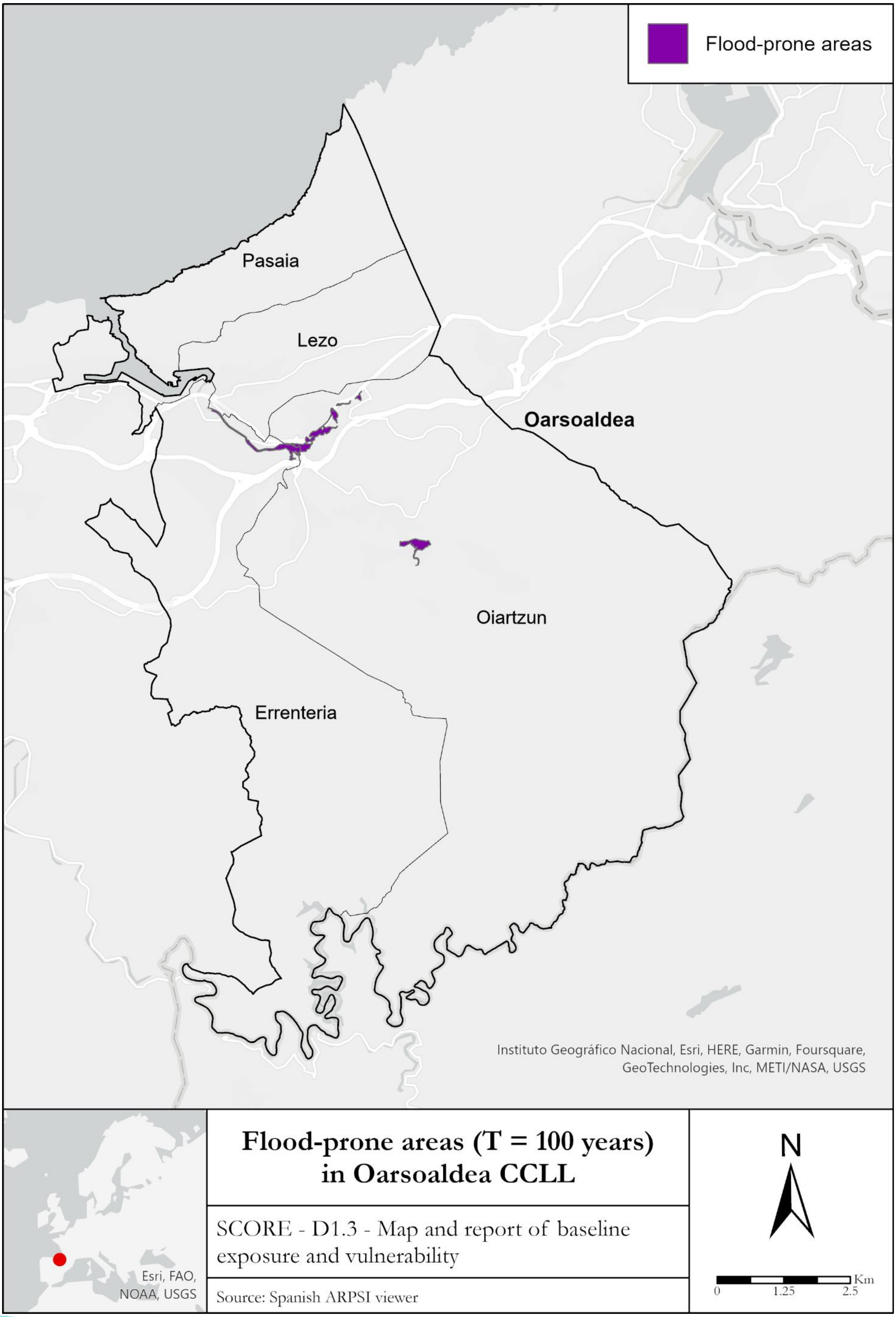


Figure 40: Oarsoaldea – land cover of flood-prone areas.

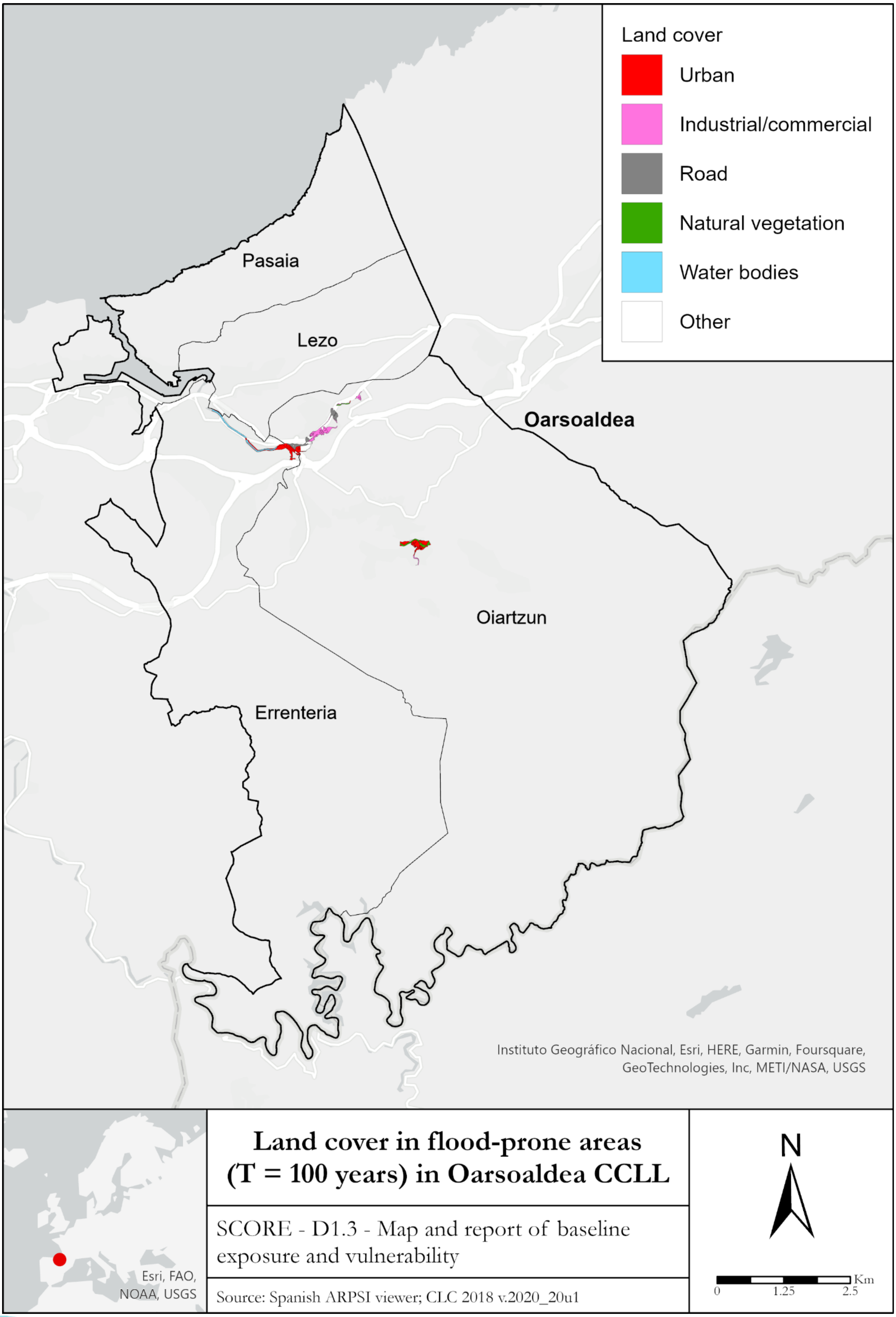


Figure 41: Oarsoaldea – landslide-prone areas.

