PROVIDE

Iberian Mediterranean and Lisbon Metropolitan Area

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D4.1 Four review reports on key overshoot adaptation challenges in Iconic Regions and Cities: Iberian Mediterranean and Lisbon Metropolitan Area

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Abstract:

Impacts of overshooting the Paris Agreement temperature thresholds will materialise globally but be particularly consequential for vulnerable regions. This report represents the initial stocktaking of overshoot adaptation challenges in the four Iconic Regions and Cities in focus for PROVIDE: Arctic Fennoscandia, with a focus on Bodø, Norway; Iberian Mediterranean, with a focus on the Lisbon Metropolitan Area; the Upper Indus Basin, with a focus on Islamabad; and The Bahamas, with a focus on Nassau.

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Glossary

Unless otherwise stated, the terminology in the report follows conventions developed by the IPCC WGII.

CONCEPT	DESCRIPTION
Adaptation challenges	Factors that make it harder to plan and implement adaptation actions.
Adaptation opportunities	Factors that make it easier to plan and implement adaptation actions, which expand adaptation options, or that provide ancillary co-benefits.
Adaptive capacity	The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
Ecosystem service	Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food, fibre, or fish, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, *livelihoods,* service provision, *ecosystems,* and environmental resources.
Limits to adaptation	A limit to adaptation is reached when adaptation efforts are unable to provide an acceptable level of security from risks to the existing objectives and values and prevent the loss of the key attributes, components, or services of ecosystems.
Overshoot	Pathways that first exceed a specified global warming level (usually 1.5°C, by more than 0.1°C), and then return to or below that level again before the end of a specified period of time (e.g., before 2100). Sometimes the magnitude and likelihood of the overshoot is also characterized. The overshoot duration can vary from at least one decade up to several decades.
Risk	The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change.
Tipping point	A level of change in system properties beyond which a system reorganizes, often abruptly, and does not return to the initial state even if the drivers of the change are abated.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Executive Summary

The 1.5°C Paris Agreement long-term temperature goal sets ambitions for global climate action to avoid the most devastating impacts of climate change. However, under current emissions trajectories, overshooting 1.5°C is a distinct possibility.

Even if we only temporarily exceed 1.5°C in the near term, we could still cross climate thresholds in ways that would severely limit our adaptation options. This would impact people and places around the world, but nowhere will this be felt more than in vulnerable regions.

To date, adaptation and urban planning do not routinely consider the implications of temporary overshoot of 1.5°C and what this would mean for sea level rise, extreme heat, extreme weather events, flooding and their impacts locally or for whole regions. To bridge this gap, the PROVIDE project is undertaking research on temperature overshoot scenarios and their expected impacts, so we can better understand under which conditions these impacts can be avoided.

This report looks at adaptation challenges in four iconic case study regions and cities:

- Arctic Fennoscandia, with a focus on Bodø, Norway.
- the Iberian Mediterranean, with a focus on the Lisbon Metropolitan Area.
- the Upper Indus Basin, with a focus on Islamabad.
- The Bahamas, with a focus on Nassau.

The findings are based on the review of relevant literature and stakeholder workshops undertaken by in-region experts, along with analyses of the structural profile of the urban environments in focus.

The four regions are very different, both in climatic and socioeconomic settings, but all are experiencing the consequences of climate change, including risks connected to more frequent and more serious severe weather events. Examples range from deadly heatwaves, hot and dry summer with forest fires, and extreme precipitation events that lead to flooding and increased risk for landslides (and avalanches). Whole ecosystems are also changing and could eventually vanish in response to shifts in the climate, including snow and ice habitats, agroforestry, and coral reefs. In the cities in focus, the built environment has often reduced the capacity of the natural environment to buffer the impacts of climate change, including intensive precipitation and extreme heat.

A common feature for all iconic regions – despite their differences – is that impacts from a changing climate are exacerbated by socio-economic factors, such as inequalities and lack of financial and human capital. Furthermore, pressures from urbanisation and migration makes adaptation more challenging. Lack of adequate adaptation governance and incentives is another common feature. These social factors affect adaptive capacity and thus create “soft” limits of adaptation.

There are also significant similarities between the adaptation challenges faced by the iconic cities. In all four cities, vulnerability to various climatic risks have increased because of anthropogenic activity, such as the urbanization of coastal areas, construction leading to discontinuity of green-blue structures, and the intensity of the built-up space. All four places have possibilities to address their respective climatic risks, but they also face challenges related to a high degree of private land ownership along with governance regimes without sufficient coherence for the needs related to climate adaptation and mitigation.

Iberian Mediterranean and Lisbon Metropolitan Area

The Iberian Mediterranean is a recognised hotspot of climate change vulnerability. Along with increasing temperatures and decreasing precipitation, the region is home to an increasing concentration of people along coastlines and in metropolitan areas.

Growing levels of desertification and an ageing population in the interior areas have led to a reduction in agroforestry activity and increased the risk of forest fires. Intense seasonal population movements associated with summer tourism further increases the vulnerability in areas already very sensitive to droughts and water scarcity.

Key climate hazards and adaptation challenges:

- Extreme temperatures and heatwaves.
- Heavy precipitation events and floods.
- Droughts and water scarcity.
- Forest fires.
- Loss of agricultural yield.
- Species loss.
- Sea level rise and storm surges.
- Hurricanes.

These hazards often occur within a combination of interacting physical processes, creating 'compound events' which pose additional challenges for climate adaptation and resilience in the region.

The strong concentration of people, infrastructure and economic activities in the Lisbon Metropolitan Area makes it highly vulnerable to scenarios of increasing climate-related risks.

Increasing temperatures and heatwaves, flash floods, droughts, storms, and wildfires are already responsible for major disruptions, and are the focus of attention of several adaptation initiatives and strategies. Longer and more frequent heatwaves and droughts are expected and will lead to increasing risks in both urban and rural areas, especially for agroforestry, tourism, health, energy, and infrastructures.

Adaptive capacity in the region is dampened by still emerging adaptation governance structures, poor administrative coordination, fragmented approaches, weak incentives, and the lack of local economic capacity. Shortage of specialised human capital, technical and financial limitations, and the lack of proper governance models were raised in the Lisbon Metropolitan Area local stakeholder workshop as key constraints for adaptation.

Transboundary risks, such as those related with the management of shared water resources, pose additional challenges and potential for conflicts and serve as an example of current limits to adaptation in the region.

The mainstreaming of climate action into spatial planning was highlighted as an opportunity for improvement. Some decision-making tools are available and in use, but workshop participants pointed out that overshoot scenarios are not yet included in risk assessments and could be of relevance to the region.

The structural profile analysis highlighted five preliminary priorities for adaptation:

1) Reorganising existing agricultural (cropland and pasture) land uses and land covers.
2) The need for a territory-wide cooling project.
3) Adapting the network of industrial and commercial units.

4) Retrofitting and installing cooling devices in the urban landscape, according to the degree of built-up intensity.
5) The reconfiguration of current protection regimes, governance structures and ownership patterns (particularly of large non-built-up spaces and transport nodes) to allow for adaptation measures.

1. Introduction

1.1. The PROVIDE project

Overshooting the Paris Agreement temperature thresholds is a distinct possibility. Potential impacts would be global in scope, with consequences which may be particularly severe where changes are abrupt, irreversible, or adaptation limits are exceeded. The aim of the EU-funded project, *Paris Agreement Overshooting – Reversibility, Climate Impacts and Adaptation Needs* (PROVIDE), is to create climate services that incorporate comprehensive information on impacts under overshoot pathways from the global to the regional and local urban level, directly feeding into adaptation action. This includes:

- Producing global multi-scenario, multisectoral climate information that integrates and quantifies impacts across scales.
- Providing comprehensive risk assessments of overshooting by assessing climate system uncertainties and feedbacks, and the potential (ir)reversibility of climate impacts.
- Co-developing a generalizable overshoot proofing methodology for adaptation strategies to enhance adaptation action in response to overshoot risks.
- Identifying and prioritizing overshoot adaptation needs in four highly complementary case study regions.
- Integrating the project outcomes into a PROVIDE Climate Service Dashboard, designed to complement established climate service platforms.
- Interacting and collaborating with a wide variety of stakeholders, to ensure usability and wide dissemination of project results and outputs.

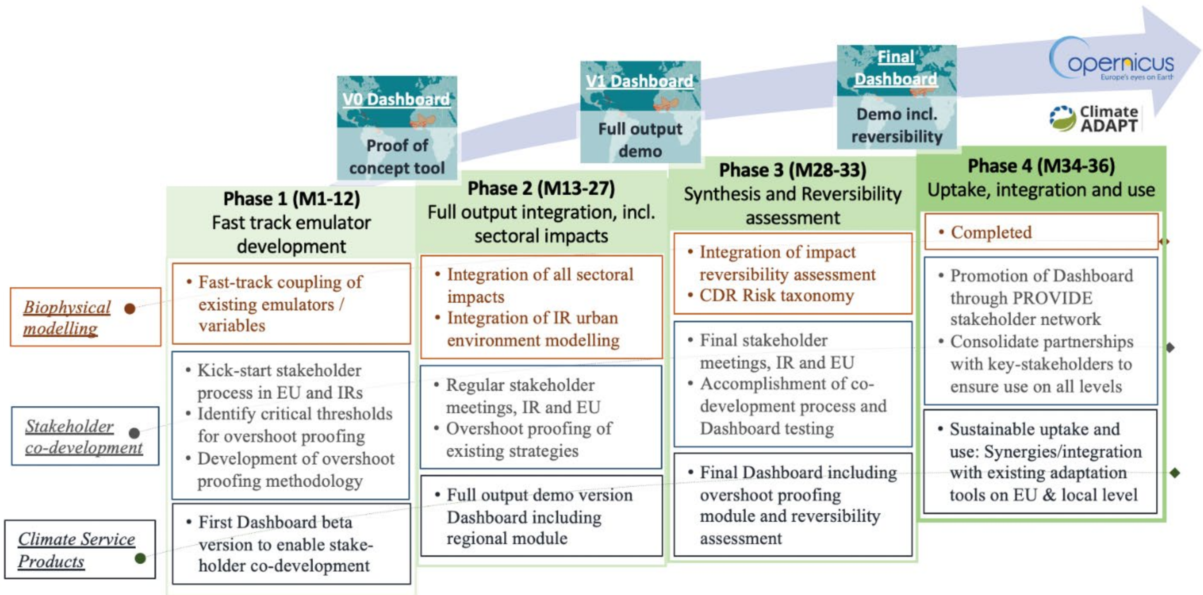

Figure 1.1. The PROVIDE project at a glance.

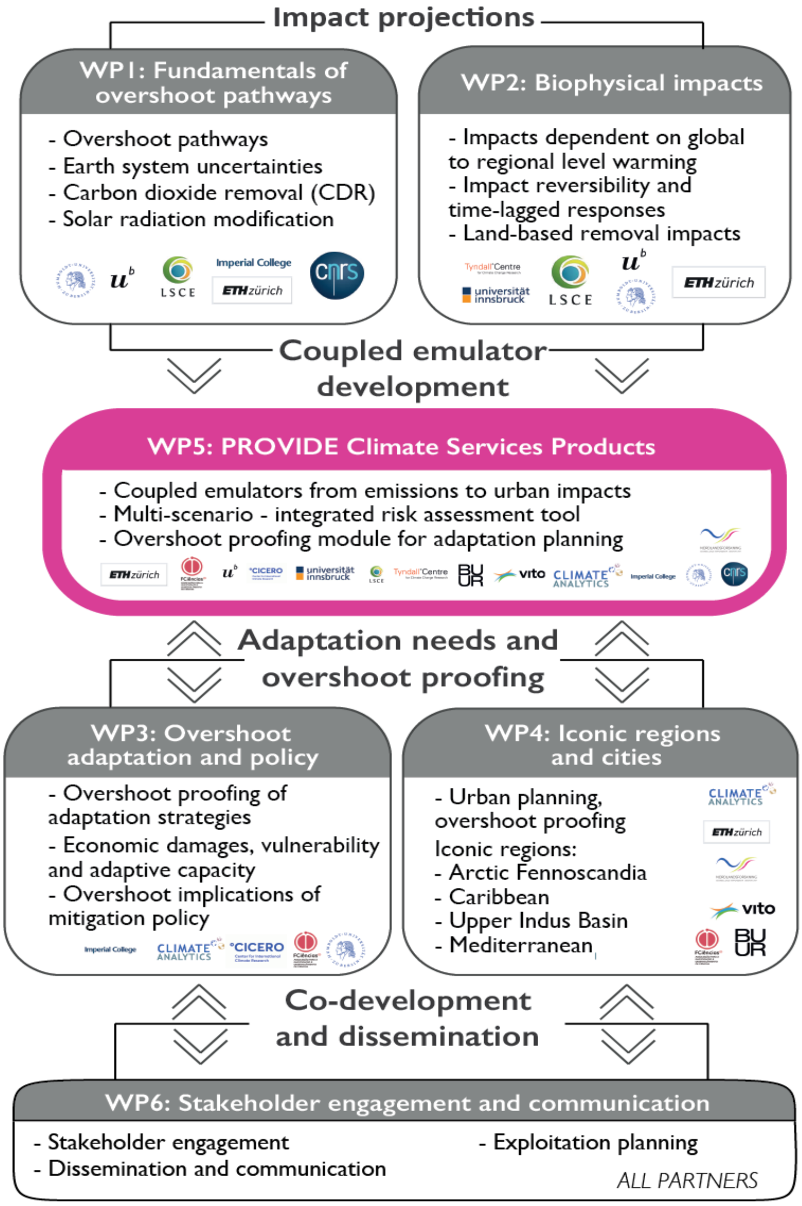

Figure 1.2. PROVIDE is organized in interlinked work packages.

1.2. Iconic Regions and Iconic Cities (WP4)

PROVIDE assesses regional and local impacts of overshoot pathways and the required adaptation responses in four Iconic Regions (IR), including a focus on selected urban environments within those regions. These regions and cities are places where physical risks overlay with specific socio-economic vulnerabilities. The Iconic Cities (IC) were selected to serve as places where the PROVIDE Overshoot Proofing Methodology can be co-developed with local and regional stakeholders. They will provide entry-points for raising awareness about the need for enhanced adaptation action under overshoot scenarios and offer a practical testbed for generalisable urban planning approaches.

Figure 1.3. Region in focus for PROVIDE.

The regions and cities in focus for PROVIDE are:

1. Arctic Fennoscandia, with a focus on Bodø, Nordland County, Norway.
2. Iberian Mediterranean, with a focus on the Lisbon Metropolitan Area, Portugal.
3. Upper Indus Basin, with a focus on Islamabad, Pakistan.
4. The Bahamas, with a focus on Nassau.

The IRs span over diverse climate zones, different environments, and different social and cultural contexts. They thus represent different adaptation challenges. Nevertheless, some conclusions are relevant across the regions, which will be particularly important for developing a generalizable overshoot proofing methodology and a Climate Services Dashboard that is credible and useful in a wide range of contexts.

2. Iberian Mediterranean and Lisbon Metropolitan Area

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2.1. Introduction to Iberian Mediterranean

2.1.1. Physical and geographic characteristics

The Iberian Mediterranean Iconic Region is located in the southwest of the Mediterranean region and includes most of the Iberian Peninsula (Portugal and Spain). The Iberian Peninsula is limited by the Pyrenees in the northeast, by the Atlantic Ocean in the western, and southwestern coasts, and by the Mediterranean Sea in the southern and eastern shores. The Iberian Peninsula has several distinct orography and climate types with the Mediterranean climate covering, by far, the largest area, see Figure 2.1.

Mediterranean climates are temperate climates with temperatures in the coldest month averaging between 0 °C and 18 °C and with temperatures in the warmest month greater than or equal to 10 °C (Köppen–Geiger climate classification system (Barceló and Nunes 2011). Mediterranean climates in the Iberian region can be further subdivided in Hot-summer Mediterranean climate (Csa) and Warm-summer Mediterranean climate (Csb). Here, average temperatures in the warmest month are above (below) 22 °C in the Csa (Csb) climate and at least four months have average temperatures above 10 °C (Barceló and Nunes 2011). These are areas were precipitation in the driest summer month of summer is less than 30 mm and represent less than one-third of the wettest winter month. To serve as context, the Csa classification is the type of climate covering most of the European Mediterranean coastal regions.

For the purposes of PROVIDE, the Iberian Mediterranean Iconic Region is broadly defined as the area covering the southern half of Portugal, and the south, central and eastern areas of Spain, including the Balearic Islands. These are areas that have a distinct hot-summer Mediterranean climate (Csa) or are transition areas that may include already semi-arid and arid climates and environments (see Figure 2.2 for a territorial definition by NUTS-2).

The Iberian Mediterranean is characterised by its mountainous nature, embodied by an inland plateau, the Meseta, at more than 600 metres above mean sea level. The mountain systems are usually arranged from west to east. The influence of topography on the climate is clear as it establishes an obstacle to the access of humid air masses from the Atlantic (Cabos et al. 2020)

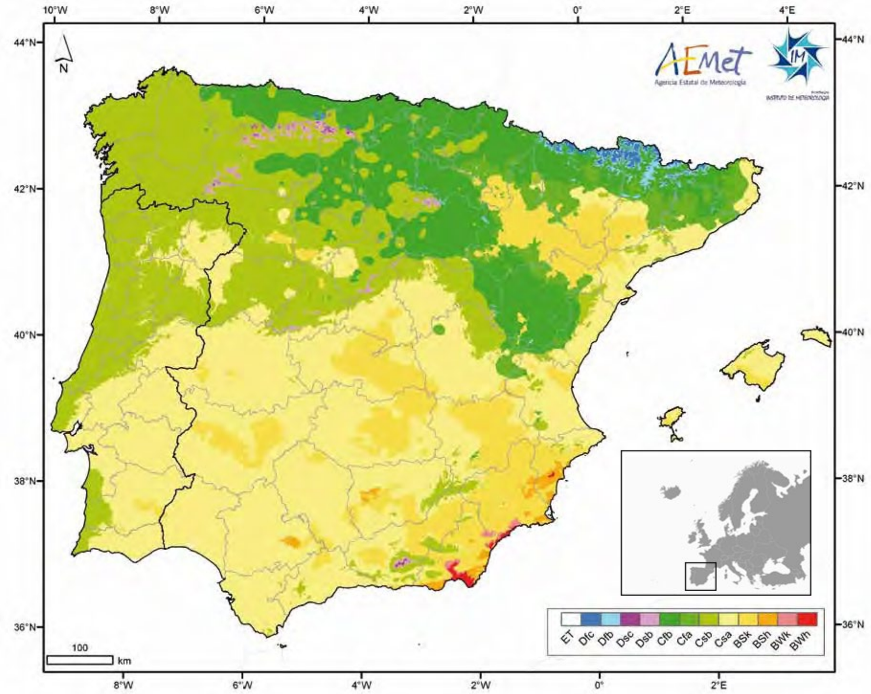

Figure 2.1. Köppen-Geiger climate classification in the Iberian Peninsula (Reproduced from the Iberian Climate Atlas, 2011); Csa and Csb are Mediterranean climates.

The territorial definition of the Iberian Mediterranean Iconic Region by NUTS-2 includes the following regions: PORTUGAL: Alentejo, Algarve, Área Metropolitana de Lisboa; SPAIN: Andalucía, Castilla-la Mancha, Cataluña, Comunidad de Madrid, Comunitat Valenciana, Extremadura, Iles Balears, Región de Murcia (Figure 2.2).

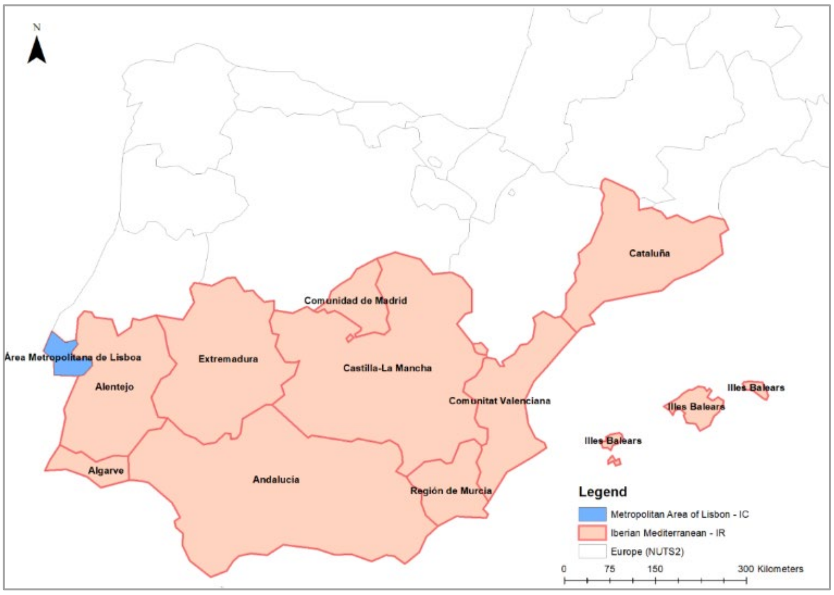

Figure 2.2. NUTS-2 territorial areas of the IR base on Mediterranean type of climate considered in the Köppen classification.

The rivers regime and hydrographic network of the Iberian Mediterranean are strongly influenced by the topography and rainfall, either through surface runoff or through underground contributions. The region's diverse morphological and geological characteristics support different hydrological profiles. The major river basins in the Iberian Mediterranean are the Tagus, Guadiana, Guadalquivir, and the final section of the

Ebro river (Figure 2.3). The shared transnational rivers in the region (Tagus and Guadiana) are jointly managed by Portugal and Spain under the 1994 Spanish-Portuguese Albufeira Convention[1] (Council of the European Union - General Secretariat 2008; Bukowski 2011).

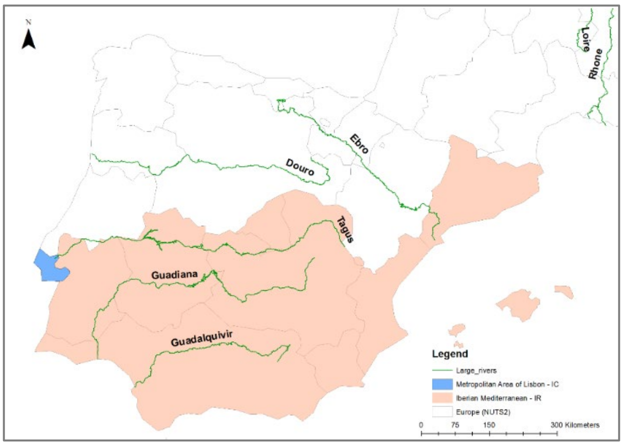

Figure 2.3. Major rivers in the Iberian Peninsula and the Iberian Mediterranean region.

The biogeographical regions in the Iberian Mediterranean are diverse and associated with a wide range of biodiversity hotspots, landscapes, ecosystem services, and natural resources. Natura 2000 sites are important hotspots for nature conservation in the region (defined by Annex I of the Habitats Directive[2]) helping to monitor conservation effectiveness and if the decline of certain habitat types is being halted (Figure 2.4).

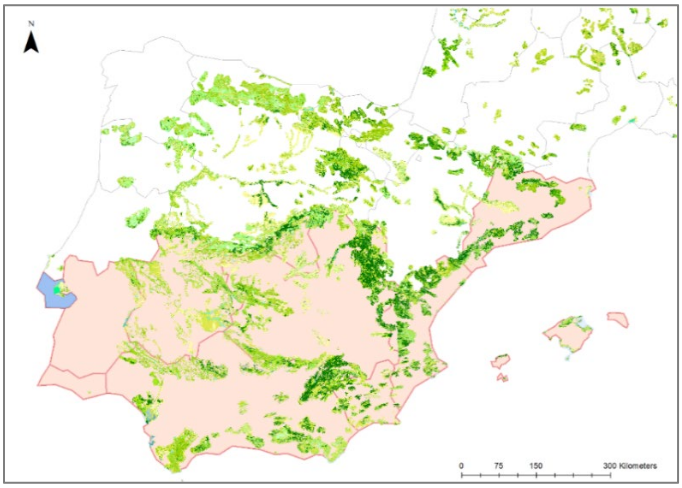

Figure 2.4. Land Cover / Land Use (LC/LU) and natural areas covering selection of Natura 2000 sites in the Iberia Peninsula and Iberian Mediterranean (Reproduced from N2K product, Copernicus, 2022)

The Atlantic Ocean and the Mediterranean Sea have a clear influence on the region's climate, which shifts gradually from the Atlantic coastline to the interior resulting in marked differences in precipitation and average annual temperature ranges (Barceló and Nunes 2011). The Mediterranean influence increases gradually from the north to south and from west to east, and during the summer, with high temperatures and low rainfall.

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[1] http://www.cadc-albufeira.eu/pt/
[2] Council Directive 92/43/EEC (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31992L0043)

The Atlantic influence increases during the winter and gradually to the west and northwest of region, promoting higher precipitation in opposition to the dry and cold winds from the Peninsula's interior (Barceló and Nunes 2011).

Recently observed climate trends in the region have been marked by a clear warming and a decrease in precipitation (both in means and extremes). Nevertheless, geographical patterns, i.e., warmer and drier inland and cooler and wetter coastal areas, have been maintained, with the noticeable exception of an increase in winter precipitation in the interior southeast of Spain (Figure 2.5 and Figure 2.6).

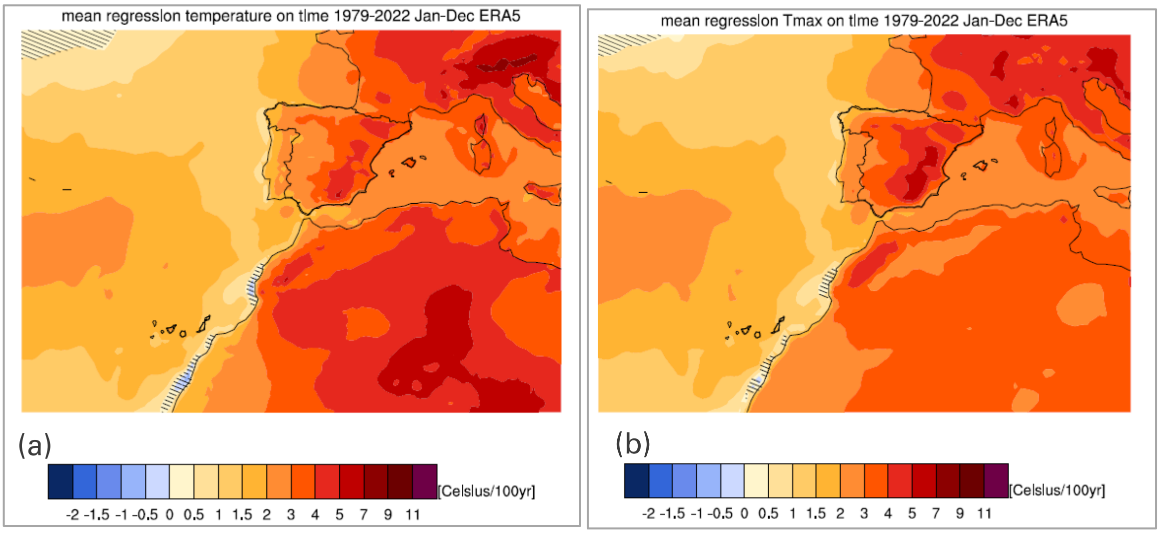


Figure 2.5. ERA5 reanalysis for the Iberian Mediterranean Region: (a) Mean regression of near-surface annual temperature 1979-2022; and (b) mean regression of maximum near-surface annual temperature 1979-2022. (Maps generated using KNMI Climate Change Atlas: http://climexp.knmi).

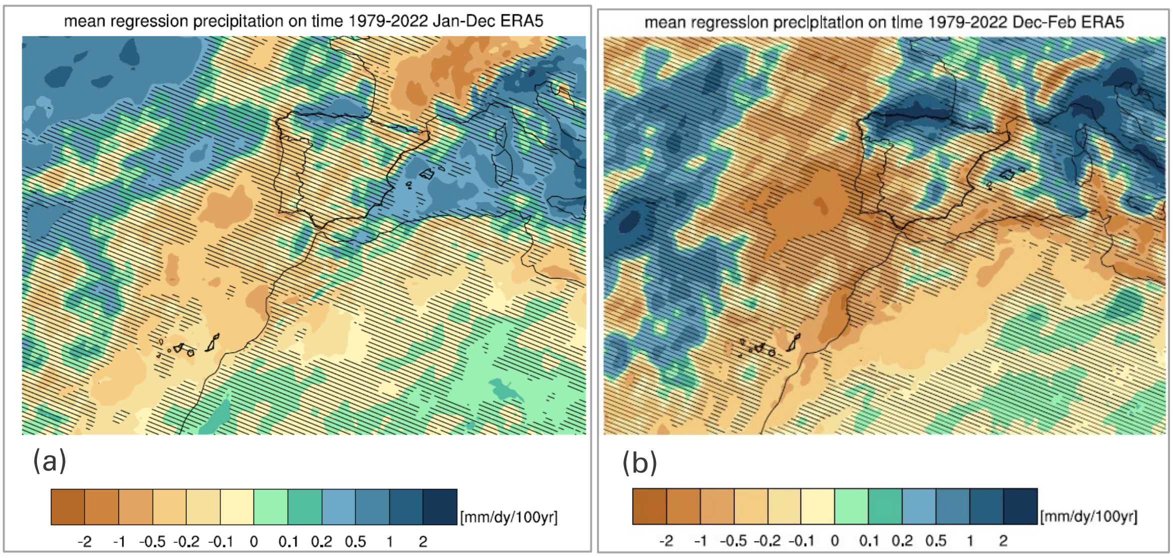


Figure 2.6. ERA5 reanalysis from January to December for Iberian Mediterranean Region: (a) Mean regression of annual precipitation 1979-2022; and (b) mean regression of winter precipitation (DJF) 1979-2022. Note: The hatching represents areas where the signal is smaller than one standard deviation of natural variability (Maps generated using KNMI Climate Change Atlas: http://climexp.knmi.nl/plot_atlas_form.py).

2.1.2. Demographics

The Iberian Mediterranean Region has a total population of about 38 million (as of January 2020)[3]. Demographic dynamics show a concentration of the population along coastlines and in metropolitan areas (Figure 2.7). Increasing desertification and ageing in the interior areas have implied a reduction in agroforestry activity and an increase in the risk of forest fires. Intense seasonal population movements associated with summer tourism increase vulnerability in areas already most sensitive to droughts.

