Towards the Implementation of Climate Adaptation Planning: Approaching the Case Study of the North Adriatic Sea Through Four Research Papers.

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XXXIV Ciclo di Dottorato di Ricerca
Culture del Progetto del Made in Italy – Fenomeni Urbani
academic year 2022-2023

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Personal Abstract

Carlo Federico dall'Omo

Carlo Federico dall'Omo, Architect and Urban Planner, is a Ph.D. candidate in Architecture, City, and Design at Università Iuav di Venezia. His research investigates the evolution of the project for the city and the landscape linking to climate change impacts. He holds a degree in Architecture from Università Iuav di Venezia with a thesis focused on the development of an alternative governance model for public heritage assets oriented to urban regeneration. Since July 2018, he has carried out several research assignments funded by the EU investment programs Interreg Italy-Croatia, Interreg Italy-Slovenia, and the Life program aimed at updating territorial governance processes for the management of climate change impacts. During his research career, he has been actively involved in the search for EU funding opportunities on the Horizon, Prima, Interreg, and Life lines. He has developed some competitive projects dealing with the constitution of project consortia managing the relationship with international and national research institutions, dealing with the scientific methodologies implemented in the projects, and related to innovative research in architecture, urban planning, and design. He has also consolidated his experience in EU funding programs through the management of both research and reporting phases of some projects in charge of the Università Iuav di Venezia. He is a member of the Planning and Climate Change LAB at Iuav and since March 2018 he has been conducting research focusing on the study of urban design processes, with specific attention to the relationship between adaptation and protection strategies for the urban environment and through decision support systems. He carries out teaching lecturing to the courses of Urban Technique and Planning in the master's degree courses in Architecture and Spatial Planning at Iuav. Furthermore, he carries out reviewer activities for MDPI, publishes continuously since 2018 scientific articles at the national and international level, and is coordinator of the research group INU Sustainability and Climate Change.

Abstract

The effects of Climate Change (CC) are radically changing the way in which we experience our planet, individual and the collective security perceptions of our habitat. Much has been done, from international climate agreements to local actions.However, it emerges how preponderant is the mitigation, which means reducing those factors which cause global warming, and how small are adaptation efforts. Urban planning and architecture play a central role in this phase of reinterpreting our habitat. Climate Adaptation Planning (CAP) could thus be the effective response we have to deal with climate-related disasters or territorial losses and economic resources.

The thesis argued in this dissertation is that CAP can be a valuable coordination approach between sectoral plannings, suggesting that climate impacts management can globally support more efficient and effective use of planning resources. The dissertation explores the interaction between CAP and 4 planning approaches: Maritime Spatial Planning (MSP), Alpine Space Planning (ASP), Metropolitan Multi-Risk Planning (MMP), and Resilience Decision Planning (RDP). The dissertation is based on four research papers published during the doctoral track, each associated with one of the interactions between CAP and planning models. The goal of the dissertation is to suggest how this research process can be expanded and effectively operationalized by testing the interaction versatility between different planning disciplines.

The four papers and dissertation focus on the case study of the Northern Adriatic, one of the main seas in the Euro-Mediterranean system by addressing the spatial dimension of the investigation through ICT modelling tools. Collective findings from the research highlight the need for a coordinated interaction among advanced planning approaches and that CAP can be the core answer to fill this gap. The dissertation is consciously oriented toward the funding horizons available for action against CC and for supporting new models of sustainable growth and aims to focus on what may be possible outputs for CAP implementation.

Acknowledge

ments

This dissertation is dedicated to the memory of Andrea Cicogna, the most wonderful friend who taught me to never give up and inspired me to live without fear.

I have always found acknowledgments difficult because they feel so final, and I feel that the submission of this dissertation is more of a beginning than an end. Nevertheless, the scientific etiquette requires me to compose this list in far too limited a space, but I want those noted here to understand their enduring importance to my work, my career and me as a person.

It goes without saying that my parents and my family, who already know how grateful I am to them for their support, have shared their strength with me, I am indebted to them for helping me to reach this point of conclusion. Caterina also already knows that I would not have completed this Ph.D. without her love and enduring patience.

This dissertation has been guided and supported by a wonderful community of peers, without whom I would not be the person I am today. The first thanks go to Francesco Musco, my mentor, friend, and supervisor. Thank you to Denis, Gianfranco, Ruzzi, Vittore, Mattia, Giulia, Filippo, Giacomo, and Fabio for sharing their knowledge with me. Thanks to Matteo, who has been fundamental in helping me to define the form of this dissertation from the mists of my many ideas. Thanks to Alessandra and Nicola, from whom I have asked too much. Thanks to all my friends and comrades at Planning Climate Change LAB, may the wind fill our sails.

A final thanks to my lions and companions: Riccardo, Alvise, Tommaso, Daniele, Olga, CDB, Giada, Carolyn and Ileana.

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FIRST CHAPTER

Introduction

CHAPTER INDEX

Abstract

The dissertation Introduction presents the structure, the theoretical background, and the case study addressed throughout the research. Each section presents an aspect of the dissertation project, recognizing the disciplinary gaps which triggered the thesis hypothesis, the state of art backbones, the relationship with the doctoral program, and the dissertation structure.

The Mediterranean basin is characterized by a strong link between maritime space, water and coastal settlements(Braudel et al., 2002). These characters have shaped the history and morphology of the land itself. Mediterranean coasts face enormous environmental and social challenges due to water scarcity, unsustainable agricultural practices, exploitation of natural resources, depletion of bioregional systems, and rapidly increasing impacts of climate change (CC) on urban areas and the environment(Cinar, 2015; Egidi et al., 2021; Jordà & Gomis, 2013; Torres & Doubrava, 2010). Understanding the present and future complexity of this interconnected scenario, both at the physical level and in terms of governance, is key to undertaking effective planning strategies and actions.

As the latest report of the Intergovernmental Panel on Climate Change (IPCC 2021) indicates, the Mediterranean represents a paradigmatic case for fragile coastal contexts, where the balance between land and sea, between human activities and nature, are at a critical level of emergency(Bruno et al., 2021). Climate change is the trigger for exponentially increasing the conflicts that already exist and generating new ones. At the same time acting on the climate scale requires enormous economic availability, planning, and coordination capacity in contexts that are often poor, in mutual conflict, and where there is insufficient stability to define long-term planning(Li et al., 2021). This condition is present in a general sense in any form of planning and design, not just linking to action addressing climate change(Whitmee et al., 2015).

The principle guiding this dissertation is that there is a global need to reformulate the basics of how growth and transformation strategies are envisioned for the Mediterranean basin. The scientific community, decision-makers, and stakeholders have in the past decade addressed in parallel and with outstanding results individual sector problems that present critical issues at the territorial scale(Poortvliet et al., 2020). For example:

- How can we improve the quality of agriculture to consume less water(Katerji et al., 2008; Olesen & Bindi, 2002)?
- How can we rethink land-sea interaction by sharing basin policies (Giorgi & Lionello, 2008; Lejeusne et al., 2010)?
- How can we produce more sustainable circularity-based economic systems (Ait-Mouheb et al., 2018; Armeli Minicante et al., 2022; Diacono et al., 2019)?
- How can we improve the quality of life in the most economically and socially disadvantaged areas to reduce migration (Linares et al., 2020; Nicholls et al., 1999)?
- How can we develop environmental monitoring tools to develop plans for habitat protection(Lejeusne et al., 2010; Malcolm et al., 2006)?

Each of these questions has produced significant results in terms of both research and empirical planning; however, this situation is not expected to last. In fact, the entire climate paradigm is, as is now well known since the first climate conferences, in a phase of rapid evolution in a gradually worsening perspective(Dhar & Khirfan, 2017). More frequent extreme weather events, and radical modifications of entire bio-ecosystems, are changing the way security is perceived globally and even more in a fragile context such as the Mediterranean basin.
Sectoral planning actions can support short-term strategies. However, they risk quickly becoming obsolete against the evolving climate framework and thus making implemented investments ineffective. The dissertation argues - through 4 papers published in international scientific journals - that climate action can be the lever to guide the

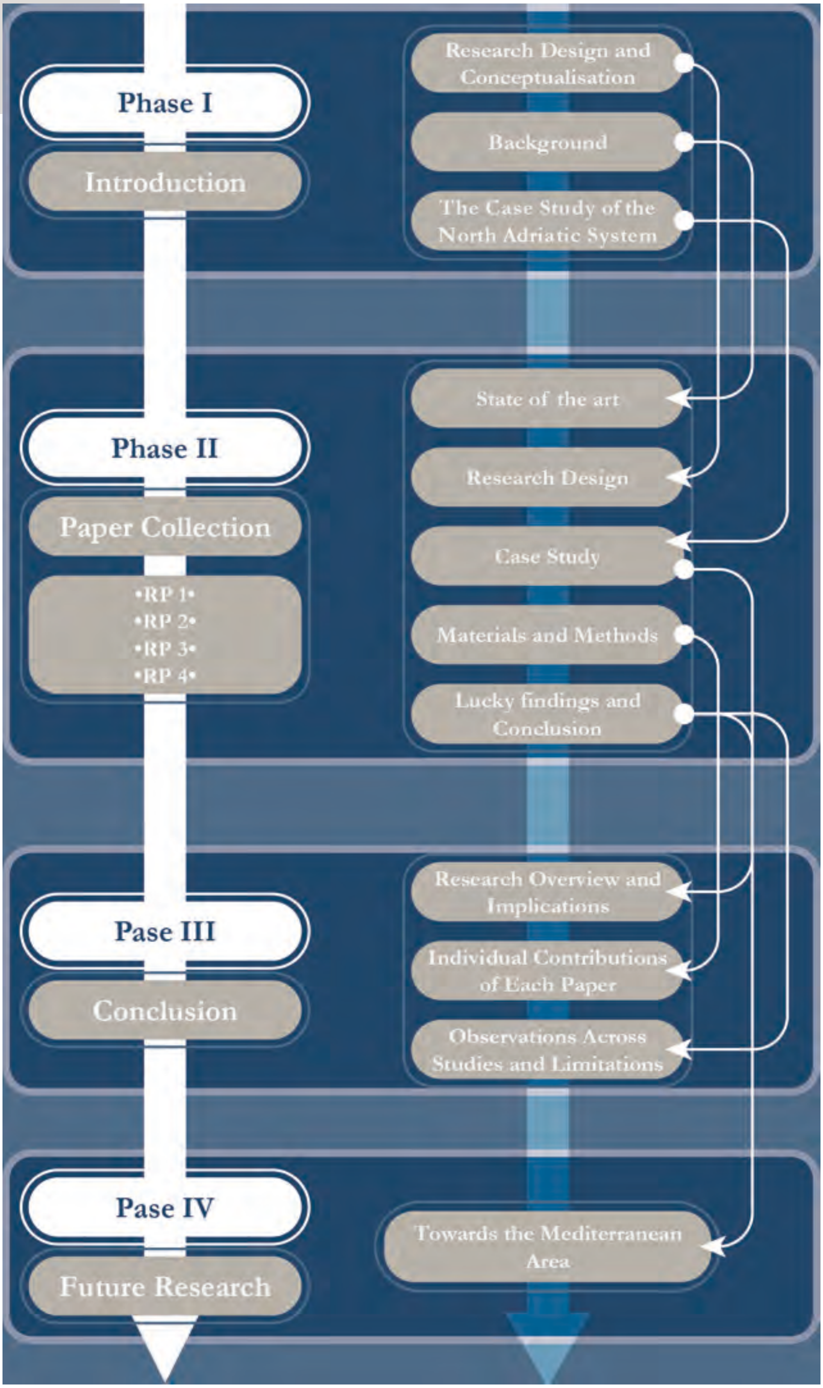
evolution of the current planning paradigm.
Climate action has evolved substantially between the 2014 IPCC report and the 2015 Paris Agreement. Since Kyoto 1997, the climate action model has been based on limiting the atmospheric emission of greenhouse gases only, by reducing energy consumption and capturing carbon dioxide. The action framework recognized adaptation as a new priority following 2014 - 2015. Adaptation is understood as the process of transforming territories to reduce the effects of climate change impacts by implementing policies and infrastructure (green, blue, and grey)(Gill et al., 2007; Reser & Swim, 2011). Droughts, floods, heat islands, sea rise, and extreme storms are some of the impacts acknowledged within international coordination agendas and in local plans. This action front is a priority to protect and preserve urban and environmental systems(Costanza et al., 2021). Central objectives are to prevent those impacts have a devastating effect on spatial assets and while the layering of these phenomena does not further worsen existing criticalities.
The so-called Climate Adaptation Planning (CAP) is a complicated, expensive, and long process. At the Euro-Mediterranean level, the main problems that CAP encounters are like those of other sectoral planning tools: the voluntary nature of action, poor commitment, lack of coordination, lack of adequate knowledge and monitoring tools to record the speed of phenomena, lack of planning capacity, and lack of coordination with other forms of planning. This dissertation funds on the confidence that the climate change adaptation process is simultaneously a priority for managing an emergency that is bound to worsen and that it is urgent to implement it consistently the soonest as possible. Likewise, the research investigates possible interactions between CAP and other forms of sectoral planning to address multiple issues simultaneously(Albrechts et al., 2020; Booth et al., 2020).

Planning and design disciplines need coordination and public commissioning when addressing complex issues of collective importance. Regulations, legislation, and strategies need to be

received and coordinated through mainstreaming actions with local stakeholders(Abunnasr & Infield, 2018). This shifting aims at more efficient use of available economic resources and making actions more acceptable. The more urgent the issues endangering people and properties are, the faster decisions will be accepted(Puskás et al., 2021). This is a possible additional risk as it can lead to harmful measures implementation, wasting limited resources and time. For example, a community endangered by frequent flooding is willing to accept measures to reduce the danger that the phenomenon will become more frequent and devastating(Bunten & Kahn, 2017).
Planning, if not supported by con knowledge, foresight, and monitoring, can lead to negative interactions, such as increasing property values or ghettoizing a disadvantaged community (Akbar et al., 2020). The opportunity provided by the interaction between CAP and other forms of planning can lead to positive synergy, and produce projects that are more conscious, coordinated, and efficient in resource use. The principle guiding this reflection is the hypothesis formulated by Urlick Beck concerning " emancipative catastrophism."(Beck, 2016) Can then CC's inexorability lead to a positive reaction? The dissertation investigates the possible interactions between CAP and other forms of planning: Maritime Spatial Planning (MSP), Alpine Space Planning (ASP), Metropolitan Multi-Risk Planning (MMP), and Resilience Decision Planning (RDP). Four papers, produced by the author of this thesis in collaboration with other authors, operationally describe each binomial from a technical perspective. Each form of planning analyzed has the same backbone: knowledge, strategy, and action.

Based on this structure the different planning models can be combined and complimentary. This approach is the heart of the dissertation, around which the chapters, sections, and steps that support the thesis are organized to answer the hypothesis and research questions. The dissertation contains images, diagrams, and graphs, mainly produced by the author, and copyrighted elements are quoted within the text.
For two reasons, it is not possible to simultaneously address the entire

Mediterranean as a single case study to support this dissertation's thesis. The first is that the Mediterranean is not unitary but a collection of multiple parts (morphological, social, economic, historical, environmental, political, etc.) with blurred boundaries continuously blending into each other for centuries(Matvejević & Heim, 1999). The second is that the tools for developing the mentioned advanced planning approaches (knowledge, strategy, action) have different base requirements which are completely absent in some areas. Scientific rigor on the one hand and planning experience on the other triggered the decision to divide a complex issue into smaller ones. As erroneous as it may be to claim that there is a "simple" dimension within a discipline that is wicked by nature (Rittel & Webber, 1973), the author decided to focus on the case study of the Northern Adriatic. This area, as presented more clearly in the following Chapters, can approximate some common issues of some of the most complex contexts of the Mediterranean basin.



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Section 1 - Research Design and Conceptualization

Figure 1 - Workflow.

1.1.

The purpose of this chapter is to present what are the aims, approaches and issues addressed by the dissertation. The sections and their contents follow a three-stage organization:

- 1.1.1. Conceptual Framework and Research Questions;
- 1.1.2. Researcher Positionality;
- 1.1.3. Format of the Dissertation;

Figure 1 presents the structure by which the dissertation is designed. The dissertation is a collection of papers, and the main challenge is to connect four different scientific products published between 2018 and 2022. The articles follow the same research design that is adapted to meet the requirements of each journal. Therefore, the dissertation follows four chained macro phases: Step 1 corresponds to Chapter 1, Step 2 to Chapters 2, 3, 4, 5, and Step 3 and 4 to Chapter 6.

The relationship between each phase is capillary and forms the backbone of the dissertation. The Northern Adriatic case study is the core of the process, which all papers address from different perspectives, and the binomials between CAP and other planning approaches. Each section presents a moment of progress related to the quality of personal research and the CAP overall state of the art.
The phased model follows the research design of the published papers, expanding and integrating it with all those contents necessary to demonstrate the thesis positioning. The goal is to connect each of the Phases with the other, presenting the methodological network with which the elaboration is designed, i.e. the comparison of the RQs and limitations recognized by each research. The dissertation is conceptualized as a snapshot of an open and ongoing process; in fact, Phase 4 goes beyond demonstrating the hypothesis and answering the research questions of Chapter 1 but to forecasting the possible futures of this research approach.

1.1.1. - Hypothesis and Research Questions

The dissertation hypothesis is that CAP can be an open planning approach capable of integrating other forms of sectoral planning. The guiding principle is that CC is such an extensive, systemic phenomenon and so urgent that it requires a comprehensive rethinking of our environment.This means acting at a planning level from the global to the local, systematically transforming the Anthropocene paradigm. Therefore, the dissertation investigates specific forms of sectoral planning that regardless of climate change are questioning how to act to solve specific problems.

At the same time, however urgent Climate Action is, it finds significant obstacles in its systematic implementation. The reason for this, as presented in the Introduction Chapter, is that there is an inertia in the adoption of the CAP process related to economic resource scarcity, lack of subsidiarity and regulatory obligation, and lack of design vision.

These problems are common to all forms of the project, supporting the further hypothesis that the current project culture model has reached a stage of stagnation. Therefore, having a comprehensive coordination tool geared to respond to one of the greatest urgencies of our time is an opportunity to systematically rethink how our habitat will evolve.

The gaps recognized within the disciplines and practices of planning, the research track experiences, and the hypotheses formulated by each of the Research Papers (RPs) allow the identification of three main Research Questions (RQ). These interrogate different aspects of both CAP and the diffuse urgency of reorganizing the current planning paradigm.

The research questions that therefore underlie the dissertation are:

RQ 1.

Can Climate Adaptation Planning integrate, and support a reorganization of planning approaches? Through which tools can this integration take place?

RQ 2.

On the city-region scale, is it possible to recognize those obstacles that inhibit the achievement of sustainable growth and climate change adaptation goals?

RQ 3.

Can the Climate Adaptation Planning approach, provide a horizontal and coordinating response between sectoral planning approaches?

RQ 4.

What are the limitations of nowadays Climate Adaptation Planning tools from the perspective of implementing strategies and measures? How can they be overcome?

As mentioned, the research questions arise from a broad reflection based on the four RPs. These follow a similar structure as far as it has been possible to do within an evolving educational journey. Therefore, each of the papers makes explicit a set of specific RQs. Each of these aims to investigate a different aspect of the interaction between CAP and other forms of planning.

Land-Sea Interaction: Integrating Climate Adaptation Planning and Maritime Spatial Planning in the North Adriatic Basin

RP 1.

- How can climate change adaptation trigger and support a successful convergence between "Land and Urban" and "Sea and Maritime" planning approaches in an LSI context?
- How can terrestrial vulnerability assessments, marine and maritime knowledge frameworks converge to define a multisystemic vision of the territorial priorities?
- Does the result between the integration between MSP and CAP in an LSI context favour and generate trans-sectoral strategic action?
- Can the ongoing urban and regional planning processes be effectively enriched by the integration of the cognitive frameworks of CAP and MSP?

Toward a trans-regional vulnerability assessment for Alps. A methodological approach to Land Cover Changes over alpine landscapes, supporting Urban Adaptation

RP 2.

- How is it possible to coordinate Trans Regional Scenario Assessment For Snow and Ice Resources monitoring?
- Can this tool support Planning Adaptation Strategies To Climate Change?

RP 3.

Mapping climate multi-risk to plan Venice metropolitan and local area adaptation

- Is the metropolitan survey scale the more effective to support local and regional authorities in developing climate change adaptation strategies and measures implementation?
- Which survey techniques and methodologies are suitable to support a knowledge framework construction to support adaptation governance and integrated territorial management?
- Can local planning incorporate metropolitan-scale adaptation strategies? Can the same knowledge framework also support conscious local adaptation measures?
- Is it possible to effectively assess exposure and define risk? Which strategic role can this assessment play in the construction of efficient and effective climate change policies?
- How can (or should) adaptation process mitigate social inequalities and urban conflicts exacerbated by CC?

RP 4.

An innovative climate adaptation planning process: iDEAL project

- Is it possible to overcome administrative limitations and sectoralisations?
- Is it possible to reach a full legitimation engaging stakeholders in useful time?

1.1.2. - Researcher Positionality

The research presented in this dissertation deeply connects to my personal background, research experiences, and positions. The research is developed within the Doctoral School of the Università Iuav di Venezia and is part of the Interdisciplinary Track "Made in Italy in Architecture and Arts" of the doctoral program in Architecture, City, and Design. The Interdisciplinary Track is divided into three main thematic cores, promoting the combination, the exchange, and the cooperation between them, namely:

- Urban phenomena;
- Fashion;
- Representation.

The research belongs to the "Urban Phenomena" thematic core. It seems appropriate to report the full description of the "Made in Italy in Architecture and Arts" track and the dissertation thematic core.

"Made in Italy" does not currently bear a specific and fully defined meaning. An incisive reconsideration of the role of the Italian intellectual and manual production is necessary in order to face modern global challenges. This is the aim of the Ph.D. interdisciplinary track, which explores mainly the following fields: urban phenomena, fashion, and representation.

Research on urban phenomena needs a full update. The "Made in Italy" definition given by the studies on urban morphology, which is a peculiar characteristic of Italian architectural culture and tradition, has almost disappeared from the research in this field. Updating and adapting the analysis of urban phenomena to contemporary global scenarios is possible and will be certainly fruitful.

Culture del progetto del Made in Italy, doctoral track abstract

While the Ph.D. school has fueled the research from an academic and theoretical perspective, the competency and most of the research opportunities gathered over the 4 years of the Ph.D. program came from the ongoing collaboration with the Planning and Climate Change Lab (PCCL). The opportunity to work with this ambitious group of young researchers and open-minded academics-deeply and adequately thanked in the Acknowledgements chapter-has been the driving force behind my curiosity and the greatest support in times of uncertainty.

PCCL was founded in 2010 and is co-founder of the Earth and Polis CLuster (EPiC) project developed in collaboration with Fondazione Eni Enrico Mattei (FEEM). Collaborating with them allowed me to technically address urban planning issues that were unimaginable for my architectural background. In particular, we tackled disparate topic as:

- Territorial Development and Strategic Planning;
- Environmental and urban planning;
- Environmental and territorial protection;
- Communication and public engagement;
- Measures and processes of adaptation and mitigation;
- Environmental assessment and monitoring;
- Risk analysis and assessment;
- Consulting and decision support.

A partial outcome of these experiences is the four papers that form the backbone of this dissertation.

Another aspect that is worth presenting to frame Research Positionality, is the research activity carried out on the European Community's competitive funding programs.

Two cases, in particular, shaped my perspective as a researcher and citizen and they both belong to the Interreg program between Italy, Slovenia, and Croatia, the projects: SECAP - Supporting Energy and Climate Adaptation Policies and DEcision support for Adaptation pLan - iDEAL.

In my double-fold role as a researcher at the PCCL and Ph.D. Student, I have been exposed to different approaches, whether theoretically focused or empirically-focused, aimed at redefining the present planning approach. Through these exposures, I have observed first-hand how important cooperation, networking, and sharing a common vision are and how important the case study of the Adriatic region and the reduction of climate change effects are to me.

Personally, I have always deeply cared about the environment in which I grew up, culturally permeated by the feeling of a Mediterraneanness in a balance between heritage and environment. As a Venetian architect and urban planner, this principle is part of the natural way I see the world and being able to protect it through the design process is an ongoing need. The four research papers that form this dissertation's basis, therefore, have a single thread, weaving together two red wires: my experience in research and my connection to this small part of the Mediterranean case study.
For much of the applied research presented in this thesis, I have chosen to use the term "we" instead of "I" when describing methods and results. One reason for this choice is that I received formal training in scientific writing, where the norm is to write in the third person. But I also chose to use this voice to acknowledge my colleagues, mentors, and friends who advised me during this process and helped bring this research to its final form.

1.1.3. - Format of the Dissertation

The typology of the dissertation is the so-called collection of papers. It funds on four papers published in international peer-reviewed journals focusing on issues related to Climate Adaptation Planning. The papers were published during the doctoral course, in collaboration with other authors, investigating the interactions between CAP and other approaches to Planning. The review of the bibliography, some evidence from the case study analysis, and the research questions arose

within the research activities related to the writing of the papers.
Some elements, presented within the Introduction Chapter, are borrowed from the research work performed within the Interreg (Italy-Slovenia) project SECAP - Supporting energy and climate adaptation policies. The dissertation adopts a structure divided into three main sections:

Chapter 1

Introduction is dedicated to the presentation of the theoretical framework to which the papers are interconnected and the structure of the dissertation.

Chapters 2, 3, 4, and 5

Present the four papers, respecting the structure with which they were peer-reviewed and published by the editors. Each paper addresses a different aspect of the interaction between CAP and other forms of planning. We found it incredibly relevant to be able to suggest how CAP can be an opportunity for an overall rethinking of the planning paradigm. The papers present, separately, a literature overview for each of the planning approaches Maritime Spatial Planning (MSP), Alpine Space Planning (ASP), Metropolitan Multi-Risk Planning (MMP), and Resilience Decision Planning (RDP).

Chapter 6

Conclusions and Implications summarises the links between papers and research questions, opening opportunities for future research based on CAP and other planning approaches. The ambition of the thesis is to extend the approach applied to the Northern Adriatic case study to the entire Mediterranean.

Section 2 - Background and Conceptual Framework

1.2.

The Background section presents the conceptual and disciplinary framework of the dissertation. The chapter is organized into two subsections:

- *1.2.1. - European Climate Action Framework;*

Is dedicated to presenting what is the state of the art of climate action in Europe and which are the main intervention programs.

- *1.2.2. - Climate Adaptation Planning (CAP) Examples of an open approach;*

Presents the core of the thesis hypothesis, i.e. the relationship between the CAP approach and other forms of planning.

The presentation of the thesis hypothesis requires to identify the limits of the disciplinary field of investigation. In this sense, the author has decided to identify two main scenarios: the first concerns the normative and strategic dimension of climate action at the European level and the second identifies how the so-called CAP interacts with other forms of spatial planning. The central theme, then described in detail in the following chapters, is that there are stratified spatial criticalities and limited resources to address them. The systems approach, therefore, is an opportunity to make the transition and in general the evolution of the Anthropocene toward more sustainable spatial use patterns more efficient and effective.

1.2.1. - European Climate Action Framework

The chapter has the task of presenting what is one of the newest disciplines in the field of land-use planning, namely that devoted to planning for land adaptation to the impacts of climate change. This section frames what the topic of climate change as it is transposed at both the national and community coordination levels. Reference is also made to the various tools-which, in contrast to the PPR, are less codified and still appear to be open to easier remodeling-which are geared toward supporting the transformation of territories toward patterns that are more resilient to the effects of a changing climate. Particular attention is given to what are complementary tools for climate action, dwelling on what is the difference between codified and normal adaptation of the planning armature and those that are exceptional tools for action. At the conclusion of this chapter, what is suggested, in accordance with the review of the relevant scientific literature, is a perspective from which to recognize the major limitations and opportunities in the adoption of climate action in relation to the design approaches for the territory.

- *1.2.1.1. - EU strategies related to climate change adaptation;*
- *1.2.1.1.1. - European climate action: from the Green Deal to the new Adaptation Strategy;*
- *1.2.1.1.2. - EU operational tools for adaptation;*

- *1.2.1.2. - The New Covenant of Mayors for Climate and Energy;*
- *1.2.1.2.1. - What is a PAESC/SECAP?;*
- *1.2.1.2.2. - The joining procedure and signatories' commitments;*

1.2.1.1. - EU strategies related to climate change adaptation.

1.2.1.1.1. - European climate action: from the Green Deal to the new Adaptation Strategy

In combating climate change, the EU is committed to implementing ambitious policies at the national level and fostering close cooperation with international partners. Since adapting to climate change means adjusting to both current and projected future impacts, it is important to develop a long-term vision and coordination between different scales of action; in this sense, the EU articulates its action on three levels:

- Ensure that all policies and actions increase Europe's resilience to the impacts of climate change;
- Support national, regional and local authorities, as well as private sector partners, to adapt to climate change;
- Globally, supporting cross-border climate resilience and preparedness through increased international finance and encouraging more meaningful adaptation efforts[1].

Since the first lines of action for climate change adaptation outlined in the 2007 Green Paper-or Green Paper-the role of the European Union has been to coordinate the actions of different states through an integrated approach that would enable adaptation goals to be achieved in a coherent, flexible and participatory manner. In this sense, the EU was committed to providing a long-term vision through strategies geared toward ensuring coherence between different sectors and levels of government so that adaptation measures are taken in time and are effective[2].

To date, Europe is continuing in this direction, and to overcome the challenges posed by both climate change and environmental degradation, it has equipped itself with a new growth strategy aimed at transforming it into a just and prosperous society with a modern, resource-efficient and competitive economy. This is the European Green Deal, published in Brussels on December 11, 2019, which is an integral part of the Commission's strategy to implement the 2030 Agenda and the United Nations Sustainable Development Goals (SDGs). It consists of a package of measures that not only focus on substantial reductions in greenhouse gas emissions but also cover investments in research, innovation, and action to preserve Europe's natural environment. Climate action is at the heart of the Green Deal, which advocates a climate-neutral Europe by 2050 and in which economic growth will be decoupled from resource use[3].

[1] *Adaptation to climate change at the European level: https://ec.europa.eu/clima/policies/adaptation_it.*

[2] *European Commission (2009), White paper - Adapting to climate change: towards a European framework for action (Commission Publication No. COM/2009/0147 final).*

[3] *Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - The European Green Deal, COM/2019/640 final, Brussels, 11.12.2019 (https://eur-lex.europa.eu/legal-content/IT/T/?uri=CELEX%3A52019DC0640&qid=1615902543719).*

The plan to achieve climate neutrality is set out within the EU Adaptation Strategy, the European Climate Change Adaptation Strategy, adopted by the Commission on Feb. 24, 2021. The importance of adaptation is increasingly recognized globally-despite multiple reports highlighting the lack of preparedness[4] - and the resulting solutions appear worthy of pursuit regardless of the ultimate climate pathway, as they result in a range of benefits, such as decreasing future human, natural and material losses, generating economic benefits by reducing risks, increasing productivity and stimulating innovation, and generating social, environmental and cultural benefits[5].
The strategy has four main objectives:

- Making adaptation more:
  - intelligent;
  - quick;
  - systematic.
- Intensify international action on climate change adaptation.

As climate change manifests itself through a large number of hazards and with impacts affecting almost all sectors, a broad knowledge base is needed in order to make interventions more effective. Adaptation actions must, therefore, be supported by robust data and risk assessment tools that are accessible to all. To achieve this, the strategy proposes to push the frontiers of adaptation knowledge so that more and better quality data are collected that are useful in increasing understanding of the link between climate risks and socioeconomic vulnerabilities and inequalities. The effects of climate change have already been widely manifested, so there is an urgent need to adapt more rapidly and comprehensively. For example, in Europe in the first decade of the 21st century, from 2002 to 2011, there was an increase in average temperature of 1.3 °C above the pre-industrial level, making it the warmest decade on record. At the same time, precipitation has decreased in southern Europe but increased in northern and northwestern Europe, leading to increasingly intense and frequent

[4] See Adaptation Gap Report 2020 and Global Commission on Adaptation reports Adapt Now and State and trends in adaptation 2020.

[5] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Shaping a Climate Resilient Europe - The EU's New Strategy for Adaptation to Climate Change, COM/2021/82 final, Brussels, 24.2.2021 (https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX%3A52021DC0082&qid=.

droughts and a decrease in the availability of water resources for agriculture in the south. Generally speaking, the types of climate hazards that occur on European territory are as follows: heat waves, extreme cold, intense precipitation, floods, rising mean sea level, droughts, storms, landslides, and forest fires[6]. In addition, climate change will have impacts at all levels of society and in all sectors of the economy; therefore, adaptation actions must also be systematic. As such, the Commission will support the further development and implementation of adaptation strategies and plans at all levels of governance with three cross-cutting priorities:

- The integration of adaptation into macro financial policy;
- Nature-based solutions for adaptation;
- Local adaptation action.

Increased support will also be given to transnational climate resilience and preparedness through the provision of resources, prioritizing action and increasing effectiveness, international finance, and through global engagement and exchanges on adaptation. In fact, the proposal commits the EU and member states to steady progress to boost adaptive capacity, strengthen resilience and reduce vulnerability to climate change. Solidarity among member states is, therefore, essential to achieving resilience in a fair and equitable manner, not least because many of the effects of climate change have a strong transboundary (as in the case of the Arctic region, macroregions or river basins) or international dimension[7].

1.2.1.1.2. - EU operational tools for adaptation

Among the instruments promoted by the European Union in order to pursue adaptation goals that can be shared among different levels of governance is the EU Covenant of Mayors for Climate and Energy. This is a voluntary-based tool launched in 2008 that brings together thousands of local governments committed to implementing EU

[6] *Neves A; Blondel L; Brand K; Hendel Blackford S; Rivas Calvete S; Iancu A; Melica G; Koffi Lefeivre B; Zancanella P; Kona A. The Covenant of Mayors for Climate and Energy Reporting Guidelines; EUR 28160 EN; doi:10.2790/586693.*

[7] *Eu Adaptation Strategy: https://ec.europa.eu/clima/policies/adaptation/what_en.*

climate and energy goals. The initiative has proposed a bottom-up approach with multilevel governance and cooperation and climate policy driven by the different territorial contexts, which has been quite successful in recent years, with 61 countries involved and more than 10 thousand signatories. The latter share a vision for 2050: to accelerate the decarbonization of their territories, strengthening their capacity to adapt to the inevitable impacts of climate change and enabling their citizens to benefit from secure, sustainable and affordable energy. These goals are achievable through the adoption of concrete long-term measures that provide an environmentally, socially and economically stable framework with a view to building more sustainable, attractive, livable, resilient and energy-efficient territories. The signatory cities pledge to support the implementation of the EU target of a 40 percent reduction in greenhouse gases by 2030[8], and the adoption of a common approach to address climate change mitigation and adaptation. In order to translate their political commitment into practical measures and projects, the Covenant Signatories commit to submit, within two years from the date of the local council decision, a Sustainable Energy and Climate Action Plan (SESCAP) outlining the key actions they intend to undertake. The plan will contain a Baseline Emissions Inventory (BEI) to monitor mitigation actions and Climate Vulnerability and Risk Assessment (RVA). The adaptation strategy can be part of the PAESC or be developed and integrated into a separate planning document. This political commitment marks the beginning of a long-term process in which cities are committed to reporting annually on the progress of their plans. In the graph below (Figure 2) you can see the increase in the number of signatories over time in mitigation and adaptation commitments, which, to date, correspond to 10,537 and 3,684 respectively[9].

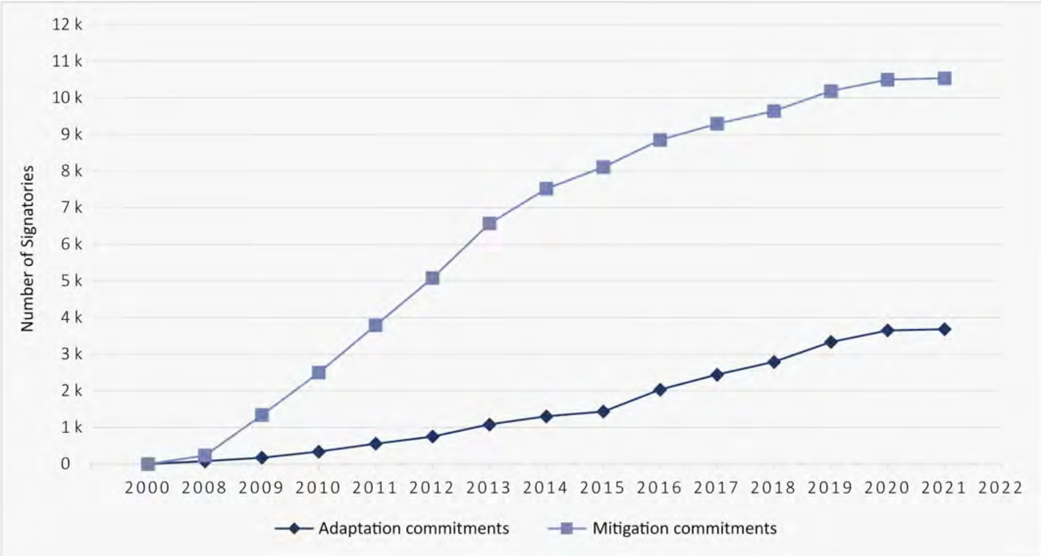
In this second graph (Figure 3), on the other hand, we see the presentation of action plans over time, which to date total 6,788 action plans and 3,371 monitoring reports, with a total of 4,604 adaptation actions distributed across sectors as follows (Figure 4). As can be seen from the graph, the sector most affected by actions is water, at

[8] With the 2030 Climate Goals Plan, the Commission is proposing that the EU be more ambitious and move the target to reduce greenhouse gas emissions from the previous 40 percent to 55 percent below 1990 levels.

[9] Convenant of Mayors: https://www.covenantofmayors.eu/en/.

Figure 2 - Active signatories over time. Source: reprocessed from Covenant of Mayors in Figures (https://www.pattodeisindaci.eu/about-it/l-iniziativa/il-patto-in-cifre.html). Site accessed on 03/24/2021.

Figure 3 - Presentation of action plans over time. Source: reprocessed from Covenant of Mayors in Figures (https://www.pattodeisindaci.eu/about-it/l-iniziativa/il-patto-in-cifre.html). Site accessed on 03/24/2021.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Number of Signatories
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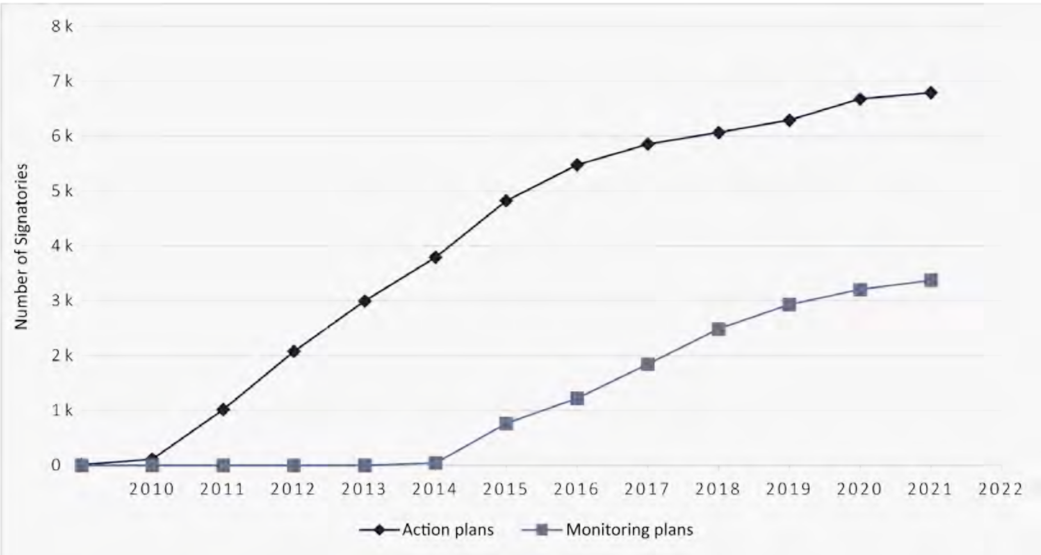
Adaptation commitments
Mitigation commitments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Number of Signatories
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Action plans
Monitoring plans

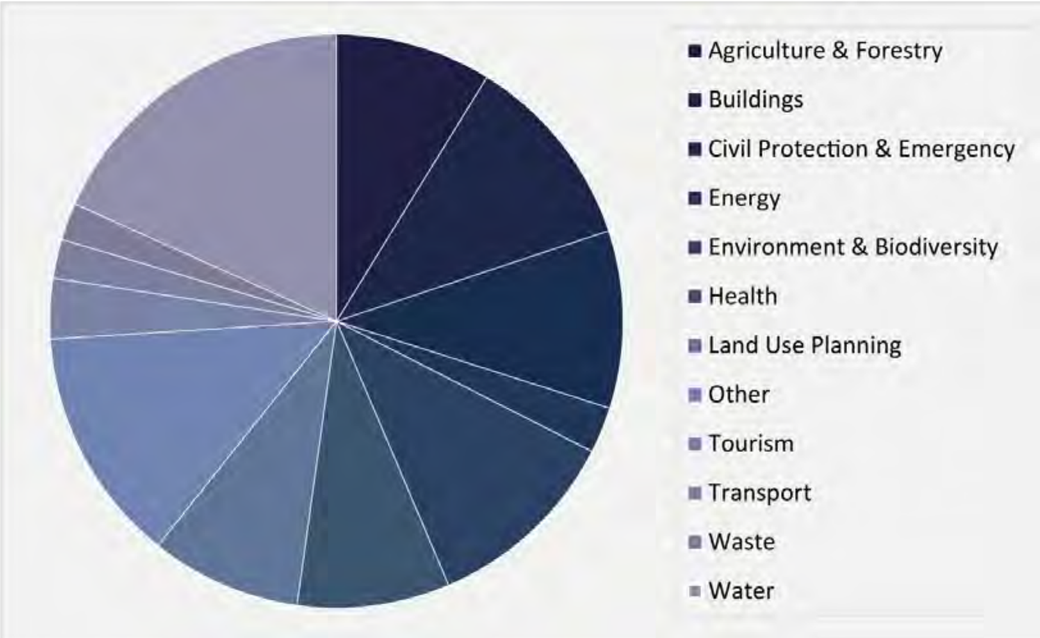


Figure 4 - Adaptation actions by sector. Source: reprocessed from Covenant of Mayors in Figures (https://www.pattodeisindaci.eu/about-it/l-iniziativa/il-patto-in-cifre.html). Site accessed on 03/24/2021.

18.3 percent, while those given less attention are waste, transport and energy, at 2.1 percent, 2.2 percent and 2.6 percent, respectively.

Given the need to conduct assessments on information and data that are reliable in order to outline appropriate and effective solutions, the EU has proposed the creation of a shared knowledge base across states through the creation of a database on climate impacts, vulnerability and good adaptation practices. This is an "integrated and shared environmental information system" through which knowledge can be exchanged on both impacts and socio-economic aspects and the costs and benefits of proposed adaptation solutions (EC, 2009). In this regard, from a partnership between the European Commission and the European Environment Agency (EEA), the European Climate Adaptation Platform, named Climate-ADAPT[10], was created in 2012 to overcome the lack of a consistent knowledge base on adaptation in Europe. Thus, the platform presents itself as an access

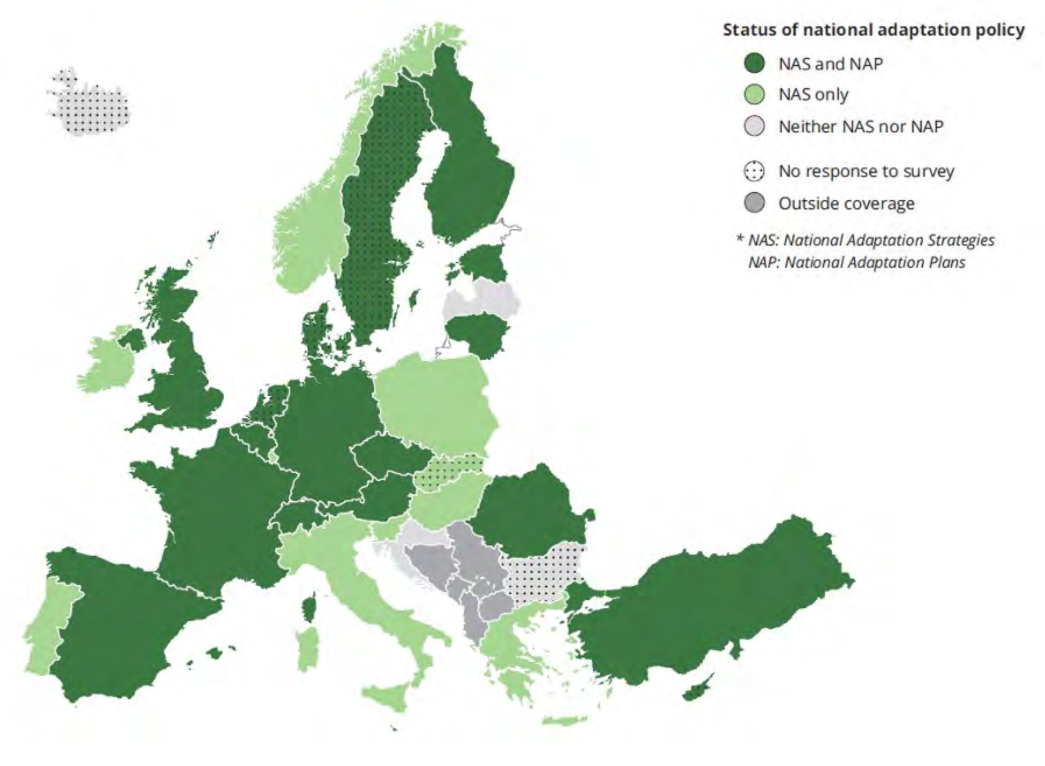
[10] *Climate-ADAPT: https://climate-adapt.eea.europa.eu/.*

point to multiple sources of information with the intention of helping member states share data to support better-informed decision-making on adaptation. In this sense, Climate-ADAPT aims not only to assist users in collecting this type of information but also to support decision-making on adaptation in Europe at all levels of governance and for all stages of the adaptation policy cycle, thereby fostering a greater level of coordination between sectors and institutional levels[11].

Nearly all European countries have published a national adaptation strategy (NAS), with the exception of Bulgaria, Croatia, Iceland,

[11] *Ibid.*

Figure 5 - Status of national policies on adaptation in Europe. Source: National climate change vulnerability and risk assessments in Europe, 2018.



Latvia and Liechtenstein, while a national adaptation plan (NAP) has been adopted by 17 countries[12], as shown in the map below (Figure 5).

1.2.1.2. - The New Covenant of Mayors for Climate and Energy

Providing a green and just recovery to the crisis due to COVID-19, creating strong and equitable economies that serve everyone, and reducing greenhouse gas emissions quickly enough to limit global warming to the Paris Agreement's 1.5°C target are actions that need to be implemented in a complementary way in order to prevent a catastrophic crisis.

The Covenant of Mayors (Covenant of Mayors), launched in 2008 in Europe with the ambition of bringing together local governments voluntarily committed to meeting and exceeding EU climate and energy targets, fits perfectly into this context. The initiative has, not only introduced for the first time a bottom-up approach to tackling climate and energy action, but has quickly gone far beyond expectations.

To date, it is the largest movement, on a global scale, of cities for climate and energy action and brings together more than 7,000 local and regional authorities in 57 countries voluntarily committed to implementing EU climate and energy goals.

In June 2016, the Covenant of Mayors entered an important new phase in its history when it chose to join forces with another initiative, the Compact of Mayors. The Compact of Mayors was a global coalition of mayors and city officials pledging to reduce local greenhouse gas emissions, improve resilience to climate change, and monitor their progress in a transparent manner. The Covenant was launched in September 2014 by UN Secretary-General Ban Ki-moon and his Special Envoy for Cities and Climate Change, Michael R. Bloomberg. The Covenant was activated under the leadership of the global urban networks - C40 Cities Climate Leadership Group (C40), ICLEI - Local Governments for Sustainability (ICLEI), and United Cities and Local Governments (UCLG) - and with the support of

[12] *Fussel, H. M., Lourenco, T. C., Hilden, M., Leitner, M., Marx, A., & Prutsch, A. (2018). National climate change vulnerability and risk assessments in Europe. Copenhagen, Denmark: European Environment Agency.*

UN-Habitat, the main UN agency for urban issues.
The resulting "Global Covenant of Mayors for Climate & Energy" is the largest movement of local governments committed to exceeding their national climate and energy targets.
Fully in line with the United Nations Sustainable Development Goals and climate justice principles, the Global Covenant of Mayors addresses three key issues: climate change mitigation, adaptation to the adverse effects of climate change, and universal access to safe, clean and affordable energy, and it does so by promoting the tool of the PAESC, Climate and Sustainable Energy Action Plan.

1.2.1.2.1. - What is a PAESC/SECAP?

The PAESC, Sustainable Climate and Energy Action Plan, is an instrument endorsed by the Global Covenant of Mayors for Climate & Energy with the support of the European Commission's Joint Research Center (JRC), which, as mentioned above, translates the political commitment made by local governments into practice and is based on comprehensive and integrated climate and energy planning in which local stakeholders can play an active role.
Local governments agree to join the Covenant and within the next two years after joining, to submit the PAESC to accelerate the decarbonization of their territories, strengthen their ability to adapt to climate change, ensure citizens' access to safe, sustainable and affordable energy, and reduce CO_2 emissions by at least 40 percent by 2030.
To do this, they must include in the PAESC strategy policies for mitigation (reducing CO_2 emissions to limit the increase in the Earth's average temperature) and those for adaptation (increasing the resilience of territories and communities to climate change that is already occurring), i.e., integrating the Covenant of Mayors with Mayors Adapt.
Given the enormous diversity of local governments that sign the Covenant, the PAESC is a very useful tool that enables all signatories,

indiscriminately:

- To have a standard communication framework;
- To collect and analyze data in a systematic and structured way, serving as the basis for good climate and energy resource management and monitoring of implementation progress;
- To set achievable and measurable goals for land development through the development and monitoring of the PAESC;
- to inspire and facilitate inter-agency exchanges and create innovative opportunities for international relationship building and experience exchange;
- To give high visibility to individual actions;
- To demonstrate the concrete impact exerted by their actions in the field
- To see their mitigation and adaptation efforts recognized and given international visibility;
- To contribute to the European energy and climate strategy;
- To improve access to financial opportunities for energy and climate adaptation projects;
- To benefit from training opportunities through regular provision of events, twinning, webinars, and hands-on support (helpdesk), information materials, etc.

1.2.1.2.2. - The joining procedure and signatories' commitments

In order to join the Global Covenant of Mayors for Climate & Energy, local governments commit to take action to achieve the goals already set forth, translating their political commitment into concrete activities. From the moment a local government signs the Covenant of Mayors and becomes a "signatory," it commits to:

- Draw up a Baseline Emissions Inventory and a Climate Change Risk and Vulnerability Assessment;

- Develop, within two years from the date of the local council's accession, a Sustainable Energy and Climate Action Plan (PAESC) outlining the main actions that local authorities plan to take;
- Publish periodically-every 2 years after the submission of the PAESC--Implementation Reports indicating the status of action plan implementation and intermediate results;
- Promote activities and involve citizens/stakeholders, including organizing local Energy Days;
- Spread the message of the Covenant of Mayors, particularly by urging other local governments to join and contribute to key thematic events and workshops.

The signatories' formal political commitment must be translated into concrete measures and projects. As signatories, municipalities agree to send reports and be monitored on the implementation of the EAPESC. They also accept the termination of their entity's local commitment to the Covenant in case of non-compliance. The European Commission created and funded the Covenant of Mayors Office (CoMO), which assists Covenant signatories by answering their questions through the Helpdesk and promoting their local actions through the Media desk. The CoMO also coordinates work with third parties and negotiates support from relevant actors. The European Commission's Joint Research Center (JRC) works closely with the CoMO to provide clear guidelines and technical templates to assist Administrations in their commitments and monitor implementation and results.
Following the guidelines proposed by the Global Covenant of Mayors for Climate & Energy with the support of the European Commission's Joint Research Center (JRC), drafted on the basis of the practical experiences conducted by municipalities and regions with the intention of conforming to the most widespread local methodologies, is the Sustainable Energy and Climate Action Plan (PAESC) form, which is the standard reporting framework for signatories to the covenant. The PAESC together with the monitoring

part allows signatories to collect and analyze data in a systematic and structured manner, serving as a basis for good management of climate and energy resources and for monitoring progress in implementation. Thus, the intent is to offer signatories guidelines that cover all stages of the communication process through a tool that can be easily consulted by all.

For a PAESC to be approved there are eligibility requirements that are checked by the CRC to ensure the credibility and reliability of the entire Covenant of Mayors initiative. Specifically, the minimum eligibility requirements for PAESCs are:

- The action plan must be approved by the city council or equivalent body;
- The action plan must clearly specify the Covenant's mitigation and adaptation commitments (i.e., at least 40 percent reduction in CO2 emissions by 2030);
- The action plan must be based on the results of a comprehensive Baseline Emission Inventory (BIE) and Climate Risk and Vulnerability Assessments;
- For mitigation, the action plan must also cover the key sectors (municipal, tertiary, residential and transportation);
- The Basic Emissions Inventory must cover at least three of the four key areas;
- Mitigation actions must cover at least two of the four key areas.

The form for drafting the climate and sustainable energy action plan (PAESC) that signatories to the Covenant of Mayors Climate and Energy Action Plan consists of 6 parts:

1. The strategy: devoted to the vision, the overall goal of reducing CO_2 emissions, targets for adaptation, allocation of human financial resources, and involvement of stakeholders and citizens. This part should contain a long-term vision that will inspire the municipality's future actions; the commitments the

municipality makes to achieve tangible and measurable goals; the specific administrative structures involved and charged with implementing the plan; the human resources allocated; and how stakeholders and citizens will be involved; the overall budget envisaged for the implementation of the plan; the ways in which it intends to monitor the implementation of its action plan; the ways in which it prioritizes among the different adaptation choices and the main outcomes; and the strategy it plans to put in place to cope with any extreme climate events.

2. Emission Inventories: dedicated to the amount of final energy consumption and related CO_2 emissions measured by energy carrier and sector during the reporting year. The session first involves completing the Basic Mission Inventory (BEI) and then provides the option of adding an Emission Monitoring Inventory (EMI). Inventories must specify:

a) The reference year,
b) The number of inhabitants in the year of the inventory,
c) Emission factors, which are the coefficients that quantify emissions for each unit of activity,
d) The emission reporting unit,
e) The methodological notes considered relevant to understanding the emissions inventory
f) Emissions inventory results including: final energy consumption, energy supply and CO_2.

3. The Mitigation Actions: devoted to the list of major mitigation actions intended to implement the overall strategy, also including timeline, allocation of responsibilities and budget allocation, and an estimate of effects. This part requires the following to be included: title, date of approval form the city council or statutory decision-making body which must be specified, web page where other information on the action plan can be found if applicable, "business-as-usual" scenario where applicable, methodological notes useful for understanding the

action plan, impact estimates of the actions in their own time horizon, main actions planned in the mitigation action plan over the medium and long term.

4. The Scoreboard: dedicated to understanding the areas where the adaptation cycle prepared by the signatories has made progress.

5. The risk and vulnerability analysis: dedicated to climate vulnerability, threats, impacts and assessments related to this. This section should include all risk and vulnerability assessments (RVAs) done by the local government and specifically:

   a) Climate change risk and vulnerability assessment,
   b) Climate hazards particularly relevant to the local government or region and the expected change in frequency and time period,
   c) Socioeconomic and physical environmental vulnerability of the local government,
   d) The expected impacts on the local government.

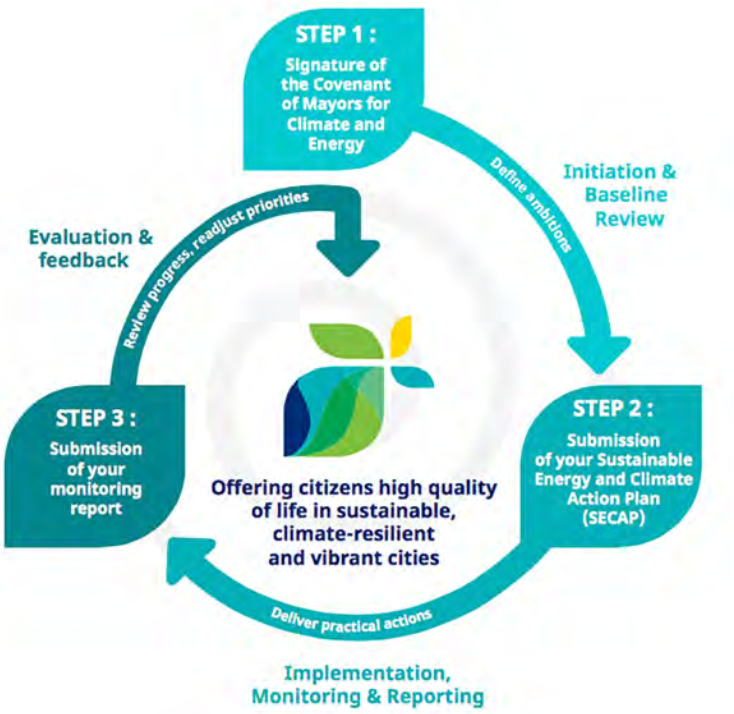
6. The Actions for Adaptation: devoted to the overall adaptation strategy and individual (key) actions including various relevant parameters (i.e. sector, time frame, stakeholders and costs).

Each of these parts must also contain within it indications on the monitoring of the status of implementation, which will then feed into the monitoring form that is to be submitted every two years from the date of submission of the EAPS and which is outlined in Section 2 of the "Covenant of Mayors Climate and Energy Guidelines for Monitoring Reporting" (European Commission, Joint Research Centre, Neves, A., Blondel, L., Hendel-Blackford, S., et al., Publications Office, 2017, https://data.europa.eu/doi/10.2790/01687). The objective of monitoring is to assess progress toward the goals set in the action plan strategy.

Monitoring is an integral part of every planning cycle that allows corrective measures to be planned.
For more specific technical questions about methodological requirements or questions regarding the JRC feedback reports, please contact:

- The CCR mitigation team at the following address: JRC-COM-TECHNICAL-HELPDESK@ec.europa.eu
- The CCR adaptation team at the following address: JRC-COM-ADAPT@ec.europa.eu

Figure 6 - The Covenant of Mayors "step-by-step" process taken from European Commission, Joint Research Centre, Neves, A., Blondel, L., Hendel-Blackford, S., et al, Covenant of Mayors Climate and Energy Guidelines for Monitoring Reporting, Publications Office, 2017, https://data.europa.eu/doi/10.2790/01687.



1.2.2. - Climate Adaptation Planning, examples of an open approach

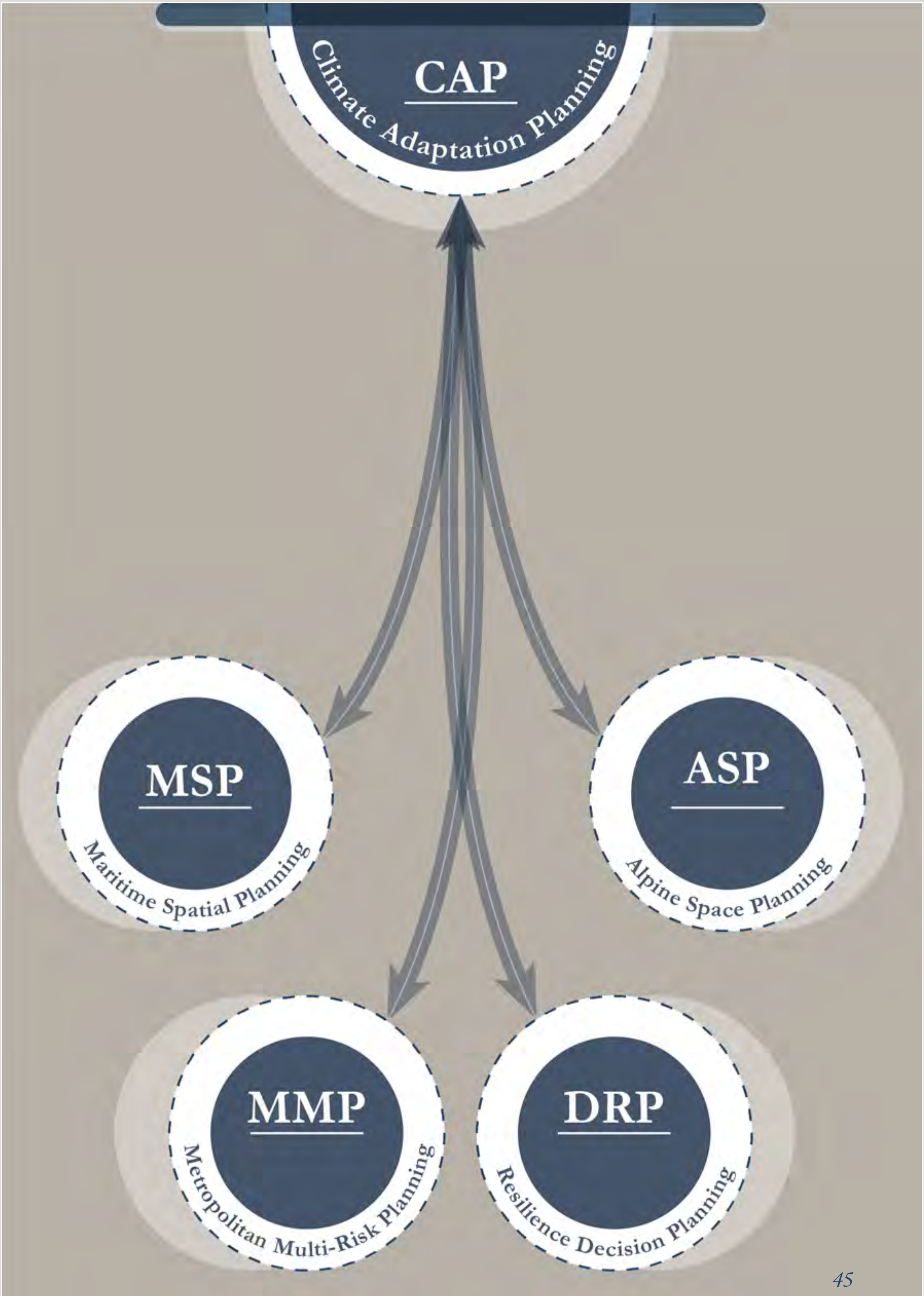
CAP framework stems from the need to develop an operative response to reduce CC impacts on territories(Baker et al., 2012; Preston et al., 2011). Therefore, CAP is a complementary process to Mitigation, which instead aims at reducing global warming-generating phenomena(Araos et al., 2016; Pietrapertosa et al., 2019). CAP represents a design approach.
Thus, it is a process that interacts with all the layers that characterize the space in which we live(Adger, 2003; Adger et al., 2009; Adger & Kelly, 1999a). Considering that design processes are usually based on three stages of operation, knowledge framework, strategic framework, and action, it is important to present what are the key principles that characterize CAP(Araos et al., 2016; Bowler et al., 2010; Hunt & Watkiss, 2011; Pelling, 2010).
Referring to the 2014 IPCC definitions, the theoretical frame is composed of 5 core concepts: sensitivity, adaptive capacity, vulnerability, exposure, and risk(Adger, 2006).
Each of these constitutes a specific layer for CAP and requires interacting operatively with heterogeneous stakeholders, decision-makers, and techniques of investigation and response(Adger & Kelly, 1999b; Brooks et al., 2005).
The goal is to understand where it is a priority to intervene and how effectively to do so(Few et al., 2007; Lister, 2001).
Figure 7 presents the relationship between CAP and other forms of sectoral planning. The dissertation briefly addresses and compares the interactions among themes that characterize Maritime Spatial Planning (MSP), Alpine Space Planning (ASP), Metropolitan Multi-Risk Planning (MMP), and Resilience Decision Planning (RDP).

The objective is to recognize possible convergences and relationships among issues by tracking the potential for convergence.

Figure 7 - Linking Climate Adaptation Planning and Sectoral Planning Approaches.