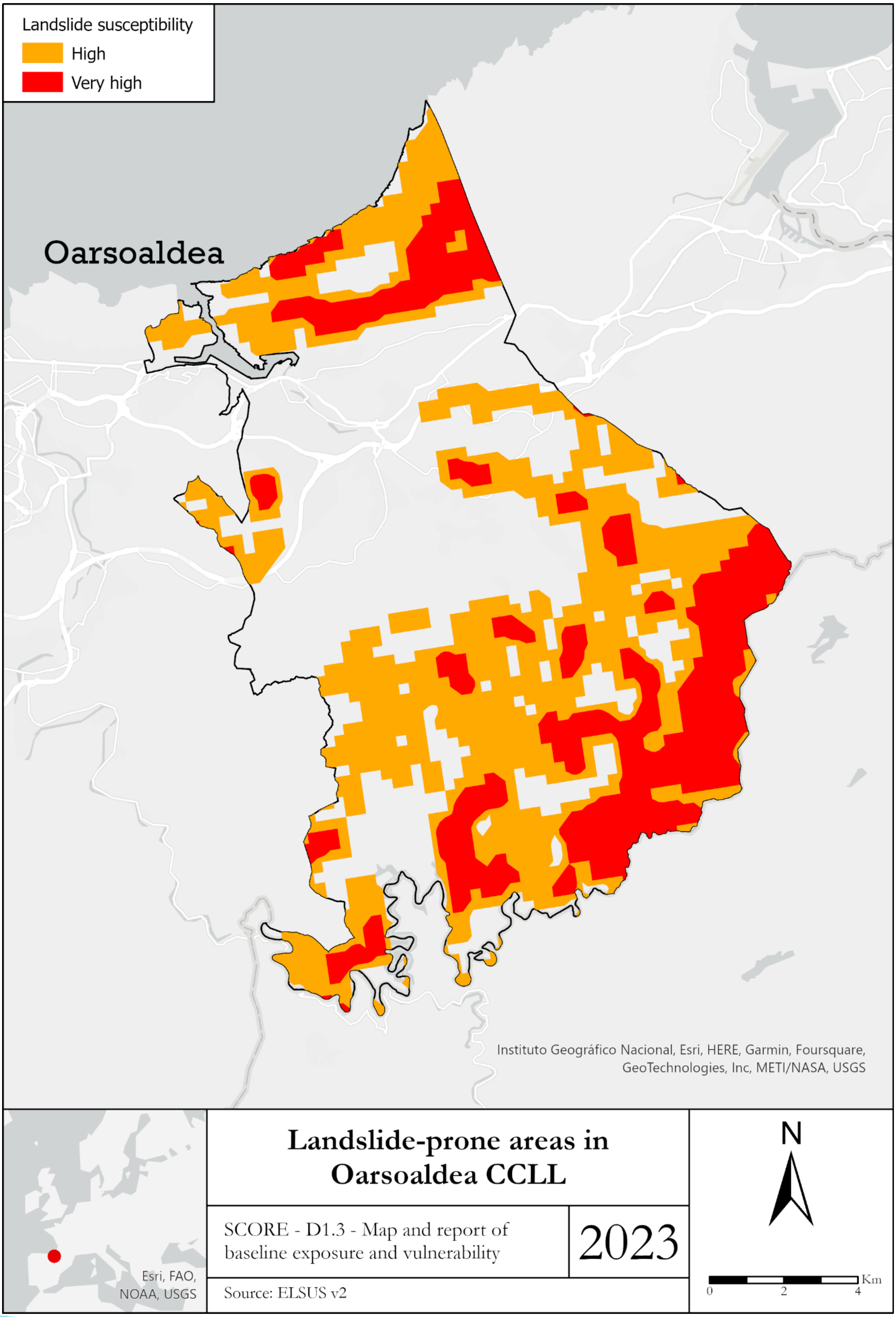
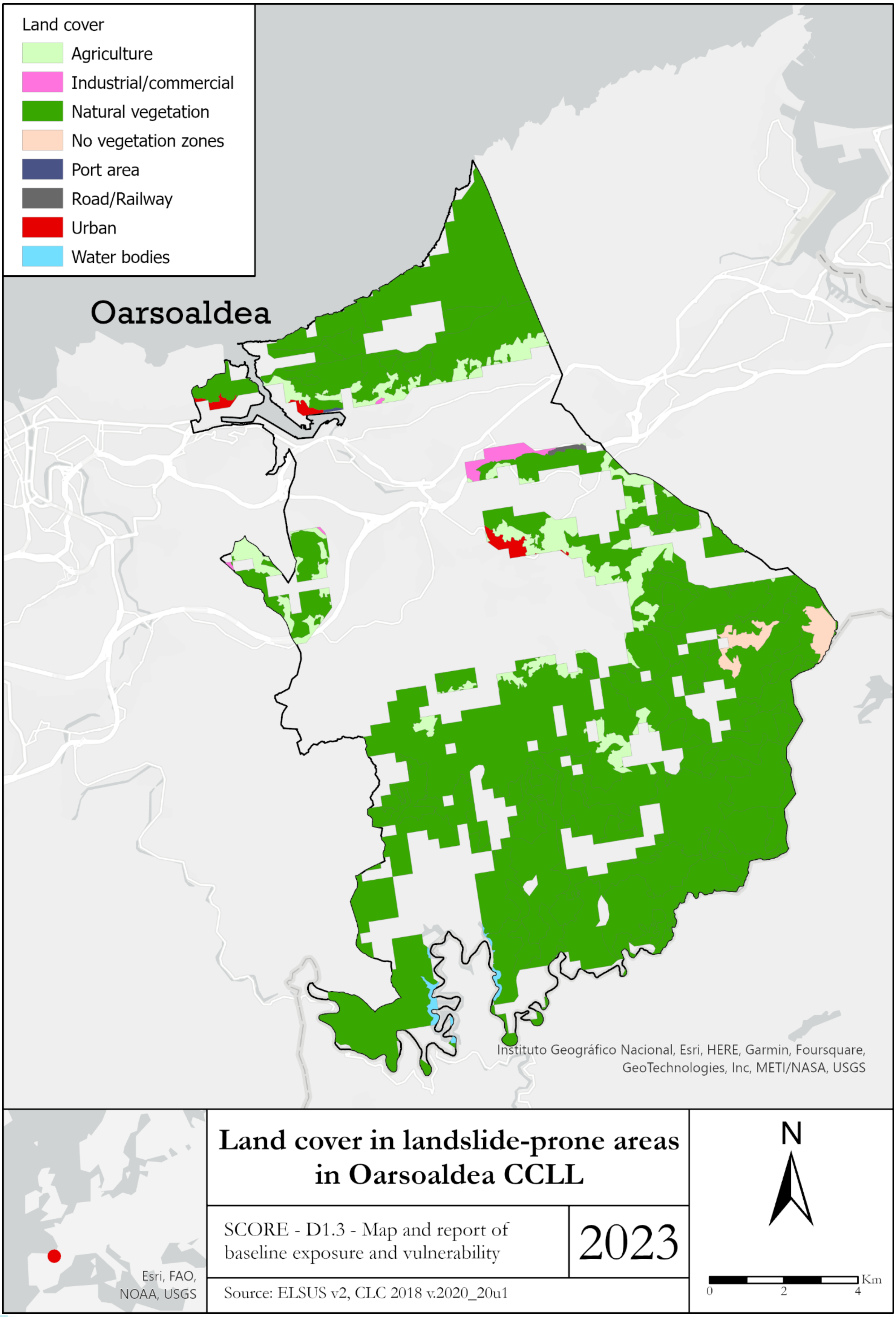


Figure 42: Oarsoaldea – land cover of landslide-prone areas.



5.6. Massa

Figure 43: Massa CCLL – LECZ.

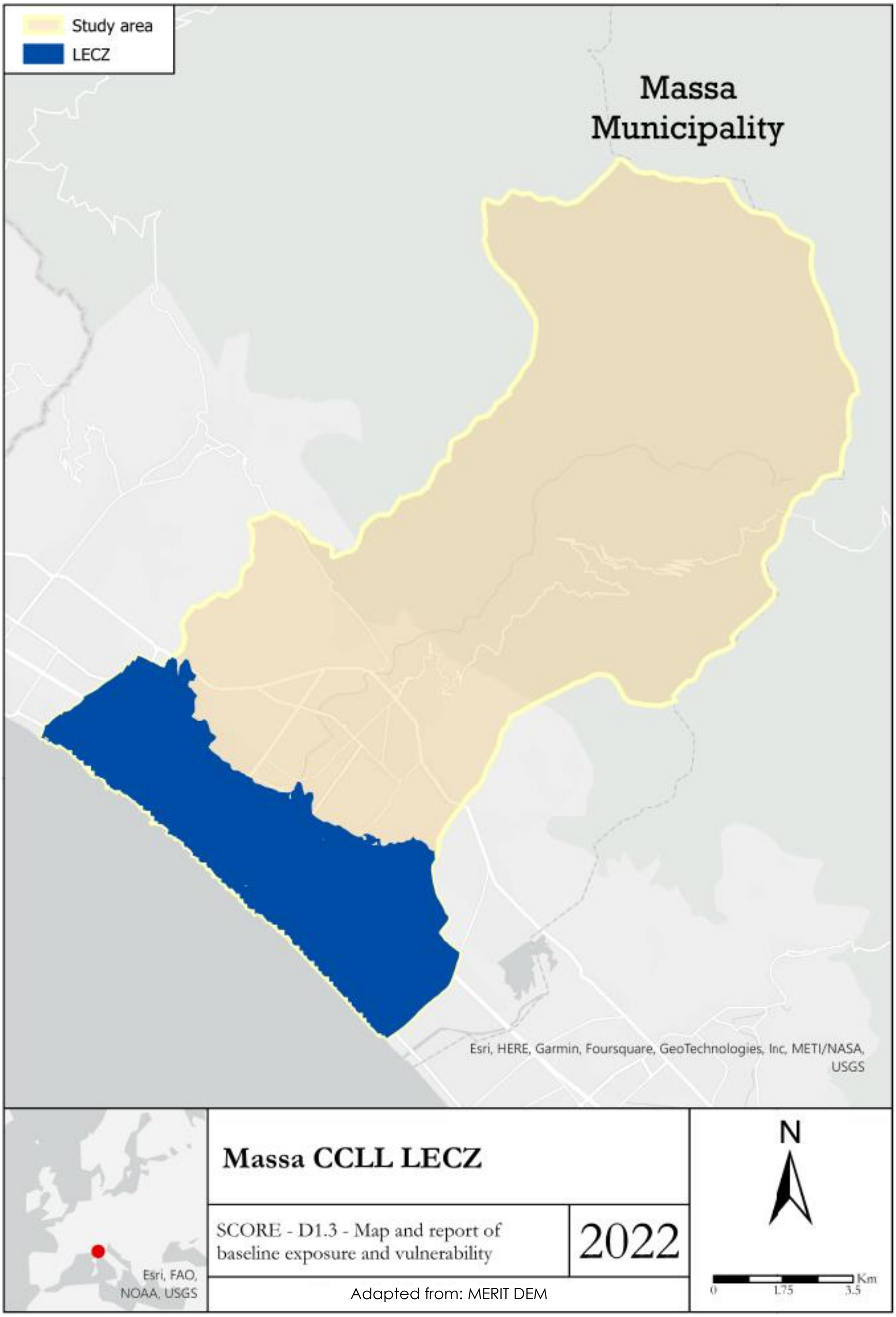


Figure 44: Massa CCLL – land cover.