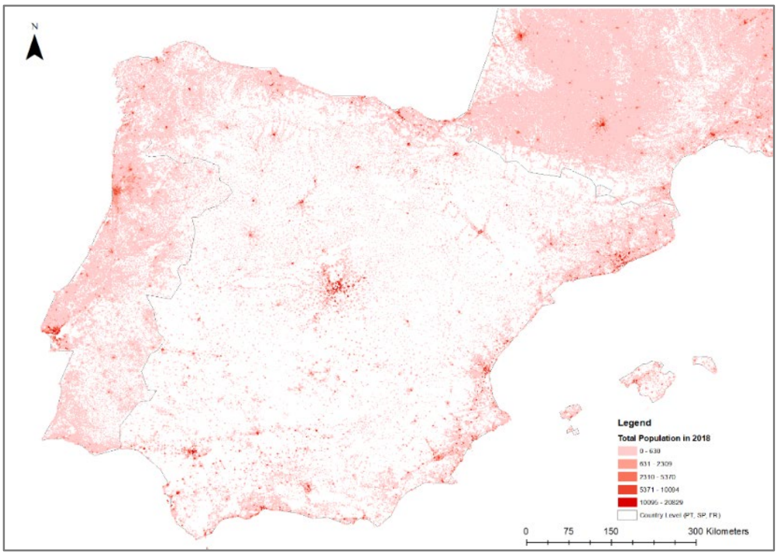


Figure 2.7. Iberian Mediterranean population in 2018, regular grid map of 1 x 1 km cells reporting the number of residents for the year 2018 for Europe (Pigaiani and Batista e Silva 2021).

The largest metropolitan areas in the region are Madrid, Barcelona, Lisbon, and Valencia, all with a population over two million.[4]

Table 2.1. Population in the major metropolitan areas. Source: Eurostat Last updated: 2021-06-14

Metropolitan Areas	Population in 2020
Madrid	6 747 068
Barcelona	5 635 100
Lisbon	2 863 272
Valencia	2 568 846

Population natural change is negative in the region, as there are currently more deaths than births each year in both Spain and Portugal. Population declining and ageing is only balanced by immigration. Significantly declining fertility rates have been registered in the region since the 1980s. Spain saw a surge in immigration during the 2000s, led by a strong economic growth, while this effect was less significant in Portugal. During the 2010s both countries, and in turn the Iberian Mediterranean, experienced a drop in population, associated with the financial crisis that led to significant emigration.

[3] https://ec.europa.eu/eurostat/web/main/data/database
[4] https://ec.europa.eu/eurostat/web/main/data/database

2.1.3. Governance

The governance structure in the Iberian Mediterranean region is mostly framed by the organizational bodies of the regional and national governments of Portugal and Spain. The regional and municipal governance structures in both countries are significantly different.

Portugal is a semi-presidential democratic republic, divided into 308 municipalities (the main elected sub-national territorial administrative unit), which in turn are subdivided into 3,092 civil parishes (the lower elected subnational administrative unit). Additionally, Portugal has two autonomous regions corresponding to the Atlantic archipelagos of the Azores (Azores Autonomous Region) and Madeira (Madeira Autonomous Region). Municipalities are responsible for enacting national law and promoting and safeguarding the interests of the population, in collaboration with the civil parishes, which includes climate action. At the regional level, the country is divided into 23 non-elected Regional Administrations (named Intermunicipal Communities, with delegated competencies from both central government and municipalities in the mainland), and the two Regional Autonomous Regions.

Spain is a constitutional monarchy, with a bicameral parliament, divided into 17 Autonomous Communities and 2 autonomous cities (Ceuta and Melilla in north Africa). These are further divided into 50 provinces (*Provincias*), which in turn are divided into 8118 municipalities (*Ayuntamientos*). The Autonomous communities are elected and have extensive legislative and executive power, with their own parliaments and regional governments.

2.1.4. Economy

The regional economic structure is based on the services sector. In Portugal, 68.9% of the population works in the tertiary sector with the figure rising to 75.5% in Spain.[5]

The forestry and agricultural sectors still represent a significant part of land uses, with large potential for economic development and job creation in the region. Tourism is an economic activity of great relevance in the region, with a widespread economic dependence on this sector.

GDP per inhabitant is higher in the north of the region, in the Lisbon Metropolitan Area and in Algarve (south Portugal). In line, unemployment rates are higher in the south of Spain than anywhere else in the region, coinciding with higher desertification rates (Figure 2.8).

[5] Data for 2019, gisco-services.ec.europa.eu

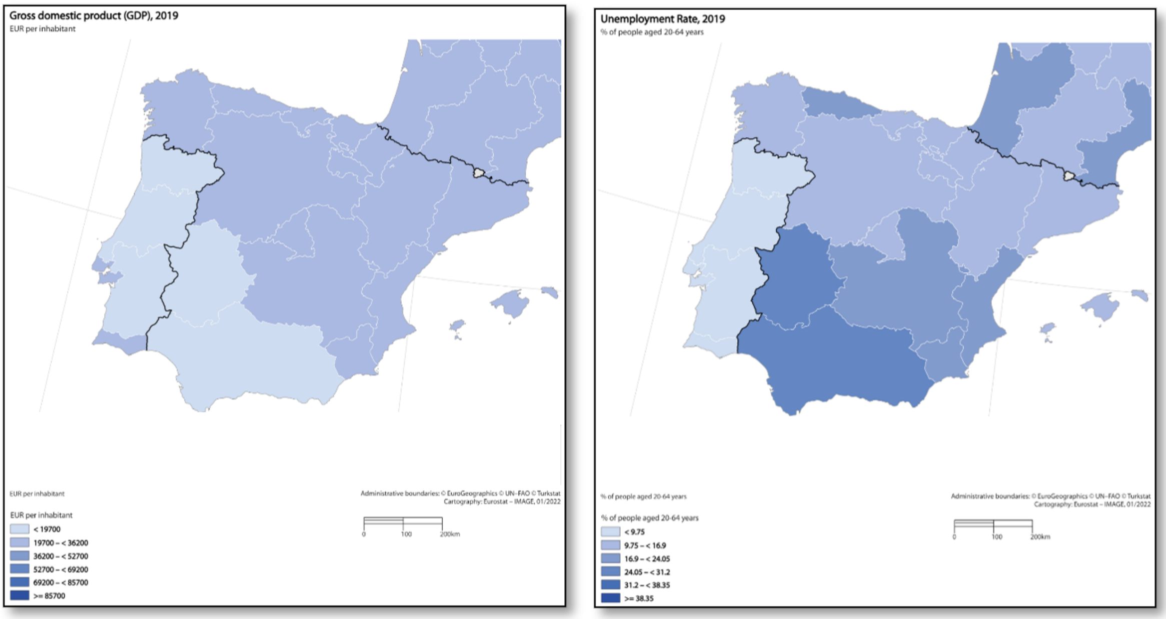


Figure 2.8. (a) Iberian Mediterranean GDP (EUR per inhabitant) by NUTS-2; (b) Iberian Mediterranean percentage of unemployed people aged 20-64 years by NUTS-2 (Maps generated from gisco-services.ec.europa.eu).

The current context is established by the global impact of SARS-CoV-2 (COVID-19) pandemic. The economic growth scenarios in the region have changed completely, compared to the outreach perspectives in 2020. The impact of the necessary measures to contain the health crisis are yet to be fully dimensioned, however, according to EUROSTAT, the changes in the first four months of 2020 represented a drop of 4% to 5% of GDP.[6] The Portuguese and Spanish economies were among the most affected in the EU, through restrictions imposed in sectors associated with tourism. The situation caused by COVID-19 led to the shutdown of the sector from the beginning of 2020. In April 2020, the flow of international visitors was reduced to zero due to the closure of borders imposed by the state of emergency.

2.2. Introduction to Lisbon Metropolitan Area

2.2.1. Physical and geographic characteristics

The Lisbon Metropolitan Area (AML) is located in south-centre of Portugal and includes 18 municipalities, with a total area of 2,892 km^2.

Located across both margins of the Tagus River estuary and to the north of the Sado River estuary (Figure 2.9) the AML has significant natural values, including relevant protected areas such as the Sado Estuary Nature Reserve, the Serra da Arrábida Natural Park, the Arrábida Marine Park, the Gruta do Zambujal Classified Site, the Tagus Estuary Nature Reserve, the Sintra-Cascais Natural Park and the Protected Landscape of the Arriba Fossil da Costa da Caparica.

[6] https://ec.europa.eu/eurostat/databrowser/view/sdg_08_10/default/line?lang=en

Figure 2.9 Lisbon Metropolitan Area and respective municipalities: south Tagus River municipalities (green), north Tagus River municipalities (purple) (Marques 2016)*.*

The average annual air temperature in the AML is around 15/16ºC, and the average monthly values vary regularly throughout the year, with a maximum in August and a minimum in January (Figure 2.10).

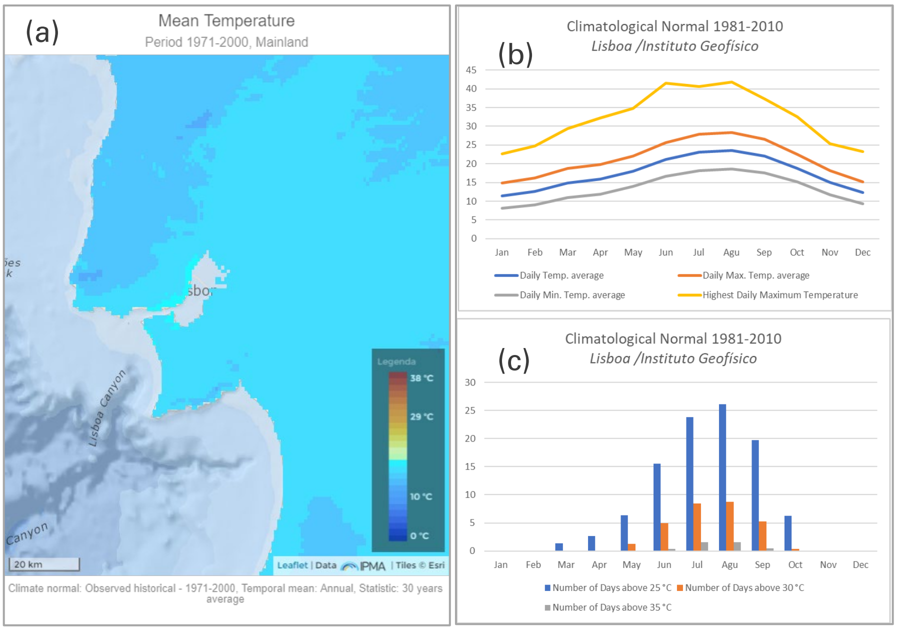


Figure 2.10. Lisbon Metropolitan Area: (a) Climate normal 1971-2000 for annual mean temperature distribution; (b) Climate normal 1971-2000 for mean temperature and (c) Climate normal 1981-2010 for number of hot days at representative weather station of Instituto Geofísico, Lisbon (IPMA 2015).

The average annual mean precipitation in the AML is around 400-600 mm, mostly concentrated between October and April. Summer precipitation is residual (Figure 2.11).

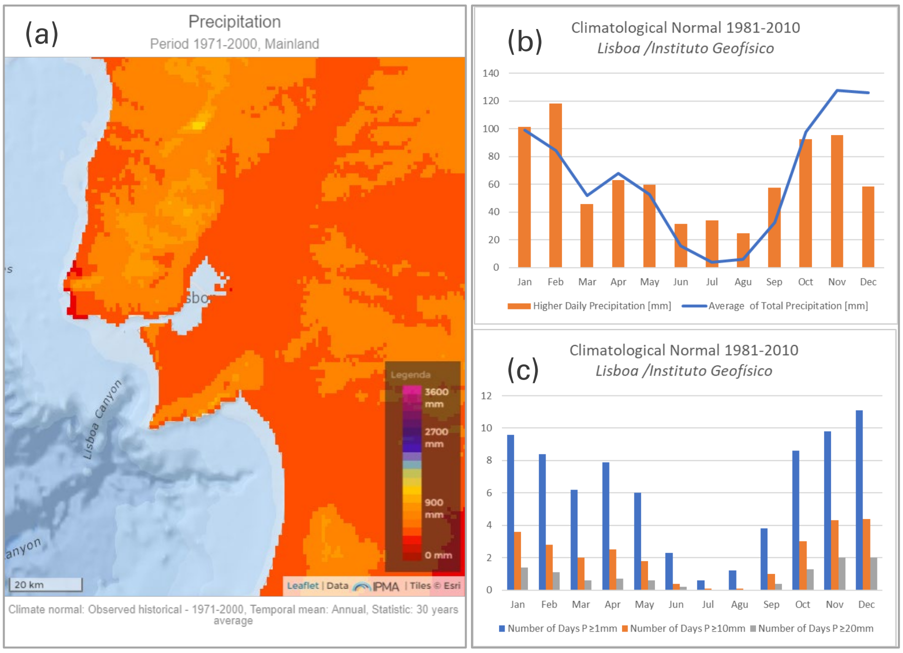


Figure 2.11. Lisbon Metropolitan Area: (a) Climate normal 1971-2000 for annual mean precipitation distribution; (b) Climate normal 1981-2010 for mean total precipitation and (c) climate normal 1981-2010 for number of precipitation days at representative weather station of Instituto Geofísico, Lisbon (IPMA 2015).

2.2.2. Demographics

The Lisbon Metropolitan Area is the third largest urban centre in Iberian Mediterranean with a population of approximately 3 million, including the Portuguese capital Lisbon and 17 other municipalities. It accounts for more than a quarter of the country's total population and over a third of its GDP. Lisbon is a typical Mediterranean coastal city, both culturally as in terms of vulnerability to extreme climate events and economic impacts such as reduced labour productivity.

In 2020 the resident population was 2,866,153, mainly located in Lisbon and Sintra municipalities (Table 2.2. Resident population, annual average (Data Sources: INE - Annual Estimates of Resident Population INE - Annual Estimates of Resident Population Source: PORDATA Last updated: 2021-06-14).Table 2.2). The AML population corresponds to 27% of the total resident population in Portugal, 26% of employment and 48% of national business production. The demographic importance of the AML results from its strong capacity to attract population.

Table 2.2. Resident population, annual average (Data Sources: INE - Annual Estimates of Resident Population INE - Annual Estimates of Resident Population Source: PORDATA Last updated: 2021-06-14).

Municipality	2001	2010	2020
Alcochete	13 191	17 329	19 860
Almada	161 294	173 634	168 852
Amadora	175 533	175 208	184 812
Barreiro	78 963	78 969	74 939
Cascais	171 997	204 767	213 775
Lisboa	563 312	549 210	509 565
Loures	198 975	204 740	214 328

Mafra	55 259	75 499	85 056
Moita	67 332	66 176	64 282
Montijo	39 682	50 593	57 853
Odivelas	134 077	143 851	162 389
Oeiras	162 347	171 786	177 602
Palmela	53 765	62 395	64 176
Seixal	150 362	157 928	167 953
Sesimbra	38 057	48 928	51 909
Setúbal	114 140	120 950	114 702
Sintra	363 575	377 301	392 145
Vila Franca de Xira	123 356	136 224	141 960
Lisbon Metropolitan Area	**2 665 212**	**2 815 483**	**2 866 153**

The capacity to attract population means that, between 1991 and 2011, the resident population in AML increased by around 12%. The demographic trends have a different expression throughout different municipalities. The municipality of Lisbon had a decrease in the number of residents (nearly -3%), on the other hand the municipalities around Lisbon registered population increases: Mafra (42%), Alcochete (35%), Sesimbra (32%) and Cascais (21%).

The population pyramid also changed over the last decade. The active population decreased from 69.7% to 66.3% between 2001 and 2011 and, for the same period, the population under 14 increased from 14.9% to 15.5%. In opposition, the elderly population (over 65) registered a considerable growth, rising from 15.4% in 2001 to 18.2% in 2011.

This evolution represents an age substitution deficit which results in an increase of elderly population proportion. In this context, the birth rate falls from 11.9‰ in 2001 to 11‰ in 2011, remaining above the national average, which was 9.2‰ in 2011. The current trend in the number of births associated with the longevity results in a demographic forcing on population ageing. This progress is particularly relevant since the elderly population is more vulnerable to extreme climate/ weather situations, such as cold or heat waves.

2.2.3. Governance

Metropolitan Areas in Portugal were created in 1991, reflecting the government objectives and needs of land-use management of the densely populated areas, and addressing the need for specific forms of territorial administration for this type of territory. Later the authority of the Metropolitan Areas was strengthened by the creation of municipal associations with responsibilities for intermunicipal planning of public transport systems, territorial strategy, regional development, and spatial planning.

In the AML, the deliberative body is Metropolitan Council that integrates all the municipal mayors. The Executive Committee, a body whose composition is indicated by the Metropolitan Council, is elected by an electoral college formed by 520 representatives of the 18 Municipal Assemblies.

2.2.4. Economy

The economic activity of the AML is relevant at the national and Iberian Mediterranean contexts. Together with Madrid and Barcelona, it represents a major economic attractor across the region, with increasing interconnectivity with its Spanish counterparts. In 2009, medium or large companies (with more than 50 employees) concentrated 50% of the staff working in the AML. The tertiary sector represented, in 2010, about 82% of national employment, which corresponded to a total of 1.2 million people.

Income distribution across the AML shows a marked concentration in the capital, Lisbon and wealthier municipalities to the West (Cascais and Oeiras) and to the East (Alcochete) (Figure 2.11). Poorer municipalities include the more urban outskirts of Sintra and Amadora, and some of the previously heavy industrialised areas on the south bank to the Tagus river.

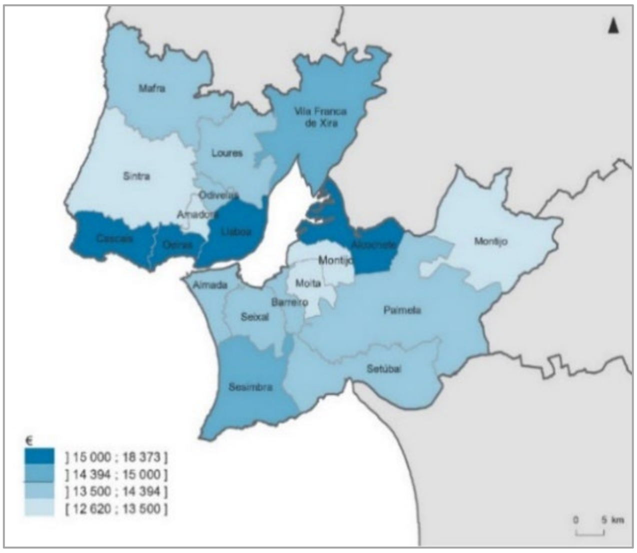


Figure 2.12. Metropolitan Area of Lisbon: (a) Median of gross income by tax person, 2019 (Source: Statistics Portugal, 2020: https://www.ine.pt/).

2.3. Climate Risks

2.3.1. Climate-related risks in the Iberian Mediterranean

2.3.1.1. Key hazards

A wide range of climate hazards are relevant for the Iberian Mediterranean and for its metropolitan areas. The risk of desertification is already intense in this region and is expected to increase in the future, under all scenarios (Figure 2.13). Current drylands (subtypes semi-arid and dry subhumid) in the Iberian Peninsula match perfectly PROVIDE’s geographical definition of the Iberian Mediterranean, but these areas are expected to expand north and transition to drier types (Figure 2.13) (Cramer et al. 2020b).

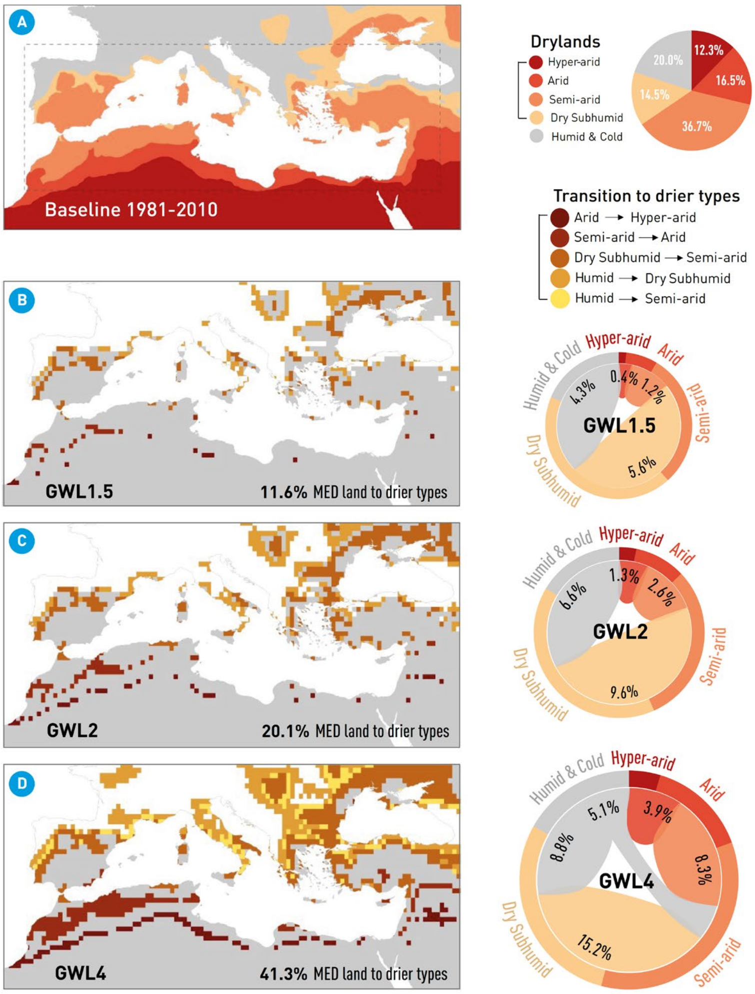


Figure 2.13. Distribution of drylands and their subtypes based on observations 1981-2010 period (A). Cover of drylands per subtype is estimated within the boundaries of the Mediterranean SREX region; (B, C, D) Distribution of projected dryland transitions for three Global Warming Levels (GWLs: +1.5°C, +2°C and +4°C above preindustrial levels), relative to the baseline period. Grey shaded areas in (B), (C) and (D) are drylands of the baseline period. Diagrams denote the extent of projected transitions in each dryland subtype (Source: Cramer et al. 2020a).

Climate risks related to extreme temperatures, droughts and water scarcity, forest fires, agriculture yield and species loss are other key hazards in this area (Seneviratne et al. 2016; Guiot and Cramer 2016). Additionally, these often occur within a combination of interacting physical processes across multiple spatial and temporal scales creating the so-called ‘compound events’ (Zscheischler et al. 2018), which may create additional challenges for climate adaptation and resilience.

Because of the Atlantic Ocean influence in this region, additional climate hazards related with sea level rise, storm surges and Atlantic hurricanes have to be considered. Atlantic hurricanes and storms provide an additional challenge as the wind they generate has been known to interact with catastrophic wildfires, fuelling them and creating devastating consequences[7].

[7] https://drmkc.jrc.ec.europa.eu/portals/0/Knowledge/ScienceforDRM2020/Files/supercasestudy_04.pdf

The following sections organise the key climate hazards in the Iberian Mediterranean region using the European Union (EU) Taxonomy following the Paris Agreement objectives (Dudout et al. 2021). The EU-taxonomy comprises four major hazard groups, namely those related to water, temperature, wind, and solid mass movements. This climate-related hazard classification distinguishes between acute (extreme) and chronic (slow onset) hazards, to consider both rapid and gradual changes in weather and climate within adaptation processes and to prevent maladaptation conditions.

Table 2.3 summarises key observed and projected hazards in the region as reported by Portugal and Spain in their National Adaptation Strategies (NASs) and National Adaptation Plans (NAPs) (Ministerio de Medio Ambiente; Presidência do Conselho de Ministros, Ministerio para la Transición Ecológica y el Reto Demográfico (MITECO) 2020).

Table 2.3: Climate-related observed and projected hazards as reported by the Portuguese and Spanish National Adaptation Strategies (NASs) and National Adaptation Plans (NAPs), organised according to the Eu-Taxonomy classification (source: as reported in https://climate-adapt.eea.europa.eu/).

Temperature	Wind	Water	Solid mass
Changing temperature (air, freshwater, marine water)	Changing wind patterns	Changing precipitation patterns and types (rain, hail, snow/ice)	Coastal erosion
Heat stress	Cyclone, hurricane	Precipitation and/or hydrological variability	Soil degradation
Temperature variability **(PT + SP)**	**Storm (including blizzards, dust and sandstorms)** **(PT + SP)**	Ocean Acidification	**Soil erosion (PT)**
Heat wave	Tornado	Saline intrusion	**Solifluction (SP)**
Cold wave/frost		**Sea level rise (PT)**	Avalanche
Wildfire (PT + SP)		**Water stress (PT + SP)** Water scarcity / quality deterioration	**Landslide (PT)**
		Drought	**Subsidence (SP)**
		Heavy precipitation (rain, hail, snow/ice) (PT + SP)	
		Flood (coastal, fluvial, pluvial, ground water)	

Legend:
Bold - Observed and Future climate hazards
(PT) – Report in Portugues territory
(SP) – Report in Spanish territory

Temperature variability

Increases in mean temperature and extreme heat and decreases of cold spells (Ranasinghe 2021a; Schleussner et al. 2021) are one of the most tangible climate-driven changes occurring in the region. Since 1950, mean and maximum temperatures, frequencies of hot days, and heat waves have increase and the cold-related hazards have decreased (Ranasinghe 2021a; Schleussner et al. 2021). The increasing intensity of heatwaves will cause additional mortality and extinction of vulnerable species, changing the provision of ecosystem services (Marbà and Duarte 2010).

Wildfires

Fire hazard conditions have substantially increased in Southern Europe from 1980 to 2019 (Urbieta et al. 2019; Fargeon et al. 2020; di Giuseppe et al. 2020). Wildfire events are related with multiple factors, from climate to social, but within this complex context, fire hazards have increased over the last decade and are project to increase in the future in the Iberian Mediterranean (Copernicus 2022; Bedia et al. 2018). Also in Mediterranean Basin, the frequency of heat-induced fire-weather is expected to increase by 14% at 2.5 °C of Global Warming Level, by the end of the century (Ruffault et al. 2020).

Water stress

In the Iberian Mediterranean, projected changes lead to more frequent and severe droughts, and as a consequence an increase in water scarcity (Ranasinghe 2021a). Additionally, impacts of compound events are emerging, such as recent crop failures due to heat and drought (Toreti et al. 2019).

In the Iberian Mountains, droughts can result in a significant reduction in ecosystems services like water provisioning and protection. It can also force the abandonment of pastoralism, which result in reduced water provision downstream. Ecosystems services will be significant affected and progressively limit the climate regulation capacity (Peñuelas et al. 2018; Xu et al. 2019).

Above 3°C Global Warming Level will likely lead to difficulties to adapt to water scarcity in parts of Southern Europe, due to geophysical and technological limits (Bednar-Friedl et al. 2022). The ability of trees to tolerate water stress can be exceeded with increasing duration of the dry season, leading to large-scale mortality, and changes in species dominance.

Storms (including blizzards, dust and sandstorms)

Storms are projected to increase in frequency across Europe over 2°C of warming, but there may be a potential decrease of their frequency in the Mediterranean region (Ranasinghe 2021a).

The frequency of windstorms can also rise substantially by 2100 (Forzieri et al. 2017), but there is limited evidence for windstorms and convective storms for most of the regions. With no scientific consensus about a climate-induced trend in windstorms over Europe, it is now evident that Southern Europe has the largest share of the area with an increase of 17% in wind extremes, in a scenario of 3°C of warming (Commission et al. 2020c).

Dust storms frequency has increased during recent years and projections suggest that it will continue to rise in response to climate change and anthropogenic activities (Schweitzer et al. 2018). The Sahara is the main source of dust deposition in the Iberian Mediterranean and in metropolitan areas like Lisbon, Madrid, and Barcelona (Salvador et al. 2014).

Sea level rise

Flood risks in low-lying coasts and estuaries are projected to increase due to sea level rise (SLR) combined with storm surges and heavy precipitation (Couasnon et al. 2020). For example, in a context of no adaptation the number of airports vulnerable may increase significantly between 2030 and 2080 along the Mediterranean coasts (Commission et al. 2018).

Heavy precipitation (rain, hail, snow/ice)

In recent decades, the number of floods has increased in summer (Blöschl et al. 2020) with increased economic damages, reflecting exposure of people and assets (Visser et al.

2014; Merz et al. 2021). There is no evidence that heavy precipitation is increasing in the region (observations from 1970-2019) but there is high confidence of an increase above 4°C of warming (Douville 2021; Ranasinghe 2021b).

Heavy precipitation events are expected to become more intense in a warming atmosphere, and rainfall totals during precipitation events may rise up to 7% per ºC of warming. Within this context it is expected that precipitation events (from sub-daily up to seasonal time scales) will intensify flood occurrence. However, the daily precipitation maximum (Rx1day), based on JRC data catalogue (Dosio Alessandro 2020) is projected to decrease in the region in both 1.5ºC and 3ºC warming scenarios (Gutierrez 2021).

2.3.1.2. Key components of exposure

Exposure is related with the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected. Key components of exposure considered for the Iberian Mediterranean are mainly vulnerable groups of people, related with the sociodemographic context, and the key vulnerable economic sectors present in the region and its metropolitan areas.

The key components of exposure described here are related to the above-mentioned hazards, with particular attention their interaction with urban areas, agriculture, tourism, human health, infrastructure, energy systems and coastal zones.

Heat and cities

The concentration of population in metropolitan areas represents a significant increase in exposure to urban heat islands, flash floods, landslides, and coastal-related risks.

Since the region is prone to desertification, especially inland areas, where ageing population and reducing economic activity will expose vulnerable groups of people to heat stress. In parallel, the exodus from rural areas to cities produces a significant pressure on environmental quality in cities.

Droughts in agriculture and tourism

The intense seasonal population movements related with tourism increases risks related to water stress and droughts in the region. The tourism sector is particularly exposed to increasing air temperatures considering that thermal comfort plays an important role in the attractiveness of a destination.

Climate change and decades of intensive agricultural practices and cultures make agriculture in the region prone to desertification and other potential risks (Spinoni et al. 2017). The region's spatial-temporal distribution of precipitation can lead to a reduction in water availability in certain areas and periods of the year, which can affect agricultural activity. The sector is very exposed to climate, and irrigation is fundamental to guarantee the viability of agriculture, particularly to develop spring-summer crops. Additionally, agriculture is exposed to climate change within a context of changing productivity and considerable moderate adaptation measures will be necessary (Feyen et al.; Bird et al. 2016; European Environment Agency 2019a; Moretti et al. 2019).

Combined with socio-economic development, the increase of frequency and intensity of heat and droughts will promote a reduction on water availability for irrigation leading to the potential abandonment of farmland (Holman et al., 2017).

For example, in the Lisbon Metropolitan Area, the annual precipitation reduction projected until the end of the century is between 20% and 25% (IPMA 2015), which, associated with the lack of development of some rural areas and the high risk of water erosion, will tend to significantly affect agroforestry production systems.

Health systems

Health systems could face significant pressure due to direct impacts on human health related with air quality, infectious diseases, natural disasters (floods, fires), or even as a result of extreme weather events (Austin et al. 2016a; Watts et al. 2021a). In extreme heat or heat waves context, greater morbidity and mortality from heat-associated causes is expected, like dehydration, fatigue, and heat strokes. It is expected that these will act more severely on the population with less protection capacity, such as the elderly, children, or non-acclimatized tourists. In cities and in urban areas such as the AML, the consequences of extreme heat or heat waves are generally amplified by the thermal and hygrometric factors in the field that tend to generate the urban heat island events.