Based on the bibliographic review, partially presented in Section 1, and based on the research experience, the central requirements and issues which characterize CAP are:

- *New Spatial Knowledge;*
- *Large Resources;*
- *Public Commitment;*
- *Design & Planning vision;*
- *Transboundary Coordination;*


CAP
Climate Adaptation Planning
MSP
Maritime Spatial Planning
ASP
Alpine Space Planning
MMP
Metropolitan Multi-Risk Planning
DRP
Resilience Decision Planning

1.2.2.1. - CAP and Maritime Spatial Planning (MSP)

MSP is a disciplinary approach that seeks to answer a question as old as man's relationship with the sea: how to subdivide, know, and plan maritime space?(Couling & Hein, 2020)

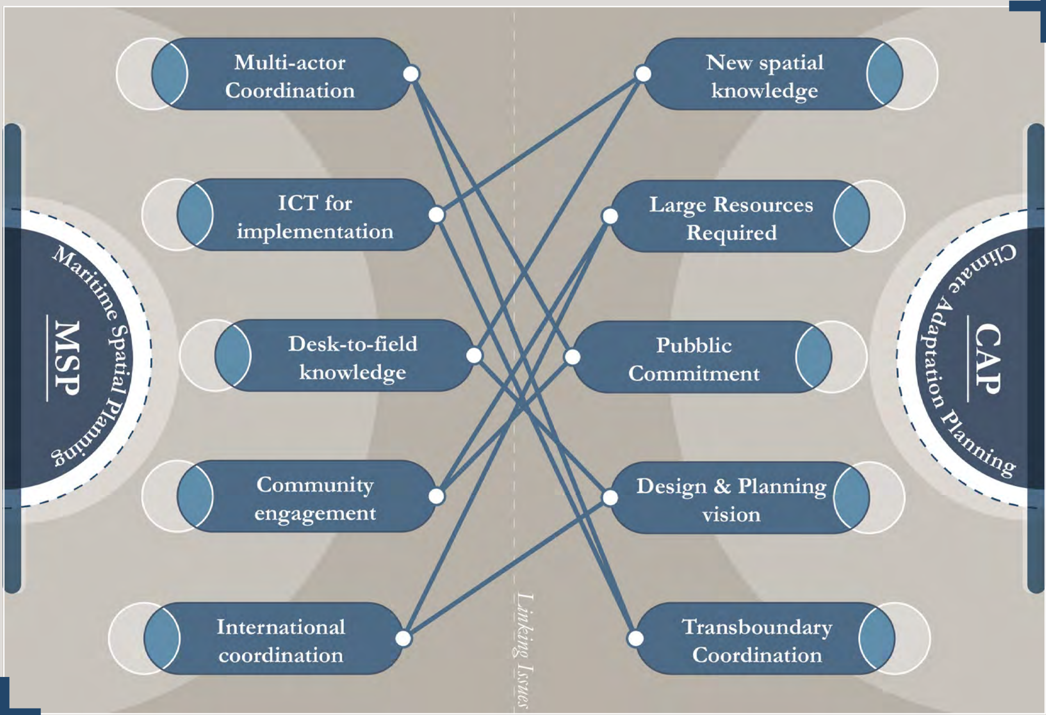
From this perspective, scientific communities and European and international coordinating organizations developed coordination protocols and strategies to avoid possible conflicts and safeguard the environment (Meiner, 2010; Suárez de Vivero & Rodríguez Mateos, 2012). MSP is characterized as CAP (Adamson et al., 2018), by different operative phases: knowledge, strategic, and action framework(Walsh, 2020).
At the same time, this approach founds on international, national, and regional coordination, up to the engagement of individual communities (Barbanti et al., 2015; Douvere & Ehler, 2011). From this perspective, MSP seeks to recognize the interactions with the marine environment and coastal systems through two parallel disciplines: integrated coastal zone management (ICZM) and Land-Sea Interaction (LSI)(Tubridy et al., 2022). Some of the main problems addressed are related to the evolution of coastal areas under a scenario of rising seas, scarcity of resources for local communities, and pollution of environmental resources through unsustainable urban practices (Carvalho & Coelho, 1998; Cooper & McKenna, 2008; Wong et al., 2014).
However, what emerges from the literature review and research experience is that there are structural problems related to the MSP approach and especially in relation to CC-related planning approaches(Frazão Santos et al., 2020).
What emerges from the literature review and research experience is that there are structural problems linked between MSP and CAP ones.
The central issues for MSP addressed in this dissertation are:

Figure 8 - Linking CAP & MSP issues.

The central issues for MSP addressed in this dissertation are:

- *Multi-actor Coordination;*
- *ICT for implementation;*
- *Desk-to-field knowledge;*
- *Community engagement;*
- *International coordination;*

Figure 8 presents the relationship between MSP and CAP. The dissertation briefly presents which are the interactions between the specific issues, argued within Chapter 2, based on RP 1: "Land-Sea Interaction: Integrating Climate Adaptation Planning and Maritime Spatial Planning in the North Adriatic Basin."



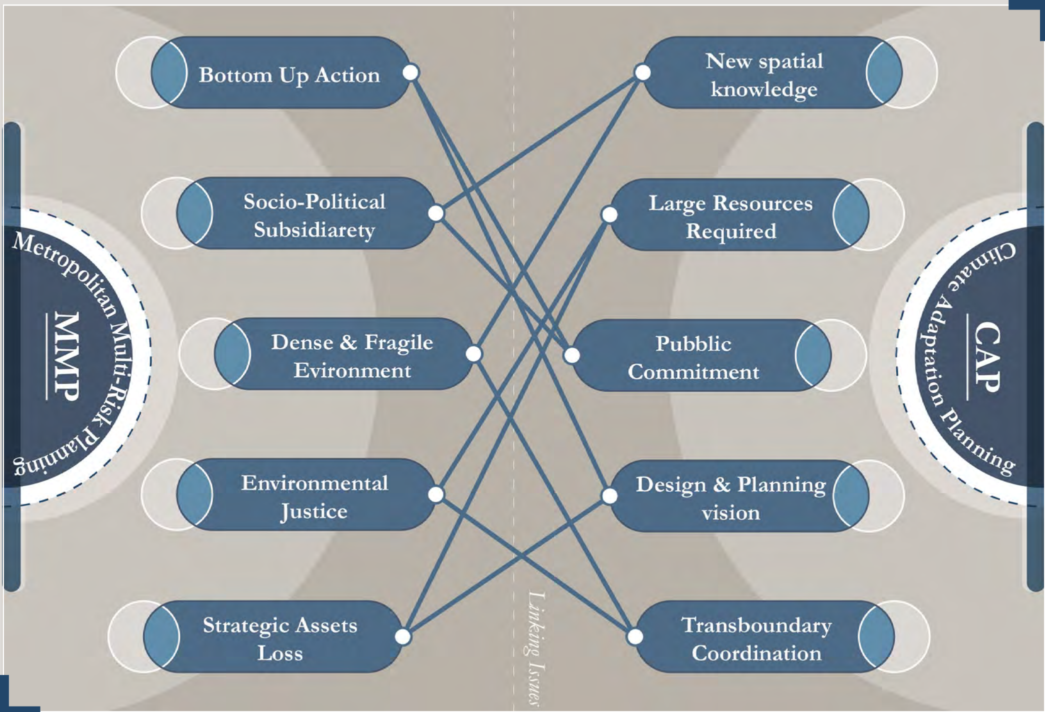
1.2.2.2. - CAP and Metropolitan Multi-Risk Planning (MMP)

MMP refers to a set of sectoral processes oriented to manage hazards for large anthropized systems(Aubrecht & Özceylan, 2013; Rosenzweig & Solecki, 2014; Zhu et al., 2007). Referring to both the Sendai framework and the IPCC prescriptions, several administrative regions implemented disaster prevention and risk reduction planning processes, as London, Zurich, Venice and most European cities(Torres & Doubrava, 2010). Also, these are planning processes characterized by a knowledge, strategic, and action framework(Viegas et al., 2013).
It is relevant to make a distinction between city, metropolis, and metropolitan area (Jacobs, 1993). In the context of this dissertation, the object of investigation is metropolitan regions (Revi et al., 2015). Namely, these territorial systems are characterized by a morphological continuity (concentration of inhabitants, buildings, and land use) such that they exceed the extent of a single administrative unit.
The difference between MMP and CAP is that the first manages, alters, and redesigns the status quo based on a linear prediction model for disaster reduction, thus reducing the exposure of vulnerable assets(Wilson et al., 2010).
The second requires a comprehensive rethinking of the planning paradigm, implementing more radical, widespread, and shared measures (including Nature-Based Solutions, green, grey, and blue infrastructures) (Galderisi & Limongi, 2021; Grothmann & Patt, 2005). What emerges from the literature review and research experience is that there are structural problems linked between MMP and CAP ones.
Figure 9 presents the relationship between MMP and CAP. The dissertation briefly presents which are the interactions between the specific issues, argued within Chapter 4, based on RP 3: " Mapping climate multi-risk to plan Venice metropolitan and local area adaptation".

The central issues for MMP addressed in this dissertation are:

- *Forecasting Complex Trends;*
- *Large territorial coordination;*
- *Economical resources;*
- *Conflicts Management;*
- *Interdisciplinary Collaboration;*

Figure 9 - Linking CAP & MMP issues.


Metropolitan Multi-Risk Planning
MMP
Bottom Up Action
Socio-Political Subsidiarety
Dense & Fragile Evironment
Environmental Justice
Strategic Assets Loss
Linking Issues
New spatial knowledge
Large Resources Required
Pubblic Commitment
Design & Planning vision
Transboundary Coordination
CAP
Climate Adaptation Planning

1.2.2.3. - CAP and Resilience Decision Planning (RDP)

RDP defines a set of protocols, agendas, and tools for achieving territorial resilience. In part, this process arose before the establishment of agendas such as the Sustainable Development Goals and the impoverishment of the resilience concept(Griggs et al., 2013; Lu et al., 2015; Sachs, 2012).

RDP originated from early attempts to implement ecology principles and environmental balance into local development policy agendas (Adger, 2000; Derissen et al., 2011). Nowadays, it is an integral part of local development programs and regional, national, and international coordination (Etinay et al., 2018; Grafakos et al., 2016; Ramirez-Rubio et al., 2019). However, it finds two main problems.

The first, is the lack of pragmatism in converting legitimate goals into operative actions, mainly because of the broadness of issues, lack of resources, and compulsoriness (Fitzgibbons & Mitchell, 2019a, 2019b).

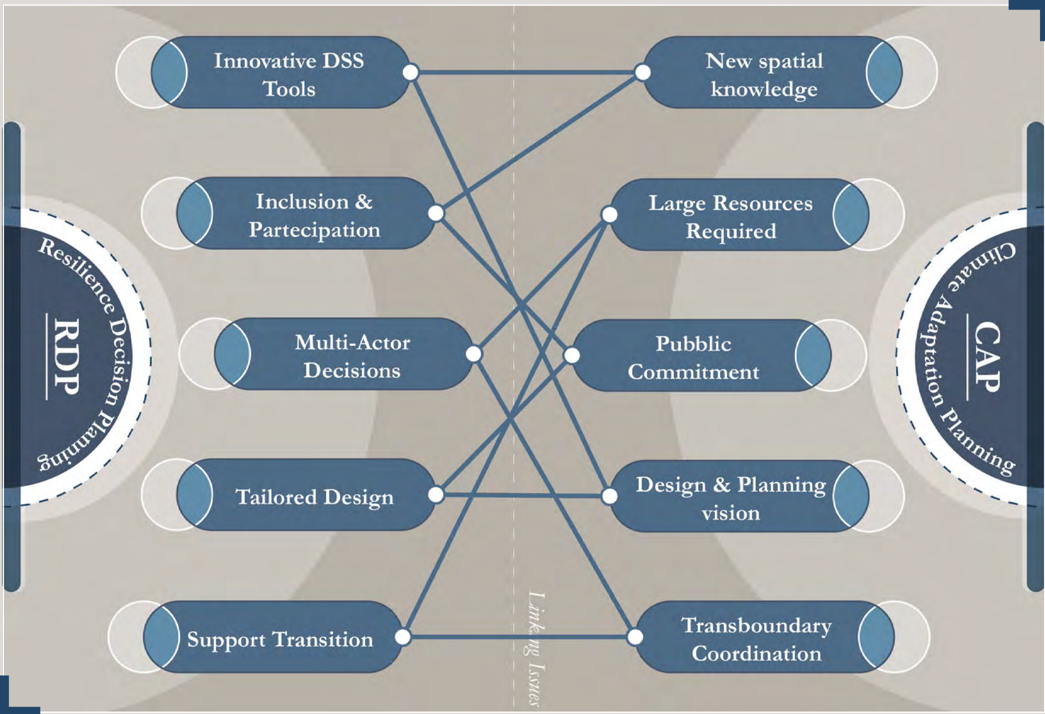
The second is that this form of planning with difficulties interacts with other forms of programming, often lacking the specific organization of a formal planning structure: knowledge, strategic, and action framework.(Fitzgibbons & Mitchell, 2021; Plum & Kaljee, 2016) Nevertheless, some territories launched operative programs to combine CAP technical action with RDP, legitimizing through an ordinary policy agenda some sectoral actions for adaptation and CC impacts management (Barzehkar et al., 2021; Leyerer et al., 2019; Pelling, 2010). What emerges from the literature review and research experience is that there are structural problems linked between RDP and CAP ones. The central issues for RDP addressed in this dissertation are:

Figure 10 presents the relationship between RDP and CAP. The dissertation briefly presents which are the interactions between the specific issues, argued within Chapter 5, based on RP 4: " An innovative climate adaptation planning process: iDEAL project".

The central issues for RDP addressed in this dissertation are:

- *Innovative DSS Tools;*
- *Inclusion & Partecipation;*
- *Multi-Actor Decisions;*
- *Tailored Design;*
- *Support Transition;*

Figure 10 - Linking CAP & RDP issues.



Resilience Decision Planning
RDP
Innovative DSS Tools
Inclusion & Partecipation
Multi-Actor Decisions
Tailored Design
Support Transition
Linking Issues
New spatial knowledge
Large Resources Required
Pubblic Commitment
Design & Planning vision
Transboundary Coordination
CAP
Climate Adaptation Planning

1.2.2.4. - CAP and Alpine Space Planning (ASP)

ASP is the set of approaches and techniques necessary for Alpine space management. Alpine space refers not only to European Alps but to the mountain environment in general. International coordinating bodies as IPCC and EUSLP (EUSALP, 2013; Teston & Bramanti, 2018), national states, and regions produced tools and programs for Alpine habitat management.

The goal is the environmental protection of these territorial systems, the natural resources, and the social-economic and cultural systems depending on them. The dangers affecting this environment connect to global warming and changes in the climate scenario(Beniston et al., 1997; Brunetti et al., 2009; Nogués-Bravo et al., 2007). At the same time, climate adaptation action implementation can support the management of impacts that affect mountain systems. Protecting water resources, forestry, and agriculture are currently managed drastically decrease the climate-altering gas emission framework (Huss et al., 2017; Immerzeel et al., 2020; Marty, 2008; Schmucki et al., 2017; Zemp et al., 2019). However, ASP has two main critical issues: the poor effectiveness of implemented actions linked to local CC impacts and the enormous economic and coordination effort to implement environmental protection actions. Territorial management tools develop from ordinary land management protocols and weather evolution scenarios.

These do not consider overlapping impacts such as glaciers and micro snowfields melting, droughts, forest fires, extreme weather phenomena, and changing precipitation regimes(Allamano et al., 2009; Brunetti et al., 2009; Huss & Farinotti, 2012; Korck et al., 2012; Lutz et al., 2014).

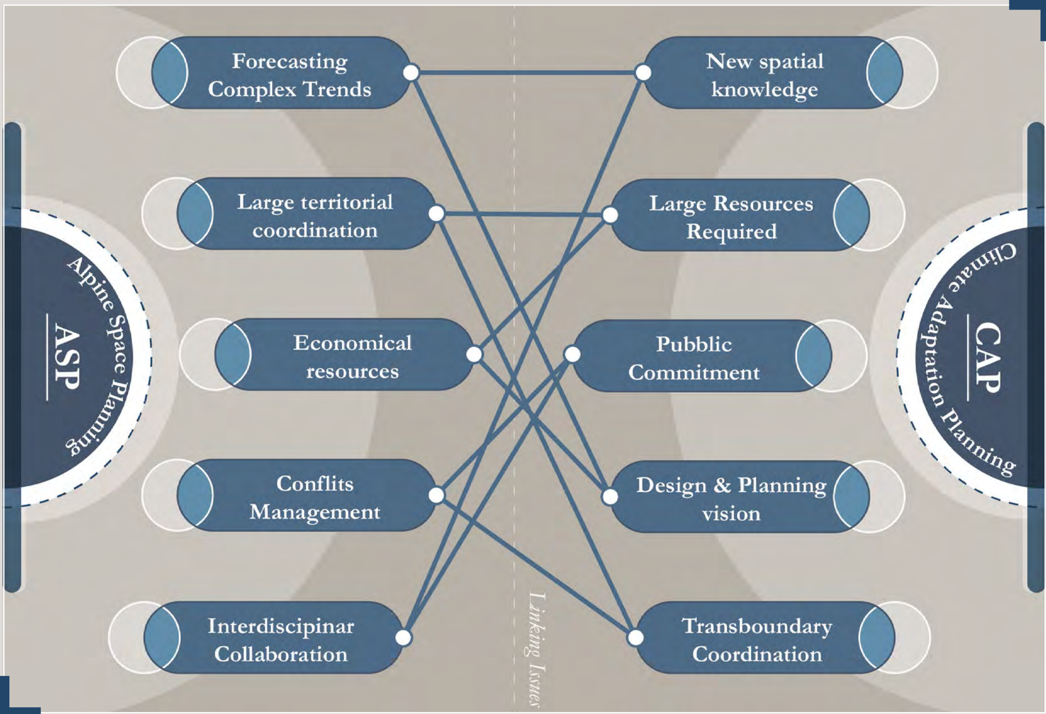
At the same time, economic systems based on mountain systems do not change their revenue expectations, making land-use increasingly expensive(Elsasser & Bürki, 2002; Macchiavelli & Andrea, 2009; Scott et al., 2003; Steiger & Mayer, 2008).

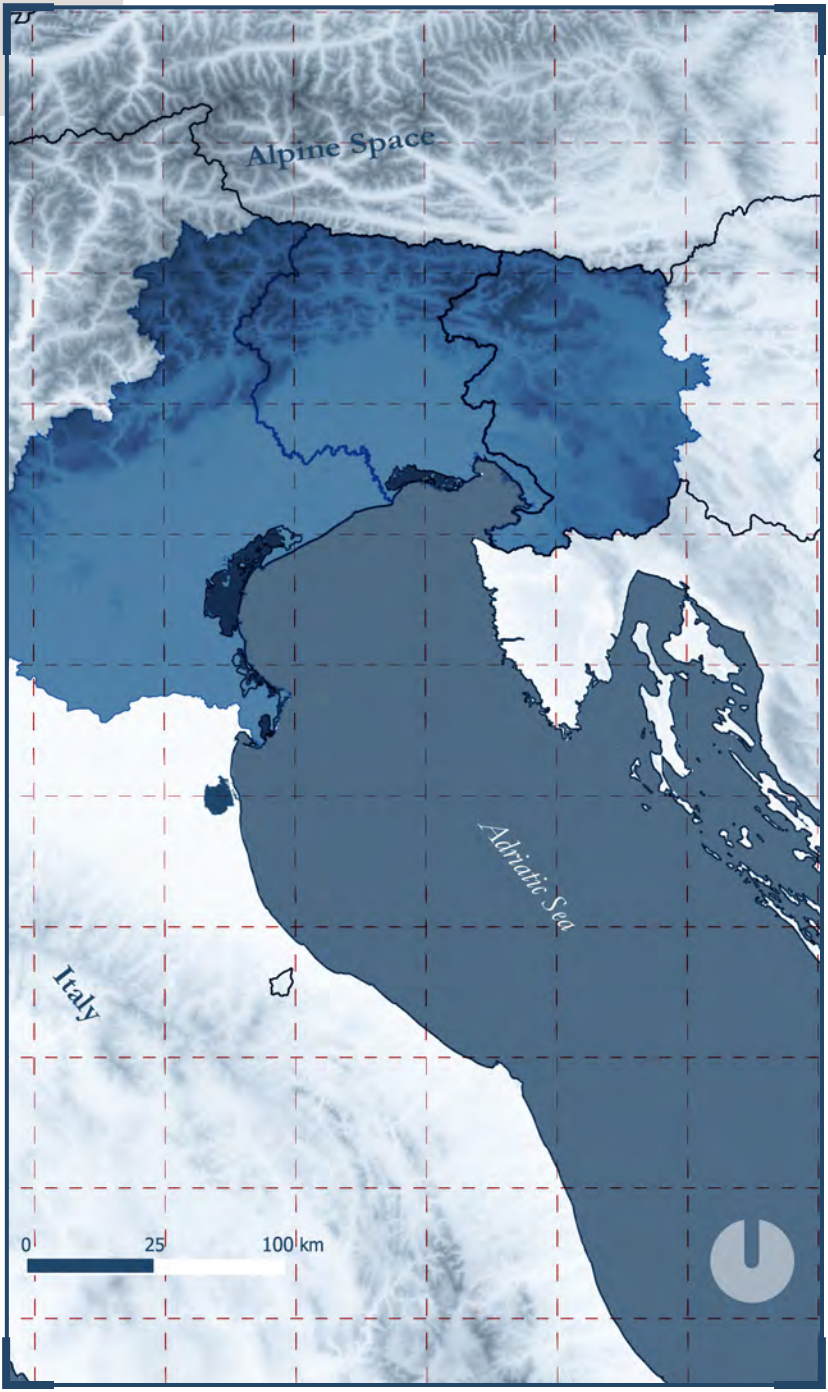
Figure 11 - Linking CAP & ASP issues.

What emerges from the literature review and research experience is that there are structural problems linked between ASP and CAP ones. The central issues for ASP addressed in this dissertation are:

- *Forecasting Complex Trends;*
- *Large territorial coordination;*
- *Economical resources;*
- *Conflicts Management;*
- *Interdisciplinary Collaboration;*

Figure 11 presents the relationship between ASP and CAP. The dissertation briefly presents which are the interactions between the specific issues, argued within Chapter 5, based on RP 2: " Toward a trans-regional vulnerability assessment for Alps. A methodological approach to Land Cover Changes over alpine landscapes, supporting Urban Adaptation".




Alpine Space
Adriatic Sea
Italy
0
25
100 km

Section 3 - The Case Study o
the North Adriatic Syste

Figure 12 - Mapping the Adriatic region.

1.3.

1.3.1. - Papers and Research Geography

The purpose of this Section is to present the case study of the North Adriatic System from three different and complementary perspectives. Namely.

- 1.3.1. Papers and Research Geography;
- 1.3.2. Local Policies towards adaptation;
- 1.3.3. Mapping Territorial Complexity and Climate Impacts;

Figure 12 presents the morphology of the Adriatic basin by connecting the spatial and administrative system analyzed in Section 3. Pursuing the hypothesis stated in Section 1 that this territory may be representative of some of the complexities present within the Mediterranean, Section 3 addresses different aspects of the case study. The first part recognizes which are the geographies of each of the four papers reported in Chapters 2, 3, 4, and 5. The second part analyzes which are the policies linked to Climate Action and CAP from a European to a local scale. The third section, on the other hand, constitutes the first step of CAP, which is the definition of the cognitive framework of vulnerability and risk related to CC impacts. Among the different case studies, or rather the different sea branches that make up the Mediterranean kaleidoscope, the Adriatic basin seems to be emblematic.
This portion of the Mediterranean, regarding its peculiar history, presents today's identity traits that can attest to how there is a subtle change, almost a stitching up of separation events imposed by history. The organization of the analysis aims to provide a replicable approach that can be extended to other Mediterranean contexts. However, for reasons of space and consistency of the research, it was not possible to emphasize the fundamental history of this area necessary to describe why some planning choices are courageous and an example for conflict territories.

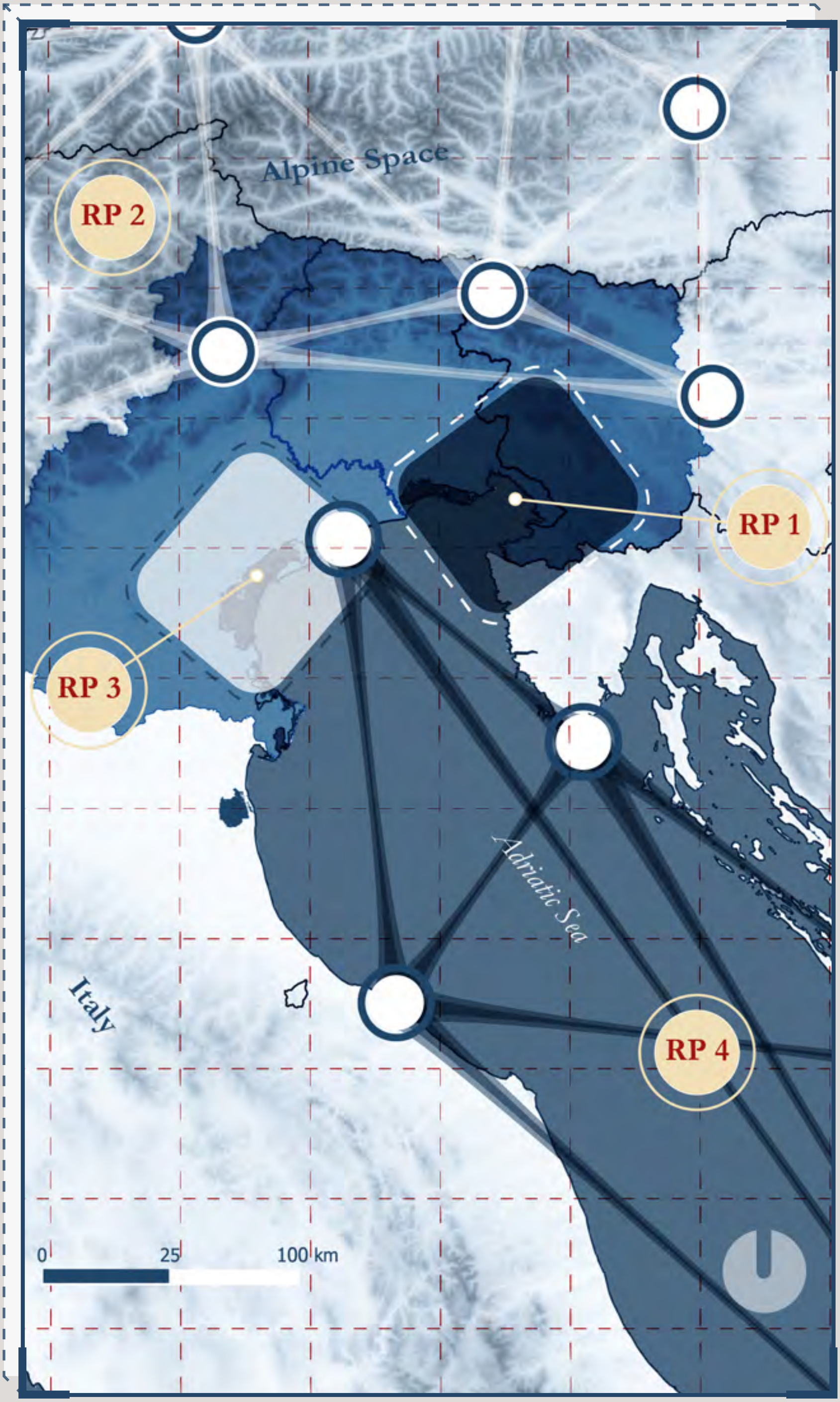
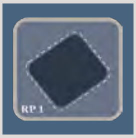

Alpine Space
RP 2
RP 1
RP 3
Adriatic Sea
Italy
RP 4
0
25
100 km

Figure 13 - Linking RPs and the Adriatic system.

Figure 13 presents the map of the North Adriatic system in link to each case study addressed by the Research Papers (RP) underlying the dissertation. Each takes a different approach to the territory and research; the diagrams show the abstract of these approaches.



RP 1 - addresses the Gulf of Trieste, the northernmost part of the Adriatic Sea. The unit of investigation is a transect for land-sea interactions analysis, considering the different analyzed features: morphology, economic context, and climate vulnerability.

RP 2 - is based on an analysis model by comparing different case studies. The objective is to monitor the Alpine system by conducting multiple surveys in different contexts and develop a quantitative and qualitative comparison. In this case, areas are evaluated according to socio-economic and morphological characteristics.

RP 3 - considers the administrative level of the Metropolitan City of Venice (CMVE). It contains 44 administrative units, of which a representative context was selected for both the morphological characterization and the population concentration and predisposition to climate vulnerability.

RP 4 - focuses on Adriatic Italian and Croatian coastal cities assessment. Here the analysis is carried out by comparing governance models and decision support tools based on local communities' perceptions of climate danger.

1.3.2. Local Policies towards adaptation

1.3.2.1. - Italian policies, strategies and plans to achieve the goals by 2030

National governments play the crucial role of linking priorities set by the European Union with local adaptation actions. In Italy, the National Strategy for Adaptation to Climate Change (SNACC) was approved in 2015, a document in which the main impacts to climate change were identified for a number of socio-economic and natural sectors and with the consequent proposal of actions for adaptation to them. In order to implement the strategy, the elaboration of the National Plan for Adaptation to Climate Change (PNACC) was initiated in May 2016, the first draft of which was presented in 2017 by the Euro-Mediterranean Center on Climate Change (CMCC) as technical-scientific support for the Ministry of the Environment and Protection of Land and Sea (MATTM) and was then submitted for public consultation; however, the document is still awaiting official adoption.
It is a strategic document that is not intended to have any prescriptive character but is intended to be an open tool that will be continuously updated with respect to what will result from its own implementation.

1.3.2.1.1. - National Climate Change Adaptation Strategy

The main objective of SNACC is to "develop a national vision on common pathways to address climate change by countering and mitigating its impacts."[13]. In this sense, the strategy "identifies actions and directions to minimize risks from climate change, protect the health well-being and assets of the population, preserve natural heritage, maintain or improve the resilience and adaptive capacity of natural, social and economic systems as well as take advantage of any opportunities that may arise with new climate conditions."
To achieve this goal, the strategy defines 5 strategic axes of action

[13] *MATTM (2015), National Strategy for Adaptation to Climate Change (SNACC).*

aimed at:

- Improve current knowledge about climate change and its impacts;
- Describe land vulnerability, adaptation options for all relevant natural systems and socio-economic sectors, and any associated opportunities;
- Promote participation and increase stakeholder awareness in the development of sectoral adaptation strategies and plans through a broad process of communication and dialogue, also with a view to integrating adaptation within sector policies more effectively;
- Support awareness and information on adaptation through widespread communication activities on the possible dangers, risks and opportunities from climate change;
- Specify the tools to be used to identify the best options for adaptation actions, also highlighting co-benefits.

The strategy reports the knowledge framework on the status of climate impacts and vulnerabilities of sectors, with a review on the main scientific evidence found in Italy; this is because the knowledge base is considered as the essential precondition for an appropriate climate adaptation strategy.

This is why it needs to be improved, involving the scientific community experienced in climate and impact assessments, in order to provide adequate decision support tools for the identification of priorities for action. Another point underpinning the strategy is the importance of multilevel governance, involving both central and local governments and public and private sector stakeholders. Participation is, therefore, seen as an added value in the adaptation process and can improve awareness and sharing of the actions that need to be taken[14].

[14] *Ibid.*

1.3.2.1.2. - National Climate Change Adaptation Plan

Differently, the overall objective of the PNACC is to provide a "tool to support national, regional, and local institutions in identifying and choosing the most effective actions in different climate areas in relation to the critical issues that most characterize them and in integrating adaptation criteria into existing procedures and instruments."[15]. This general objective is declined into four specific objectives:

1. To contain the vulnerability of natural, social and economic systems to the impacts of climate change;
2. Increase the adaptive capacity of the same;
3. Improve the exploitation of any opportunities;
4. Promote the coordination of actions at different levels.

In pursuit of these goals, the Plan proposes actions that can be most effective in adaptation, and also indicates the timelines for implementation and the relevant agencies and bodies for their implementation, so as to provide decision support based on scientifically rigorous evidence.

The Plan is structured in three parts (Figure 14):

1. Context analysis, climate scenarios, and climate vulnerability;
2. Adaptation actions;
3. Tools for participation, monitoring and evaluation.

Specifically, in the first part, the Plan aims "to define homogeneous climate macroregions and national homogeneous climate areas from the analysis of the present and future climate condition and their characterization and description in terms of risk propensity and impacts and vulnerability for the specific areas already defined as relevant to climate change in Italy within SNACC."[16].

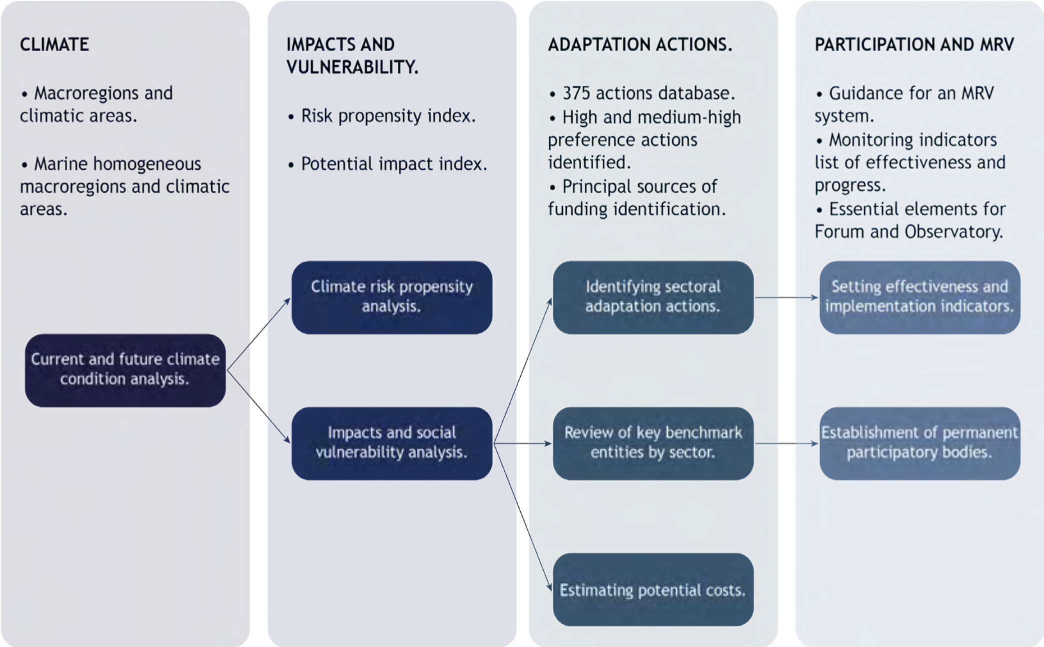
[15] *MATTM, CMCC (2017), National Climate Change Adaptation Plan (NACCP).*

[16] *Ibid.*

[17] *Ibid.*

Figure 14 - Representation of the structure of the document, its essential elements and main working steps. Source: reprocessed from PNACC, 2017.

Homogeneous climate areas are defined as "portions of the national territory that on the basis of the scenarios used are likely to be exposed to similar climatic variations by relating them to a present climatic condition."[17]. Homogeneous climate areas are, therefore, characterized by the same present climate condition and same future climate projection, and are the outcome of the overlap between homogeneous climate macroregions-having similar historical-climatic conditions-and an analysis of expected climate anomalies for the 21st century.
Beyond the methodological approach adopted for its drafting, the Plan recognizes for the development of an effective and shared



adaptation pathway the importance of creating a working group that is as interdisciplinary as possible, that is, that has within it a multiplicity of different skills and experiences in the areas relevant to adaptation and includes experts from different territorial institutions. The Plan, therefore, is proposed as a dynamic tool subject to periodic updates, strongly focused on the specific needs presented by the Italian territory and its parts.

1.3.2.1.3. - Synergies between the Strategy and the Adaptation Plan.

As seen in the previous chapters, in the Adaptation Strategy the strategic vision and principles that the administration intends to follow are defined. These will lead to the identification of adaptation options that will then be selected and transformed into priority actions, the concrete implementation of which will be promoted by the Plan. To guide this process, the development of a vision, that is, "an idea of the territory in a long-term horizon, which pictures it in a positive and integrated sense in its orientations, for development that is adapted to climatic conditions, appears to be essential." [18].
The path can be divided into the following stages:

1. Defining a vision for land development under conditions of climate change;
2. Definition of general adaptation goals;
3. Identification of specific adaptation goals;
4. Proposal of possible options to achieve the set goals, the concrete actions of the adaptation plan and their targets.

The vision represents the future projection of the adapted territory useful to guide the administration in choosing the most appropriate goals for its territory. In the context of the European Green Deal that aims for climate neutrality by 2050, this means establishing a long-term vision that contemplates an "adapted" territory consistent

[18] *Guidelines for regional climate change adaptation strategies - MasterADAPT, 2019.*

[19] *ICLEI, Guide and Workbook for Municipal Climate Adaptation, 2014, p. 48.*

with sustainable development between now and the target date. "General goals" mean adaptation intentions that are still not entirely clear about the expectations of the process and are, therefore, not measurable. An example at the local level is the following: "increase public awareness of climate change, increase technical capacity to prepare for expected impacts, increase adaptive capacity of built, natural and human systems in one's community." [19]. As for "specific objectives," these are the specific ways in which the community or territory intends to overcome the impacts of climate change including, for example, increasing irrigation efficiency or decreasing soil erosion. Since the goals can be as much about specific areas as they can involve broader interventions, the function of the vision turns out to be precisely to ensure the coherence and integration of the goals of the different thematic areas. At this point, the "options" represent the point solutions that contribute to the achievement of the defined objectives and can be translated into "plan actions," which represent "possible interventions useful for managing climate change-induced risks or exploiting climate change opportunities" and can "be geared: I) reducing vulnerability (reducing sensitivity and/or increasing adaptive capacity) or II) reducing exposure." [20]. Finally, setting a "target" means identifying what each specific objective intends to pursue; targets, based on the scale and detail of the objective, can be set qualitatively or quantitatively. The Adaptation Strategy provides a national vision of how to deal in the future with the impacts of climate change in the multiple socioeconomic sectors and natural systems for which it has previously identified the main critical issues. Thus, as a result of sectoral vulnerability analyses, a set of adaptation actions and directions are identified in order to counter these impacts-as well as the synergies that can be created between mitigation and adaptation strategies, especially at the local and sectoral levels. These are sectoral proposals for action that can be classified into 5 categories:

- Non-structural or "soft" actions;
- Actions based on an ecosystem or "green" approach;
- Infrastructural and technological or "gray" actions;

[20] *MATTM, Competencies and Networks for Environmental Integration and Improvement of PA Organizations (CReIAMO PA) Project: https://creiamopa.minambiente.it/index.php/creiamopa.*

- Short- and long-term actions;
- Cross-sectoral actions (soft, green or gray).

Consequently, within the Adaptation Plan, an analysis of adaptation actions, roles for their implementation and resources needed, and identification of available funding sources are proposed. The adaptation actions presented address each individual sector and are associated with the main climate impacts and related homogeneous climate areas.

1.3.2.2. - Slovenian policies, strategies and plans to achieve the goals by 2030

There are many different regions and different types of climates in Slovenia, so the uncertainty is great when predicting the severity of individual impacts of climate change. A particular challenge in the future will be more effective implementation of existing legislation and the development of knowledge and new approaches to adapting to climate change. Many sectors, managers and individuals have planned or are already implementing climate change adaptation activities. An example are the efforts in agriculture and forestry, which are most exposed to the effects of climate change and where a sectoral adaptation strategy was prepared in 2008.

If sectoral policies, which largely derive from commonly agreed European policies, are implemented completely in specified time frame, the adaptation process in Slovenia will largely be automatic and without significant additional costs. This can be illustrated by the example of flood protection measures, for which it was calculated that every euro invested saves six euros in the future. The long-term implementation of adaptation activities in other sectors undoubtedly brings savings, less damage in natural disasters, protection of health and greater safety of the population, as well as new jobs, new business opportunities and greater investment security.

Investing in knowledge about the effects of climate change and ways of adapting, wider cooperation and networking, raising education, skills and awareness is essential. Activities for successful adaptation to the effects of climate change also require more effort to secure funding, especially funds for the preparation and implementation of individual key measures and exploiting synergies between individual policies and measures in the field of climate change. At the same time, it is also important to implement the applicable legislation comprehensively and in the right time.

Slovenia's target is to become a society adapted and resilient to the effects of climate change with a high quality and security of life, which use full potential of opportunities in the conditions of changed climate on the basis of sustainable development.

Climate changes affect all sectors and economic activities. They are manifested in the gradual change of environmental conditions and more frequent occurrence and greater extent of damage caused by natural disasters and other phenomena. Due to their multiple and related effects, it is difficult to artificially separate them into individual sectors of social activities or to address them only within a single field. An important step toward increasing society's resilience and adaptability is therefore to integrate and take into account the impacts of climate changes in activities, policies and measures at all levels: at the level of the state, local community, business and individual.

The following activities, which must necessarily be planned in advance and in parallel with the implementation of individual measures for adaptation to climate change by sector are divided into four segments:

- Inclusion;
- Wider cooperation;
- Research and knowledge transfer;
- Education and training, awareness raising and communication.

1.3.2.2.1. - Inclusion

The impacts of climate change should be fully included into the design and implementation of all policies, measures and activities, both at the state level and at the level of regions and local communities, economic operators and individuals.

The adaptation process requires the definition of the country's development vision and strategic orientations, taking into account the impacts of climate change. In all planning processes, and in particular in regional planning and local spatial planning procedures, it is necessary to ensure the coherence of the plans with each other and with the country's development guidelines.

Regional spatial planning and coordination of public interests or decision-making in case of disparity of public interests in specific areas are key tools for adapting to climate change and thus redirecting the development of settlements away from areas endangered by natural and other disasters. The key challenge will be to ensure that spatial development and spatial processes in the country do not deviate from the set development strategic guidelines.

In the field of environmental impact assessments, it is important to strengthen integration, content coherence assessment and the horizontal integration of climate change impacts into cross-border, comprehensive and project-based environmental impact assessments. In the field of comprehensive environmental impact assessments, the achievement of the environmental objective "resilience and adaptation to climate change" must be included in the assessment of all programs, plans, spatial or other acts and their amendments or supplements.

The environmental report should include a chapter on climate change, proposed professionally relevant versions and mitigation measures, which should be presented to the public and included in the assessment plan.

1.3.2.2.2. - Wider cooperation

Climate change adaptation is a highly dynamic process that requires inclusion and integration at all levels, among all stakeholders.

Appropriate cooperation in the field of climate change adaptation will ensure coordinated cooperation of sectors in the preparation and implementation of strategic documents,
Climate change is one of the world's greatest challenges and its consequences go beyond national borders and are of an economic, social and environmental nature. Adaptation to climate change is thus closely linked to sustainable development and the implementation of the 2030 Agenda for Sustainable Development.

International cooperation is crucial for the implementation of the obligations arising from the agreement. The challenges of climate change are connected with other issues, including the issue of stability. The effects of climate change can, among other things, destabilize less resilient parts of the world (including parts near Slovenia), which can jeopardize security, increase the influx of climate migrants and more. Slovenia must actively and constructively engage in international processes and contribute to the search for well-thought-out solutions in this field.
Efforts will be focused on providing conditions and support for the involvement of Slovenian stakeholders in European (cross-border, transnational and other) and international projects at all levels. At national level, priorities for cooperation in climate change adaptation of the most vulnerable activities / sectors are identified. Established climate web portal will provide an overview of active and past international programs and projects in the field of adaptation to climate change and related international activities.

It is important to contribute to the transfer of knowledge to developing countries, where Slovenia's contribution can have a major impact on reducing risks (e.g. water regime in the region) and vulnerability to climate change impacts (e.g. adaptation of cultivated species in agriculture) or transfer of general management skills to increase climate resilience (e.g. on forest management in forest-rich countries). We already have some mechanisms in place in this area (e.g. the Drought Management Center for South Eastern Europe), so we will maintain and strengthen them.

We have 212 municipalities in Slovenia (of which 11 are urban), which are connected in 12 statistical regions and a number of other networks and connections according to the needs. Municipalities have a wide range of tasks in areas that have a significant impact on exposure to climate change, they also have the leverage to strengthen resilience to these impacts, so it is important to guide, support and encourage municipalities to adopt adaptation strategies and implement measures. Municipalities are joining various international networks of cooperation and exchange of experiences, which should be further encouraged. Municipalities and regions are supported in the preparation of strategic and implementation plans for adaptation also by providing guidelines and resources.

We will look for ways to further strengthen mechanisms for coordinating policies and measures, especially in the field of climate change, and set out long-term integration and encouragement to involve various stakeholders in climate change adaptation.

1.3.2.2.3. - Research and knowledge transfer

In order to implement the guideline of Continuous strengthening of knowledge on the effects of climate change following activities will be encouraged:

- Constantly updating knowledge on future climate change;
- Research and development in the field of climate change monitoring;

- Dissemination of research results, latest findings, innovations, good practices.

We will continuously increase the scope and depth of our expertise to formulate effective policies and measures, combining knowledge with experience in the field and from the past.

Regular participation of researchers and decision-makers will be ensured by organizing meetings with workshops for the exchange of knowledge and good practices, as well as presentations of the latest findings, databases and research results, which will take place at least once a year.
A climate web portal will be established and regularly updated, where all the information and results of past and future research projects will be collected. At the same time, the climate web portal will also enable two-way communication between key stakeholders.

1.3.2.2.4. - Education and training, awareness raising and communication

At the global level, in Europe and also in Slovenia, various practical approaches to education, training and communication on adaptation to climate change have been developing in recent years. Therefore, an overview of good practices in the field of education, training and communication on climate change adaptation and support for their development will be prepared, focusing on innovative models and dissemination of good practices.

In support of the goals and measures in the field of adaptation to climate change and more broadly in order to achieve the goal of informing the target public about the impacts of climate change, various communication campaigns will be implemented. The campaigns will be tailored to the target public and will contribute to raising the awareness of the general public.

In support of the planning, implementation of measures and the achievement of adaptation objectives, it is essential to increase the long-term awareness and involvement of all stakeholders in the ongoing process of education, training and information. Permanent cooperation with the non-governmental and private sector will be established for the purpose of raising awareness and continue our efforts to strengthen and improve the quality of content, which are related to the field of adaptation to climate change.

1.3.3. Mapping Territorial Complexity and Climate Impacts

1.3.3.1. - Geography and Governance

1.3.3.1.1. - Metropolitan City of Venice

The Metropolitan City of Venice is included in the Veneto Region, of which it occupies the easternmost part; it borders the Adriatic Sea to the east, the provinces of Udine and Pordenone in Friuli Venezia Giulia to the north-east, and the Veneto provinces of Treviso, Padua and Rovigo to the north, west and south respectively.
Its territory, which covers about 2,500 square kilometres, is flat and includes elements that indissolubly bind it to the water element: the sandy coastline on the Adriatic Sea, which stretches for about 90 km; the lagoon areas, which extend for almost 600 square kilometres and include the Lagoon of Venice (about 550 square kilometres), the Lagoon of Caorle (about 30 square kilometres) and the smaller Lagoon of Mort (about 2 square kilometres) in the Municipality of Jesolo; of the approximately 1,900 square kilometres of dry land, one third is reclaimed land with a height of less than 0 above sea level. Finally, the Tagliamento (which marks the north-eastern boundary of the territory), Lemene, Livenza, Piave, Brenta, Bacchiglione and Adige (which defines part of the southern boundary) cross its territory and flow into the Adriatic from north to south, while the Zero, Dese and

Marzenego rivers flow into the Venice Lagoon.
These characteristics of the territory also characterise the main vulnerabilities to climate change, such as: erosion and infiltration of the saline wedge on the coast, hydraulic instability and changes in the ecosystems in the lagoons due to the increase in average temperatures and the rise in the average sea level, vulnerability to flooding phenomena in particular in the reclaimed areas; to these vulnerabilities are added those linked to urbanisation, such as the heat island effect and urban flooding, and those affecting the various activities present on the territory, in particular agriculture and tourism.
The climate is Po Valley, mitigated by the proximity of the sea; according to the Koppen climate classification, it falls into the Cfa class (humid subtropical climate), while as regards the climate zones as defined by Presidential Decree 412/1993, all the municipalities in the territory are in zone E (day degrees between 2,101 and 3,000). The average temperature in Venice is 13.0 ° C, with an average of 75.8 rainy days/year and 748.4 mm of precipitation.

1.3.3.1.1.1. - Administrative organisation of the territory

The Metropolitan City of Venice is a local territorial authority established following the Constitutional Law 56/2014, succeeding the Province of Venice in most of its tasks. The population is 851,100 residents (ISTAT data as of 01/01/2019), for a density of 343 inhabitants/sq km (about 450 inhabitants/sq km excluding the lagoon areas), higher than the national figure of 196 inhabitants/sq km.
There are 44 municipalities; the capital Venice has 260,000 residents, almost one third of the total.
The housing stock and all services are affected by the considerable importance of tourism, with five municipalities in the top ten in Italy for tourist presences (2019 data): Venice (2nd city in Italy with 12.9 million overnight stays) and the seaside resorts of Cavallino-Treporti (6th with 6.3 million), San Michele al Tagliamento (7th with

5.8 million), Jesolo (8th with 5.4 million), and Caorle (9th with 4.3 million); these are joined by Chioggia (37th with 1.4 million). The seaside resorts are those where the impact of tourism is greatest, with a ratio in August between 'equivalent inhabitants' (residents + tourists) and residents alone that ranges from 5.4 in Cavallino-Treporti and San Michele al Tagliamento to 2.8 in Jesolo, the municipality with the highest number of residents.

1.3.3.1.1.2. - Main Decision Makers

With regard to energy and environmental sustainability issues, the main decision makers are:

- Veneto Region, in particular: Directorate for Environment and Ecological Transition; Directorate for Soil and Coastal Protection; Directorate for Research, Innovation and Energy
- Metropolitan City of Venice, in particular: Territorial Planning Service; Environment and Civil Protection Area
- Municipal administrations; it should be noted that all 44 municipalities of the Metropolitan City adhere to the Covenant of Mayors
- ARPAV, in particular: Department for Territorial Safety with particular reference to meteorological services; Department for Environmental Quality
- Land Reclamation Consortia
- Eastern Alps Basin Authority
- Chamber of Commerce of Venice and Rovigo
- Trade associations of the tourism, trade, industry and craft sectors, agriculture.

1.3.3.1.2. - Regione Autonoma Friuli Venezia Giulia

Friuli Venezia Giulia occupies the north-eastern tip of Italy and has an

area of 7845 km2. The regional territory is made up of the historical-geographical region of Friuli, which makes up the vast majority of its surface area, and the part of Venezia Giulia that remained with Italy after the Second World War: the demarcation between the two historical-geographical regions is the mouth of the Timavo River, on the border of the former provinces of Gorizia and Trieste.
The region borders Slovenia to the east, Austria to the north, Veneto to the west and the Adriatic Sea to the south. The climate of Friuli Venezia Giulia ranges from a Mediterranean climate in the coastal areas, to a more humid temperate climate in the plains and hilly areas, to an Alpine climate in the mountains. The average annual temperature is 12.9° (2019) and the average precipitation is 1715 mm (2019). Compared to an average annual temperature of 12.6 °C, which was the norm in the 30-year reference period (1961-1990), in recent years much higher values have been reached, with a peak of 14.6 °C in 2014. Over the entire 1961-2016 period, the average temperature increase was 0.3 °C every 10 years, with a clear accelerating trend in the most recent decades.
The region has important rivers such as the Tagliamento, classified as one of the least man-made rivers in Europe, which flows from Carnia to the Adriatic. Another important river in the region is the Isonzo in Venezia Giulia, which rises from the Julian Alps and flows to the sea, as well as the Livenza, Torre, Stella, Natisone, Judrio, Timavo, Cormor, Fella and Piave. 17 small to medium-sized lakes are also present.

1.3.3.1.2.1. - Administrative organisation of the territory

By Constitutional Law No. 1 of 31 January 1963, Friuli-Venezia Giulia became an Autonomous Region with a special statute. The Autonomous Region of Friuli-Venezia Giulia has established four regional decentralisation bodies, corresponding to the former four provinces, and comprises 215 municipalities.
The population is 1,211,357 with a population density of 153 inhabitants per square kilometre, lower than the national average

of 199 inhabitants per square kilometre, with significant territorial variations between the mountains (18 inhabitants per square kilometre), the hills (283 inhabitants per square kilometre) and the plains (240 inhabitants per square kilometre).
The percentage of people over the age of 14 using public transport is 25.8%, electricity consumption per capita is 8472 KWh in 2019, far higher than the national average of 5,024 KWh/inhabitant.
The employment rate is 74.5% for men and 58.6% for women.
The average total income is 22,561 euros, which places the Region last among those in Northern Italy.
The Region ranks first in Italy in the Export/GDP ratio: 40.7 followed by Emilia-Romagna (38.1%) and Veneto (37.9%). The top three most exported products: 1. Ships and boats (2,092 million euros, 5.6% of FVG GDP); 2. Steel products (1,629 million euros) 3.

1.3.3.1.2.2. - Main Decision Makers

Friuli Venezia Giulia Region

Central Directorate for Environmental Protection, Energy and Sustainable Development.

It deals with the protection and defence of terrestrial and aquatic ecosystems and the containment of risks posed by human activities through sectoral plans and policies.
The Directorate plays a central role in regional climate policies. It is the coordinator of the interdepartmental Nipoti table set up by General Council Decision 1303/2020 and Regional Presidency Decree 381/2020 defining its participants.The purpose of the Nipoti working group is to coordinate, define and organise plans, programmes and actions in the key sectors of regional decarbonisation by 2045: Industry, Agriculture, Transport (public and private, logistics, etc.), Building system (public and private), Energy production, transport and distribution system, Finance, Research, education and work.

ARPA FVG

ARPA FVG provides technical and scientific support to the Autonomous Region of Friuli Venezia Giulia in several areas of regional planning and expresses several competences necessary to support decision-making processes on climate change adaptation. In particular, through its OSMER and GRN structure, the Agency produces knowledge on climate change with reference to the Friuli Venezia Giulia territory, knowledge that represents a fundamental element in adaptation planning paths and in particular in risk and vulnerability assessment.

On behalf of the Region, ARPA FVG carried out the "Cognitive study of climate change and some of its impacts in Friuli Venezia Giulia" (ARPA FVG, 2018) in collaboration with the Universities of Udine and Trieste, ICTP, OGS and CNR-ISMAR. ARPA FVG is therefore the entity to which the Region has entrusted the coordination of the FVG Regional Climate Committee, composed precisely of the entities that had contributed to this first Study. Moreover, the Agency is strengthening the integration of competences and activities related to climate, adaptation, mitigation and sustainable development and the synergies with the environmental modelling.

ARPA FVG is also involved in various ways in cross-border cooperation projects aimed at improving knowledge of climate change and its impacts and at supporting adaptation paths. In particular, it is currently a partner in the Interreg Italy-Croatia AdriaClim project, for which it is responsible for the development of activities in the pilot area represented by the Friuli Venezia Giulia coast and lagoons.

APE

The Friuli Venezia Giulia Energy Agency supports local communities in achieving significant and measurable improvements in the rational use of energy and its renewable sources. The EPA has activated a specific HelpDesk for municipalities that have joined the PAES(C)s The Agency provides independent, timely, relevant and reliable information and support to key political, economic and citizen actors on energy saving, energy efficiency and the use of renewable energy sources.

Municipalities participating in the Covenant of Mayors

The 74 municipalities, slightly less than a third of all regional municipalities, which have joined the European initiative to turn local communities into actors of regional sustainability and energy transition, are key players in adaptation policies on the territory.

Land Reclamation Consortia

The Consorzi di Bonifica Pianura Friulana, Cellina Meduna, Venezia Giulia implement the regional programmes on land reclamation and irrigation and carry out activities on soil protection and water use.
the quality of their activities and management of water, particularly irrigation water, could play a key role in adapting to drought and flood risk.

Civil Protection

At the moment, the Civil Protection has not developed through the Regional Emergency Plan a specific assessment and lines of action related to climate adaptation. The management of emergencies - is not linked or indexed to the climate risk as there is no planning linked to a statistical assessment of the increased risk of extreme events exacerbated by the climate crisis.

1.3.3.1.3. - Slovenia

According to the EUROSTA report of 2001 [21]:

"Slovenia, is one of Europe's youngest nations, emerged on the political world map in 1991 [...]. At the meeting-point of four large European regions (the Alps, the Pannonian Basin, the Mediterranean and the Dinaric Mountains), a picturesque mosaic of landscapes developed in this naturally diverse area where cultural influences from all sides intertwined throughout the centuries. This was further stimulated by the country's position astride the "historic draught", the easiest passage from the Pannonian Basin to the Mediterranean and from Western and Central Europe towards South-eastern Europe. As part of former Yugoslavia, Slovenia was administratively divided among 65 relatively large municipalities, which were the basis of the socialist self-management system and therefore had considerable political power. After independence, the country's administration was centralised, however there has been a constant debate about the establishment of administrative-political regions (provinces) as an intermediate level between the state and the municipalities. The state administration is currently organised into 58 administrative units that are mostly based on the former municipalities. The old municipalities were abolished with the Act on the Establishment of the Municipalities (1994) and new municipalities were established to undertake local self-government. Slovenia is now divided among 212 municipalities (12 of these are city municipality), extremely diverse in terms of population and economic power: the largest in terms of population is the city municipality of Ljubljana (271 000), while Hodoš municipality has a population of only 371. The division of Slovenia into 12 statistical regions was based on the socio-geographic regionalisation of Slovenia (functional medium-size regions). Statistical regions coincide with the socalled planning regions determined for the purposes of spatial planning. They have no political or administrative function and, apart from several minor exceptions, follow the boundaries of the existing municipalities".

[21] Portrait of the regions - Volume 9: Slovenia, EUROSTAT, 2001.

1.3.3.1.3.1. - Administrative organisation of the territory

As a member of the EU, Slovenia has the right to be involved in the preparation of the legislation of the EU and European policies. Slovenian government representatives attend and meet the meetings of the committees of the Council of the EU on a daily basis and represent Slovenia's interests in the process of drafting and adopting EU acts and decisions.

On the basis of strategic documents of the European Commission and the Council of the EU, the Government of the Republic of Slovenia every year prepares and adopts Slovenia's priorities for work in the EU Council. Key tasks in the field of environmental protection include addressing some of the thematic strategies from the Seventh Environment Action Program, activities in the field of climate change, consideration of numerous legislative acts in the field of nature and biodiversity protection, protection of health and quality of life, waste management, implementation of the Action Plan for the Environmental Technologies and various initiatives to promote sustainable development at the international level.
In accordance with Slovenia's Development Strategy, Slovenia's future development will be strongly dependent on its ability to respond and adapt to global trends and challenges. Prosperity can be achieved through more efficient use of natural (environmental) capital, nature conservation and raising the quality of the living environment.
Integrating environmental requirements into all policies and activities is essential to promote sustainable development. The state, regions and municipalities must, when adopting policies, strategies, programs and plans promote such economic and social development of society that takes into account equal opportunities for next generations and the long-term preservation of the environment.
One of the instruments for integrating environmental content into policies is the implementation of an environmental impact assessment (EIA). EIA is implemented for all those plans, programmes and policies that have a significant impact on the environment. The aim

of implementing the EIA is to ensure a high level of environmental protection and to contribute to the integration of environmental aspects into the preparation and the adoption of plans and programs to promote sustainable development.

1.3.3.1.3.2. - Main Decision Makers

MINISTRY OF THE ENVIRONMENT AND SPATIAL PLANNING

The Sector for the Environment and Climate Change of Ministry of the Environment and Spatial Planning is responsible for the preparation and monitoring of basic strategic documents and strategic guidelines in the field of climate change mitigation and adaptation, reduction of greenhouse gas emissions and other air pollutants. They develop policies to achieve adequate air quality, soil protection, prevention of industrial pollution and the prevention of major industrial accidents, protection against noise, electromagnetic and light pollution.

GOVERNMENT OFFICE FOR DEVELOPMENT AND EUROPEAN COHESION POLICY

The Office for Development and European Cohesion Policy is responsible for sustainable development and the implementation of the European cohesion policy. It provides advice to the Government and ministries on adopting measures and legal acts referring to the implementation and monitoring of development and cohesion policy. It is responsible for the consistency of national development planning documents and their consistency with the development documents of the European Union and other international organisations. The Office also performs management tasks related to other financial mechanisms, such as the Norwegian Financial Mechanism and the EEA Financial Mechanism.

SLOVENIAN ENVIRONMENT AGENCY

Slovenian Environment Agency performs expert, analytical, regulatory and administrative tasks related to the environment at the national level. The Environment Agency is a body of the Ministry of the Environment and Spatial Planning. Its mission is to monitor, analyse and forecast natural phenomena and processes in the environment, and to reduce natural threats to people and property.

BIOTECHNICAL FACULTY

Research and education on the Biotechnical Faculty are crucial to the creation of relevant professional and scientific foundation and the promotion of an atmosphere that ensures sustainable development. Their field of work include Environmental and landscape protection, the protection of the natural heritage, environmentally friendly and sustainable use of natural resources and production of quality food.

ENERGY EFFICIENCY CENTRE OF JOZEF STFEAN INSTITUTE

The main focus of Energy Efficiency Centre of Jozef Stefan institute is strategic energy planning and policy makers support, which is primarily oriented to fields of energy efficiency, reduction of GHG emissions and reduction of air pollutants. They provide expert support for Ministries in the preparation of strategic and action documents in the fields of energy climate policy and policies on the reduction of air pollutant emissions by developing complex model tools for analysis and projections of energy consumption and emission development.

UMANOTERA

Umanotera, The Slovenian Foundation for Sustainable Development is one of the leading non-governmental organizations in the field of sustainable development in Slovenia. They systematically, cohesively and continuously promote the themes of sustainable development Umanotera has the status of a non-governmental organization acting in the public interest in the field of environmental protection (granted by the Ministry of the Environment and Spatial Planning).

LOCAL ENERGY AGENCIES

Local energy agencies assist local institutions in planning projects for energy consumption reduction and energy efficiency maximisation. They support the introduction of good energy management practices, advocate the concept of sustainability and provide information and guidance. Their activities are directed towards raising public awareness in the transition from fossil fuels to renewable energy sources such as biomass, biogas, geothermal, solar and hydroelectric energy.

ECO FUND, SLOVENIAN ENVIRONMENTAL PUBLIC FUND (ECO FUND)

Eco Fund, Slovenian Environmental Public Fund (Eco Fund), was established in 1993. Its main purpose is to promote development in the field of environmental protection by offering financial incentives such as soft loans and grants for different environmental investment projects. It began with soft loans for investments in environmental protection as a revolving fund. Perhaps the most significant aspect of Eco Fund's operating environment is the requirement that Eco Fund maintains the real value of its assets. For this reason, Eco Fund has provided support to environmental investments through soft loans and developed a strong focus on the financial sustainability of the projects it supports. In 2008, Eco Fund was granted the use of additional financial mechanisms such as grants to support environmental investments. Grants are financed mostly by fees paid by end users of energy and funds from the climate change fund (revenues from CO_2 allowances).

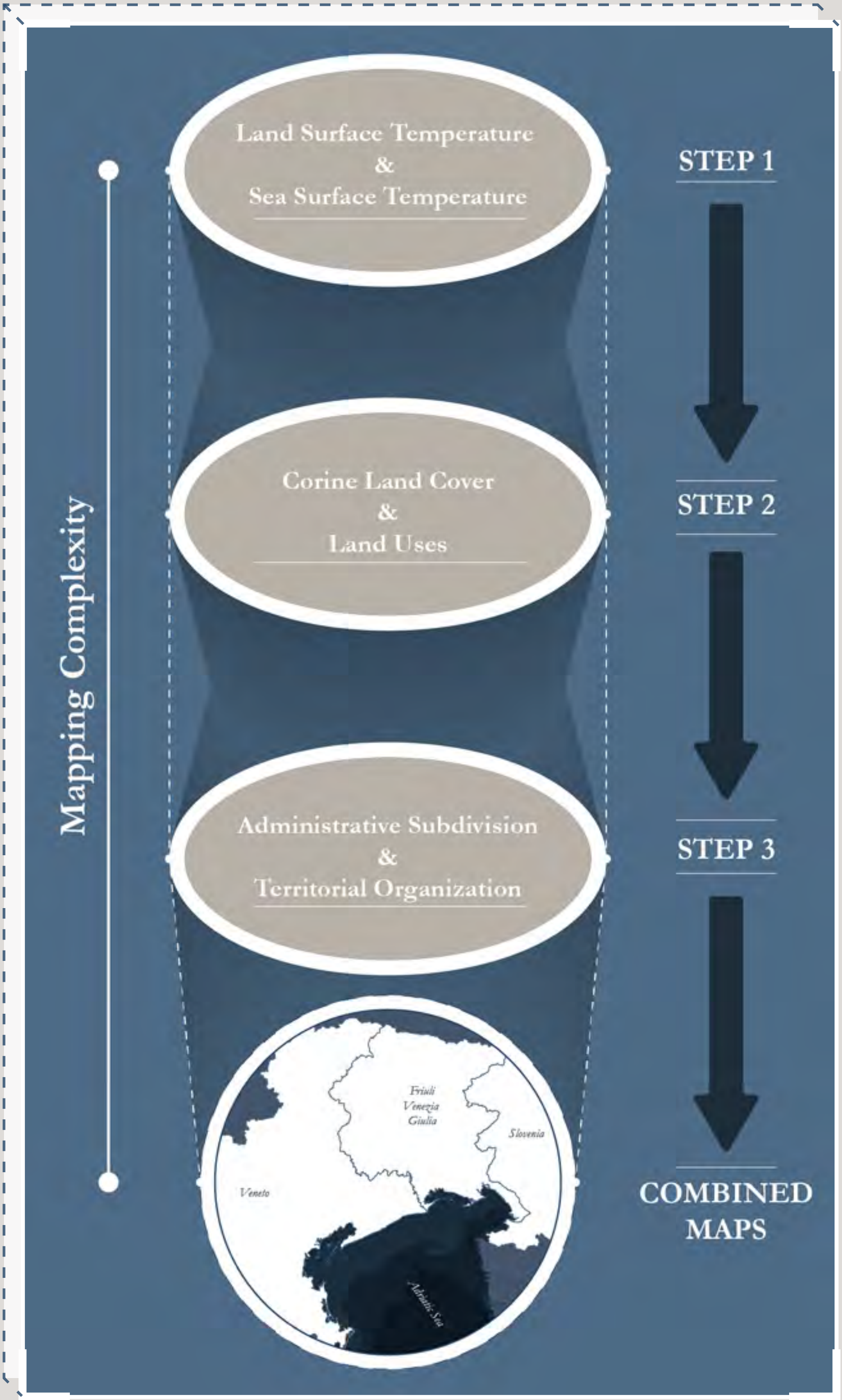

Mapping Complexity
Land Surface Temperature
&
Sea Surface Temperature
STEP 1
Corine Land Cover
&
Land Uses
STEP 2
Administrative Subdivision
&
Territorial Organization
STEP 3
Friuli
Venezia
Giulia
Slovenia
Veneto
Adriatic Sea
COMBINED
MAPS

Figure 15 - Mapping Complexity Steps.