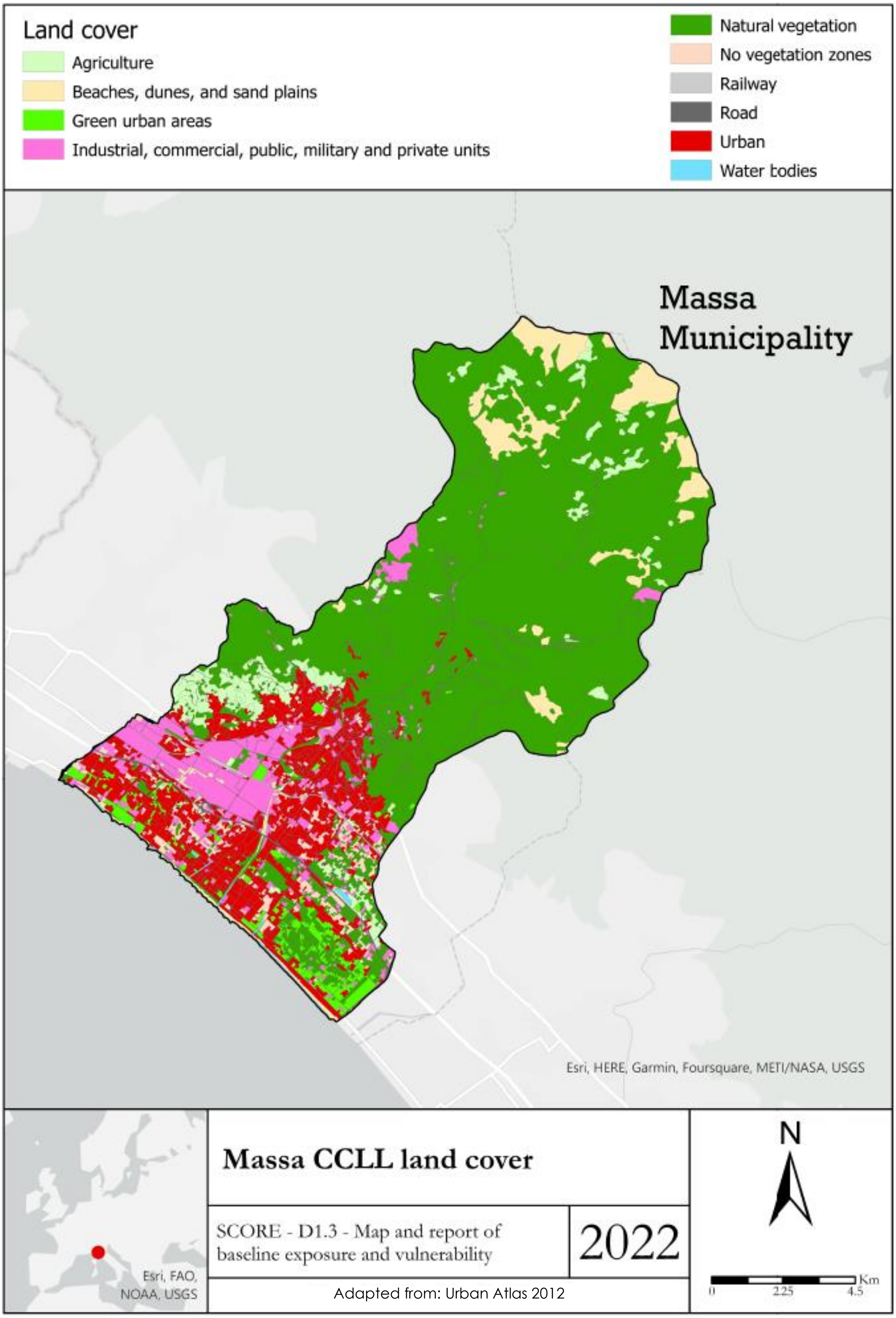


Figure 45: Massa CCLL – LECZ land cover.

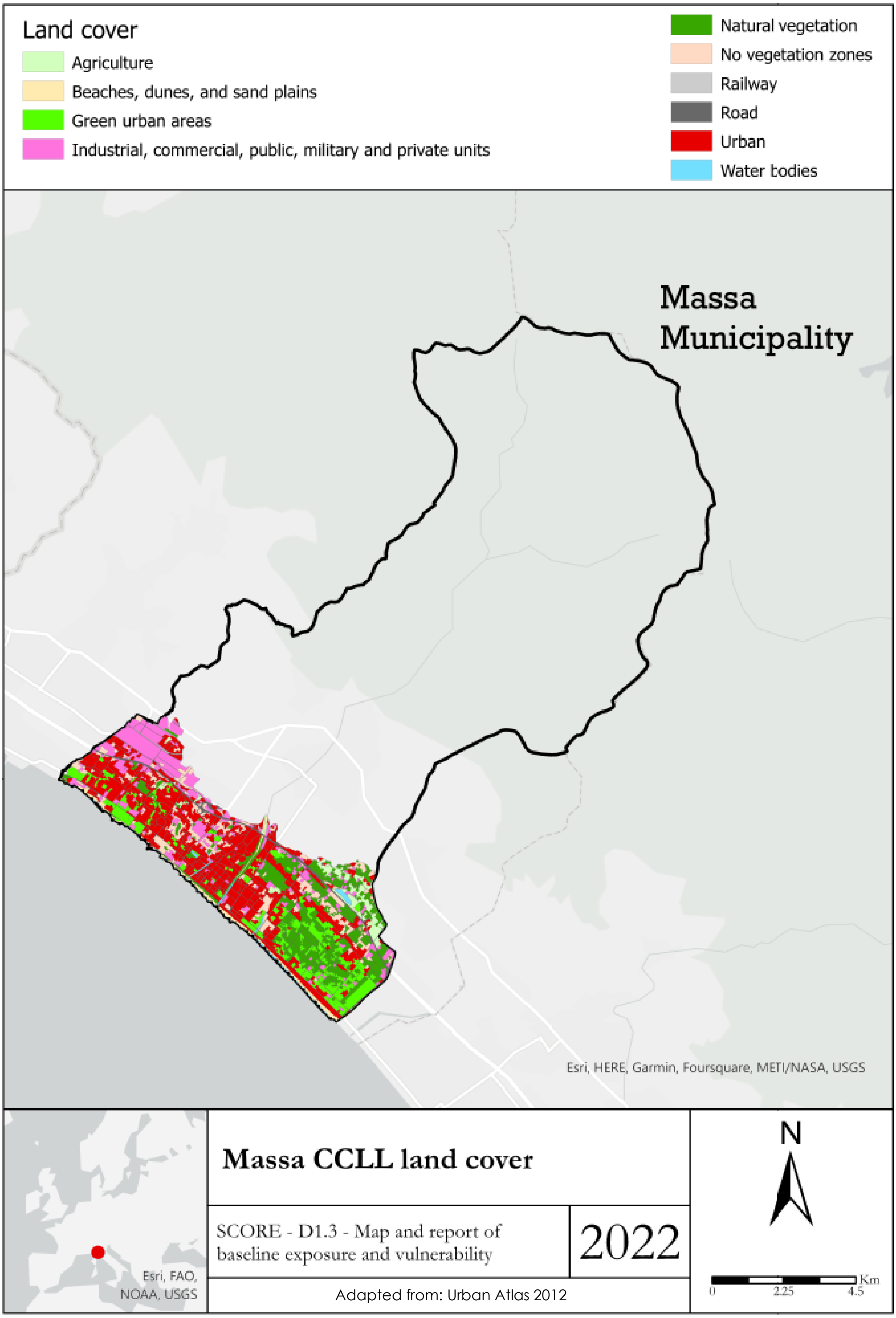


Figure 46: Massa CCLL – landslide-prone areas.