Infrastructures

The exposed assets are current related with river floods and storms. However, heat and drought will become major drivers in the future. Considering the companies located in exposed locations the probability of financial default may increase to up to four times until 2050, in all sectors (Central Bank 2021). Additionally, it is projected that exposure to urban flooding will increase with urbanization (Jongman et al. 2012; Jones and O'Neill 2016; Paprotny et al. 2018; Dottori et al. 2018).

Coastal areas have already started to be affected by sea level rise and human exposure to coastal hazards is projected to increase in the next decades (Merkens et al. 2016; Reimann et al. 2018). Exposure differs between scenarios for the coastal population for the 21st century. With the exception of SSP3, the coastal population will grow faster than the inland population (Merkens et al. 2016), which will increase exposure in coastal areas.

Energy

The region's energy systems are exposed to climate change in different contexts: (1) supply dependence from renewables, considering the potential changes in electricity production associated with wind, photovoltaic and hydroelectric production; (2) distributions and storage systems disruptions due to occurrence of extreme weather events; and (3) temperature variations and the associated increase in final consumption, both for heating and cooling. All these are expected to increase under climate change scenarios (Pina et al. 2018).

Coastal zones

Sea level rise is a threat for coastal communities and infrastructures, particularly beyond 2100. Coastal areas will be affected by sea levels and this context is also a great risk for the Mediterranean cultural heritage (Marzeion and Levermann 2014; Clark et al. 2016; Reimann et al. 2018). Extreme water levels, coastal floods, and sandy coastline recession are projected to increase along the region's coastline, especially in Atlantic coastlines in (Ranasinghe 2021b). Additionally, some of the most vulnerable ecosystems in the region are also highly exposed and will be significantly impacted (Marani et al. 2007; Ranasinghe 2021a). In Portugal, the number of additional people at risk of a 100-year coastal flood is not expected to change significantly while in Spain this number is expected to increase by at least 100.000 until the end of the century, when compared with current exposure and the number of people at risk (Haasnoot et al. 2021).

2.3.2. Climate-related risks in the Lisbon Metropolitan Area

2.3.2.1. Key hazards

The key climate hazards are presented in the Lisbon Metropolitan Area Climate Change Adaptation Plan (PMAAC-AML) and are based on scenarios that include the following variables (Pina et al. 2018):

- **Temperature**: average, maximum, minimum, number hot of days, summer days, tropical nights, frost days.
- **Precipitation**: total precipitation, number of days with intense precipitation.
- **Drought**: Standard Precipitation Index (SPI).
- **Wind**: average speed.
- **Thermal comfort**: Heat waves, cold waves, bioclimatic comfort (UTCI).

The major hazards projected for the AML will be related to increasing temperatures. Warmer conditions and the increase of length of the dry season will promote wildfire conditions that will cause the loss of natural habitats in the region. Forest fire are a major cause of disturbance in Mediterranean habitats and one of the biggest causes of loss of natural habitats (Batllori et al. 2019).

Table 2.4 summarises key climate-related hazards for the AML, classified according to the EU-Taxonomy.

Table 2.4. Climate-related hazards based on AML's Climate Change Adaptation Plan, organised according to the Eu-Taxonomy classification (projections: minimum value is for 2041-2070 and RCP4.5 and maximum value is for 2071-2100, RCP8.5).

Temperature	Water
Heat stress Increase in days under conditions of thermal discomfort: 24 to 66 days/year	**Precipitation and/or hydrological variability** Decrease of 5% to 17% annual precipitation Decrease of 25% (2071-2100, RCP8.5) in spring and autumn
Temperature variability Increase in average from 1,3ºC to 3,2ºC Increase in tropical nights from 6 to 34 days/ year	**Drought** Increase in annual average SPI: from -0,23 to -0,36
Heat wave 10 to 23 days in heat wave per year	**Heavy precipitation (rain, hail, snow/ice)** Increase in days with heavy precipitation: 1 to 2 days/ year

2.3.2.2. Key components of exposure

The AML vulnerability to extreme events, combined with the strong concentration of people, infrastructure and economic activities, results in a strong exposure to climate change, whose impacts can result in risk situations for people and assets, economic, property and cultural losses and, consequently, a deterioration of the social and economic situation, which is reflected in the increase of poverty.

The forestry sector is exposed to forest fires as a result of the decrease in average annual precipitation, temperatures, and frequency of heat waves. The exposure is higher in the municipalities of Mafra, Loures, Sintra, Setúbal and Sesimbra.

The key sectors reported as heavily exposed to climate change in the Lisbon Metropolitan Area Climate Change Adaptation Plan are (Pina et al. 2018):

- Forest and agriculture
- Biodiversity
- Industry, tourism e services
- Energy
- Water resources
- Human Health

The demographic evolution in AML is relevant for climate change since an ageing population is more vulnerable to extreme weather events, such as heat waves. This particular climate context can expose the National Health Service to moments of pressure, which can limit the response of the health services. Additionally, the Adaptation Plan refers the potential degradation of air quality by high ozone levels and as result of an increase in air temperature and less precipitation (Pina et al. 2018).

AML is directly influenced by the Atlantic Ocean, which leads to a significant exposure to sea-level rise, hurricanes, storms, and high energy waves that can cause coastal erosion and flooding, as well as saline intrusion. Along the coast, buildings, communication infrastructures, port areas, coastal defence structures, water reservoirs, pluvial systems, beaches, dunes, and other ecosystems are very exposed, as it is evident from historical impacts.

2.4. Adaptation

2.4.1. Key components of adaptive capacity

Adaptive capacity is the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to the consequences of climate change. The opportunities and constraints for adaptation in the Iberian Mediterranean and in the Lisbon Metropolitan Area include links to ongoing changes in the socio-economic and environmental context, including potential social-ecological tipping points.

We considered the ability of natural and human systems, institutions, and organisms to adjust to different potential impacts of climate change, taking advantage of opportunities or being limited by constraints in responding to the consequences that arise.

Table 2.5 summarises the key opportunities and enabling conditions for adaptation in the Iberian Mediterranean region.

2.4.1.1. Regional assessment of adaptation opportunities and constraints

Table 2.5.: Opportunities and enabling conditions for adaptation in the Iberian Mediterranean region

OPPORTUNITY	REGIONAL OVERVIEW
Awareness raising	- Heat-related casualties in Southern European cities are at a low level due to the application of prevention plans, individual and household adaptation measures and growing awareness of citizens (de' Donato et al. 2015). - Limited mainstreaming of climate change is observed, particularly due to low societal pressure to change, confidence in existing health systems, and lack of awareness of links between human health and climate change (Austin et al. 2016b; Watts et al. 2021b). - Even in companies that experience consequences of extreme weather events or stakeholder pressure, the action to adapt are limited due to underestimation of exposure to risk (Pinkse and Gasbarro 2016). - There remains little research on private-sector awareness of or responses to cascading or compound risks associated with climate change (Miller and Pescaroli 2018). - Higher climate change risk perceptions observed in Spain and Portugal (Duijndam and van Beukering 2021). - In Portugal, people living in the coast were more likely to attribute local natural hazards to climate change and to take some adaptive measures (Luís et al. 2017). - Many behavioural changes such as personal and home heat protection have already been implemented in South Europe (Martinez et al. 2019a).
Capacity building	- The main instrument to improve knowledge within adaptation to climate change is the definition adaptation strategy to climate change, identifying vulnerabilities and defining measures that strengthen resilience (Ranger et al. 2013). - Action Program for Adaptation to Climate Change (P-3AC) implement adaptation measures, with concrete lines of action for direct intervention in the territory and infrastructure. - The risk associated with human heat mortality is influenced by socio-economic scenarios. The consequences are more severe under SSP3, SSP4 and SSP5 scenarios than SSP1. - Within a context of extensive water consumer, crop production in Agriculture sector (Gerveni et al. 2020)(Gerveni et al. 2020) the adaptive capacity is reduced beyond 3°C GWL (Ruiz-Ramos et al. 2018).
Tools	- The governance tools to reduce impacts related with are the establishment of networks of protected areas. The cost-effective adaptation strategy with multiple additional co-benefits should be considered (Berry et al. 2015; Roberts et al. 2017).
Policy	- The climate change actions on mitigation and adaptation remain largely sectoral. - Many behavioural changes such as personal and home heat protection have already been implemented in South Europe
Learning	- Ecosystem-based solutions require space, which trend to be unavailable in cities. Flood options to protect are effective in reducing inland flooding risk but regional variation occur considering a cost-benefit ratio (Alfieri et al. 2018; Commission et al. 2020b).
Innovation	- Adaptation across Europe and sectors are more frequently incremental than transformative actions and should promote new opportunities and associated benefits (European Environment Agency 2019b).

Table 2.6 summarises the key constrains for adaptation in the Iberian Mediterranean region.

Table 2.6: Key constrains for adaptation in the in the Iberian Mediterranean region

CONSTRAINTS	REGIONAL OVERVIEW
Physical and Biological	- Low water availability (Ranasinghe 2021a). - Dense urbanized areas and coastal population agglomerations (Merkens et al. 2016).
Economic and Financial	- There are structural and economic barriers to household adaptation due to lack of policy incentives or regulations (European Environment Agency 2017). - Building interventions alone have low to medium effectiveness independent of the region (Martinez et al. 2019b). - Most of the budget EU spending is going to mitigation (Berkhout et al. 2015; Hanger et al. 2015; Leitner et al. 2020).
Human Capacity	- Key barriers to adaptation include both external (e.g., lack of support/guidance) and internal factors (e.g., few resources, managerial perceptions (Halkos et al. 2018). - Lack of knowledge, feeling climate change is not a salient risk, and lack of social learning or collaboration, appear to be key barriers to private sector adaptation (Dincă et al. 2014; Romagosa and Pons 2017; André et al. 2017).
Governance Institutions Policy	- Decrease in hydropower potential in South Europe are expected beyond 3°GWL (Commission et al. 2020a; Spinoni et al. 2020). - There are considerable barriers to mainstreaming adaptation (Runhaar et al., 2018). - Barriers to climate services: lack of perceived usefulness, outdated statistics, mismatch needs, insufficient effective engagement lack of business models to sustain climate services over time (Räsänen et al. 2017; Cavelier et al. 2017; Bruno Soares et al. 2018; Christel et al. 2018; Oberlack and Eisenack 2018; Hewitt et al. 2020).
Knowledge Awareness Technology	- Across Europe, and particularly in relation to gradual change, non-experts continue to under-estimate climate change risks compared to experts. (Taylor et al. 2014). - Non experts have low awareness of adaptation options and confuse adaptation and mitigation (Harcourt et al. 2019). - Adaptation responses across European regions and sectors, are more often incremental than transformative options (European Environment Agency 2019c). - Under medium warming a larger portfolio of measures might be needed, while it may not be able to completely avoid water shortages at high warming (Greve et al. 2018). - At higher GWL, ecosystems are projected to experience impacts due to temperature changes (Malhi et al. 2020)and SLR combined with human pressures (Mangan et al. 2020). - Models underestimate the total costs of climate change impacts by neglecting systemic risks, tipping points (van Ginkel et al. 2020), indirect and intangible costs, and limits of adaptation (Ercin et al. 2021; Piontek et al. 2021). - There is little research on public responses to risks and to multiple and cascading risks (van Valkengoed and Steg 2019).
Social/Cultural	- Water efficiency measures in anticipation of, or response to drought are also limited (Bryan et al. 2019), while water recycle in Mediterranean and some other EU countries is increasing (Aparicio 2017).

2.4.2. Adaptation governance and key polices

In climate change adaptation, policy makers like to require detailed and precise information about the likelihood and dimension of the climate impacts (Capela Lourenço 2015). Adaptation to climate change impacts must come after focused evaluation and planning (Füssel 2007), and depend on the conditions and background of each sector and location in focus. It is recognized that integrated complementary approaches need to be developed, which can benefit from the input of stakeholders at different times, setting critical thresholds for specific climate change vulnerabilities (Adger et al. 2005).

The integration of long temporal and large spatial scales in adaptation is a challenge that needs to be integrated into the rationale of governance practices. Adaptation can be based on uncoordinated, ad hoc choices and actions of individuals and different stakeholders, or based on collective choices, coordinating numerous actions at various levels – local, regional, national, or supranational (Swart et al. 2009).

Therefore, key elements of adaptation governance and policy-making for the Iberian Mediterranean region and its metropolitan areas require an assessment across scales, from the EU to the local level. The following sections highlight the key polices, strategies and plans of relevance for the adaptation governance in this region.

2.4.2.1. EU and the Mediterranean

Table 2.7

Table 2.8 summarise key EU adaptation policies, plans and strategies and other EU Policies plans and strategies with adaptation components of key relevance to the Iberian Mediterranean.

Table 2.7. Current EU adaptation policies, plans and strategies with major relevance to the Iberian Mediterranean.

Policy/Plan/ Strategy	Overview/Scope
EU Adaptation Strategy	The new strategy sets out how the European Union can adapt to the unavoidable impacts of climate change and become climate resilient by 2050. The Strategy has four principles objectives: to make adaptation smarter, swifter and more systemic, and to step up international action on adaptation to climate change.
EU Adaptation Strategy – Impact Assessment	
EU taxonomy for sustainable activities	Regulatory diploma to meet the EU's climate and energy targets for 2030. It defines a common classification system for sustainable economic activities.
The European Green Deal	It is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient, and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use.

Table 2.8. Current EU Policies plans and strategies with adaptation components of key relevance to the Iberian Mediterranean.

Policy/Plan/ Strategy	Overview/Scope
Biodiversity strategy for 2030	The EU's biodiversity strategy for 2030 is a comprehensive, ambitious, and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030 and contains specific actions and commitments.
EU Common Agricultural Policy	https://www.europarl.europa.eu/factsheets/en/sheet/103/the-common-agricultural-policy-cap-and-the-treaty.
EU Farm to Fork	Within the framework of the Green Deal, the European Commission launched in May 2020 the EU Farm to Fork Strategy that aims to ensure a sustainable food value chain. Sustainable agriculture and sustainable fishery within Protected Areas can be a model to provide safe, nutritious and high-quality products.
EU Climate Law	A new legislation to complement the existing framework to tackle Climate Change by irreversibly enshrining the 2050 carbon neutrality target in the law. This legislative act is in line with the Green Deal and the Union's desire to position itself as a global climate leader.
Floods Directive	Directive to assess and manage flood risks in water courses and coast lines, aim to map the flood extent and assets and humans and planning process.
Water Framework Directive	Aims at long-term sustainable water management based on a high level of protection of the aquatic environment by achieving a good ecological status in all waterbodies. EU Member states agreed that climate-related threats and adaptation planning have to be incorporated in the River Basin Management Plans (RBMPs) elaborated under the WFD.
Marine Strategy Framework Directive	The aim of the European Union's ambitious Marine Strategy Framework Directive is to protect more effectively the marine environment across Europe.
Strategy for Financing the Transition to a Sustainable Economy	The European Commission adopted today an ambitious and comprehensive package of measures to help improve the flow of money towards financing the transition to a sustainable economy.
New EU Forest Strategy for 2030	Aims to overcome these challenges and unlock the potential of forests for our future, in full respect for the principle of subsidiarity, best available scientific evidence and Better Regulation requirements.
Land use and forestry regulation for 2021-2030	The Land Use, Land Use Change and Forestry (LULUCF) Regulation implements the agreement between EU leaders that all sectors should contribute to the EU's 2030 emission reduction target, including the land use sector.
EU4Health Programme	EU4Health is the EU's ambitious response to COVID-19. The pandemic has a major impact on patients, medical and healthcare staff, and health systems in Europe. The new EU4Health programme will go beyond crisis response to address healthcare systems' resilience.
Interreg MED Programme	Gathers 13 European countries from the Northern shore of the Mediterranean. They are working together for a sustainable growth in the region.

2.4.2.2. Iberian Mediterranean (Portugal, Spain)

Adaptation governance in the Iberian Mediterranean is incipient with the notable exception of some past efforts from both countries' Environmental Agencies[8]

Both Portugal and Spain have heavy and centralised national, regional, and autonomic regional levels of governance (see section Governance). This is also reflected on the climate action governance structures of both countries.

Tables Table 2.9 Table 2.10 summarise key existing adaptation plans and other sectoral policies and plans that incorporate an adaptation dimension in the Iberian Mediterranean.

Table 2.9. Existing adaptation policies, plans and strategies in the Iberian Mediterranean.

Policy/Plan/Strategy
National Climate Change Adaptation Plan 2021-2030 - Spain
Climate Change Adaptation: 3° Working Programme (National adaptation plan)
National Adaptation to Climate Change Strategy (ENAAC 2020) - Portugal
Action Plan for Adaptation to Climate Change (P-3AC) - Portugal

Table 2.10. Key policies, plans and strategies with adaptation components in the Iberian Mediterranean.

Policy/Plan/Strategy
Adaptation Strategy for the Spanish Coast
Forest Adaptation Plan to Climate Change - Portugal
National Strategy for Preventive Civil Protection - Portugal
Southwest Europe Programme

2.4.2.3. Lisbon Metropolitan Area

Climate change is a national priority for Portugal since it is one of the European countries most vulnerable to the impacts of climate change. The Lisbon Metropolitan Area is a relevant hotspot of impacts due to its location and socioeconomic relevance.

The Lisbon Metropolitan Area is overcoming relevant transformational efforts in terms of decarbonisation and adaptation. Eight municipal strategies and one intermunicipal adaptation strategy have already been adopted, and collaboration with the cities and metropolitan officials. With regional and local stakeholders, the regional governance facilitates the overshoot planning into the rapidly growing discussion about the implementation of adaptation actions, such as those included in the Metropolitan Adaptation Strategic Plans for heatwaves (see section 3.6 Insights from stakeholder engagement meeting).

Tables Table 2.11,Table 2.12 Table 2.13 summarise key existing adaptation polices strategies and plans, other sectoral plans with that incorporate an adaptation dimensions and upcoming adaptation strategies and plans in the AML.

[8] LIFESHARA project: https://www.lifeshara.com/

Table 2.11: Existing adaptation policies, plans and strategies in the Lisbon Metropolitan Area

Policy/Plan/Strategy
Climate Change Adaptation Metropolitan Plan – Lisbon Metropolitan Area[9]
Climate Change Adaptation Municipal Strategy/ Plan – Barreiro[10]
Climate Change Adaptation Municipal Strategy/ Plan – Lisbon [11]
Climate Change Adaptation Municipal Strategy/ Plan – Mafra[12]
Climate Change Adaptation Municipal Strategy/ Plan – Loures[13]
Climate Change Adaptation Municipal Strategy/ Plan – Oeiras
Climate Change Adaptation Municipal Strategy/ Plan - Odivelas
Pacto para o Desenvolvimento e Coesão Territorial da Área Metropolitana de Lisboa (PDCT-AML).[14]

Table 2.12: Other policies, plans and strategies with adaptation components in the Lisbon Metropolitan Area

Policy/Plan/Strategy
18 Municipal Master Plans (original name: Plano Director Municipal – PDM).
Municipal Plans for Forest Defence against wildfires (original name: Planos Municipais de Defesa da Floresta Contra Incêndios).
Municipal and Multi-municipal Plans for Floods Management Risk (original name: Planos de Gestão dos Riscos de Inundações (PGRI).
Hydrographic Region Management Plans (original name: Planos de Gestão de Região Hidrográfica), two plans aplei in AML: • RH5 — Tejo e Ribeiras do Oeste (Alcochete; Almada; Amadora; Barreiro; Cascais; Lisboa; Loures; Mafra; Moita; Montijo; Odivelas; Oeiras; Seixal; Sintra; Sesimbra; Setúbal; Vila Franca de Xira) • RH6 — Sado e Mira (Montijo; Palmela; Sesimbra; Setúbal)
Planos e Programas da Orla Costeira (1. Alcobaça – Mafra; Cidadela – São Julião da Barra; Sintra – Sado; Sado – Sines).
Human Heat stress in AML.

9 https://www.lisboa.pt/fileadmin/atualidade/noticias/user_upload/plano_metropolitano_de_adaptacao_as_alteracoes_climaticas.pdf
10 https://www.cm-barreiro.pt/cmbarreiro/uploads/writer_file/document/10297/00_EMAAC_Barreiro.pdf
11 https://www.lisboa.pt/fileadmin/cidade_temas/ambiente/qualidade_ambiental/EMMAC/EMAAC_2017.pdf
12 https://www.cm-mafra.pt/cmmafra/uploads/writer_file/document/1555/emmac_mafra.pdf
13 https://www.cm-loures.pt/AreaConteudo.aspx?DisplayId=1284
14 https://www.am-lisboa.pt/documentos/1518972446X5wIG6ed3Po44JT3.pdf

Table 2.13: Upcoming adaptation policies/plans/strategies in the Lisbon Metropolitan Area

Policy/Plan/Strategy	Lead Agency	Overview/Scope
Climate Change Adaptation Municipal Strategy/ Plan,Palmela	Palmela Municipality	The Project PLAAC - Arrábida (developed by ENA - Energia e Ambiente da Arrábida) will develop three Climate Change Adaptation Municipal Plans in Setúbal, Palmela and Sesimbra. This project intends to adapt the territory to cope to climate change by identifying vulnerabilities, reducing risks and impacts, and promoting resilience. The elaboration of the plans involves a participatory process with the key actors of the community.
Climate Change Adaptation Municipal Strategy/ Plan - Sesimbra	Sesimbra Municipality	
Climate Change Adaptation Municipal Strategy/ Plan - Setúbal	Setúbal Municipality	
Climate Change Adaptation Municipal Strategy/ Plan - Vila Franca de Xira (PMAAC-VFX)	Vila Franca de Xira Municipality	The PMAAC-VFX will be developed under the EEA-Grants financing resources. It will involve a communication planning with 4 workshops and 2 public participatory moments with citizens, companies, public institutions, and municipal bodies.
Climate action Plan – Lisbo 2030	Lisbon Municipality	Identify the current climate vulnerabilities and risks until the end of the century. Define the adaptation options to respond to future challenges – like heat waves, cold weather, intense precipitation and floods

2.5. Insights from stakeholder engagement meeting

2.5.1. Workshop purpose and setting

The first PROVIDE Stakeholder Engagement Meeting in the Iconic City of Lisbon Metropolitan Area (AML) was held on 4th March 2022 at the AML office, in Lisbon. Invitations to meeting were co-ordinated between the PROVIDE team and the AML, who sent out an official invite on behalf of the project to all members of the standing Metropolitan Working Group on Spatial Planning, Environment and Urbanism (Grupo de Trabalho Metropolitano Ordenamento do Território, Ambiente e Urbanismo). These included both decision-makers and technicians/planners in all the 18 municipalities that comprise the AML. The meeting took place in-person, with some participants connecting online. The meeting language was Portuguese with the exception of the online presentations by the PROVIDE team and direct questions to the presenters. There was a total of 26 participants (four online) covering 14 of the 18 AML municipalities. The meeting was supported and moderated by three members of the PROVIDE FC.ID team, who also provided notetaking. Additional AML technical local staff supported the meeting.

2.5.2. Climate risks and current adaptation efforts

After some introductory words and an opening address by the AML’s Secretary Filipe Ferreira, which addressed some of the current climate-related challenges in the area, participants were introduced to PROVIDE, including the project’s expected results and key concepts, such as overshoot pathways, reversal of the impact chain, limits to adaptation, critical thresholds and overshoot proofing. Participants were asked to share their perspective on how climate change is affecting their municipalities and how they are currently framing climate action across sectors and territories. There were comments and a general agreement that all the questions were valid and interesting for their work but that it was difficult to respond directly without further information on how thresholds and limits would be treated considering the current strategies already in place. The notion that impacts may be different before and after overshoot was noted by the participants as quite interesting and that it was something they had not thought about before.

A presentation from the AML illustrated the key elements of the current climate adaptation policy and practices in the region, with a particular emphasis on the Metropolitan Climate Change Adaptation Plan (PMAAC-AML). João Lopes from AML presented the climatic context of the plan, based on the definition of eight homogeneous morphoclimatic units that covered the entire region, and the local climate projections until 2100 (temperature and precipitation related variables) used to assess current and future climate vulnerabilities and risks. He noted that, in fact, it was not known if the temperature rise in the region was already above the 1.5ºC threshold set by the Paris Agreement, acknowledging that it was interesting to think about how this could frame the local adaptation context. It was noted that 14 (out of 18) municipalities already have their own Municipal Adaptation Strategy or Plan, with the remaining four being under development, which provides a comprehensive climate action coverage in the region.

During the follow-up discussion participants from three neighbouring municipalities that are working together, explained that the application of scenarios is relevant for territorial plans at the municipal level. For example, scenarios have been already developed for agriculture and tourism, but overshooting scenarios were never considered, even if their existence is known, noting that this kind of scenarios would be difficult to introduce in this phase of the process. However, they all agreed that this is an interesting perspective, especially considering the notion of (ir)reversibility of impacts and associated consequences for adaptation (loss of beach area and was given as an example). One participant asked how to measure and communicate where we are (locally) in relation to the overshoot trajectories (globally).

2.5.3. Overshoot, opportunities and constrains to adaptation

During the meeting's several discussion moments, participants were asked to identify major opportunities and constrains to adaptation, under different climate and socio-economic change trajectories, including the newly introduced overshoot pathways.

2.5.3.1. Opportunities

Several participants noted that it would be interesting to have a clear guidance on how to integrate adaptation measures at the local level. This would promote a better integration of climate change scenarios with territorial decision-making. In this context, one participant added that the recently approved Climate Framework Law (Lei de Bases do Clima, 31st December 2021) will make it mandatory that all municipalities to produce climate action plans (mitigation and adaptation) within two years if they do not have them already. She noted that municipalities will need to connect these plans with all other existing Territorial Management Instruments (IGTs - Instrumentos de Gestão Territorial), which creates a new reality and raises questions about how municipalities will be able to incorporate all relevant variables. AML noted that the ongoing PMAAC-AML monitoring and governance mechanism can be seen as a platform to exchange knowledge. The 47 projects from 7 municipalities that were already surveyed are an example, and they expect that more are to come about soon from the municipalities that have ongoing or concluded adaptation plans.

2.5.3.2. Constrains

Participants recognized that they face difficulties in the area of adaptation and even with clear information about the importance of climate change, there are always problems in a context of strained human resources, especially among technicians in the fields of urbanism and environment. Additionally, technicians in the field must collaborate with a fixed governance structure, making implementing changes challenging. As a follow-up several participants alluded to the need to collaborate directly with communities (and not in a closed circuit) so that adaptation action is well accepted and relevant, which adds another level of complexity when using many scenarios. One participant explained that the regional governance model is not flexible and may present some problems of articulation, noting that what is important at this stage is to implement the measures and develop what is in the plans. One participant pointed out a technical limitation to address heat waves in urbanized areas, especially considering the new regulation on 'Urban trees.' This regulation will require the planting of different amounts and species of trees by municipalities over the next two years, but there are areas where it is exceedingly difficult to apply proper arborization solutions. It would be important to understand how to adapt some "grey areas" without trees in city centres by analysing what parts of the surrounding area could be used to plant trees (and if this would ameliorate the heat in those areas). One participant noted the difficulty of promoting shaded areas in historic centres because there is no available space for trees or because there is resistance from conservation services that want to protect the architectural heritage. Some municipalities do have large forest areas but not in the urban centre or where they are (really) necessary. Additionally, some tree species may be disappearing, making it important to understand which species could/should be introduced (with care not to introduce aggressive invasive species). One participant mentioned that most of the currently available scenarios are focused on municipal territories and not in the region as a whole. Several participants expressed difficulties in the definition of thresholds, especially if there is a need to define a specific value or limit (e.g., number of hot nights) or define information within specific sectors.

2.5.4. Tools and spatial planning

One participant noted that to accomplish the objective of incorporating the spatial profile with climate information, risk and exposure maps (or layers) need to be overlaid onto existing Territorial Management Instruments. In particular, Municipal Director Plans (PDMs – Planos Directores Municipais) are planning layers of interest for this work. She added that risk is being considered in most cases, but the mapping is done without data from the Territorial Management Instruments. This is done separately and then risk mapping is incorporated into the planning instruments. Participants agreed that the mapping developed by PROVIDE can be useful to calibrate the development of the Territorial Management Instruments and to validate if the use of a certain territory parcel is appropriate in terms of climate change adaptation. Exposure factors and soil data are also relevant to be added to the mapping. Participants agreed that tools like the Dashboard will be necessary in the near future, and that the work presented should be integrated (overlaid in a first approach, analysed later) with the scale of the Municipal Director Plans. They suggested that a good approach could be the overlaying of cartography about the regulatory aspects with climate change risk scenarios, which could lead to a practical application of the concepts of PROVIDE in the adaptation planning context of the AML. One participant pointed out (and was backed up by several others) that the threshold context and definition are relevant to define the level of priorities to be tackled in overshoot adaptation. Overall, participants suggested that this is relevant as a new way of presenting information to promote the establishment of priority levels, that necessarily need to take Territorial Management Instruments into account. And added that a tool like the Dashboard linking the assessment with the decision-making process will be important

3. Spatial structural and strategic profile of the Lisbon Metropolitan Area

3.1. Introduction: The Role of the Spatial Profile in Relation to Climate Change Impacts and Adaptation: from Structure to Strategy

3.1.1. Foundations

The structure of an urbanized landscape is an important parameter in climate change mitigation and adaptation due to the spatial nature of associated measures and strategies. Spatial planning for the management of (climatic) risk, necessitates the incorporation of a conceptualization of risk within the design-research and planning process (Klijn et al. 2015). This is both because "the spatial distribution of (…) risk is an outcome of [the] relationship between urbanisation and nature (…) [n]amely, land use/land cover patterns alter (…) processes and the likelihood of (…) hazards" (Kuzniecow Bacchin 2015), as well as because "development concerns the introduction and growth of new activities, and the successful mutual adaptation of the landscape and the population to these changes, leading to their maintenance and continued development" (Allen 1997).

Both in general climate change-related spatial planning, as well as, and particularly, in the context of the PROVIDE project, that is, an inquiry into climate overshoot scenarios, the spatialization of climatic risk and corresponding responses is, essentially, an evaluation of their respective spatial impact and limits both to their deployment, and to their performance. The question that the elaboration of spatial and strategic profiles for the case-study Iconic Regions and Cities seeks to address, thus, is: 'how does a spatial system need to be adapted in order for the impacts of climate overshoot not to impede adaptation'. This is approached, here, through the mapping and cartographic analysis of the composition and configuration of a series of spatial systems, from the perspective of evaluating whether or not (and to what degree) said composition and configuration is manifested according to the particularities of the specific climatic risks the project is concerned with. Further, the aforementioned evaluation is concluded by a characterization of the associated space in reference to, on one hand, the overall presence of the space necessary for mitigation and adaptation, as well as, on the other, its specificity in terms of the possible measures and strategies it could host.