1.3.3.2. - Complexity mapping

Section 1.3.3.2. Mapping Territorial Complexity and Climate Impacts analyzes the North Adriatic case study, as reported in Section 1.3, using three approaches: examining the regulatory framework, the morphological-geographical framework, and vulnerability and risk predisposition.

This section deals with the morphological and geographical analysis following a process divided into 6 consequential steps divided into two macro stages: Mapping Complexity (Figure 15) and Combining Complexity (Figure 16). The area of investigation is the Gulf of Venice and the Gulf of Trieste and covers 3 regions: Veneto, Friuli Venezia Giulia, and Western Slovenia. The analysis considers two investigation units in parallel, namely the system delimited by the three regions' administrative boundaries and two transects.
The transects are based on the four papers' study areas trying to focus the analysis on the same territories to provide an element for empirical comparison of territorial complexity. Respectively:

- Transect 1;
- A & B correspond to RP 2;
- Transect 2,
- C corresponds to RP 3;
- D corresponds to RP 3 & 4;

Each step presents a different cognitive framework based on data, spatial information, and processing. The objective is to support the dissertation by answering the research questions enunciated in Section 1 of Chapter 1. A total of 5 generic maps presents the territory framing, 15 maps the Mapping Complexity step, and 15 the Combining Complexity step.

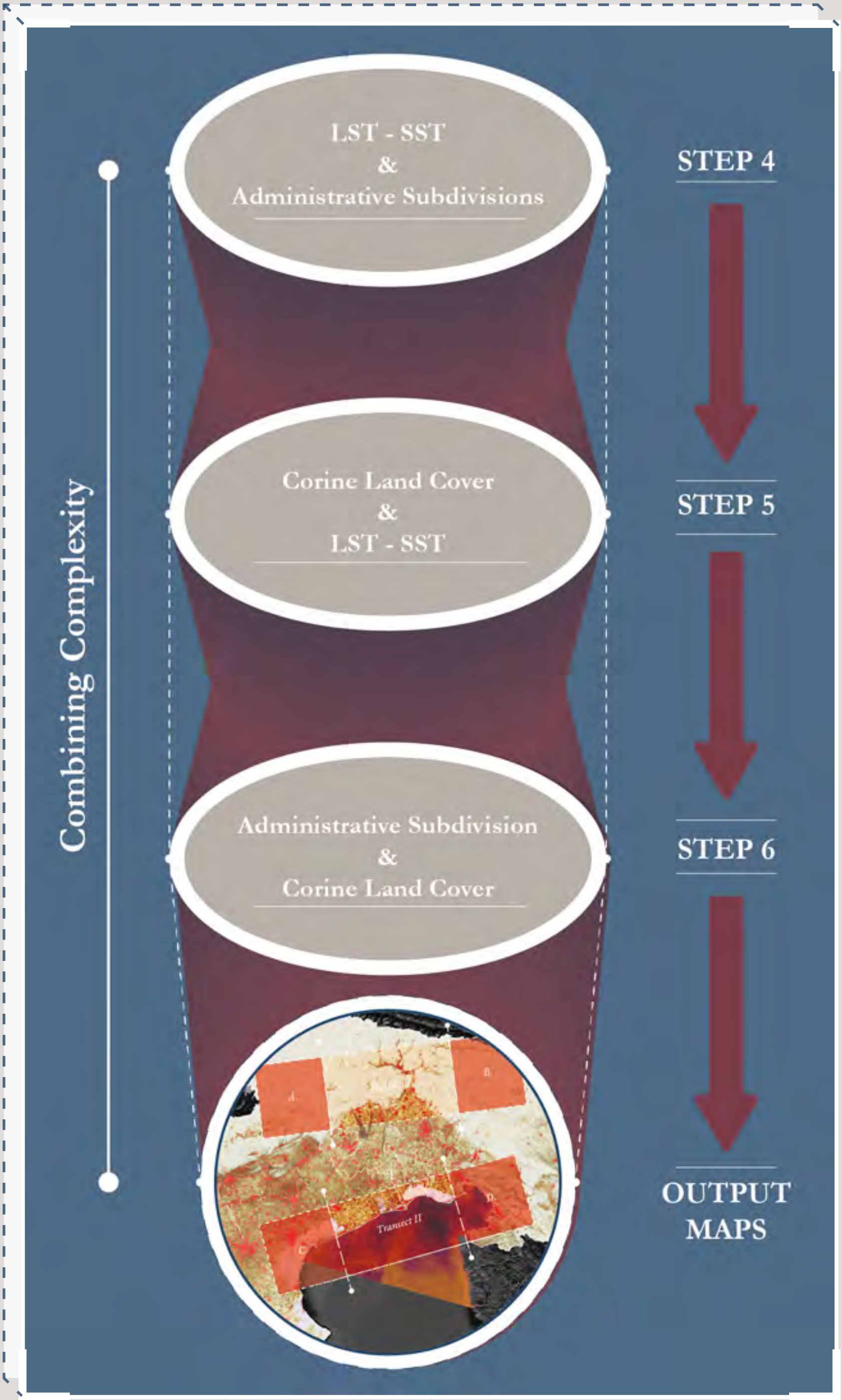

Combining Complexity
LST - SST
&
Administrative Subdivisions
STEP 4
Corine Land Cover
&
LST - SST
STEP 5
Administrative Subdivision
&
Corine Land Cover
STEP 6
A.
B.
C.
D.
Transect II
OUTPUT
MAPS

Figure 16 - Combining Complexity Steps.

Ph. 1

First phase

Corresponds to Steps 1, 2, and 3, and the second phase to Steps 4, 5, and 6. The first aims to present individual information layers to describe the soil and sea thermal behavior of the study areas (Step 1), land use and prevalent uses (Step 2), and administrative subdivisions and concentration of municipalities (Step 3). Each of these steps supports Section 1.3.3.3. Climate Vulnerability Perspectives and complements what Section 1.3.2. Local Policies for Adaptation produces.

Ph. 2

Second phase

Shows the overlap between the different layers and aims to highlight the degree of complexity of the study areas. Specifically, the second step shows the overlap between thermal framework and administrative subdivision (Step 4), between land, uses, and thermal framework (Step 5), and between the administrative subdivision and land uses (Step 6). The goal of this section is to demonstrate the level of complexity of this area from a morphological perspective only, suggesting that the implementation of sectoral planning approaches is limited from an overall point of view. Each layer and each overlay present an ecosystem of interconnected critical issues and are limited to the selection made within this dissertation. This cognitive framework, based on open-source tools, was developed in a GIS environment, and is based on ICT. However, the interpretation of the map overlay requires a degree of discretion that must have the intention of formulating a design action, returning to the hypothesis expressed in the Introduction. The 6 steps present what is a generic process, which in this case is limited to the spatial overlay, of geostatistical analysis in support of the CAP.

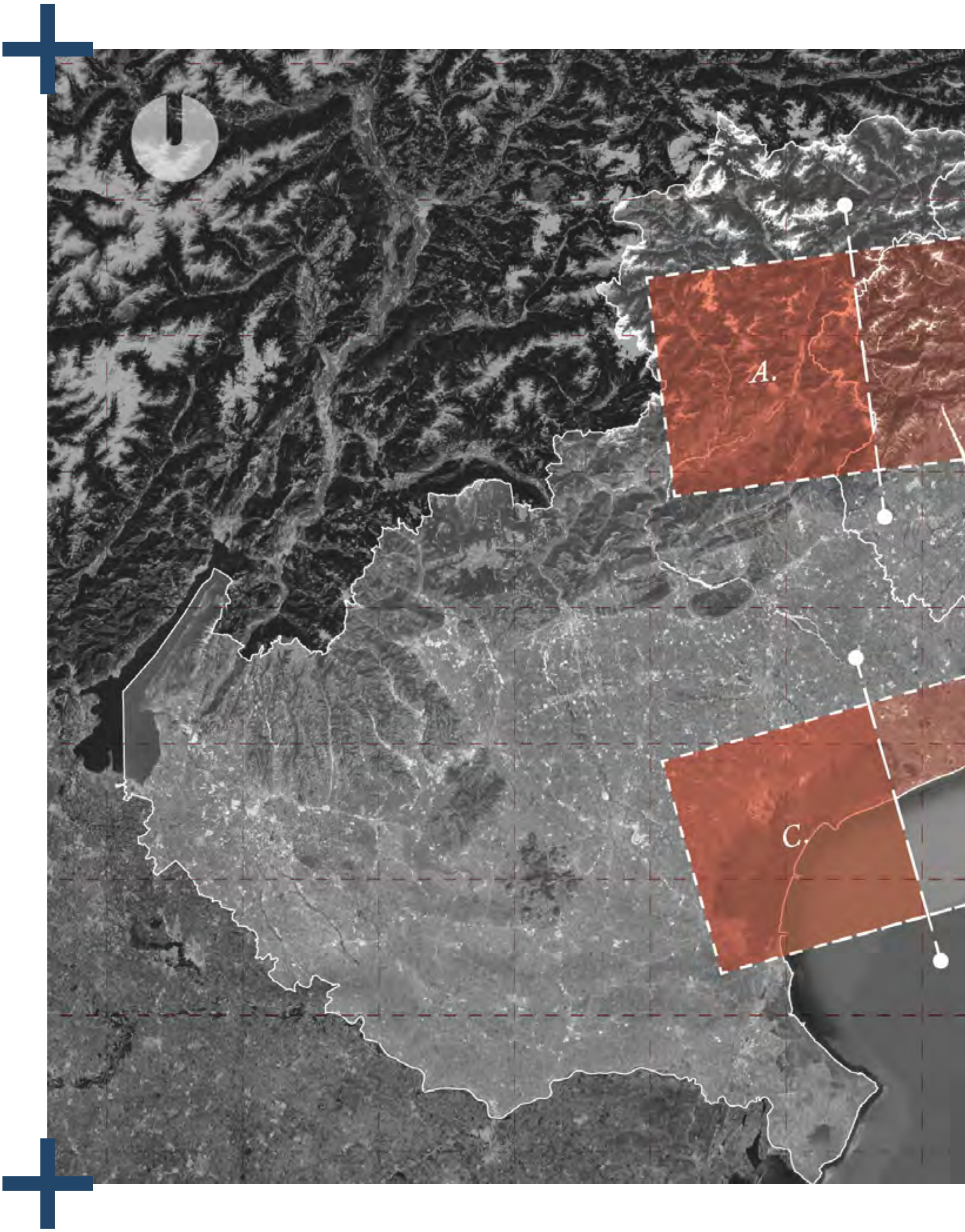
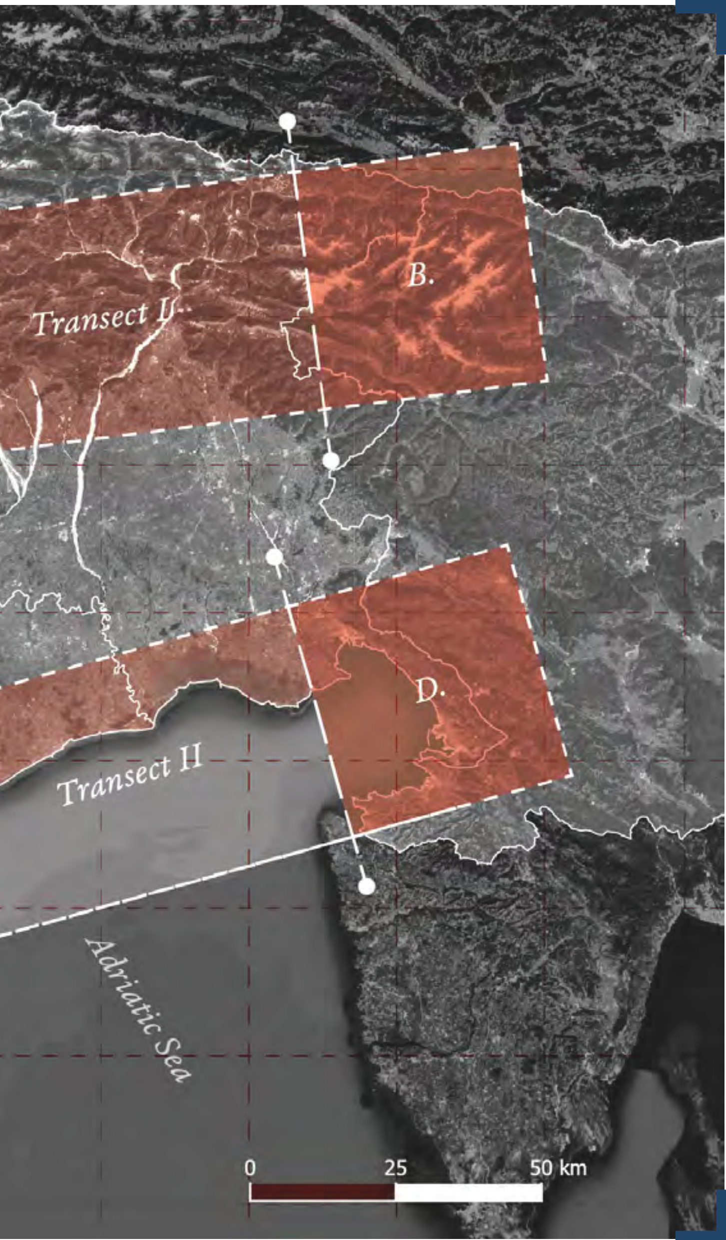


Figure 17 - The North Adriatic System and the Transects assessment areas.



The transects frame two transboundary areas between the three regions (Figure 17).
Each of the transects responds to a study area of the RPs. Transect I includes the Italian and Slovenian Alpine arc. Transect II frames the Gulf of Trieste and the Gulf of Venice, the northern part of the Adriatic system. The transects connect territories that are on the one hand heterogeneous from a morphological and administrative point of view but similar from the point of view of susceptibility to climate change vulnerability. As reported in previous chapters, the administrative organization has different levels of complexity and autonomy related to the suitability of each context.

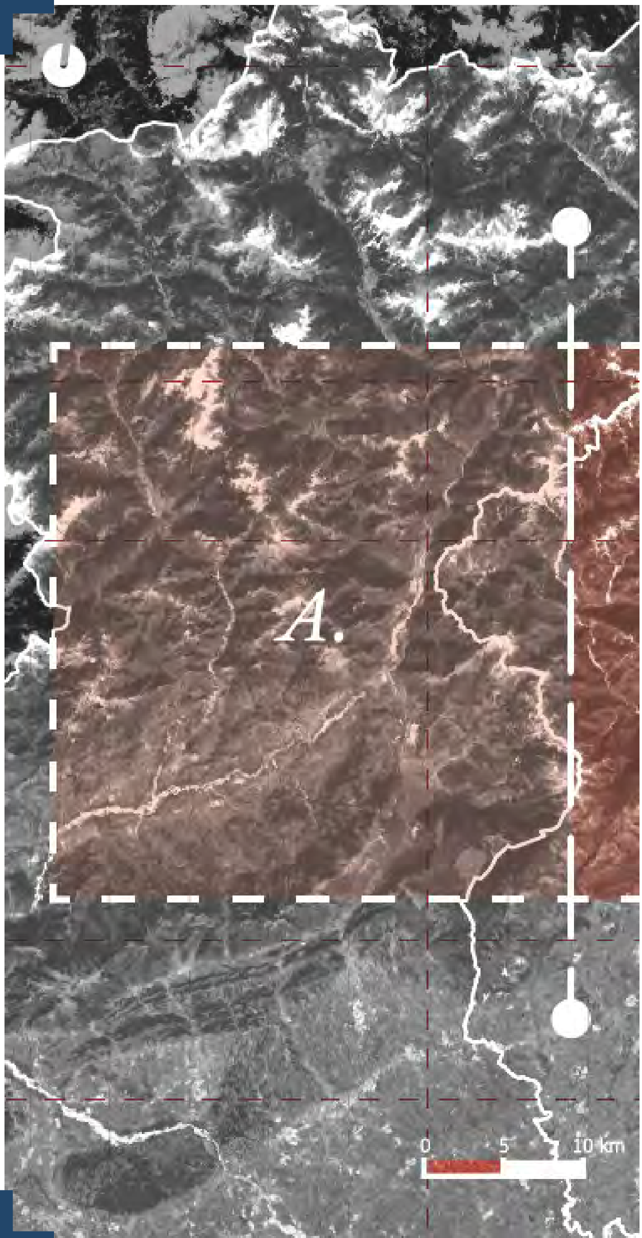
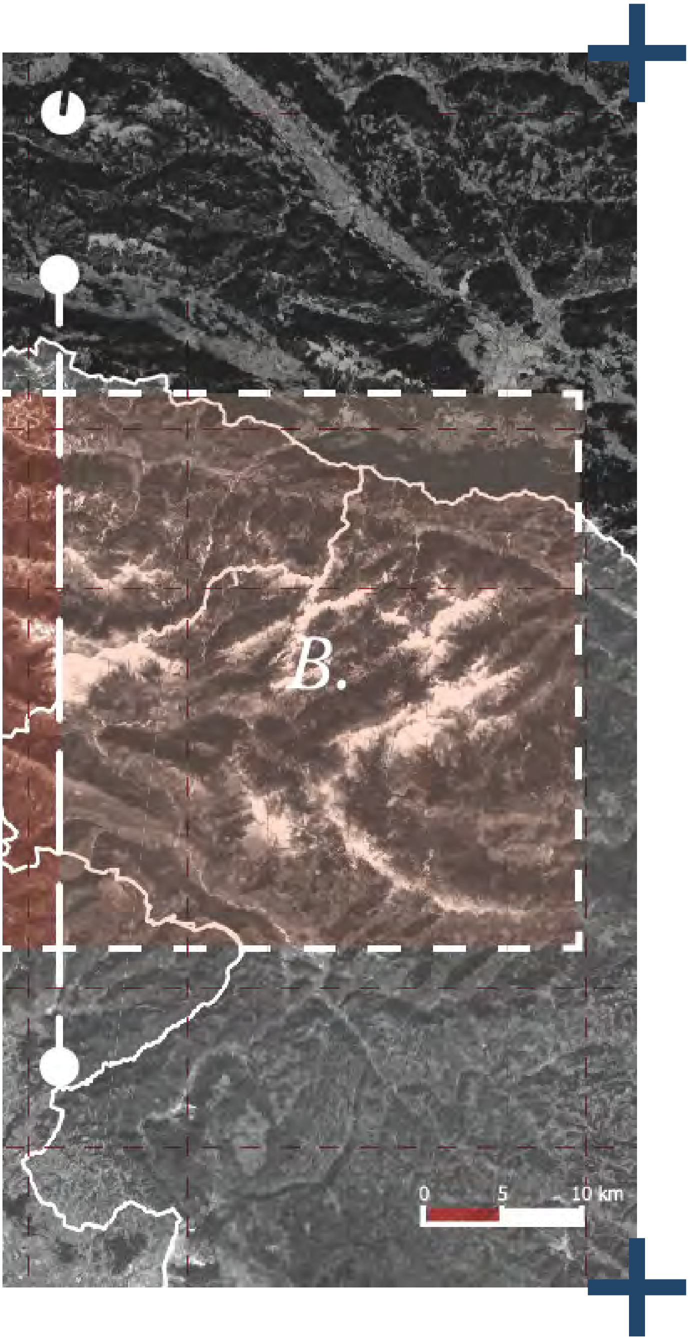


Figure 18 - Zooming Transect 1 A.

Figure 19 - Zooming Transect 1 B.



Area A of Transect I is the alpine system of the Dolomites. This area is shared between 3 different regional systems: Veneto, Friuli Venezia Giulia, and Trentino Alto Adige, and for a small portion with Austria (see Figure 18). Area B of Transect I concerns is the Alpine system of the Julian Alps. This territory is shared between 3 different states: Italy, Slovenia, and Austria (Figure 19). Both areas are characterized by great social and economic complexity, as described in the previous sections.

Figure 20 - Zooming Transect II C.

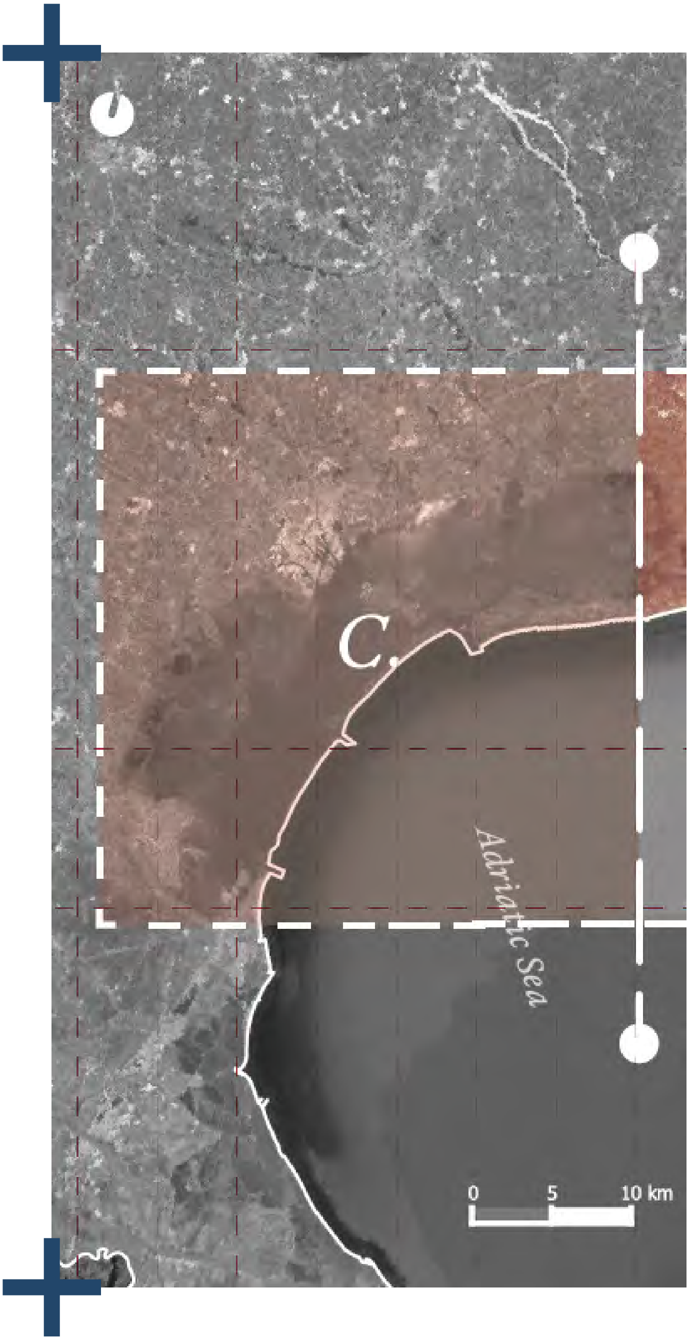
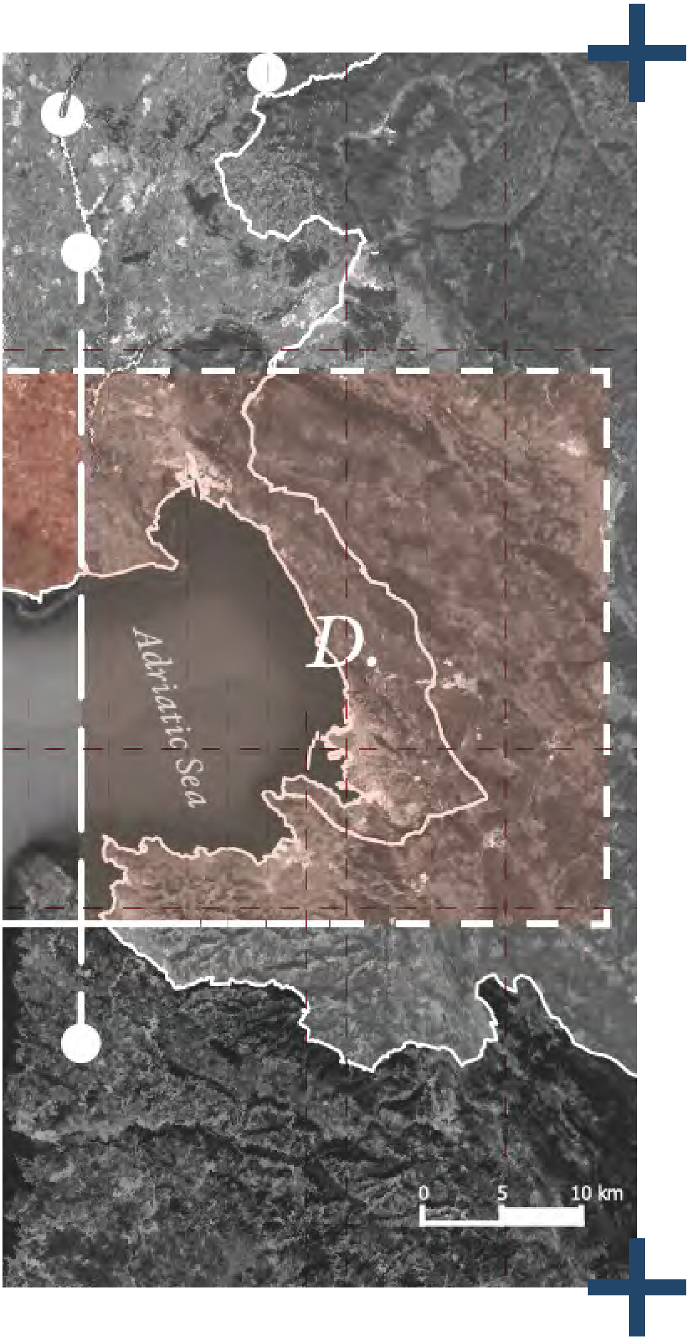


Figure 21 - Zooming Transect II D.



Area C of Transect II is the gulf of Venice. The area is administered by the Metropolitan City of Venice, which encompasses 44 municipal units and includes the Venice Lagoon (Figure 20).

Area D of Transect II is the Gulf of Trieste. This area is divided between Italy, Croatia and Slovenia and is the latter's only access to the sea (Figure 21).

Both areas present great economic and social complexity and are closely linked to the relationship with the sea.

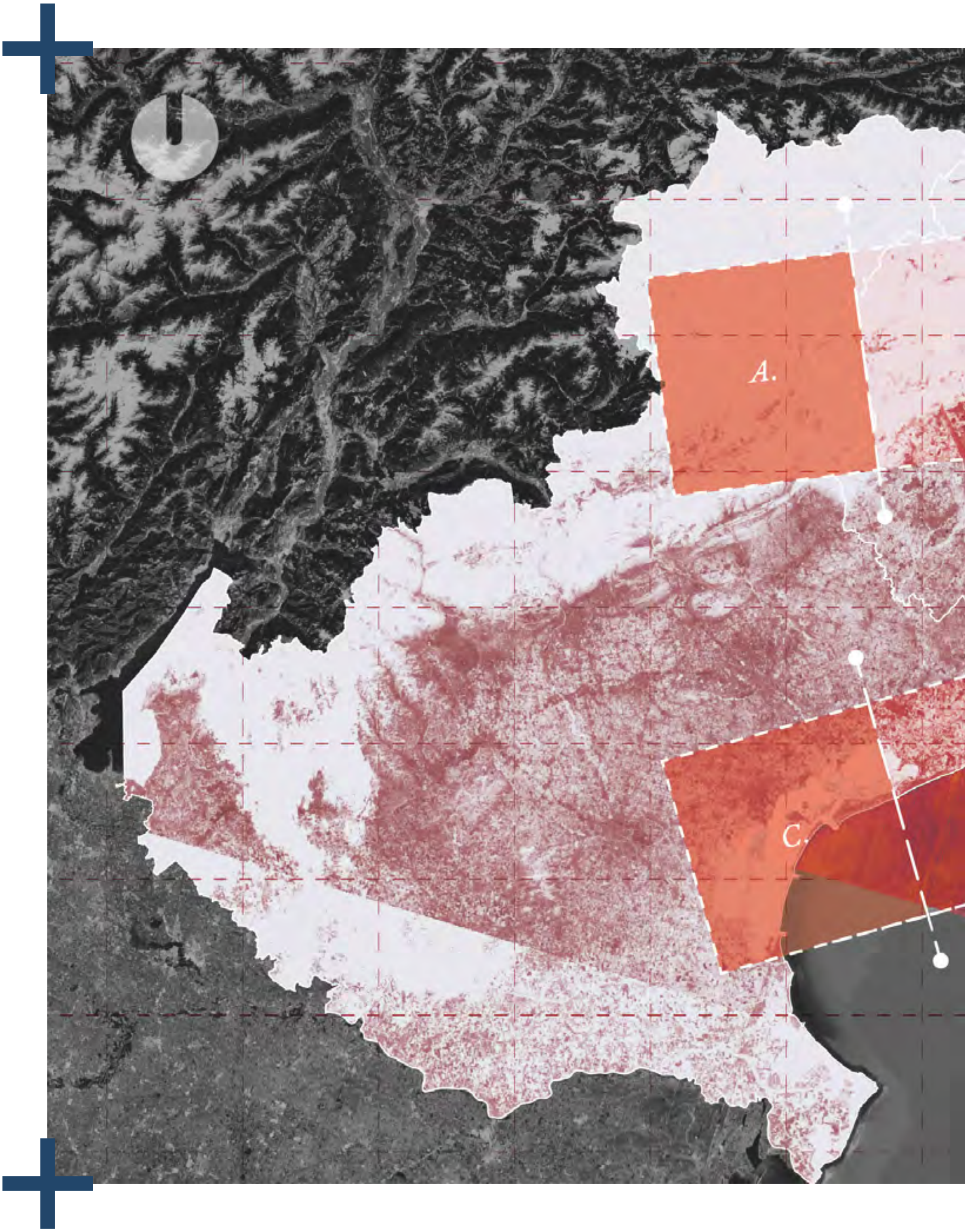
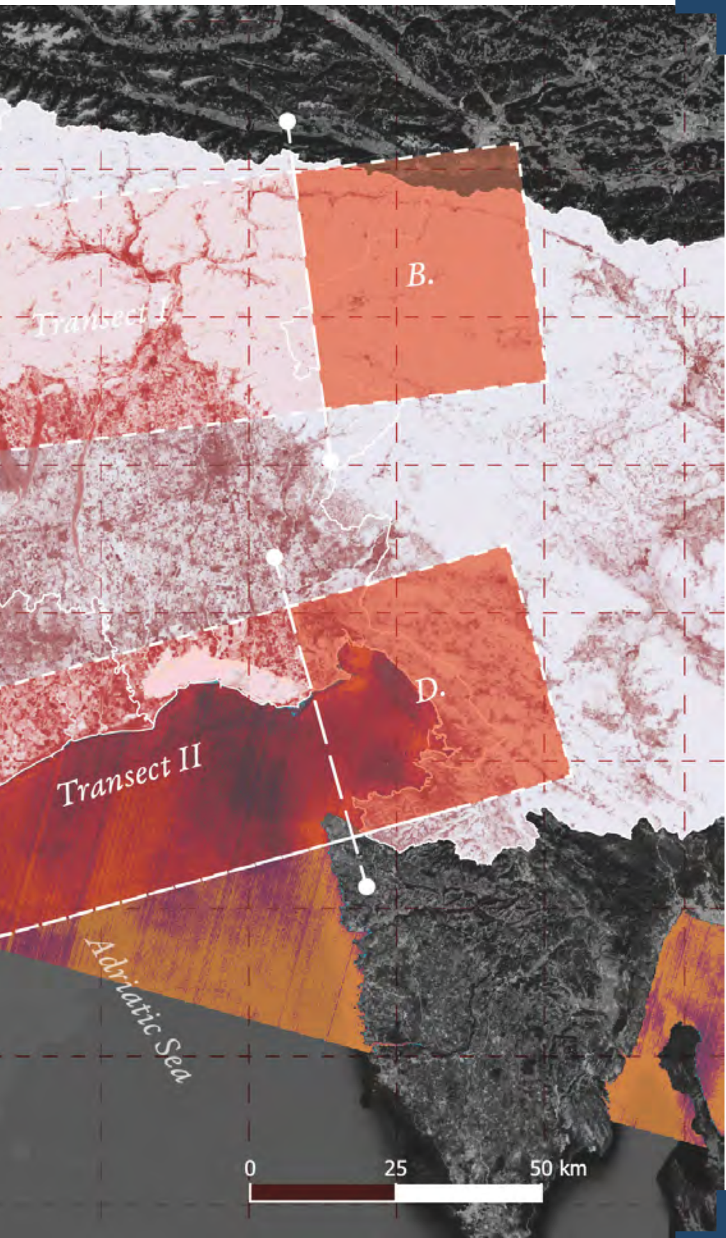


Figure 22 - Step 1: Land and Sea Thermal scenario.



Step 1.

Legenda:

Land Surface Temperature

High < 45°

Medium < 35° <

Low > 25°

Sea Surface Temperature

High < 32°

Low > 28°

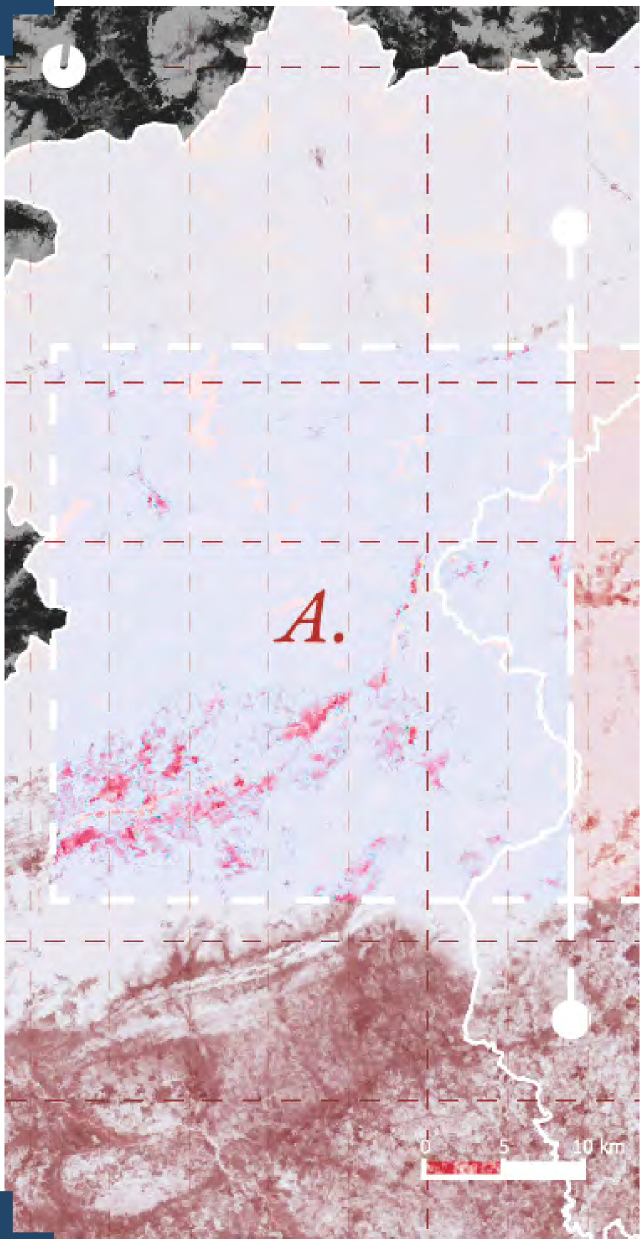
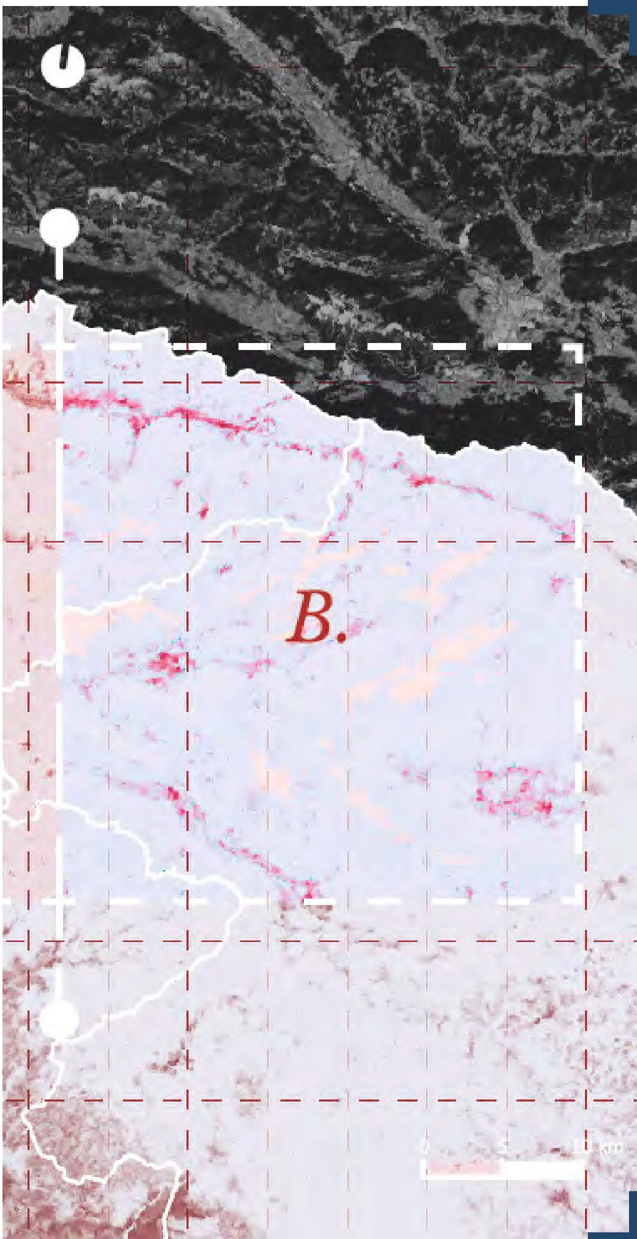


Figure 23 - Linking Climate Adaptation Planning and Sectoral Planning Approaches A.

Figure 24 - Linking Climate Adaptation Planning and Sectoral Planning Approaches B.



Step 1.

Legenda:

Land Surface Temperature

High < 45°

Medium < 35° <

Low > 25°

Sea Surface Temperature

High < 32°

Low > 28°

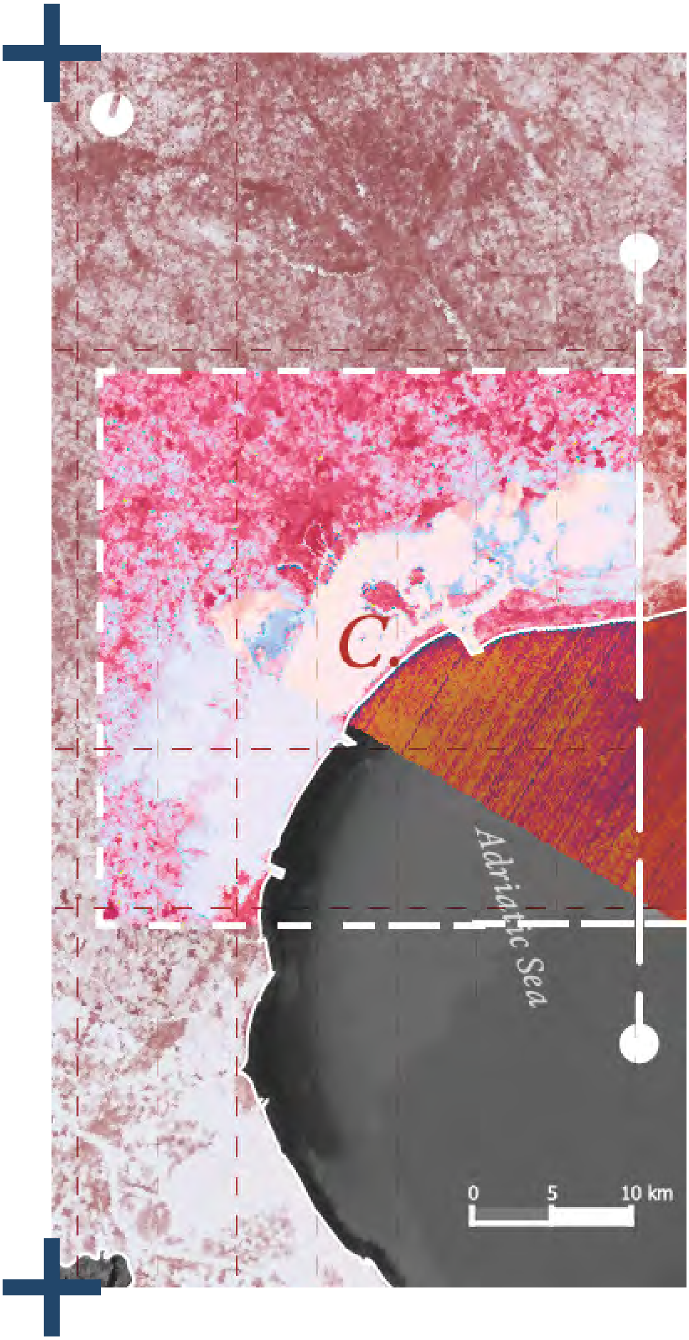
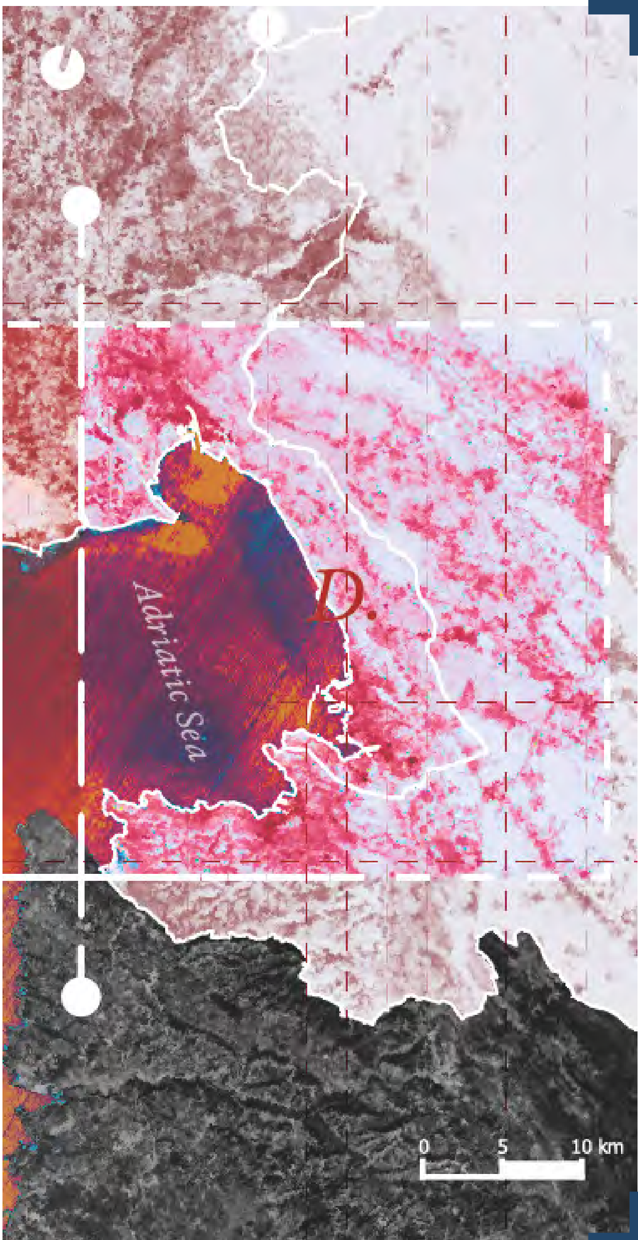


Figure 25 - Linking Climate Adaptation Planning and Sectoral Planning Approaches C.

Figure 26 - Linking Climate Adaptation Planning and Sectoral Planning Approaches D.



Step 1.

Legenda:

Land Surface Temperature

High < 45°

Medium < 35° <

Low > 25°

Sea Surface Temperature

High < 32°

Low > 28°

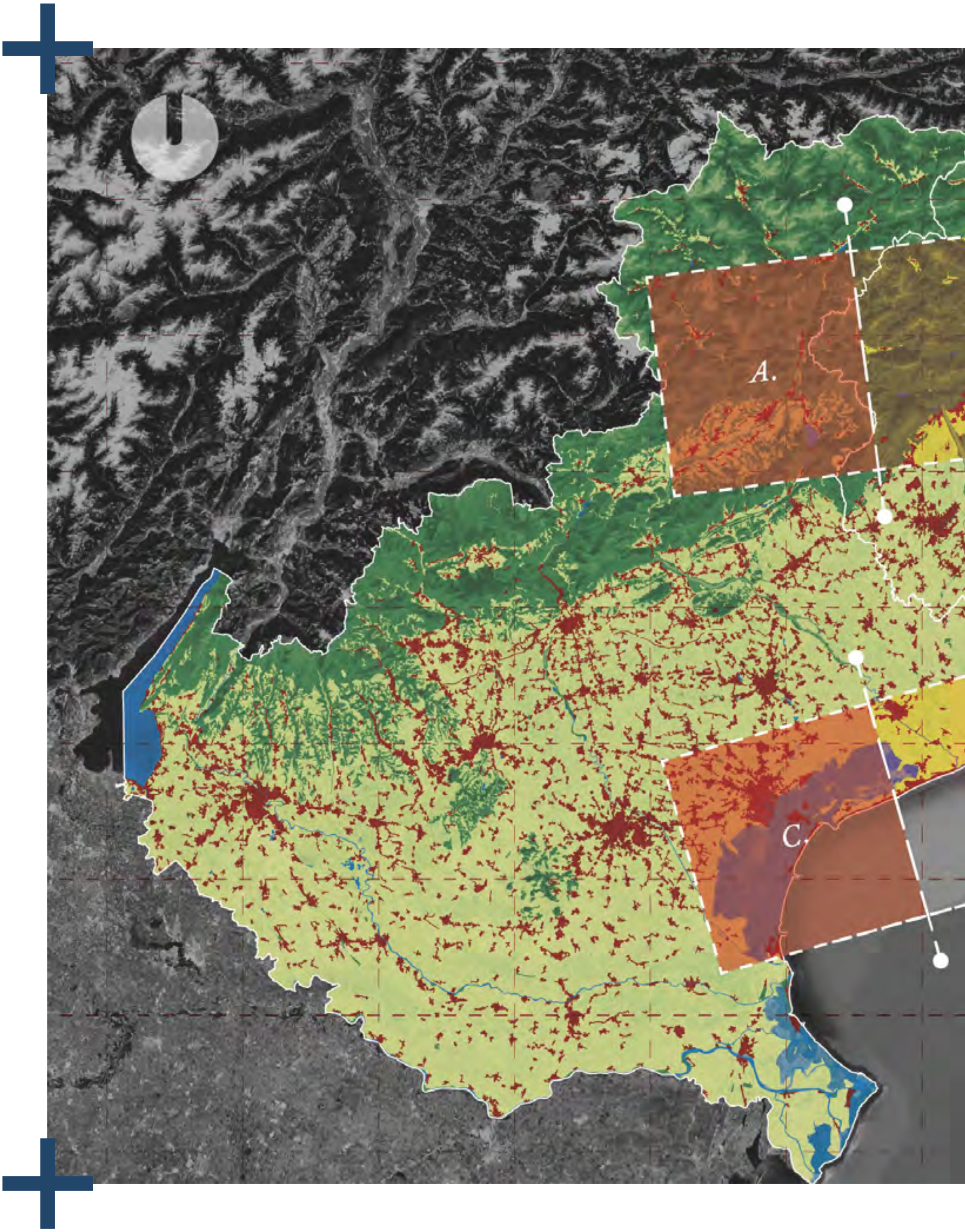
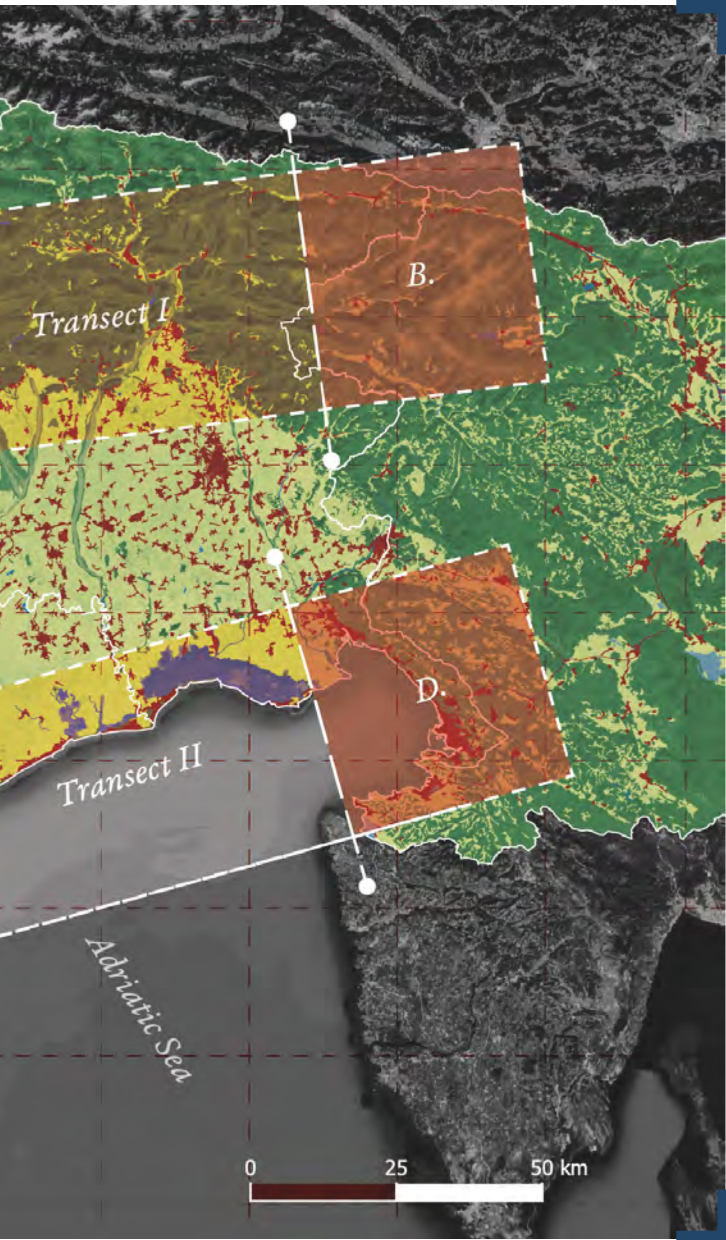


Figure 27 - Step 2: Corine Land Cover & Land Uses.



Step 2.

Legenda:

Crorine Land Cover

- *Artificial Surfaces;*
- *Agricultural areas;*
- *Forest and seminatural areas;*
- *Wetlands;*
- *Water bodies;*

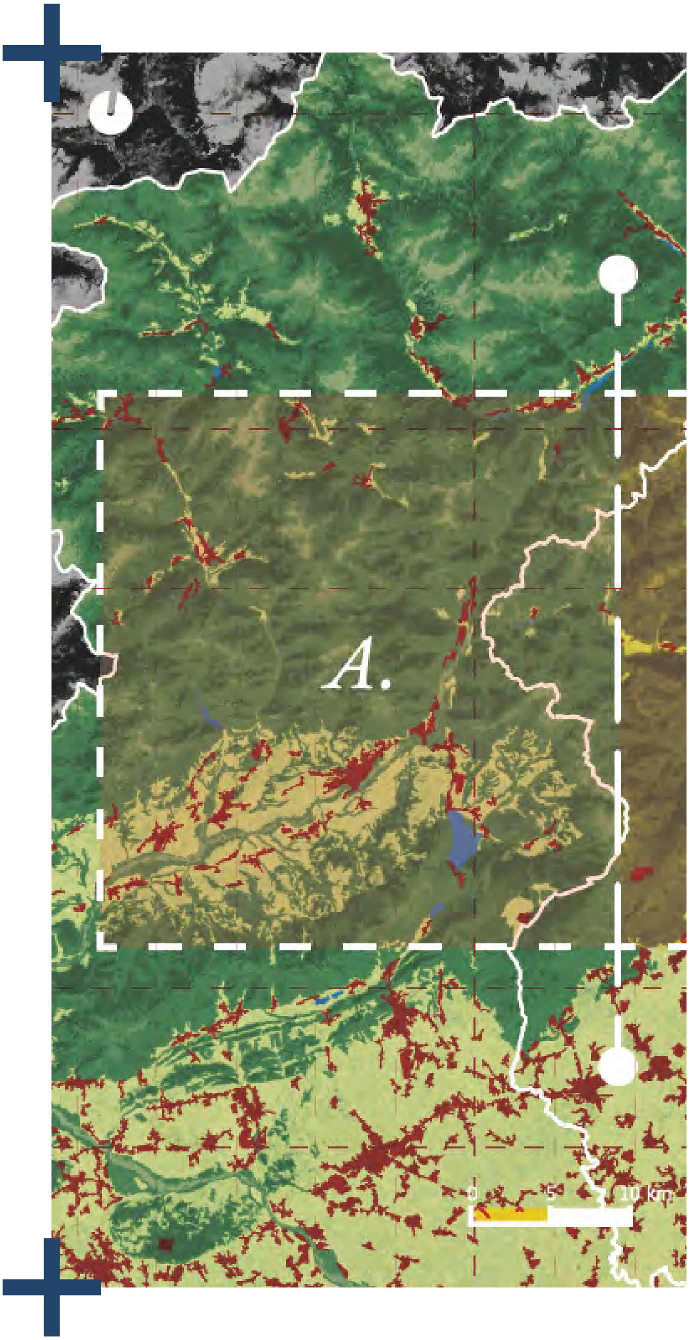
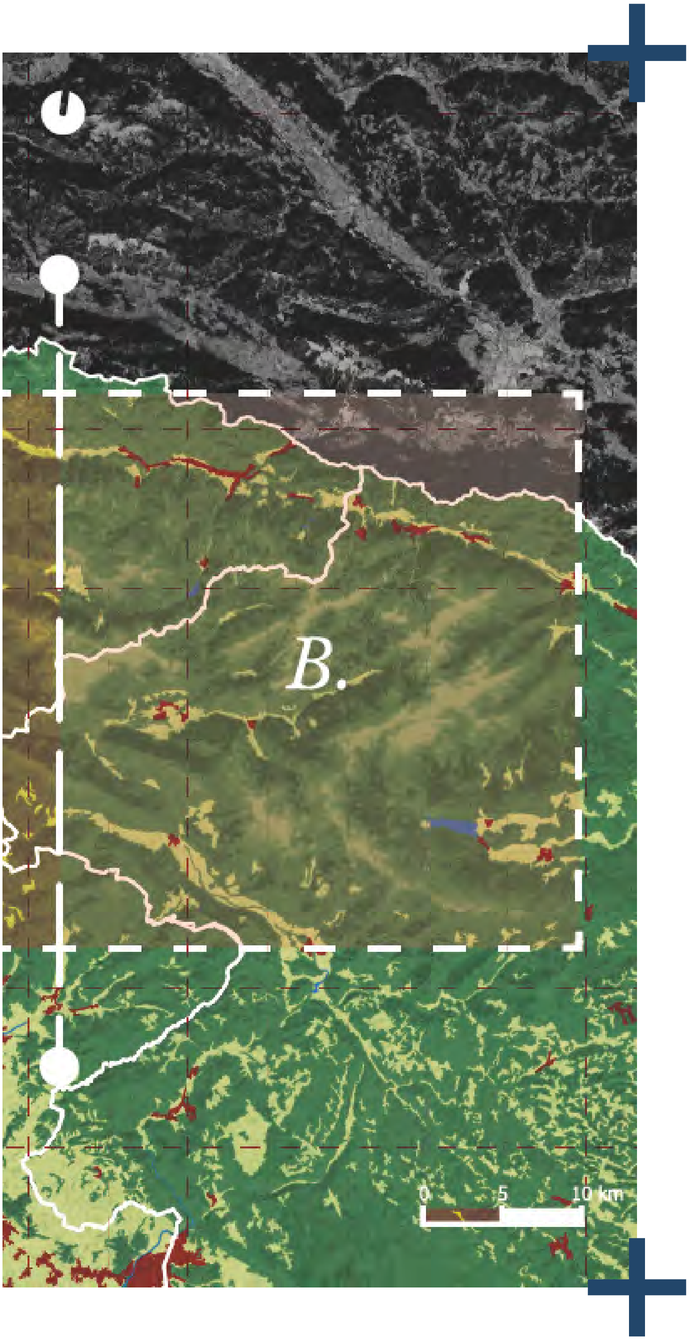


Figure 28 - Linking Climate Adaptation Planning and Sectoral Planning Approaches A.

Figure 29 - Linking Climate Adaptation Planning and Sectoral Planning Approaches B.



Step 2.

Legenda:

Crorine Land Cover

- *Artificial Surfaces;*
- *Agricultural areas;*
- *Forest and seminatural areas;*
- *Wetlands;*
- *Water bodies;*

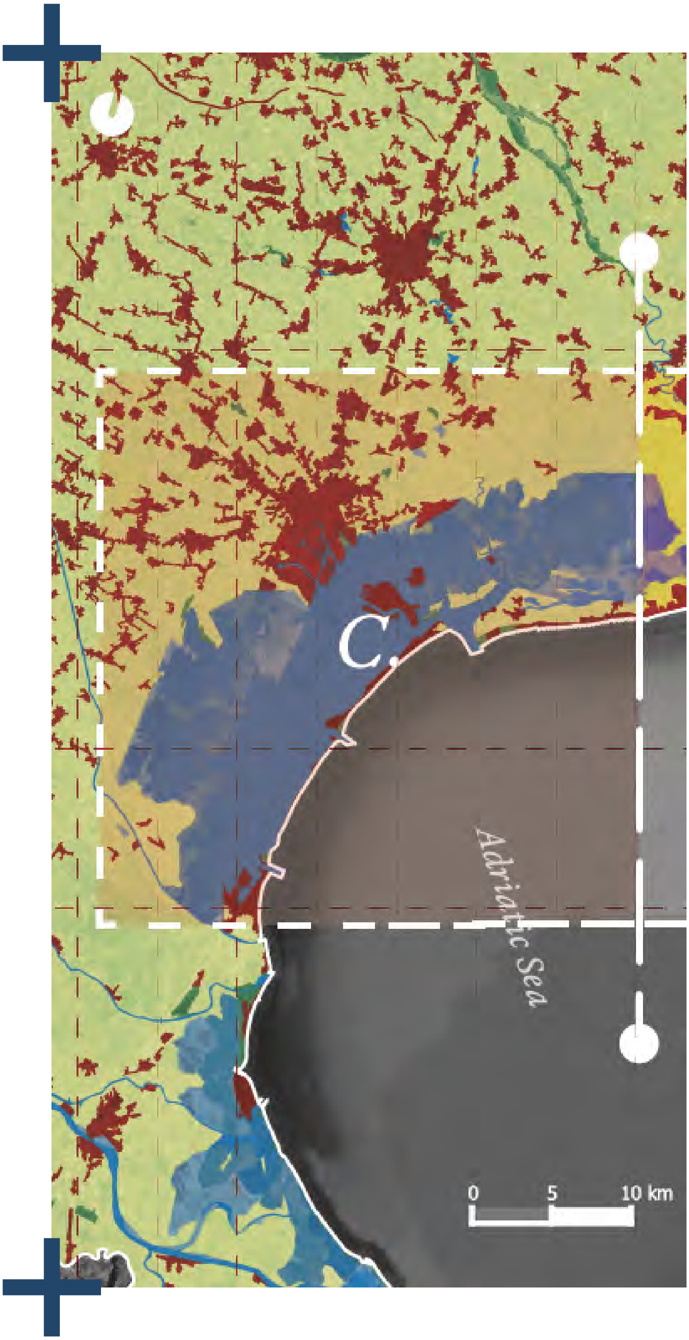
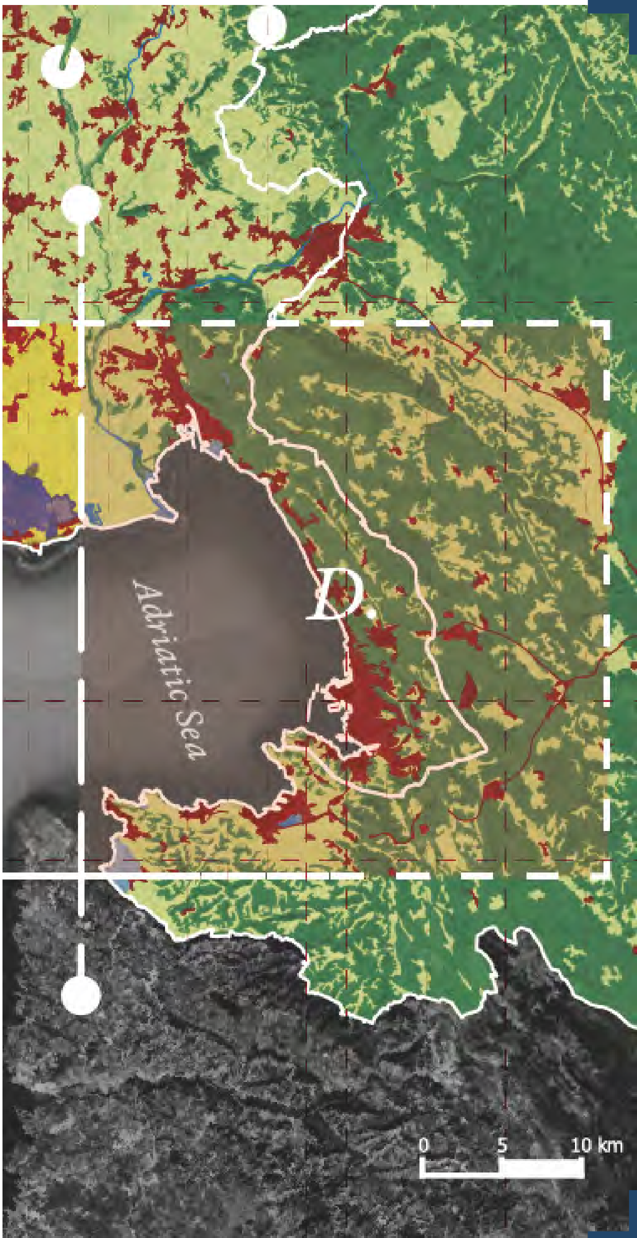


Figure 30 - Linking Climate Adaptation Planning and Sectoral Planning Approaches C.

Figure 31 - Linking Climate Adaptation Planning and Sectoral Planning Approaches D.



Step 2.

Legenda:

Crorine Land Cover

- *Artificial Surfaces;*
- *Agricultural areas;*
- *Forest and seminatural areas;*
- *Wetlands;*
- *Water bodies;*

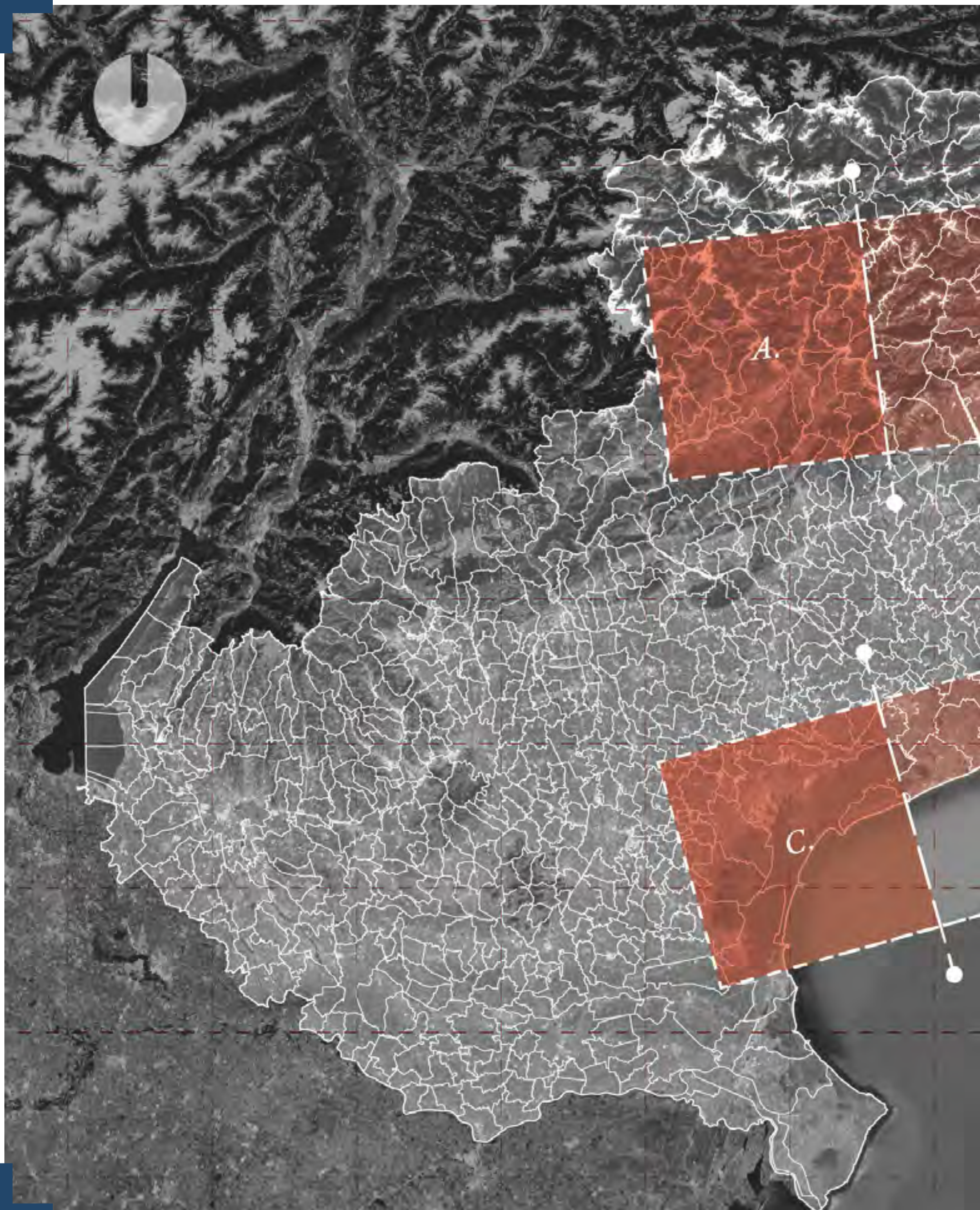


Figure 32 - Step 3: Administrative Subdivision & Territorial Organization.