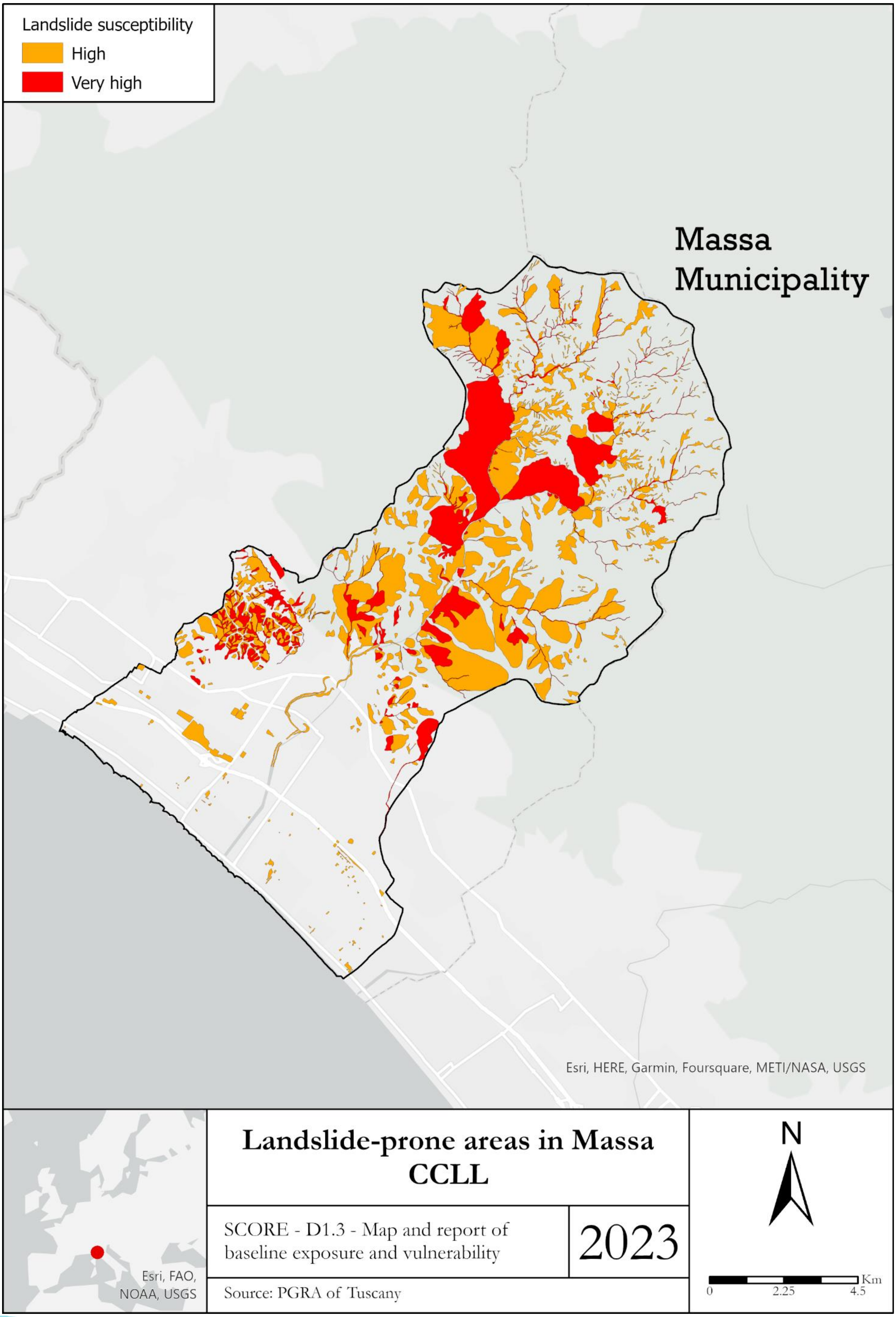
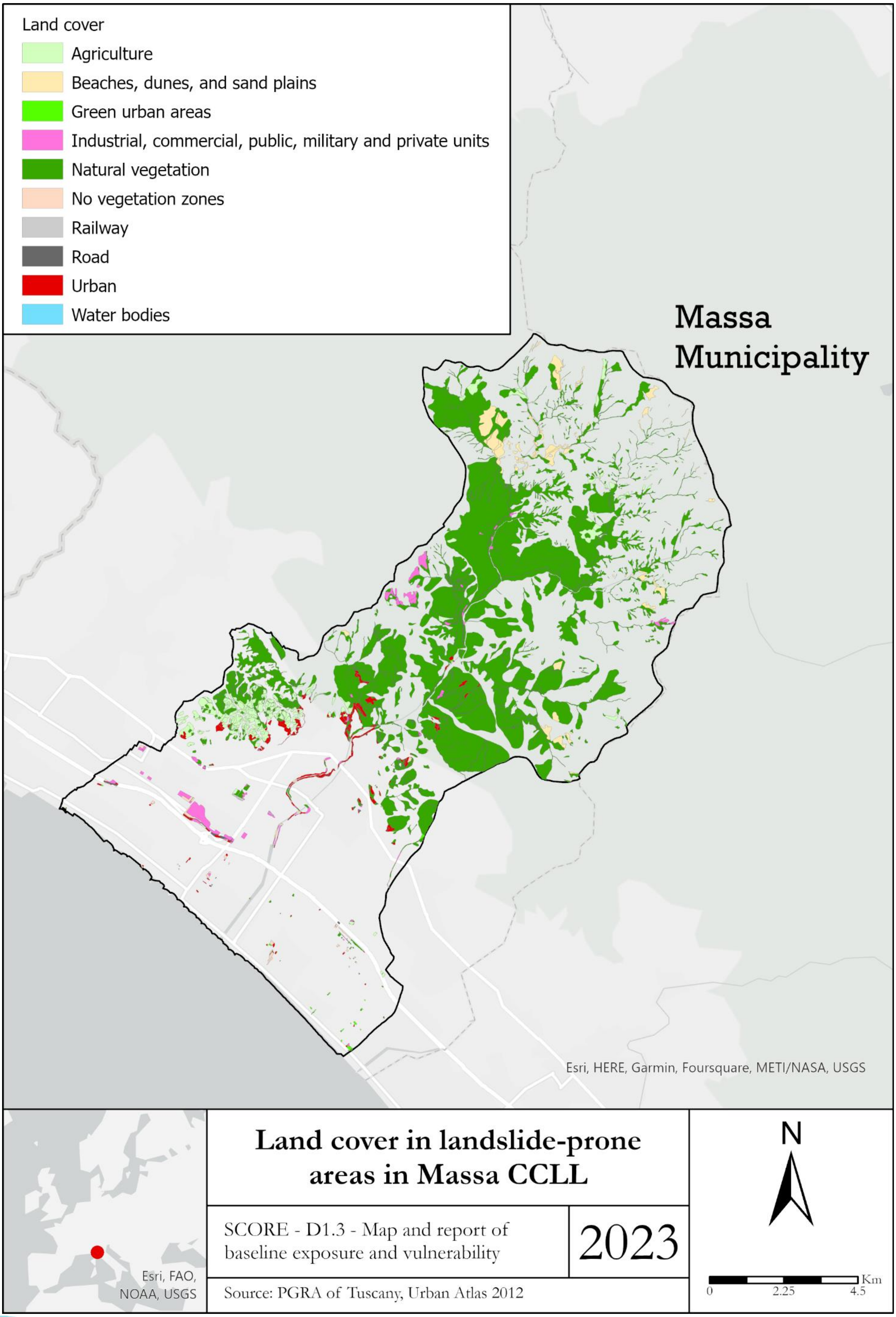


Figure 47: Massa CCLL – land cover of landslide-prone areas.



5.7. Piran

Figure 48: Piran CCLL – LECZ land cover.

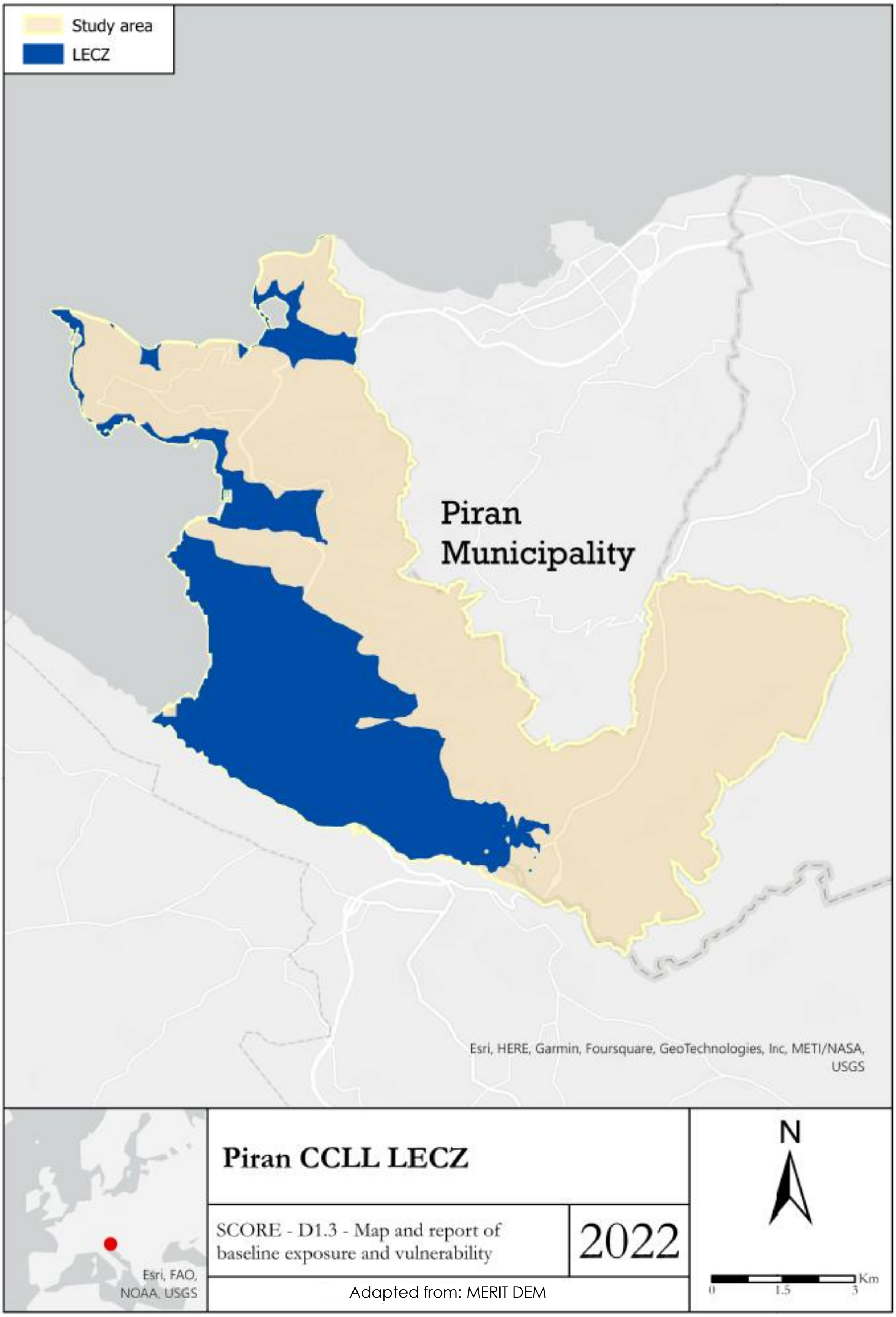


Figure 49: Piran CCLL – land cover.