In the context of the PROVIDE project, and contrary to 'traditional' approaches to climate-related spatial planning, the important issue is the design of the capacity of a spatial system to not only adapt to changing climatic conditions (in this case, climate overshoot), but, also, that the associated measures and solutions utilized steer the system back to a desired situation. As such, the project seeks to determine whether and how adaptation/mitigation actions can: 1. be effective to limit or avoid overshoot, 2. be effective under overshoot conditions, and 3. be effective in restoring climatic conditions to the desired levels during overshoot. With the emphasis, thus, being on dealing with the effects of climate overshoot, the 'starting-from-limits reverse-impact-chain' methodology of the PROVIDE project is translated, in reference to the spatial conditions of the case-study Iconic Regions and Cities, into an inquiry in their spatial structure, where the 'limits' are the evaluation of said structure from the perspective of dealing with a particular climatic risk: that is, whether or not, and to what extent, appropriate space is available to be transformed and organized in such a way so at for the territories in question to be able to mitigate and adapt to the associated climatic changes.

3.1.2. Methodology

The overall approach for the development of the Spatial and Strategic profiles of the Iconic Regions and Cities is summarized in Figure 3.1. The mapping and cartographic analysis process is underpinned by the attempt to correlate the spatialization of various urban and regional systems (right) with the parameters of climatic risk (left). The latter refer to the concepts of exposure and vulnerability/sensitivity (Klijn et al. 2015) and, particularly, how these affect and are affected by the presence of appropriate spatial potential to address them, that is, either protect against them, or cope with them, or, ultimately, accommodate them (Meyer et al. 2015).

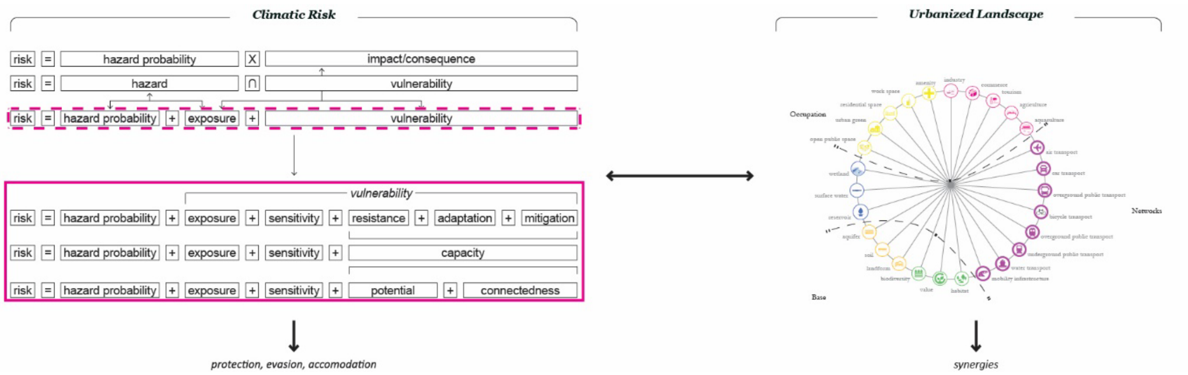


Figure 3.1. Theoretical, conceptual and analytical basis for the mapping and cartographic elaboration of the Structural and Strategic Profiles for the Iconic Regions and Cities (BUUR PoS, 2022)

Resistance, resilience, adaptation and mitigation against a stress/stressor are core components of the functioning of any complex system: in order for a system to be able to perform accordingly, the stress/stressor/changes have to be within its ability to address them, that is, the limits/thresholds of its associated capacity must not be breached. This means: 1. enlarging the limit/threshold range (i.e. increase the resistance of the system through defences), 2. moving the limit/threshold further from the system (i.e. increase the resilience of the system through embedding within it its exposure to the manifestation of a hazard), and 3. moving the system away from the limit/threshold (i.e. increase the adaptive capacity of a system through decreasing its vulnerability/sensitivity by safe-proofing its development) (van Veelen 2016). It is these limits/thresholds that are to be analysed through this project: all three indicate the spatial/physical and functional/institutional capacity of a system to implement and embed within it measures of resistance, resilience, adaptation and mitigation. Adaptive capacity is precisely that, and, it is defined as whether or not the system has the sufficient capital for such measures, as well as the possibility to reorganize it accordingly: potential and connectedness are the measures of adaptive capacity (Holling 2001), which gives the final expression of risk as seen in Figure 3.1 (Füssel and Klein 2006; van Veelen 2016; Georgiou 2019). As such, the extent to which spatial/physical and functional/institutional capital exists, as well as the extent to which this can be reorganized, determine the adaptability of a system, that is, the possibility of integrating and embedding relevant measures.

Reiterating, thus, what was described in the previous sub-section, the elaboration and development of the Structural and Strategic Profiles for the Iconic Regions and Cities is an inquiry into the presence of adequate potential and the possibility of its corresponding reorganization: following (Alberti 2008), (Kuzniecow Bacchin 2015) and (Georgiou 2019), potential, here, refers to the ecological structure, the non-built-up-space system and the mobility and surface hydrography networks. The corresponding evaluation is done according to the particularities of the specific climatic risks that are of relevance to the project and to each of the case-study sites.

Finally, the selection of the various spatial systems that compose the case-study sites is based on, as also mentioned above, complex socio-ecological/technical systems theory (McHarg and American Museum of National History 1969; Ostrom and Cox 2010; McGinnis and Ostrom 2014): "[i]n the layered approach, interactions are investigated between three layers which are said to determine the spatial contours of a region: the "base layer": the substratum, made up of the system of water, soil and the life forms inherent in them; the "network layer": the physical infrastructure of shipping routes, road transportation and railways; the "occupation layer": the spatial patterns resulting from human use of the substratum and networks, for example, urbanization and agriculture" (Meyer et al. 2015) [(Zagare 2018) proposes a 4th layer "governance" so as to account for the dynamics of the institutional frameworks, processes and tools that shape a system].

The outcome of such an approach is the ability to create composite images of a region that showcase the interrelationships between its elements. Based on the challenges faced by the 4 Iconic Regions and Cities, an indicative selection is as shown in Figure 3.1. These are a selection of systems whose spatial and temporal distribution is directly related with the adaptation needs of the Iconic Regions and Cities as described in the PROVIDE project proposal: water availability, primary production, rain/storms/snow and avalanches, sea level rise and wave heights, flooding (coastal/tidal, fluvial, pluvial), temperature changes and drought, biodiversity, pollution, transport, economy, culture and urban expansion.

As such, the aforementioned composition and configuration of the spatial extent of the Iconic Regions and Cities and the evaluation of the spatial limits to their adaptive capacity, that is, their potential and connectedness, is done according to this selection of spatial systems. It is, thus, the interrelationship between the ecological structure, the non-built-up space and the infrastructural networks, on one hand, and, on the other, the various urban and territorial systems, that is mapped and cartographically analysed in order to determine their correspondence with the manifestation of a particular climatic risk and the ability to address it: the limits that are not to be crossed are, essentially, said correspondence and the presence of adequate space for the deployment of mitigation and adaptation spatial solutions.

3.1.3. Workflow

The overall methodology for the development of the spatial and strategic profiles for the Iconic Regions and Cities is illustrated in Figure 3.2. Through the project progress, the specificity of the case study sites, and the particularities of the climate risks to be addressed, the mapping and cartographic analysis delineates a series of appropriate spatial scales (spatial extents). Through these (and a corresponding resolution) a series of spatial systems belonging to different layers (Meyer et al. 2015) is mapped and further quantitatively and qualitatively analysed. Said analysis is done on the basis of established criteria (indicators, variables and metrics) that, each time, pertain to the risk at hand (Kuzniecow Bacchin 2015). The first, thus, step, corresponds to the elaboration of the overall 'spatial profile' of the Iconic Region and City, while the latter corresponds to the 'strategic profile'. The difference between the 2 is that the first is a description of the current situation, while the latter is an evaluation of its performance when confronted with a risk. For each different risk, different criteria (and, thus, different indicators, variables and metrics) will be touched upon, stemming from the particular functions and services the corresponding case-study site has to perform and provide (Millennium Ecosystem Assessment 2005).

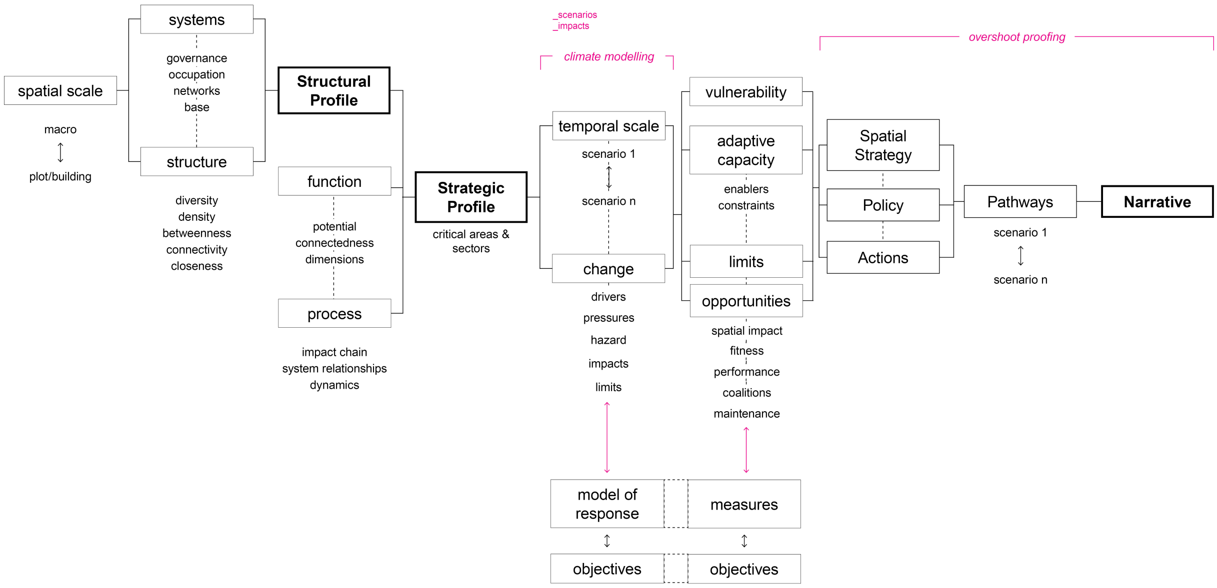


Figure 3.2. Methodological flow diagram of the work process (BUUR PoS, 2022)

Risk mapping takes the form of the evaluation of the spatial extent from the perspective of its capacity to deal with a particular risk, that is, the correspondence of its spatial structure and the specificities of the spatial manifestation of said risk. In other words, the Strategic Profile is an indication of the spatial limits that should not be in order for the territory in question to be able to deal with a particular risk. The critical role of risk mapping has been established in scholarship and practice (Pieterse et al. 2013), and is of particular relevance to the inquiry of adaptation needs, thanks to the fact that it can be used to show how the structural profile of a region and its various systems will be impacted by a hazard. The importance of risk mapping rests, thus, in its ability to indicate the impacts of a hazard on a spatial system, its different characteristics that may be of relevance to policy and plan making, as well as, through showing how adaptive capacity (potential and connectedness) is affected, indicate adaptation needs. As such, it is a crucial element for the move from the structural profile of a region to how it should be adapted.

The difference between 'traditional' risk mapping and the one that is carried out within the scope of overshoot planning for the PROVIDE project is that instead of overlaying the spatial and temporal characteristics of a hazard (represented in a hazard map) over some aspects of a region [e.g. the composition and configuration of a spatial system, or the characteristics of the affected aspects like economic loss, fatalities etc. (de Moel et al. 2015)], mapping here takes on the role of characterizing the composition and configuration of an urbanized landscape in reference to the issue and task at hand, that is, highlight the spatialization of the particular patterns of manifestation of a specific climatic process in terms of the corresponding urbanization patterns that signify adaptive and mitigative capacity. The resulting Strategic Profile is, essentially, a map that illustrates spaces of critical importance and their inherent characteristics in reference to adaptation and mitigation to the risk at hand. Through the employment of different climatic and socio-economic scenarios, the Structural Profile is subsequently evaluated from the perspective of changes in vulnerability and adaptive capacity through the limits and opportunities of a determined mode of response, resulting in a series of mapping narratives of adaptation. Said scenario-based projection of adequate land availability for specific adaptation and mitigation actions is an elaboration of the feasibility and the performance of overall adaptation strategies to address overshoot conditions. The present chapter (and the corresponding sections within the reports of the Iconic Regions and Cities) deal with the Structural and Strategic Profiles, while the subsequent steps will be carried out during the next phases of the project.

3.2. Spatial and Strategic Profile: Lisbon Metropolitan Area, Portugal

3.2.1. Introduction

The Lisbon Metropolitan Area is being confronted with increased surface and air temperatures, resulting in high stress from heat and the associated heat-island effects (as described in this report). As such, there is a need for the urbanized landscape to be planned, designed and engineered in such a way so as to provide for heat regulation (this follows the overall objectives of the PROVIDE project for this Iconic Region and Iconic City case-study site, which is focused on researching on and addressing heat stress under overshoot conditions). The purpose of this chapter is to evaluate the capacity of the spatial structure of the Lisbon Metropolitan Area to regulate heat. For this, an identification of the degree to which the composition and configuration of the various spatial systems that compose the territory in question correspond to the capacity to regulate heat, is performed.

The specific functions for said service provision that the spatial structure needs to perform are summarized in Figure 3.3. Measures that can mitigate heat stress range from shading devices, increase in surface water and vegetation (for evapotranspiration), unsealing paved soils to absorb heat, as well as introducing a network of cool spaces to allow for ventilation and the overall lowering of surface temperatures ("Urban Green-Blue Grids for resilient cities", n.d.; (World Bank 2021)). These follow the ecosystem services-functions paradigm (Millennium Ecosystem Assessment 2005) and those that are of interest here are, primarily, heat regulation, but, also, drought and air quality regulation, due to the interconnected nature between them (the absence of moisture in the soil directly affects its capacity to regulate heat, while the different particles in the air affect both its temperature as well as its reflectivity and light absorption indices).

Services

- heat regulation
- drought regulation
- air quality regulation

Functions

- shading
- evapotranspiration
- heat reflection/emmission
- cooling
- air filtering

Strategies & Measures

higher heat reflection/emission - lower heat absorption

surface unpaving/unhardening - soil unsealing
increase in ground vegetated surfaces
cool construction materials (high albedo/emissivity)
green roofs & facades

evapotranspiration

increase in plant cover (particularly, tree canopy)
increase in surface water
increase in green riparian zones
fountains/sprinklers

cooling/shading

regularly-placed cool urban spaces
increase in tree cover
street trees and tree-lined lanes
urban forests and parks
green ventilation grids/corrdors (inter city-countryside)
greening valley landforms/green connections with ridges
urban farming
constructed shadow facilities and devices

Figure 3.3. Ecosystem services, functions and associated strategies and measures for heat-stress management (BUUR PoS, 2022, adapted from Millennium Ecosystem Assessment, 2005; World Bank, 2021; "Urban Green-Blue Grids for resilient cities", n.d. (https://www.urbangreenbluegrids.com/heat/))

The above measures can be both based on 'nature-based solutions' that is, green-blue devices, as well as anthropogenic and technological solutions. For the purposes of this part of the work, the space of the Lisbon Metropolitan Area and the Municipality of Lisbon will be treated as though from a 'nature-based solutions' lens, that is, it will be the existence and network of green and blue spaces (or spaces that could be green and/or blue) that the analysis will be based on. As such, other measures such as the materials of the buildings (for light, and thus, heat reflection and emission) will not be incorporated at this stage. Consequently, the structure of the spatial extent will be, primarily, evaluated on the basis of increasing its green cover and its configuration for overall cooling (thus addressing the aforementioned functions and services). Since these are based on the environmental and spatial conditions of the urbanization patterns of the territory in question, the important indicators for cooling devices and the variables of the spatial morphology that will be looked upon are summarized in Figure 3.4.

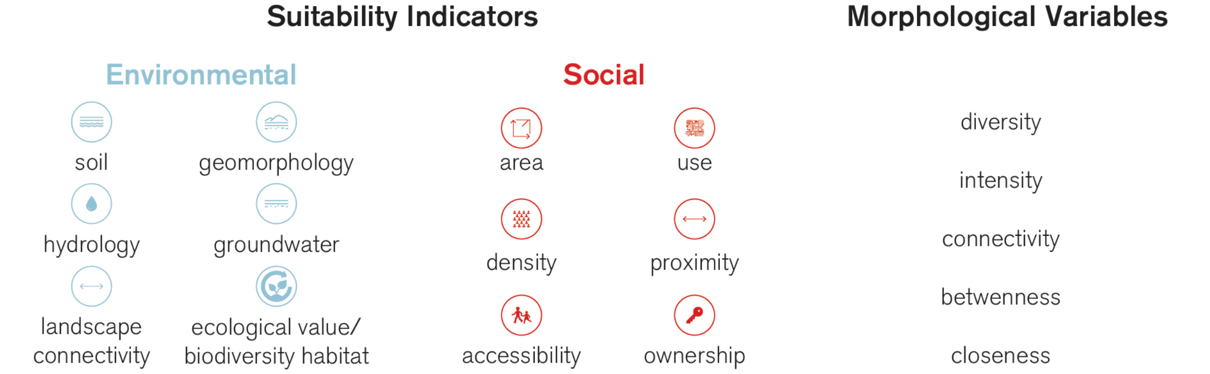


Figure 3.4. Indicators for spatial planning for heat-stress management (adapted from World Bank, 2021; Alberti, 2008; "Urban Green-Blue Grids for resilient cities", n.d. (https://www.urbangreenbluegrids.com/heat/))

The overall process of the elaboration of the Structural and Strategic Profiles for the Lisbon Metropolitan Area and the Municipality of Lisbon is shown in Figure 3.5. The various spatial systems and the spatial layer they belong to are illustrated on the left, where a selection of them, namely, the ecological structure, the open space and the infrastructural networks are positioned as regulation systems. These 3 correspond to the organization of potential and its configuration in reference to heat regulation. As such, the general mapping of the composition and configuration of the spatial extent is, subsequently, evaluated on the basis of its interaction and relationship with these 3 systems. On the right, the criteria according to which said evaluation is carried out are listed.

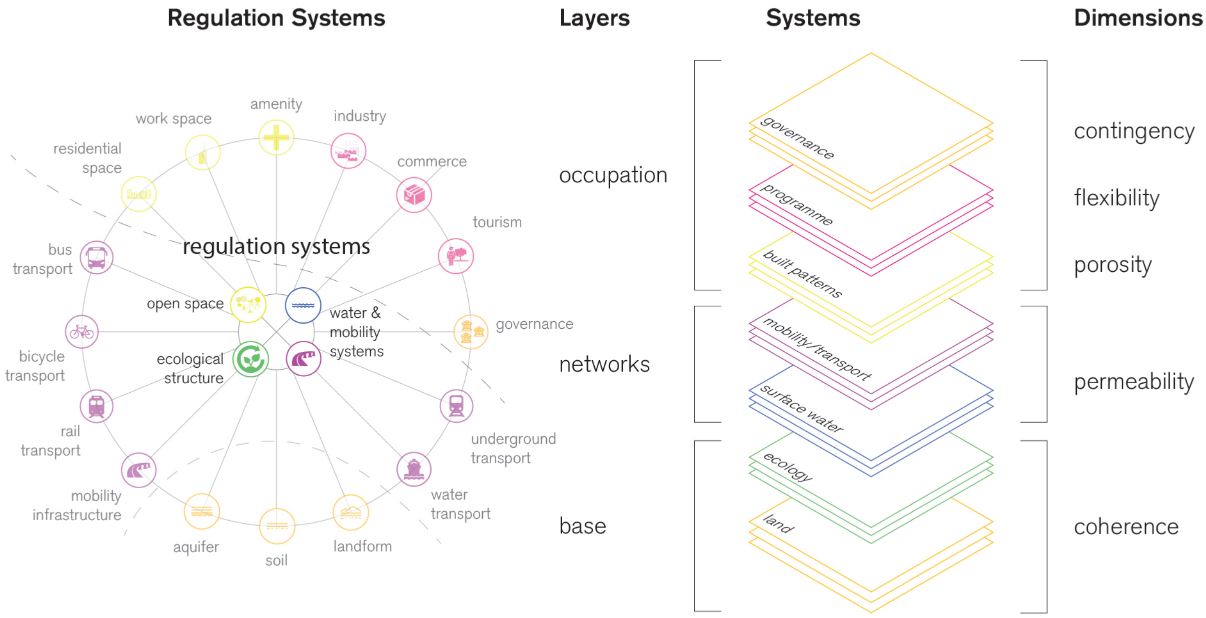


Figure 3.5. Methodology for the evaluation of spatial structure and the elaboration of a strategic profile in reference to heat-stress management (BUUR PoS, 2022)

3.2.2. Spatial Profile

The Lisbon Metropolitan Area is embedded within a spatial context populated, primarily, by the agriculture- and forestry-related sectors. Figure 3.6 showcases the extensiveness of irrigated cropland and pastures, as well as the prevalence of woodland formations (mostly broad-leaved or mixed coniferous/broad leaved forests) and vineyards, olive groves and fruit plantations. Within this type of land use and land cover, the built-up ('urban') space is located, almost exclusively, towards the edge of the Tagus estuary, with other (smaller) settlements areas dispersed throughout.

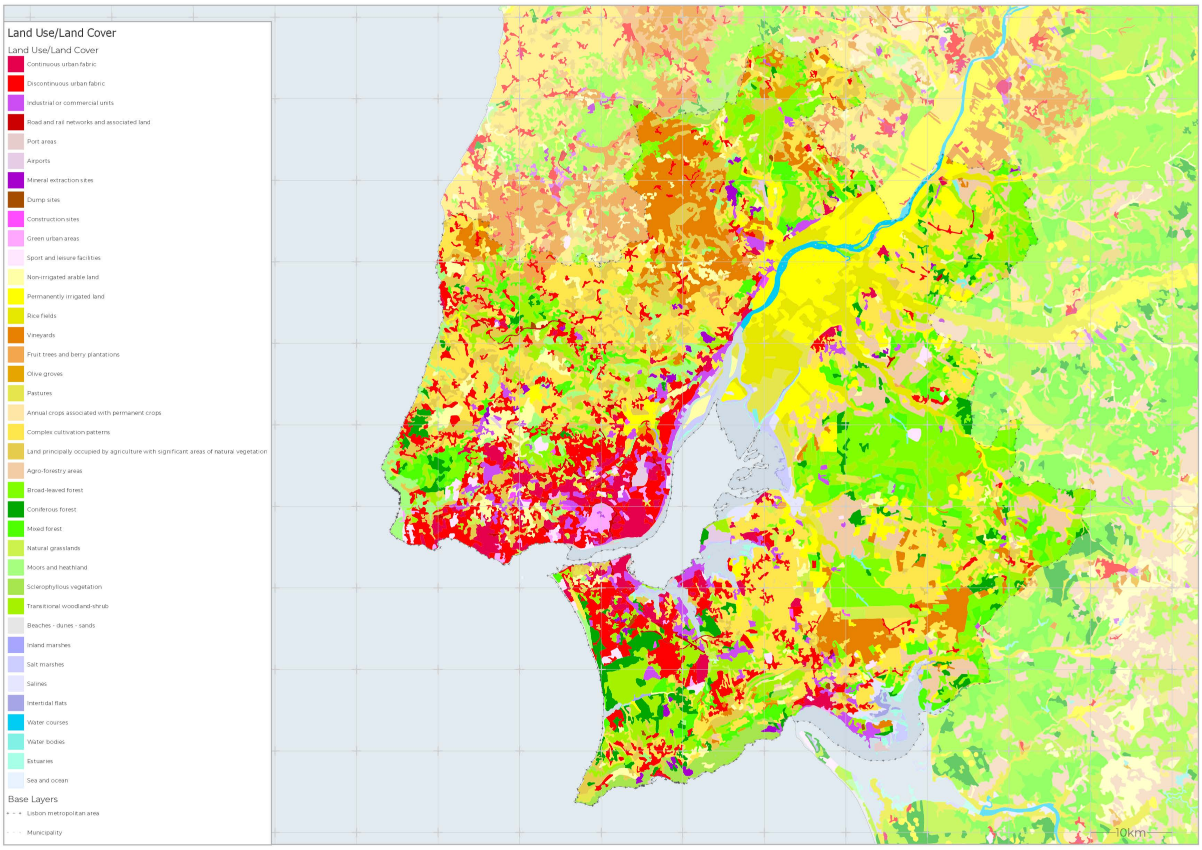


Figure 3.6. Land cover of the Lisbon Metropolitan Area and its surrounding context (BUUR PoS, 2002, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/pan-european/corine-land-cover/clc2018))

Taking a closer look at the land use and land cover composition of the Metropolitan Area itself, Figure 3.7 validates the previous insight: almost 60% of the area is covered by croplands, pastures and forests, with a significant percentage of herbaceous vegetation, while all other land use and land cover classes take up together the remaining around 20%. A zoom-in to the Municipality of Lisbon, on the other hand, reverses the previous picture: around 60% of the land is covered by a dense urban fabric, road infrastructure and industrial/commercial built units. From a climate risk perspective and, particularly, mitigating heat stress, the above understanding necessitates the elaboration of different measures and spatial strategies depending on the land use and land cover class, with emphasis on both how agricultural and forestry configurations can assist in lowering surface temperatures, as well as how associated measures and solutions can be retrofitted within and throughout the built environment.

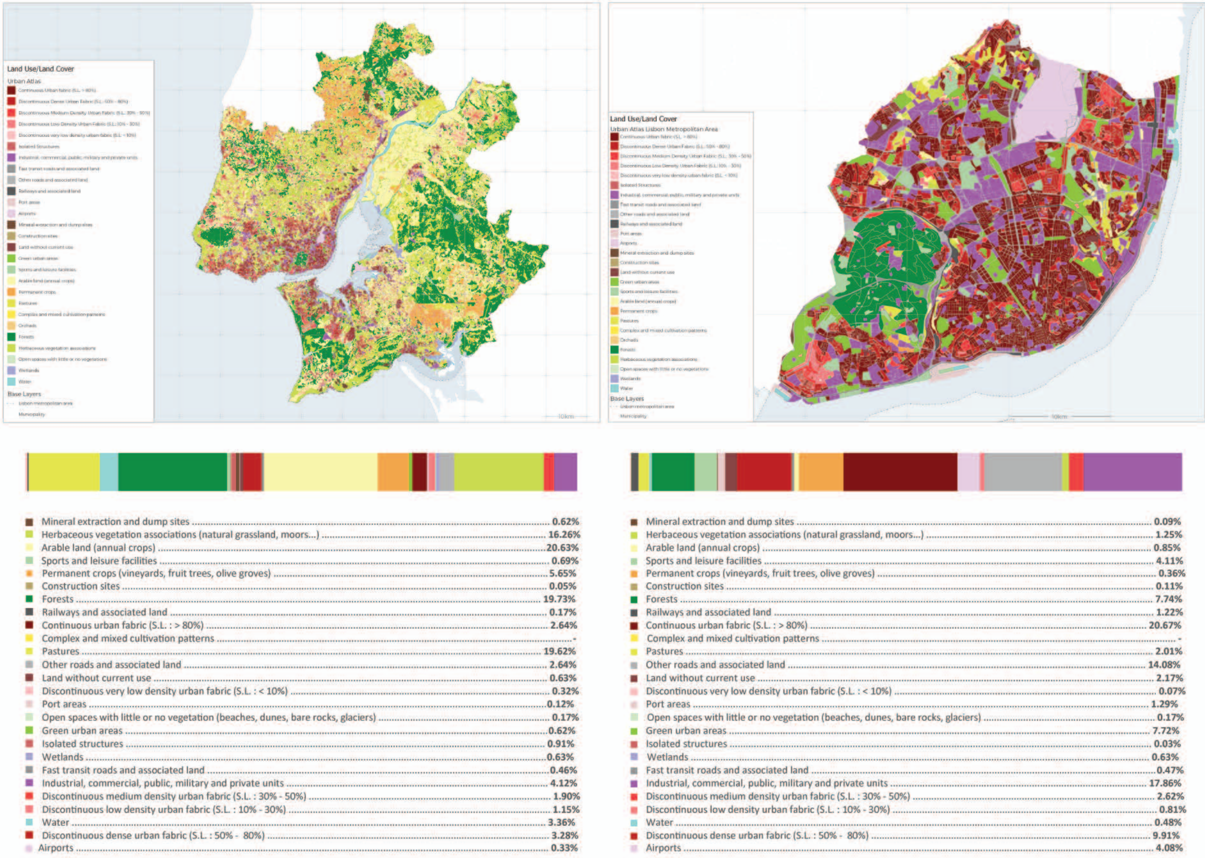


Figure 3.7. Urban Atlas for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (bellow) (BUUR PoS, 2002, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

Looking at population levels in corelation with land use and land cover (Figure 3.8), not surprisingly, the urban fabric is associated with higher numbers of presence of people than the rest of the agricultural and forestry mosaic of the Metropolitan Area. The exodus of demographic groups from the countryside to the urban cores, as well as the influx of tourist populations to the urban centres, have been documented as issues affecting the vulnerability and adaptive capacity of the region and, therefore, adaptation scenarios and mitigation solutions will have to take this phenomenon into account.