Step 3.

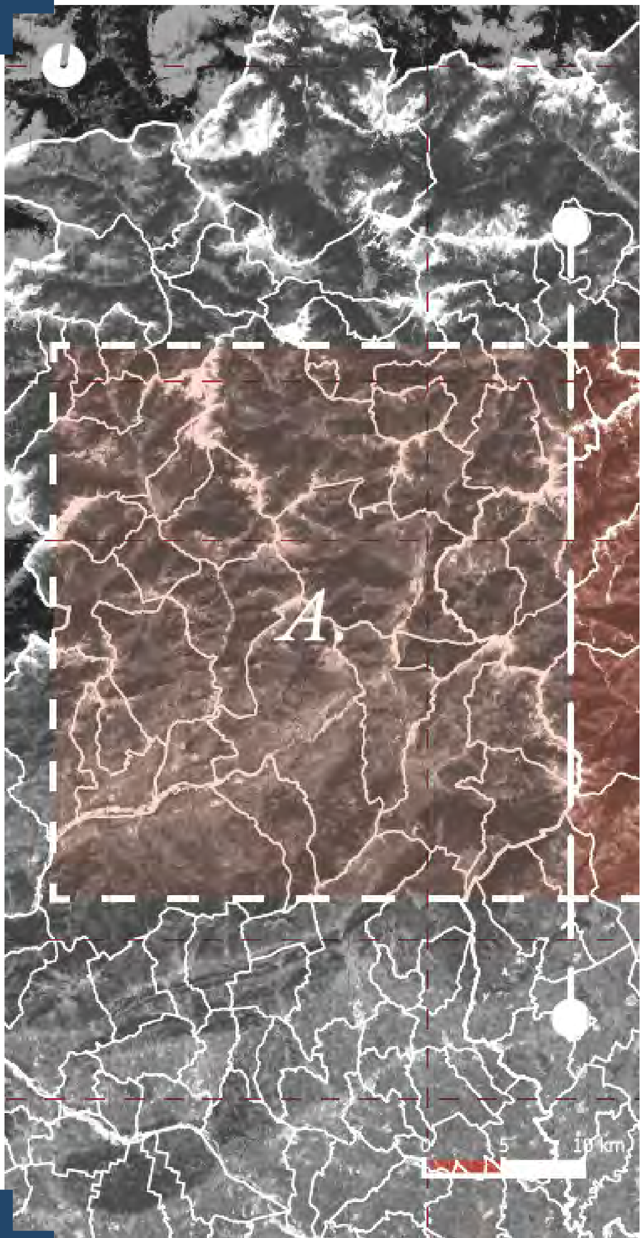
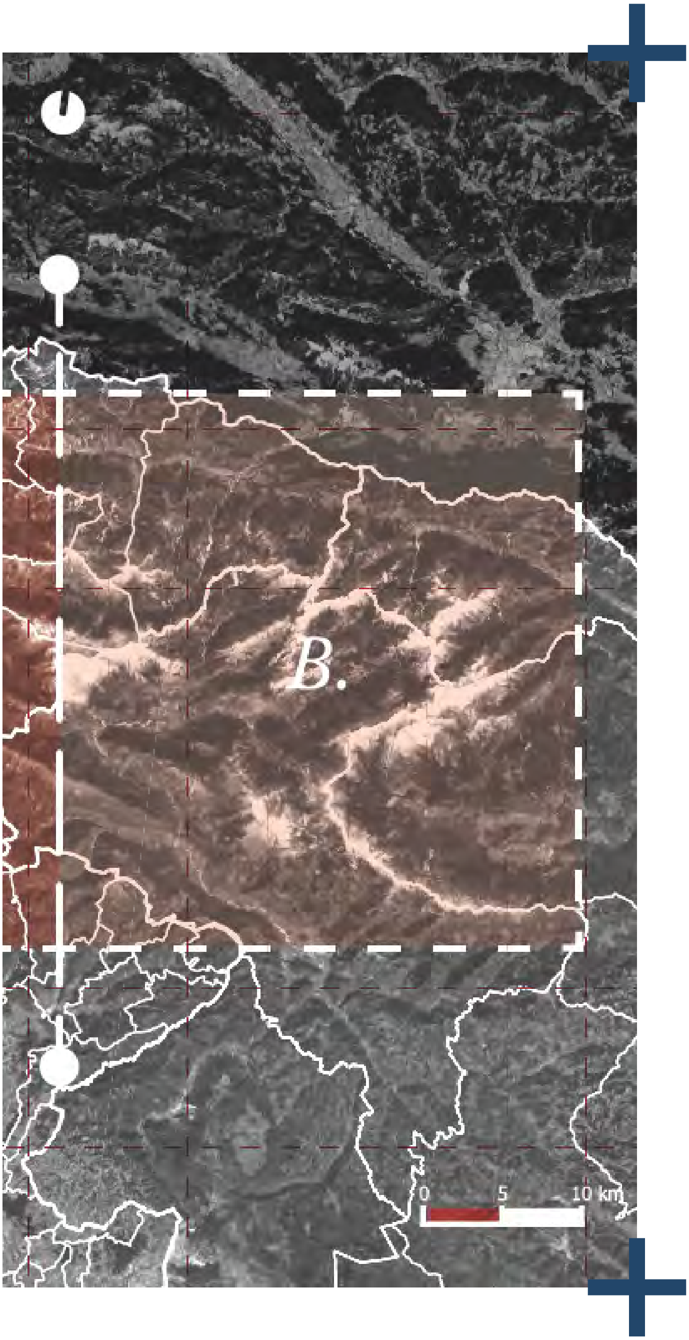


Figure 33 - Linking Climate Adaptation Planning and Sectoral Planning Approaches A.

Figure 34 - Linking Climate Adaptation Planning and Sectoral Planning Approaches B.



Step 3.

Figure 35 - Linking Climate Adaptation Planning and Sectoral Planning Approaches C.

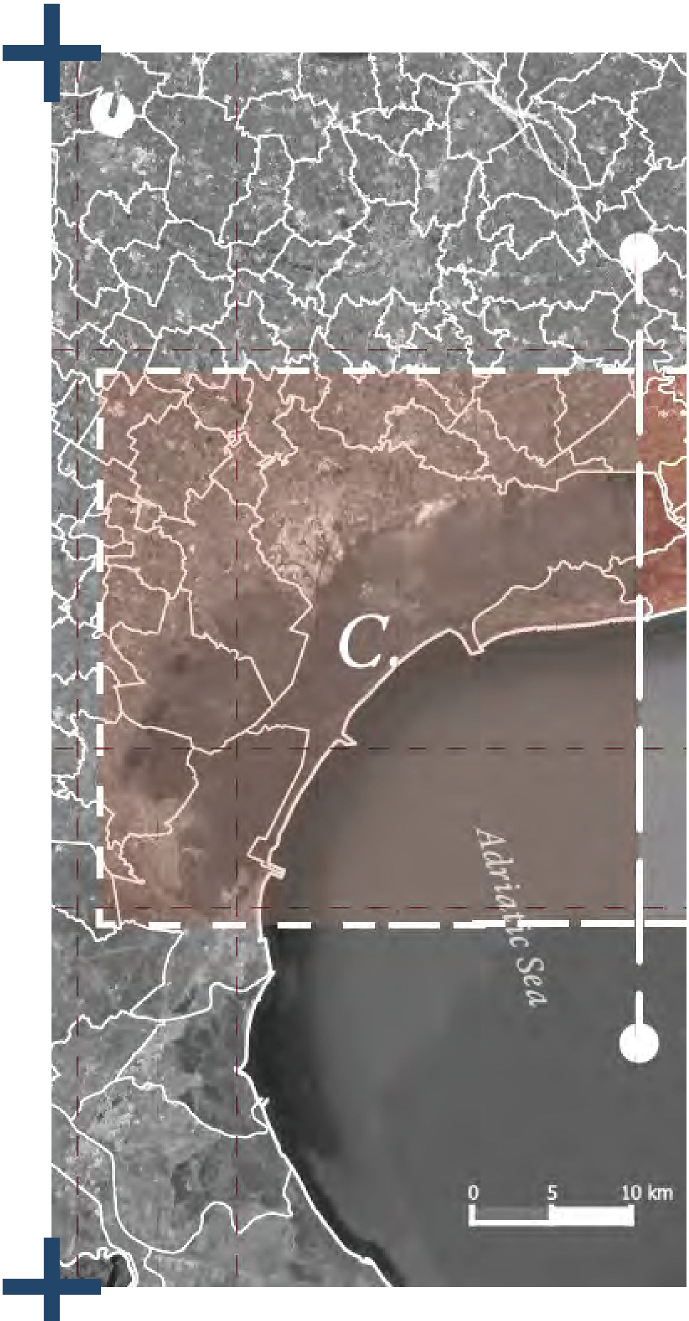
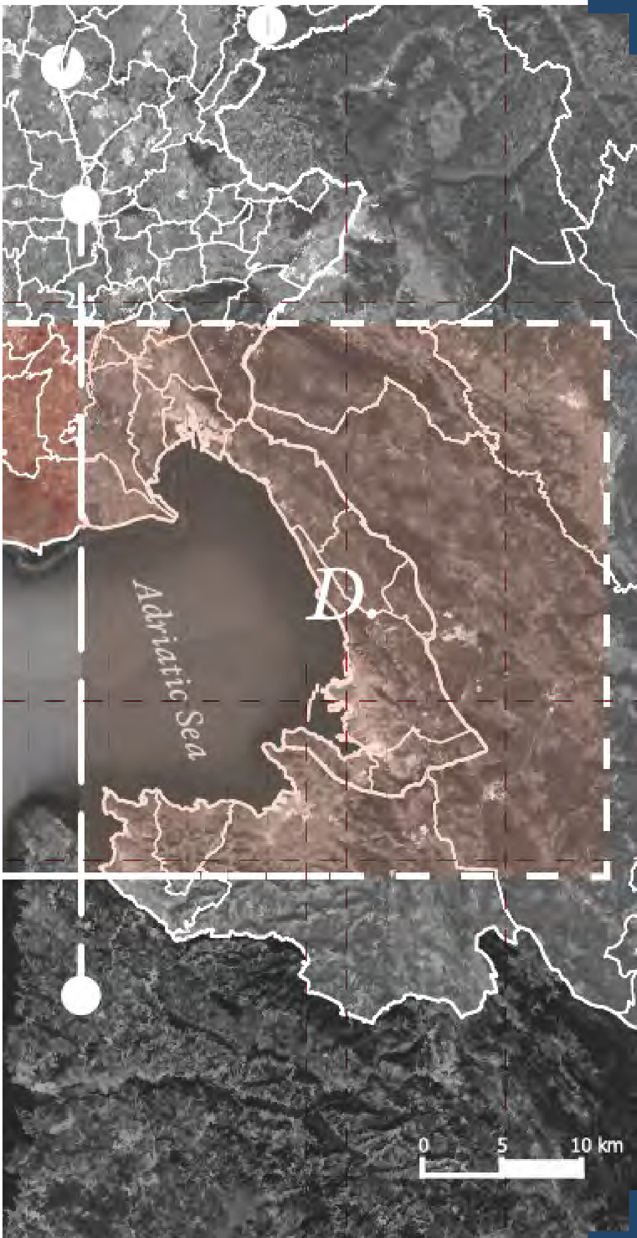


Figure 36 - Linking Climate Adaptation Planning and Sectoral Planning Approaches D.



Step 3.

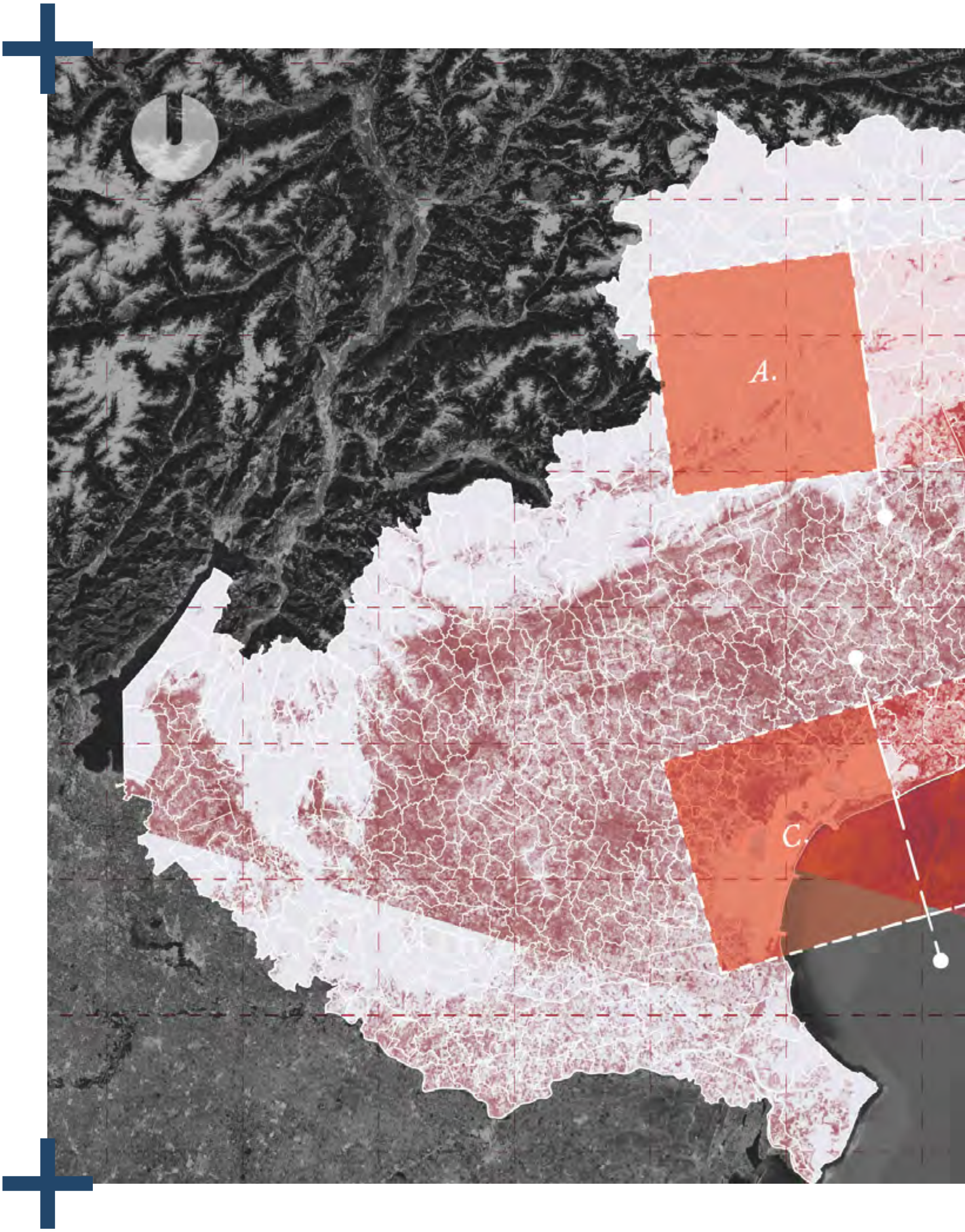
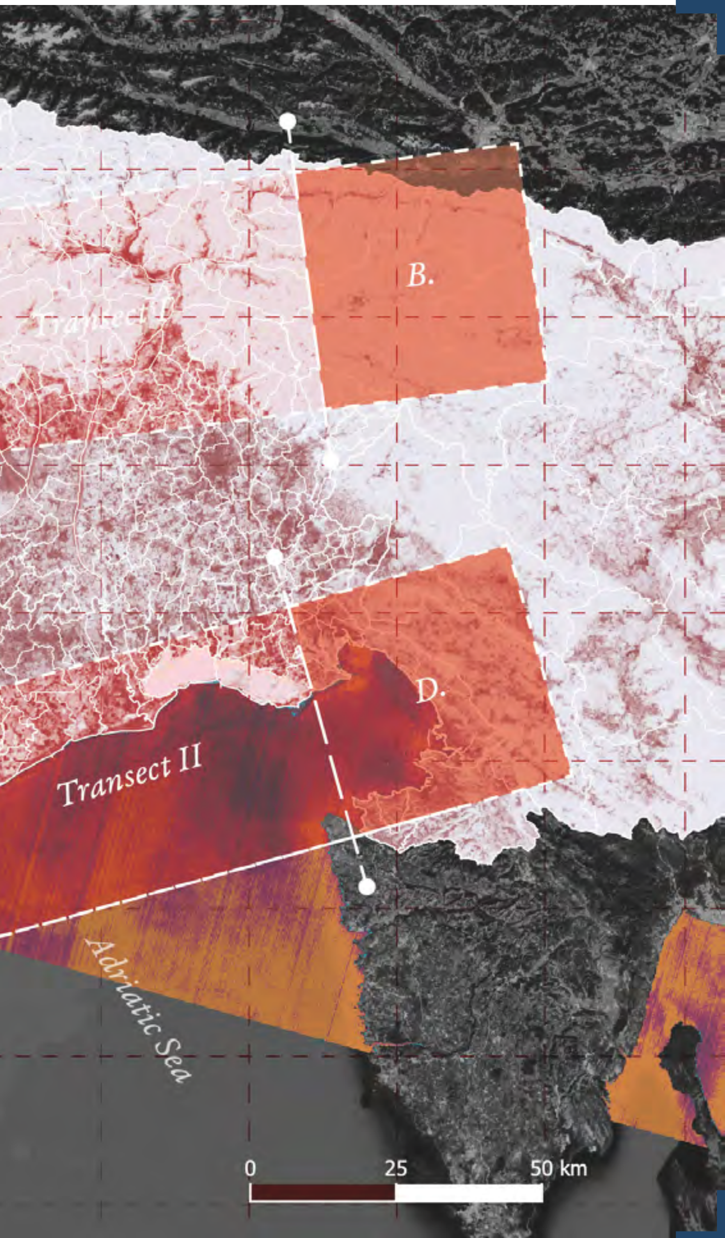


Figure 37 - Step 4: LST – SST & Administrative Subdivision.



Step 4.

Legenda:

Land Surface Temperature

High < 45°

Medium < 35° <

Low > 25°

Sea Surface Temperature

High < 32°

Low > 28°

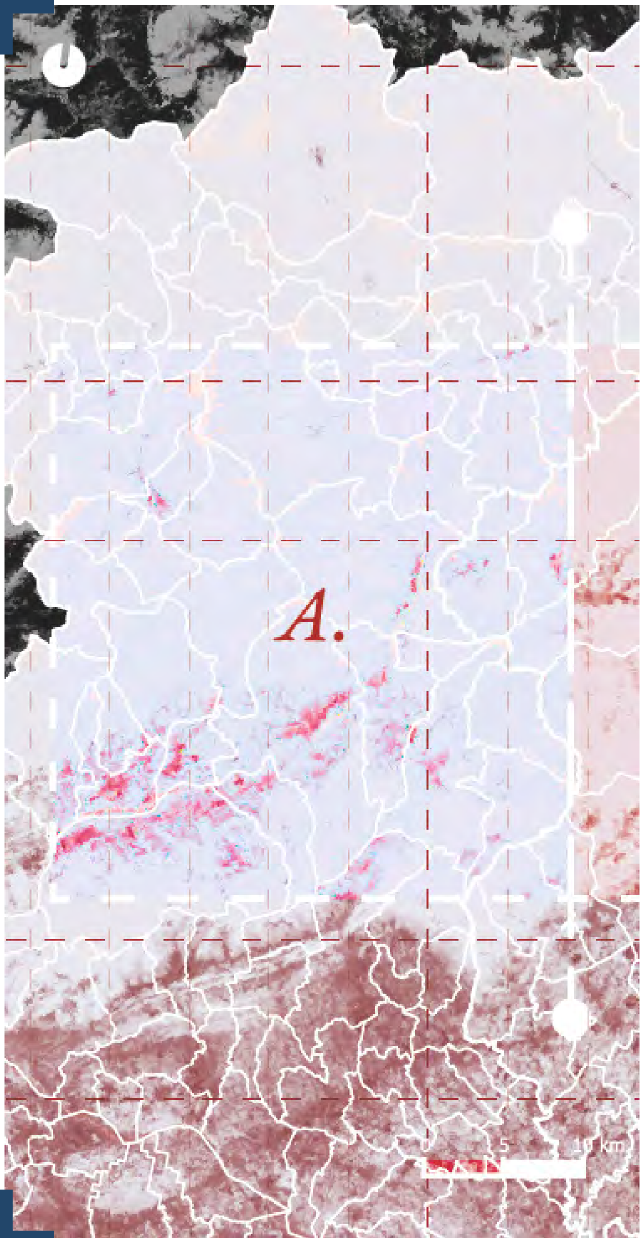
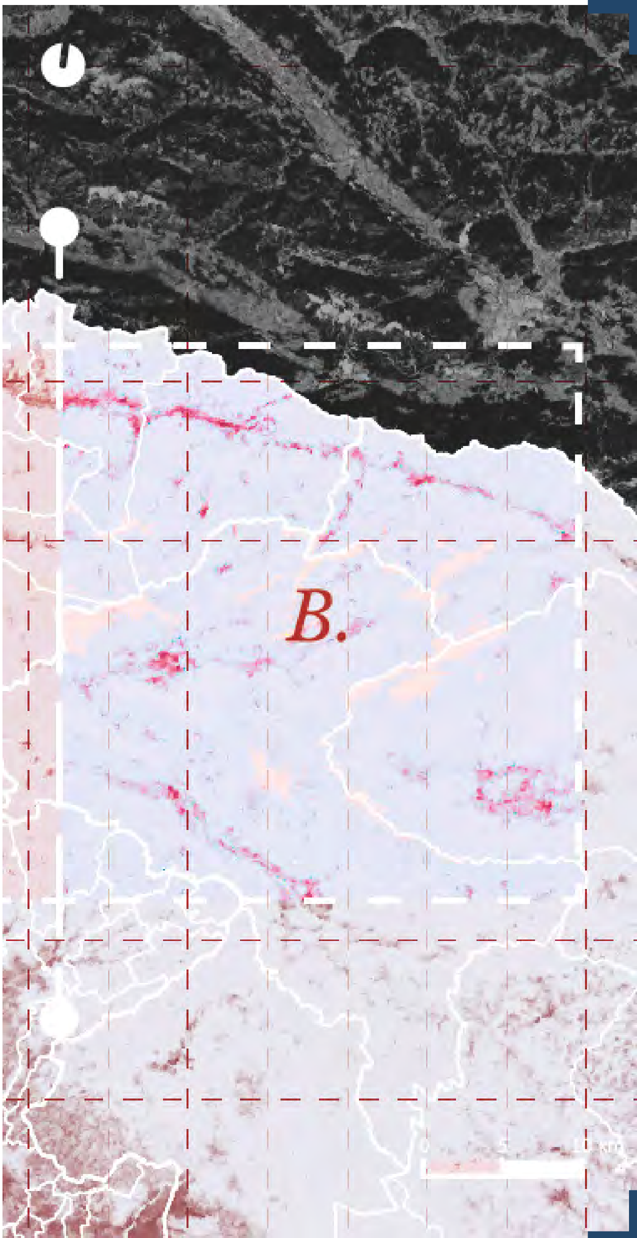


Figure 38 - Linking Climate Adaptation Planning and Sectoral Planning Approaches A.

Figure 39 - Linking Climate Adaptation Planning and Sectoral Planning Approaches B.



Step 4.

Legenda:

Land Surface Temperature

High < *45°*

Medium < *35°* <

Low > *25°*

Sea Surface Temperature

High < *32°*

Low > *28°*

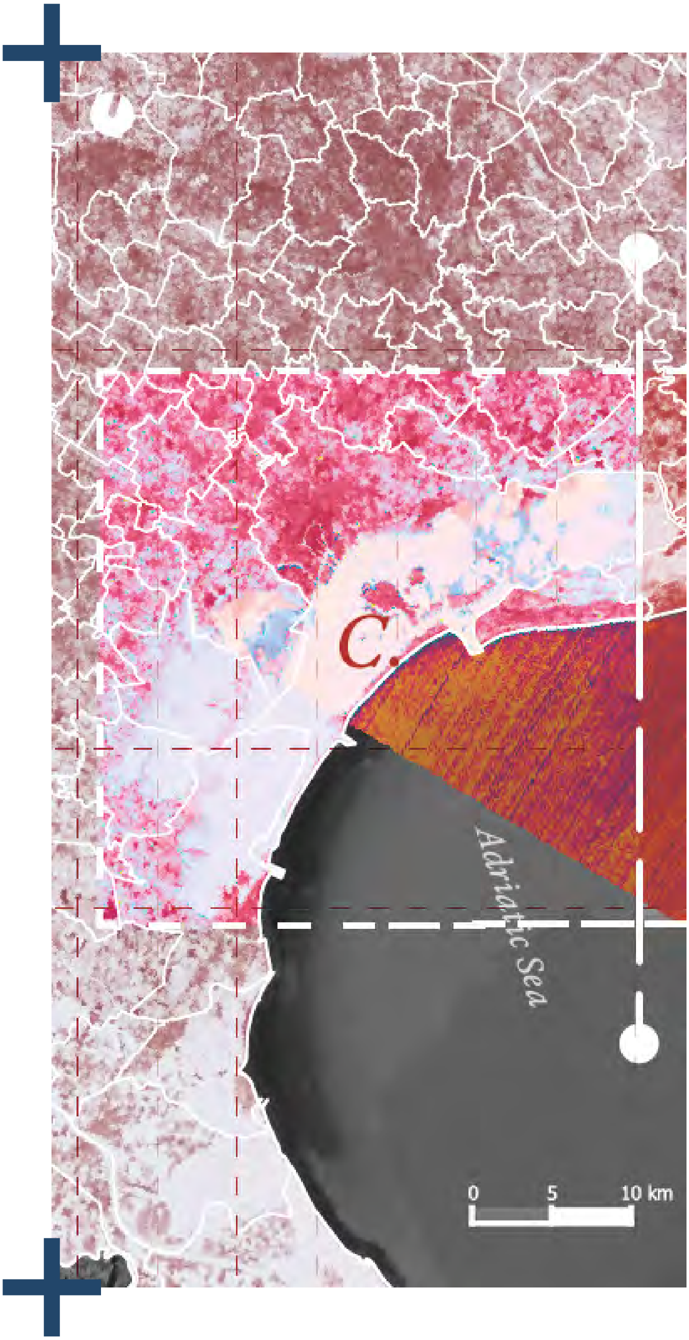
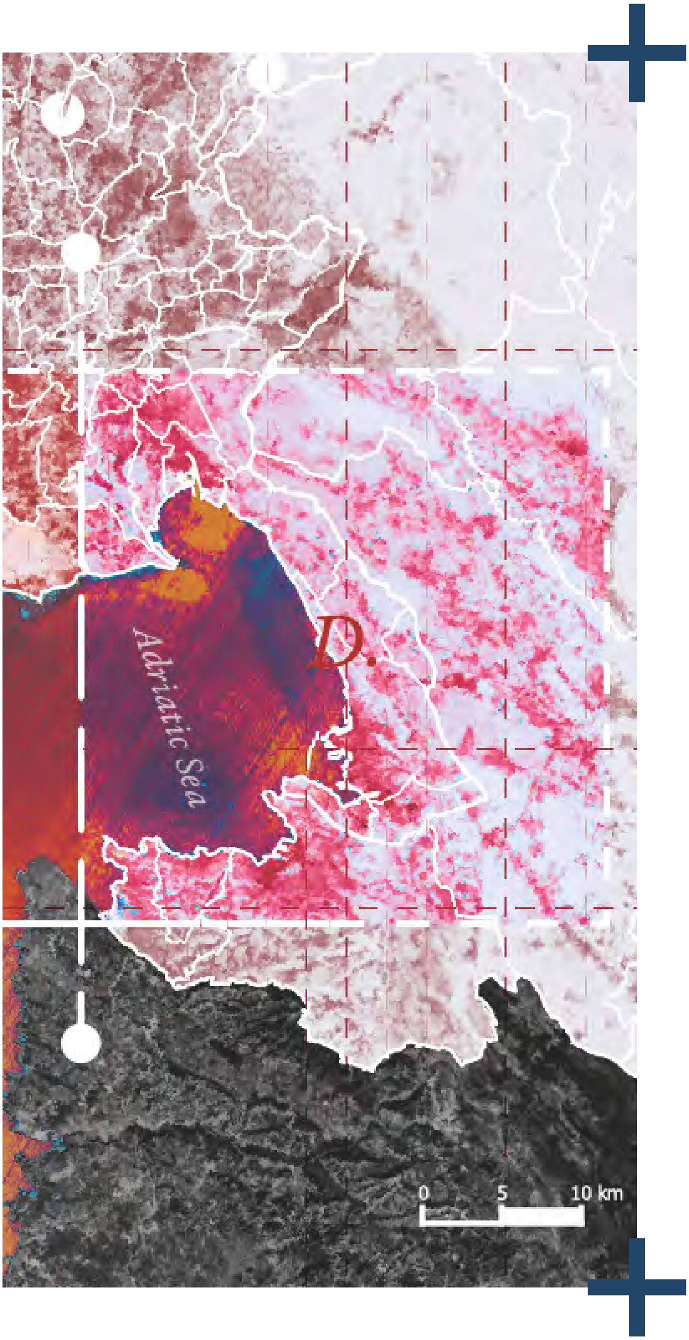


Figure 40 - Linking Climate Adaptation Planning and Sectoral Planning Approaches C.

Figure 41 - Linking Climate Adaptation Planning and Sectoral Planning Approaches D.



Step 4.

Legenda:

Land Surface Temperature

High < 45°

Medium < 35° <

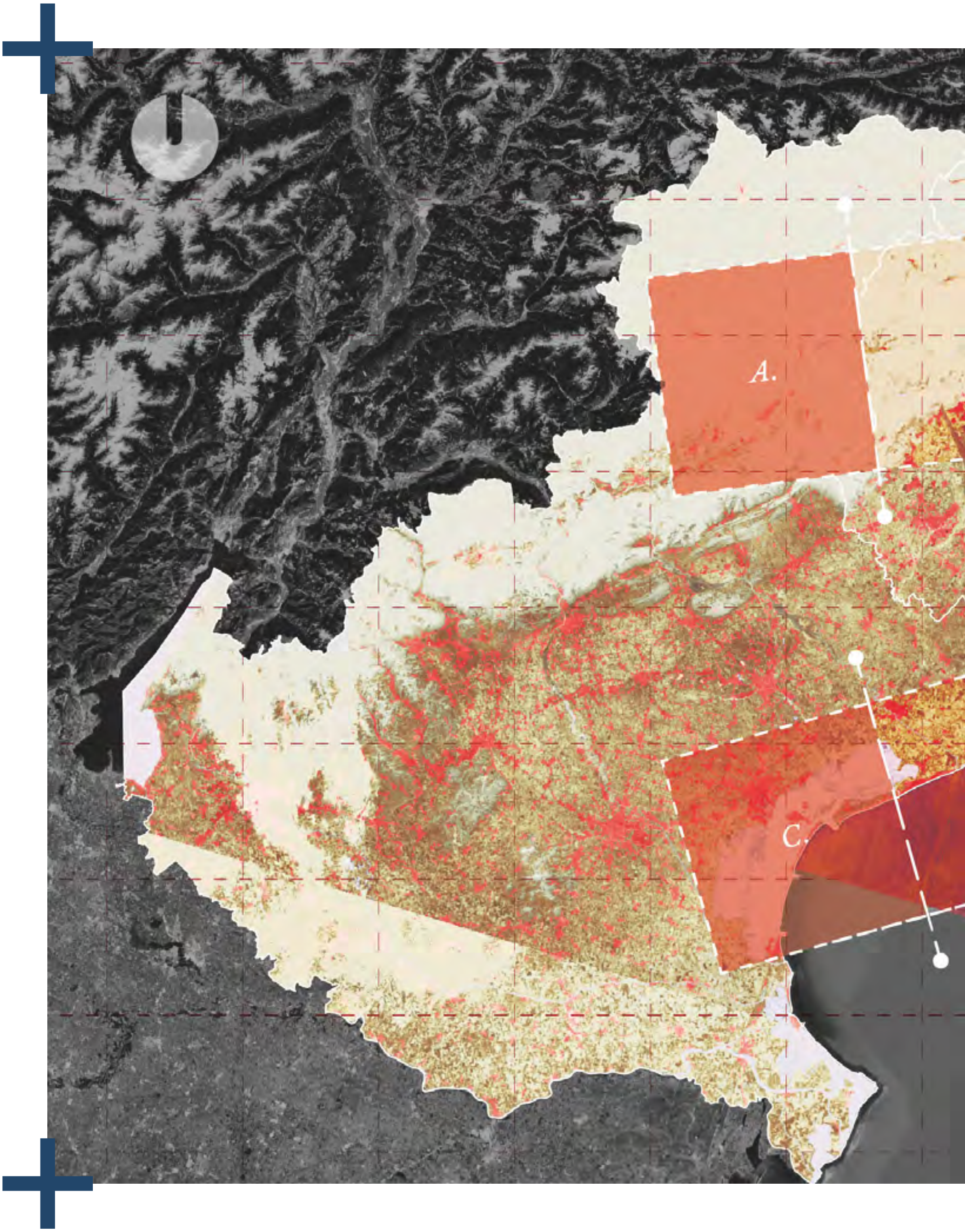
Low > 25°

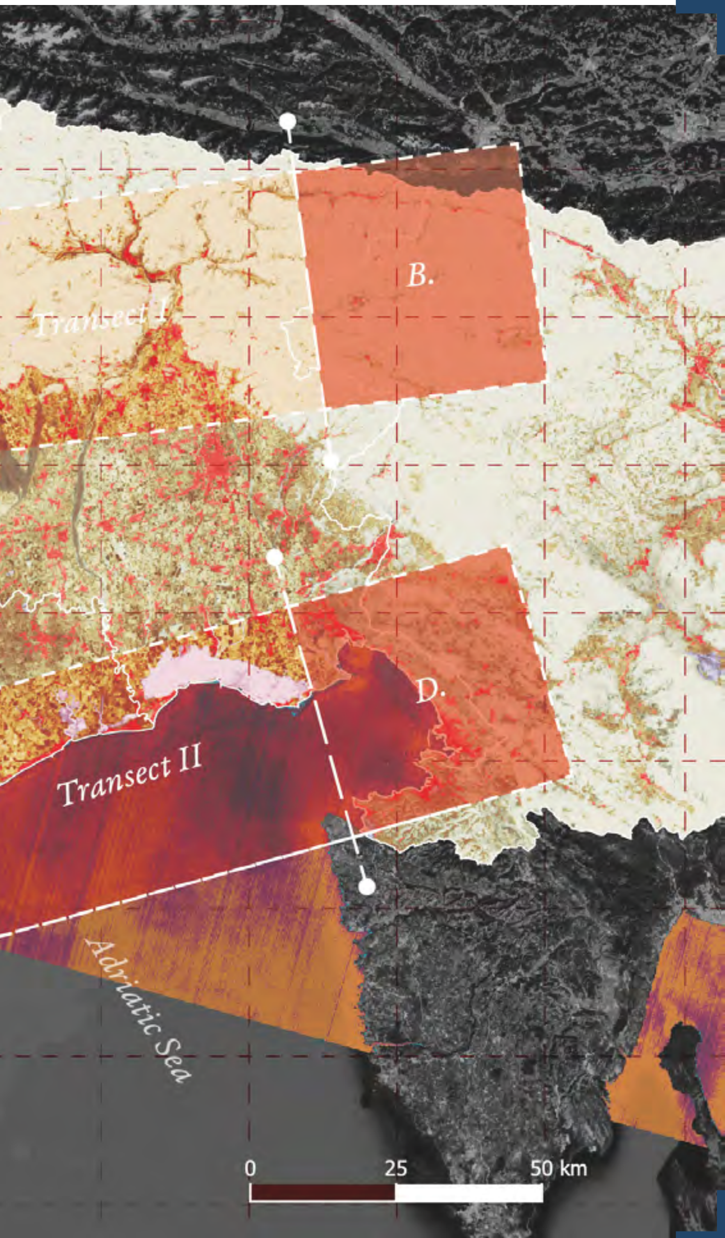
Sea Surface Temperature

High < 32°

Low > 28°

Figure 42 - Step 5: Corine Land Cover & LST – SST.





Step 5.

Legenda:

Land Surface Temperature

High < 45°

Medium < 35° <

Low > 25°

Sea Surface Temperature

High < 32°

Low > 28°

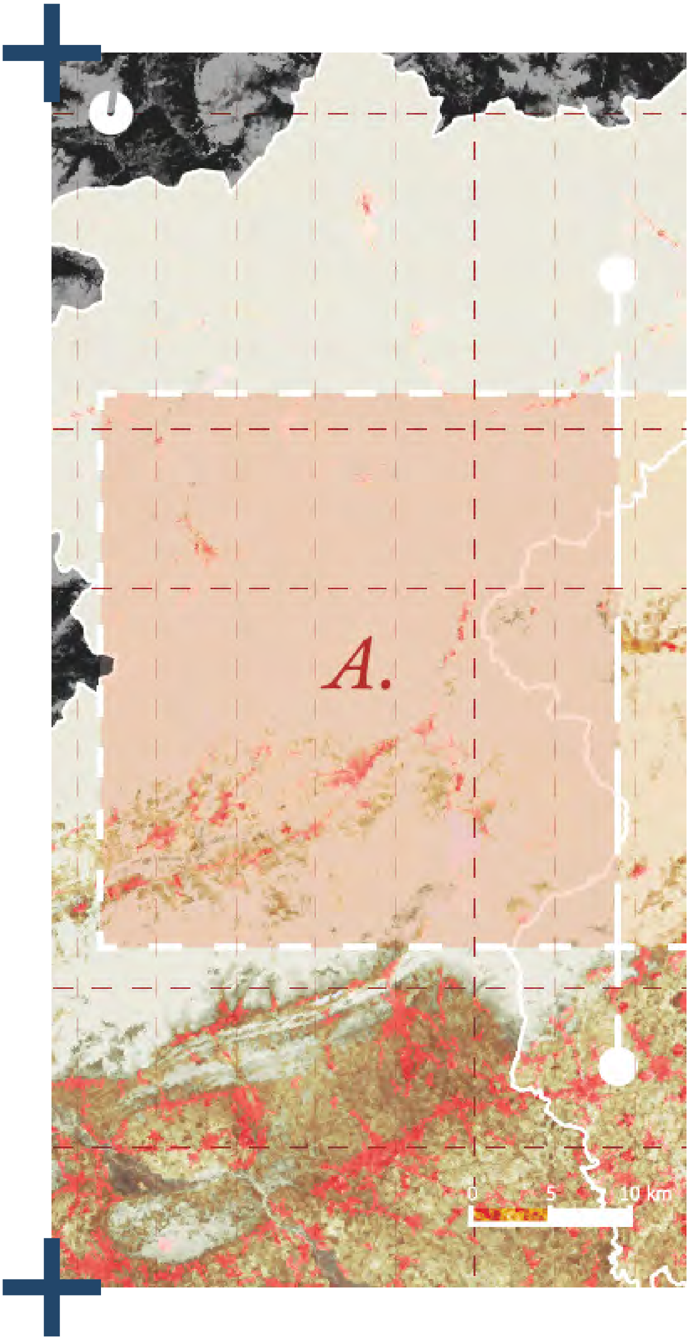
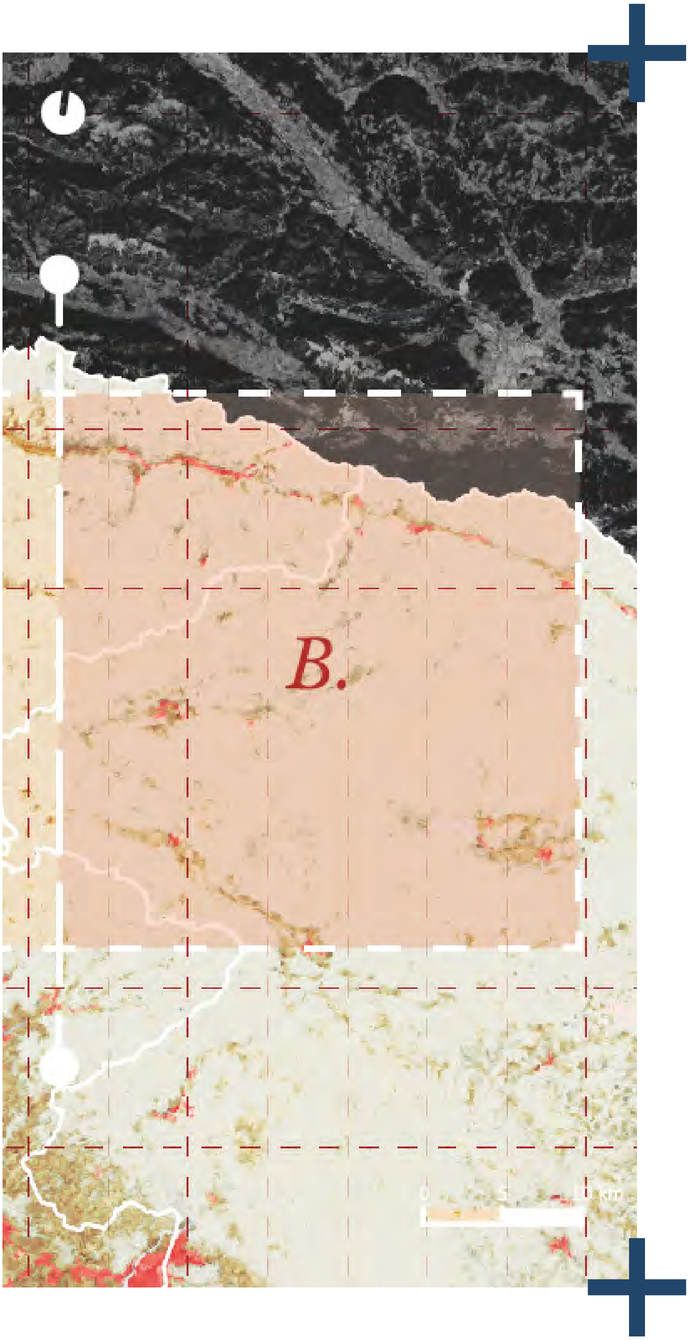


Figure 43 - Linking Climate Adaptation Planning and Sectoral Planning Approaches A.

Figure 44 - Linking Climate Adaptation Planning and Sectoral Planning Approaches B.



Step 5.

Legenda:

Land Surface Temperature

High < *45°*

Medium < *35°* <

Low > *25°*

Sea Surface Temperature

High < *32°*

Low > *28°*

Figure 45 - Linking Climate Adaptation Planning and Sectoral Planning Approaches C.

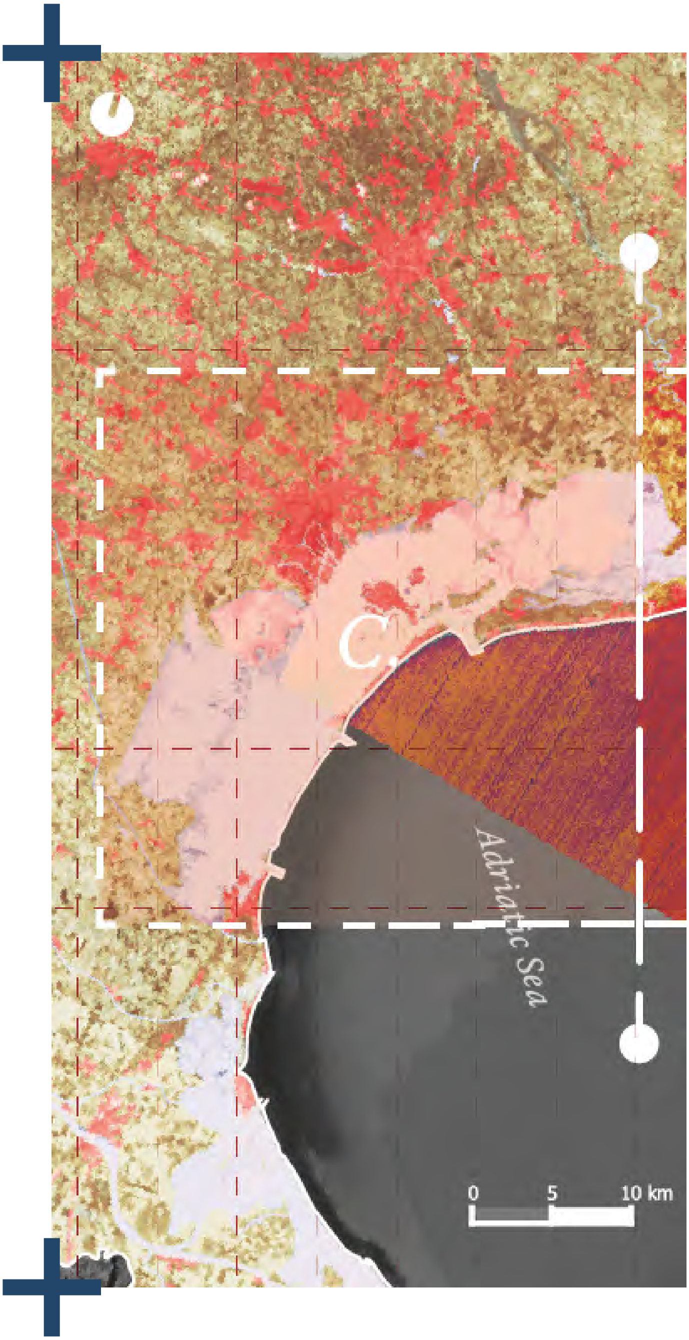
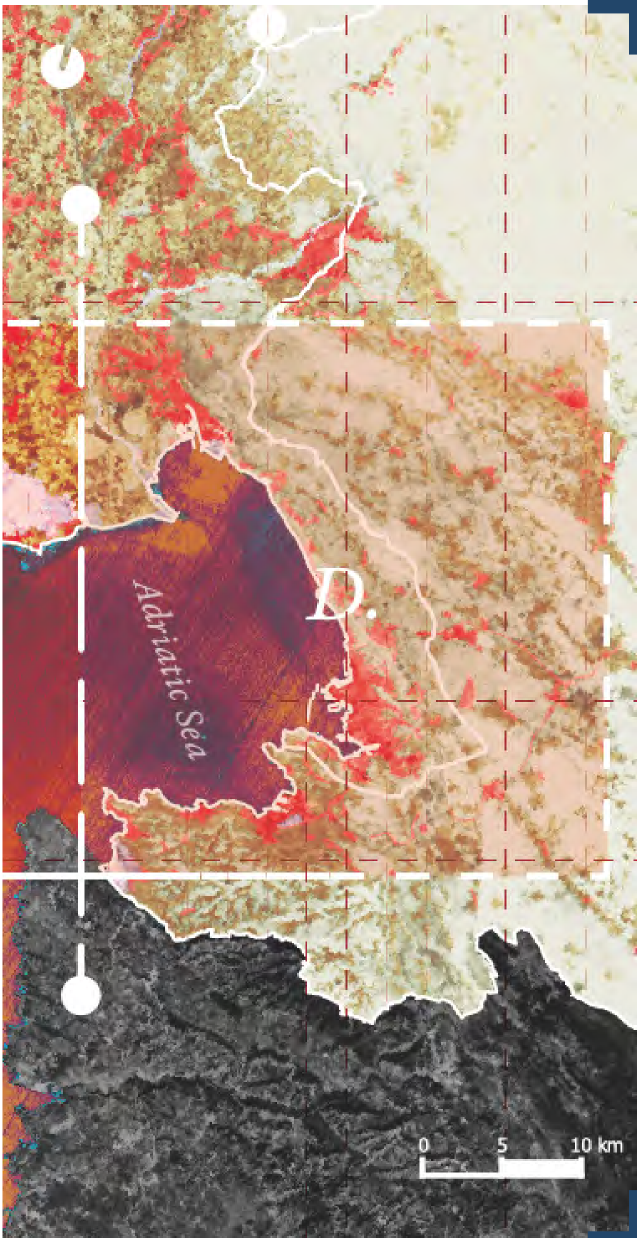


Figure 46 - Linking Climate Adaptation Planning and Sectoral Planning Approaches D.



Step 5.

Legenda:

Land Surface Temperature

High < *45°*

Medium < *35°* <

Low > *25°*

Sea Surface Temperature

High < *32°*

Low > *28°*

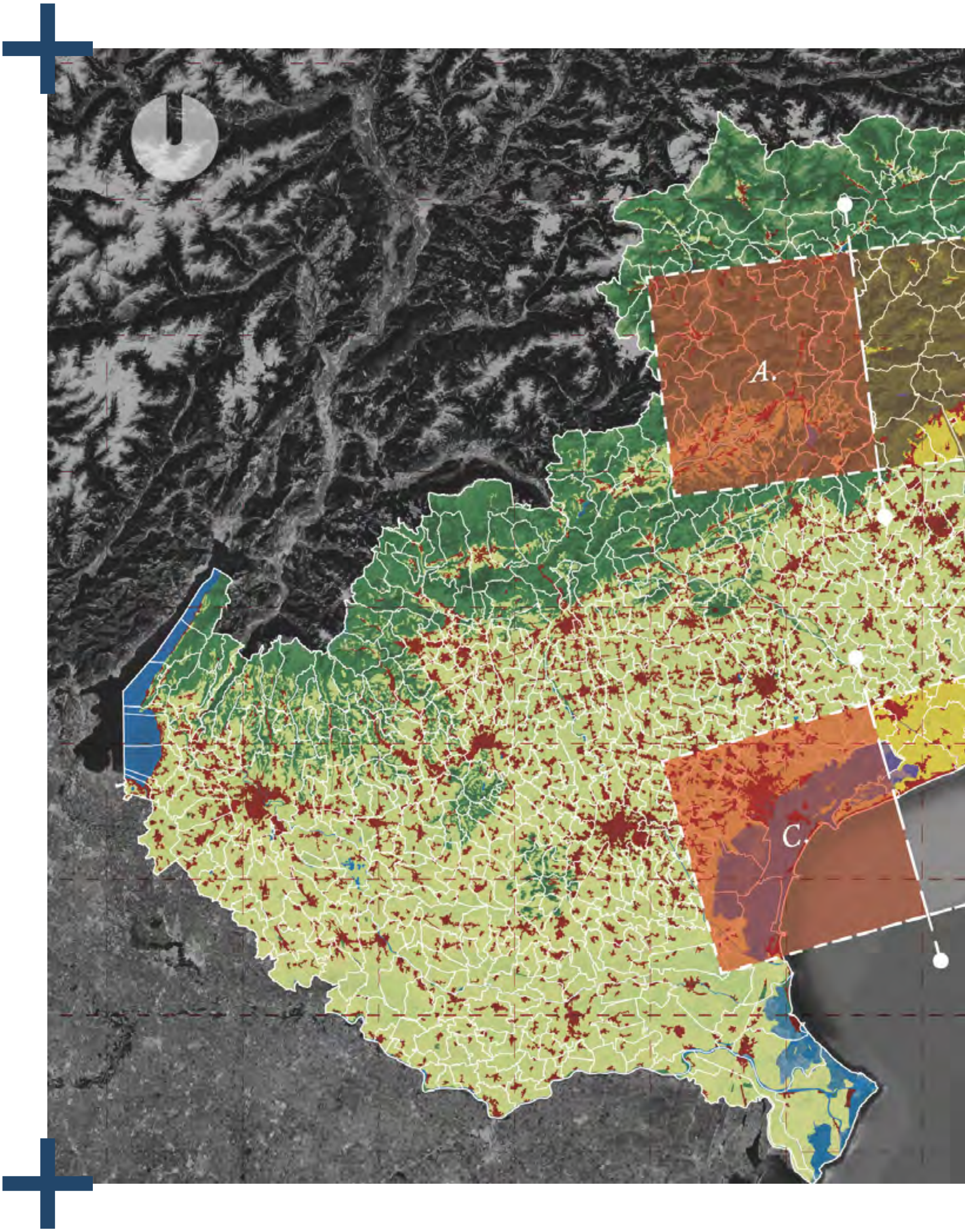
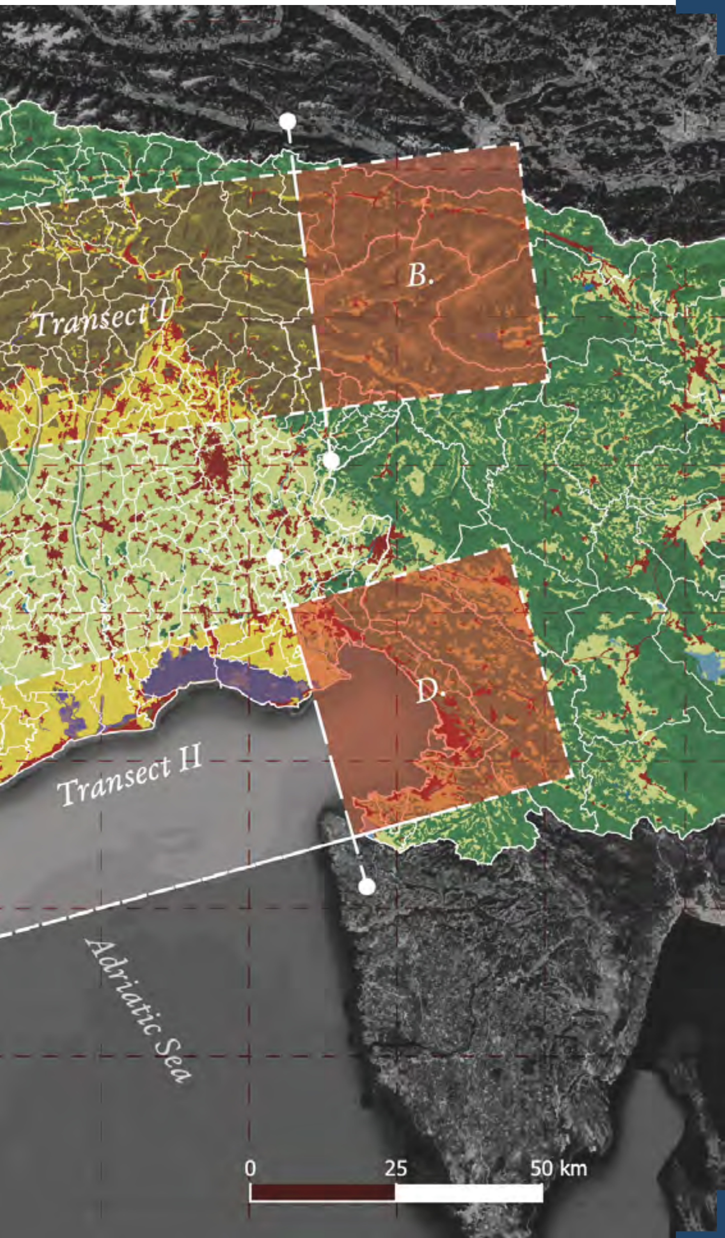


Figure 47 - Step 6: Administrative Subdivision & Corine Land Cover.



Step 6.

Legenda:

Crorine Land Cover

- *Artificial Surfaces;*
- *Agricultural areas;*
- *Forest and seminatural areas;*
- *Wetlands;*
- *Water bodies;*

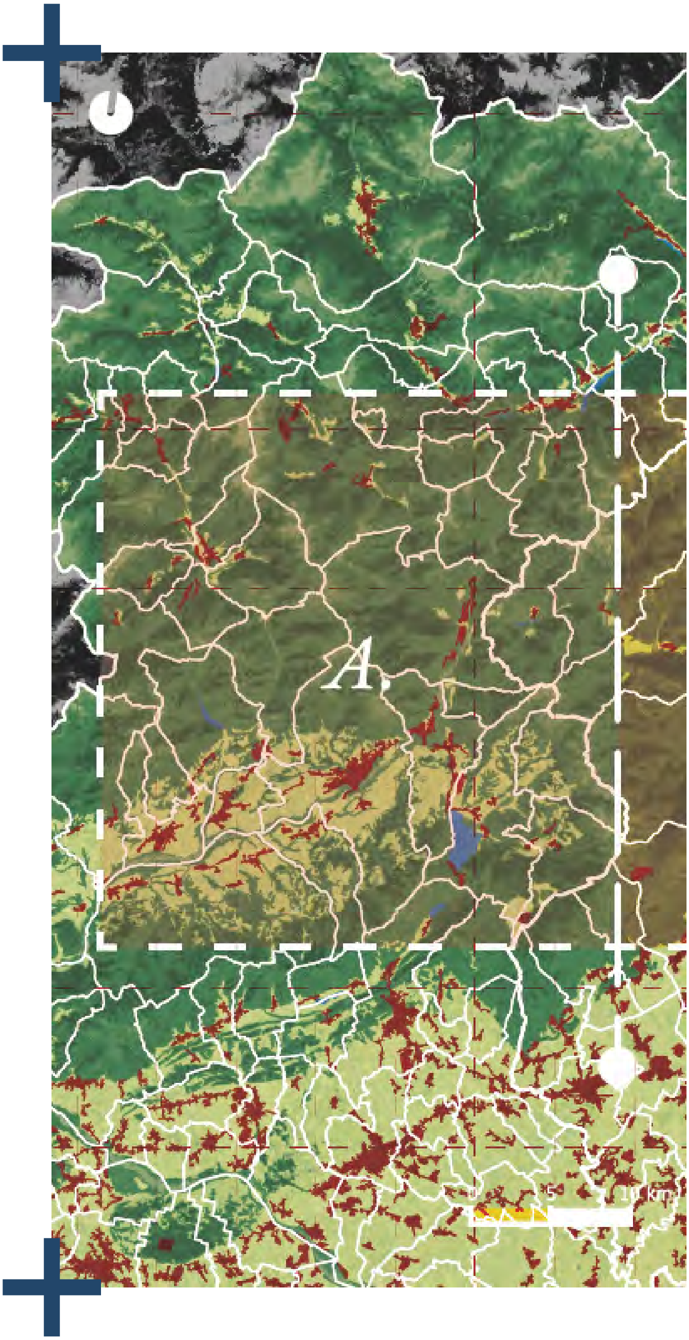
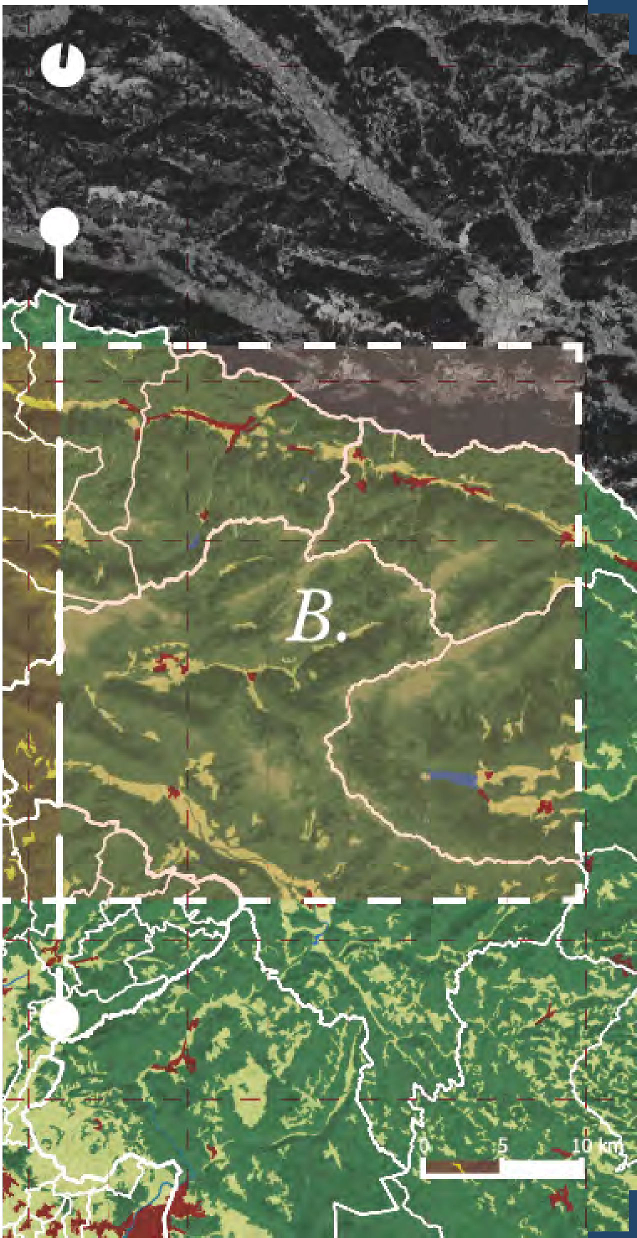


Figure 48 - Linking Climate Adaptation Planning and Sectoral Planning Approaches A.

Figure 49 - Linking Climate Adaptation Planning and Sectoral Planning Approaches B.



Step 6.

Legenda:

Crorine Land Cover

- *Artificial Surfaces;*
- *Agricultural areas;*
- *Forest and seminatural areas;*
- *Wetlands;*
- *Water bodies;*

Figure 50 - Linking Climate Adaptation Planning and Sectoral Planning Approaches C.

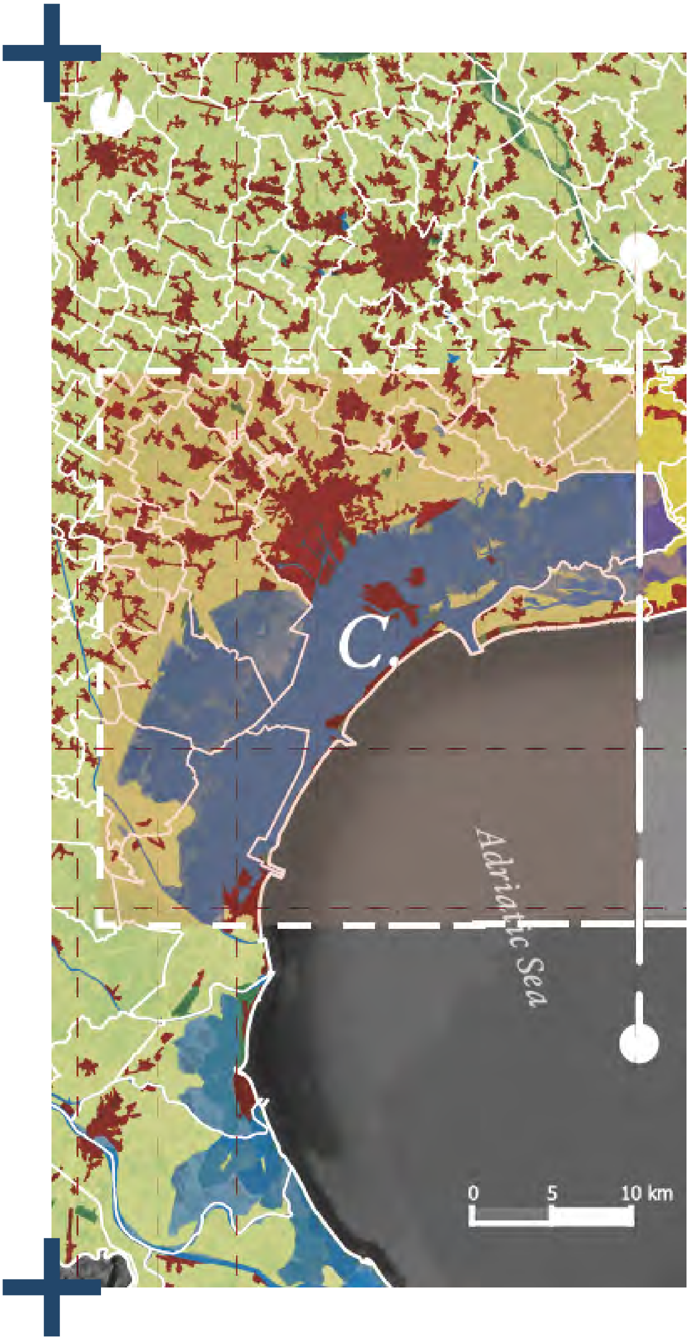


Figure 51 - Linking Climate Adaptation Planning and Sectoral Planning Approaches D.