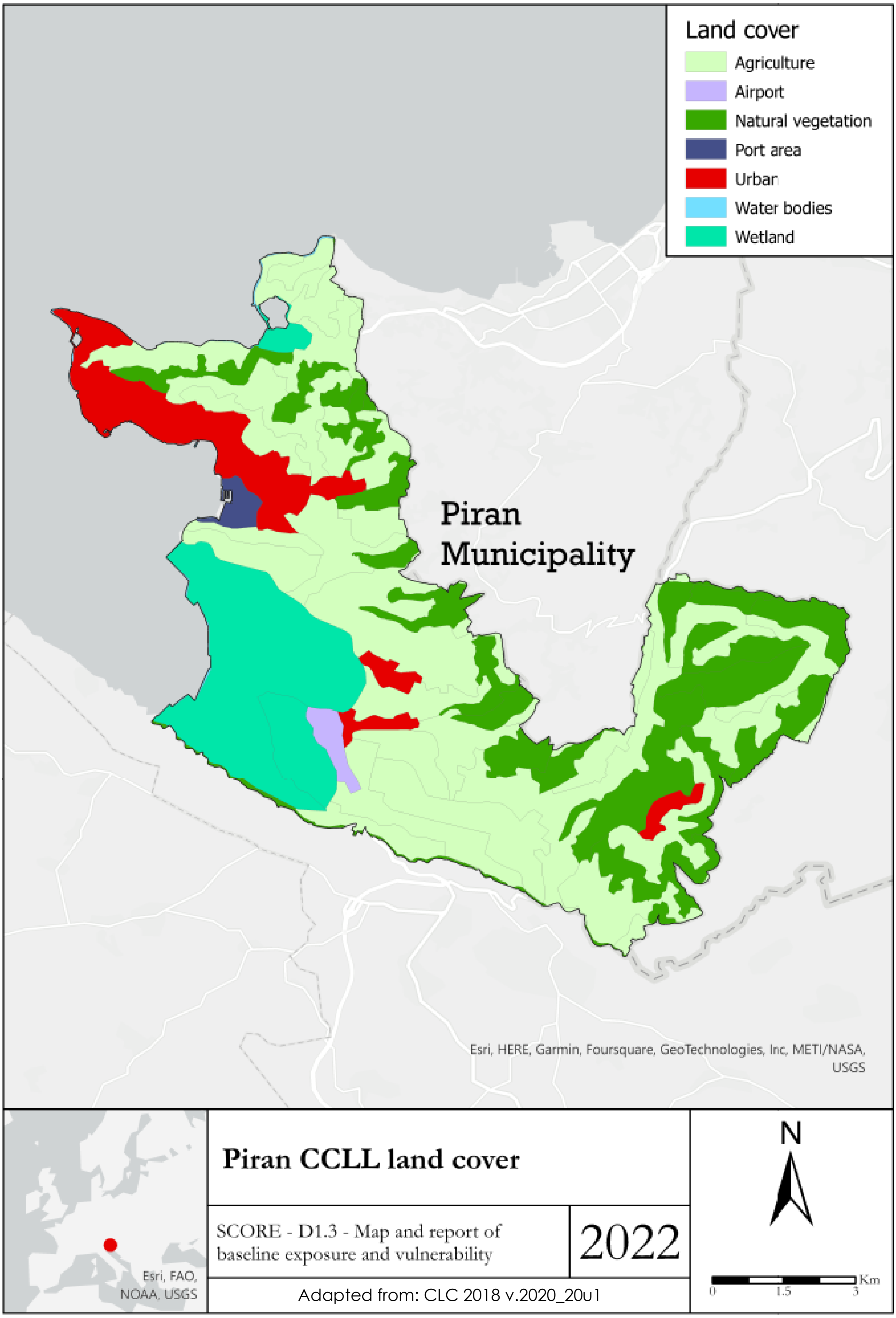
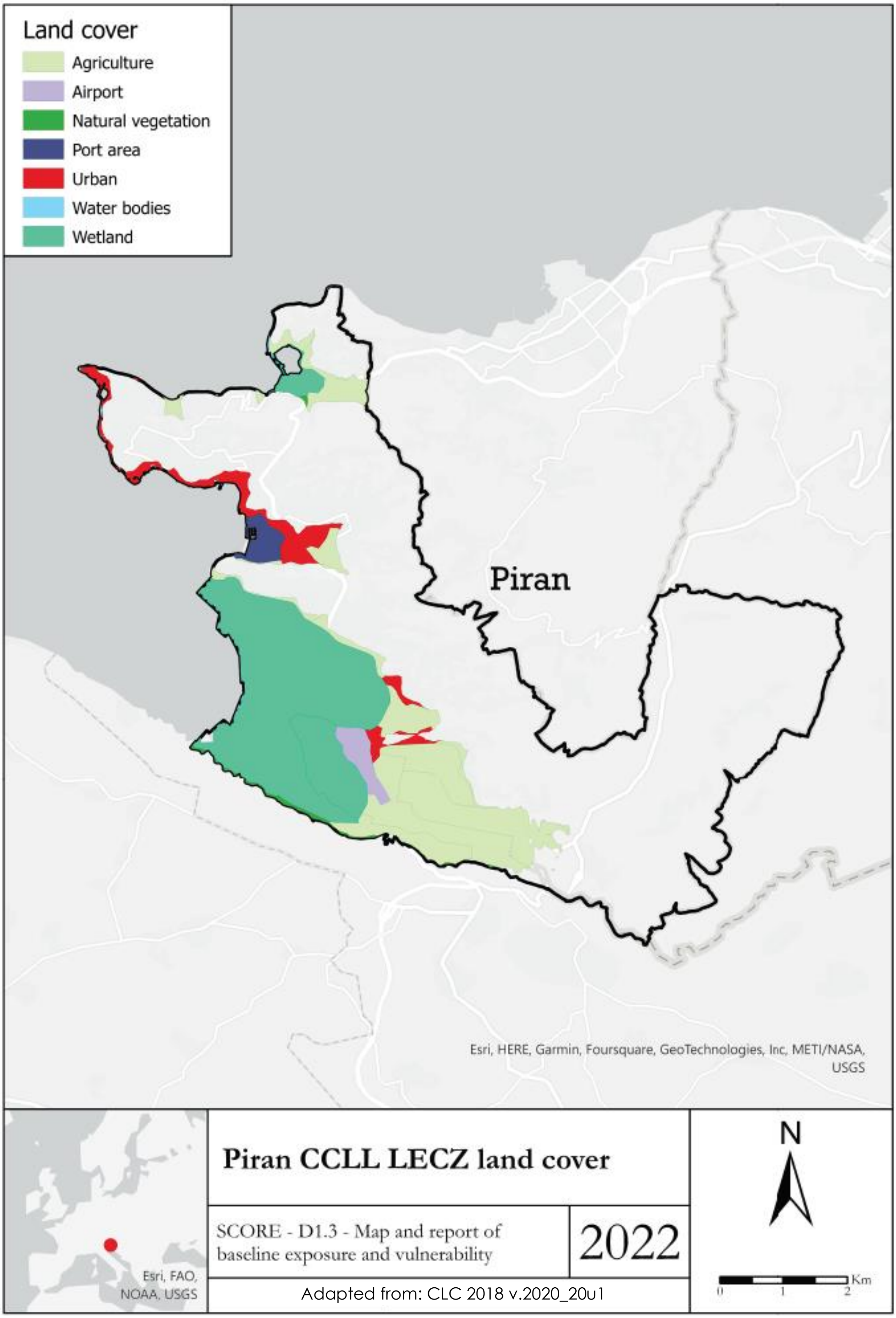


Figure 50: Piran CCLL – LECZ land cover.



5.8. Gdańsk

Figure 51: Gdańsk CCLL – LECZ.