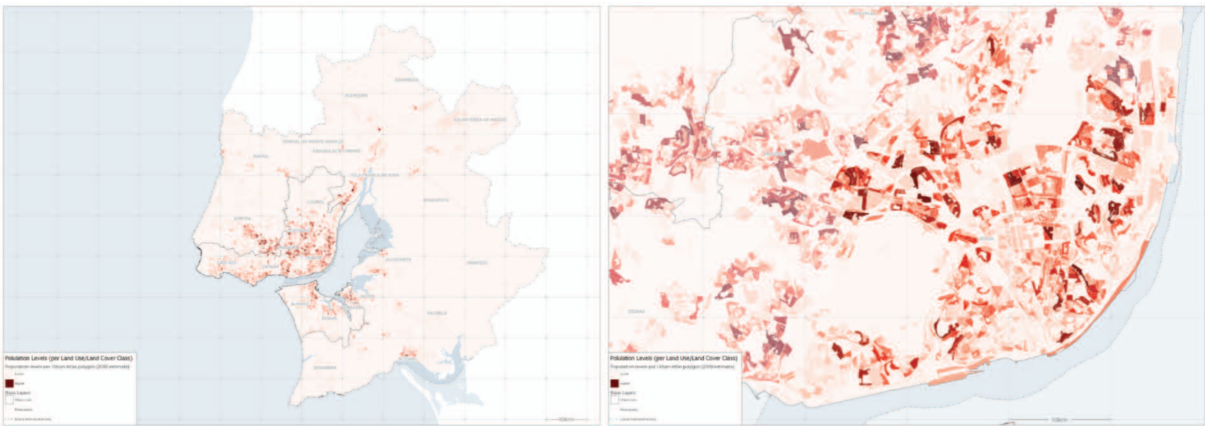


Figure 3.8. Population levels per Urban Atlas class polygon (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

3.2.2.1. Systems and Form

3.2.2.1.1. Base

Soil and Topography

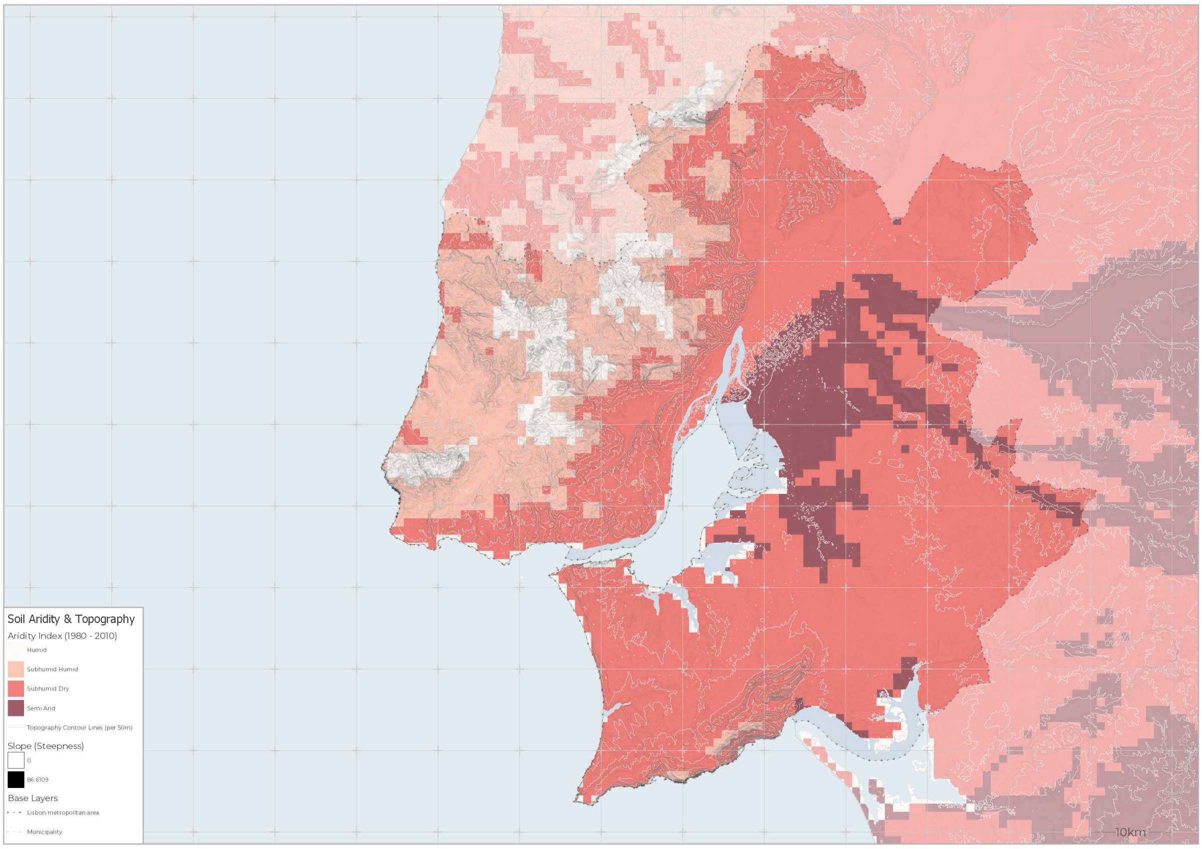


Figure 3.9. Soil aridity and topography for the Lisbon Metropolitan Area and its surrounding context (BUUR PoS, 2022, with data from "Instituto da Conservação da Natureza e das Florestas", 2020 (https://sig.icnf.pt/portal/home/item.html?id=0b30c87b509440e88968387a9a494046); "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1)

The aridity (important indicator for heat absorption by the soil, as well as for the overall performance of vegetation and precipitation of possible heat-mitigation options) of the soil is shown in Figure 3.9. Here the majority of the spatial extent of the Metropolitan Area is characterised as 'Semi-humid Dry', with a significant proportion as 'Arid' or 'Semi-humid Humid' and a small percentage as humid. The above classification is, associated, respectively, with high degree of urbanization and soil sealing and/or intensive and extensive agricultural practices (as mentioned before) and/or a mostly flat terrain, or the presence of herbaceous vegetation and forestry and more rugged terrains. This emphasizes the need to include geomorphology as an important parameter in the elaboration of heat mitigation measures and adaptation scenarios for the entire territory.

Geomorphology

Figure 3.10 illustrates the extreme difference in landform between the northern and the southern parts of the Metropolitan Area. The former is characterised by an extensive array of ridges and valleys, while the latter is, primarily, a flat terrain that turns out to occupy slightly more than half the extent of the entire Metropolitan Area (see Figure 3.11). Such a striking difference reinforces the need for landform-contextual elaboration of heat mitigation solutions and the associated adaptation scenarios. The Municipality of Lisbon exhibits a picture similar with the Metropolitan Area, albeit with a higher degree of balance between the different landform classes. Still, however, the historical centre and more dense urban fabric seem to be situated in the more rugged part of the municipality, while urban extensions and built-up spaces of lower densities occupy the less rugged terrain.

Figure 3.10. Landform classification for the Lisbon Metropolitan Area and its surrounding Context (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1))

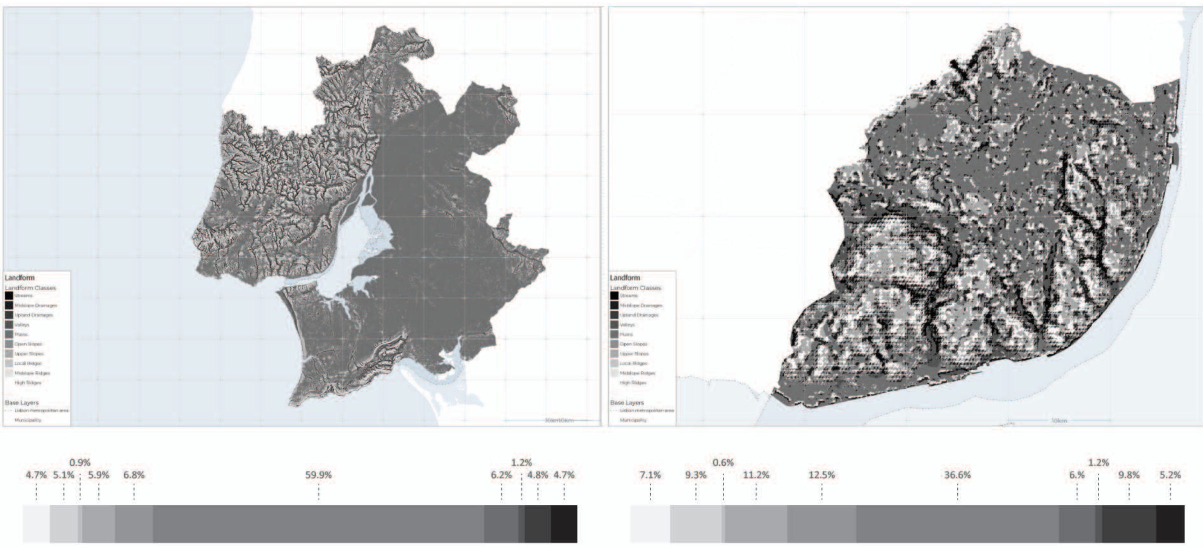
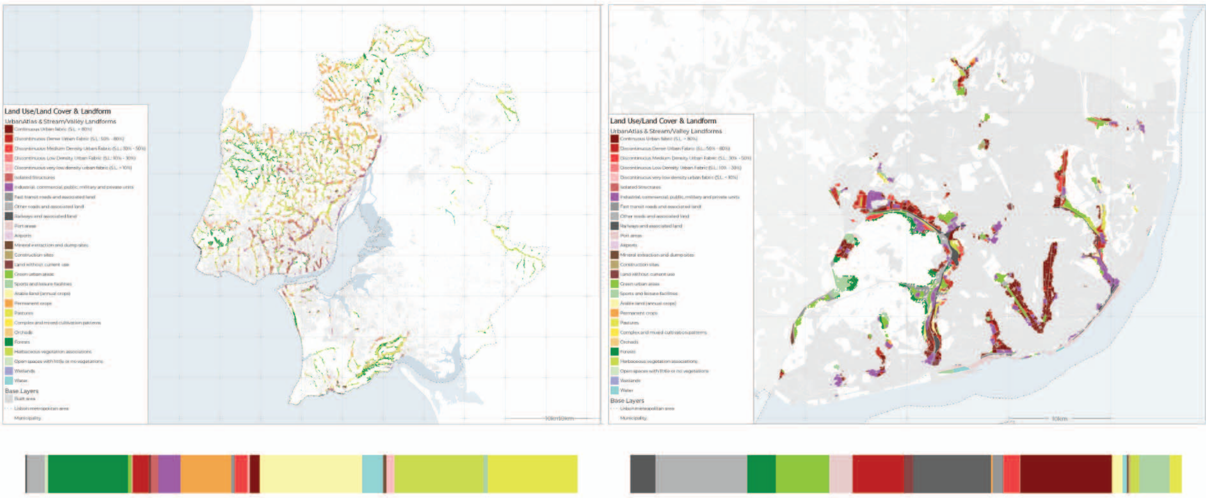


Figure 3.11. Landform classification for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (bellow) (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1))



Mineral extraction and dump sites	0.55%	0.22%
Herbaceous vegetation associations (natural grassland, moors...)	16.10%	1.68%
Arable land (annual crops)	18.55%	1.92%
Sports and leisure facilities	0.79%	5.51%
Permanent crops (vineyards, fruit trees, olive groves)	9.23%	0.33%
Construction sites	0.05%	0.24%
Forests	14.45%	5.15%
Railways and associated land	0.29%	4.54%
Continuous urban fabric (S.L. : > 80%)	1.76%	16.64%
Complex and mixed cultivation patterns	0.01%	-%
Pastures	16.25%	2.16%
Other roads and associated land	3.19%	16.68%
Land without current use	0.41%	1.68%
Discontinuous very low density urban fabric (S.L. : < 10%)	0.32%	0.10%
Port areas	0.21%	4.24%
Open spaces with little or no vegetation (beaches, dunes, bare rocks, glaciers)	0.65%	-%
Green urban areas	0.62%	9.71%
Isolated structures	1.28%	-%
Wetlands	0.07%	-%
Fast transit roads and associated land	0.62%	1.64%
Industrial, commercial, public, military and private units	4.01%	14.09%
Discontinuous medium density urban fabric (S.L. : 30% - 50%)	2.31%	2.95%
Discontinuous low density urban fabric (S.L. : 10% - 30%)	1.45%	1.68%
Water	3.78%	0.83%
Discontinuous dense urban fabric (S.L. : 50% - 80%)	2.96%	9.33%
Airports	0.33%	-%

Figure 3.12. Urban Atlas at the valley and stream landform formations for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (bellow) (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018)

In terms of land use and land cover composition of the repressed landform formations (See Figure 3.12), at the scale of the Lisbon Metropolitan Area these seem to be, primarily occupied by vegetated covers (herbaceous vegetation, forests, agriculture and pastures), while at the scale of the Municipality of Lisbon, dense urban fabric, road infrastructure and industrial and commercial units dominate. This picture, together with the prevalence of flat terrains, further reinforces the necessity for a comprehensive heat-regulation strategy that takes into account, on one hand, the mixite of agricultural land with more intense vegetation throughout the flat landforms (either solely spatial mixite, of functional mixite e.g. agroforestry regimes), and, one the other, the adaptive infusion or transformation of urban functions with appropriate heat mitigation measures.

Ecological Structure

The ecological structure of the Lisbon Metropolitan Area (see Figure 3.13) comprises large formations of high density vegetation (mostly forests), as well as a network of protected areas. The selection that has been done according to intensity of vegetative land cover (primarily) is thanks to the fact that a network of dense woodland cover is characterised by the potential at delivering cooling performance. As such, while other land cover classes (e.g. herbaceous vegetation, grassland etc.) are, also, significant for, e.g. heat absorption, these are featured, first and foremost, in the overall land use and land cover analysis. Similarly, the Municipality of Lisbon exhibits a network of big parks, gardens and forests that can be conceived of as the 'spine' of a comprehensive ecological structure (see Figure 3.14).

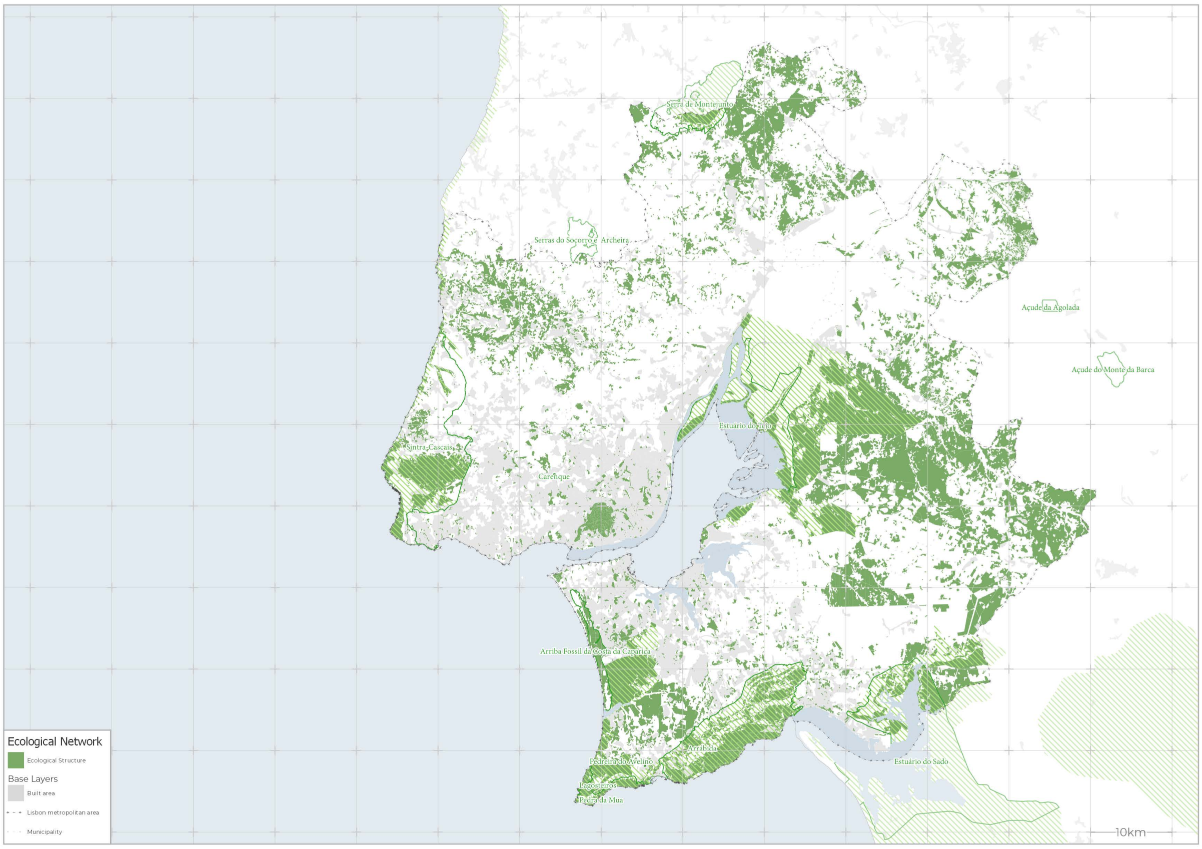


Figure 3.13. Major ecological structure for the for the Lisbon Metropolitan Area and its surrounding context: large forested and intensely vegetated areas, "National network of Protected Areas" and "Sites Designated under the Habitats Directive 'RN2000/SIC-Zec" (BUUR PoS, 2022 with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018); "Sistema Nacional de Informação Geográfica", 2018 (https://snig.dgterritorio.gov.pt/rndg/srv/por/catalog.search#/metadata/b683a2af7911447bb0ceaa6264a5c446); "Instituto da Conservação da Natureza e das Florestas", 2022 (https://sig.icnf.pt/portal/home/item.html?id=a158877a57eb4f5fbad767d36e261fab))

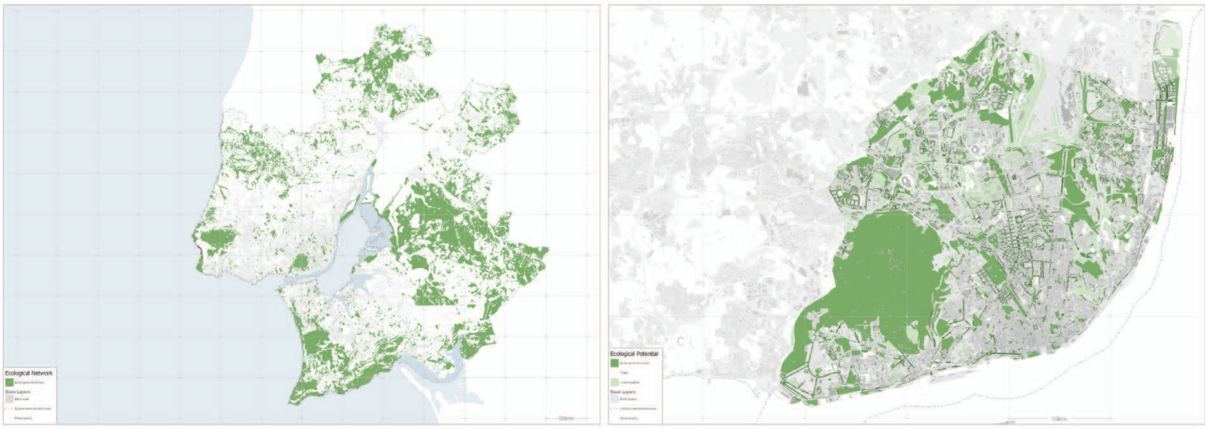


Figure 3.14 Ecological structure for the for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right): large forested and intensely vegetated areas, "National network of Protected Areas", "Sites Designated under the Habitats Directive 'RN2000/SIC-Zec" and "Grandes parques e Jardins de Lisboa" (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018); "Sistema Nacional de Informação Geográfica", 2018 (https://snig.dgterritorio.gov.pt/rndg/srv/por/catalog.search#/metadata/b683a2af7911447bb0ceaa6264a5c446); "Instituto da Conservação da Natureza e das Florestas", 2022 (https://sig.icnf.pt/portal/home/item.html?id=a158877a57eb4f5fbad767d36e261fab); "Câmara Municipal de Lisboa", 2022 (https://geodados-cml.hub.arcgis.com/datasets/CML::cartografiabase/about?layer=4))

3.2.2.1.2. Networks

Surface Hydrography

Although the significance of surface water systems in heat regulation is not always evident, for the purposes of this study the water network is approached as a possible agent for the population of the region with relevant heat stress mitigation devices and the overall organization of the associated adaptation scenarios. The Lisbon Metropolitan Area is characterised by the Tagus estuary that divides it in 2 parts, with an extensive system of rivers, canals and ditches that occupy its territory (the latter 2 mostly in reference to agricultural areas).

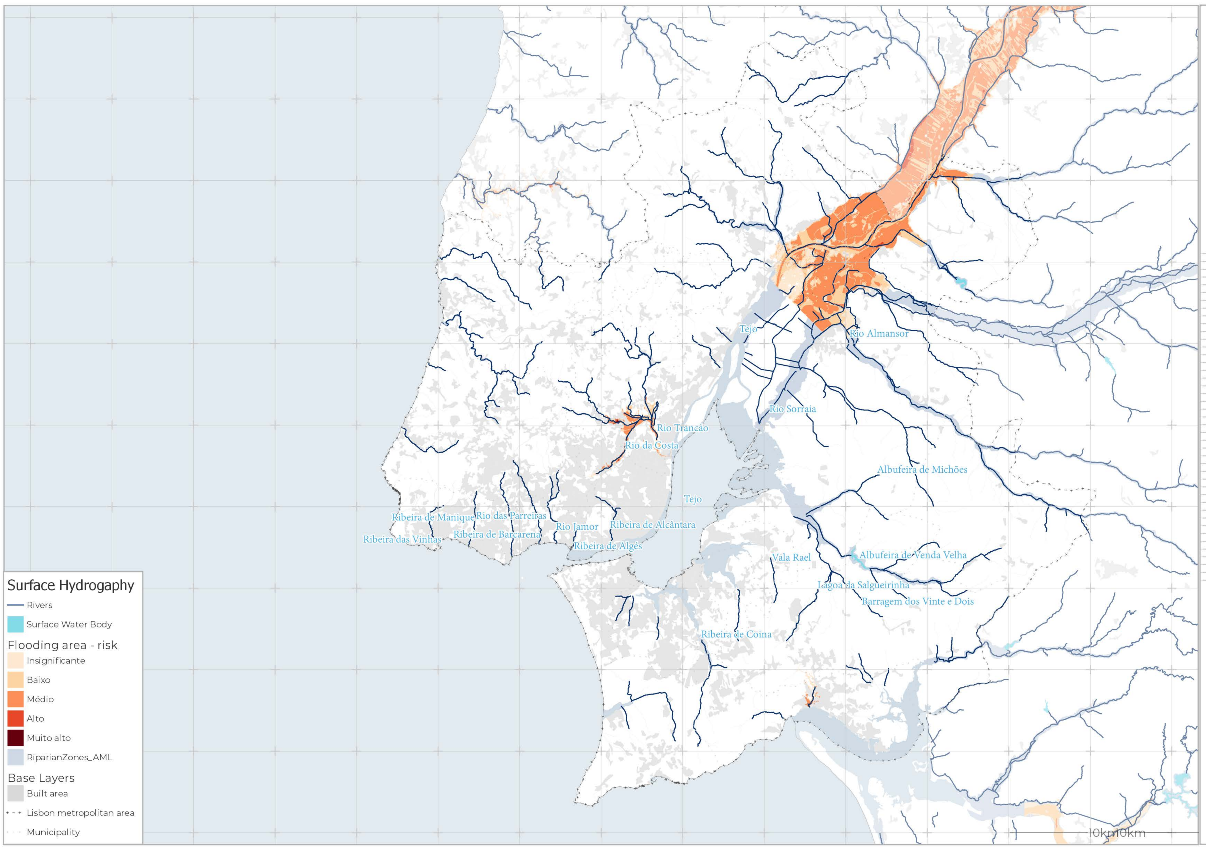


Figure 3.15. Surface hydrographic system for the Lisbon Metropolitan Area and its surrounding context (BUUR PoS, 2022, with data from "Instituto da Conservação da Natureza e das Florestas", 2018 (https://snig.dgterritorio.gov.pt/rndg/srv/por/catalog.search#/metadata/F6C851DA-1416-4670-86BC-6425883B46D4); "Instituto da Conservação da Natureza e das Florestas", 2015 (https://snig.dgterritorio.gov.pt/rndg/srv/por/catalog.search#/metadata/C7D63919-EC30-4B99-8533-A76B77958063); "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/imagery-in-situ/eu-hydro/eu-hydro-river-network-database); "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

Figure 3.16 draws a more complete picture of the surface hydrographic systems and the various water-related events and phenomena. On one hand, the northern part of the Metropolitan Area features a significant network of smaller streams, while the southern part is mostly occupied by larger rivers (following, evidently, the landform as discussed previously). The larger rivers are associated, mostly, with cultivated land, either within the estuaries and river floodplains themselves or not (where, also, the majority of hydrogeological risk is found). However, the Municipality of Lisbon exhibits a significant lack of surface water systems: both waterways as well as retention water formations.

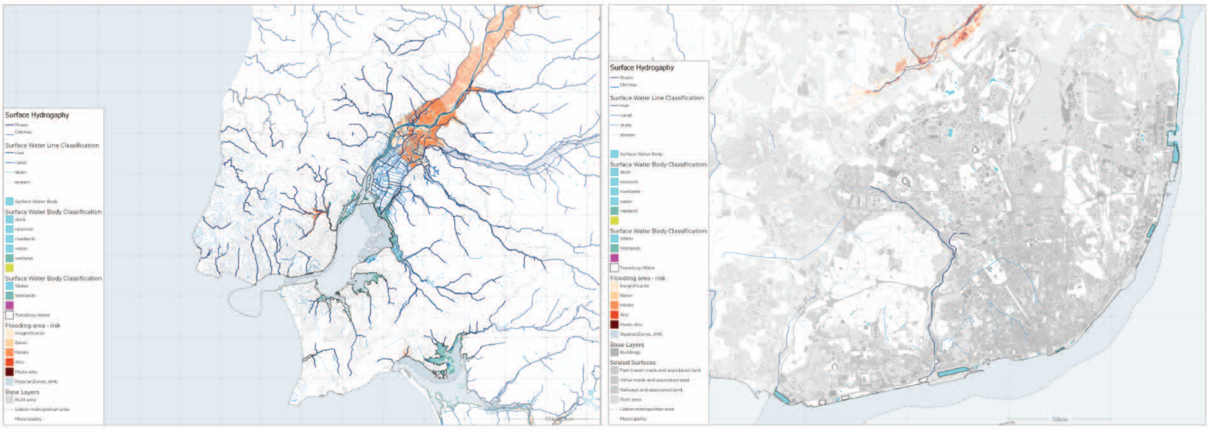


Figure 3.16. Surface hydrographic system for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) (BUUR PoS, 2022, with data from "Instituto da Conservação da Natureza e das Florestas", 2018 (https://snig.dgterritorio.gov.pt/rndg/srv/por/catalog.search#/metadata/F6C851DA-1416-4670-86BC-6425883B46D4); "Instituto da Conservação da Natureza e das Florestas", 2015 (https://snig.dgterritorio.gov.pt/rndg/srv/por/catalog.search#/metadata/C7D63919-EC30-4B99-8533-A76B77958063); "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/imagery-in-situ/eu-hydro/eu-hydro-river-network-database); "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

Mobility Infrastructure

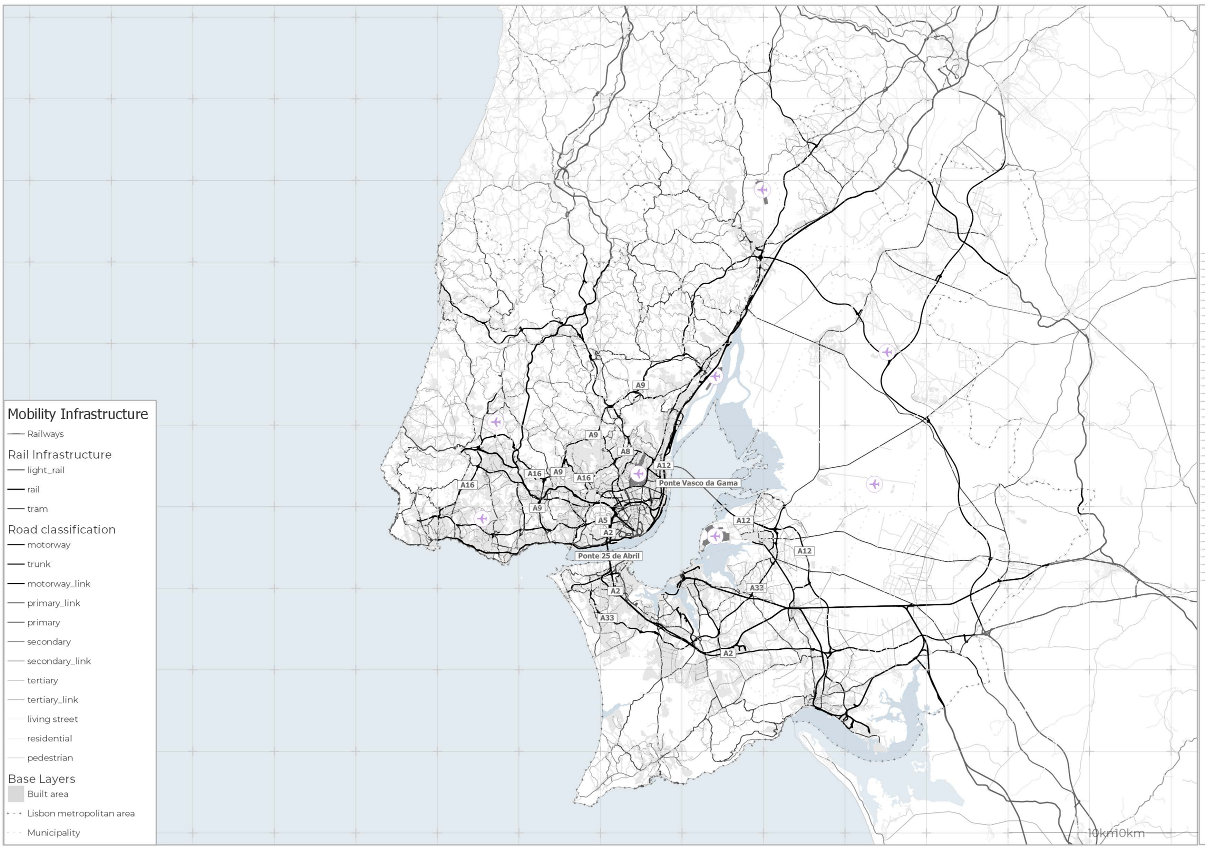


Figure 3.17. Mobility infrastructure for the Lisbon Metropolitan Area and its surrounding context (BUUR PoS, 2022, with data from "Portal de dados abertos da Administracao Publica", n.d. (https://dados.gov.pt/en/datasets/rede-ferroviaria-nacional/); "Câmara Municipal de Lisboa", 2022 (https://geodados-cml.hub.arcgis.com/datasets/CML::rede-vi%C3%A1ria/about); "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

The mobility infrastructure system, also, shows difference between the northern and the southern part of the Metropolitan Area (see Figure 3.17): related, observably, with the presence of various settlement patterns and lower degrees of agricultural land, as well as with the landform, the northern part features a capillary network of roads, while the southern is characterised by a main axis of movement (east-west) and secondary movements (north to south).

In general, Figure 3.18 illustrates how the mobility system encircles the mouth of the estuary and traces the highly urbanized region around the coast, on the one hand, and, on the other, how a comprehensive network of crossing movements structures the connectivity of the urbanized region with the entire territory.