Step 6.

Legenda:

Crorine Land Cover

- *Artificial Surfaces;*
- *Agricultural areas;*
- *Forest and seminatural areas;*
- *Wetlands;*
- *Water bodies;*

1.3.3.3. - Climate Vulnerability perspective

Referring to the process of identifying the elements that can support the definition of transboundary adaptation strategies, a key role is played by the ability to recognize the predisposition of territories to be vulnerable to climate change impacts. This chapter takes forward the territorial vulnerability assessment, with a focus on soil types potentially impacted by urban heat island (uhi) and urban flooding (uf).

These impacts are therefore recognized as indicators, as described extensively in the Vulnerability Atlas, of the susceptibility of territories to be affected by extraordinary variations in temperature and precipitation. In this sense, heat and water are used as spatial markers to identify certain morphological conditions of the territory - such as the scarce presence of greenery or high levels of waterproofing - that are configured as elements that generate a reduced capacity to adapt to climate impacts. These contexts, therefore, can be considered as the elements with the highest priority for intervention from a strategic point of view.

The reading key used to recognize the territorial systems most exposed to these two climatic impacts is the definition of land uses, which well summarizes the main morphological-functional characterisations of the territory. Specifically, the third level of classification of the Corine Land Cover updated in 2018 was used. It should be noted that, since these are urban impacts, only the classes strictly related to this context have been selected:

1. Construction sites (CS);
2. Continuous urban fabric (CUF);
3. Discontinuous urban fabric (DUF);
4. Industrial or commercial units (ICUs);
5. Major infrastructural nodes (MIN);
6. Road and rail networks and associated land (RRN);
7. Sports and leisure facilities (SLF).

Observing and comparing the distribution of these classes on the project territories (Figure 52) it is immediately evident that the discontinuous urban fabric is the prevalent type. This is because these territories are characterized by the phenomenon of urban dispersion, which sees the countryside interspersed with small urban centers and industrial and commercial settlements. The latter, in fact, represent

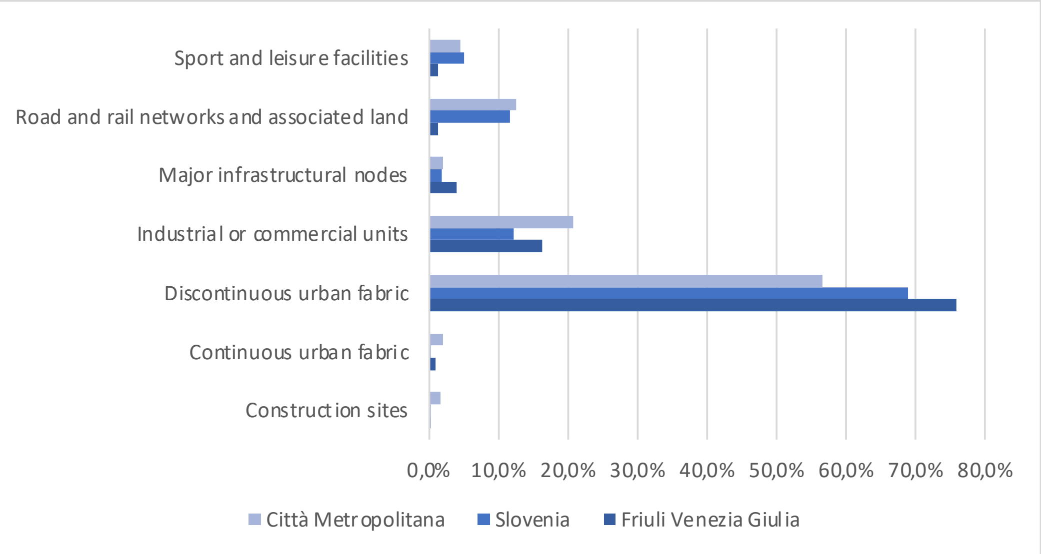


Figure 52 - Distribution of sealed land use classes in the three project territories.

the second most widespread class in all three areas.
Starting from the hexagonal mesh, the most vulnerable class was extracted and reclassified according to 4 levels of susceptibility to uhi and uf: low (L), medium-low (M-L), medium-high (M-H) and high (H). This results in a new extreme class vulnerability mapping. At this point, the impacted soil was compared with the reference statistical unit in two different ways: in the first case, with the surface area occupied by the most critical class and, in the second case, with the total extension of the matrix within each project territory - which, as we recall, in the case of the FVG Region and Slovenia does not

cover the entire surface area. To facilitate the reading of the statistical elaborations that follow, the table below (Table 1) shows the degree of detail with which the analyses were conducted; the symbol will act as a navigator next to each return for this purpose.

Table 1 - Reference for reading statistical elaborations.

Symbol	Code	Description	Level of detail
	V/T_1	Ratio of vulnerable soil (V) to project area (T)	Vulnerability classes
	V/T_2	Ratio of vulnerable soil (V) to project area (T)	Land use typology and respective vulnerability classes
	V/V	Ratio of vulnerable soil (V) to land area (V)	Land use typology and respective vulnerability classes

1.3.3.3.1. - Metropolitan City of Venice

Analyses carried out on the sealed surfaces of the territorial system of the Metropolitan City of Venice (Figure 53 e Table 2) allow us to recognize that most of the territory is made up of a discontinuous urban fabric. What is instead relevant is how there is a preponderance of areas for industrial use and associated with road and rail transport networks.

Table 2 - Statistical detail of absolute values (ha) and percentages by type of impermeable land use in the Metropolitan City of Venice.

Legend	Area (ha)	Percentage
Construction sites	536,97	1,6%
Continuous urban fabric	667,43	2,0%
Discontinuous urban fabric	18714,60	56,6%
Industrial or commercial units	6837,22	20,7%
Major infrastructural nodes	644,93	2,0%
Road and rail networks and associated land	4146,46	12,5%
Sports and leisure facilities	1500,32	4,5%
Total area	33047,94	100,0%

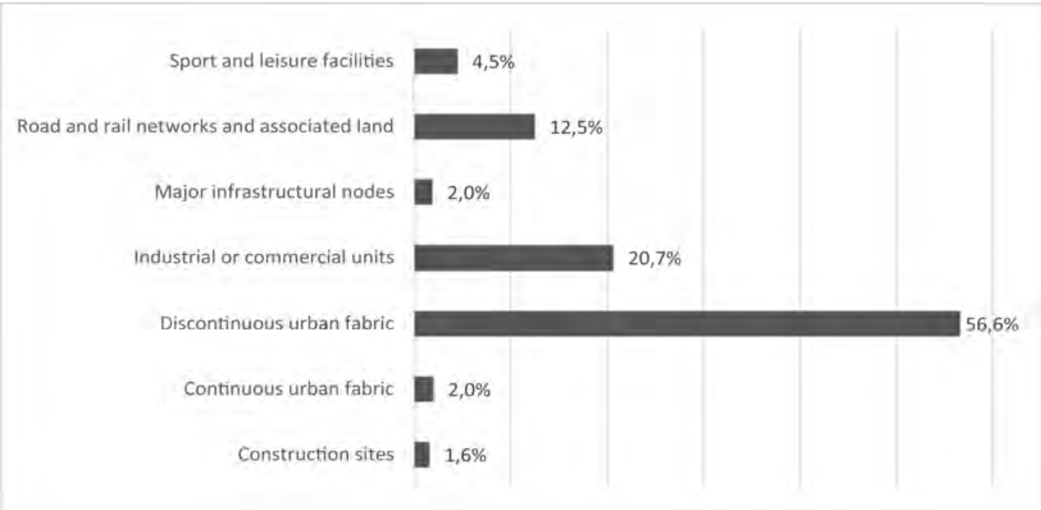


Figure 53 - Percentage by type of impermeable land use in the territory of the Metropolitan City of Venice.

1.3.3.3.1.1. - Urban Heat Island (UHI)

The following (Figure 54) a summary of the main results obtained from the overlap between the vulnerability to urban heat island and land use classes is proposed. In Box 1, the map of the extreme vulnerability degrees is represented with respect to the hexagonal matrix filtered on the built-up area.
In relation to the extent of the hexagonal matrix, Box 2 shows that 42.4% of the territory is potentially vulnerable to urban heat island; of this percentage, 6.2% has a high vulnerability, 9.7% medium-high, 11.4% medium-low and 15.2% low.
Finally, the infographics in Box 3 show how the degrees of vulnerability are distributed in each soil typology in relation to the total impact of that typology.
The most critical situation is represented by continuous urban fabric and large infrastructure nodes, where the percentage in the highest vulnerability grade exceeds 50%.
Proceeding with the first statistical survey, in the histogram in Figure

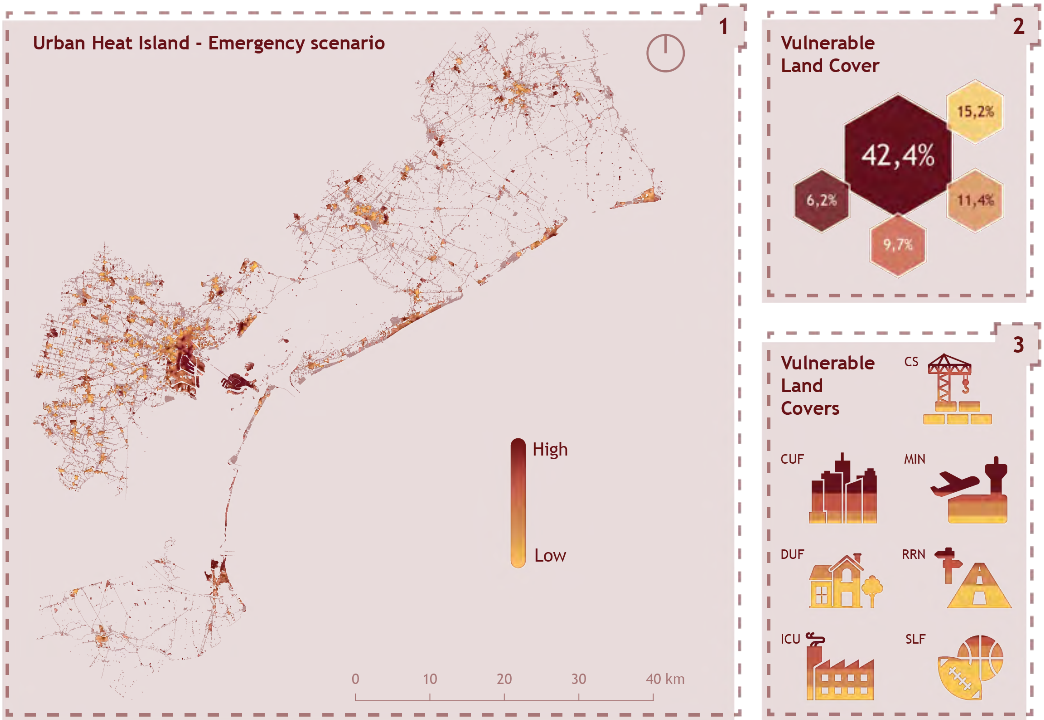
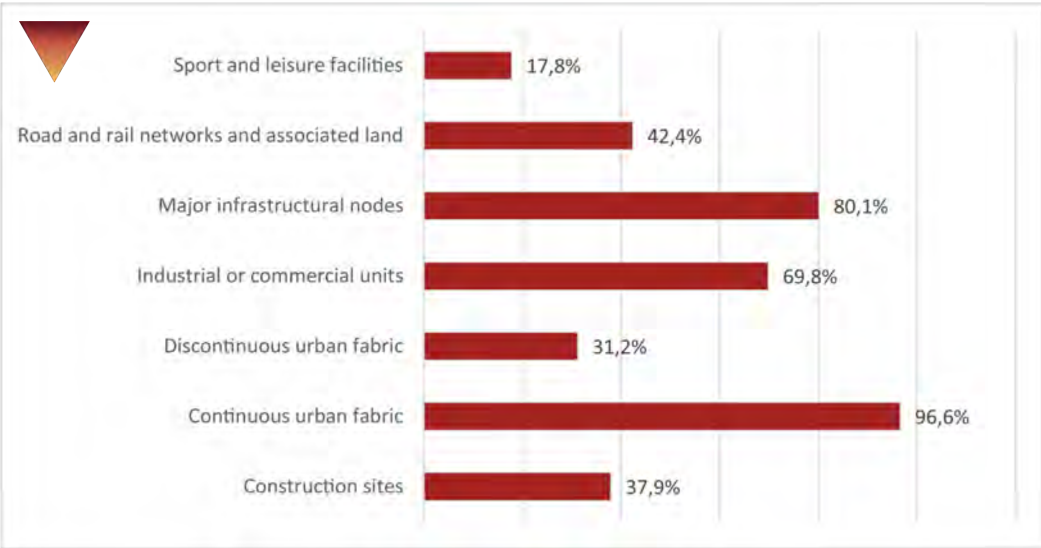


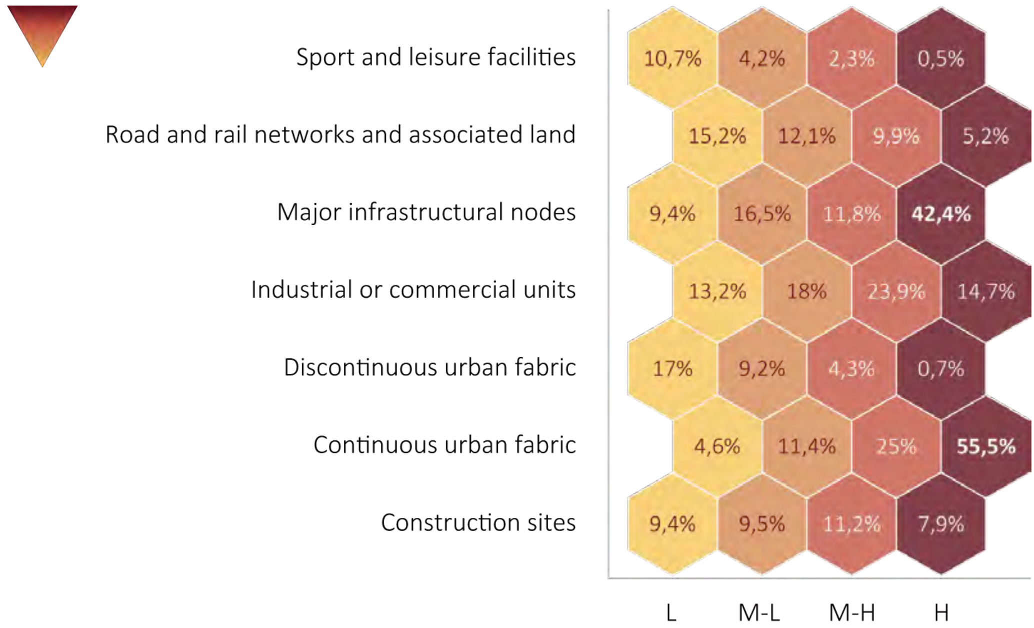
Figure 54 - Vulnerability in extreme class to urban heat island in an emergency scenario2. Percentage of soil vulnerable to uhi on the total territory, with respective criticality classes3. Distribution of vulnerability degrees in each impacted soil type.

Figure 55 - Percentage of land impacted by uhi by type of use on the territory of the Metropolitan City of Venice.

Figure 56 - Matrix of uhi vulnerability by land use type in relation to the total metropolitan area considered.

55 the percentage of land vulnerable to the impact of uhi can be seen for each class. The most vulnerable type appears to be continuous urban fabric, followed by large infrastructure nodes; however, it is necessary to consider the weight that these classes have on the total metropolitan soil which, as we recall, for both is only 2%. In general, it appears that the percentages of almost all the typologies investigated approach or exceed 50% potential vulnerability to heat island.
The matrix in Figure 56 is therefore intended to illustrate the degree of vulnerability of each soil type. What emerges is a greater criticality in the two sectors found above, which in a scenario of extreme high level vulnerability correspond to 42.4%, for the large infrastructure nodes, and 55.5%, for the continuous urban fabric.


Sport and leisure facilities
17,8%
Road and rail networks and associated land
42,4%
Major infrastructural nodes
80,1%
Industrial or commercial units
69,8%
Discontinuous urban fabric
31,2%
Continuous urban fabric
96,6%
Construction sites
37,9%


Sport and leisure facilities
10,7% 4,2% 2,3% 0,5%
Road and rail networks and associated land
15,2% 12,1% 9,9% 5,2%
Major infrastructural nodes
9,4% 16,5% 11,8% 42,4%
Industrial or commercial units
13,2% 18% 23,9% 14,7%
Discontinuous urban fabric
17% 9,2% 4,3% 0,7%
Continuous urban fabric
4,6% 11,4% 25% 55,5%
Construction sites
9,4% 9,5% 11,2% 7,9%
L
M-L
M-H
H

As mentioned above, the second level of analysis examines the ratio of impacted land uses to the vulnerability class itself. What emerges is that 41.7% of the most extreme impact class is made up of discontinuous urban fabric, followed by 34.1% of industrial and commercial units. For each of these items, priority levels were investigated on the basis of the degree of vulnerability, shown in Table 3 and in the respective graphs (Figure 57 e Figure 58).

Table 3 - Degrees of vulnerability to uhi for the most impacted soil types.

	Vulnerabilità alta	Vulnerabilità medio-alta	Vulnerabilità medio-bassa	Vulnerabilità bassa	Totale
Discontinuous urban fabric	**2,2%**	**13,9%**	**29,6%**	**54,4%**	**41,7%**
Industrial or commercial units	**21%**	**34,2%**	**25,8%**	**19%**	**34,1%**

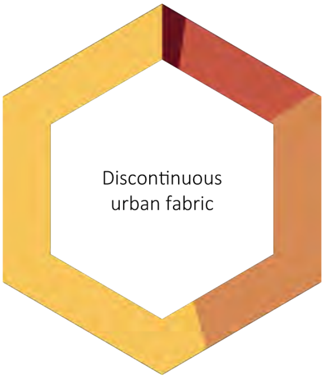


Figure 57 - Degrees of vulnerability: Discontinuous urban fabric.

Figure 58 - Degrees of vulnerability: Industrial or commercial units.

1.3.3.3.1.2. - Urban Flooding (UF)

In the following summary (Figure 59), the main results obtained from the overlap between vulnerability to urban flooding and land use classes are proposed. In box 1, the map of the extreme vulnerability degrees with respect to the hexagonal matrix filtered on the built-up area is represented. Of this total land area, potentially vulnerable to urban flooding is 29.9%, of which 3.1% has high vulnerability, 11.7% medium-high, 6.3% medium-low and 8.8% low vulnerability box 2. The infographics in Box 3 show the distribution of vulnerability levels in each soil type, with the highest level of vulnerability being found in the continuous urban fabric, where the percentage at the highest level is 65.2%.

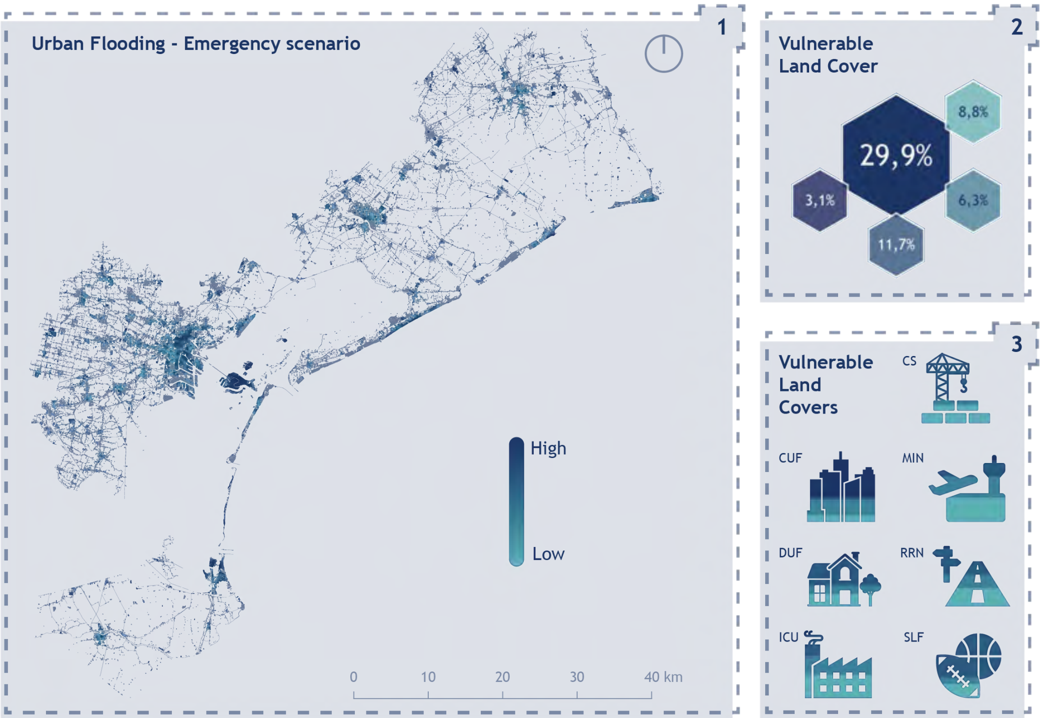
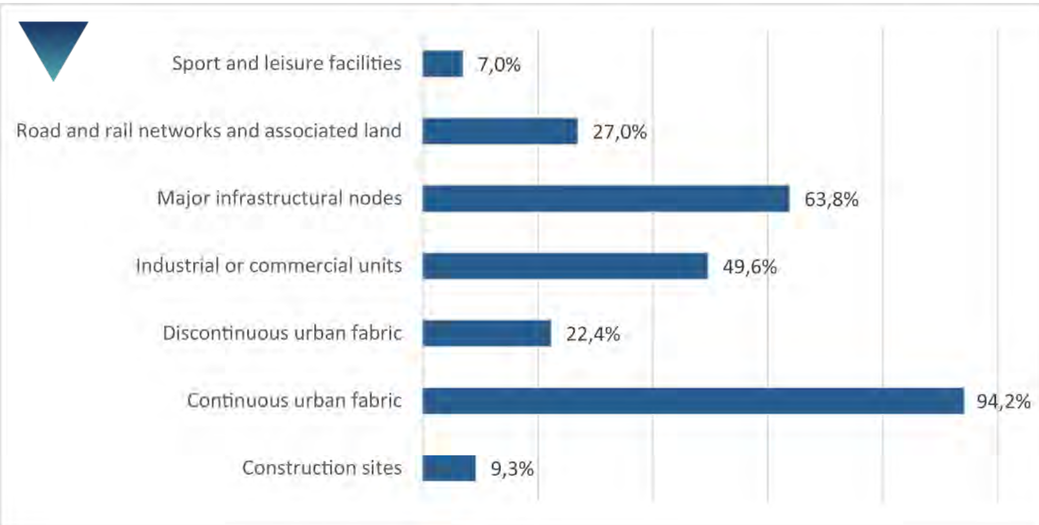


Figure 59 - Extreme class vulnerability to urban flooding in an emergency scenario2. Percentage of soil vulnerable to uf on the total territory, with respective criticality classes3. Distribution of the degrees of vulnerability in each impacted soil type.

This is followed by sites under construction and sports and recreational areas, with a percentage of 64.7% and 68.5% respectively in the medium-high vulnerability class.

As it emerges from the Figure 60 as can be seen from the figure, the soil type with the highest vulnerability is the continuous urban fabric (94.2%), followed by the large infrastructure nodes (63.8%); the observation made regarding the weight of these classes in the total is also valid in this case. In contrast to the results obtained for the UHI, the percentages are generally lower, with the majority being less than 50%.

Figure 60 - Percentage of soil impacted by uf by type of use on the territory of the Metropolitan City of Venice.



If we look at the matrix in Figure 61 matrix, the only high value is found in the continuous urban fabric section, equal to 61.4%. This percentage amplifies its significance as it falls within the maximum level of vulnerability in an already extreme condition.

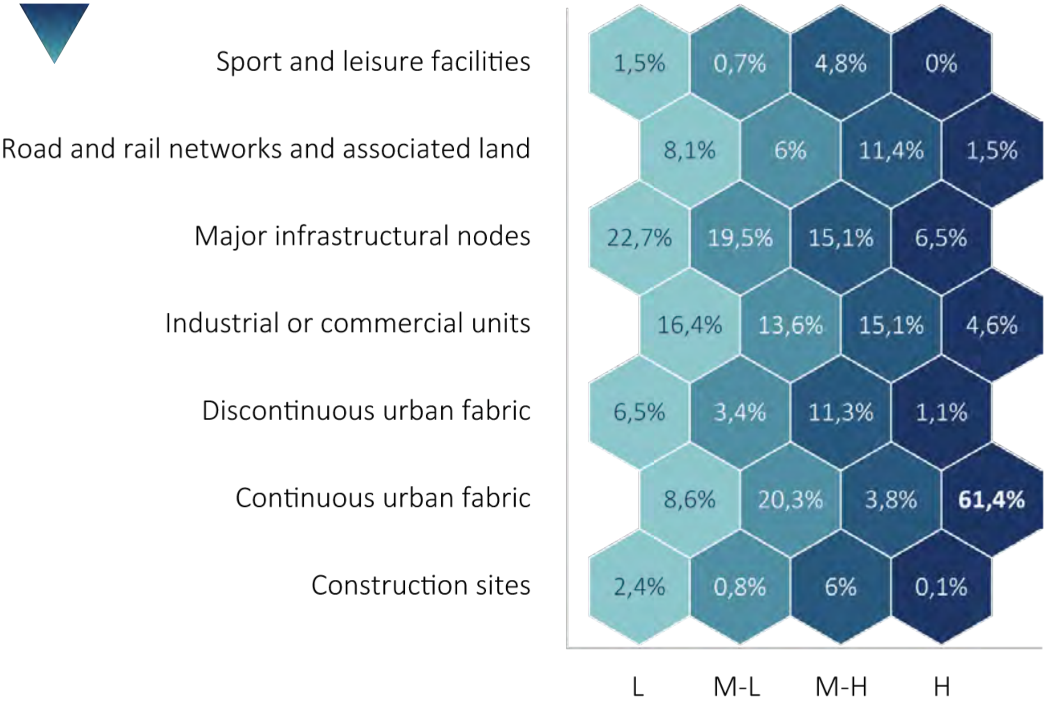


Figure 61 - Matrix of land use vulnerability by land use type in relation to the total metropolitan area considered.

Table 4 - Degrees of vulnerability to uf for the most impacted soil types.

Continuing with the second level of analysis, the class in which the impact from uf is more present is the discontinuous urban fabric with 42.3%, followed by industrial and commercial units with 34.3% (Table 4, Figure 62 e Figure 63). With regard to the former, the highest percentage, 50.7%, falls within the medium-high vulnerability level, while with regard to the latter, 33% corresponds to a low vulnerability level.

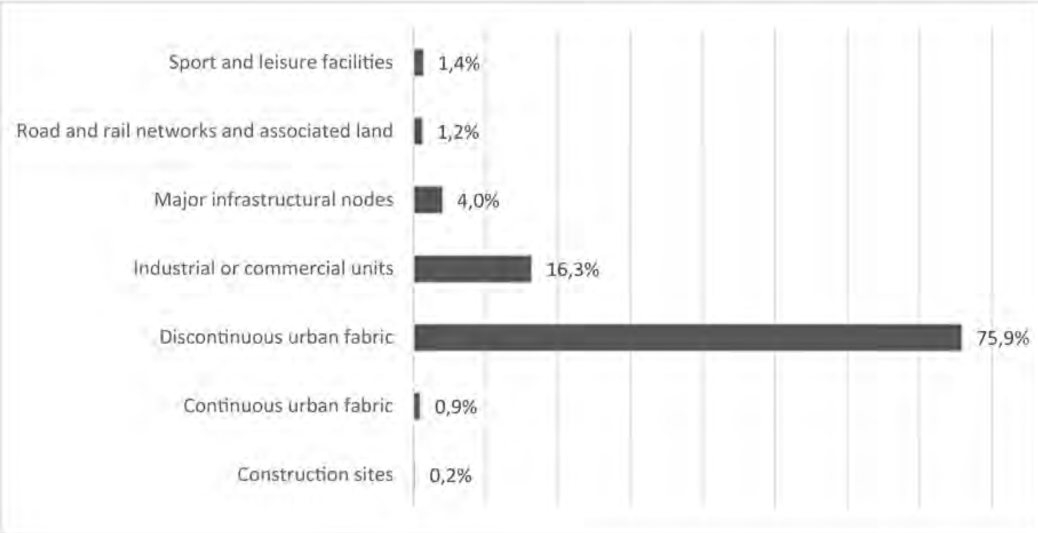
	Vulnerabilità alta	Vulnerabilità medio-alta	Vulnerabilità medio-bassa	Vulnerabilità bassa	Totale
Discontinuous urban fabric	**4,8%**	**50,7%**	**15,4%**	**29,1%**	**42,3%**
Industrial or commercial units	**9,4%**	**30,3%**	**27,3%**	**33%**	**34,3%**

Figure 62 - Degrees of vulnerability: Discontinuous urban fabric.

Figure 63 - Degrees of vulnerability: Industrial or commercial units.

1.3.3.3.2. - Friuli Venezia Giulia

From the analyses carried out on the sealed surfaces of the territorial system of the Autonomous Region of Friuli Venezia Giulia (Figure 64 e Table 5) it emerges that almost all of them are destined for the discontinuous urban fabric.
However, the percentage covered by industrial and commercial settlements is important, followed in this case by the areas occupied by the major infrastructure nodes.



Legend	Area (ha)	Percentage
Construction sites	138,41	0,2%
Continuous urban fabric	579,79	0,9%
Discontinuous urban fabric	46490,93	75,9%
Industrial or commercial units	10016,52	16,3%
Major infrastructural nodes	2475,89	4,0%
Road and rail networks and associated land	757,27	1,2%
Sports and leisure facilities	830,42	1,4%
Total area	61289,23	100,0%

Figure 64 - Percentage by type of impermeable land use present on the territory of the Autonomous Region Friuli Venezia Giulia.

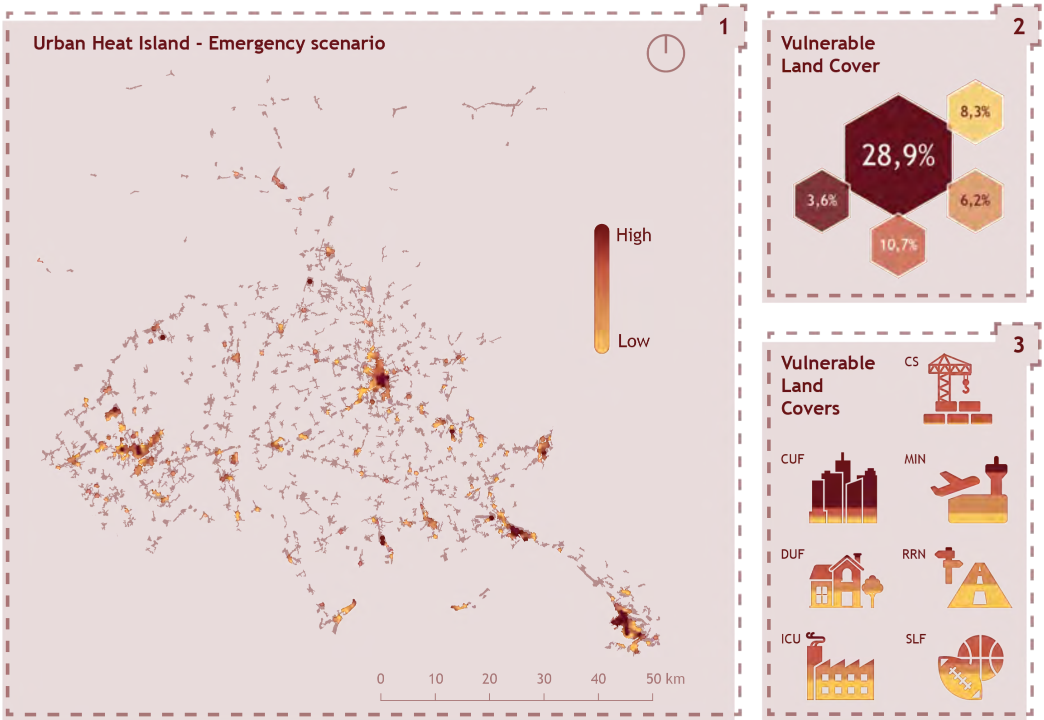
Table 5 - Statistical detail of absolute values (ha) and percentages by type of sealed land use in the Autonomous Region Friuli Venezia Giulia.

1.3.3.3.2.1. - Urban Heat Island (UHI)

Figure 65 shows the summary sheet with the main results obtained from the overlap between the vulnerability to urban heat island and the land use classes. In box 1, the map related to the extreme vulnerability degrees with respect to the hexagonal matrix filtered on the built-up area is represented. Compared to the regional territory of

Friuli Venezia Giulia considered, 28.9% are vulnerable to uhi impact, of which 3.6% are high, 10.7% medium-high, 6.2% medium-low and 8.3% low box 2. Observing the infographics in Box 3, it can be observed that the highest degree of extreme vulnerability is present almost exclusively in the continuous urban fabric, occupying a percentage of 78.4%. Another noteworthy figure is the 99.8% represented by the medium-high criticality class for sites under construction.

Figure 65 - Vulnerability in extreme class to urban heat island in an emergency scenario2. Percentage of soil vulnerable to uhi on the total territory, with respective criticality classes3. Distribution of vulnerability degrees in each impacted soil type.

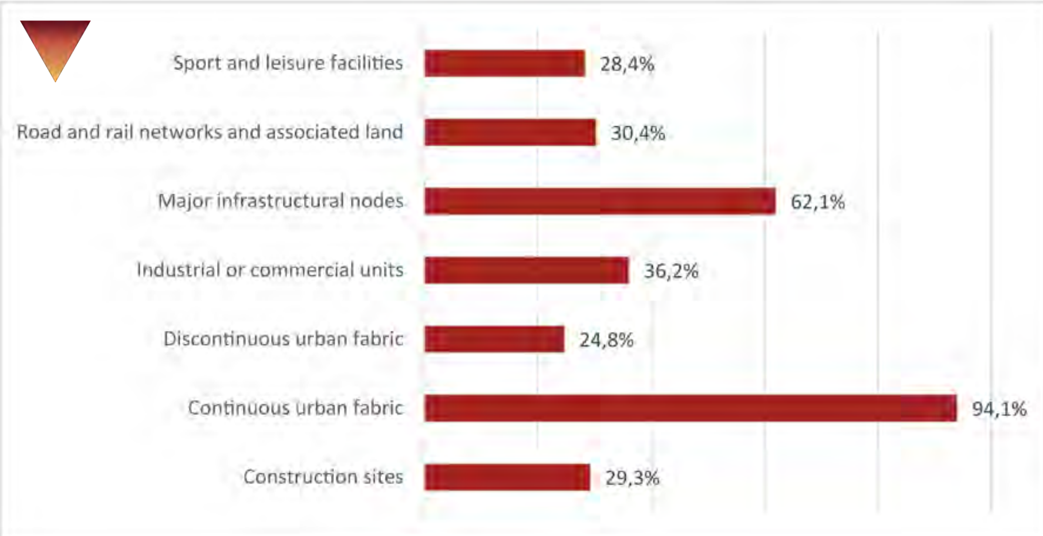


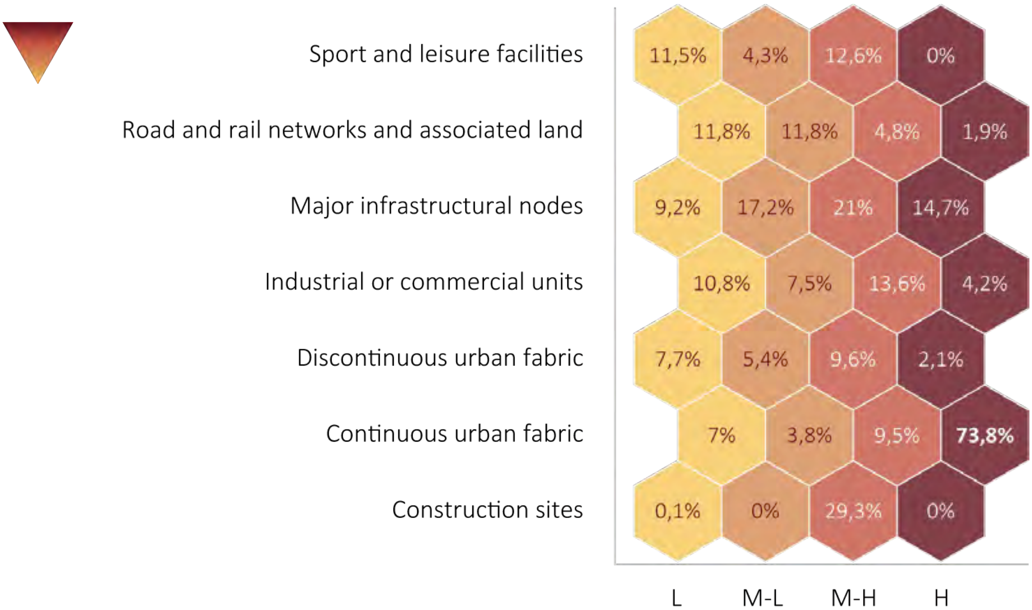
Of the 75.9% of the RAFVG territory, characterized by a discontinuous urban fabric, 24.8% are potentially exposed to the impact of the urban heat island. Observing the histogram in Figure 66, it can be seen that the most vulnerable item is, instead, the continuous urban fabric (94.1%), also in this case - as for the Metropolitan City of

Figure 66 - Percentage of land impacted by uhi by type of use on the territory of the Autonomous Region Friuli Venezia Giulia.

Figure 67 - Matrix of uhi vulnerability by land use type compared to the total regional area considered.

: Venice - followed by the large infrastructural nodes (62.1%).





Of this continuous vulnerable urban fabric, almost all is in a condition of extreme high vulnerability, with a percentage of 73.8% (Figure 67). If, however, the individual levels of vulnerability are analyzed, irrespective of the type of land use they represent, it can be seen that more than half do not exceed 10%.
When each land use is related to the statistical unit filtered on the extreme vulnerability class, the discontinuous urban fabric emerges as the most vulnerable sector, with 65%. The other typologies, therefore, present minimal vulnerabilities around 1%, except for industrial and commercial units (20.4%) and large infrastructure nodes (8.7%). Going into detail about the vulnerabilities represented in Table 6 the distribution appears rather homogeneous between the medium-high, medium-low and low levels (Figure 68).

Table 6 - Degrees of vulnerability to uhi for the most impacted soil type.

	Vulnerabilità alta	Vulnerabilità medio-alta	Vulnerabilità medio-bassa	Vulnerabilità bassa	Totale
Discontinuous urban fabric	8,7%	38,7%	21,7%	31%	65%

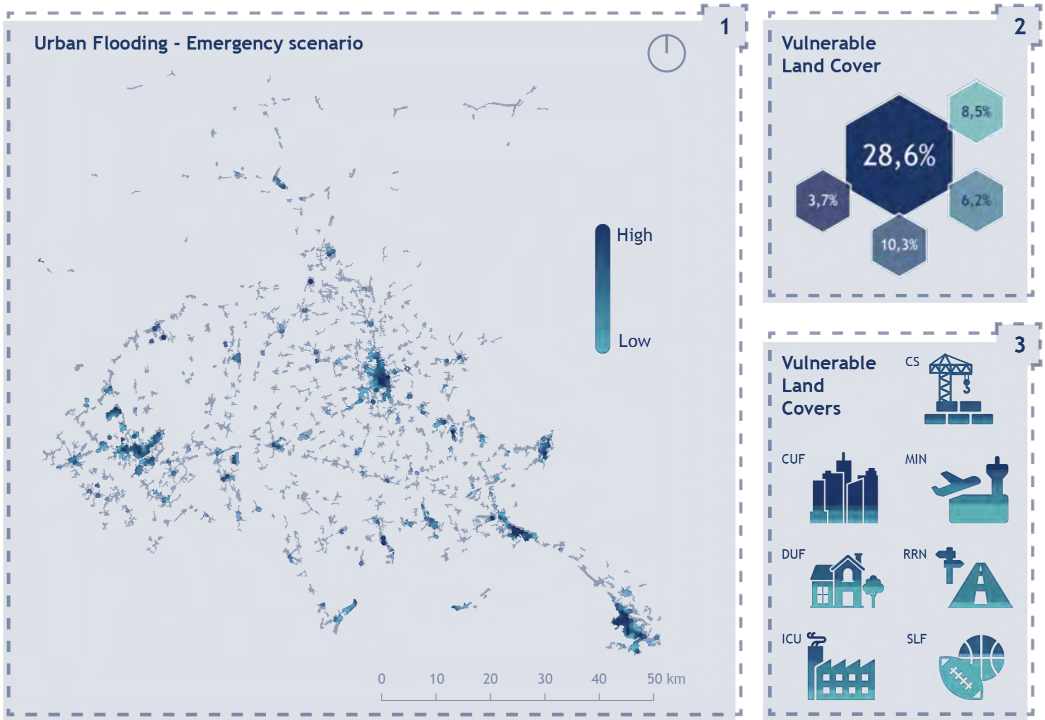
Figure 68 - Degrees of vulnerability: Discontinuous urban fabric.

1.3.3.3.2.2. - Urban Flooding (UF)

Reported in Figura 69 the summary sheet with the main results obtained from the overlap between vulnerability to urban flooding

Figure 69 - Extreme class vulnerability to urban flooding in an emergency scenario2. Percentage of soil vulnerable to uf on the total territory, with respective criticality classes3. Distribution of the degrees of vulnerability in each impacted soil type.

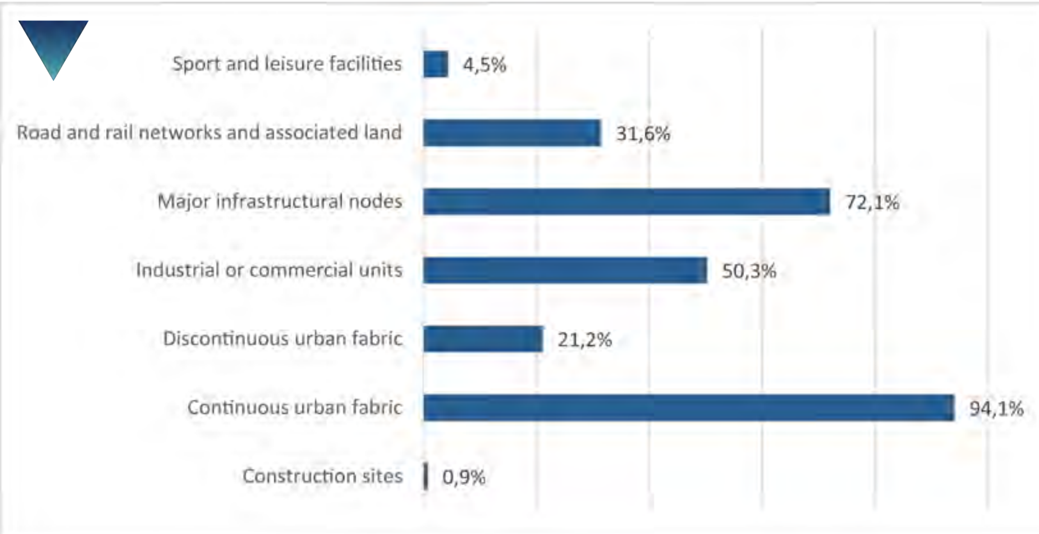
and land use classes. In the box 1 ( ), the map of extreme vulnerability degrees with respect to the hexagonal matrix filtered on built-up land is shown. Out of the total built-up land covered by the hexagonal matrix, 28.6% is vulnerable to impact from uf; in detail, 3.7% with high criticality, 10.3% medium-high, 6.2% medium-low and 8.5% low box 2. In box 3 the distribution of vulnerability degrees shows a higher criticality in the continuous urban fabric, whose percentage at the highest level corresponds to 76.2%. Another significant figure is the 93.2% in the medium-high vulnerability class for sites under construction.



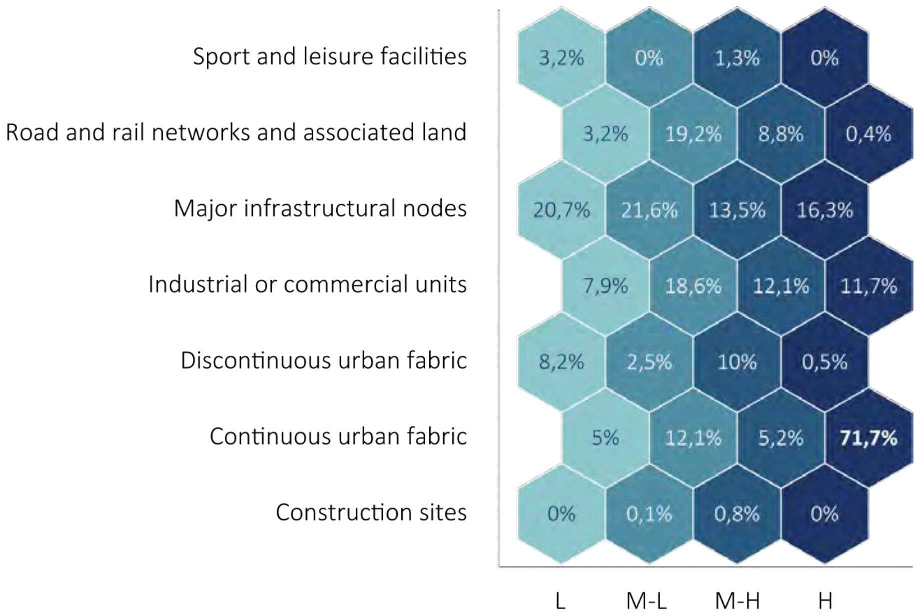
The continuous urban fabric presents the same percentage of vulnerability for both urban heat island and urban flooding impacts.

This is because, looking at the baseline data on which the statistical surveys were carried out, the hectares involved are equivalent. As for the other types, the results are rather in line between the two impacts, except for an increase in the industrial and commercial sector, half of which is affected (50.3%) and, on the contrary, a strong decrease in construction sites (0.9%) and sports and recreation activities (4.5%), which are almost not affected (Figure 70).

Figure 70 - Percentage of soil impacted by uf by type of use on the territory of the Autonomous Region Friuli Venezia Giulia.



Consequently, a similar figure is found in the matrix in Figure 71 where the most significant figure is the high degree of extreme vulnerability of the continuous urban fabric (71.7%).
If we now analyze the distribution of vulnerability on impacted soils only (Table 7 e Figure 72), it is the discontinuous urban fabric that is most at risk, with 56.4%, of which the highest values are contested between the medium-high level (46.9%) and the low level (38.7%). This is followed by the industrial and commercial sector with 28.8%, while the other types hover around 0-1%, except for infrastructure nodes with 10.2%.



	Vulnerabilità alta	Vulnerabilità medio-alta	Vulnerabilità medio-bassa	Vulnerabilità bassa	Totale
Discontinuous urban fabric	**2,5%**	**46,9%**	**11,9%**	**38,7%**	**56,4%**

Figure 71 - Matrix of land use vulnerability by land use type compared to the total regional area considered.

Table 7 - Degrees of vulnerability to uf for the most impacted soil type.

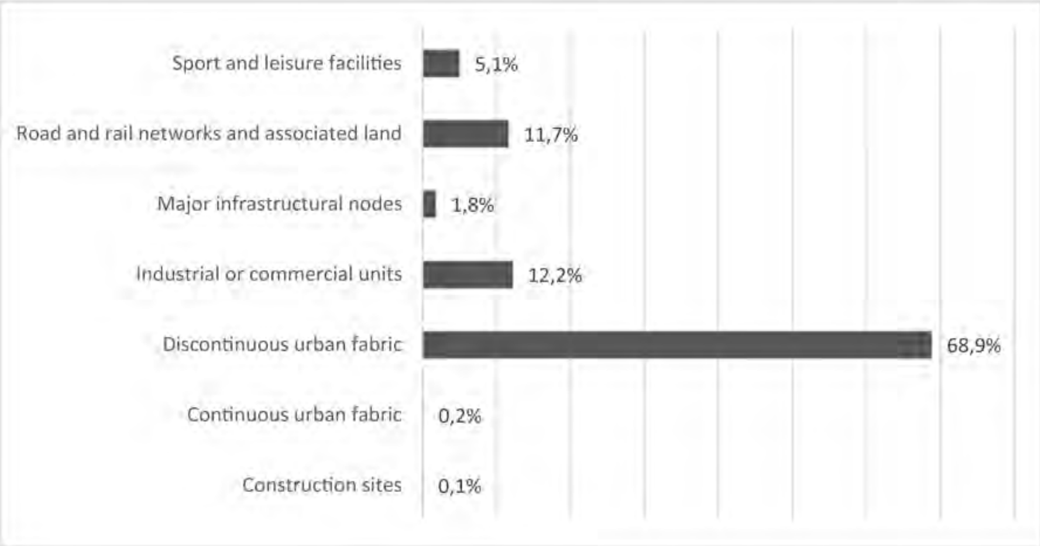
Figure 72 - Degrees of vulnerability: Discontinuous urban fabric.

1.3.3.3.3. - Slovenia

Analyses carried out on the sealed surfaces of the Slovenian spatial system (Figure 73 e Table 8) show that most of the soil is occupied by discontinuous urban fabric, followed by road infrastructure and industrial and commercial settlements with a similar percentage. In addition, the proportion of sports and recreational facilities is interesting.

Figure 73 - Percentage by type of sealed land use present on the territory of Slovenia.

Table 8 - Statistical detail of absolute values (ha) and percentages by type of sealed land use in Slovenia.

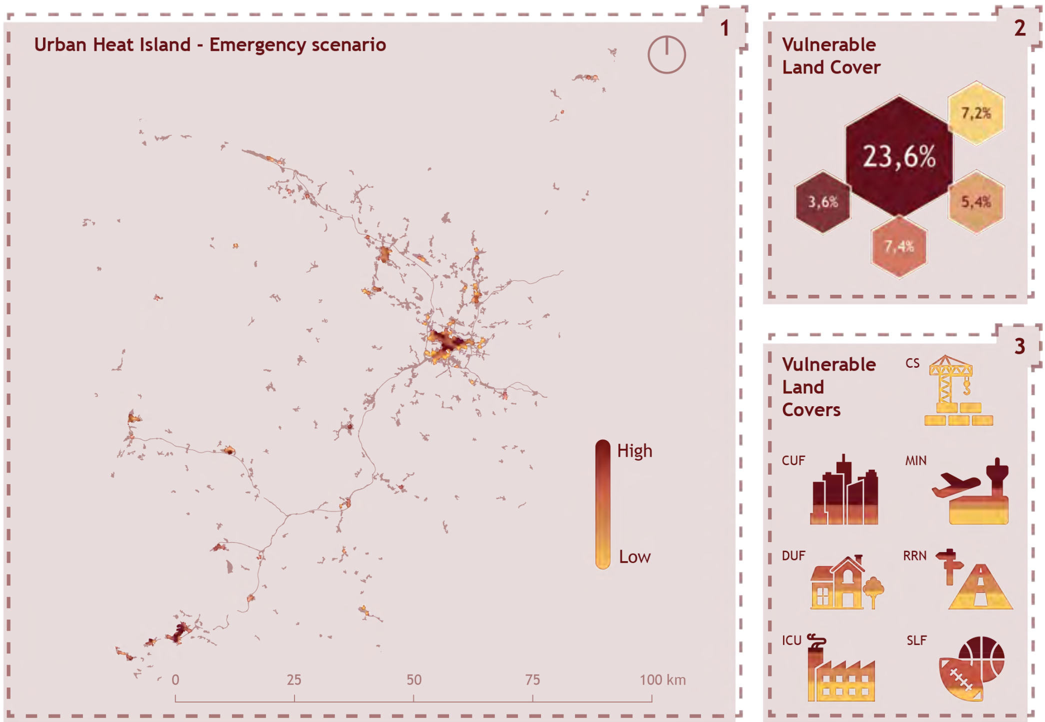


Legend	Area (ha)	Percentage
Construction sites	42,01	0,1%
Continuous urban fabric	55,83	0,2%
Discontinuous urban fabric	23669,64	68,9%
Industrial or commercial units	4206,65	12,2%
Major infrastructural nodes	633,22	1,8%
Road and rail networks and associated land	4016,28	11,7%
Sports and leisure facilities	1738,35	5,1%
Total area	34361,98	100,0%

1.3.3.3.3.1. - Urban Heat Island (UHI)

In Figure 74 The summary sheet with the main results obtained from the overlap between the vulnerability to urban heat island and the land use classes can be read. In box 1, the map of the extreme vulnerability degrees with respect to the hexagonal matrix filtered on the built-up area is depicted. The 23.6% of the Slovenian built-up area that falls within the statistical unit used for the analysis appears to be vulnerable to impact from uhi. Of this percentage, 3.6% is high, 7.4% medium-high, 5.4% medium-low and 7.2% low Box 2. The infographics in box 3 show a higher vulnerability in the high grade in the continuous urban fabric, accounting for 72.7% of the total of this type of impacted soil. This is followed by 46.6% in the area of large infrastructure nodes.

Figure 74 - Vulnerability in extreme class to urban heat island in an emergency scenario 2. Percentage of soil vulnerable to uhi on the total territory, with respective criticality classes 3. Distribution of vulnerability degrees in each impacted soil type.



69.8% of the territory considered is represented by discontinuous urban fabric, but of this only 21.2% is vulnerable (Figure 75). On the contrary, all the continuous urban fabric is at risk (100%), although it has a weight of 0.2% on the total investigated soil. Although the other classes are also low, vulnerability levels appear high, at least half of them being involved: large infrastructure nodes (50%), industrial and commercial units (50.3%) and construction sites (85.8%).
Going into detail, the continuous urban fabric presents the highest

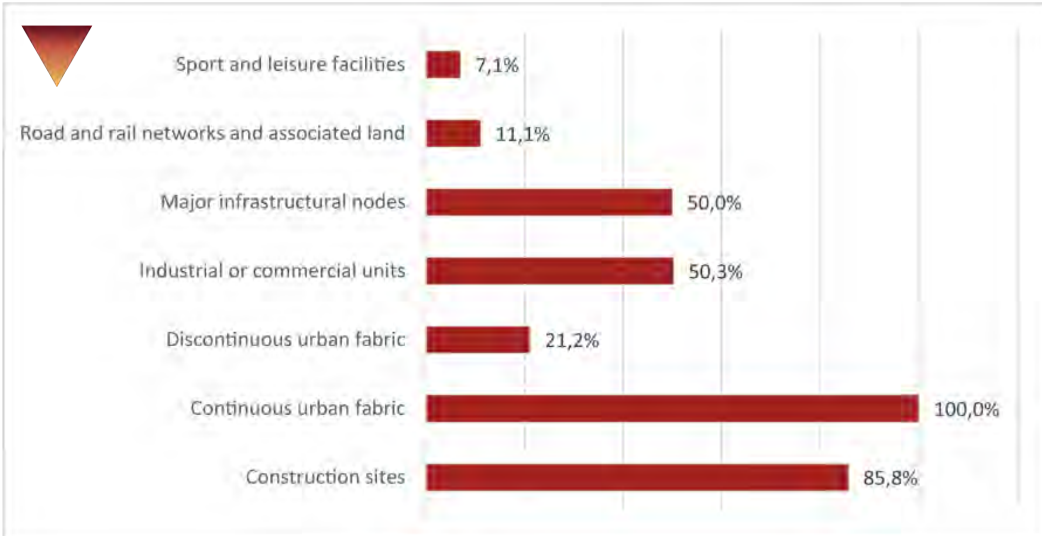
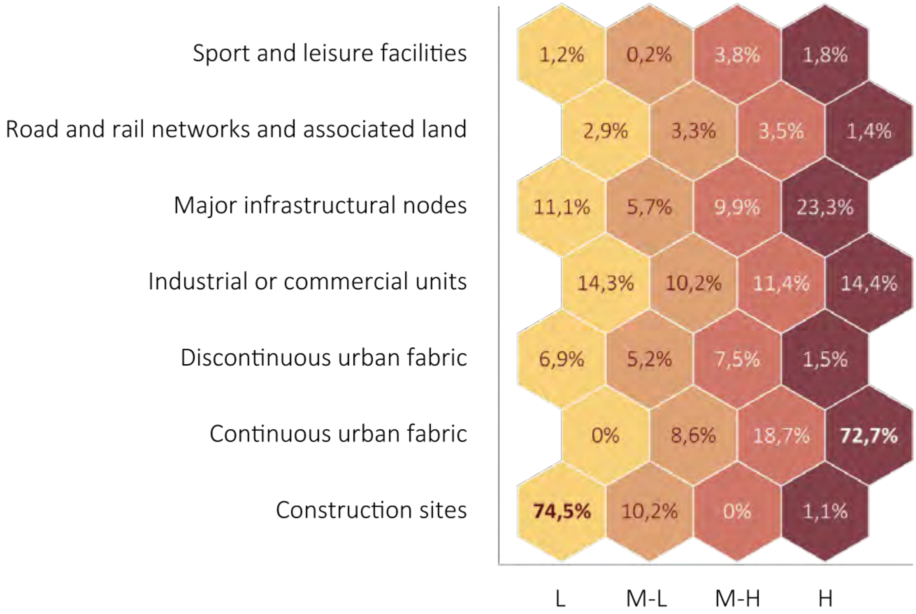


Figure 75 - Percentage of land impacted by uhi by type of use on the territory of Slovenia.

level of extreme vulnerability with 72.7%, while another significant figure is 74.5% at the low end of the sites (Figure 76). For the other typologies the values are distributed quite homogeneously among the different degrees of vulnerability. Of the total land impacted, 61.8% is represented by the discontinuous urban fabric, mainly spread between the medium-high, medium-low and low levels (Table 9 e Figure 77). This is followed by the industrial and commercial sector with 26.1%, while the other types are less than 6%.



	Vulnerabilità alta	Vulnerabilità medio-alta	Vulnerabilità medio-bassa	Vulnerabilità bassa	Totale
Discontinuous urban fabric	**7%**	**35,6%**	**24,7%**	**32,7%**	**61,8%**

Figure 76 - Matrix of uhi vulnerability by land use type in relation to the total Slovenian area considered.

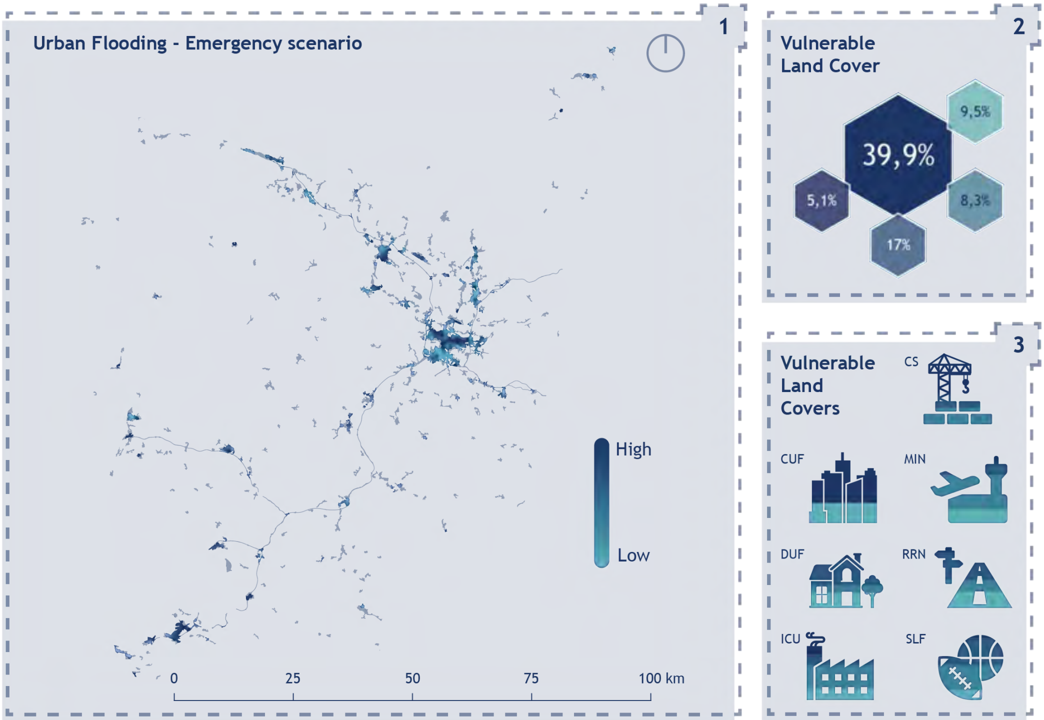
Table 9 - Degrees of vulnerability to uhi for the most impacted soil type.

Figure 77 - Degrees of vulnerability: Discontinuous urban fabric.

1.3.3.3.3.2. - Urban Flooding (UF)

Figure 78 shows the summary sheet related to the main results obtained from the overlap between vulnerability to urban flooding and land use classes. In box 1, the map of the extreme vulnerability degrees with respect to the hexagonal matrix filtered on the built-up area is shown. In contrast to land impacted by uhi, land impacted by urban flooding has a higher percentage of almost 40%, of which 5.1% is in the highest class, 17% medium-high, 8.3% medium-low and 9.5% low box 2. In box 3 the distribution of vulnerability degrees shows a higher criticality in the continuous urban fabric (71.5%) and in the construction sector (59.6%). As for the medium-high degree of vulnerability, the discontinuous urban fabric (55%), the transport

Figure 78 - 1.1 Extreme class vulnerability to urban flooding in an emergency scenario 2. Percentage of soil vulnerable to uf on the total territory, with respective criticality classes 3. Distribution of the degrees of vulnerability in each type of impacted soil.



network (45.3%) and sport and recreation activities (41.5%) stand out.

For both uhi and uf, all land characterized by continuous urban fabric appears vulnerable (100%). The percentages (Figure 79) are much higher in the case of infrastructure nodes (73.3%) and industrial and commercial units (81%). They are also higher for discontinuous urban fabric (35.1%), the transport network (33%) and sports and leisure activities (7.9%), and lower for sites under construction (13.5%).

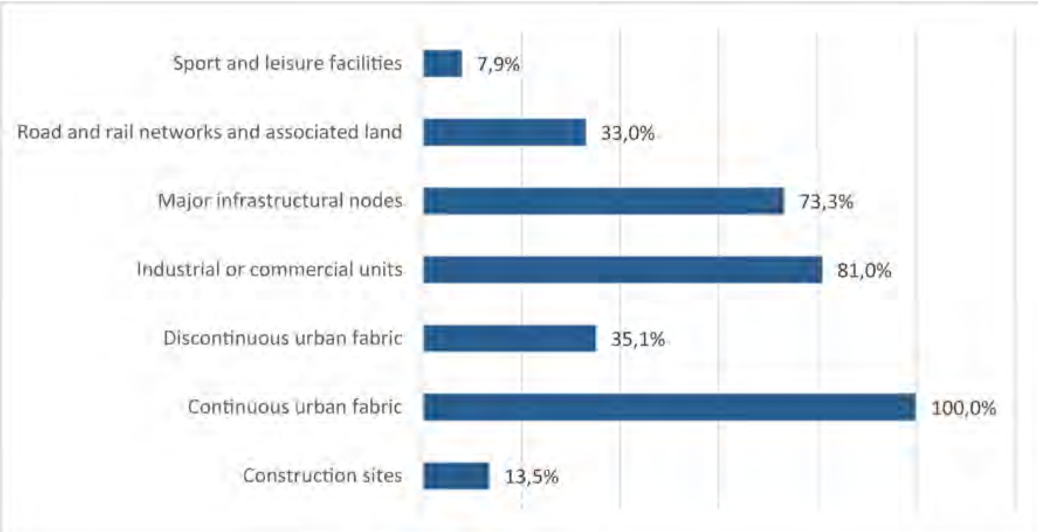
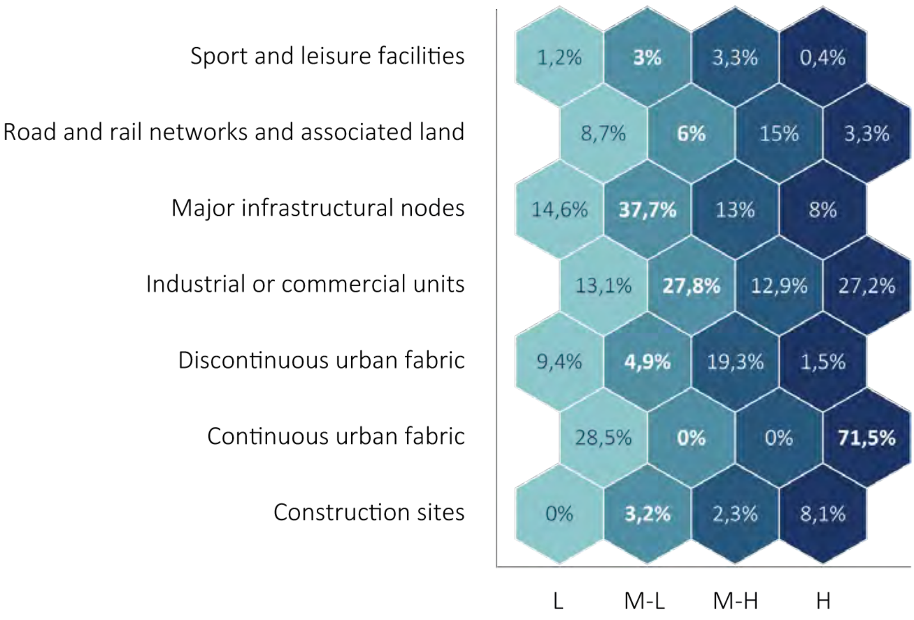


Figure 79 - Percentage of land impacted by uf by type of use on the territory of Slovenia.