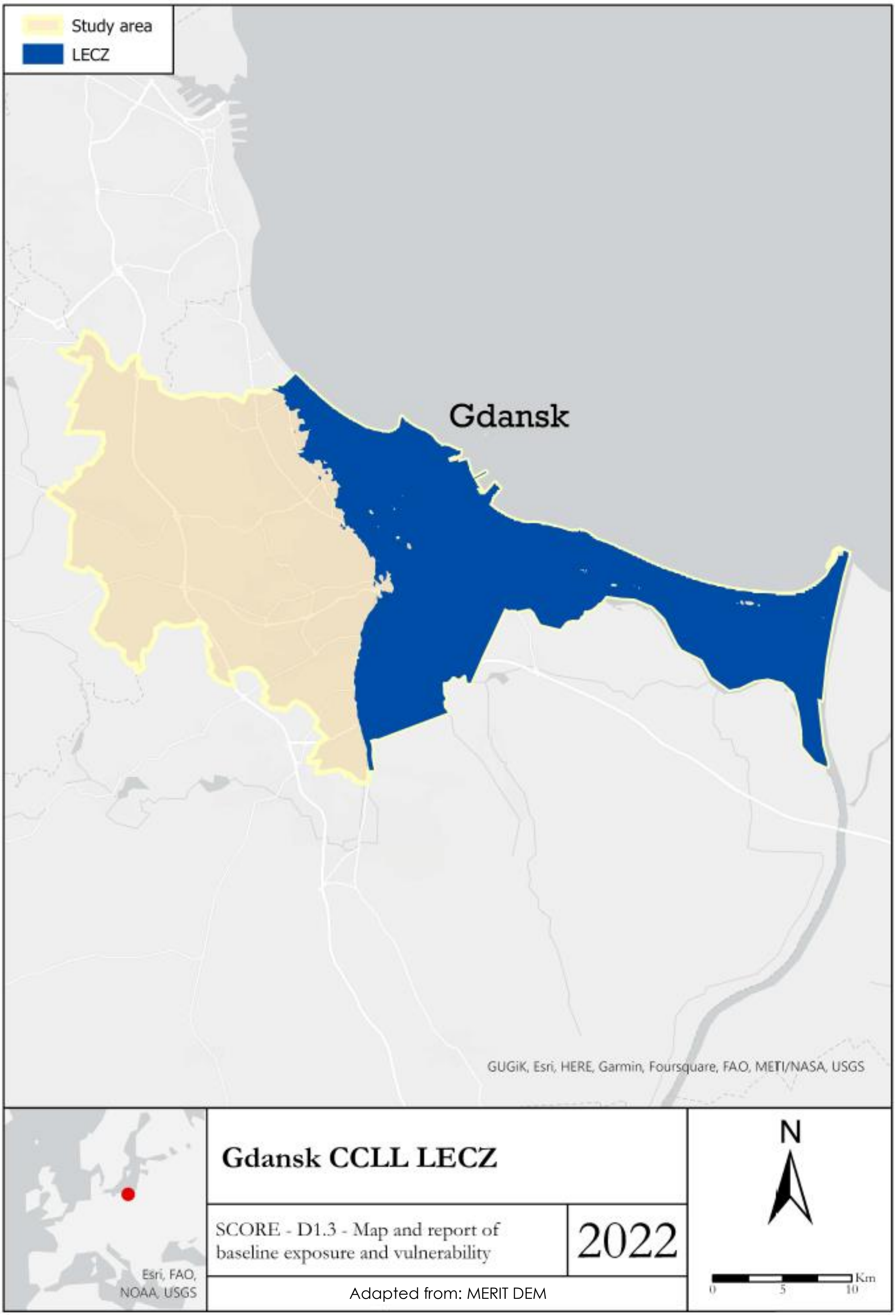


Figure 52: Gdańsk CCLL – land cover.

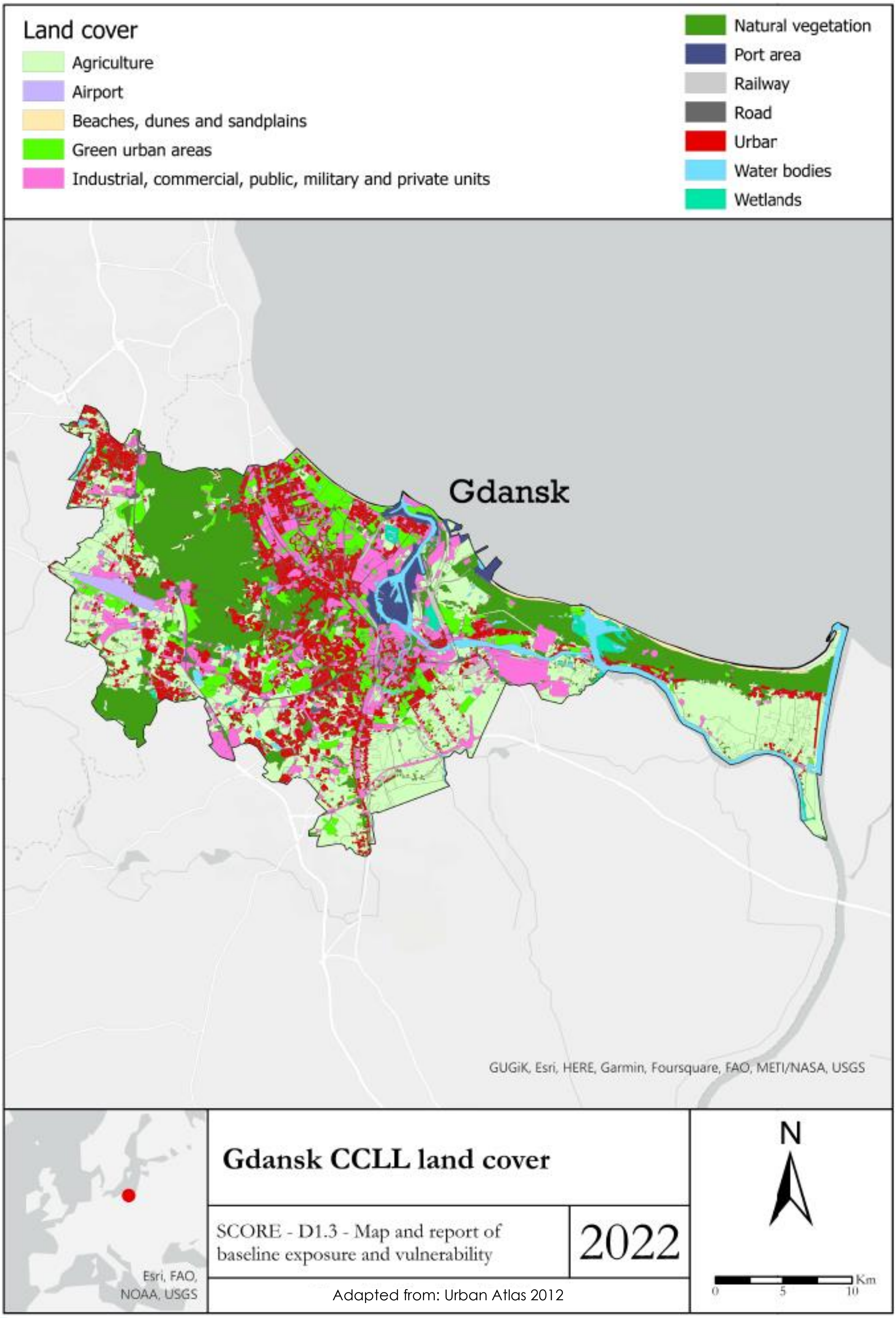


Figure 53: Gdańsk CCLL – LECZ land cover.

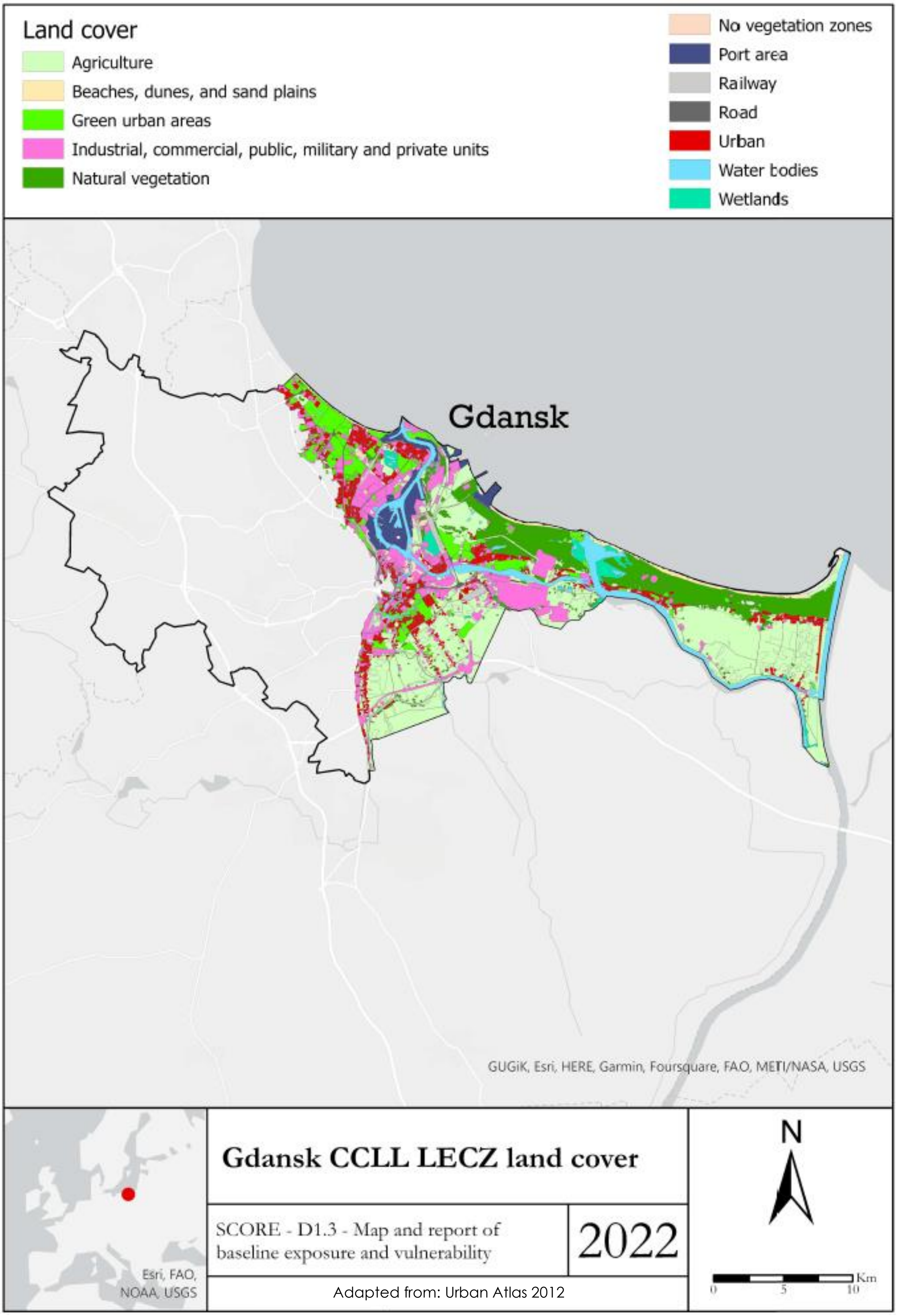


Figure 54: Gdansk CCLL – flood-prone areas.