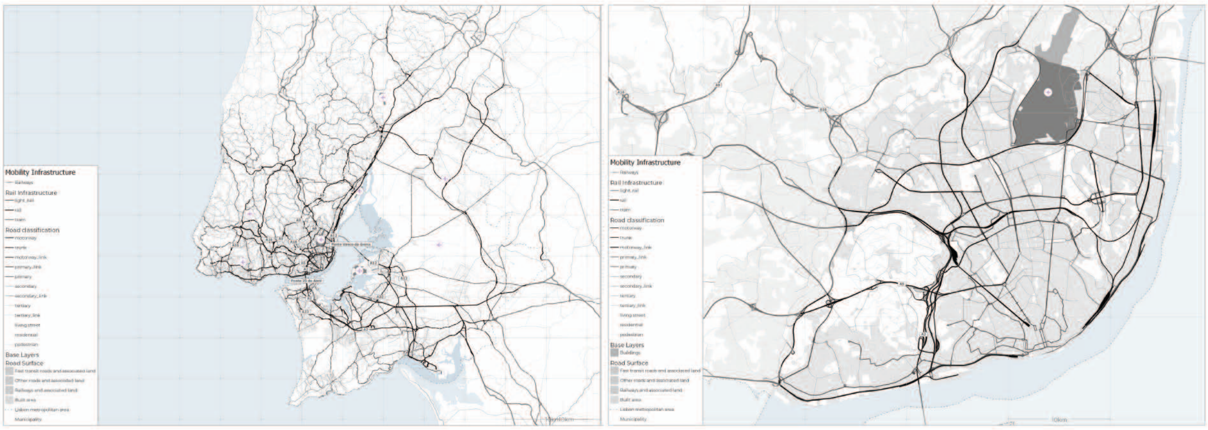


Figure 3.18. Mobility infrastructure for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) (BUUR PoS, 2022, with data from "Portal de dados abertos da Administracao Publica", n.d. (https://dados.gov.pt/en/datasets/rede-ferroviaria-nacional/); "Câmara Municipal de Lisboa", 2022 (https://geodados-cml.hub.arcgis.com/datasets/CML::rede-vi%C3%A1ria/about); "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

Transport Networks

Figure 3.19 shows how the transport networks showcase a similar configuration with the overall mobility and land use and land cover systems, with a railroad network that follows the general movement of tracing the urbanized coasts of the mouth of the estuary, and various transport modes populating the settlement areas. Interestingly enough, the buffer of 300m that is suggested for the proximity between public transport stops and stations exhibits profound coverage in the both the Metropolitan Area as well as the Municipality of Lisbon (see Figure 3.20).

One point of reflection in reference to the transport networks is that their importance to heat regulation rests, primarily, at the scale of everyday movement (between residences, work spaces and/or amenities). What is important is that there is sufficient space along those routes to mitigate the experience of heat. Therefore, the overall structure of transport infrastructure loses relevance in the regional scale if one is to approach it from the perspective of heat regulation.

On the other hand, however, large-scale transport nodes, like airports and ports, not only occupy a large portion of land (and, therefore, contribute to the heat related performance of the territory), but, also, form nodes within the physical mobility infrastructure system, that is, they are connected with the general regional and urban movement. As such, it is important to note the presence of multiple airports and ports (as well as the planning of new ones) which will have to be taken into account for the formulation of adaptation narratives for the entire territory, as well as for the elaboration of specific contextual physical and spatial heat-regulation solutions and measures, per land-use/land-cover class and physical and spatial characteristics.

As such, the transport network regains its importance in reference to planning for heat-regulation, insofar as it indicates spaces to be utilized as such, which will be, undoubtedly, part of the overall associated structure.

Figure 3.19. Transport infrastructure for the Lisbon Metropolitan Area and its surrounding context (BUUR PoS, 2022, with data from "Portal de dados abertos da Administracao Publica", n.d. (https://dados.gov.pt/en/datasets/rede-ferroviaria-nacional/); "Câmara Municipal de Lisboa", 2022 (https://geodados-cml.hub.arcgis.com/datasets/CML::rede-vi%C3%A1ria/about); "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

Figure 3.20. Transport infrastructure for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with 300m buffer zone overlay from public transport stops (BUUR PoS, 2022, with data from "Portal de dados abertos da Administracao Publica", n.d. (https://dados.gov.pt/en/datasets/rede-ferroviaria-nacional/); "Câmara Municipal de Lisboa", 2022 (https://geodados-cml.hub.arcgis.com/datasets/CML::rede-vi%C3%A1ria/about); "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

3.2.2.1.3. Occupation

Built Form

Intensity- and form-wise, urbanization patterns exhibit different characteristics in different areas: i.e. the center of Lisbon is characterized by dense urban blocks, while, further, form and intensity become less compact and/or less dense (see Figures 3.21 to 3.23). The importance of built-up patterns for heat regulation rests on their configuration: the proximity of high-rise buildings, the layout and intensity of urban blocks, or, finally, open space within them, affect the manifestation of heat (U.S. Environmental Protection Agency 2012), and suggest measures ("Urban Green-Blue Grids for resilient cities", n.d.).

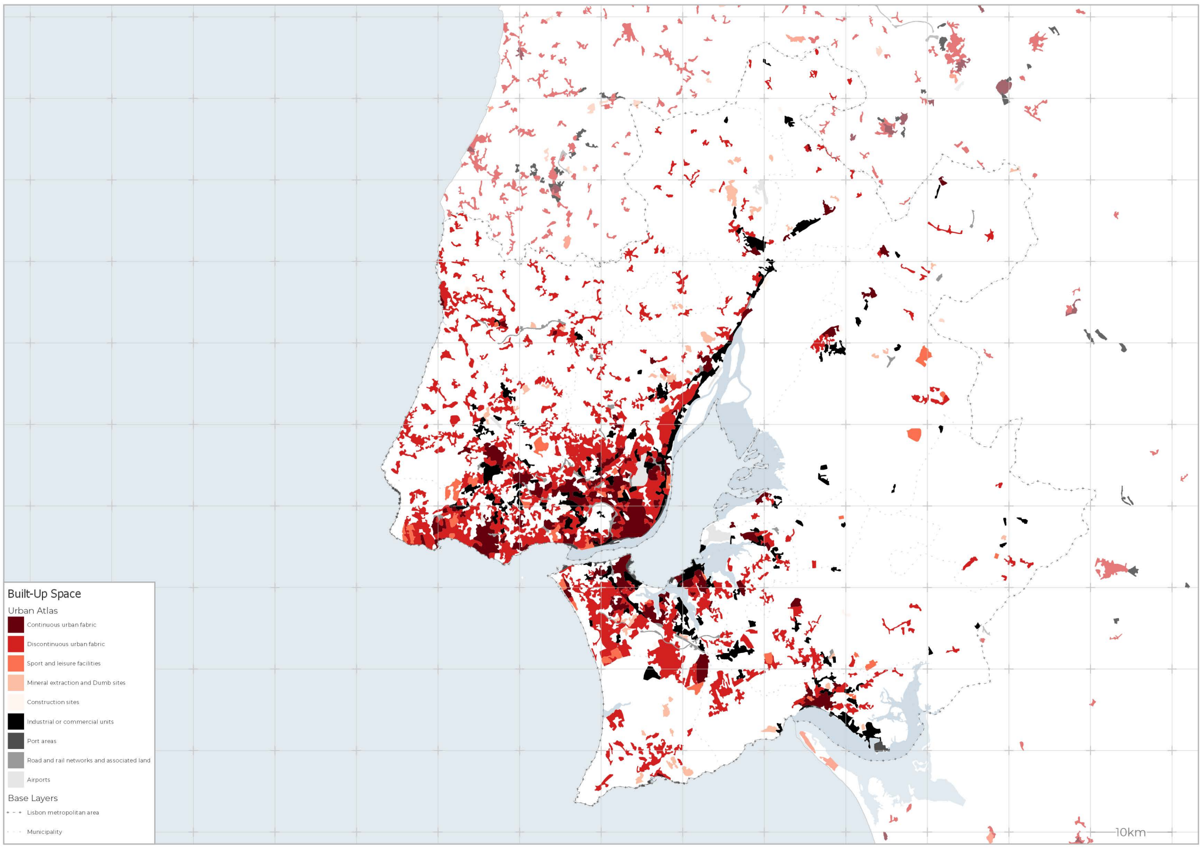


Figure 3.21. Intensity of built-up space for the Lisbon Metropolitan Area and its surrounding context (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/pan-european/corine-land-cover/clc2018))

Figure 3.22. Built-up space for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) (BURR PoS, 2022, with data from "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

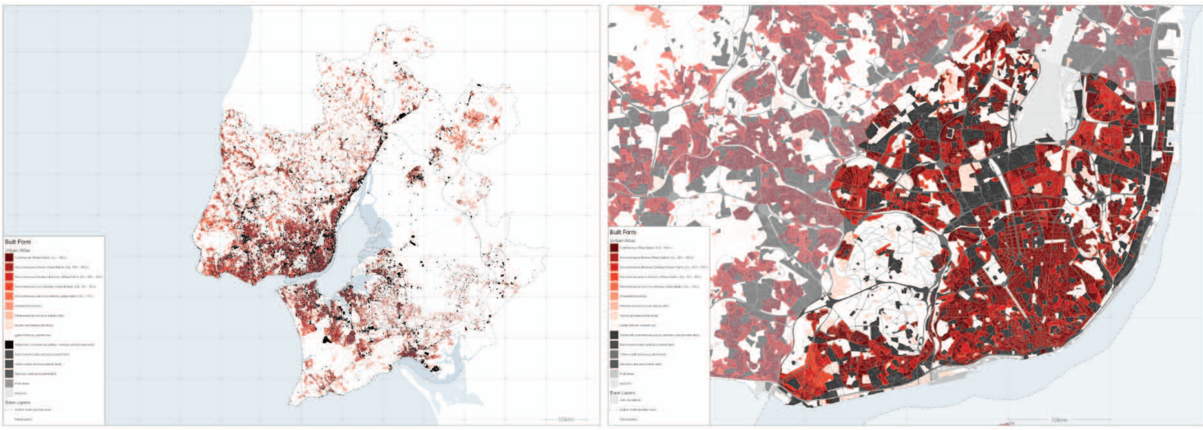


Figure 3.23. Intensity of built-up space for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) (BUUR PoS, 2022, with data form "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

Spatial Programs

The distribution of various everyday spatial programs and urban functions within and throughout the territory is mapped in order to discern patterns of use that may be affected by heat stress and/or patterns of use according to which to plan for the associated heat regulation. The corresponding significance of both can be seen in Figure 3.24 and Figure 3.25.

Figure 3.24 showcases the various zones of secondary and tertiary economic activity of the region in reference to the hierarchy of the mobility network. As becomes evident, these are organized around major mobility and transport infrastructural axes. As such, any climatic risk that might affect patterns of movement may directly affect the economic activity throughout the territory. Similarly, the significance of the presence of people in and around the aforementioned zones positions them at the forefront for heat mitigation measures in order to lessen the experience of heat stress. Finally, the hierarchical importance of the mobility network illustrates how it seems appropriate that it be used as a spine for the elaboration of a territory-wide cooling spatial planning, design and engineering project.

Figure 3.25, on the other hand, makes the case for the evaluation of the overall distribution of everyday spatial programs and functions to correspond to patterns and potential of cool spaces (not surprisingly, the Municipality of Lisbon and, particularly, its center, exhibit abundance in such programs and functions).

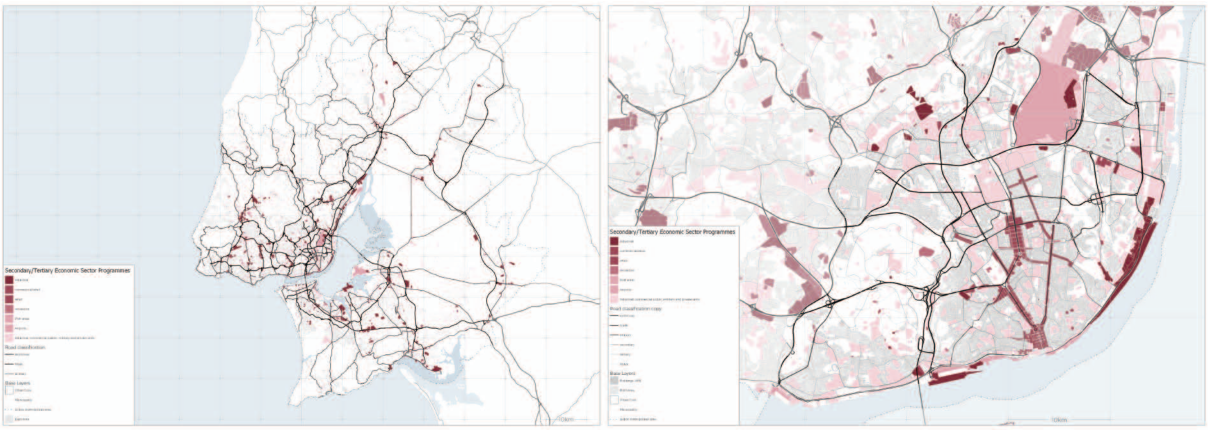


Figure 3.24. Correlation between spaces of secondary/tertiary sector economic activity and the hierarchy of the mobility network (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d.

(https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018); "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

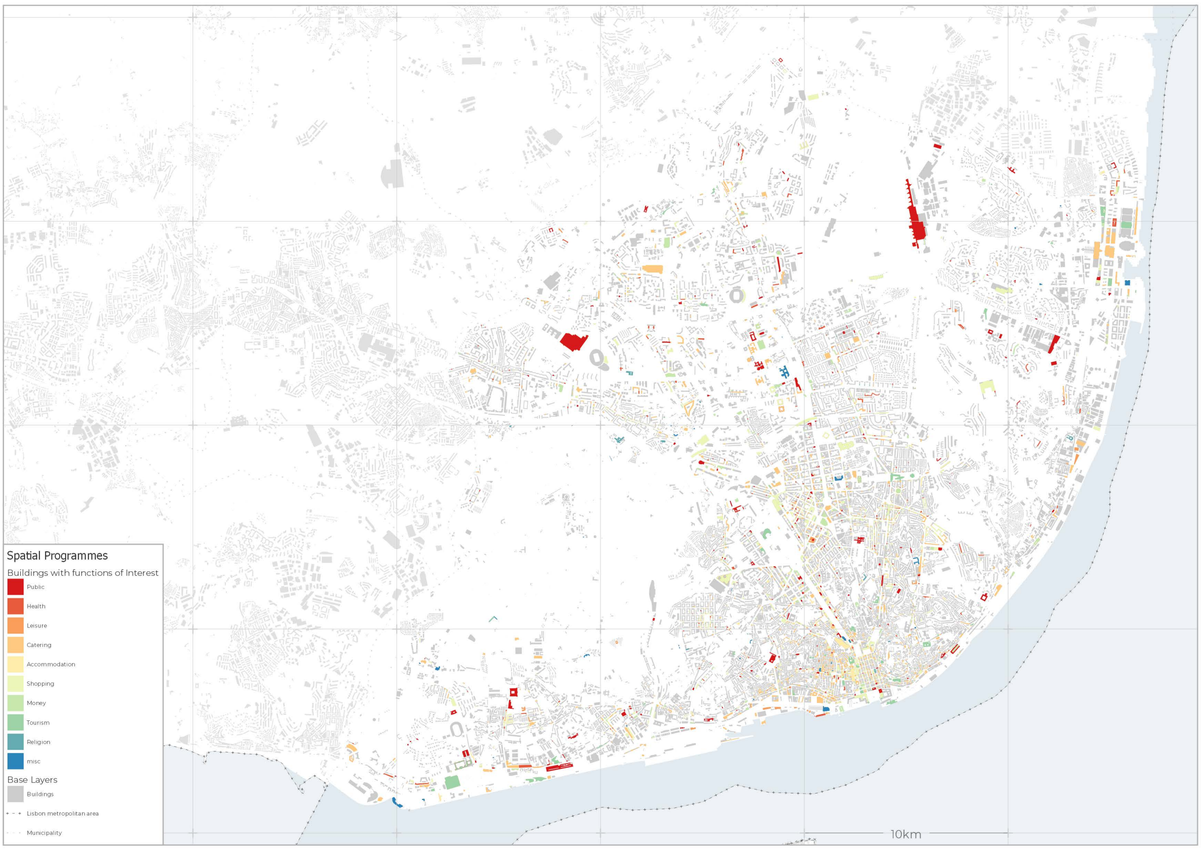


Figure 3.25. Land use, spatial programmes and urban functions for the Municipality of Lisbon (BUUR PoS, 2022, with data from "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

Governance

Governance (at this stage) is concerned with those parts of the territory that are under a regime of protection due to their importance for the ecological performance of the region. This includes the Natura 2000 network, as well as the nationally defined areas of preservation for the entire country of Portugal (ecological corridors also fall under this category). For the Municipality of Lisbon, the established network of parks and gardens is indicative of areas of public governance of ecologically important spaces (see Figure 3.26).

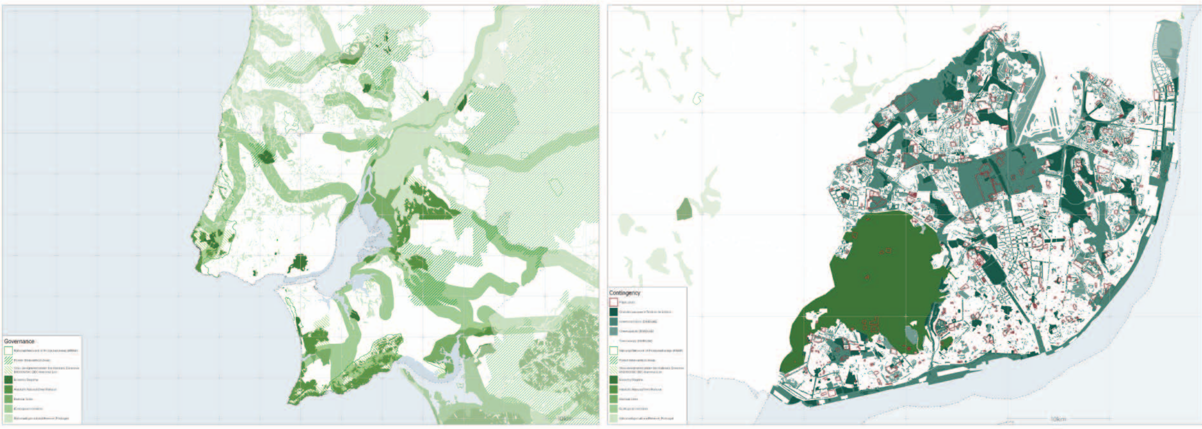


Figure 3.26. Cumulative representation of protected areas of ecological value for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right), with indication of plots of public ownership and/or significance for the smaller scale (BUUR PoS, 2022, with data from "Rede Nacional de Áreas Protegidas (RNAP)", 2018

(https://snig.dgterritorio.gov.pt/rndg/srv/por/catalog.search#/metadata/b683a2af7911447bb0ceaa6264a5c446); "Habitats Naturais e Semi-Naturais - Plano Setorial da Rede Natura 2000", 2008 (https://snig.dgterritorio.gov.pt/rndg/srv/api/records/d73dca0d-4a45-4a5c-9e7c-5da3cb3f02a3/formatters/snig-view); "Corredor Verde", 2022 (https://geodados-cml.hub.arcgis.com/datasets/CML::corredor-verde/about))

3.2.3. Strategic Profile

As described earlier, the Strategic Profile for the Lisbon Metropolitan Area in reference to heat stress regulation is an inquiry into the presence of appropriate potential and its configuration, as well as how this relates to the rest of the spatial systems that form the territory in question. Said potential refers to, essentially, the system of open/non-built-up space. Figure 3.27 illustrates this through a categorization of its land use and land cover classes for the Municipality of Lisbon. For the context of the Municipality of Lisbon, Continuous urban fabric and industrial and commercial units take up the majority of the spatial extent, with their, consequent, little amount of adequate (and flexible) space for mitigation and adaptation measures. This signifies that, on one hand, it will be the other (more or less prominent) land use and land cover classes that will feature greatly in heat regulation strategies (namely, forests and green urban areas), and, on the other, that more point interventions will need to be deployed throughout and within the highly urbanized landscape.

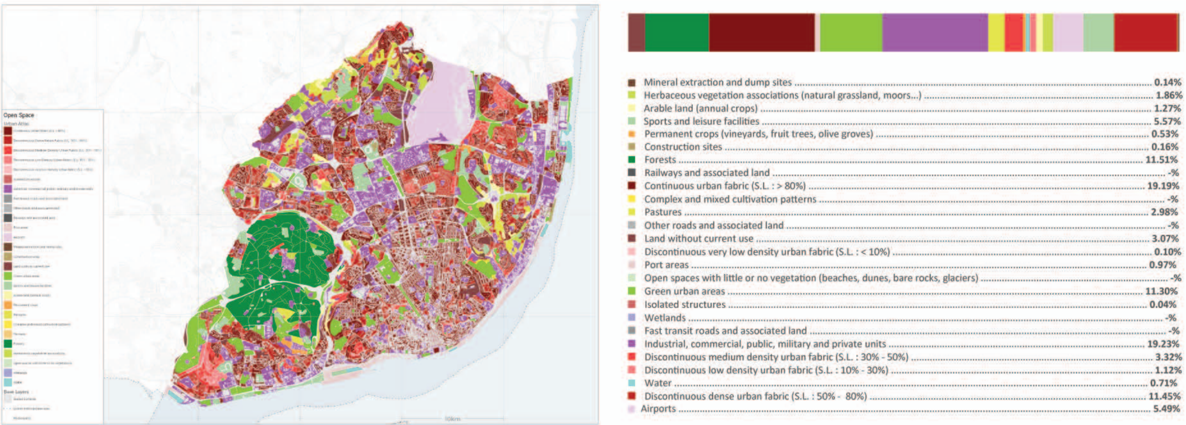


Figure 3.27. Urban Atlas at the non built-up space for the Municipality of Lisbon (BURR PoS, 2022, with data form "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

3.2.3.1. Regulation Systems

The 3 spatial systems that compose the spatial capacity of the Lisbon Metropolitan Area and the Municipality of Lisbon, namely, the ecological structure, the system of non-built-up spaces, and the infrastructural networks, are analysed here in reference to their inherent correspondence with the particularities of heat regulation. For the first 2, this refers to size and proximity, while the latter is approached in terms of the land use and land cover composition of its surroundings, where the issue is to gauge the degree to which they can function as a spine to support a broader heat regulation spatial planning, design and engineering project. The 3 regulation systems will be, in the next sub-section correlated with the rest of the spatial systems from the perspective of heat mitigation and adaptation.

3.2.3.1.1. Ecological Potential

Ecological potential follows the previous analysis of the ecological structure of the Metropolitan Area. A subsequent analysis of said system of patches and corridors is done on the basis of size and proximity. Size is in indicator of types of cooling devices, namely, forests and large urban parks. The categorization of green spaces identifies spaces of at least 200m² and spaces of at least 2.5 hectares. It has been found that the latter size is the minimum for an urban forest, while the former is the minimum for an adequately cooling urban green space. Similarly, cool spaces should not be further than 300m apart, so that the air movement and ventilation capacity of the system is not hindered ("Urban Green-Blue Grids for resilient cities", n.d.; (Nuijten 2008; Kluck et al. 2020).

The maps in Figure 3.28 and Figure 3.29 illustrate the above 2 aspects. The ecological potential and the network it creates will be further evaluated in reference to the general occupation patterns of the urbanized landscape further down this chapter. Specifically, what will be sought is whether there is sufficient open green space to cover the entire urban population, both in terms of green patches of adequate size, as well as in terms of the existence of 'gaps' characterized by the absence of green within a radius that exceeds 300m. The preliminary analysis shown here already indicates the need for further integration of the exiting green spaces, as well as the design of new ones.

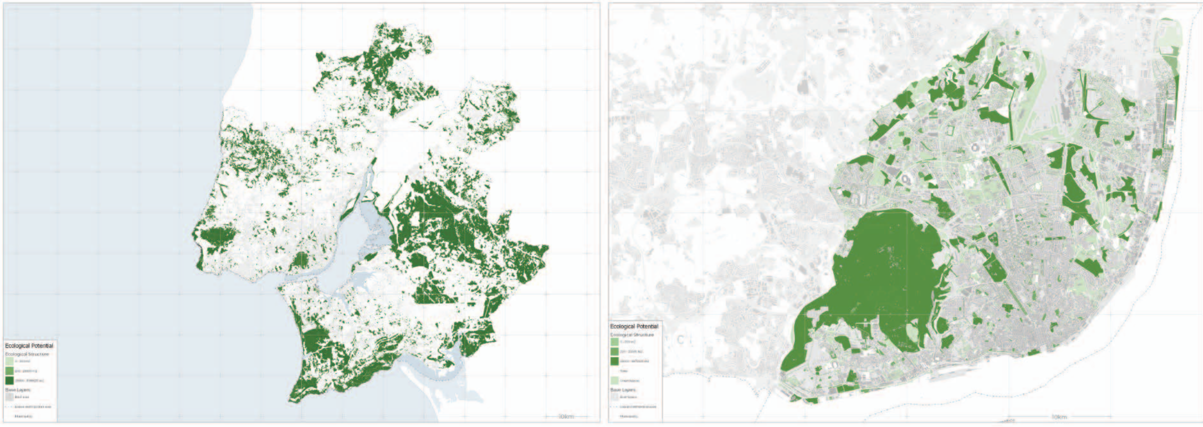


Figure 3.28. Ecological potential per size for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) (BUUR PoS, 2022)

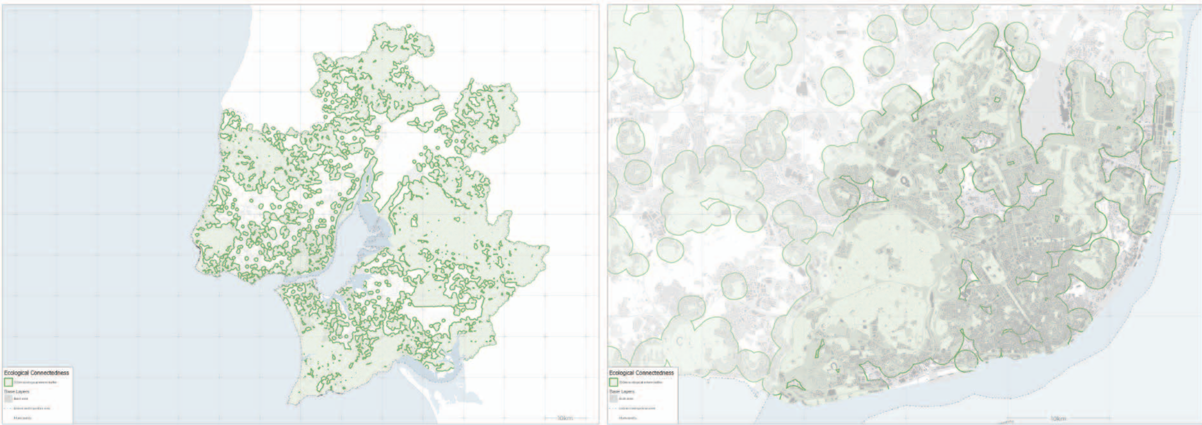


Figure 3.29. Ecological connectedness per 300m buffer zone for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) (BUUR PoS, 2022)

3.2.3.1.2. Spatial Potential

Overall spatial potential (differentiated from ecological potential) refers to the system of non-built-up spaces of the spatial extent. Similarly to the ecological potential, this is, also, classified according to size and proximity. The difference between the 2 lies in the different land use and land cover classification (and, by extension, the possibilities for heat regulation planning), such that spatial potential is approached so as to determine necessary measures that the existing ecological potential is unable to address. As shown in Figure 3.30 and Figure 3.31, the coverage of large open spaces takes up the majority of the spatial extent of the Municipality of Lisbon. However, further analysis is needed to determine the degree of flexibility of manipulation of said spaces (a function of their use and cover classes, as well as ownership and governance patterns).

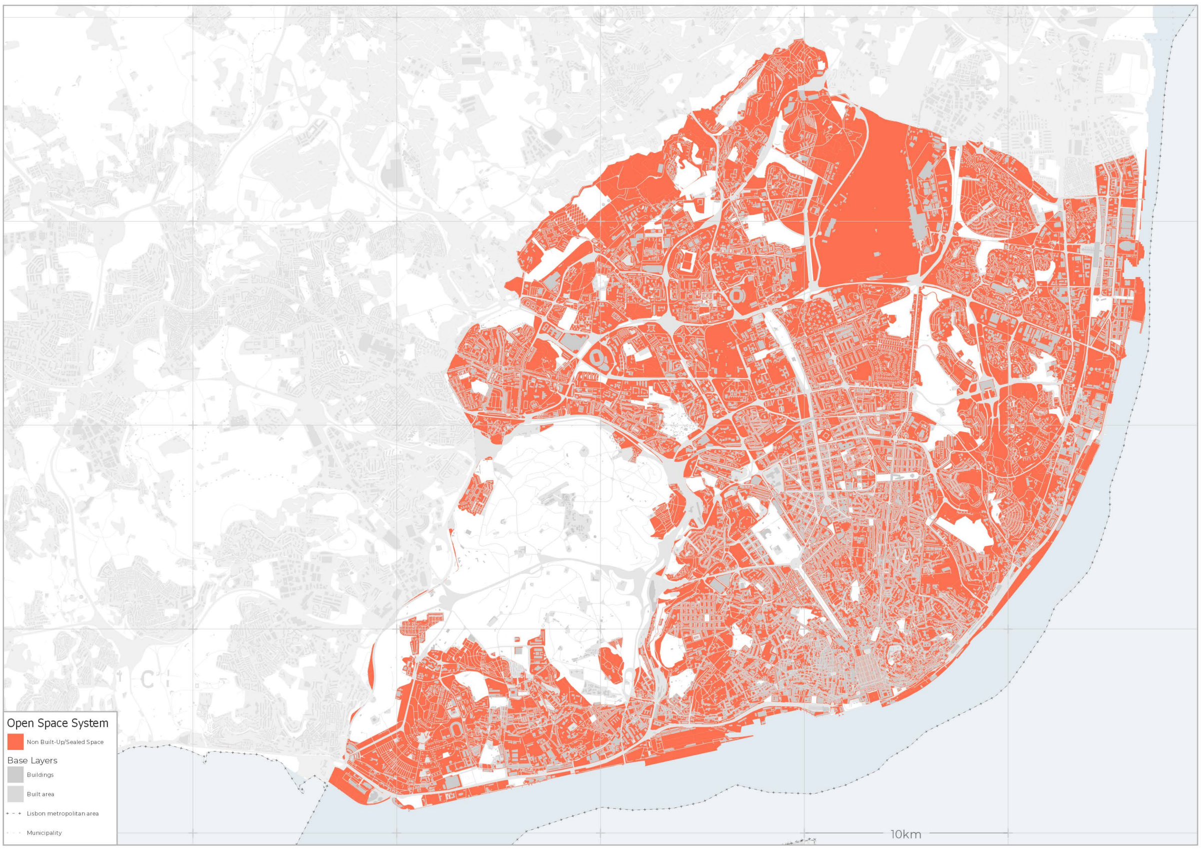


Figure 3.30. Non built-up (and non-ecological) space for the Municipality of Lisbon (BUUR PoS, 2022)

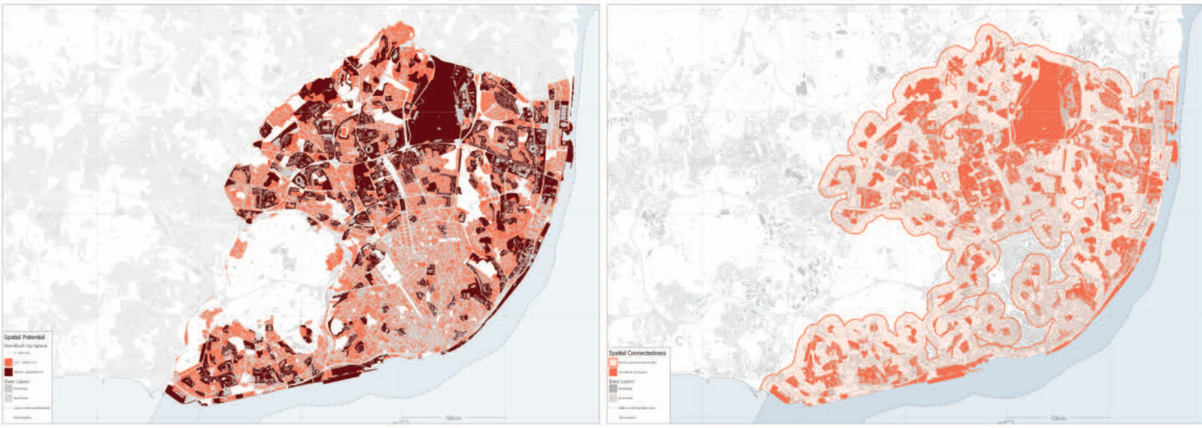


Figure 3.31. Size categorization and spatial connectedness of non-built-up space for the Municipality of Lisbon (BUUR PoS, 2022)

3.2.3.1.3. Infrastructural Potential

Infrastructural potential refers to the possibility of organizing mitigation and adaptation measures along the major networks of the territory. 2 different types of networks are being discussed here: surface hydrography and mobility, and the issue is the evaluation of the degrees that different land use and land cover classes take up their respective buffer zones. For the purposes of this project, riparian zones are classified according to "Copernicus Land Monitoring Service" (n.d.) and a 6m buffer around the watercourse axis (Pötz et al. 2010) (see Figure 3.32). The mobility infrastructure system is categorized in 5 classes with respective buffers of: 822m for the motorway, trunk and railway axes, 117m for the primary roads, 85m for the secondary and tertiary courses, 36m for minor axes and 6m for the very small roads (Viganò et al. 2016) (see Figure 3.33).