71.5% of the continuous urban fabric shows an extreme high vulnerability, zero in the medium-high and medium-low level and followed - although with a notable difference - by a medium-low vulnerability in the soil occupied by the large infrastructure nodes (Figure 80). The second level of analysis shows with 60.6% the discontinuous urban fabric, mainly impacted in a medium-high way (Table 10 e Figure 81). The 24.9% is represented by industrial and commercial units, while in general it is found that the most significant degree of vulnerability is medium-high, with a percentage of 42.7%.



	Vulnerabilità alta	Vulnerabilità medio-alta	Vulnerabilità medio-bassa	Vulnerabilità bassa	Totale
Discontinuous urban fabric	**4,3%**	**55%**	**14%**	**26,7%**	**60,6%**

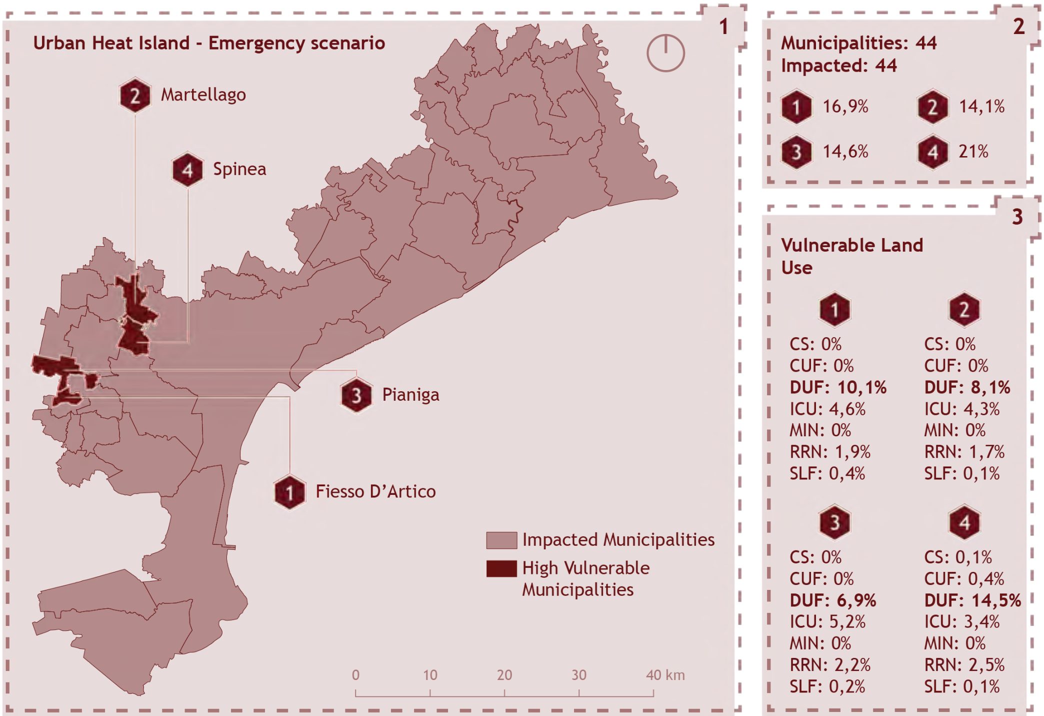
Figure 80 - Matrix of vulnerability to UF by land use type in relation to the total Slovenian area considered.

Table 10 - Degrees of vulnerability to uf for the most impacted soil type.

Figure 81 - Degrees of vulnerability: Discontinuous urban fabric.

1.3.3.3.3. - Comparing Territories

Statistical analyses of land uses potentially vulnerable to urban heat island and flooding identified the municipalities most likely to be affected. For each project area, therefore, the administrative units were superimposed on the hexagonal grid with the highest level of vulnerability. In the following summaries, three boxes are provided: the first shows the distribution of the municipalities affected by the impacts, with a focus on the first 4 in order of vulnerability; the second provides data on the number of vulnerable municipalities in relation to the total and the percentage detail - for the first 4 - referring to the km2 of vulnerable land in relation to the extension of the municipality in which it falls; finally, the third analyzes the distribution of this last percentage in the various classes of land use.
What emerges from the Figure 82 is that of the 44 municipalities that are part of the Metropolitan City of Venice, 100% are affected, even if only slightly, by uhi impacts. The municipalities with the highest vulnerability are Fiesso d'Artico, Martellago, Pianiga and Spinea, with a percentage of 16.9%, 14.1%, 14.6% and 21% respectively. Investigating the types of land use involved, it is evident that in all four cases it is the discontinuous urban fabric that prevails; however, most of the land included in this category falls into the lowest degree of vulnerability.



In Figure 83 It can be seen that of the 217 municipalities in the Friuli Venezia Giulia Autonomous Region, 88, or approximately 41%, are affected by uhi. The most vulnerable municipalities are Monfalcone, Pordenone, Udine and Vajont, with a percentage of 43.3%, 41.7%, 36.5% and 32.7% respectively. As far as the types of soil involved are concerned, in this case too the discontinuous urban fabric prevails, but unlike the Metropolitan City of Venice the degree of vulnerability is largely between high and medium-high.

The map in Figure 84 shows the 32 Slovenian municipalities affected, representing 15% of the total 212, of which the most vulnerable are Ankaran, Domžale, Izola and Ljubljana, with a percentage of 29.6%,

Figure 82 - CMVE municipalities vulnerable to the extreme uhi vulnerability class in an emergency scenario 2.
Percentage of vulnerable land for the most exposed municipalities 3.
Percentage distribution of impacted land by land use class.

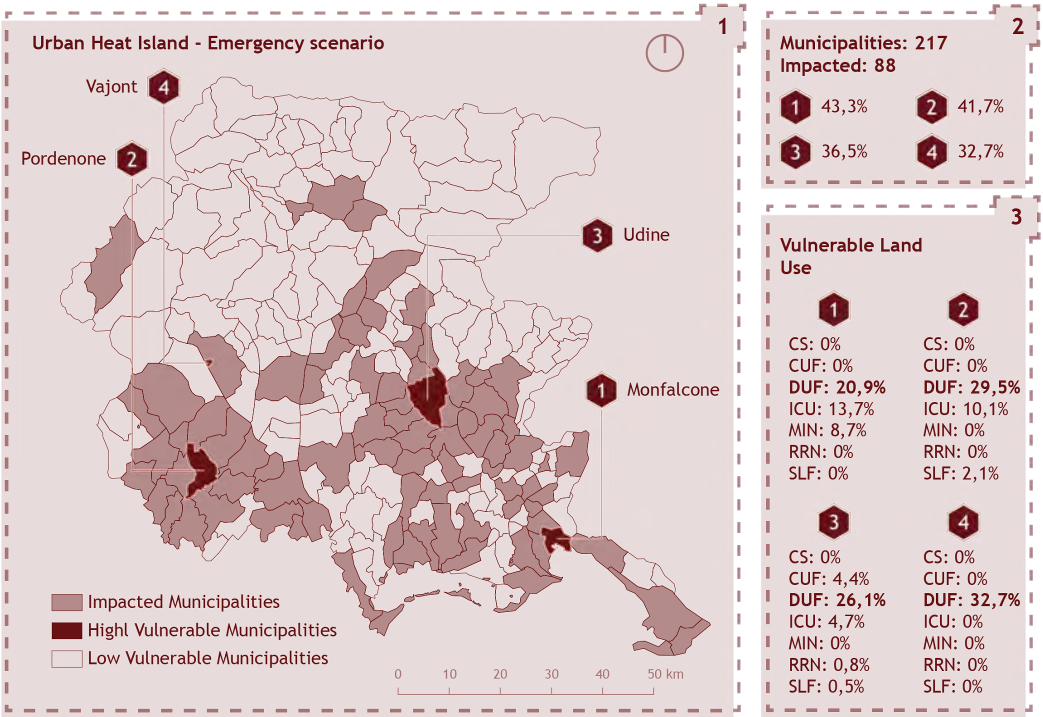


Figure 83 - Municipalities in RAFVG vulnerable to extreme uhi vulnerability class in an emergency scenario 2.
Percentage of vulnerable soil for the most exposed municipalities 3.
Percentage distribution of impacted territory by land use class.

5.5%, 6.1% and 12.2% respectively. In the municipality of Ankaran, industrial and commercial units and large infrastructural nodes are most affected, with almost the same percentage (12.2% and 12.9%) and a medium-high to high degree of vulnerability. For the other municipalities, however, it is the discontinuous urban fabric that prevails, with a mainly medium-high degree of vulnerability.

When comparing the vulnerabilities from urban heat island of the three project areas, it is immediately evident that the most affected territory is the Metropolitan City of Venice. However, the municipalities with the highest degree of extreme class vulnerability belong to the territory of the Autonomous Region Friuli Venezia

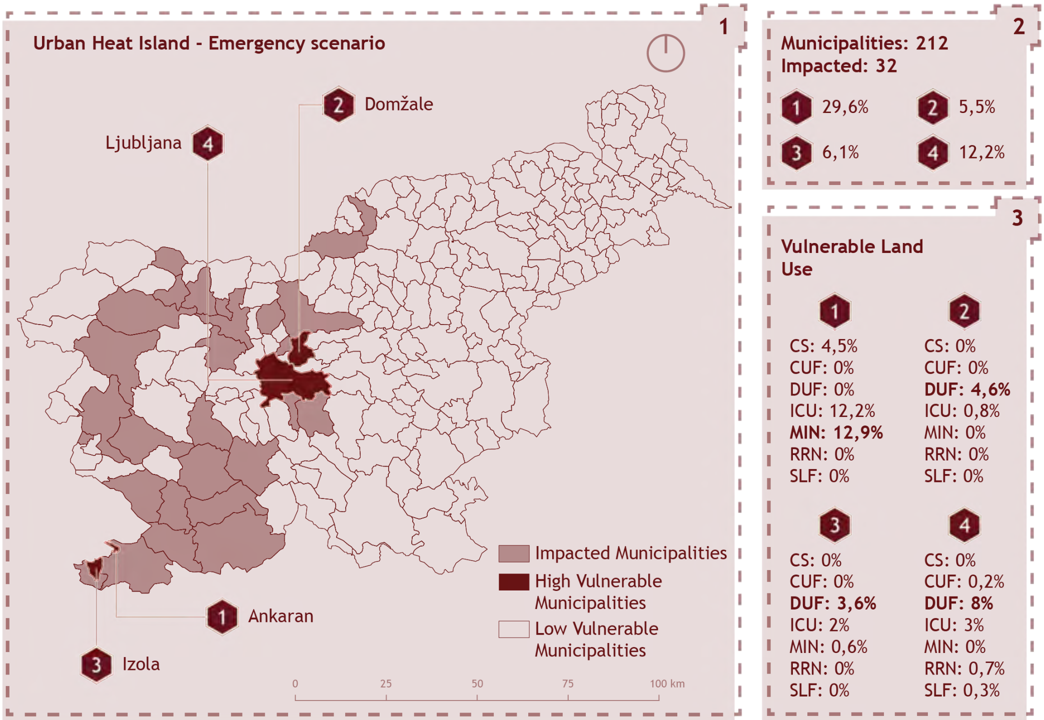


Figure 84 - Municipalities in Slovenia vulnerable to the extreme uhi vulnerability class in an emergency scenario 2.
Percentage of vulnerable soil for the most exposed municipalities 3.
Percentage distribution of impacted land by land use class.

Giulia. In relation to the type of soil affected, on the other hand, the discontinuous urban fabric predominates, characterizing the so-called 'diffuse city' that is common to the project areas.

Continuing with the analysis of the impact from urban flooding, in the Figure 85 it can be observed that, as for the urban heat island, also in this case 100% of the municipalities of the Metropolitan City of Venice present a degree of vulnerability, although the percentages are lower. The most affected municipalities are Fiesso d'Artico, Fossò, Spinea and Venice, with the following values: 8.7%, 8%, 14.9% and 8.5%. These vulnerabilities are concentrated in the land use classes of discontinuous urban fabric and industrial and commercial units, with a medium-low to low level of vulnerability.

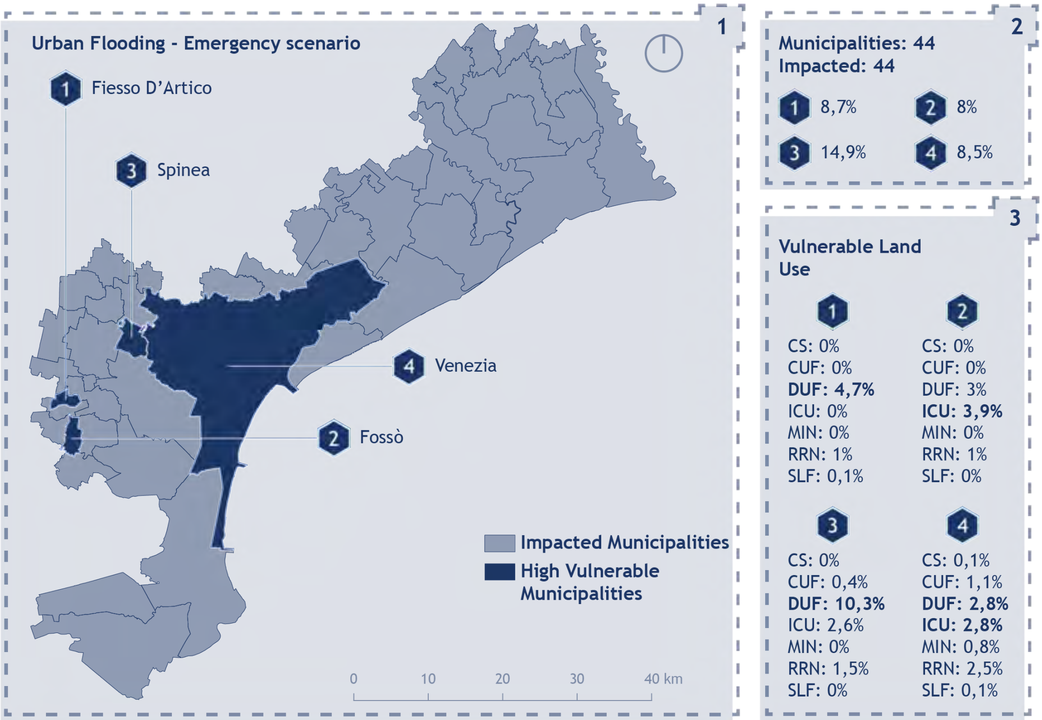


Figure 85 - Municipalities in the CMVE vulnerable to extreme uf vulnerability class in an emergency scenario 2.
Percentage of vulnerable soil for the most exposed municipalities 3.
Percentage distribution of impacted land by land use class.

In contrast to the results for uhi, the Figure 86 shows a slight increase in the number of municipalities affected by uf, which rises to 96 and thus to 44%. However, the most affected municipalities remain the same - namely Monfalcone, Pordenone, Udine and Vajont - with the following percentages: 42.2%, 39.3%, 34.9% and 32.7%. The only value that remains unchanged is that of the municipality of Vajont, also with regard to the type of vulnerable soil. For the other municipalities, however, although the values remain rather in line with the previous ones, it should be noted that the prevailing degree of vulnerability is medium-low.

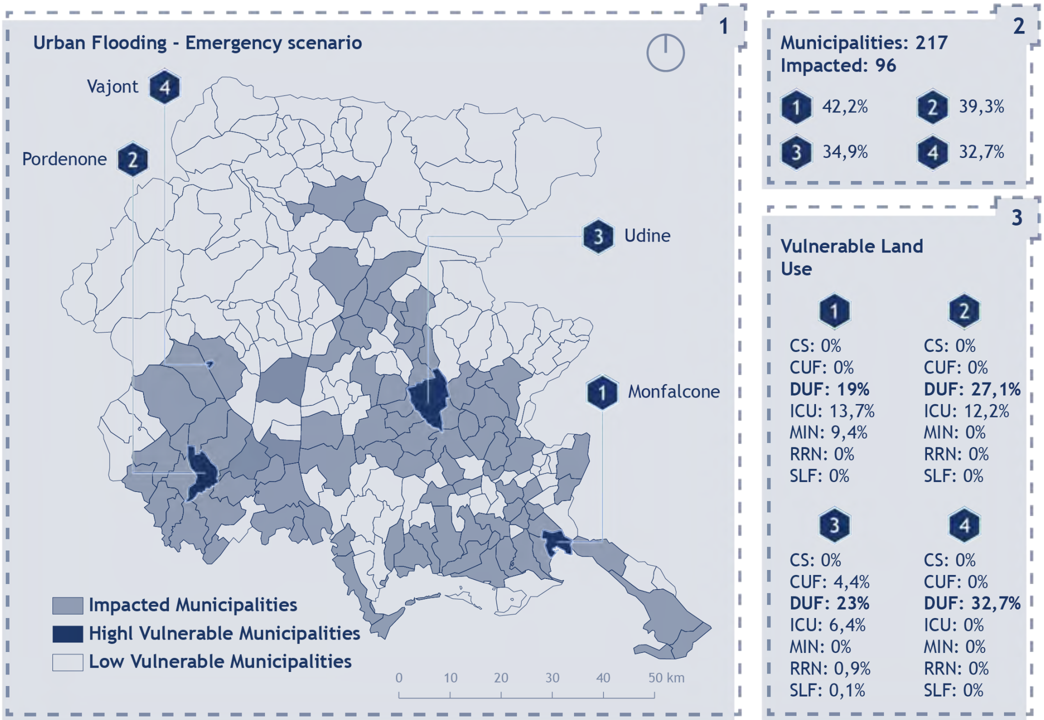


Figure 86 - Municipalities of RAFVG vulnerable to the extreme class of vulnerability to uf in an emergency scenario 2.
Percentage of vulnerable soil for the most exposed municipalities 3.
Percentage distribution of impacted territory by land use class.

Also in the case of Slovenia, as can be seen in Figure 87, there is an increase in the number of affected municipalities to 25%, and the same municipalities affected by uhi - Ankaran, Domžale, Izola and Ljubljana - are recorded with the percentage of 28%, 10.5%, 6.8% and 17.9% respectively. The affected soil types show similar values, but with a rather significant increase in the low vulnerability level for the municipality of Ljubljana and in the amount of affected soil in the municipality of Domžale, which even doubles.

At the end of the analyses described above, a summary reading of the municipalities affected by the individual impacts (Figure 88 e Figure 89) and by the overlapping of the impacts (Figure 90), in order

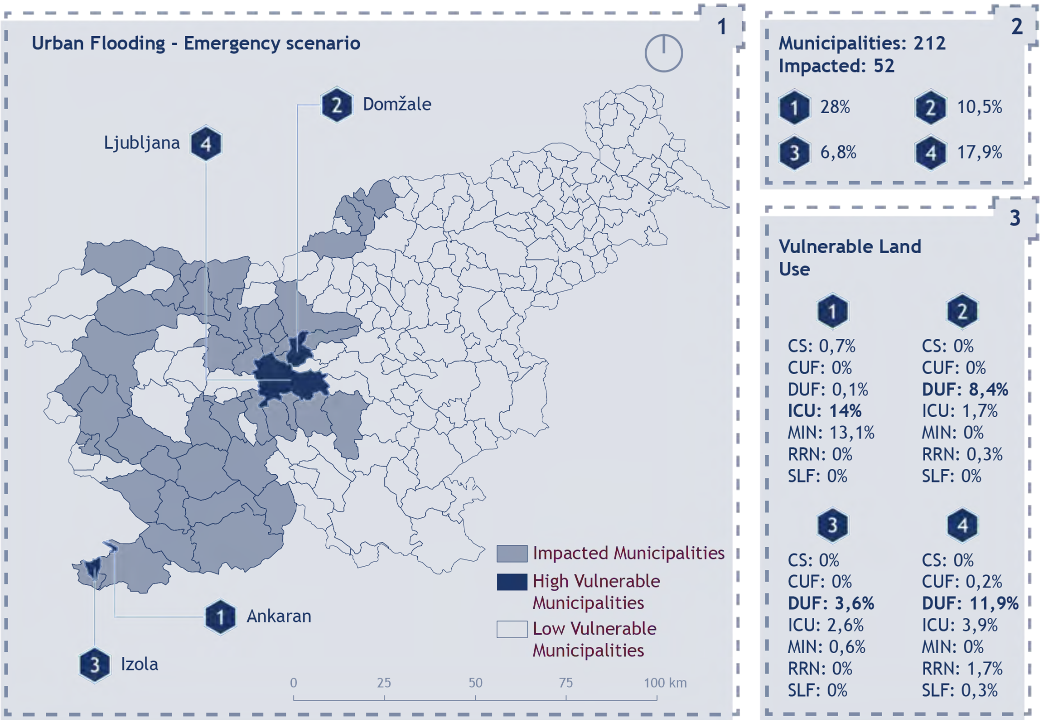
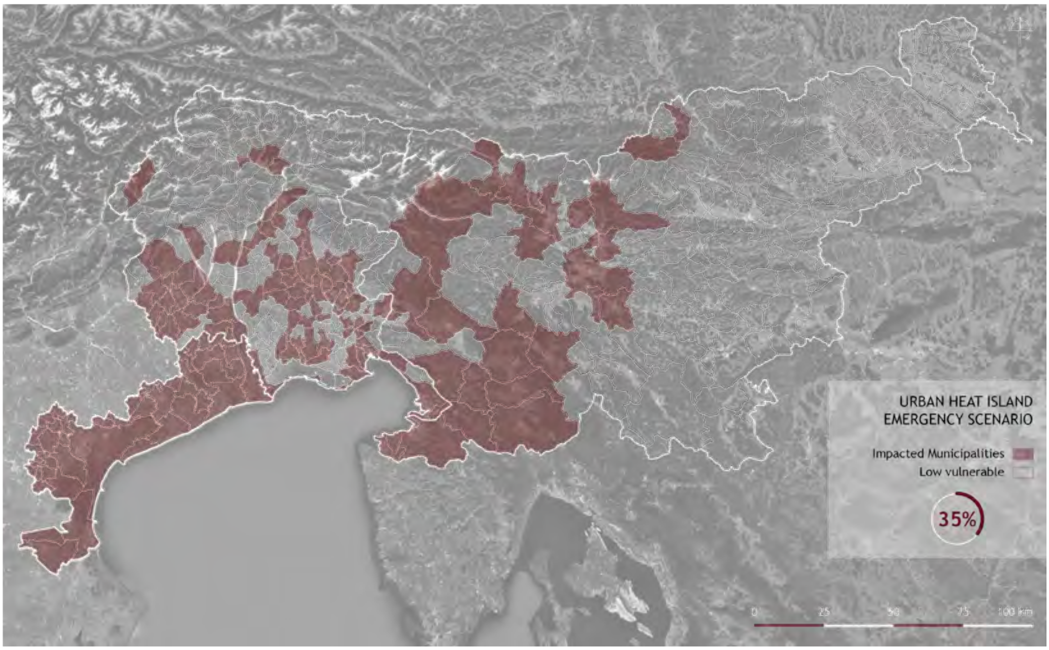


Figure 87 - Municipalities in Slovenia vulnerable to the extreme uf vulnerability class in an emergency scenario 2.
Percentage of vulnerable soil for the most exposed municipalities 3.
Percentage distribution of impacted land by land use class.

to have a complete view of the potential impacts within the project areas. Out of the total number of municipalities in the surveyed areas, 35% are potentially subject to the impact of urban heat island, while the percentage of urban flooding is 41%. From the overlapping of these two it is interesting to note that the majority of the involved municipalities, corresponding to 33% of the whole area, presents a predisposition to suffer both impacts. What emerges from the intersection between the land use statistics and the municipalities of the three project territories is, therefore, a higher vulnerability to the impact from urban flooding, in particular for the discontinuous urban fabric with a degree that oscillates between medium-low and low. On the contrary, for RAFVG and Slovenia the same fabric presents a medium-high to high level of vulnerability to urban heat island. Another element that these two territories have in common are. the 4 municipalities most affected by the two impacts, which remain unchanged.

Figure 88 - Municipalities affected and not affected by the urban heat island impact compared to the total number of municipalities in the project area.



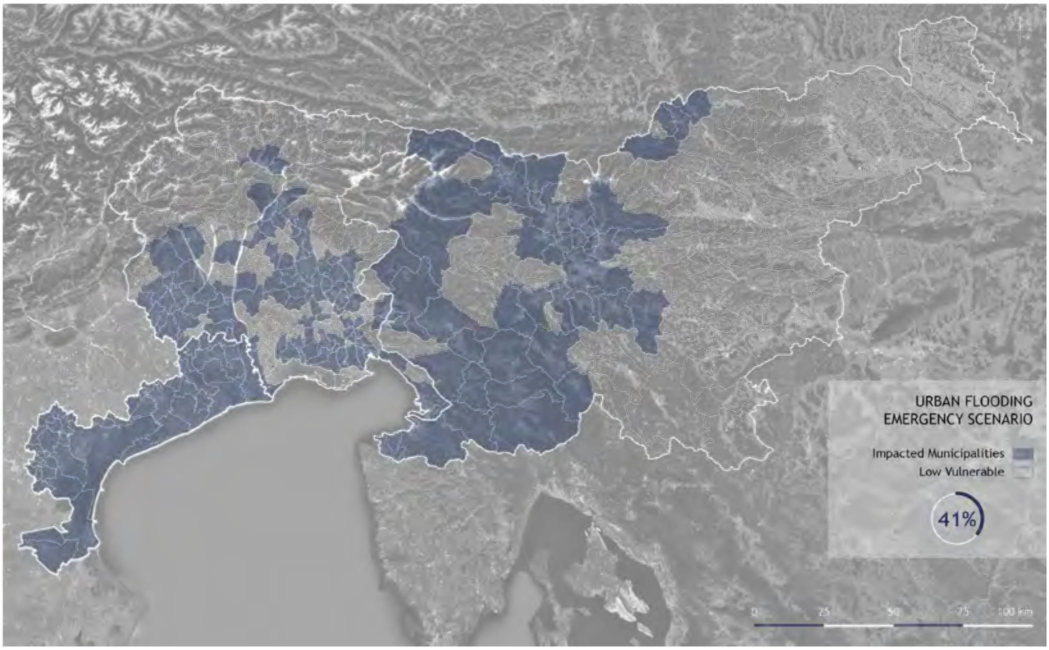


Figure 89 - Municipalities affected and not affected by urban flooding compared to the total number of municipalities in the project area.

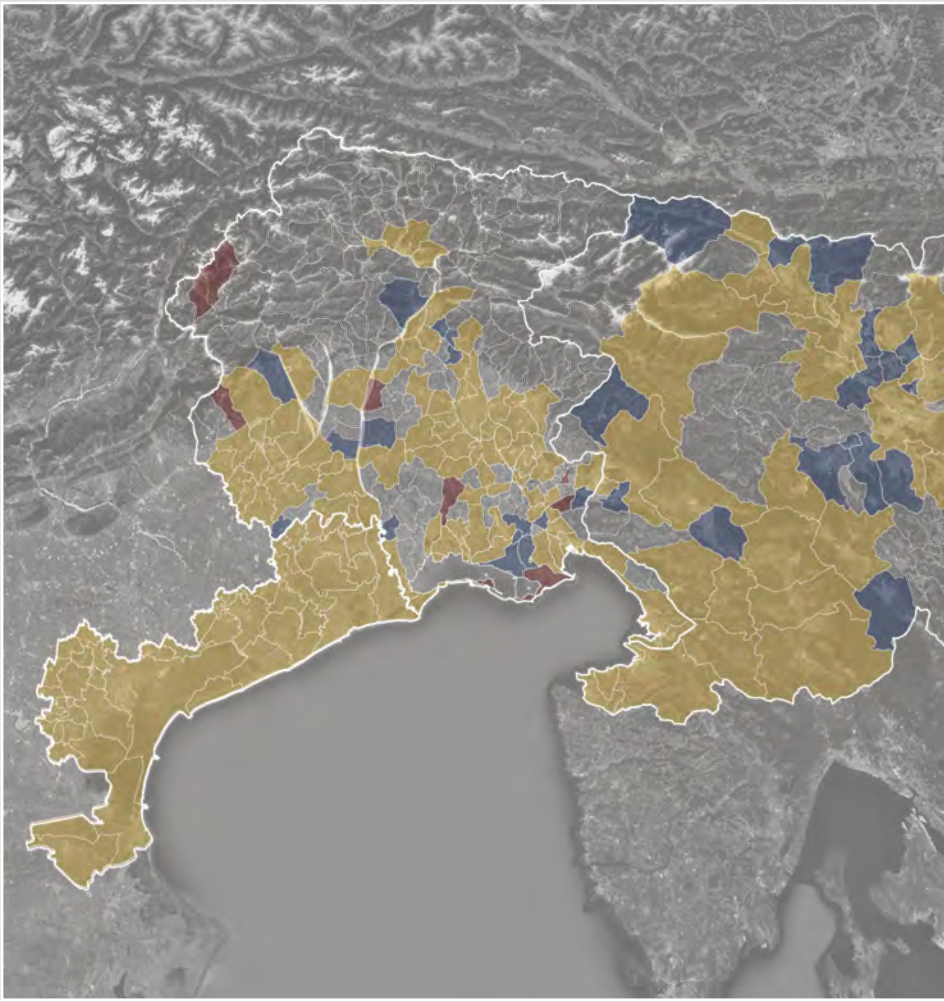
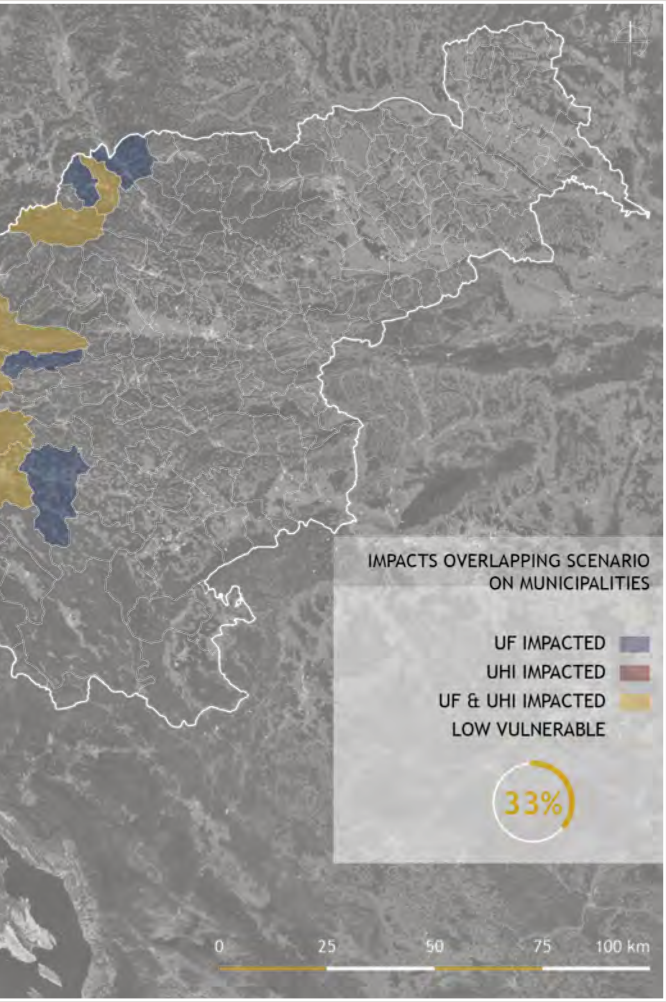


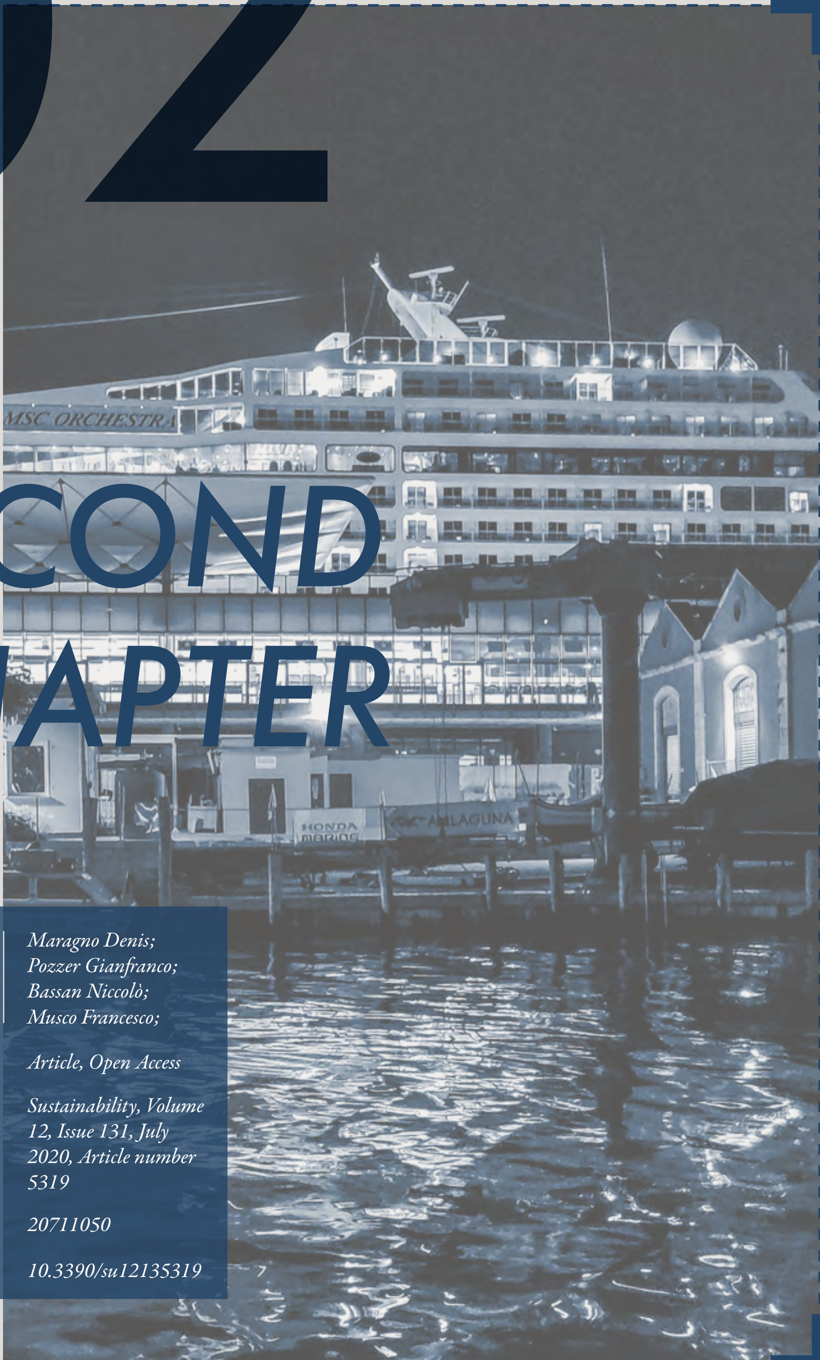
***Figure 90** - Municipalities impacted and not impacted by ubi and uf and their overlap compared to the total number of municipalities in the project area.*



The overall analysis shows how the study area is generally vulnerable to the CC impacts considered. From this dissertation point of view, the assessment verifies how there is substantial overlap (one-third) of municipalities with a high risk of vulnerability with more than one impact simultaneously. The assessment considers the morphological predisposition of each urban area factors such as the presence of vegetation, albedo, elevation, and concertation of buildings. The approach is the first step in developing the risk analysis and implementing effective CAPs.

02

SECOND CHAPTER



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Document Type:	*Article, Open Access*
Journal:	*Sustainability, Volume 12, Issue 131, July 2020, Article number 5319*
ISSN:	*20711050*
DOI:	*10.3390/su12135319*

Article Title:

Land–Sea Interaction: Integrating Climate Adaptation Planning and Maritime Spatial Planning in the North Adriatic Basin

CHAPTER INDEX

Article Abstract

Land–sea interaction dynamics are physiologically regulated by an exchange of matter (and energy) between the anthropic system and the natural environment. Therefore, the appropriate management of land–sea interaction (LSI)contexts should base on those planning approaches which can holistically support coastal development, such as Maritime Spatial Planning (MSP) and Climate Adaptation Planning (CAP). One of the main limiting factors for this integration is the fragmentation of existing databases and information sources, which compose the territorial knowledge framework. Investigations have sought to address the representation and assessment of "wicked" and interconnected coastal problems. The present research focuses on the production of the necessary information to fill sectorial knowledge gaps and to merge the available data into a single framework. The research methodology is based on remote sensing assessment techniques and is designed to be replicated in other coastal areas to integrate CAP and MSP. The application of the assessment techniques is developed on a case study in the north Adriatic Basin. The Gulf of Trieste constitutes a representative case study for the Mediterranean Basin due to its transboundary nature. The relationship and the ongoing projects between Slovenia and Italy make the case study an interesting context in which to test and train the proposed integrated planning approach.

2.1. - Introduction

Coastal management is a complex matter assessed through territorial planning disciplines [1]. This paper presents an innovative and integrated approach developed to address two of the primary issues which affect Mediterranean coasts: climate change impacts and anthropic pressures on the marine environment [2–4]. This study aims to demonstrate that the overlapping of sectoral assessment techniques can lead to integrated knowledge, which can effectively support different planning approaches. The research methodology design combines Maritime Spatial Planning (MSP) and Climate Adaptation Planning (CAP) knowledge framework development into a single planning approach. The efficacy of this theory is empirically deployed on the Gulf of Trieste case study, located in the northern Adriatic Basin.

2.1.1. - Sea and Maritime Overview

Marine environments and coastal settlements are fundamental components of the European geopolitical context. The EU has 68,000 km of coastline, spanning more than 20 Member States and half of the total continental population [5]. With more than 1000 ports and shipyards, the maritime sector is a strategic economic asset. In this context, economic growth and related social wellbeing have environmental costs, while being dependent on the health of the coastal ecosystem [6]. This study focuses on land–sea interaction (LSI) areas and the required consciousness to sustainably act on these contexts, anticipating the interconnected consequences that a non-holistic approach might generate. [7–9]. While the LSI approach is capable to recognize the interdependency between land and sea systems, it is not implemented into the established planning models [10–12]. To support a retrofit of actual sectoral governance systems and to sustainably perform territorial management strategies, this research combines separate approaches into an integrated framework [13]. At present, the current paucity of integrated strategies between land and sea management and holistic management practices are hindered by the following barriers:

- Lack of comparable local information systems;
- Extensive and inaccurate forecasting systems;
- Lack of integrated governance between the land and sea systems;
- Multilevel governance organization;
- Inertia of public administrations in the adoption of medium- to long-term knowledge systems;
- Absence of guiding regulations.

Maritime Spatial Planning (MSP) is a relatively new planning approach which aims at analyzing and organizing human activities in the sea space to achieve ecological, economic, and social objectives. The growth of the pressures induced by anthropic activities on the global marine environment urgently requires more sustainable coastal and maritime management [3]. The adoption of the MSP approach enriched, in the marine spatial dimension, coastal territorial planning, with the possibility of combining different necessities and solutions. At the EU planning level, the intensification of maritime activities and the exploitation of marine and coastal resources within the "blue economy" framework [14] became key elements in understanding the geopolitical panorama. In this context, the Integrated Maritime Policy of the European Union (IMP) [1,15] was adopted to provide a more coherent approach to maritime issues, calling for an increased coordination between different policy areas under a comprehensive policy "umbrella". The backbone of the environmental aspect of the IMP is the Marine Strategy Framework Directive (MSFD), regulated by European Directive 2008/56/EC [16], which considers the marine environment from an integrated perspective. Specifically, the directive requires each coastal EU Member State to develop a strategy to prevent and restore damaged ecosystems to Good Environmental Status

(GES) [2]. The MSP pillar of the EU's IMP is regulated by European Directive 2014/89/EU [17], and makes MSP mandatory in planning policies of all coastal Member States [18]. The MSP Directive requires the EU Member States to develop a national maritime spatial plan by 31 March 2021 [19,20], with a minimum review period of 10 years, and establishes an MSP framework, aimed at i) promoting the sustainable growth of maritime economies; ii) the sustainable development of marine areas; iii) the sustainable use of marine resources. Moreover, the Directive states that the minimum requirements for maritime spatial plans must include land–sea interactions, an ecosystem-based approach, coherence between MSP and other processes such as integrated coastal management, the involvement of stakeholders, the use of the best available data, transboundary cooperation between Member States, and cooperation with third countries [21,22]. Therefore, initiatives aiming at integrating land-based and maritime spatial planning are clearly promoted by the Directive.

In Italy, the MSP Directive was implemented via the Italian Legislative Decree 17 October 2016, n. 201 [23], together with the recommendations adopted by the Decree of the President of the Council of Ministers of 1 December 2017 [24]. The Ministry of Transport and Infrastructure was appointed to implement MSP in Italy, and an Inter-Ministerial Coordination Committee (ICC) was established. The ICC identified the maritime areas where specific maritime plans should be implemented; these correspond to three sub-regions referenced within the Marine Strategy Framework Directive (Article 4 of Directive 2008/56/EU): the western Mediterranean Sea, the Adriatic Sea, the Ionian Sea and the central Mediterranean Sea. The need for climate change adaptation in coastal areas is particularly evident and are predicted to become progressively more significant over time due to the long-term forecasts of climate variables and sea level changes [25].

Different research argues that reactive and spatially isolated efforts are less effective than proactive and integrated coastal management. For example, European and international policy strategies [26,27] recognize the central role of Integrated Coastal Zone Management

(ICZM), which is considered the most appropriate process to deal with climate change impacts, such as sea-level rises. Integration refers to measures which combine adaptation with various planning sectors and multi-scalar policies.

2.1.2. - Coastal Territories and Climate Change Impacts

In general, climate impacts are linked to the physical shape of coastal regions. Local characteristics can amplify the effect of single impacts or can trigger chained ones. In Europe, there is approximately 140,000 km2 of land located 1 meter below mean sea level [28]. Therefore, it is crucial to address the climate-related coastal vulnerabilities to avoid damage to the economy, society, and the environment. These regions are often characterized by strategic socio-economic assets (i.e., those linked to tourism, fishing, harbours, and shipyards). This makes coasts particularly sensitive to climate change impacts, which primarily expose infrastructure and the local populations. Human activities are also responsible for additional pressures on coastal ecosystems. These activities often generate more immediate impacts than those expected from climate change and aggravate existing vulnerabilities. Therefore, the definition of Climate Adaptation Planning (CAP) must take specific local socio-economic contexts into consideration. International scientific communities [26,27,29–31] state that coastal area adaptation should be iterative and dynamic, in recognition of the continuously evolving dynamics present in coastal territorial systems. Furthermore, adaptation measures should consider the local ecology, economy, society, politics and technology [26,32–35].

The Urban Heat Island (UHI) effect and urban runoff are among the more relevant impacts because of their capability to represent the more common and widespread effects of climate change on cities [36]. UHI is a micro-climatic alteration which determines an additional risk for the health of urban populations. It is relevant to consider that even a modest climatic event can significantly impact many people and areas with a high concentration of strategic infrastructure. Besides the high exposure of these assets, urban infrastructural networks tend to amplify these phenomena [37]. Therefore, the overlap of climatic events and anthropic stresses can impact both the environment and human activities.

2.1.3. - Framing the Problem

What emerges from this overview is an articulated set of wicked problems and interconnected dangers which afflict the same territorial context. From this perspective, the current system is ineffectively defended due to the isolated nature of planning models and the (over) simplification of complex problems. One possible approach to address these challenges is the integration between Maritime Spatial

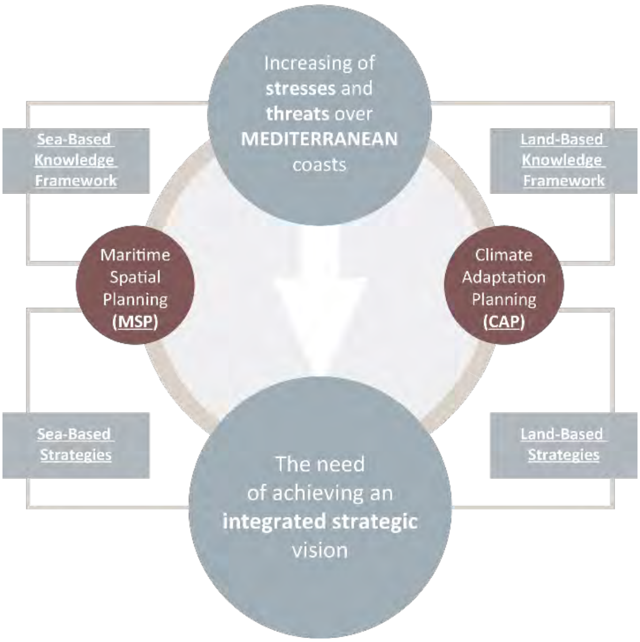
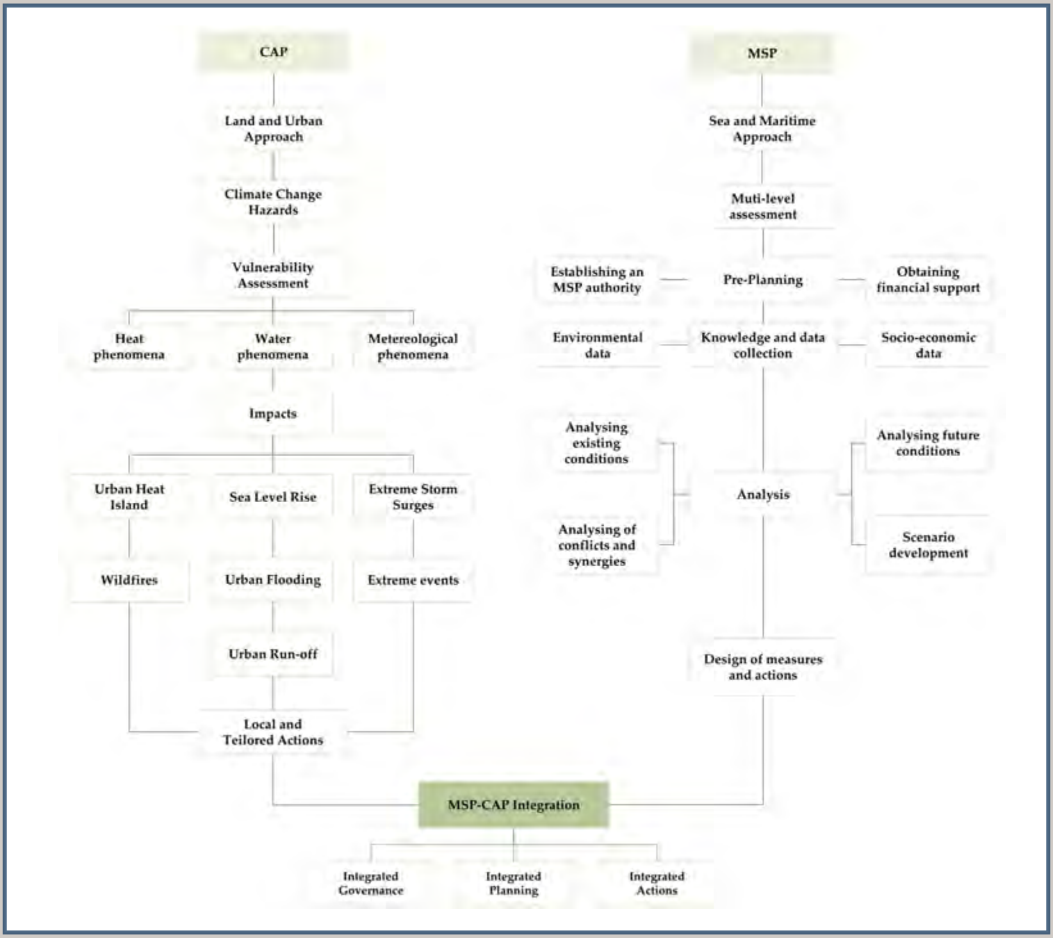


Figure 2. - CAP and MSP combination workflow (source: authors' elaboration).

Figure 1 - Graphical Abstract of Maritime Spatial Planning (MSP) and Climate Adaptation Planning (CAP) integration.

Planning (MSP) and Climate Adaptation Planning (CAP) [38–40] (Figure 1).
Territorial planning and, in general, the territorial governance culture, tend to limit and separate actions, strategies, and knowledge frameworks. Figure 1 describes the current separated nature of coastal planning workflows. The Land and Urban Approach on the left refers to the spatial mapping of climate-triggered relationships and impacts in the built and natural environment. The Sea and Maritime Approach on the right describes the general method for maritime environmental assessment and planning. It is based on the evaluation of sea uses and the identification of marine ecosystems. Although the two macro-environments have distinct and non-complementary governance



strategies, environmental issues related to climate change are critical to both planning approaches.

The authors recognize, in this methodological separation (Figure 2), both a problem and an opportunity for action. On the one hand, it is possible to recognize a lack of dialogue between planning models and on the other hand, it is, however, possible to recognize that the objective of these processes is the management of the same territory. Even if the oversimplification of "wicked" problems is ineffective due to criticalities which are intrinsically connected, it is possible to develop spatial knowledge, which allows for aware territorial management. The fact that this knowledge already exists, even if stored in separate databases, leads us to suppose that the core of the problem is the will and interest to implement an integration by decision makers. From this perspective, the threat of climate change, recent disasters and ongoing international projects could generate the necessary interest and give rightful priority to a holistic coastal planning approach [41].

2.1.4. - Research Questions

This study aims at demonstrating that the integration of sectoral planning approaches would be a viable first step to generate proactive and responsive territorial governance models. Furthermore, it could lead to an effective and sustainable management of complex phenomena, such as the interrelated dynamics of climate change and human pressures on ecosystems. This research is structured around the following research questions (RQ):

- RQ1. How can climate change adaptation trigger and support a successful convergence between "Land and Urban" and "Sea and Maritime" planning approaches in an LSI context?

- RQ2. How can terrestrial vulnerability assessments, marine and maritime knowledge frameworks converge to define a multisystemic vision of the territorial priorities?

- RQ 3. Does the result between the integration between MSP and CAP in an LSI context favour and generate trans-sectoral strategic action?

- RQ 4. Can the ongoing urban and regional planning processes be effectively enriched by the integration of the cognitive frameworks of CAP and MSP?

2.2. - Research Methodology

The research methodology is organized into four sections aimed at answering the research questions and to support the development of the initial hypothesis.

The Research Methodology Chapter is organized into four paragraphs: Research Design, Planning Approach, Assessment Techniques and Empirical Research.

2.2.1. - Research Design

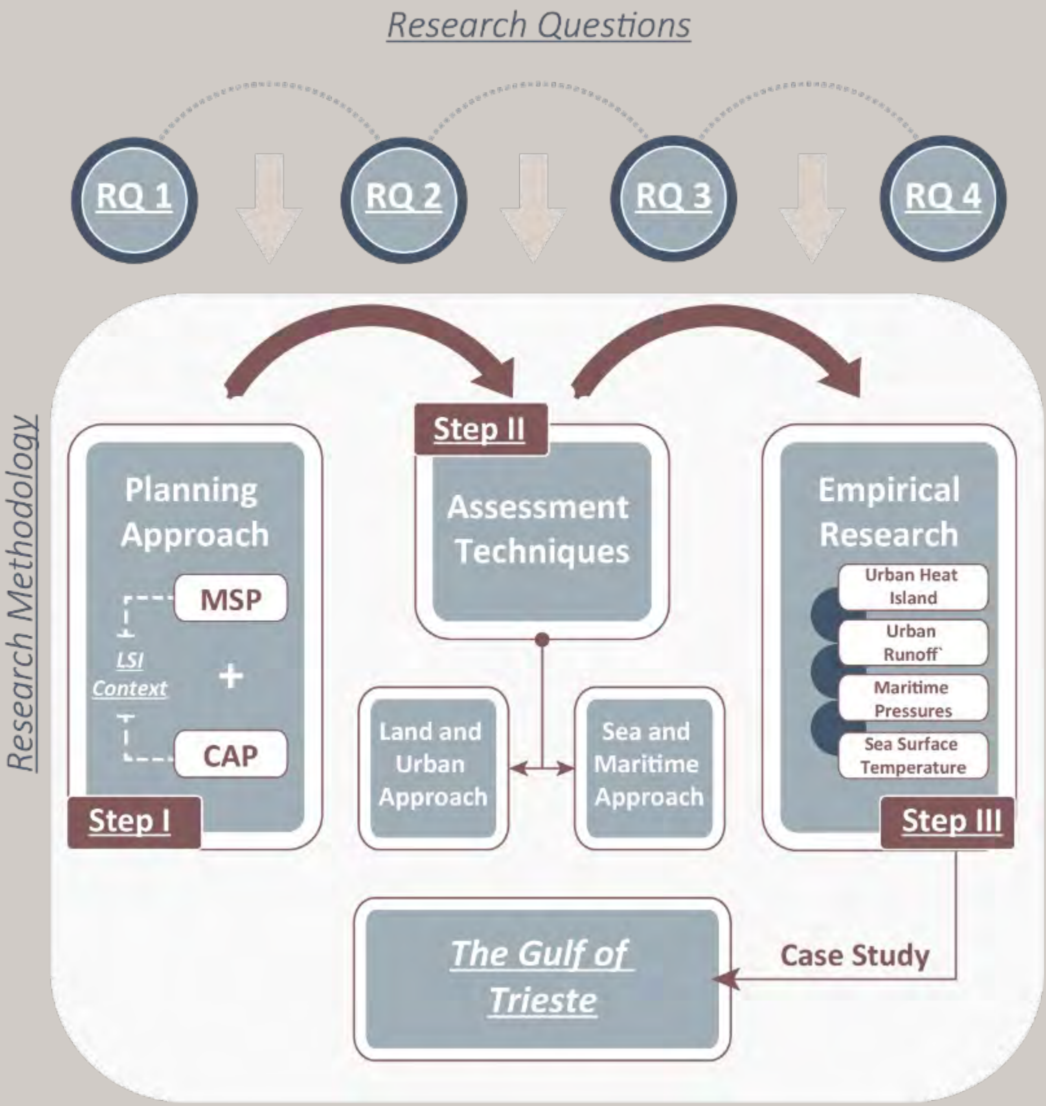
The initial phase of the research consists of developing the design of the investigation process. Figure 3 presents the workflow through which the research is structured. Research questions RQ1, RQ2, RQ3 and RQ4 are integrated into the three operational steps of the research methodology and support the chosen operational decisions.

Step 1:
Defines the planning approach adopted, and the integration between MSP and CAP in an LSI context, to support its implementation.

Step 2:
Presents the investigation techniques for the development of land and sea knowledge frameworks, to produce an integrated and replicable investigation methodology.

Step 3:
Applies the investigation techniques for climate change impacts and marine pressures on the Gulf of Trieste case study. The three-step approach proposes an integration process at different levels, which can be replicated in other coastal contexts.

Figure 3 - Research design organization.


Research Questions
RQ 1
RQ 2
RQ 3
RQ 4
Research Methodology
Step I
Planning Approach
MSP
LSI Context
+
CAP
Step II
Assessment Techniques
Land and Urban Approach
Sea and Maritime Approach
Step III
Empirical Research
Urban Heat Island
Urban Runoff`
Maritime Pressures
Sea Surface Temperature
Case Study
The Gulf of Trieste

2.2.2. - Planning Approach

The authors propose a planning approach which integrates Climate Adaptation Planning and Maritime Spatial Planning. This combination aims at giving support to local authorities in managing wicked and overlapping issues. The approach provides a single, shared management framework for land and sea, designed to address climate change adaptation measures through monitoring and analysis of both local and regional vulnerabilities and impacts.
The integration of these two systems requires shared geospatial information, relevant to multi-temporal, multi-scalar, and multi-disciplinary assessments. Land-based information is processed by computational and data analysis technologies (vector and raster) from both local geodatabases and raw satellite data. The methodology is based on theoretical and procedural frameworks, tested and validated in scientific literature [42–46]. The approach considers the vegetational, thermal and urban parameters. These parameters can be used to describe urban spatial structures and their vulnerability level. Sea-based information considers the variable impacts of natural events (i.e., extreme storm surges), and anthropogenic environmental disturbances. The maritime approach is based on ecological, environmental, and socio-cultural information, and maps economic and territorial assets (see dataset of the Adriplan.eu portal) [47]. This approach does include some hybrid computational methods, similar to those used by the Land and Urban Approach, for calculations such as the estimate of the Sea Surface Temperature (SST).
The knowledge framework developed through this planning approach aims at allowing a technical comparison between land and sea, which can help spatial planning to recognize existing interactions. This integrated representation of information can trigger sustainable governance actions and support decision makers in undertaking multilevel territorial strategies. A cooperative territorial planning process is a conceptual approach which combines theoretical investigation with operational management. This is achieved through merging two parallel datasets:

1) Heatwaves and flood impact analysis (land-based).
2) Analysis of SST and multilevel evaluation of environmental components, uses, conflicts and synergies in the maritime space.

2.2.2.1. - The Development of the Integrated Approach

The Land and Urban Approach uses two parallel assessment processes: the first is the definition of a set of parameters derived from the urban shape; the second uses satellite images to identify the principal groundcovers (water, artificial soil, surface temperature and vegetation). The set of indicators is divided into:

- Normalized Difference Vegetation Index (NDVI).
- Normalized Difference Moisture Index (NDMI).
- Land Surface Temperature (LST).
- Surface runoff (ϕ).

The Sea and Maritime Approach instead tests the level of integration of maritime planning systems with opportunities, practices and territorial conflicts triggered by the use and the unsustainable exploitation of natural resources. It uses two distinct but integrable methods: the estimation of the SST and the assessment of climatic and anthropic impacts linked to the coastal area (e.g., urban runoff).
In particular, the assessment that refers to the maritime environment is composed of the following elements:

- Environmental data;
- Socio-economic information.

The integration between the Land and Urban Approach, and the Sea and Maritime Approach creates a "multi-objective" spatial information system, which is able to represent landscape/seascape patterns of change, induced by the interaction between anthropic and ecosystem processes (e.g., protection of the coasts or protection of the marine ecosystem). This integration generates new knowledge/action systems, with significant implications in terms of our ability to analyze climate impacts. The process is described in Figure 4.

This supports two investigation phases:

1) The construction of a theoretical–operational frame through which to interpret and assess the land–sea context.
2) The identification of criteria and analysis models relevant to the integrated management between coastal and terrestrial planning.

2.2.2.2. - Vulnerability Approach Definition

The proposed planning approach gives a basisbases on to the definition of vulnerability in relation to the concepts introduced by the Interoperative Panel on Climate Change (IPCC) in 2014 [27].

It uses two analytical variables, namely:

- Sensitivity: "in the IPCC approach, determines the degree to which a system is adversely affected by a given exposure";
- Adaptive capacity: the ability of a natural or a built system to adapt to climate change.

These variables allow for a replicable comparison at both urban and regional scales, based on the following equation:

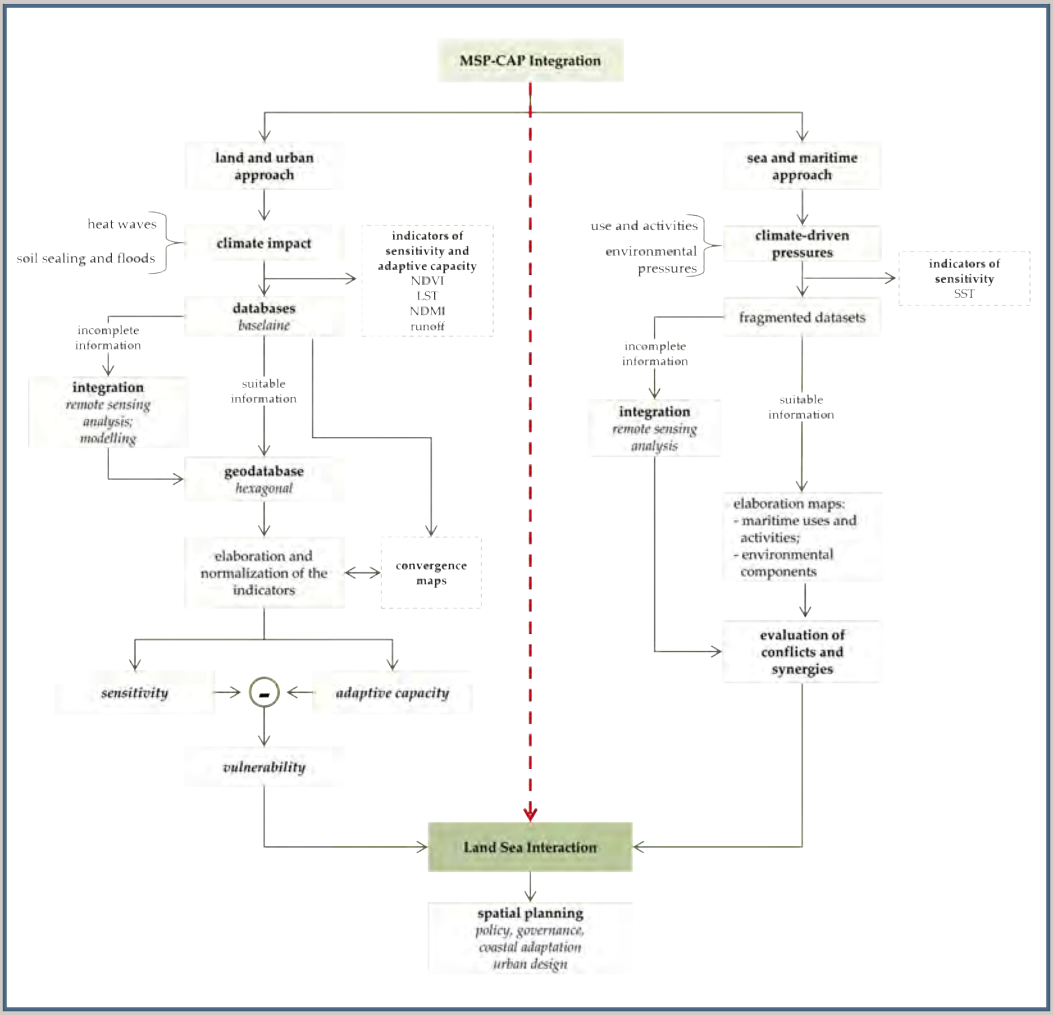
$$V=S-AC=((S_1+S_2+\dots+S_n)/n)-((AC_1+AC_2+\dots+AC_3)/n)$$

where
V = vulnerability;
S = sensitivity;
AC = adaptive capacity;
n = number of used indicators.

Figure 4 - Schematic integration of the assessment workflows (source: authors' elaboration).

interconnection among land-based vulnerabilities and the territorial characteristics that trigger climatic impacts. An example is the interrelated actions and distribution of temperatures between coastal infrastructure and the sea surface, and the related phenomena of heating associated with rivers and infrastructure behavior.

2.2.2.3. - Data Sources



The study uses a set of territorial data sources (Table 1): a combination of geodatabases produced by public bodies and remote-sensed surveys produced by the authors. The database structure is designed according to the interpretative framework.

2.2.2.4. - Integrated Geodatabase Preparation

Approach	Category	Description	Typology and Resolution	Source
Land and urban approach	Basic Map	Digital Terrain Model	Raster 25 × 25m	Copernicus Program
	Basic Map	Primary watercourses	Vector	CCM2
	Thematic Map	Corine Land-Cover 2018 Photo-interpreted satellite survey of European land cover.	Vector/Raster The production of CLC data returns digital cartography at a scale of 1: 100,000.	Copernicus Program
	Remote sensing	Multispectral Satellite Image: LC08_L1TP_191028_20170706	Raster-Geotif – 16 bits, 30m	Landsat 8 (United States Geological Survey – USGS)
	Morphological parameters and indices	LST; NDVI; NDMI	Raster-Geotif – 16 bits, 30m	Data derived from Landsat 8 image (USGS)
Sea and maritime approach	Basic Map	Adriatic-Ionian Macro-region	Vector	Adriplan project
	Maritime transport and tourism	Ports and harbours	Vector	Shape Adriatic Atlas
	Basic Map	Artificial reef (Veneto-Friuli-Venezia Giulia)	Vector	ISMAR (Venezia)
	Coastal defence and sand extraction	Offshore sand deposits	Vector	CNR-ISMAR (Venezia)
	Coastal defence and sand extraction	Artificial coastline	Vector	Adriplan project
	Maritime transport and tourism	Ferry routes	Vector	Shape Adriatic Atlas
	Maritime transport and tourism	Marine traffic corridor	Vector	Shape Adriatic Atlas
	Environment and ecosystems	Natura 2000	Vector	EEA (European Environment Agency)
	Environment and ecosystems	Coralligenous communities (model)	Vector	MEDISEH-MAREA project
	Environment and ecosystems	Coralligenous outcrops	Vector	MEDISEH-MAREA project
	Environment and ecosystems	Posidonia oceanica distribution	Vector	MEDISEH-MAREA project
	Environment and ecosystems	Marine mammals' sightings	Vector	European Marine Observation and Data Network (EMODne)

Table 1 - Data sources.