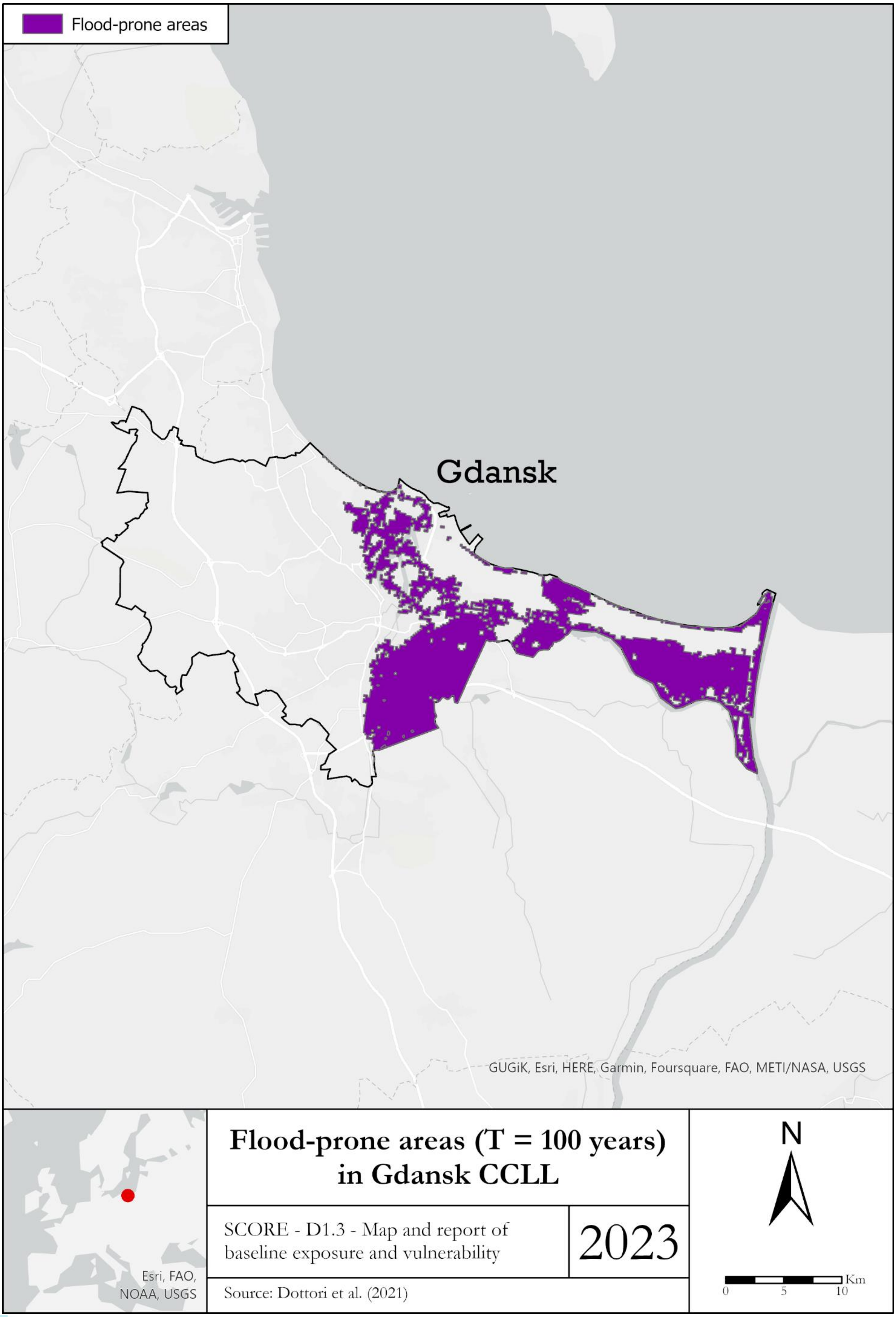
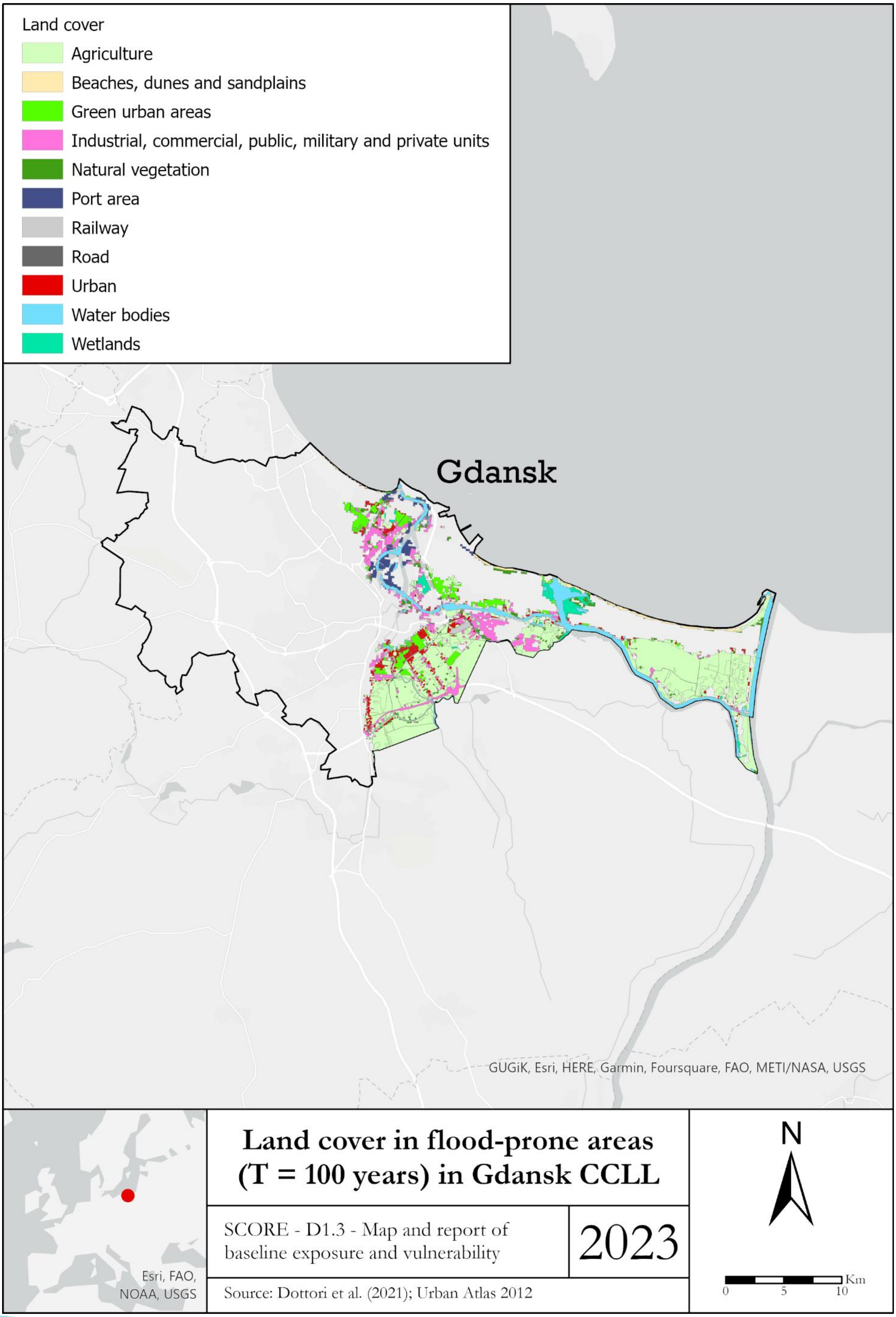


Figure 55: Gdansk CCLL – land cover of flood-prone areas.



5.9. Samsun

Figure 56: Samsun CCLL – LECZ.

Figure 57: Samsun CCLL – land cover.