As regards the surface hydrographic system (see Figure 3.32), for the Lisbon Metropolitan Area, the riparian zones are mainly associated with irrigation for agricultural lands and pastures, as well as associated herbaceous vegetation. For the Municipality of Lisbon, they form, largely, part of the mobility infrastructure and, secondarily, of the urban fabric (primarily dense urban fabric). As such, the capacity of the surface water network to host heat regulation devices articulates, the need for the embedding of said measures and solution within and throughout the agricultural and urbanized mosaics.

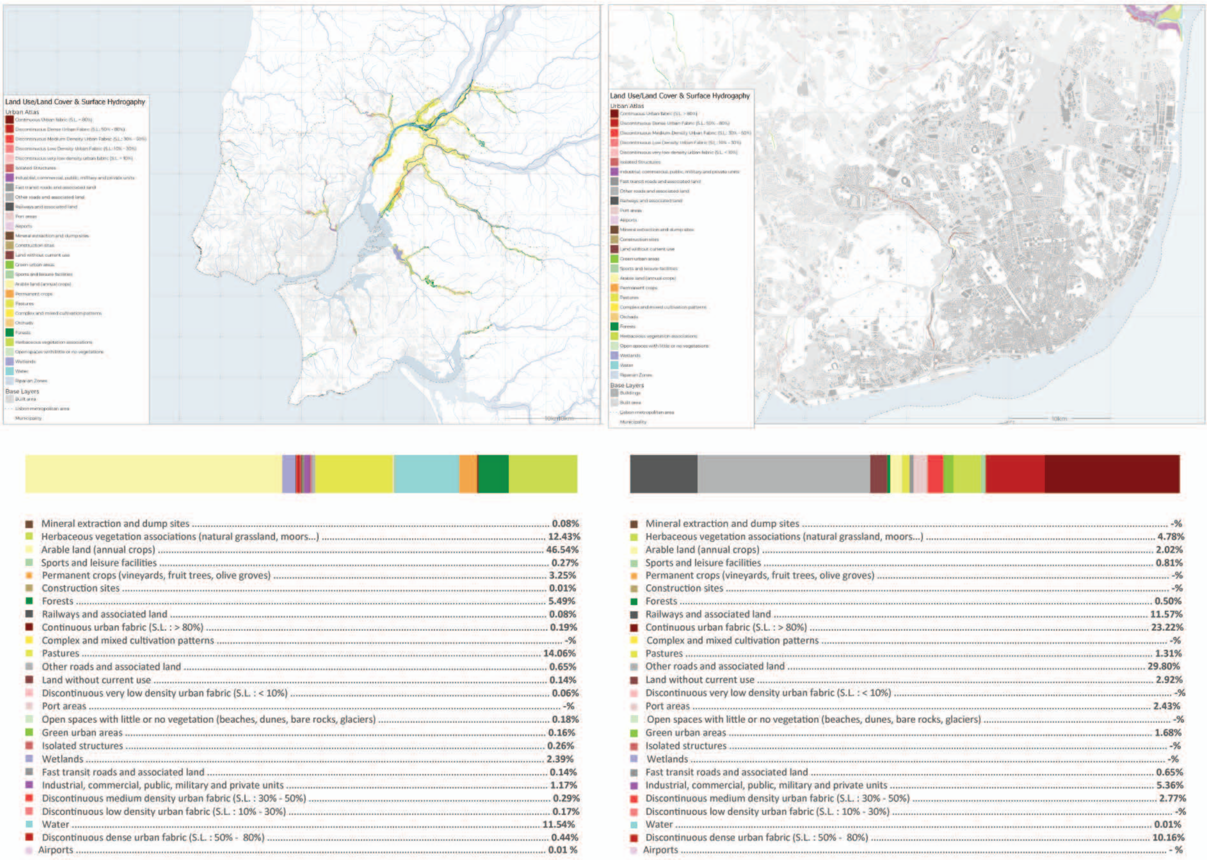


Figure 3.32. Urban Atlas at the riparian zones for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

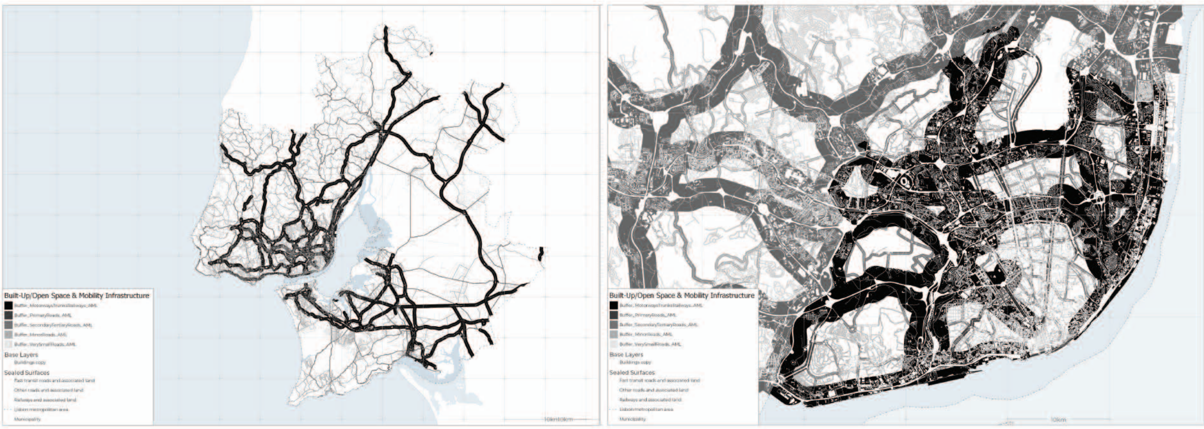


Figure 3.33. Classification of mobility infrastructure for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) (BUUR PoS, 2022)

A similar image is being gauged by the land use and land covers of the mobility infrastructure buffers: they are primarily characterized by herbaceous vegetation, arable land, pastures, forests and to a lesser degree industrial/commercial units and dense urban fabric, for the Lisbon Metropolitan Area, and, for the Municipality of Lisbon primarily dense urban fabric and industrial/commercial units, and secondarily green urban areas (see Figure 3.34). This picture is, almost identically, replicated throughout the 5 different classed of the hierarchical categorization. The mobility infrastructure traverses and connects herbaceous vegetation formations, croplands and pastures, forests and urban green areas, industrial and commercial units, and the densest instances of the urban fabric (see Figure 3.35 to Figure 3.39). This signifies the capacity of the road network to organize a territory-wide cooling spatial plan, organize a mixite between intense vegetation and agricultural uses and covers, enhance, protect and connect the existing herbaceous vegetation structures and woodland covers, provide for cool spaces in close proximity and/or in tandem with work environments and amenities, as well as the residential areas. A further classification of the above associated spaces in reference to their inherent capacity at hosting the corresponding heat regulation measures and/or being transformed accordingly needs to be done and will be discussed further down this chapter.

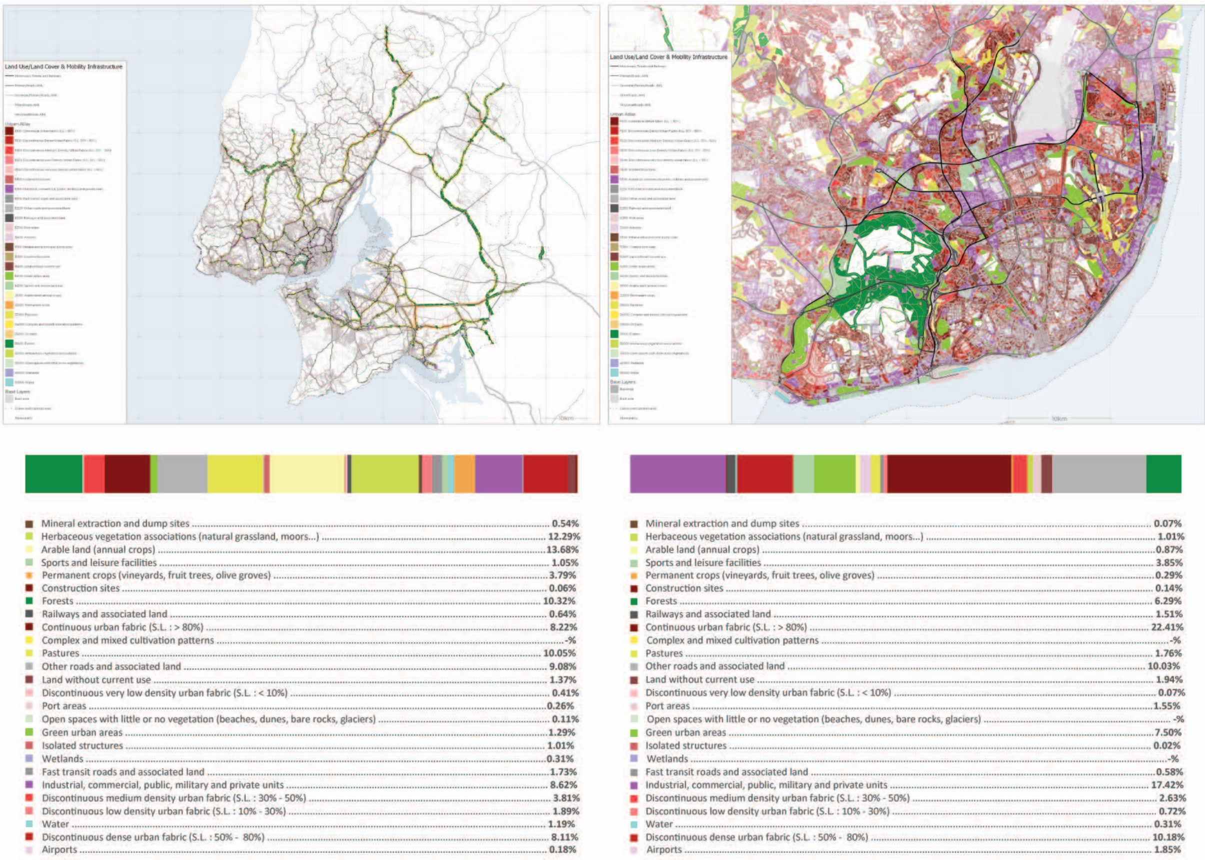


Figure 3.34. Urban Atlas at the mobility infrastructure buffer zones for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

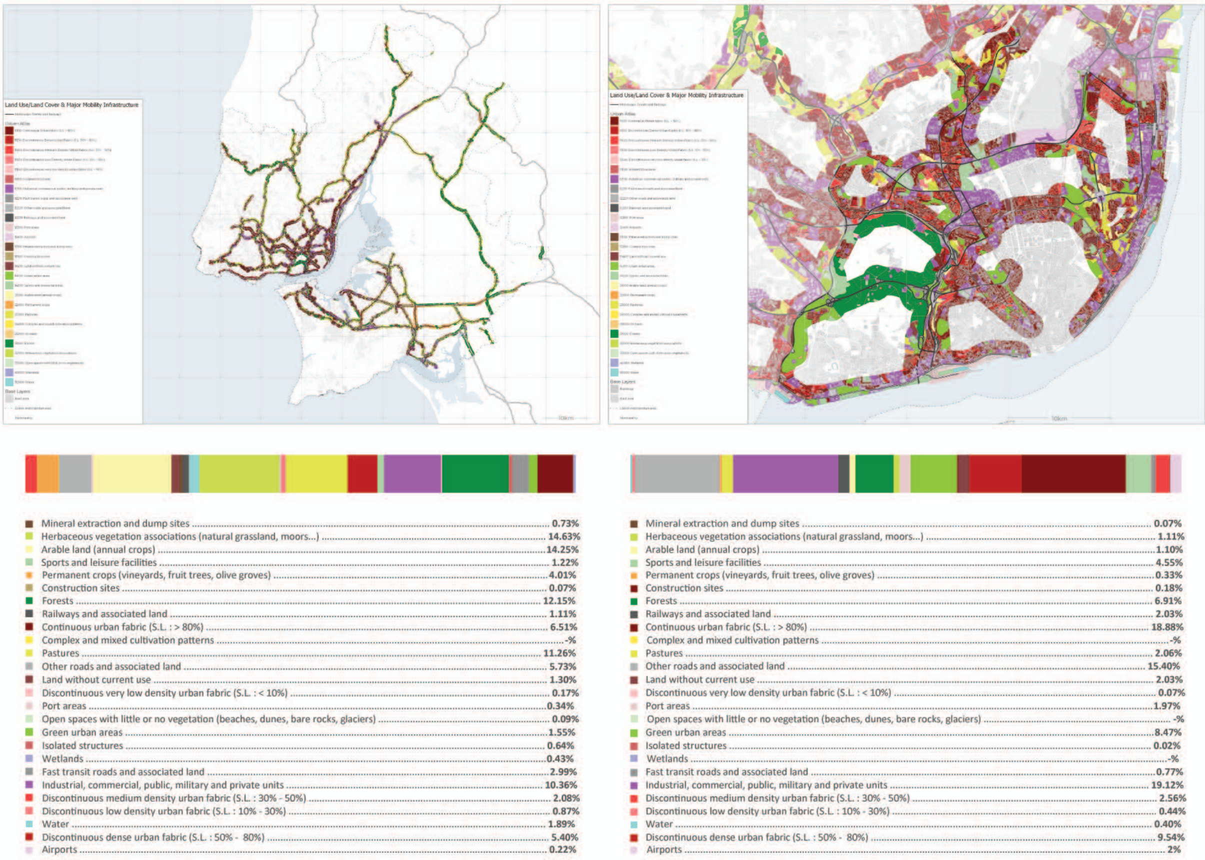


Figure 3.35. Urban Atlas at the major mobility infrastructure buffer zones for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

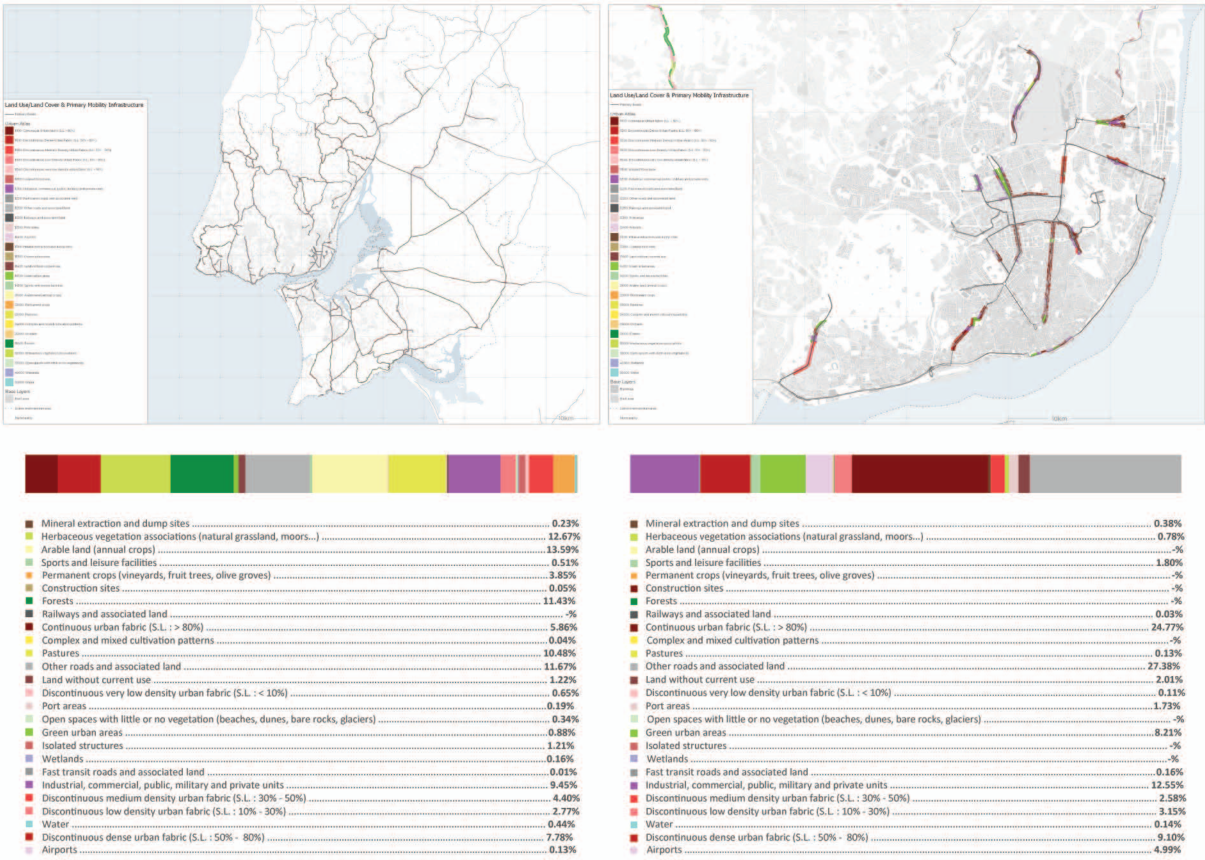
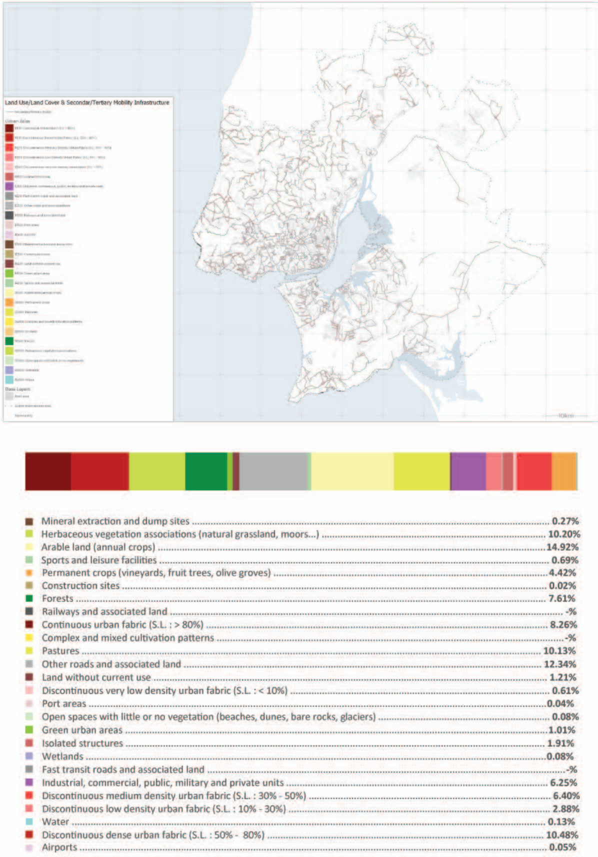


Figure 3.36. Urban Atlas at the primary mobility infrastructure buffer zones for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))



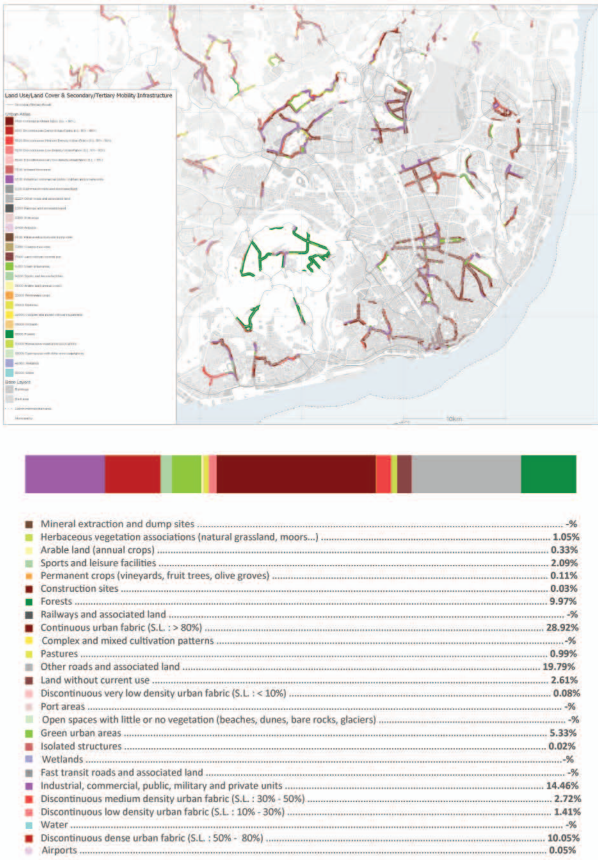


Figure 3.37. Urban Atlas at the secondary and tertiary mobility infrastructure buffer zones for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

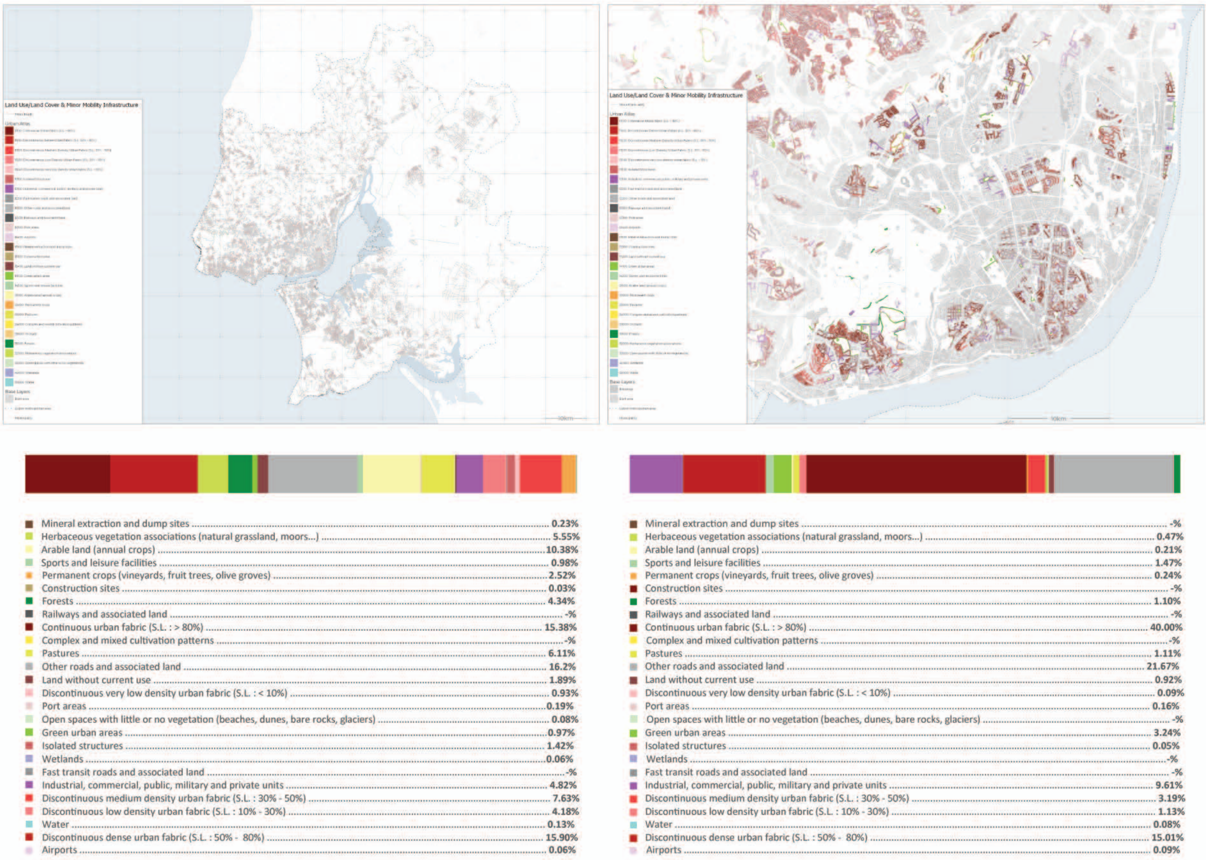


Figure 3.38. Urban Atlas at the minor mobility infrastructure buffer zones for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

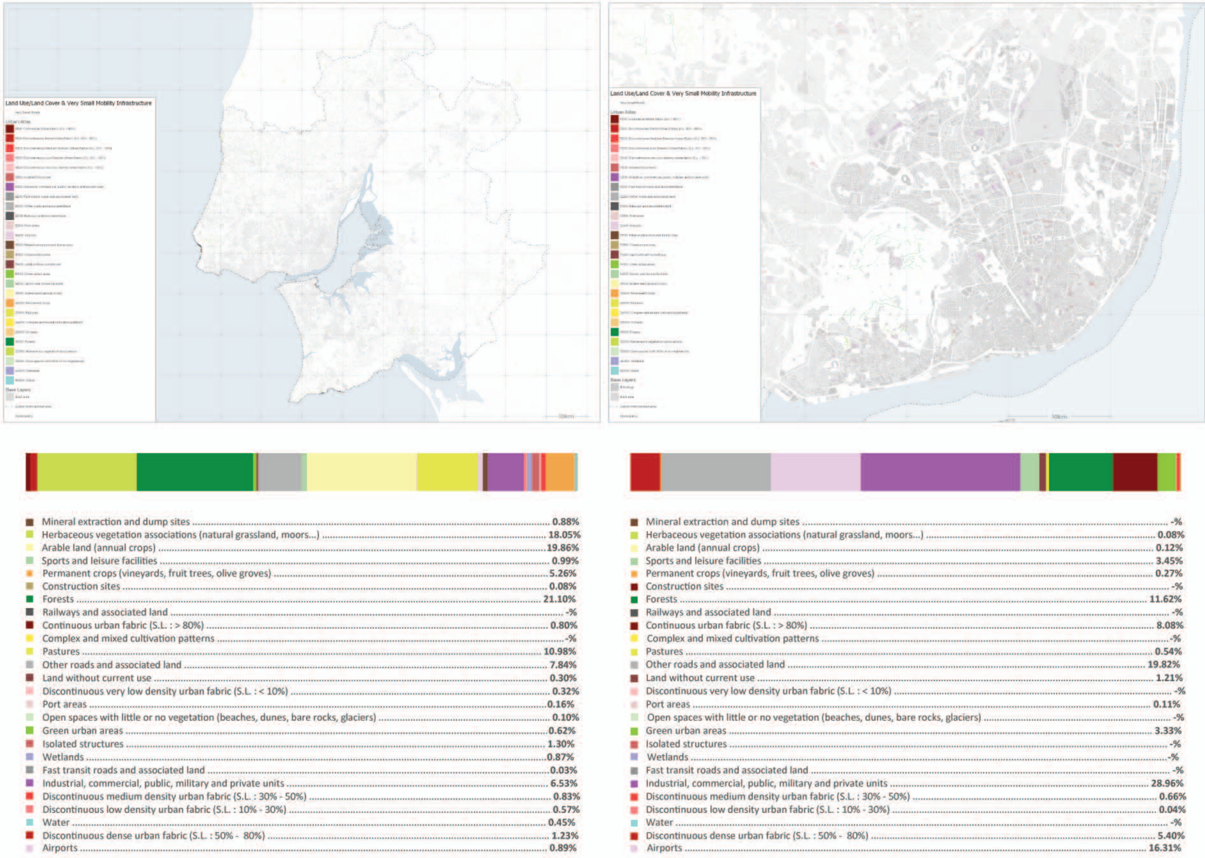


Figure 3.39. Urban Atlas at the very small mobility infrastructure buffer zones for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) with calculation of Class Area Proportion (CAP) for the associated classes (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018))

3.2.3.2. Spatial Dimensions for Heat Regulation

This section is concerned with the evaluation of the spatial structure of the Lisbon Metropolitan Area and the Municipality of Lisbon from the perspective of heat regulation. This evaluation is done through looking at the characteristics of the regulation systems, as elaborated upon previously, in relation with the overall urbanized landscape, according to specific criteria for heat-related performance. Said criteria follow (Kuzniecow Bacchin 2015) and are as follows: coherence, permeability, porosity, flexibility and contingency, and each looks at the aforementioned interrelationship in reference to a particular need for appropriate heat stress management, namely, the ground system, the territorial appropriation of cooling spaces, their significance for everyday life, their inherent capacity to provide for heat regulation and their correspondence with existing management regimes.

3.2.3.2.1. Coherence

Coherence signifies the organization of the composition and the configuration of land use and land cover throughout a spatial extent in reference to a particular issue (here: heat stress regulation) according to the base layers (soil, topography, geomorphology, ecological structure etc.) (Kuzniecow Bacchin 2015). For the purposes of heat stress regulation, this implies the cooling of urbanized landscapes that sit on valley and stream landform formations, the increase of vegetation throughout flat landform formations and along riparian corridors, and the planning and design of ecological corridors that bridge the gaps between existing areas of ecological value (Pötz et al. 2010, 2014). That is, the determination of limits to heat stress mitigation and adaptation is related with: 1. the evaluation of the possibility that corresponding devices be infused within the those parts of the city that rest on repressed geomorphological structures, 2. the renaturalization and further greening of riparian zones, 3. the increase in vegetation on plain fields (and the associated mixite between intense vegetation and agricultural covers), and 4. the utilization of the mobility infrastructure network as carrying structures to connect areas of ecological value that have more than 300m distance between them. The spaces themselves are, further, categorized according to the level of cooling potential which is a factor of their land use and land cover class (following (Bryan Ellis et al. 2012).