The preparation of the geodatabase can be generally divided into six distinct operations:

1) The construction of the information system structure to support climate adaptation actions.
2) The processing of satellite images to provide NDVI, NDMI, LST and SST spatial distribution values.
3) The modelling of surface water outflows (ϕ).
4) The selection of variables to calculate and spatially identify the effects of climate change on natural and built systems.
5) The synthesis of comparable data values.
6) The normalization of the sensitivity, adaptive capacity, and vulnerability indicators.
7) Overlapping Sea and Maritime spatial knowledge frameworks.

The geodatabase considers, in its preliminary setting, the climatic vulnerabilities and ecosystem pressures. Vulnerability considers the relationship between land sensitivity and maritime adaptive capacity. In the Land and Urban Approach, a vulnerability assessment of the urbanized (or natural) environment requires adequate knowledge of territorial landcover and urban shapes. Moreover, it requires an interpretation of the environmental complexity within its ecosystem services.

2.2.3. - Assessment Techniques

As Figure 4 presents, the assessment techniques necessary to effectively describe coastal behaviors and characteristics, both from a terrestrial and a marine perspective, require a combination of information and geospatial processing. Therefore, this research presents the generic operative processes that can support knowledge framework development to assess the main issues related to LSI contexts. The "Land and Urban" approach is oriented to assess UHI and urban runoff phenomena, due to their relevance both for the extension of their impacts and the interest in these issues with ongoing projects. Specifically, the IPCC and the EU community recognize the importance of these climate change effects and the necessity to support local-to-regional Climate Adaptation Planning processes. Moreover, their nature is deeply linked to coastal urban areas' morphological characteristics and their effects consequently impact marine ecosystems and maritime activities. To prove this relationship, the "Sea and Maritime" approach spatializes the available information about sea uses and correlates the overheating of land through a Sea Surface Temperature (SST) assessment. These techniques are presented in their abstracted form and empirically implemented in the Gulf of Trieste case study to demonstrate their tailored replicability.

2.2.3.1. - Land and Urban Approach

The Land and Urban Approach copes with the following issues:

1) Urban Heat Island phenomenon effects.
2) Urban Flooding effects (surface runoff).

To assess the first phenomenon, the technique is based on satellite data analysis. The assessment of the first phenomenon bases on satellite data analysis. The second issue assessment requires a morpho-dynamic model of runoff coefficients developed in a GIS (Geographic Information System) environment through a Digital Terrain Model elaboration (DTM 25 m). Although the objectives of these two techniques are different, both contribute to defining local vulnerabilities. Since each system uses different data and analytical criteria, the use of the additive function (1) is weighted based on the necessity of the proposed planning approach (Figure 4). Furthermore, Table 2 illustrates, in detail, the different parameters used to spatialize, assess sensitivity and adaptive capacity. The vulnerability assessment uses GIS to spatially represent the output elaborations. The process illustrates the relation between sensitivity and adaptive capacity, and these ratios correspond to the characteristics of the single climatic impact.

Impact	Statistical Unit	Data, Indicators, Indexes	Vulnerability		Process
			Sensitivity	Adaptive Capacity	
Urban Heat Islands	Hexagonal Cell	LST	LST (average value)	NDVI (average value)	Sensitivity (-) Adaptive Capacity
		NDVI		NDMI (average value)	
		NDMI			
Urban Flooding	Pixel	Digital Terrain Model (DTM)	0.9 no permeable areas	0.1 permeable areas	Sensitivity and adaptive capacity relationship illustrated using a GIS spatial association algorithm
		Land Cover			
		Surface Outflow Index			

Table 2 - Land and urban vulnerability processing techniques.

Urban Heat Island Assessment

The UHI assessment process uses remote sensing techniques, which calculate the NDVI and LST values based on satellite multispectral images. The NDVI parameter quantifies the vegetation groundcover, while the LST represents surface temperature and allows us to understand the thermal relation between surfaces (i.e., artificial and natural). NDVI monitors the living state of plant organisms according to their chlorophyll activity. The theoretical threshold values are between -1 and +1: normally the presence of vegetation is indicated by values greater than 0.2, while values close to zero or lower are, in general, anthropic elements.
NDVI is calculated according to Equation (2), with the reflectance measured by near-infrared (RNIR) and red (RRED).

$$NDVI = \frac{R_{NIR} - R_{RED}}{R_{NIR} + R_{RED}}$$

The LST estimation is based on the NDVI index and the thermal IR spectral region, using band 10 (10.60 ÷ 11.19 µm). The LST definition requires us to convert the radiance to the numerical output of band 10 using expression (3):

$$L_\lambda = M_L Q_{cal} + A_L$$

where:
Lλ = Spectral radiance on the top of atmosphere (TOA): (Watts/ (m2 × sr × µm));
ML = band-specific multiplicative rescaling factor from the metadata (0.0003342);
AL = band-specific additive rescaling factor from the metadata (0.1);
Qcal = quantized and calibrated standard product pixel values (DN).

After the transformation of DN into radiance, the radiance is converted into Brightness Temperature (BT10). BT is a parameter which expresses the rate of energy radiated, in terms of temperature, by a hypothetical black body that emits the same amount of radiation observed. This is calculated through the thermal constants of the MTL (Landsat Metadata File) and a Kelvin temperature value is obtained. The equation for calculating the BT10 is as follows:

$$BT = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)}$$

where:
BT = top of atmosphere brightness temperature (K);
Lλ = TOA spectral radiance (Watts/(m2 ×srad × µm));
K1 = band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_774.8853);
K2 = band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_1321.0789).

The LSI calculation also requires a surface emissivity (LSE) value.

To obtain this data, a proportional coefficient of vegetation presence (PV) is applied, as defined by the NDVI variation.

$$PV=\left(\frac{NDVI-NDVI_{min}}{NDVI_{max}-NDVI_{min}}\right)^2$$

$$LSE=0.004\times PV+0.986$$

Once all the variables are known, the LST raster can be calculated, using the central value from the thermal spectral band (w) and the parameter (p), defined according to the Planck constant (h), the Boltzmann constant (σ) and the speed of light (c).

$$LST=\frac{BT}{1+w\times\left(\frac{BT}{p}\right)\times \ln LSE}$$

where:
BT = brightness temperature;
W = 10.895;
p = (h × c / σ) = 1.438 × 10 – 2 mK;
LSE = spectral emissivity.

For common use, LST values can be converted to degrees Celsius.

$$°C=°K-273.15$$

The result is a raster map, which represents the terrestrial thermal behavior of the assessed territory.
The calculation uses the NDMI parameter to assess the impact of the UHI phenomenon and the relation to the urban fabrics' shapes. The NDMI estimation indicates the soil moisture as a ratio between the difference and the sum of the radiation reflected in the near-infrared and SWIR, i.e., as (NIR-SWIR) / (NIR+SWIR). NDMI values range from +1 to –1: (+1) indicates a high humidity condition, while

(-1) low humidity (or dryness).

Equation 10 illustrates the relationship between the thermal behavior of the land's surface and the characteristics of land use:

$$V=S - AC= (LST)_S - ((NDVI + NDMI)/2))_{AC}$$

A core element of this technique is the adoption of a hexagonal grind used to homogenize the collected data. This element collects the results of satellite data elaboration and geographical information. The hexagons which compose the grid have an area of 500 square meters. The following variables/indicators are associated with each statistical unit (hexagonal cell) (Table 3).

Table 3 - Matrix attributes.

Statistical Unit	LST	NDVI	NDMI
Hexagonal cell	Average value	Average value	Average value

The indicators range from a scale of values between zero and one. This distribution allows us to represent and compare values with different characteristics. The overall vulnerability is measured by a synthetic index: the difference between the sensitivity and adaptive capacity parameter (Table 4).

Table 4 - Vulnerability attributes.

LST	NDVI	NDMI
Sensitivity	Adaptive capacity	Adaptive capacity

Vulnerability values range between –1 and one. Negative values correspond to good adaptive performances, while positive values correspond to critical conditions.

This geodatabase represents graphical data and interrelated indices at the same time. It links different phenomena within each hexagonal cell, defining a territorial spatial unit of vulnerability. This vector matrix provides the calculation base to test and represent the capabilities of the proposed planning approach, which could serve the following uses:

- Spatial statistics development and neighbourhood-scale analysis techniques implementation;
- Design of complex computational calculations;
- Assessment of precise spatial relationships;
- Clear and concise graphical data representation.

Surface Runoff Assessment

The estimation of territorial hydraulic performance is often developed with specific simulation models for "inflow–outflow" dynamics [48–53]. The assessment technique deployed in this paper uses an algorithm to spatially estimate the surface runoff derived by land uses [44]. The algorithm, executed in the GIS environment, allows for the simultaneous representation of surface runoff dynamics [45]. It uses specific land use classifications (i.e., agricultural, urban residential and industrial, wooded, wet and semi-natural). The direction and accumulation functions are calculated at a hydrogeological basin scale. The data required for hydrological modelling are:

- DTM with 25-m pitch with Geotif extension;
- Land uses (CLC 2018, Copernicus Program);
- Administrative boundaries in shapefiles of water management consortia.

The equation for estimating the surface runoff is:

$$\varphi_i = \left\{ \frac{[P \cdot F_U + P^{\circ} \cdot (F - F_U)]}{F} \right\}_i$$

where:
P = runoff coefficient associated with impermeable areas,
P = runoff coefficient associated with permeable areas,

F = flow accumulation calculated on DTM,
FU = accumulation of flow related to land cover,
U = land use in i.

The function allows us to associate the flow accumulation F with P and provides the hydraulic impacts ϕİ. The result is expressed as the percentage (%) of rain that turns into the surface runoff, and its values range from 0.2 to 0.9.
The result is a 25-meter resolution raster map, which considers the water accumulation within the hydrogeological basin. The processing returns a graphic index capable of assessing the different hydraulic performances of an area, in terms of ecosystem services. In this case, vulnerability is measured as the surface water runoff coefficient. The sensitivity and adaptive capacity indicators are embedded in the prosses as shown below (Table 5):

Statistical unit	DTM	Land Use	Runoff Coefficient	
			0.9 Impermeable Areas (worse condition)	0.1 Permeable Areas (best condition)
Pixel	Sensitivity	Sensitivity	Adaptive capacity	Adaptive capacity

Table 5 - Vulnerability attributes.

The runoff vulnerability assessment is spatially calculated, as is the UHI one, and this set of information can be integrated into the same geodatabase.

2.2.3.2. - Sea and Maritime Approach: Conflicts and Synergies

The Sea and Maritime Approach is based on two assessment techniques:

1) The SST estimation.
2) The Maritime uses/activities and environmental components maps.

The combination of these analytical tools provides an understanding of the relationships between uses and natural components, and how these correspond with SST variability. SST can be based on multispectral satellite images; otherwise, maritime and marine mapping can be based on existing geodatabases or specific and tailored analyses about environmental components and sea uses. Moreover, the output of this approach can also be integrated into the hexagonal grind used for the land-based assessments. The interpretation of these layers' integration within the same vector-unit allows us to evaluate the overall sea-based context and its spatial characteristics, connecting the Sea and Maritime Approach with the Land and Urban Approach.
Sea Surface Temperature Estimation
SST assessment is based on thermal infrared images from different satellite sources, including the Advanced Very High Resolution Radiometer (AVHRR) aboard National Oceanic and Atmospheric Administration (NOAA), Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Terra (originally known as EOS AM-1) and Thermal Infrared Sensor (TIRS) onboard the Landsat 8 satellite (NASA-USGS).. The estimation requires two data control phases: a) calibration of the SST calculation coefficients and b) validation of the calculation algorithm. The conventional approach to validate the SST calculation algorithms is the comparison with onsite temperature measurements. This method introduces four specific processing algorithms: 1) Planck [54]; 2) Mono-Window Algorithm (MWA) [54]; 3) Syariz [55]; 4) Split Window Algorithm (SWA) [56]. These methodologies have been largely tested in China and Southeast Asia seas, and in areas with vast databases collected using simple linear regression statistics. The tests describe the degree of correlation between the infrared bands, Enhanced Thematic Mapper (ETM) and Thermal Infra-Red (TIR) radiance and onsite collected data.

The scientific literature on SST recognizes the SWA algorithm as the most accurate to support water body thermal analysis [57–60].
The SWA model uses the BT10 and BT11 spectral signatures from

a satellite multispectral image; frequencies with an interval between 10.60 μm and 12.51 μm. BT10 and BT11 are subject to various atmospheric absorption contributions. Therefore, SST is calculated through Equation (12):

$$TS = BT_{10} + (2.946(BT_{10} - BT_{11})) - 0.038$$

where:
Ts = Sea Surface Temperature (°C), while 2.946 and 0.038 = values extracted with linear regression (regression conducted on a sample of values containing the temperature data collected onsite and the thermal values calibrated according to the atmospheric conditions that influence the radiation and thermal transmittance of the channel).

The result is a raster map of the sea surface temperature spatial distribution, with a 30-meter resolution.

Uses and Environmental Components

The approach considers different anthropic and natural components of the maritime context through the spatial relationships between maritime uses and environmental elements. This typology of assessment is based on geodatabases such as the one indicated in Table 1, which are the result of sectoral studies developed to support both the environmental protection and sustainable resource exploitation. This phase of the integrated planning approach focuses on providing a coherent and logical integration between aspects of the Land and Urban Approach and the objectives of MSP. Through the interpretation of the layer overlapping output, it is possible to identify those characteristic "land impacts" that can trigger the extension of impact effects on the marine environment and maritime activities.

2.2.4. - Empirical Research

Empirical research is the third step of the research methodology presented in Figure 4. This chapter presents the application of the assessment techniques developed to illustrate the general knowledge framework elaboration for the MSP and the CAP approaches (Figure 4). Presenting the assessment results, the authors aim to present the possible potentiality of the proposed planning approach and to highlight the opportunities that this knowledge integration can generate in managing an LSI context. As the empirical elaboration has the objective to answer different RQs, the case study choice considers the opportunity to test the possible implementation of the planning approach within ongoing projects aimed at MSP and CAP. Two of the more relevant ongoing projects with a strong connection to LSI planning in the Mediterranean region are the Interreg Italy–Slovenia project "Supporting Energy and Climate Adaptation Policies" (SECAP) and the European Maritime and Fisheries Fund (EMFF) "Towards the operational implementation of MSP in our common Mediterranean Sea" (MSP-MED). The Gulf of Trieste is a study area in both these projects, so the authors' choice is connected to the opportunity of implementing the proposed integrated planning approach within these ongoing activities. Moreover, SECAP is oriented to develop a transboundary adaptation strategy and represent a strong and innovative example of CAP in coastal areas. Alternatively, MSP-MED is a project that has the challenging objective of developing shared Mediterranean guidelines for Maritime Spatial Planning based on the concept of Integrated Coastal Zone Management (ICZM). From this perspective, the Gulf of Trieste case study can be considered one of the best options to immediately implement an integrated knowledge framework and can be considered as the appropriate context in which to undertake an integrated planning approach using MSP and CAP.

2.2.4.1. - Case Study

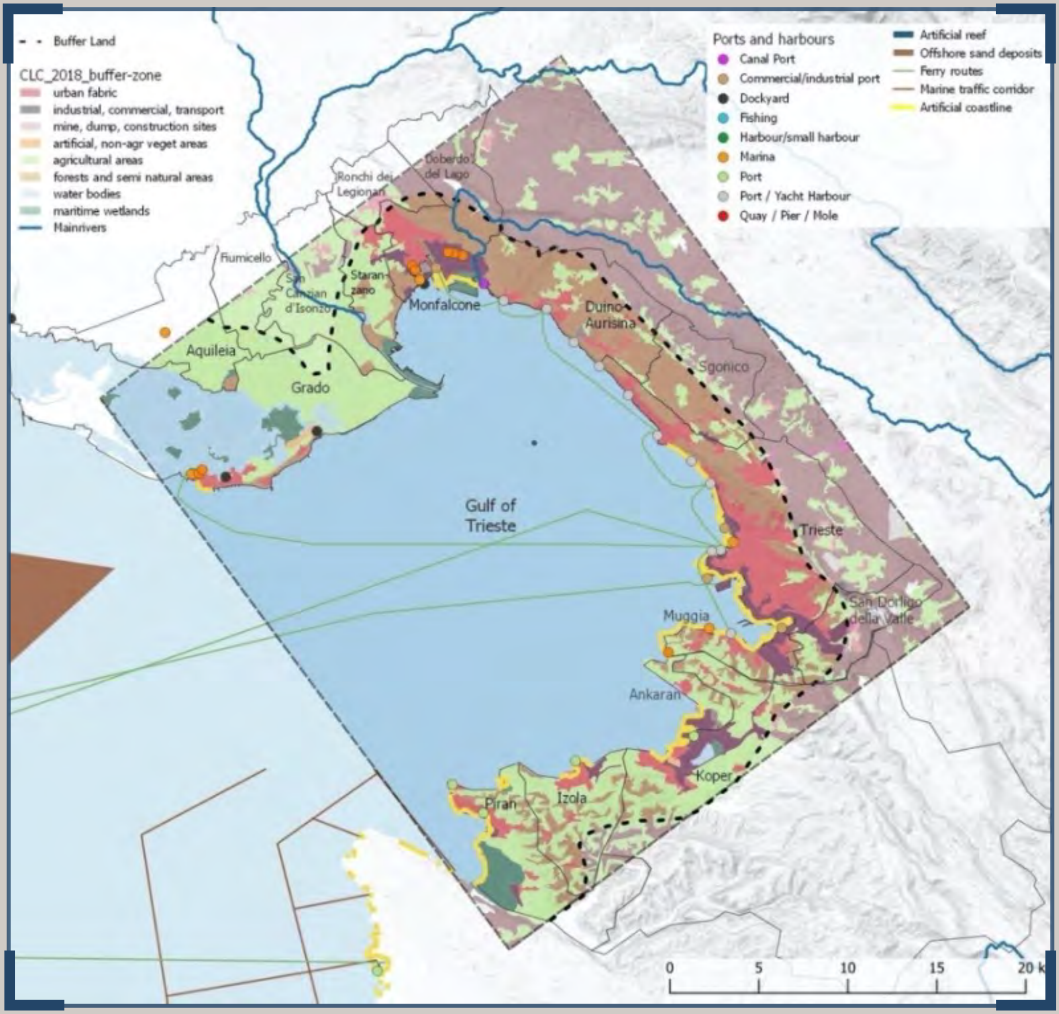
The study area is located in the northeast of Italy, at the border with Slovenia and Croatia, and covers the entire Gulf of Trieste (Figure

5). The selected area is representative of Adriatic and Mediterranean general LSI contexts. The research uses mapping techniques to understand regional criticalities and opportunities and present different administrative regions and maritime spaces [61]. The urban areas have a high built-up index, with a high proportion of residential fabric [62,63].

The Adriatic Sea and the Gulf of Trieste support three primary economic sectors: maritime trade, tourism, and fishing. The port of Trieste is one of the most developed shipyards and commercial harbours in the Mediterranean, with national and international trade flows. The gulf coastline is attractive for tourism due to the quality of the water (for swimming), local gastronomy, and the natural, aesthetic value of the landscape. The Karst plateau is an environmental protected area due to its fauna, biodiversity and its heritage value [64]. From a transboundary perspective, this is a highly representative region of the eastern Mediterranean, and its characteristics are highly relevant to an LSI planning perspective. This study examines Italian and Slovenian municipalities within the Gulf of Trieste. The Italian area considers the Friuli Venezia–Giulia Region, with the coastal (and inland) provinces of Trieste, Gorizia and Udine. The Slovenian area assesses the Littoral–Karst census region (Obalno–Kraška statistična Regija), with the municipalities of Ankaran, Koper, Izola and Piran.

To aid the LSI approach, the framework considers the necessary physical and spatial characteristics needed to develop an integrated, transboundary planning approach. The land-based analysis focuses on the morphological characteristics of a coastal buffer, according to coastal adaptation concepts [33,65]. This is useful to recognize and quantify different settlement typologies. Land use data, provided by Corine Land Cover 2018 (CLC 2018) and integrated with Normalized Difference Vegetation Index (NDVI) values, is used to characterize the land–sea coastal buffer. The NDVI value criteria are set to a threshold of lower than or equal to 0.4 (data updated in July 2017). Two groups of criteria were selected to illustrate positive relationships within the CLC variations of non-permeable surfaces. In this way, an indirect assessment of the effects of urbanization on

Figure 5 - Gulf of Trieste study area.


Buffer Land
CLC_2018_buffer-zone
urban fabric
industrial, commercial, transport
mine, dump, construction sites
artificial, non-agr veget areas
agricultural areas
forests and semi natural areas
water bodies
maritime wetlands
Mainrivers
Ports and harbours
Canal Port
Commercial/industrial port
Dockyard
Fishing
Harbour/small harbour
Marina
Port
Port / Yacht Harbour
Quay / Pier / Mole
Artificial reef
Offshore sand deposits
Ferry routes
Marine traffic corridor
Artificial coastline
Ronchi dei Legionari
Doberdò del Lago
Fiumicello
Staranzano
Monfalcone
Aquileia
Grado
Duino Aurisina
Sgonico
Gulf of Trieste
Trieste
San Dorligo della Valle
Muggia
Ankaran
Koper
Izola
Piran
0
5
10
15

the vegetation system in the buffer zone can be obtained. It should be noted that, in this analysis model, the NDVI values are particularly sensitive to three specific conditions: a) characteristics of the climatic zone; b) geomorphological and orographic aspects; c) climatic conditions and angle of incidence of sunlight.
The calculations graphically illustrate a buffer zone with a depth of about 3.5 km (measured from the coastline); the two variables influence the delineation of the buffer zone. The selected criteria support both the study of the relationship between the natural and anthropic environment and the relationship between the maritime space and the effects of climate change [66,67]. Three primary landscapes represent the urbanized character of the buffer zone and are defined by land use. The three configurations are based on the first level of CLC 2018 and on the following classes: a) agricultural areas, b) forest c) water bodies. The second level is also used to define a) artificial surfaces and b) wetlands.
The selected configurations are:

1) Areas with high urban density, where artificial surface (1.1; 1.2; 1.3; 1.4) values are higher than 25%;
2) Areas with medium urban density, with values between 15–25%;
3) Mainly natural areas with a low urban density, with values between 0–14%.

Table 6 illustrates an area characterized by a large concentration of rural and forestry land (approximately 68% of the total area of the buffer zone), with a lower percentage of residential and industrial uses (about 25%). Artificial surfaces are common in the Monfalcone area and the coastal areas of Trieste–Muggia and Ankaran–Koper. In these cases, the data for each municipality highlights the following distribution: Monfalcone 55%; Trieste 65%; San Dorligo della Valle 36%; Cow 44%; Ankaran 28%; Koper 25%. The expansion of industrial and residential areas tends to amplify the pressure of climate-triggered impacts. This indicates a relationship between MSP and land-based planning.

Municipality	Buffer * Area for Municipal Partition (sq Km)
Grado (GO) **	45.67
San Canzian d'Isonzo (GO)	7.44
Aquileia (UD)	12.04
Fiumicello (UD)	3.12
Staranzano (GO)	15.56
Monfalcone (GO)	20.31
Ronchi dei Legionari (GO)	1.74
Doberdò del Lago (GO)	3.95
Duino-Aurisina (TS)	38.02
Sgonico (TS)	14.6
Trieste	52.74
San Dorligo della Valle (TS)	9.28
Muggia (TS)	13.51
Koper	41.52
Ankaran	7.96
Izola	25.25
Piran	29.52
Overall profile	**342.25**

Table 6 - Distribution of land use in the municipalities of the buffer area.

1.1	1.2	1.3	1.4	2	3	4.2	5
rban Fabric %	Industrial, Commercial and Transport Units %	Mine, Dump and Constructi on Sites %	Artificial, Non-agricultural Vegetated Areas %	Agricult ural Areas (2.1; 2.2; 2.4) %	Forest and Semi Natural Areas(3.1; 3.2; 3.3) %	Maritime Wetlands %	Water Bodies(5.1 ; 5.2) %
5.96	0	0	1.84	64.39	3.37	13.73	10,71
0	0	0	0	81.91	8.85	0	9,24
0	0	0	0	92.76	4.5	2.2	0,55
0	0	0	0	100	0	0	0
7.8	1.63	0	0	54.93	21.73	10.13	3,78
27.02	27.77	0	0	4.87	32.76	7.42	0,16
0	0	0	0	11.01	88.99	0	0
0	0	0	0	0.66	99.34	0	0
10.19	2.74	1.06	0	12.75	73	0.13	0,14
4.33	1.33	0	0	21.25	73.09	0	0
50.29	13.97	0	0.59	5.67	28.99	0	0,48
10.31	25.88	0	0	37.51	26.31	0	0
19.33	23.42	0	0	30.99	25.8	0	0,46
9.83	14.88	0.03	0.76	57.23	13.99	0.93	2,35
6.78	17.11	5.12	0	52.77	14.28	0	3,94
9.62	4.04	0	0	58.84	26.78	0	0,71
11.83	2.63	0	0	49.44	12.85	21.79	1,45
15.94	**8.59**	**0.24**	**0.43**	**39.61**	**27.87**	**4.82**	**2,49**

[1] The choice of a depth of 3.5 km is also attributable to a steep strip of coast, whose urbanization depth (of about 2/4 km) is largely influenced by the morphological conditions of the karst plateau.

[2] For the Grado area, a part of the water body values was excluded from the buffer zone count, as it is a marine transition lagoon element.

2.2.4.2. - Climate Change Impacts and Maritime Pressures

The investigation examines the Gulf of Trieste from an LSI perspective, considering local climate change impacts [68] and anthropic pressures. The interpretation of the maritime space is based on maps of the Gulf's ecological characteristics. The study aims to determine a multidisciplinary knowledge database to aid a new, integrated planning methodology for maritime and terrestrial areas and dynamics [3]. The analysis also aims to detect and define the variety of stresses and effects generated by the anthropic use of the sea. In the Gulf of Trieste, climatic impacts affect both environmental and human activities, such as sea biodiversity and coastal economies. Understanding, quantifying, and placing these phenomena within the spatial realm is necessary to define both local and regional policies. This set of possible mitigation and adaptation measures has to consider a wide scenario of possible risks [69]. Ecosystem services play a central role in both approaches, as green and blue infrastructures can enhance the adaptive capacity of territories and mitigate greenhouse gas (GHG) emissions. Adaptation measures tend to be more complex in urbanized areas, due to the varying characteristics of human settlements.

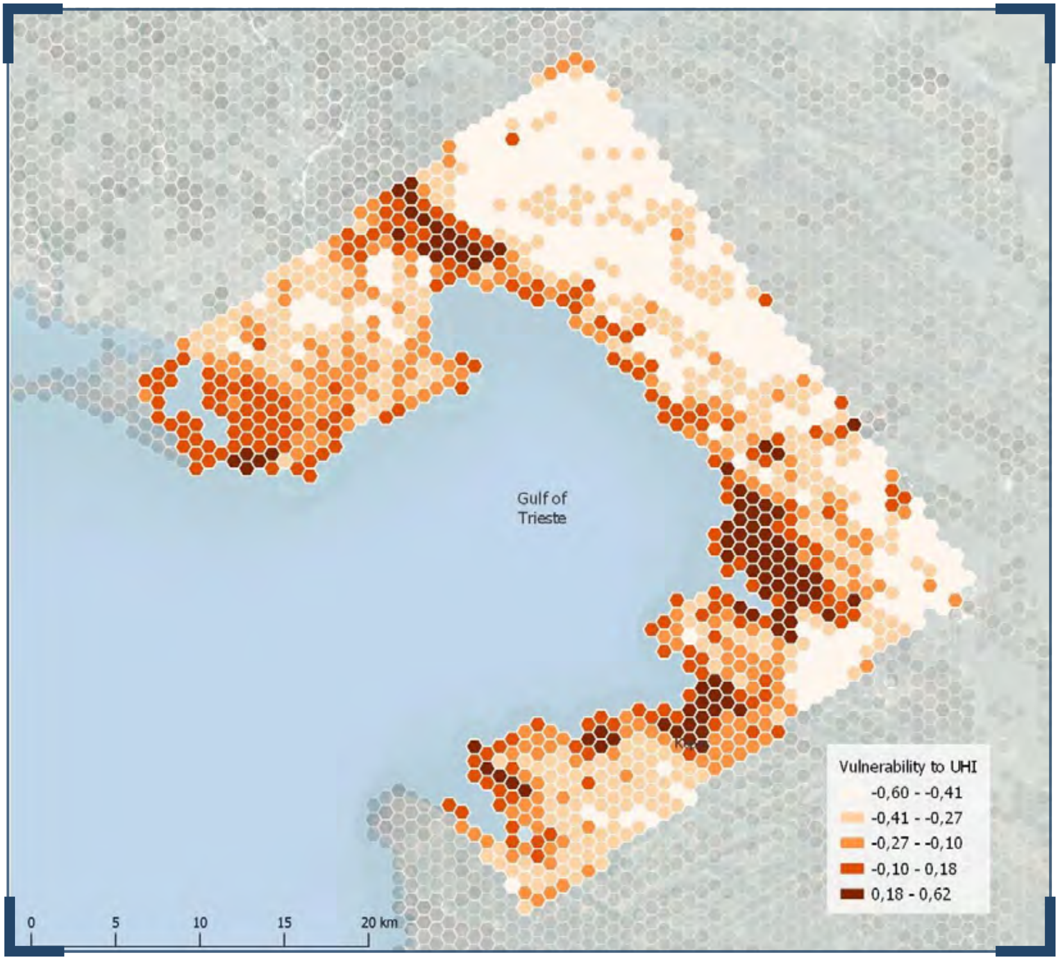
Figure 6 - Map of vulnerability to Urban Heat Island (UHI).

2.2.4.3. - Climate Change Impacts and Maritime Pressures

Part of the research methodology consists of the application of the assessment techniques on the case study to test their capability to effectively highlight and quantify the overlapping of information aimed at CAP and MSP. The results of the application are presented to describe the double nature of LSI contexts, so the Assessment Results are divided into land-based approach results and sea-based approach results.

Land-Based Assessment Results

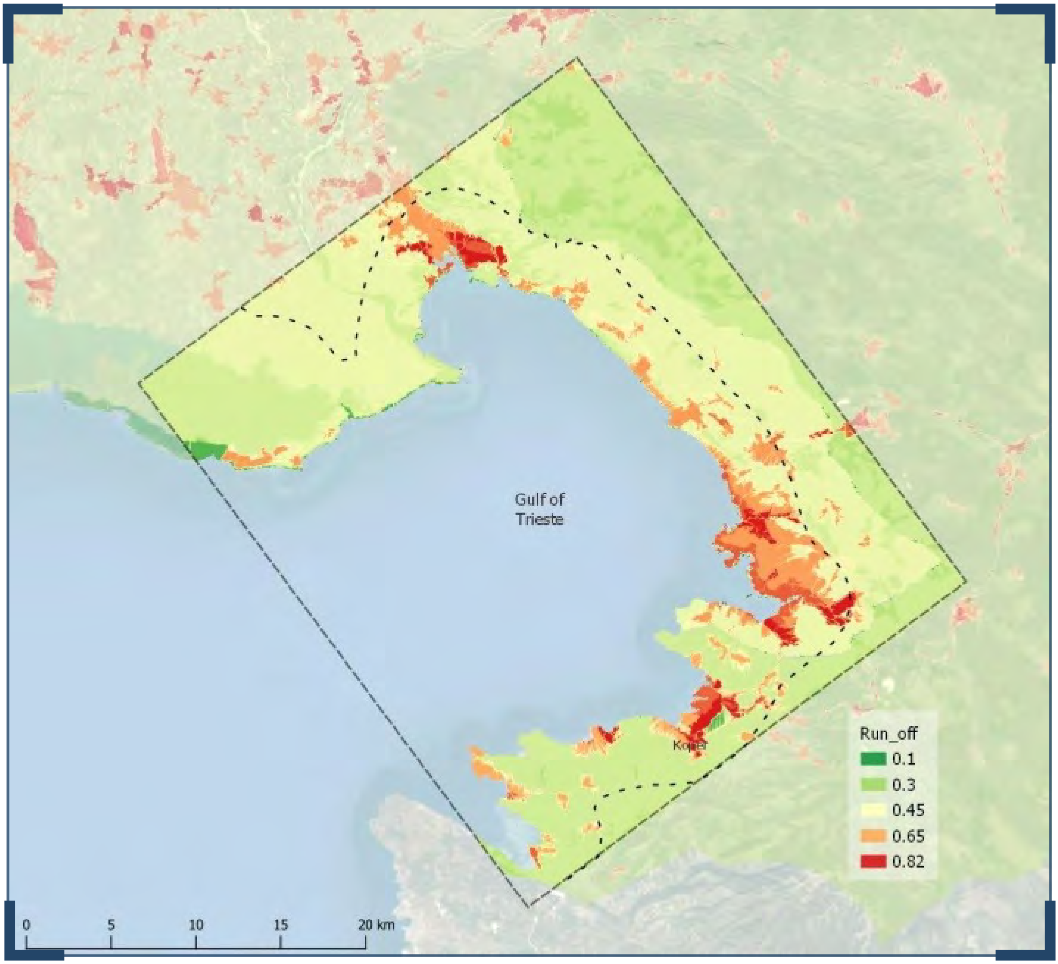
The UHI assessment is based on a multispectral image from the Landsat 8 sensor, evaluating the extension and the intensity of the phenomenon on the study area. The assessment technique implementation is based on the image LC08_L1TP_191028_20170706-USGS acquired on 6 July 2017. The UHI vulnerability assessment returned several impact responses; Figure 6 shows the relationship between the thermal behavior of the land's surface and the characteristics of land use, according to Formula 10. The relationship is illustrated graphically, matching the four CLC classes, based on the Natural Breaks (Jenks) algorithm (vulnerability between −0.60 to + 0.62). The results of the analysis visually illustrate UHI stresses presented by the area's densely urbanized territories. The UHI effect is particularly prominent in the urban areas of Trieste, Monfalcone and Capodistria, where vulnerability levels reach the maximum limit of +0.62. The territories highlighted by this analysis are generally of historical–residential, industrial, and port matrix types.



The runoff assessment simulates the behavior of surface waters by the modelling flow and outflow areas (Figure 7). The method provides a map of hydraulic criticality (see Equation 11 and Table 5). The hydraulic criticality gradient is calculated and weighted according to the topography (sensitivity) and the hydraulic response to the land uses (adaptive capacity). The hydraulic response is measured according to the rainfall absorption capacity. The study allows for a) the quantification of runoff coefficients at the basin scale and b) the recognition of the mainland uses that affect territorial hydraulic performances in terms of exposure and vulnerability. DTM hydrological modelling illustrates a significant increase in the runoff coefficient for areas with intensive and complex urbanisation. In residential and industrial areas, the runoff coefficient varies between 0.6 and 0.8. These are important geographic territorial areas that are especially vulnerable to flooding. Figure 7 highlights three inter-municipal areas which are more prone to high surface runoff: 1) Monfalcone–Staranzano–Duino; 2) Trieste–Muggia; 3) Ankarari–Koper. The residential and neighbouring industrial areas of Monfalcone–Staranzano–Duino constitute a particularly critical flood risk zone. Trieste–Muggia has two sub-areas with significant flood hazards. The first area is within the historical core of the city, while the second is located within the industrial port area between the two municipal boundaries. In the port of Trieste, the surface runoff is equal to 0.64. Ankarari–Koper presents hydraulic pressures localized in industrial areas and areas of recent urban expansion. In rural or sparsely urbanized areas, surface runoff tends to decrease significantly, with values lower than 0.46.

The final comparison between the results obtained by the Land and Urban Approach provides an analytical framework for both physical management and climate adaptation planning. Table 7 illustrates the comparison between the average UHI values and runoff, correlating them to the effects on the urbanized buffer zone. UHI and surface runoff are phenomena attributable, in part, to the progressive and complex soil-sealing of the area. Complex urban systems tend to compromize the ecological balance of the territory, increasing the vulnerability of coastal areas to climate change impacts.

Figure 7 - Map of surface runoff.


Gulf of
Trieste
Koper
Run_off
0.1
0.3
0.45
0.65
0.82
0
5
10
15
20 km

		1.1	1.2	1.3	1.4	2
Municipality	**Buffer * Area for Municipal Partition (sq Km)**	**Urban Fabric %**	**Industrial, Commercial and Transport Units %**	**Mine, Dump and Constructi on Sites %**	**Artificial, Non-agricultural Vegetated Areas %**	**Agricult ural Areas (2.1; 2.2; 2.4) %**
Grado (GO) **	45.67	5.96	0	0	1.84	64.39
San Canzian d'Isonzo (GO)	7.44	0	0	0	0	81.91
Aquileia (UD)	12.04	0	0	0	0	92.76
Fiumicello (UD)	3.12	0	0	0	0	100
Staranzano (GO)	15.56	7.8	1.63	0	0	54.93
Monfalcone (GO)	20.31	27.02	27.77	0	0	4.87
Ronchi dei Legionari (GO)	1.74	0	0	0	0	11.01
Doberdò del Lago (GO)	3.95	0	0	0	0	0.66
Duino-Aurisina (TS)	38.02	10.19	2.74	1.06	0	12.75
Sgonico (TS)	14.6	4.33	1.33	0	0	21.25
Trieste	52.74	50.29	13.97	0	0.59	5.67
San Dorligo della Valle (TS)	9.28	10.31	25.88	0	0	37.51
Muggia (TS)	13.51	19.33	23.42	0	0	30.99
Koper	41.52	9.83	14.88	0.03	0.76	57.23
Ankaran	7.96	6.78	17.11	5.12	0	52.77
Izola	25.25	9.62	4.04	0	0	58.84
Piran	29.52	11.83	2.63	0	0	49.44
Overall profile	**342.25**	**15.94**	**8.59**	**0.24**	**0.43**	**39.61**

Table 7 - Average UHI and runoff values in relation to the soil-sealing of the buffer zone.

A statistical analysis of the study area suggests the presence of some environmental areas with weakened ecological systems.

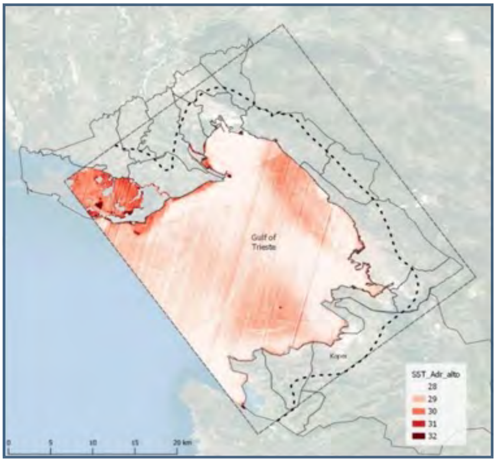
Sea-Based Assessment Results

The "Sea and Maritime Approach" examines the interaction between natural and human environmental components. The SST assessment describes air–sea interaction and the thermal state of superficial water. This thermic evaluation is important for its possible applications, i.e., the monitoring of climate change effects on hydric resources, oceanographic and coastal water observations, and ecological and microclimatic analyses.
Gulf of Trieste's sea surface manifests considerable surface thermal

3	4.2	5
orest and Semi Natural Areas(3.1; 3.2; 3.3) %	Maritime Wetlands %	Water Bodies(5.1 ; 5.2) %
3.37	13.73	10,71
8.85	0	9,24
4.5	2.2	0,55
0	0	0
21.73	10.13	3,78
32.76	7.42	0,16
88.99	0	0
99.34	0	0
73	0.13	0,14
73.09	0	0
28.99	0	0,48
26.31	0	0
25.8	0	0,46
13.99	0.93	2,35
14.28	0	3,94
26.78	0	0,71
12.85	21.79	1,45
27.87	**4.82**	**2,49**

variations, particularly in the central marine areas, near the coasts and river estuaries (see Figure 8). Some of these variations can be attributed to the following dynamics: i) vertical water currents; ii) mix of different water densities; iii) salinity variations; iv) seabed depth; v) land proximity; vi) climatic conditions.

a.



b.

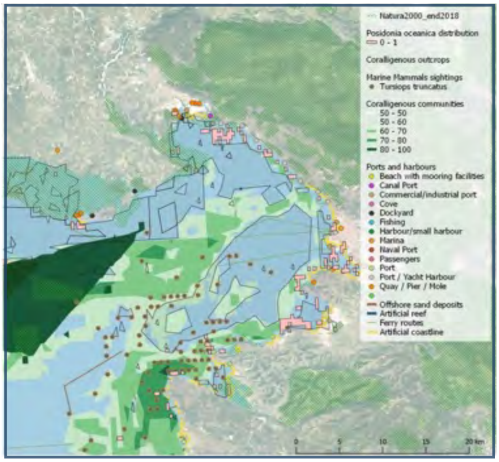


Figure 8 - Sea assessment:

(a) map of sea surface temperature;

(b) map of environmental components (source: authors' elaboration based on Table 1—Sea and Maritime Approach).

In the case study area, various important environmental components are impacted by land and sea-based anthropic activities. The main pressure comparisons identified using the SST distribution help us to understand the relationship between rising temperatures and environmental degradation. This could also help to distinguish the main pressures derived from land-based activities. What has emerged from this preliminary analysis is the interrelation between water circulation and surface runoff, which indirectly affects the distribution of the main pressures, contaminants and nutrients [70]. The thermal structure of the Gulf of Trieste is fed by an anti-clockwise thermohaline circulation, which flows from Trieste–Koper to the regional margins of the Isonzo and Timavo estuary (Grado-Monfalcone locality). This cooling circuit transports energy and materials (dissolved particles and solids), significantly influencing the coastal climate and marine biology of the area.

From this perspective, integrated planning should consider a transboundary dimension to achieve a strategic framework that is aware of the highly dynamic nature of this marine environment. Moreover, the climatic impacts, anthropic pressures, and use conflicts of the inland will not remain isolated, but territorial characteristics will extend their effects on the maritime space, and vice versa.

2.3. - Discussion

This study is based on the ADRiatic Ionian maritime spatial PLANning (ADRIPLAN) project's database, which allowed us to integrate information about the ecological and biological interconnections of the area into the planning approach knowledge framework. Terrestrial and marine dynamics, analyzed through the obtained maps, allowed for the consideration of the relationships between these two systems, increasing the understanding of the LSI context from a planning perspective.

The proposed integrated planning approach knowledge framework plays a fundamental role in understanding the complexity of the connections between land and maritime contexts. Merging different information allows for the implementation of multi-disciplinary and multi-systemic perspectives. Figure 9 represents the results of overlapping the empirical research, overlaid to provide an integrated, holistic re-examination of the relationships between the maritime and terrestrial environments of the case study area.

Planning the maritime space begins on the coastline, but it should also consider the dynamics of landward areas (for example, the climatic effects of agriculture, urban areas and human wellbeing). The proposed integration between CAP and MSP highlights the connection between UHI and SST, and between runoff and SST. The spatial relationship between UHI and SST is clearly represented in Figure 10: the presence of a considerable number of SST anomalies (hot spots) correspond with high UHI vulnerability values (see Figure 10a). The logical connection between SST and surface runoff can be seen as a consequence of terrestrial soil-sealing on the quality of marine waters and the associated levels of toxicity [22,71–73].
The clear relationship identified between these factors justifies the recommendation of the integration of the scientific disciplinary approaches of CAP, MSP and LSI planning requirements.

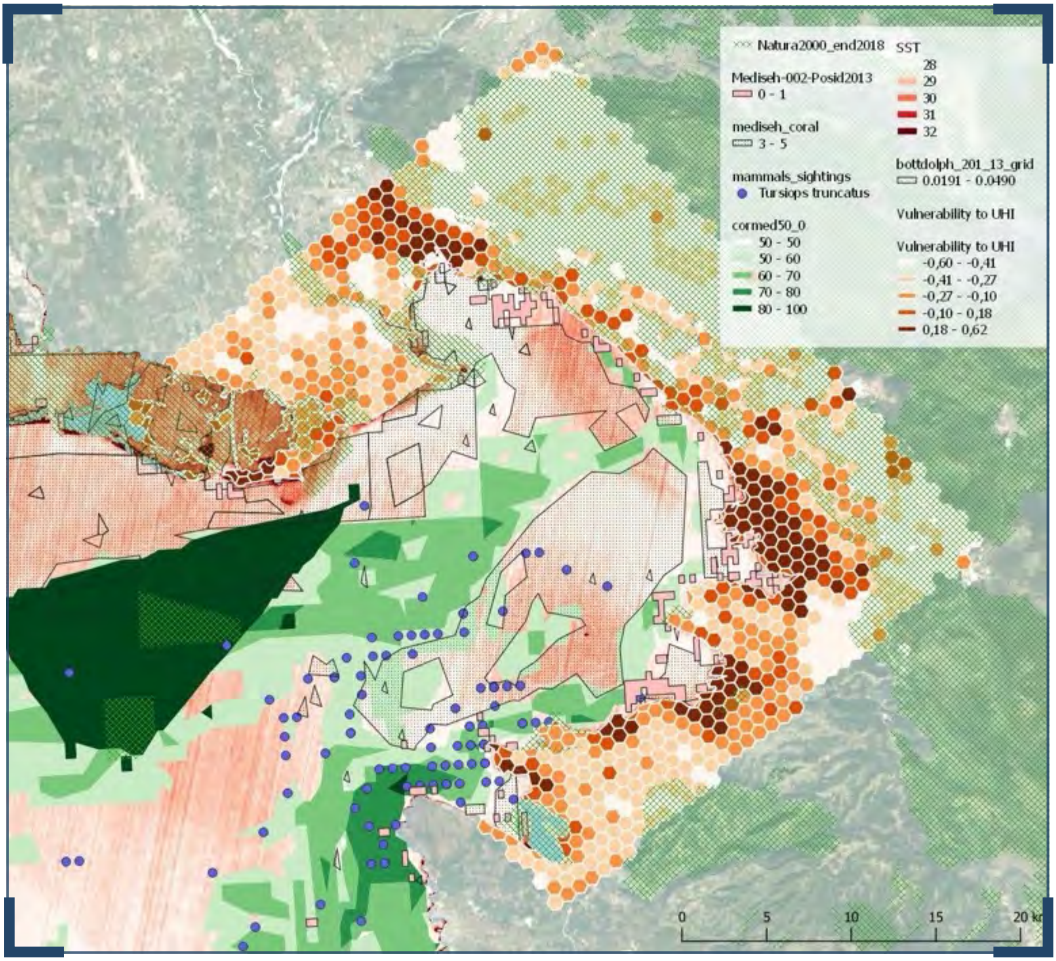

Natura2000_end2018
Mediseh-002-Posid2013
0 - 1
mediseh_coral
3 - 5
mammals_sightings
Tursiops truncatus
cormed50_0
50 - 50
50 - 60
60 - 70
70 - 80
80 - 100
SST
28
29
30
31
32
bottdolph_201_13_grid
0.0191 - 0.0490
Vulnerability to UHI
Vulnerability to UHI
-0,60 - -0,41
-0,41 - -0,27
-0,27 - -0,10
-0,10 - 0,18
0,18 - 0,62
0
5
10
15
20 km

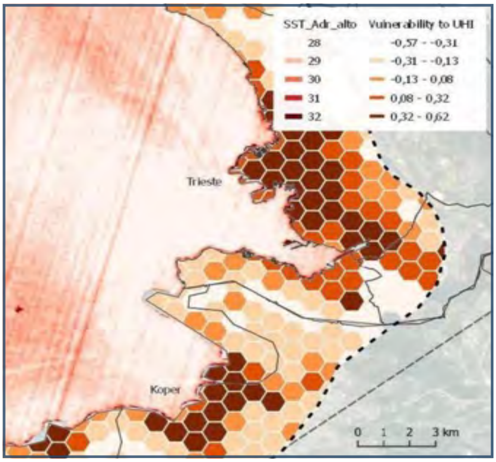
Figure 9 - Land–sea interaction (LSI) area: systemic analytical map.

Figure 10 - Maritime and coastal area of Trieste–Koper:

(a) UHI and Sea Surface Temperature (SST);

(b) runoff and SST.

a.



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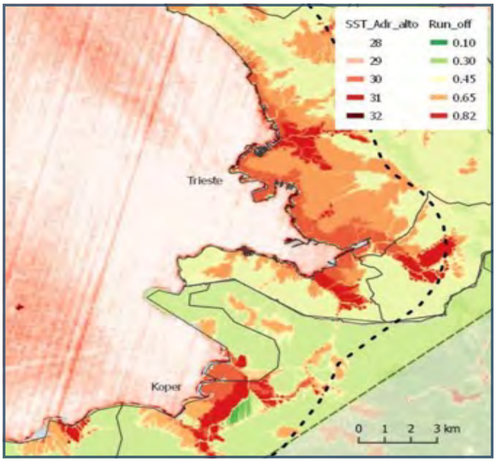


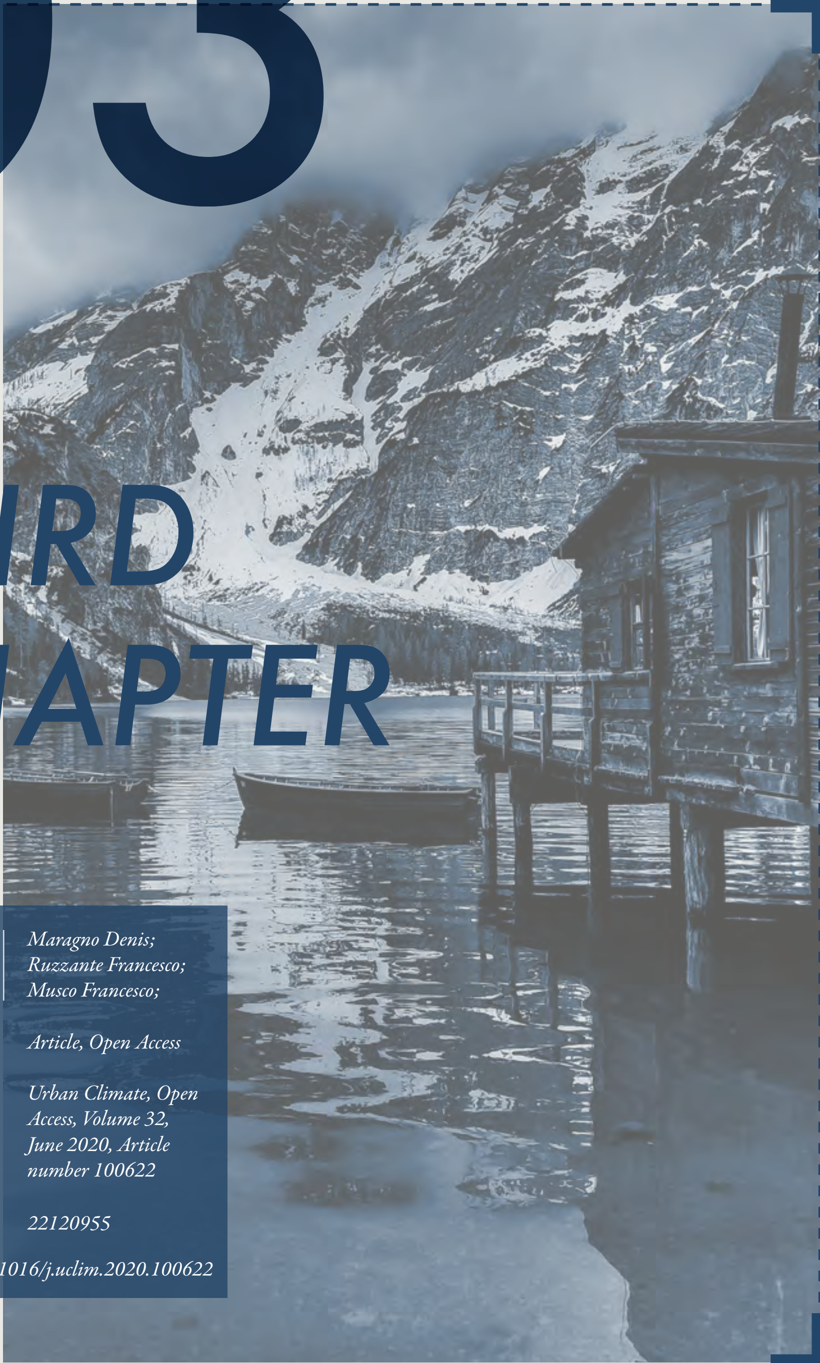
The assessment techniques presented in Chapter 2.3 could be updated using local micro-climate indicators and considering climatic trends [74–76]. Therefore, the test could be used to provide a more detailed definition of vulnerability and consequent adaptation actions. Local planning authorities should consider, as a priority, the integration of

this approach in their databases. Furthermore, a loss of information with different origins and natures could lead to the misunderstanding of territorial criticalities in such complex environments as coastal ones.
The research methodology, presented in Chapter 2, is designed to support decision makers with the identification of the more efficient strategies to cope with climate change challenges and maritime space management. The stresses related to heat and urban flooding assessed in the study could also be applied and adapted to other impacts, (such as wildfires, droughts, coastal erosion, and the impact of sea level rises). The opportunity to capitalize on and exploit existing databases can represent an economic saving for public bodies, avoiding the duplication of existing assessments. In this sense, one of the most relevant conclusions emerging from this research is its possible applications in ongoing projects and strategic funding opportunities. As anticipated in the Empirical Research chapter, the present study is partially based on data sets produced within the Adriatic Ionian Maritime Spatial Planning project, started in 2013 and completed in 2015 and financed by the program "DG MARE/2012/25 - Project on Maritime Spatial Planning in the Mediterranean Sea and/or the Black Sea". This project, like others developed at the Euro-Mediterranean level and for the European coastal context in general (see SUPREME project [77]), was limited by the segregated assessment of land and sea. One of the more interesting opportunities to test the model presented by this paper is cross-border cooperation projects in the Mediterranean area. This model has already been included within the strategic definition of the Interreg Italy–Slovenia project, financed by the European community "Supporting Energy and Climate Adaptation Policies" and in the European Maritime and Fisheries Fund (EMFF): MSP-MED.

2.4. - Conclusions

Responding to the RQs highlighted, the opportunities and the implications of an integrated planning approach for coastal areas, climate change constitutes an environmental condition that impacts the whole coastal ecosystem and requires the appropriate tools to holistically plan these contexts' transformations. Through the implementation of our three-step research methodology, the authors proposed three different levels of merging between CAP and MSP. This union of different knowledge frames can support the retrofitting of ongoing processes or the gradual transition of sectoral planning. The answer developed for RQs 1 and 2 consists of the development of a territorial unit—the hexagonal grid—which can contain information with different natures and origins. From this perspective, the authors define a tool through which we can integrate information that already exists and finalize its output readings. Nevertheless, the necessary condition to implement this approach is the will to use the already available tools and to share information among public authorities. Furthermore, this process generates the opportunity to systematically analyze the responses of the marine coastal environment to the pressures produced by human-driven processes and climate change. The planning approach is based on three elements, (Figure 3): 1) the theoretical–methodological framework, which composes a system that allows for interoperability between spatial information; 2) a scientific approach, which uses investigation techniques for the analysis of climatic impacts and the systemic representation of sea components; 3) an empirical application, which allows for the strategic contextualization of the integrated planning approach. The integration process between CAP and MSP (Figure 9) demonstrates the need and the opportunity for the holistic management of LSI dynamics. This study is considered as a first step to lead to a general transformation of sectoral planning approaches. The present research is designed to provide an overview of the possible analytical tools that can integrate land and sea planning. However, further and multi-disciplinary studies are required to fully implement this approach within local regulations without generating further conflicts and misunderstandings. Because of this, the conclusion of this study remains open to new research and the urgency of a pragmatic understanding of the ongoing processes remains strong. Chapter 2.3 (Empirical Research) confirms the strategic nature of the work, answering RQs 1 and 3, and presents a tool which can be scaled and replicated in other coastal contexts. This assessment, developed based on the Gulf of Trieste case study, synergistically considers land and sea components. This combination relates different territorial information levels to a specific area and can be updated and modified over time with new technological skills and knowledge. The result achieved by the study can support an integrated coastal planning approach, where local planning processes are supported by summary maps that characterize and facilitate the choice of intervention measures (RQ4). The proposed framework for a new LSI planning model could support i) guidelines to monitor the performance of planning outcomes; ii) methodologies to support environmental protection and the sustainable development of coastal areas; iii) spatial modelling algorithms and remote sensing analysis techniques to support the implementation of cognitive frameworks concerning urban and territorial planning.

03



THIRD CHAPTER

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Document Type: *Article, Open Access*

Journal: *Urban Climate, Open Access, Volume 32, June 2020, Article number 100622*

ISSN: *22120955*

DOI: *10.1016/j.uclim.2020.100622*

Article Title:

Toward a trans-regional vulnerability assessment for Alps. A methodological approach to Land Cover Changes over alpine landscapes, supporting Urban Adaptation.

CHAPTER INDEX

Article Abstract

The contribution presents a possible assessment methodology for land cover change over ice and snow, between 1990 and 2018 in the Dolomites and the Alpi Giulie. The methodology aims to build surface atlas to assess the land cover changes. The tool is intended as a support for environmental management, forecasting and, as support for territorial government systems in climate-proof planning processes. In the "business as usual" global warming scenario, ice and snow resources will become one of the most affected subjects by Climate Change, with heavy consequences on ecosystems, urban environments and socioeconomic. Current monitoring and assessment systems are fragmented both by survey methodology and by local distribution. The methodology is developed in using GIS, following remote sensing (RS) processes and spatial analysis tools to manage multispectral satellite images. The process uses spectral signatures from satellite images to identify homogeneous areas in material and morphology. The process takes into account the actual systems of assessment and local socioeconomic exposures. The methodology takes a proactive approach to future hazards and impacts considering their management in alpine habitats to support local administrations. The project develops transboundary assessment techniques and aids the adaptation of planning strategies in the context of Climate Change.

3.1. - Introduction

3.1.1. - State of the Art

The Alps are the most significant mountain system on the European continent in terms of elevation and contribution to water resources, in the form of snow deposits (Beniston et al., 2018; Teston & Bramanti, 2018a). The articulation of the mountain range covers eight national states: Italy, France, Switzerland, Liechtenstein, Germany, Austria, Slovenia, and Hungary. The mountain range is a permanent presence in the landscape for a population of 14 million people and, in Italy, it covers seven administrative regions: Liguria, Piemonte, Val d'Aosta, Lombardy, Trentino Alto Adige, Veneto, and Friuli - Venezia Giulia. This complex system, made by a fragile environment and heterogeneous socioeconomic context, is highly exposed to the effects of Climate Change; the dynamic conditions in high altitude territories increase climatic impacts on those downstream. (Agrawala & Organisation for Economic Co-operation and Development., 2007; Allamano, Claps, & Laio, 2009; Bavay, Lehning, Jonas, & Löwe, 2009; Brunetti et al., 2009; Gobiet et al., 2014; Marty, Schlögl, Bavay, & Lehning, 2017).

There are a large number of studies concerning the climatic variability in the short, medium and long term, from the local to the global scale (Bartolini, Claps, & D'Odorico, 2009; Brunetti et al., 2009; Field et al., 2012). These studies generally tend to connect historical analyses, forecast estimates, and territorial anthropic systems which evaluate different investigative tools; implicitly they are the necessary structure on which to base possible strategies of action (Farinotti, Usselmann, Huss, Bauder, & Funk, 2012; Huss, Zemp, Joerg, & Salzmann, 2014). Considering the economic importance of the Alpine mountain range, its sizable population, the forms of settlements and territorial infrastructures, it is necessary to investigate the relationship between trans-regional governance, local planning actions, and analysis methods. (Balbi, Giupponi, & Bonzanigo, 2011; Giorgi & Mearns,

1991; Laghari, Vanham, & Rauch, 2012).
These considerations are linked to the need to define a series of fixed coordinates around which strategies to protect and adapt the alpine system, and its peculiarities, can be developed. The uncertainty in definition of the most effective or generally correct adaptation methodologies lies in the correct interpretation of the given scenario and in the limited capacity of the monitoring tools to provide forecasts and complete cognitive frameworks. (Majone, Villa, Deidda, & Bellin, 2016; Schmucki, Marty, Fierz, Weingartner, & Lehning, 2017). The main indicators that define the growing vulnerabilities and exposures of these territories are the water resources which, in this study, are defined in terms of square meters covered by ice and snow (Stefanicki, Talkner, & Weber, 1998; Steger, Kotlarski, Jonas, & Schär, 2013). The morphology and availability of these resources are connected to the combined temperature and precipitation change (Bavay et al., 2009; Durand et al., 2009). The quantitative variation of the glaciated water surfaces can be measured using Remote Sensing techniques, developing a replicable methodology and testing its effectiveness on two specific study areas. Test results have been related to socio-economic changes in the territories to emphasize the connection between water resources and the human habitat in Alpine area. (Balbi, Giupponi, Perez, & Alberti, 2013; Bavay et al., 2009; European Environment Agency., 2009; Gilaberte-Búrdalo, López-Martín, Pino-Otín, & López-Moreno, 2014)

The variation in the presence of snow and ice over the period 1990-2018, referring to the vast scientific literature related to climate monitoring and land cover, suggests a substantial loss of icy surfaces and an increase in anthropized surfaces (Barthel et al., 2008; Marinucci et al., 1995). The summer periods have been compared to illustrate the connection between climatic hazard, economic activities (connected with seasonal tourism), habitat loss, the safety of human activities and impacts on economic productive sectors (agriculture and industry) (Elsasser & Bürki, 2002; Gilaberte-Búrdalo et al., 2017; Rogora et al., 2018). The summer deposits were identified and quantified, referring to international literature and national monitoring systems, and interpreted as a "Base Line" for the entire year (Field et al., 2012; François, Morin, Lafaysse, & George-Marcelpoil, 2014). The selection of summer satellite images brings two benefits: a lower presence of clouds at high altitudes and consequently a greater availability of information for analysis; a proximity to the periods of the year with greater frequency of climatic episodes of calamity (landslides, avalanches, wildfires, infestations of alien species, extreme meteorological phenomena, etc.) (Frey, Haeberli, Linsbauer, Huggel, & Paul, 2010; Montesarchio, Zollo, Bucchignani, Mercogliano, & Castellari, 2014).

The research was developed to take into account the ambitions, visions of governance and strategic integration developed by governmental and non-governmental institutions (Macchiavelli & Andrea, 2009; Stern, 2007). Two illustrative and representative cases were selected both for their territorial coverage, the relevance of the results and for the stated objectives, namely: CIPRA [1] (Köhler, Siegrist, & Weixlbaumer, 2003) and EUSALP [2] (Teston & Bramanti, 2018b). The "Commission Internationale pour la Protection des Alpe"(CIPRA) is an autonomous non-governmental and non-profit umbrella organization which has been committed to the protection of sustainable development since 1952. The EU Strategy for the Alpine region (EUSALF), was founded October 18 2013. The latter is a key reference in the identification of threats to the Alpine context and for the definition of the objectives and potential opportunities for these territories. EUSALP connects 7 nations and 48 administrative regions of the Alpine region (including non-EU states) within a strategic agreement, with the aim of creating a coordinated approach to the challenges of economic globalization, demographic trends, climate change, energy. Furthermore, the assembly sets an important precedent for the project of cohesion; one of the objectives declared by the EUSALP Presidency 2019 was considered fundamental for the selection of the focus areas. With the awareness of the planning dynamics in Alpine coordination and the aspirations for growth of

[1] https://www.cipra.org/en/about/mission.

[2] https://www.alpine-region.eu/eusalp-eu-strategy-alpine-region.

these territories, it is fundamental to implement the connection to the ongoing agreements aimed to merge local strategies into the legal framework of the Cohesion Policy 2021-2027.

The phases followed in the research process have followed parallel and interdisciplinary paths. It is possible to recognize three core strategies within the presented work. The first relates to the selection of the Remote Sensing methodology (Bhardwaj et al., 2015; Dewan & Yamaguchi, 2009; Hall, Ormsby, Bindschadler, & Siddalingaiah, 1987) The second relates to the development of a site-specific analysis on Cortina D'Ampezzo and Tarvisio, in relation to climatic data and the specific morphologies of the territories (SOIUSA [3]). The third develops a quantitative and comparative analysis of water resources, urban development, and territorial governance. This last study was undertaken in relation to the local administration nature of these territorial systems and highlighted the need for a tool to analyse and monitor the effects of climate change in a trans-regional context, in order to allow for adaptation and the future mitigation of its effects. (Kim, 2011).

3.1.2. Objectives

The project findings aim to support local authorities in their interpretation and governance of Alpine territories. Awareness and knowledge of current phenomena are considered as the conditio sine qua non to protect the alpine habitats. The objectives are summarized in the figure below. The two objectives presented are both parallel and integrated. The purpose with which they are defined and described is to highlight the importance of each aspect of research. It is not possible to fully understand the territory without considering each of these aspects. The complex scenario of rapid change and the increase of the dangers for the Alps (both for natural environments and for human activities), defines a system of problems and solutions that must be investigated explicitly.