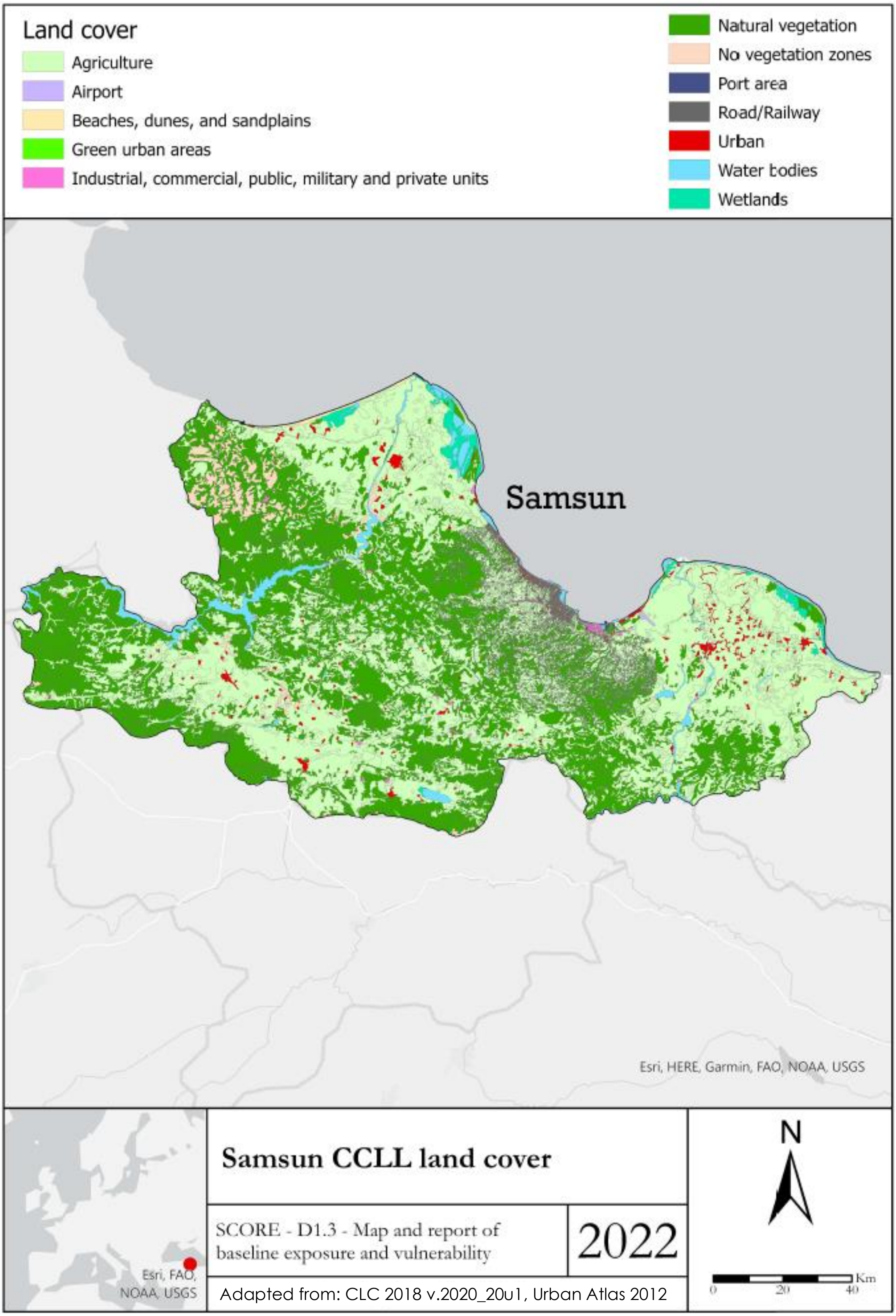


Figure 58: Samsun CCLL – LECZ land cover.

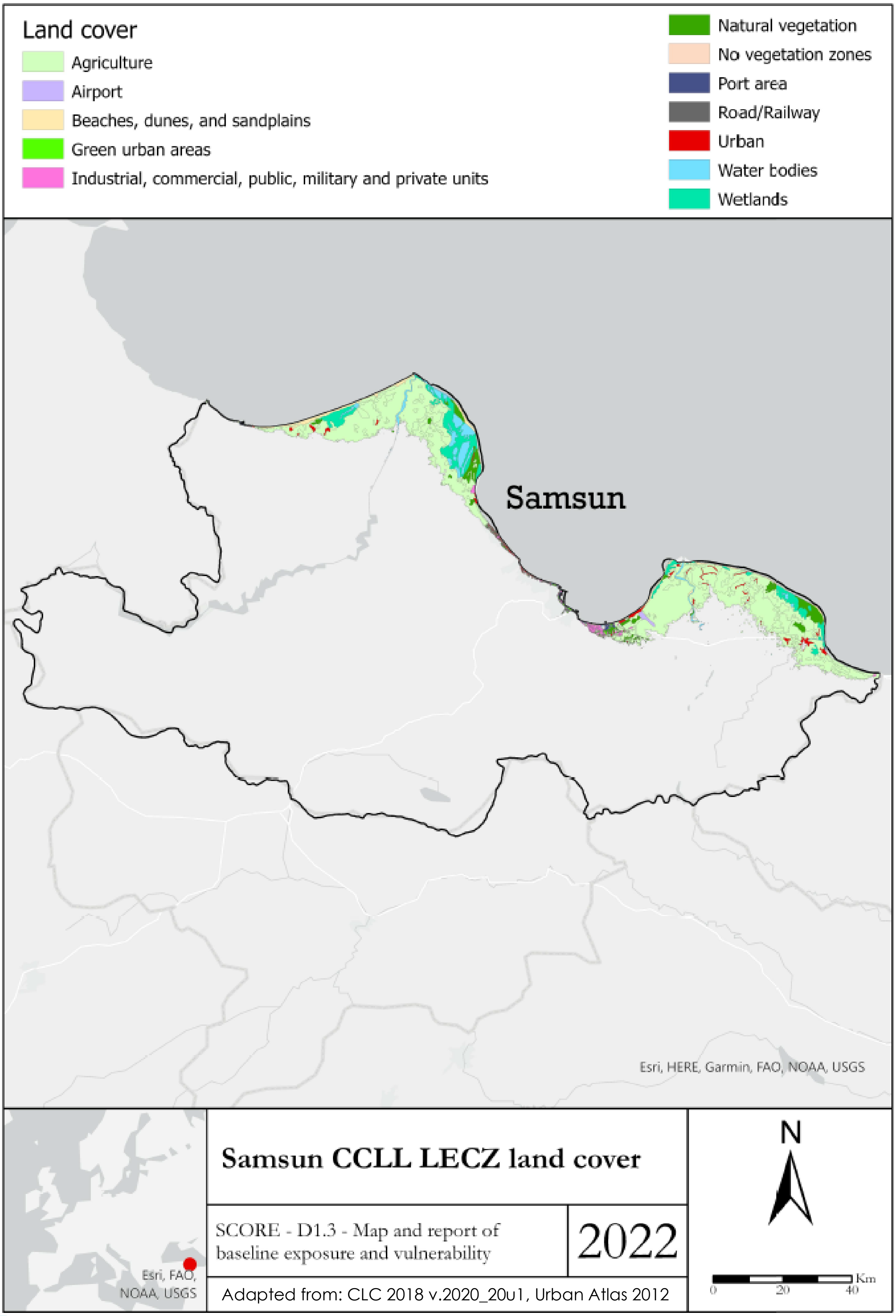


Figure 59: Samsun CCLL – flood-prone areas.

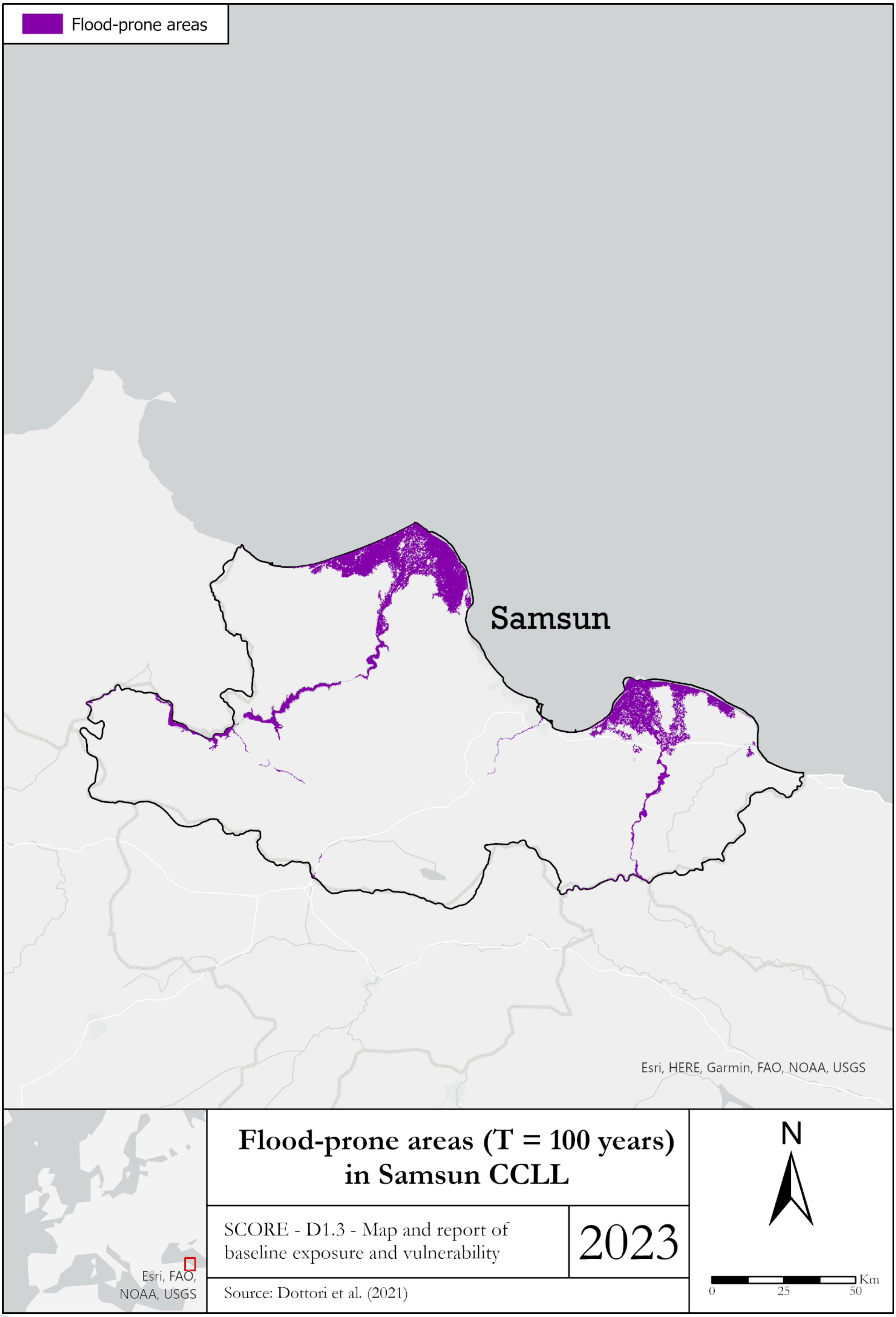


Figure 60: Samsun CCLL – land cover of flood-prone areas.