The maps of Figure 3.40 show the resulting network of cooling spaces and the rate of cooling potential for the Lisbon Metropolitan Area and the Municipality of Lisbon.

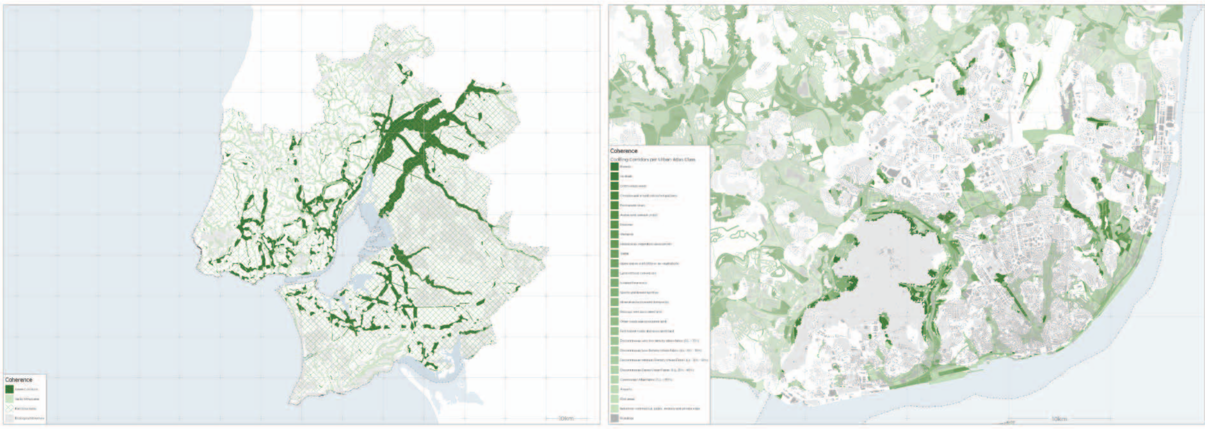


Figure 3.40. Cooling spaces in coherence with the geomorphology and the ecological structure for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) per degree of cooling potential (BUUR PoS, 2022)

3.2.3.2.2. Permeability

Permeability signifies the organization of the composition and the configuration of cooling spaces throughout a spatial extent in such a way so as to allow for ventilation (thus, reducing the heat island effect) by connecting urban cores with the (cooler) surrounding countryside and allowing air currents to move (Martin et al. 2005; Ministerium für Klimaschutz Klimawandel in Nordrhein-Westfalen 2011). For the purposes of this work, this implies the utilization of the mobility infrastructure and surface hydrographic networks and carrying structures for said permeability, by infusing them and their corresponding buffer zones with cooling devices. That is, the determination of limits to heat stress mitigation and adaptation is related to the degree of existence of spaces (and their degree of cooling capacity) along the aforementioned corridors, as well as, the resulting cooling effect for the territory.

The maps of Figure 3.41 show the resulting cooling network, further categorized (as above) according to land-use/land-cover-based cooling potential (Bryan Ellis et al. 2012)), for the Lisbon Metropolitan Area and the Municipality of Lisbon.

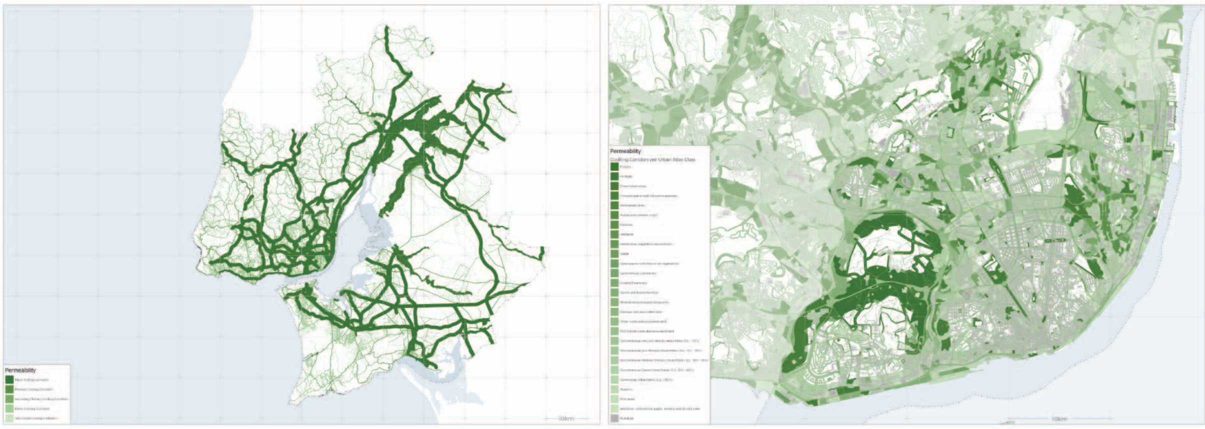


Figure 3.41. Cooling corridors permeating the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) per degree of cooling potential (BUUR PoS, 2022)

3.2.3.2.3. Porosity

Porosity refers to the presence of "spaces of significance" (Viganò et al. 2016). For the purposes of this work, 'spaces of significance' pertain to cool spaces along everyday inhabitant routes, e.g. from residence to work, amenities and/or public transport stops. Figure 3.42 shows the relationship between population levels and: 1. health service provision, 2. proximity to the major ecological structure, 3. proximity to large non-built-up spaces, and 4. public transport stops. Figure 3.43 does the same for tourist attractions. The point here is to inquire on whether or not (and to what extent) places of everyday mitigate the experience of heat, as well as, also, for the population at large.

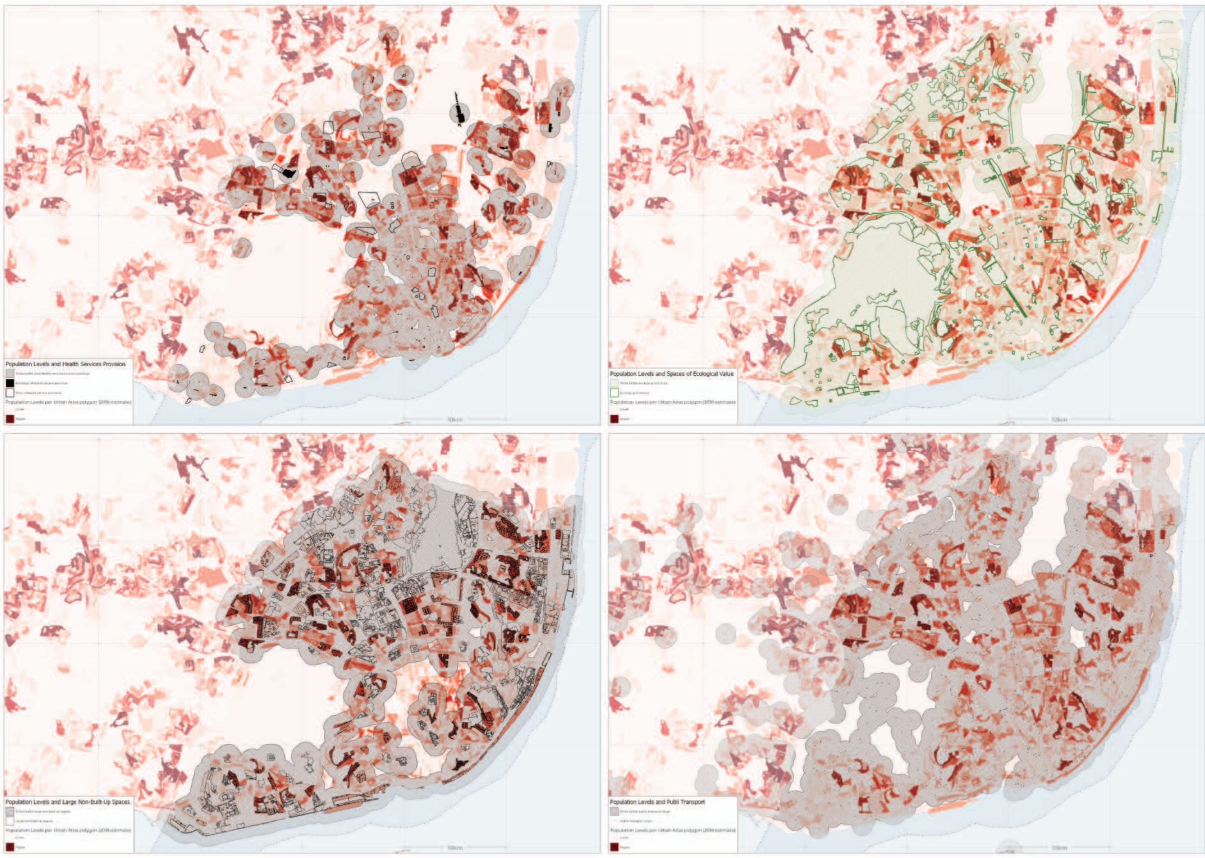


Figure 3.42. Correlation between population levels and (from upper left to lower bottom): 1. health service provision, 2. proximity to the major ecological structure, 3. proximity to large non-built-up spaces, and 4. public transport stops (BUUR PoS, 2022, with data from as is in Figure 14, Figure 20 and Figure 25)

Figure 3.43. Correlation between the position of tourist places and (from upper left to lower bottom): 1. health service provision, 2. proximity to the major ecological structure, 3. proximity to large non-built-up spaces, and 4. public transport stops (BUUR PoS, 2022, with data from as is in Figure 14, Figure 20 and Figure 25)

As discussed in this report, the experience of heat stress, as well as other aspects that my exacerbate it, are present in the Lisbon Metropolitan Area and the Municipality of Lisbon particularly thanks to the, at least seasonal, but, also, absolute, movement of people from the countryside towards the urban centers, as well the seasonal tourist influx, specifically, again, in and around the urban centers. This not only leads to further pressures in e.g. water availability or health service provision due to increase in population levels, but, also, further pressures to embed within the urbanized landscape heat regulation measures to cater for said increase in population levels. Figure 2.55 highlights the underlying conditions in reference to population levels, while Figure 2.56 does so in reference to tourist spaces.

It has been found and suggested that along quotidian movement, cool spaces should be placed at a maximum of 300m between them (Nuijten 2008; Kluck et al. 2020). As such, an analysis of proximity levels between the built stock and: 1. the ecological structure, 2. non-built-up spaces, 3. functions/programmes and spaces of public interest and 4. public transport stops is presented in Figure 2.57.

The 4 maps of Figure 3.44 represent differences between the distinct proximity analyses. As such, an intersection of their results is necessary. This is done by, first, isolating those buildings that are further than 300m from both the ecological structure, as well as large non-built-up spaces. Subsequently, the buildings that are positioned further than 300m from amenities and public transport stops are merged together. The resulting collection is evaluated on the basis of its own buffer of 300m and the results are shown in Figure 3.45.

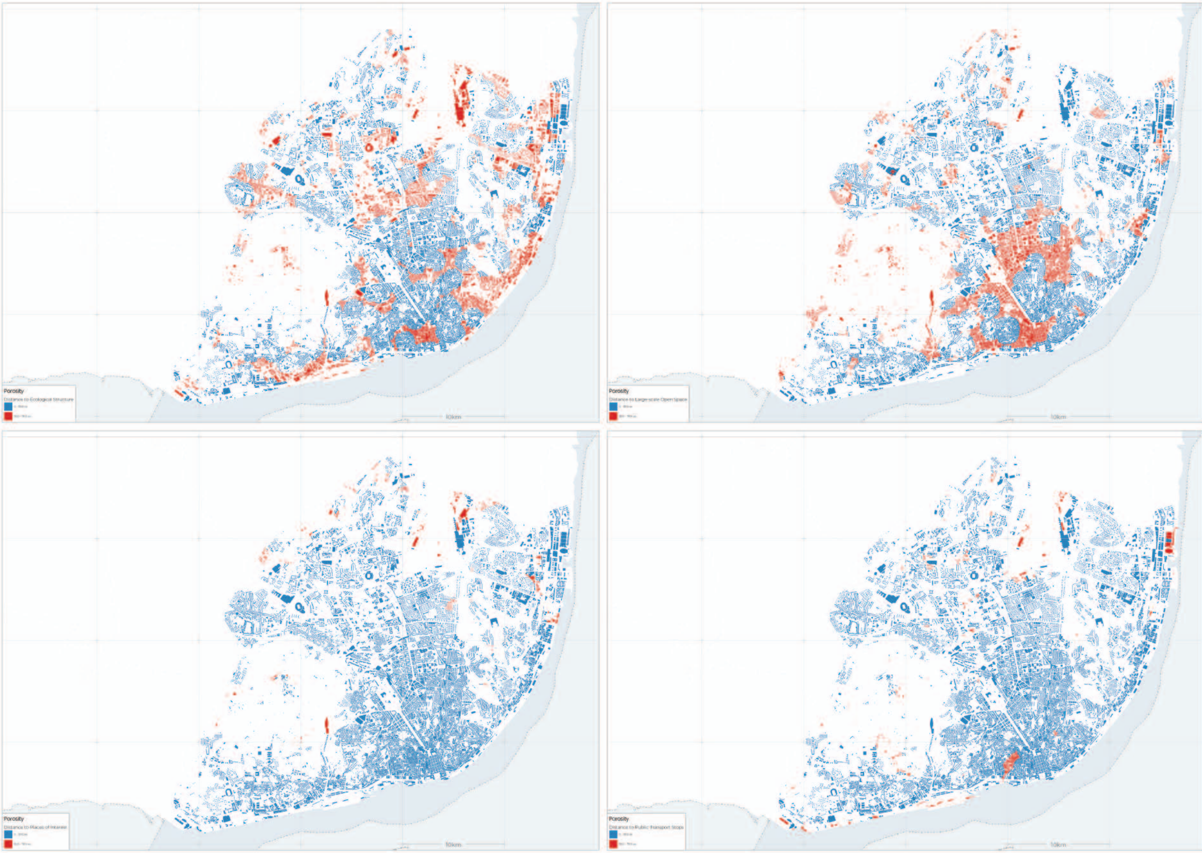


Figure 3.44. Distance between buildings and (from upper left to lower right): 1. spaces of ecological value, 2.non built-up space, 3. functions/programmes and spaces of public interest, and 4. public transport stops and stations (BUUR PoS, 2022, with data from "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

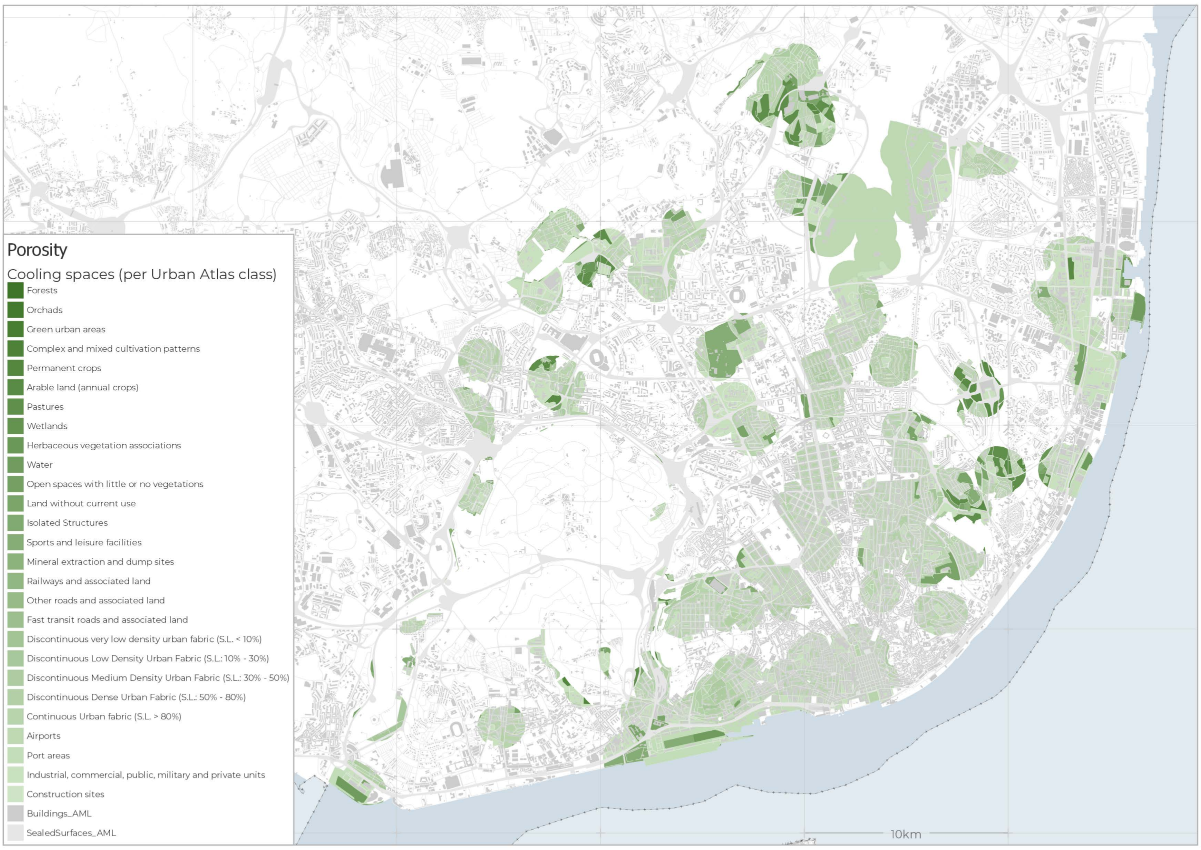


Figure 3.45. Cooling spaces for a porous system for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right) (BUUR PoS, 2022)

The map in Figure 3.45 illustrate the extents within which to plan for cool spaces so as to sufficiently address the porosity of the heat stress regulation infrastructure throughout the Municipality of Lisbon. That is, the determination of limits to heat stress mitigation and adaptation is related to the degree that of existence and degree of cooling potential of spaces within the showcased buffers. The categorization of the highlighted spaces follows, once again, their land-use/land-cover class as an indicator of cooling potential (Bryan Ellis et al. 2012).

3.2.3.2.4. Flexibility

Flexibility signifies the overall potential of a specific space to be transformed to perform a particular function (here: cooling), the degree of said performance, as well as the different possibilities for transformation and use (Kuzniecow Bacchin 2015).

Figure 3.46. Degree of flexibility of spaces for cooling per Urban Atlas Class, public ownership and size (BUUR PoS, 2022, with data from "Copernicus Land Monitoring Service", n.d. (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018); "Geofabrik", 2022 (http://download.geofabrik.de/europe/portugal.html))

Flexibility is a function of land-use and land-cover, size and ownership. The former follows the logic presented for the previous 3 dimensions: according to (Bryan Ellis et al. 2012), different land-use/land-cover classes host different potentials at performing specific ecosystem functions and providing associated services. Following this logic, spaces with lower built-up area and higher intensity of vegetation are positioned higher on the corresponding scale, while human activities such as mobility infrastructure, the urban fabric and industrial/commercial units are positioned, respectively, at the lower part of the spectrum. Ownership patterns suggest which spaces host greater or lower potential at transformation, due to the governance structure that regulates them. These range from large scale afforestation (in terms of public estates) all the way to private gardens (in terms of private ownership) ("Urban Green-Blue Grids for resilient cities", n.d.). Finally, size, as previously discussed, is an indicator of the scale of heat regulation measures, as well as of the overall possibility for such, since, for example, spaces of less than 200m2 have significantly lower capacity to perform for heat mitigation and adaptation.

The map of Figure 3.46 illustrate the above 3 aspects for the Municipality of Lisbon. It is interesting to note that there is a discrepancy between the overlay of public programmes, large patch size and land-use/land-cover-related flexibility, which indicates the importance that the existing ecological structure (and its upgrading) will play, as well as the importance of point-scale measures and their deployment throughout the entire spatial extent.

3.2.3.2.5. Contingency

Contingency signifies the organization of the composition and the configuration of spaces that address a particular issue (here: heat stress regulation) in reference to a particular issue (here: heat stress regulation) according to governance and ownership patterns (Kuzniecow Bacchin 2015). For the purposes of heat stress regulation, this implies the areas thar are classified as protected thanks to their involvement in the ecological performance of the territory, as well as to those spaces of the public estate that are part of the overall network of cool (or with the associated capacity) places. That is, the determination of limits to heat stress mitigation and adaptation is related with the evaluation of the degree to which existing plans and policies for nature conservation and large cool public spaces corresponds to the elaborated upon system of adequate spaces. For this, and overlay of the former over the latter is utilized. The result illustrates possible mismatches, as well correspondences, indicating the need for the introduction of heat regulation to the various strategies and plans for nature conservation.

The maps of Figure 3.47 show the resulting network of cooling spaces and the rate of cooling potential for the Lisbon Metropolitan Area and the Municipality of Lisbon.

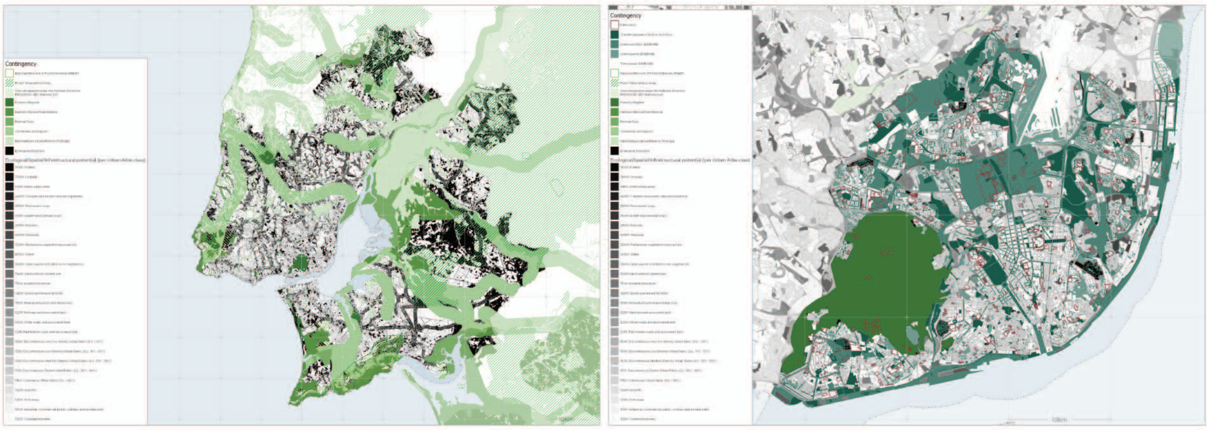


Figure 3.47. Overlay of protected areas of ecological value for the Lisbon Metropolitan Area (left) and the Municipality of Lisbon (right), with indication of plots of public ownership and/or significance for the smaller scale, over the existing ecological structure and the possible networks of cool spaces (BUUR PoS, 2022, with data from as in Figure 14, Figure 26 and Figure 41)

3.2.3.3. Synthesis

The maps in Figure 3.48 and Figure 3.49 represent the synthesis of the Structural Profile for the Lisbon Metropolitan Area and the Municipality of Lisbon after the evaluation of their interrelationship with the regulation systems according to the spatial dimensions for heat regulation as elaborated upon in the previous sub-sections.

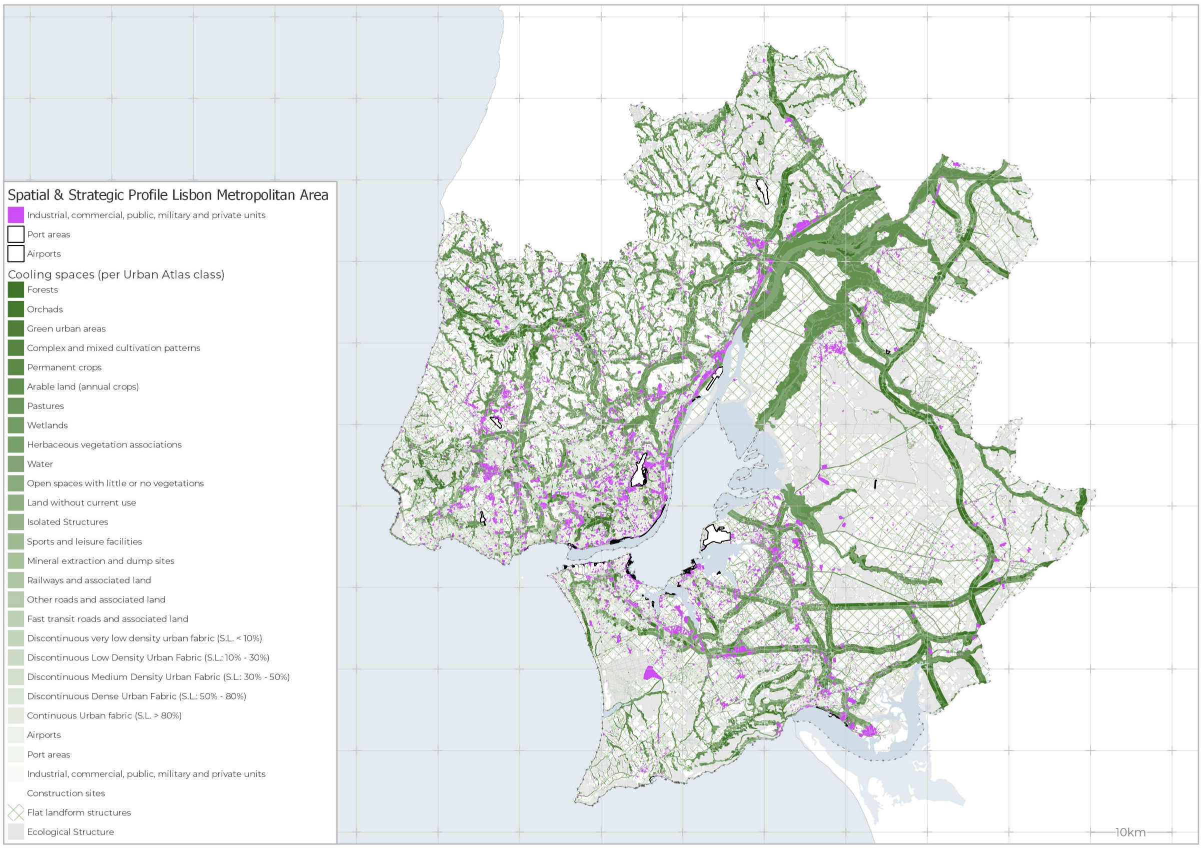


Figure 3.48. Strategic Profile for the Lisbon Metropolitan Area for heat stress regulation (BUUR PoS, 2022)

Figure 3.49. Strategic Profile for the Municipality of Lisbon for heat stress regulation (BUUR PoS, 2022)

3.2.4. Conclusion

This section summarizes an evaluation of the capacity of the spatial structure of the Lisbon Metropolitan Area to regulate heat, for details see Chapter 9. The analysis is based on an identification of the degree to which the composition and configuration of the various spatial systems that compose the territory in question correspond to the capacity to regulate heat, with focus on the existence and network of green and blue spaces (or spaces that could be green and/or blue).

The ecological structure, the system of non-built-up spaces and the space along the infrastructural networks (collectively referred to as 'regulation systems') were evaluated from the perspective of the size and inter-proximity of available spaces that could (or already do) perform heat stress mitigation and adaptation services. This evaluation was done according to: 1) their coherence with the conditions of the ground (landform and areas of ecological value); 2) the possibility that the surface hydrographic network and the mobility infrastructure are appropriated 'spines' that permeate the entire territory and organize a system of cool spaces for overall regional ventilation; 3) the transformation of spaces in close proximity to amenities and along quotidian routes between residences, work environments, amenities and public transport stops, into cool spaces (porosity); 4) the flexibility towards spatial manipulation allowed by the various land-use/land-cover classes, governance regimes and ownership patterns; and 5) the degree of correspondence between the suggested places for cooling and the current array of protection and nature conservation plans (contingency).

Figure 2.61 and Figure 2.62 represent the synthesis of the Structural Profile for the Lisbon Metropolitan Area and the Municipality of Lisbon respectively, after the evaluation of their interrelationship with the regulation systems according to the five above-mentioned spatial dimensions for heat regulation. The figures show (in shades of green) spaces that are suggested to participate in a regional and urban cooling strategy (in reference to landform, ecological value, and position along the surface hydrographic and mobility infrastructure networks), classified according to the degree of flexibility and cooling capacity (from darker to lighter green). Particular places and spaces of significance are emphasized, namely, the network of industrial and commercial units and the degrees of intensity of built-up space, due to the fact that associated heat regulation measures, as well as the overall strategy, has to consider possibilities of transformation of the economic sector and infusion of cooling devices within urbanized areas. Finally, a correlation is drawn between said spaces and their governance and ownership regimes.

At the scale of the Lisbon Metropolitan Area what stands out is the imperative for the reorganization of the patterns of existing agricultural (cropland and pasture), land uses and land covers, as well as areas of herbaceous vegetation that rest primarily on flat landform structures (and populate the largest extent of the region), so that they incorporate higher degrees of intense vegetation. The areas where the agricultural sector is prevalent are facing a demographic reorganization and, consequently, an increase in the risk of desertification and wildfires, exacerbated by and increasing the risk of heat stress. Subsequently, the utilization of the mobility and surface hydrographic systems as carrying structures for a territory-wide cooling project is evident, thanks to their high degree of territorial penetration and their position across areas of ecological value. At the same time, the greening of the valley structures that rest primarily at the northern part of the Metropolitan Area presents itself of strategic importance (particularly due to the high presence of settlement patterns). Finally, the significance of the adaptation of the network of industrial and commercial units, transportation nodes, as well as is the infusion and retrofitting of cooling devices within the urbanized landscape (according to the degree of built-up intensity) completes the picture.

For the scale of the Municipality of Lisbon, the emphasis is on the correspondence between those spaces that participate in the everyday life of the inhabitants and visitors to the city, and the governance and ownership systems. It has already been argued that the exodus from the countryside towards the urban cores, as well as the influx of tourist populations, increase both the risk of exceeding the capacity of the region to mitigate and adapt to higher temperatures, as well the overall exposure of populations to heat stress. As such, there is a need for embedding cooling measures in close proximity to and together with places of public significance, namely, amenities, tourist spots, health service provision buildings, public transport stops, as well as general residential areas. While the current system of green spaces exhibits a high degree of adequacy in reference to heat regulation, the network itself needs a higher level of retrofitting along the mobility infrastructural network (that corresponds to that of the entire Lisbon Metropolitan Area). While it could be possible to be fill the gaps thanks to the existence of large non-built-up spaces, such efforts might stumble upon difficulties related to management regimes, private ownership, or inflexible uses.

As such, the issue further for the mitigation of heat stress and the adaptation of the territory in question to higher surface and air temperatures rests on two interconnected aspects in reference to the work to be carried out within the PROVIDE project: 1. elaboration of scenarios of transformation of ownership, governance and use regimes of particular spaces within the urbanized landscape, and 2. elaboration of contextual (from large-scale to point interventions) strategies and physical solutions according to the spaces indicated in the maps above and their inherent characteristics. These will be, at the same time, evaluated through climate modelling, in terms of their performance in heat regulation, as well as in contrast to current territorial instruments and plans/strategies/policies for climate adaptation in general, and heat stress mitigation in particular.

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