The specific objectives are summarized in the image below (Figure 1):

[3] *SOIUSA is an acronym for Suddivisione Orografica Internazionale Unificata del Sistema Alpino - in English: International Standardized Mountain Subdivision of the Alps.*

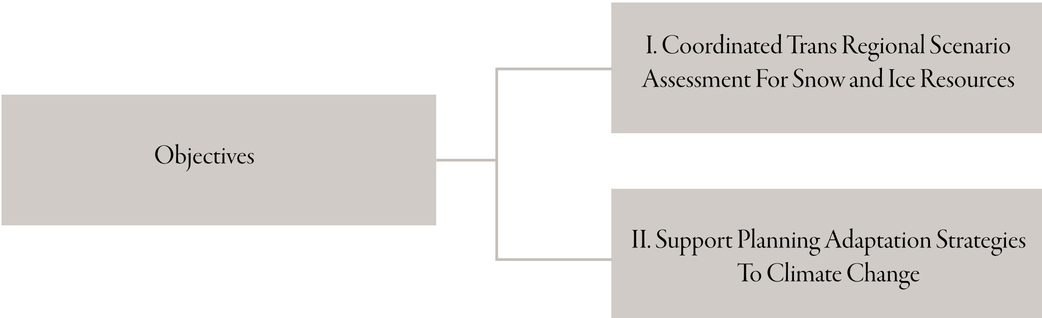


Figure 1 - Objectives of the study.

Each objective takes into account the following considerations:

- Coordinated Trans Regional Scenario Assessment for snow and ice resources

As stated in the Introduction, the Alpine territory involves different nations and regions with populations who have a particular relationship with the mountain environment. It has emerged, especially within the Italian areas of study, that there is discontinuity in the monitoring and administration of the territories at different levels, from the scale of the single municipalities to the territorial agencies for monitoring and environmental protection (ARPA).

Available data is extremely limited and localized on glaciers of significant collective interest and skiing infrastructure. There is also the problem of temporal continuity. Through the elaboration of this study, a discontinuity was found in the information provided by the detection devices, as they are switched off during the summer periods. The objective of this study is, therefore, to provide an analytical tool capable of representing a transnational and transregional aware framework, aimed to support the medium and long-term territorial governance and climate adaptation processes. This requires the possibility to assess the now and ice situation throught costruction of spatial information. This knowledge is fundamental for defining the causality between environmental change at high altitude and the related impact on downstream areas.

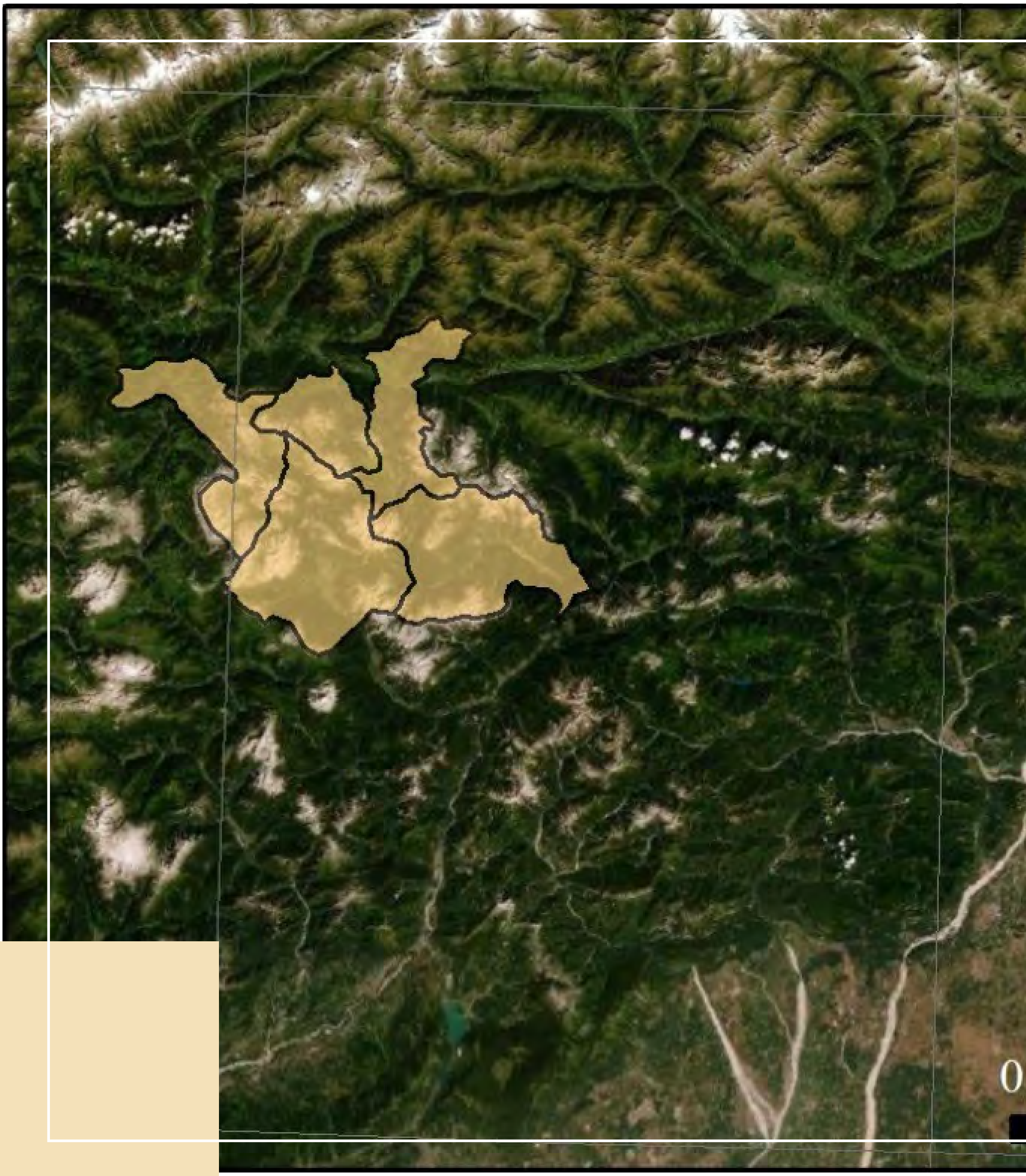
- Support planning adaptation strategies to climate change

In reference to international climate agreements and the goals agreed by each nation, Italy has adopted two important documents at the national level: the National Adaptation Plan (PNAC), the National Adaptation Strategies (SNAC). A process is currently underway to upgrade regional and municipal planning structures and methods concerning mitigation and adaptation. The process promoted by the European Commission has references some examples of beneficial coordination between municipalities (eg. the Covenant of Mayors for Climate and Energy) and will become a strategic reality by 2030 with the Sustainable Energy and Climate Action Plan (SECAP). It is therefore necessary to have an integrated knowledge of the territories in order to be able to effectively manage their future transformation. Today, the primary knowledge resources available to local government structures are the traditional knowledge of spatial morphology and some specific studies related to dangers that are marginally aware of climate change. Given these considerations, it is a strategic objective to have an integrated system of geo-localized information that relates environmental transformations and the socio-economic evolution of the anthropized territories.

3.1.3. Study Area

Study areas were selected due to their representative complexity and characteristics. In contrast to what was stated in the previous chapters, an evaluation was carried out throughout the Alpine area following the SOIUSA classification, giving priority to the Italian side. Focus areas were selected according to the transnational

Figure 2 - Focus Areas Location.



Legenda:

- Area 1: Dolomiti - Cortina D'Ampezzo;
- Area 2: Alpi Giulie - Tarvisio;

and transregional shape of the orographic system, the functional connection between the socio-economic fabric and the mountain environment, the availability of data, and the cultural value of the landscape and human activities (Pohl et al., 2019; Suklitsch, Gobiet, Leuprecht, & Frei, 2008). Among the seven Italian regions, Veneto, Trentino Alto Agide and Friuli Venezia Giulia were preferred. Specifically, two binomials were chosen, consisting of an orographic complex and a reference municipality, specifically: Dolomites - Cortina D'Ampezzo and the Julian Alps - Tarvisio. The two areas were evaluated according to the objectives defined in the previous chapter and with the expectation that the analysis conducted on this territory can be replicated in areas of similar complexity. To represent the complexity of the relationship between mountain and urban system, the extension of analysis includes all those administrative realities that intersect the selected mountain complex.

Specifically, the characteristics of each location are:

- Area 1: Dolomiti – Cortina D'Ampezzo

The first area, which covers 1.231,60 km2, includes the Veneto region and the Friuli Venezia Giulia region, and five municipal units: Cortina d'Ampezzo, Auronzo di Cadore, Marebbe, Braies, and Dobbiaco. This area is a representative example for the relationship between mountains and tourism (both winter and summer); Cortina d'Ampezzo hosted in the 1956 Winter Olympics and - along with Milan - will host the games again in 2026 (CIO, 2019). In addition, the Dolomites complex has been a World Heritage Site since 2009 (UNESCO, 2016). These attributes have been judged to be fundamental to the complexity of the governmental structure of this territorial area.

- Area 2: Alpi Giulie – Tarvisio

The second, slightly smaller, area covers 840,70 km2 and includes the Friuli Venezia Giulia region and extends into the state of Slovenia. There are five municipal zones within the area: Tarvisio (Italy), Chiusaforte (Italy), Resia (Italy), Kranjska Gora (Gorenjska - Slovenia), Bovec (Goriška - Slovenia). In this case, the two most relevant socio-economic and cultural contexts are within the municipality of Tarvisio, which is the main ski centre of Friuli region, and Kranjska Gora, which is an annual FIS Alpine Ski World Cup event (FIS, 2019). The geomorphological and administrative characteristics of this context are judged to be illustrative both for the transnational distribution of the orographic system and the discontinuity of their governance. An experimental project was implemented in this area to coordinate the transnational adaptation strategies promoted by the European Community program (Interreg V-A Italy-Slovenia program 2014-2020, 2018).
The selection of the areas described above is functional to the elaboration of this study on two distinct and consequential levels: the first concerns the selection of the Remote Sensing

method for the processing of satellite images and the second concerns the territorial analysis on the target areas. The first level is carried out on a sample portion of satellite images related to the territory of the Julian Alps - Tarvisio. This choice was made considering the objectives of the research and evaluating the opportunity to establish a relationship between the ongoing strategic transformation design processes and the development of the present study.

3.2. - Material and Methods

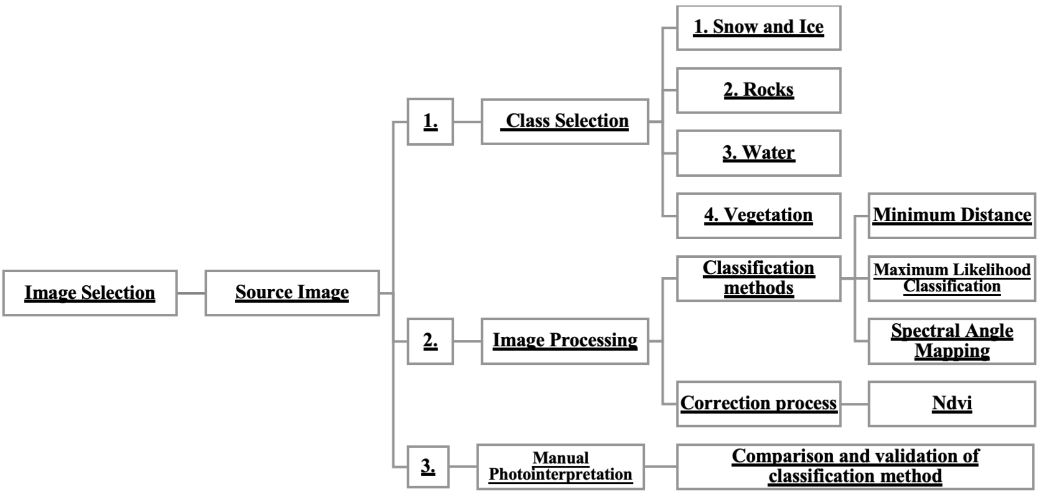
The territorial observation and analysis give the possibility, through a space-time evaluation, to recognize the changing happened in the past, to control the ongoing processes and to forecast possible trends. In this sense, the principal deployable tool is the nadiral observation which allows a homogeneous interpretation of those features by which the landscape is composed. One of the main parameters of the choice of the sources is the scale of resolution. To reconstruct the information of a specific area it is necessary to use the most appropriate tool of representation among the thousand possible ones. Generally, for detailed, precise and restricted spatial observation, an analysis "from the ground" is preferred, as in the case of a topographic survey. To solve and assess problems connected to the urban and territorial scale, a more extensive source is required. In some cases, aerial photogrammetric surveys can give the first response to some large-scale assessment, but remote sensing techniques can allow bypassing some problems like costs and transboundary governance issues. The bases of remotely sensed assessment are satellite data, which can be an "open" or "close" source as this information gives the possibility to geomorphologically assess the territories and the environmental quality. The application of image classification methods derives from the use of satellite-earth observation platforms with an optical-passive sensor, capable of returning a multispectral image for the bands of the visible and non-visible range. In the case of the present research, it has been selected a set of data available in open source and with the longest possible continuity over time. These two aspects are fundamental to develop a public based monitoring system as they allow a cyclical, free and accessible retrieval of information. The supervised-classification techniques developed and integrated into the tools for remote sensing processing are also widespread and available under an open-source license, another point in favor in terms of portability of operations. The processes followed in this methodology aim to automate analysis as much as possible. It is necessary to provide

Figure 3 - Geoprocessing workflow for method validation.

spatial analysis of the water resource in order to quantify the surface area that is exposed to climate change. This is possible through geoprocessing operations on remotely sensed data (Oerlemans, 1994; Wolf, Lazzarotto, & Bugmann, 2012). The methodological structure is necessary to achieve an optimal classification method, and therefore accomplish the objectives in the introduction. Two macro processing phases were necessary to do this: the first phase with the choice of the most performing process in relation to the data objectives; the second one of replication and extension of the method validated in the first phase on the study areas with quantification and comparison of results with respect to a significant period of time.

3.2.1. - Selection of Remote Sensing method

The general process (Figure 2), is divided into three main steps that will be described indepth in this chapter, following the workflow diagram below. The elaborations are performed using the functionalities of the



GIS OpenSource client QGIS 3.4.8 -'Madeira' with the support of a plug-in for the supervised classification of remote sensing images, Semi-Automatic Classification Plugin (SCP) (Congedo, 2016).

3.2.2. - Class selection

Class selection is necessary to define the target of the remote sensing assessment (Valt & Cianfarra, 2014). The proposed classes enclose and synthesize the set of homogeneous conformations of surfaces that can be found on the territory, so from this point the distribution and the variation of them. Concerning the objectives to be achieved through the application of this methodology, it's necessary to elaborate an interpretative tool of the mountain territorial context, structuring a surface atlas based on natural morphological aspects (Kääb, Haeberli, & Gudmundsson, 1997; Shukla & Ali, 2016). The classes identified within this atlas dedicate a specific observation to the following typological surfaces: 1) Glaciers/Snow, 2) Rocks, 3) Water, 4) Vegetation. In this sense, the macro-classes represents a set of land covers and land uses. For land use is meant the ground material typology, such as soil, vegetation, water, asphalt, etc. (Fisher e Unwin 2005). Selected classes namely contain: 1) Glaciers/Snow: surfaces with presence of ice and snow deposits; 2) Rock: mountainous walls, bare rock, quarries, surface no longer covered by snow; 3) Water: bodies and watercourses of inland waters, rivers, lakes, streams; 4) Vegetation: permeable natural soils, forests, woodlands, grasslands, land for agricultural use. To distinguish these differences a Region of Interests (ROI) assessment was elaborated assuming as class-representative the portion of pixels of the satellite image contained in the polygon designed to sample each specific type of surface. Then, ROIs are used to establish the Training Inputs for the classification algorithm representing each class, and on a second level, by grouping these elements in material representative macro-classes. The Regions of Interest, from which spectral signatures are calculated for the application of the classification algorithms (Congedo, 2016), are determined with the operator intervention in comparison to the source image. In this sense, the classification method used is called supervised.

3.3. - Theory and Calculation
3.3.1. Class selection

In the first phase, with awareness of the potential and the limits of the satellite products (Kuenzer, et al., 2014), an image acquired from the Landsat 8 platform was used (Hall et al., 1987; Menenti et al., 2015). Once the bands were imported, the product was pre-processed by applying atmospheric correction and using the pansharpening technique to improve its geometric resolution. In accordance with the objectives, images are elaborated taking into account the geographical relevance of the focus areas. The process was developed through the evaluation of accessible sources linked to the availability of formal local data and researching the best meteorological condition (in terms of the presence of clouds and image quality). This last factor may affect the quality of the obtainable result with the applied remote sensing technology.
The most recent images are available through the Landsat 8 platform, so the image selected to use for the first phase comes from a recent satellite scene from this platform, focused in the easternmost area of Alpi Giulie group (Tab. 1).

Table 1 – Satellite metadata extracted from the source.

YEAR	WRS2 PATH/ROW	SATELLITE	LANDSAT SCENE ID	LANDSAT PRODUCT ID	DATE ACQUIRED	CLOUD COVER SCENE (%)	CLOUD COVER LAND (%)
2017	191/28	LANDSAT 8	LC81910282017187LGN00	LC08_L1TP_191028_20170706_20170716_01_T1	2017-07-06	0.85	0.99

A sample area of this image was used to test the algorithms. This sample area depicts a location near Tarvisio and Slovenia Goriniska (46 ° 26 ' 7.30 " N, 13 ° 41 '30 04 " E) and is defined by a 480 m square, equal to 23 ha; centered on the target point. This portion is used in the comparison and validation phase, through manual photointerpretation operation on the last high-resolution imagery

(0.5 m) provided by CNES/Airbus via Google Earth, 2019 Google Map data.

3.3.2. - Semiautomatic classification

Classification allows the initial data to define a discrete datum across the mapped the surfaces, or rather for the surfaces to be analysed as composites of distinguishable elements, identified and declared in the macro-classes that reflect each land cover. The project tested a set of three algorithms refine the methodology according to the stated objectives.

The first algorithm tested is Maximum Likelihood. MLH calculates the probability distributions of the classes, as defined by Bayes' theorem, and estimates if a pixel belongs to a land cover class. (Richards e Jia 2006). The second algorithm tested is Minimum Distance (MD). This algorithm calculates the Euclidean distance between spectral signatures of image pixels and training spectral signatures. (Richards e Jia 2006). The final algorithm is Spectral Angle Mapping (SAM); this calculates the spectral angle between spectral signatures of image pixels and training spectral signatures (Kruse 1993).

3.3.2.1. - NDVI Correction

To improve the accuracy of the surface estimation, a correction operation is performed using remote sensing indexes. Specifically, this means Normalized Difference Vegetation Index (NDVI) (Rouse, 1973), calculated both on Red and Near-Infrared bands values, is used to improve vegetation estimation. The results of the semi-automatic

Table 2 – NDVI's thresholds applied for the correction process.

NDVI'S thresholds applied for correction				
Area target	*Alpi Giulie – Tarvisio*		*Dolomiti – Cortina d'Ampezzo*	
Year	1990	2017	1990	2017
Value	> 0.5	> 0.6	> 0.5	> 0.5

classification, obtained through the applications of available algorithms, are reported in the tables below (Tab. 3, Tab. 4, Tab. 5).

Each algorithm is compared with the Manual Photo Interpretation process, which is described in the following paragraph.

3.3.2.2. - Maximum Likelihood

Table 3 – ML results.

Class	# pixel	Area (m²)	Area (km²)	LC Percentage (%)
ice	315	70875	0.071	7%
rock	3250	731250	0.731	75%
water	50	11250	0.011	1%
vegetation	741	166725	0.167	17%
total		980,100.00	0.980	100%

3.3.2.3. - Maximum Likelihood

Table 4 – MD results.

Class	# pixel	Area (m²)	Area (km²)	LC Percentage (%)
ice	170	38250	0.038	4%
rock	2995	673875	0.674	69%
water	141	31725	0.032	3%
vegetation	1050	236250	0.236	24%
total		980,100.00	0.980	100%

3.3.2.4. - Spectral Angle Mapping

Table 5 – SAM results.

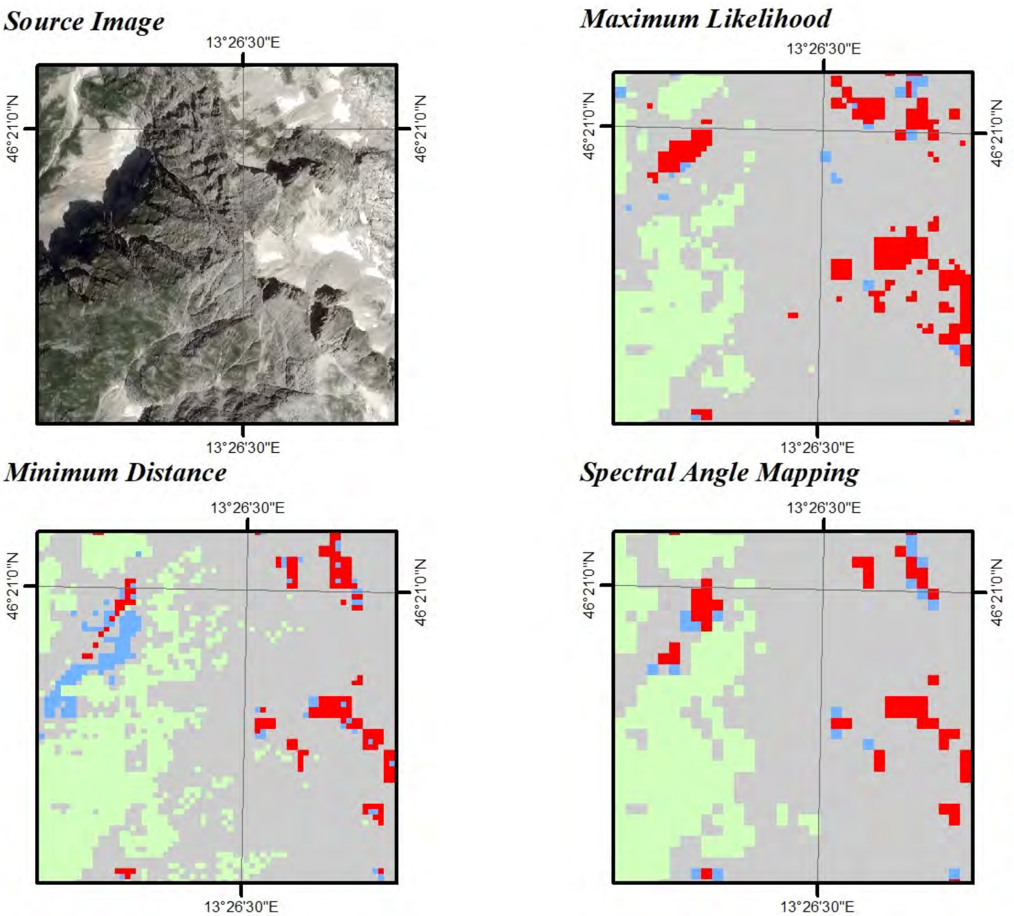
Class	# pixel	Area (m²)	Area (km²)	LC Percentage (%)
ice	194	43650	0.044	4%
rock	3038	683550	0.684	70%
water	74	16650	0.017	2%
vegetation	1050	236250	0.236	24%
total		980,100.00	0.980	100%

Legenda:

- *Ice / Snow;*
- *Rocks;*
- *Water bodies;*
- *Vegetation;*

3.3.3. - General results of the process

The results obtained from the processes are presented to show the particular distribution of each identified class. (Fig. 4).



The final results on the sample area show a different spatial distribution depending on the algorithm applied in the classification process. Overall, the most visible heterogenous is found on the water. The results were used to make a comparison between the surfaces identified by the algorithms and the reality of the status quo.

3.3.4. - Manual photo interpretation

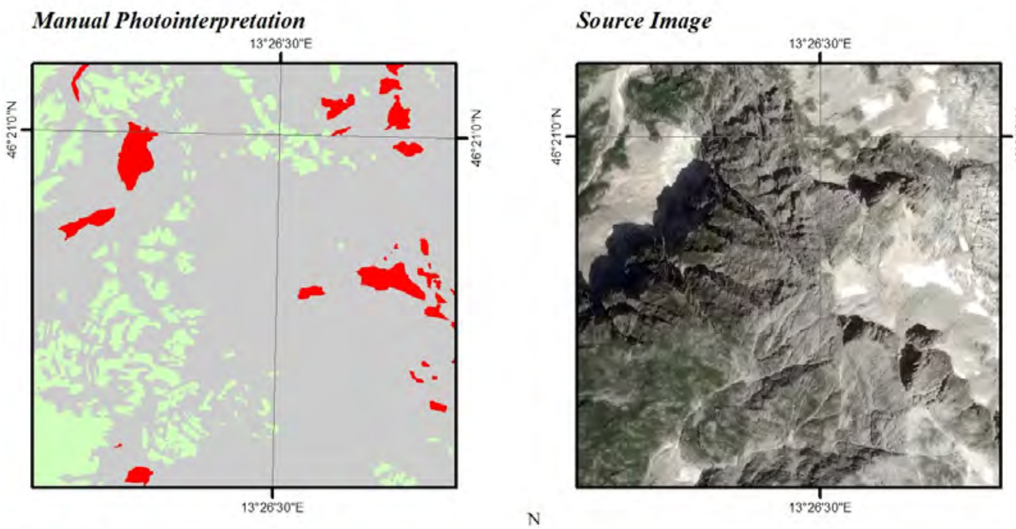
The effectiveness of the classification and the validation of the classification algorithm were assessed by comparing the automated results to a manual interpretation of a source image for the same sample area. In this way, it was possible to evaluate the performance of the tested algorithms and to then make an informed choice as to which was the best suited to represent the various surface typologies which characterize the specified area of the mountain.

Figure 4 - Results comparison.

Figure 5 - MP and SI comparison.

Legenda:

- *Ice / Snow;*
- *Rocks;*
- *Vegetation;*



Class	Area (m²)	Area (km²)	Percentage (%)
ice	37,290.29	0.037	4%
rock	804,317.48	0.804	82%
water	-	-	0%
vegetation	138,929.68	0.139	14%
total	980,537.45	0.981	100%

Table 6 – MP results.

3.3.5 . - Comparative Selection

The comparison examines the sample portion and the spatial relevance of each homogeneous area. On the table below (Tab. 7) illustrates the extension of each homogeneous area and the percentage proportion.

Class	*Maximum Likelihood*	*Minimum Distance*	*Spectral Angle Mapping*	*Manual photo interpretation*
ice	*7%*	*4%*	*4%*	4%
rock	*75%*	*69%*	*70%*	82%
water	*1%*	*3%*	*2%*	0%
vegetation	*17%*	*24%*	*24%*	14%
total	*100%*	*100%*	*100%*	*100%*

Table 7 – Classification comparison.

The difference between the various automated results and the MPI is significant in terms of quantity (Tab. 7) and spatial distribution (Fig. 4). The MLH results show minimal deviations between the classification results and the MPI: the water class (1%) is close to the 0% of water existing in reality; even the vegetation detected (17%) is very close to manually recorded (14%), with a minimum deviation of 3%. The MD and SAM algorithms have an equal amount of ice, although the image (Fig. 5) does not correspond with the current state. For these reasons, the analysis was conducted using the MLH algorithm.

3.4.1. - Image Selection

The images selected to analyse the two case studies were taken in the summer period over two dates for comparison. The selection criteria was based on weather conditions and images availability. Images were selected on dates as close as possible to each other to try to analyse the study areas in a homogeneous condition. A comparison was made with the climatic information provided by the regional monitoring centres with respect to the air temperature and the possible presence of snow. In the absence of snowfall, the potential sample across several years of the summer season was considered.

Climate data for this range was collected by reference stations in the site areas from 1986; at this time the Landsat 5 platform was already operational. The best scenes - in terms of image quality for the remote sensing applications and the reduced presence of clouds - were identified, in line with the availability of data, from 1986 onward and 2018 backward. Following this process, 1990 and 2017 were selected as the sample years.

This section presents the results achieved by applying the methodology described in the previous chapter. The results concern the two study areas and conclusions related to the processed data.

Table 8 - Satellite metadata extracted from the source.

YEAR	WRS2 PATH/ROW	SATELLITE	LANDSAT SCENE ID	LANDSAT PRODUCT ID	DATE ACQUIRED	CLOUD COVER SCENE (%)	CLOUD COVER LAND (%)
2017	191/28	LANDSAT 8	LC81910282017187LGN00	LC08_L1TP_191028_20170706_20170716_01_T1	2017-07-06	0.85	0.99
	192/28	LANDSAT 8	LC81920282017162LGN00	LC08_L1TP_192028_20170611_20170627_01_T1	2017-06-11	3.97	4.41
1990	191/28	LANDSAT 5	LT51910281990193FUI00	LT05_L1TP_191028_19900712_20180214_01_T1	1990-07-12	2.00	2.00
	192/28	LANDSAT 5	LT51920281990200FUI00	LT05_L1TP_192028_19900719_20180214_01_T1	1990-07-19	6.00	6.00

3.4.2. - Image Elaboration

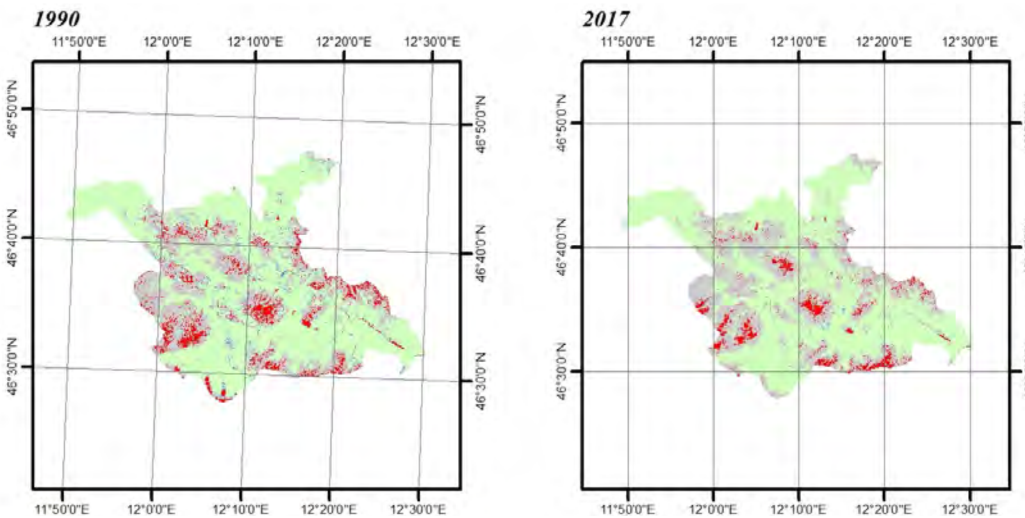
The testing process for the case study results followed the phases presented below:

1. Selection of the survey extension in relation to the municipal boundaries defined in the Area Selection chapter;
2. Analysis through the process defined in Methodology;
3. Site specific correction in relation to land cover through known data – Corine Land Cover. These corrections were lead with the aim to link environmental and anthropic evolution on a specific area. To enforce the result of this step, in the paragraph Driving Forces Effectes, is integrated to socioeconomic evolutions between 1990 and 2018.

Figure 6 - Area 1 Classification results.

Legenda:

- *Ice / Snow;*
- *Rocks;*
- *Water bodies;*
- *Vegetation;*



	1990			2017			
Class	Area (m²)	Area (km²)	Percentage (%)	Area (m²)	Area (km²)	Percentage (%)	Variation (%)
Ice	53.648.100,00	53,65	6%	35.467.875,00	35,47	4%	-34%
Rock	250.676.100,00	250,68	30%	303.049.800,00	303,05	36%	21%
Water	26.826.300,00	26,83	3%	2.831.850,00	2,83	0%	-89%
Vegetation	511.497.000,00	511,50	61%	499.342.500,00	499,34	59%	-2%

Table 9 - Area 1 Classification results.

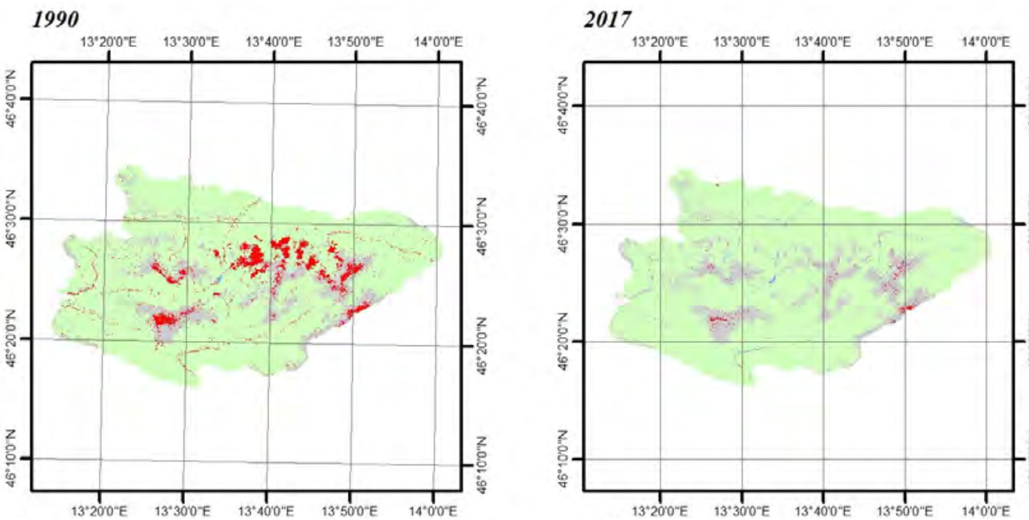
3.4.3. - Focus area 1: Dolomiti – Cortina D'Ampezzo

The data collected shows a reduction, from 1990 to 2017, of the water resource classified as both glaciers (with a reduction of -34%) and for bodies of water (-89%). The vegetation class also shows a slight contraction (-2%). The rock class, on the other hand, is the only increase (+21%), demonstrating that the bare areas (i.e. without vegetation) are expanding.

Figure 7 - Area 2 Classification results.

Legenda:

- *Ice / Snow;*
- *Rocks;*
- *Water bodies;*
- *Vegetation;*



	1990			2017			
Class	**Area (m²)**	**Area (km²)**	**Percentage (%)**	**Area (m²)**	**Area (km²)**	**Percentage (%)**	**Variation (%)**
Ice	60.742.800,00	60,74	5%	6.218.550,00	6,22	1%	-90%*
Rock	195.259.500,00	195,26	16%	212.717.925,00	212,72	17%	9%
Water	1.462.500,00	1,46	0%	6.943.725,00	6,94	1%	375%*
Vegetation	978.817.500,00	978,82	79%	1.005.722.100,00	1.005,72	82%	3%

Table 10 - Area 2 Classification results.

3.4.4. - Focus area 2: Alpi Giulie – Tarvisio

For 1990 it was used Landsat 5 which operates with the Thematic Mapper (TM) sensor, while for 2018 it was used Landsat 8 which operates with the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). This aspect can affect the results derived from a multi-band image classification application due to the different acquisition platforms, each one with different band's intervals. For example to control the anomalies in water variation, caused by difference in sensors, it can be calculated throu a remote sensing index, the water ratio (WRI) (Shen & Li, 2010; Rokni, Ahmad, Selamat, & Hazini, 2014). The strong variation between 1990 and 2017 in the Water Class is therefore connected to a different sensibility between the sensors used in the source satellites.

The data also shows a reduction in the snow presence on the ground for this complex, from 1990 to 2017, equal to -90%. It is important to note, however, that this difference is overestimated due to the limitations of the image because it was not always possible to find a scene of the same period without clouds. In fact, one of the limits is that the detectable spectral signature above the clouds conflicts with the spectral signature of the ice. This generates an error, as can be seen in the 1990 image above the mountain groups of the Slovene part of the Mangart Group, Jalovec-Bavški Grintavec Group, Škrlatica Group.
The surfaces with ice decreased by -90%, the rocky surfaces increased slightly (9%), while the water bodies are increasing (375%), the vegetated surfaces are almost unchanged, experiencing a slight increase (3%).

3.5. - Discussion

The previous chapter presents the results of the survey methodology on the two focus areas. In summary, what emerges is a marked decrease in the ice-class for both territories. This result illustrates the impacts of rising global temperatures, and of Climate Change more generally, in the Alps.
The result isn't "only" a statistical result of changing, but trough the spatial information is possible to understand "where" territories are changing. Identifying where the land cover varied allows to assess which adaptation strategies can be deployed to cope with specific impacts.
The results underline how the reduction of surfaces covered by ice and snow is related to the general territorial context. What emerges is a reduction of that resource that turns out to be strategic both from ecosystemic and from the economic point of view. It is possible to hypothesize, in the light of the information obtained, that economic activities connected to tourism could contract in the medium term due to the lack of resources. Both focus areas are renowned ski resorts, where continuous public and private investments have been made in recent decades.
The case of Cortina D'Ampezzo is particularly representative of the relationship between the presence of ice and snow deposits and winter tourism infrastructure. In Figure 8 are relates the land-cover changes over the presence of perennial snow between the two decades, with the current ski areas and accommodation facilities localization. The map highlights how these human activities are exposed to the phenomenon of snow and ice melting. These information are a structural support for planning activities as they can forecast the progressive exposure of economic activities in a perspective of loss of the resource. The proposed methodology is consequently oriented to present a framework of risk and vulnerability to support the planning of the territory in the function of adaptation to climate change, in this case to the impact of a loss of a structural resource.

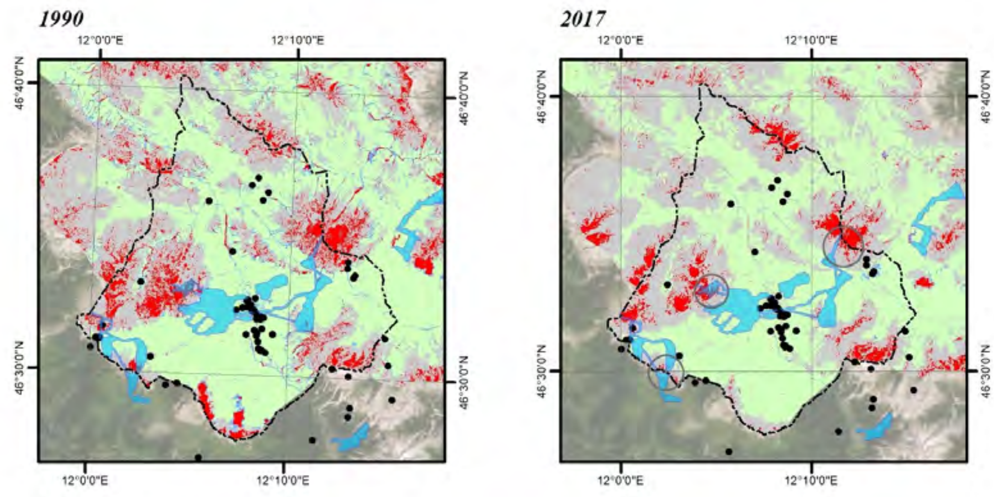


Figure 8 - Ski economy distribution.

Legenda:

- *Cortina d'Ampezzo;*
- *Sky Areas;*
- *Accomodations facilities;*
- *Ice / Snow;*
- *Rocks;*
- *Water bodies;*
- *Vegetation;*

Economic investment models have been based on the continuous availability of ice and snow over time. The reduction of this resource amounts to -90% in Tarvisio and -34% in Cortina D'Ampezzo, while it is appreciable the expansion of urban settlements in the same period of time. The results do not aim to present a reduction in snowfall or a microclimatic modification, but rather they are aimed at providing a survey tool related to human activities in the area and to provide the cognitive basis for adaptation strategies to an ongoing phenomenon. The limits recognized during the research process are mainly related to the availability of images and socio-economic and climatic data.
As reported in the previous chapters, the following limitations were found in the image processing methods:

1. the use of satellite images is necessary to address the gaps in territorial monitoring systems, but there is a limited availability of images with good geometric resolution and suitable atmospheric conditions;
2. the lack of a continuous set of satellite images can make the assessment of territorial micro-variation unprecise;
3. There is a shortage of sources – both from the climatic

and the imagines point of view - capable to provide, from medium to long periods of time, the necessary data for effective statistical processing.

Despite the described limitations in the sources used for this study, it illustrates the potential to define a baseline which combines natural, environmental factors and anthropogenic trends in the Alps; an Atlas which monitors the variation in surface materials over time, in relation to climatic factors. In future, this tool could be integrated with new technologies; for this reason it has been designed with continuous implementation in mind. For example, Big Data could provide the necessary socio-economic data; this could permit a live stream of the various territorial dynamics, from CO2 emissions to the emergency management of extreme events. In addition, open-source access to high resolution satellite images with more frequent orbits would be highly beneficial for public administration and transboundary government agencies.

3.6. - Conclusion

Local administrations will be increasingly committed to dealing with the impacts of climate change which, due to their nature and size, are difficult to locate and predict with precision. While international symposia usually define mitigation efforts, adaptation aims to solve local needs. These needs must, therefore, be identified for specific territorial areas as climate-related impacts differ according to each territory's geography and socio-economic function.

The Alpine territories, a popular location for winter tourism, exhibit local economies that are highly dependent on the presence of snow in the winter period. In addition, the reduction of the layer of snow and ice deplete water reserves, increase the warming effect and degrade the regions' biodiversity.

From this perspective, it is essential that local administrations have access to shared, holistic frameworks so they can develop adaptive policies and management strategies for the future climate.

In summary, what emerges is a marked decrease in the ice-class for both territories. This result helps to understand what are the impacts of the phenomenon of rising temperatures, and generally of Climate Change, concerning the environments of the Alps. Nevertheless, this variation only partially describes the organic relationship that exists between the natural environment and the anthropic system. To obtain this complete vision and achieve the objectives set out in the Introduction, it is also necessary to consider the factor of urban and socio-economic evolution.

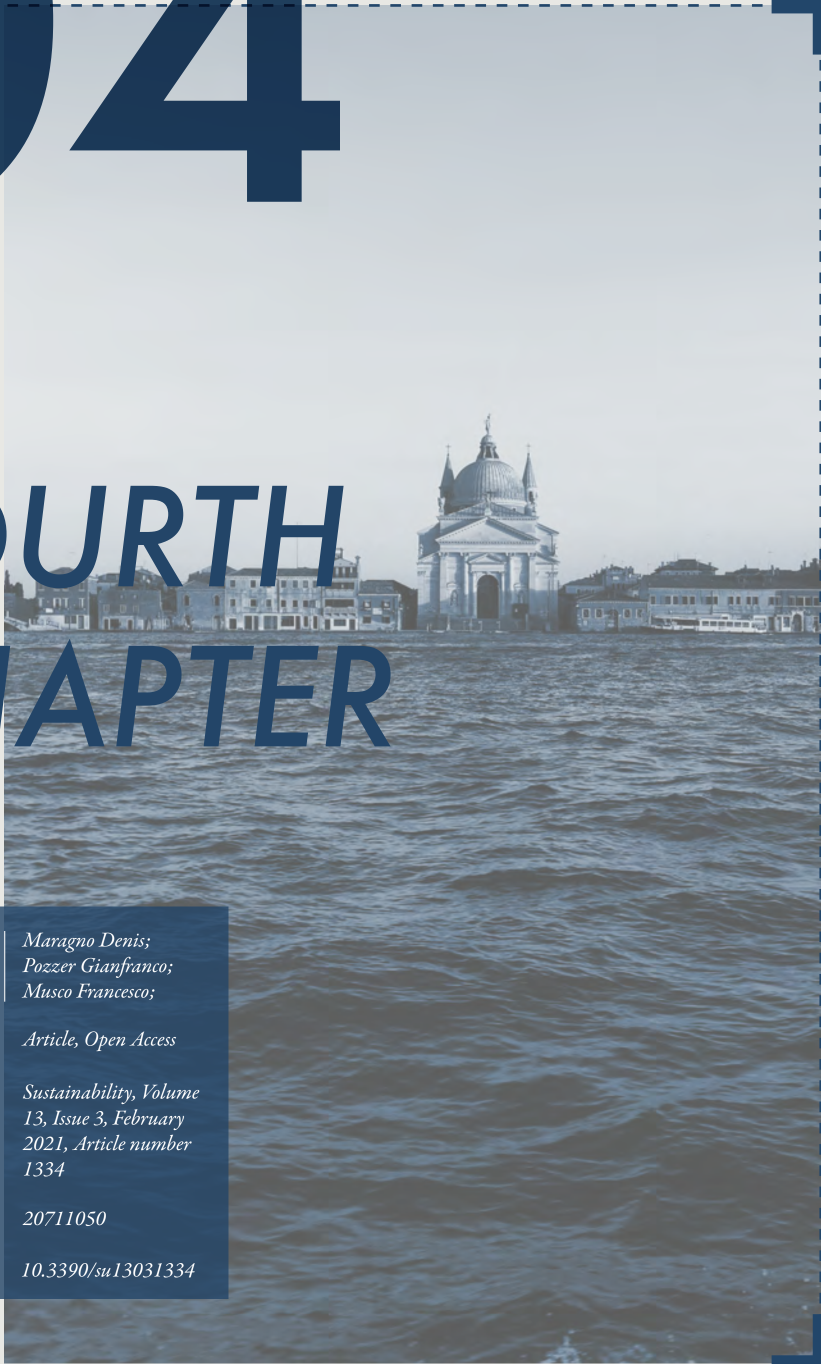
This study aims to define a tool which can support collaborative strategies between different municipal and national bodies, by addressing the discontinuity of available data caused by administrative limits.

This paper has focused on a case study examining the Italian-Slovenian border, but its findings could be applied elsewhere. Implicitly, project aims to support territories in transitioning to alternative, sustainable

forms of tourism and developing models for urban growth which reduce environmental fragility. The results define the extent of the impact of the climate on the reduction of ice and snow.
The reduction is not homogeneous and depends on the exposure of the Alpine slope. To account for this, the developed methodology does not just quantify the variation but constantly recalculates the permanent snow baseline. This factor is related to the socio-economic variations of the target territories and suggests that is necessary to develop an integrated and holistic approach, functional to the dynamics, of planning and governance. To define territorial adaptation strategies, it is therefore necessary to confront the actual vulnerabilities and the present and future risks of the territories. The current dynamics of urban planning and urban design are encouraged at European level through national, regional and local funding. These design dynamics network scientific research with local government agencies. This research is therefore oriented towards its pragmatic and paradigmatic use, with the aim of being a replicable methodology in the European Alpine area.

04

FOURTH CHAPTER



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Document Type: *Article, Open Access*

Journal: *Sustainability, Volume 13, Issue 3, February 2021, Article number 1334*

ISSN: *20711050*

DOI: *10.3390/su13031334*

Article Title:

Mapping climate multi-risk to plan Venice metropolitan and local area adaptation

CHAPTER INDEX

Article Abstract

Climate change risk reduction requires cities to undertake urgent decisions. One of the principal obstacles that hinder effective decision making is insufficient spatial knowledge frameworks. Cities climate adaptation planning needs to become strategic opportunities holistically rethink and transform urban fabrics. Contemporary urban planning should merge future threats with older and unsolved criticalities, like social inequities, urban conflicts and drosscapes. Retrofitting planning processes and redefining urban objectives require the deployment of innovative and performing spatial information frameworks. This paper proposes a combination of approaches to overcome knowledge production limits and to support climate adaptation planning. This research is the collaboration with the Metropolitan City of Venice and the Municipality of Venice result. The interaction with the two public bodies required a climate impact multi-risk atlas definition supporting their spatial planning activities. The assessment tool works as a Spatial Decision Support System (SDSS), boosting adaptation actions and coordination strategies effective implementation. The model recognises and assesses two climate impacts: Urban Heat Island and Flooding, representing the Metropolitan City of Venice (CMVE) case study behavioural complexity. The model, composed by multiple assessment methodologies, maps vulnerability and risk. The atlas links urban fabrics morphological and functional conditions and land use that triggers climate impacts. The atlas bases on exposure assessment considering urban assets which describe local economies and social services, mapping impacts heterogenic distribution. The approach supports planning systems with a replicable and scalable mapping assessment going from the metropolitan to the local level. The model performances are tested on the CMVE area, investigating the limits and the opportunity of the atlas.

4.1. - Introduction

Continuous international studies and warnings highlight the current state of environmental emergency and the dramatic worsening of future scenarios [1][2][3]. The effects of climate change are extensive and will simultaneously affect different aspects of the biosphere [4].

From an urban planning and land management point of view, climate change affects the relationship between climate hazard and territorial adaptive capacity. Generally, it can be considered that higher adaptive capacity corresponds to lower climate impact effects (IPCC, 2014). [5]. Generally, it links climatic variations effects and territorial peculiarities [6]. Climatic impacts are different and indeterminable according to climatic regions [7]. This consideration allows us to understand the connection and the reflections on geographical peculiarities, morphological, functional, and environmental characteristics. Geographical characteristics and settlement patterns favour and trigger different impacts that may affect human life in the urban environment (i.e., UHI, urban flooding) or the natural environment (i.e., loss of ecosystem services, loss of biodiversity). The adaptive capacity, of urban and natural contexts, can vary in strength, producing geographies which are more vulnerable to impacts and others that are more resilient [8]. Undertaking an effective adaptation process requires to (re)read and (re)interpret territories considering those variables which cause vulnerability and to classify territories into portions considering their propensity to suffer impact(s) [9]. Thus, the territorial vulnerability assessment aims to outline vulnerability geographies within urban and natural environments. The research presented in this paper focuses on the strategic role of spatial information within the decision-making processes of planning.

The climate urgency obliges the implementation of digital spatial knowledge, forcing "business as usual" planning processes innovation [10][11]. Therefore, the use - systematic and aware - of new information technologies opens new fields of investigation. Furthermore, it can support a pragmatic retrofit for territorial planning disciplines. This Paper aims at supporting public administrations in operative planning. Thus, the combination of several elements - i.e., statistically, and quantitatively assessable scenarios, predictive models, scenario surveys - makes it possible to explore unknown environmental conditions reorganising existing knowledge.

The research presents a methodology to develop an innovative territorial knowledge framework through information-communication technologies (ICT) to support the strategic implementation of actions aimed at climate change adaptation [12]. The proposed model allows a new way to develop spatial knowledge and produces climate risks atlas. The atlas is designed as a Spatial Decision Support System (SDSS) – made of a Geodatabase – for the Metropolitan Area of Venice administration (CMVE) and to support local municipal administrations, as the Municipality of Venice (CM). The atlas supports both levels of territorial governance:

- At the metropolitan level, it allows the development of coordinated adaptation strategies;
- At the local scale, it allows the identification of less resilient areas. From this perspective, SDSS allows managing intervention priority at the municipal level.

The most effective tool to support administrations in developing objective-oriented adaptation strategies is risk analysis. As vulnerability is the relationship between adaptive capacity and sensitivity, so the risk is the expression of the relationship between vulnerability and exposure (exposure, IPCC 2014). Exposed factors are those spatial assets that are affected by a climate impact and can be: the presence of people, livelihoods, species or ecosystems, functions, services and resources, infrastructure, cultural, economic or social assets[13]. Therefore, the risk assessment can be considered as a strategic field of investigation in contemporary and future urban planning. Measuring the factors exposed requires that urban governance tools and knowledge frameworks acquire tools capable of representing rapid and complex dynamics in addition to those of a physical and organisational nature[14]. One example is the rapid change in the distribution and typology of urban services, economic activities, population micro-migrations or ecosystem behaviours. In summary, the investigation of exposure and risk allows understanding (perhaps for the first time) the relation between social and economic dynamics, and the connection with climate risk issues. Moreover, this approach can support the boundary definition of the more critical socio-economic urban contexts [12]. From this perspective, reconstructing the distribution of services, economic activities, and the location of the more critical communities (e.g., gender, age, income), allows for the identification of places of urban inequity and conflict. Climate change often affects the most fragile and ghettoised communities, and the exposure and risk analysis approach enable informed urban planning [15]. This background allows for the implementation of strategies and actions that parallel adaptation goals while integrating issues of urban justice and social equity [16][17]. From this point of view, the adaptation process is enriched with strategic factors, acting as an opportunity to rectify past planning errors, regenerating and maintaining the urban fabric, allowing marginalised communities access to the services, infrastructure and livelihoods necessary for growth and urban recovery [18]. Therefore, the frontiers and tasks of spatial planning are widening, and obstacle as obsolete tools and practices are becoming insurmountable. Tasks such as sustainability, adaptation, mitigation, and urban regeneration become unachievable without an innovative framework of knowledge. Local municipal governments seem to be the natural actors to physically implement, at the urban and neighbourhood level, superordinate (metropolitan, regional and national) adaptation and transformative strategies. In this sense, the main objective of the research proposed in this paper is to provide a tool to develop territorial awareness and operationally support the beginning of this process [19,20][21][22]. The presented research aims to overcome the difficulty of identifying the more vulnerable fabrics and more exposed assets to two of the more common climate impacts: Flooding (F) and Urban Heat Island

(UHI). Adaptation is a process rather than a goal [23]. It cannot be expressed through a single urban planning tool but needs a systematic integration into local governance tools with an awareness of future scenarios [24]. Therefore, the inclusion of strategies and measures focused on increasing territorial resilience to the effects of climate change requires "integrating" innovative processes [25]. The research aims at studying vulnerabilities and assessing risk and resiliency through an articulated and integrated monitoring process into territorial governance activities. Therefore, the issue of adaptation of cities to climate impacts becomes a (necessary) opportunity for urban planning and territorial governance to innovate and experiment. For public administrations, it becomes a chance to recover, enhance, regenerate, safeguard urban and natural heritage. Adapting the territories to the new climatic externalities also becomes an opportunity to remedy the planning mistakes of the past. Strengths of this process for an urban renaissance are financial availability, political will and above all knowledge. The availability of a dynamic technological innovation ecosystem supports and is already supporting strategic spatial information tools[26][6]. The research presented in this paper stems from the virtuous collaboration between academic research and territorial administration. The methodology developed addresses the adaptation needs of the CMVE and the CV following the requirements of the Green New Deal. Three favourable factors allow the organization of this research in a perspective of urban planning innovation, such as the political will to implement a transformation in the status quo of a region; mature research and technological availability; and financial availability. Funding derived from the European project (Interreg Italy-Slovenia) SECAP allowed to develop, empirically test, and implement the theory. The result produced is an atlas of vulnerability operationally adopted by CMVE and CV. In this sense, the lack of information encouraged this research towards innovation and on the topic of exposure assessment. Specifically, the research questions that the paper tries to answer, starting from this theoretical background, are:

N.	Research Question
RQ 1.	Is the metropolitan survey scale the more effective to support local and regional authorities in developing climate change adaptation strategies and measures implementation?
RQ 2.	Which survey techniques and methodologies are suitable to support a knowledge framework construction to support adaptation governance and integrated territorial management?
RQ 3.	Can local planning incorporate metropolitan-scale adaptation strategies? Can the same knowledge framework also support conscious local adaptation measures?
RQ 4.	Is it possible to effectively assess exposure and define risk? Which strategic role can this assessment play in the construction of efficient and effective climate change policies?
RQ 5.	How can (or should) adaptation process mitigate social inequalities and urban conflicts exacerbated by CC?

Table 1 - Research question.

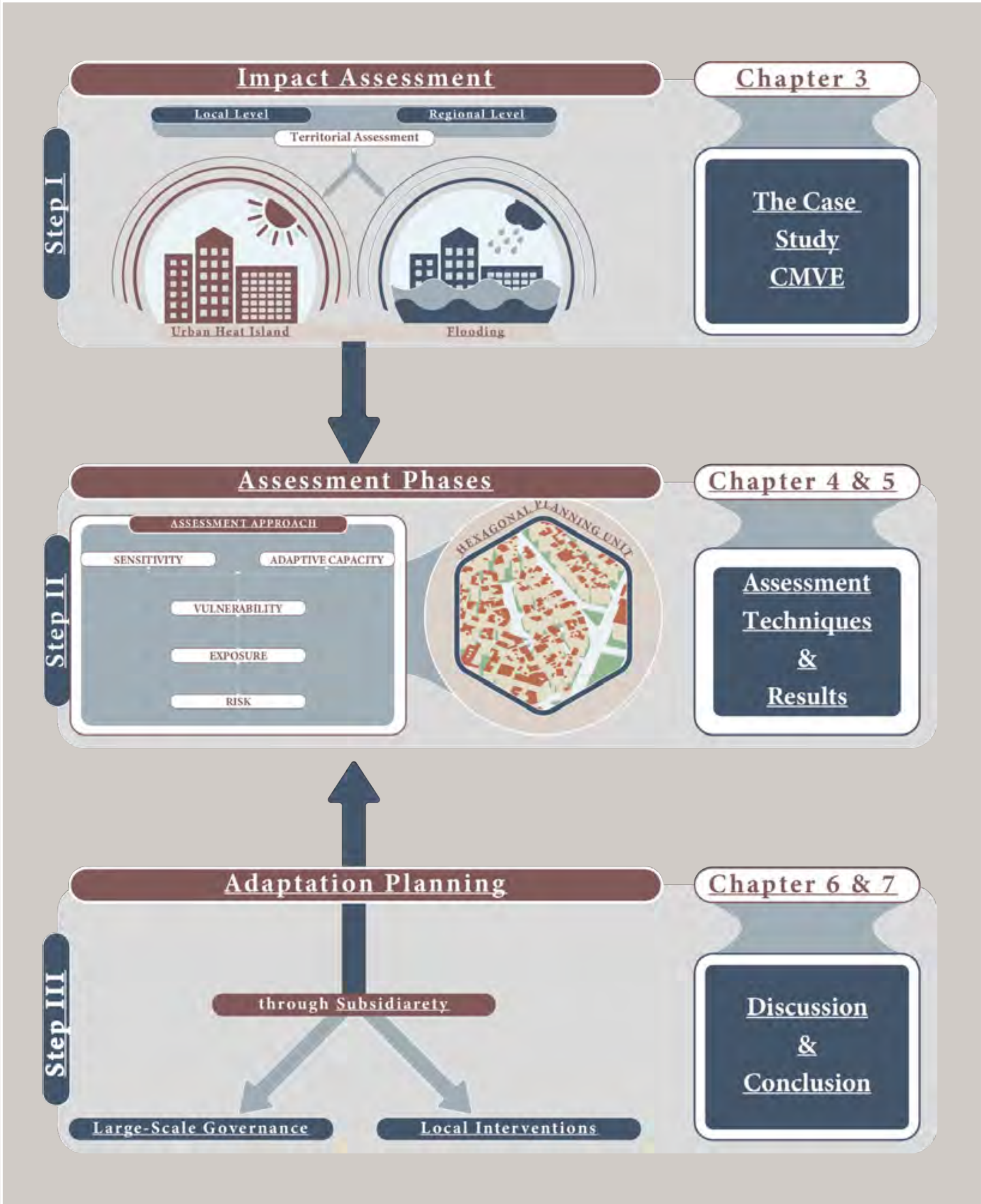
4.2. - Research Design

Figure 1 presents the operational steps which organise the logical process of research. Each step is related to Research Questions, presented in the Introduction Chapter. From the point of view of logical consequentiality, the study bases on three different levels: the first one aims at identifying two of the most relevant impacts of climate change on urban systems; the second one aims at defining impacts assessment techniques linked to urban activities, considered as exposed factors; the third step aims at contextualising the evaluation processes considering the territorial governance system and in particular referring to the subsidiarity principle.

4.2.1. - Step 1 - Impact Assessment

Research Step 1 has a theoretical and empirical nature. The Step examines two phenomena which affect the Metropolitan City of Venice territory: UHI and Flooding. The approach employs a geo-database which integrates a set of morphological-environmental indicators. The indicator selection aims at identifying physical and environmental character that can amplify or reduce urban climate impacts. The methodologies presented in this paper focuses on two climate impacts: Flooding and Urban Heat Island. Therefore, the approach assesses the surface runoff coefficients [27][28] linked to Flooding, and Urban Heat Island causes [29,30]. Different working phases organizes Step 1 to achieve the two-impact assessment, namely:

a) Data collection by interoperable sources;
b) Application of algorithms for the processing of morphological information of impacts;
c) Mapping of environmental components for chromatic restitution of vulnerability according to spatial coordinates.



Impact Assessment
Chapter 3
Local Level
Regional Level
Territorial Assessment
Step I
Urban Heat Island
Flooding
The Case Study CMVE
Assessment Phases
Chapter 4 & 5
Step II
ASSESSMENT APPROACH
SENSITIVITY
ADAPTIVE CAPACITY
VULNERABILITY
EXPOSURE
RISK
HEXAGONAL PLANNING UNIT
Assessment Techniques & Results
Adaptation Planning
Chapter 6 & 7
Step III
through Subsidiarety
Large-Scale Governance
Local Interventions
Discussion & Conclusion

Figure 1 - Research Design.

Impact identification is an obligatory operational step in any planning context. Step 1 recognises UHI and F climate impacts and bases on the empirical research developed within the SECAP project (Interreg Italy - Slovenia). From this perspective, the impact recognition includes project partners' choices, including CMVE. The impacts recognition is fundamental in all models which support local climate adaptation planning - i.e., New Covenant of Majors, C40 -. Therefore, the developed model can support different climate adaptation approaches, from the local to the regional level.

4.2.2. - Step 2 - Assessment Phases

Step 2 defines the impact evaluation techniques and tests it on the case study to answer the RQs. The Step consists of two complementary phases: methodological the first and empirical the second. The first phase aims at defining the model for local risk recognition, integrating a consolidated methodology. The assessment starts from the definition of vulnerability and considers as exposed factors the economic assets and services, which characterize the case study urban context. Step 2 aims at - using a geo-database - localizing the risks driven by the two impacts within the CMVE context. Risk localization is the result of Step 2 and leads to Step 3. The last Step evaluates the proposed process limitations and potentialities linking to RQs. The general objective of Step 2 is to develop a stable and replicable approach to assess climate change risk spatial, supporting the effective implementation of strategies and measures.

4.2.3. - Step 3 - Adaptation Planning

Step 3 represents the convergence point of Step 1 and 2 analytical and empirical investigations. In Step 3 vulnerability, exposure and risk assessment results allow the definition of a new knowledge paradigm. This knowledge framework can directly and operationally support public authorities in multi-governance climate adaptation planning. From this perspective, sensitivity and adaptive capacity indicators definition play a central and innovative role. Furthermore, Step 3 presents the relationship between results and responses to RQs. The tool limitations and potentialities base on the atlas implementation within CV and CMVE spatial planning systems. In the first case, the atlas supports the Venice Adaptation Plan implementation, and in the second, the tool supports the metropolitan adaptation strategies definition.

4.3. - The case study of Metropolitan City of Venice

Chapter 3 describes the spatial study system on which the vulnerability, exposure and risk assessments were elaborated and tested. This First Step of the research (Figure 1) contextualises the case study and the regional system describing the link with climate change impacts and aims at responding to RQ 1. The empirical research has as object of investigation the territory of the Metropolitan City of Venice (CMVE) and Mestre, part of the municipality of Venice (CV) administrative territory. The CMVE is the only special-status sub-regional administration - i.e., with an operational planning function - in the Veneto region and coordinates 44 municipal units territorial governance [31]. Among these, the Municipality of Venice can represent the complexities of the sub-regional system. CV is peculiar for the complex structure of its planning governance and for the relation that its urban morphology has with climate impacts. The authors of this paper selected this territory for the nature and quality of climate resilience-oriented ongoing processes. From the point of view of applied research, this area presents a high concentration of projects financed both by the European Commission - such as Life and Interreg projects - and others directly by local authorities. The Veneto Region, the CMVE and the CV carried out in the last five years an extensive programme to update planning tools - from the cognitive framework to the strategic planning - emerging as good practices at Italian level in the fulfilment of New Covenant of Majors and C40 commitments. It is possible to divide the territory of the Municipality of Venice into two parts: the first is the city of the lagoon islands made up of water and the historical urban fabric; the second is the modern city of the hinterland. From a scientific point of view, both components are highly relevant about the effects of climate change, considering Urban Heat Island and Flooding phenomena. The choice of the modern area of Mestre as a case study is linked to the availability of

information on which to base the empirical research. Moreover, the choice is motivated by the fact that the historic city has characteristics that require further investigation to carry out a reliable survey. These characteristics that limit accurate investigations on climate risk are morphologically complex urban fabric and a peculiar relationship with the environmental system.
Two examples of this complexity are:

- The compactness of the urban fabric needs to be considered assessing UHI. This requires precise modelling and high-resolution thermal images. Both elements require a specific investigation process;
- In Flooding, assessment is necessary to investigate the behaviour of urban surfaces morphology and how the system of canals - which define the old town - receives rainwater.

Therefore, the objective is to develop a sound assessment methodology for contemporary urban fabrics, which can be integrated in a second moment to analyse historical centres.
Authors chose to implement empirical research on Mestre because in the area gives the possibility to develop a risk assessment basing on existing data and using open-source tools. Moreover, the result can support the definition of metropolitan scale coordination strategies, responding to the RQs and objectives of the article. Mestre presents historical sprawl problems associated with the economic growth of the industrial pole of Marghera. Furthermore, insufficient city growth supervision led to a diffuse deficiency of green areas, overbuilding and social conflict situations.
The survey considers the information necessary to describe both the sensitivity and adaptive capacity of the area to map vulnerability. The exposure of the main economic activities and services highlights risk distribution in proportion to the quality of the urban fabrics. The assessment is replicable and extendible at the whole CMVE territorial system and can effectively integrate the current governance system. Table 2, quantitatively presents the relationship between the study

Territory	Surface (Km2)	Population	Population Density (pop/ Km2)
Veneto Region	18.345,00*	4.907.704*	267,52***
Metropolitan City of Venice	2.472,91*	851.663*	344,40***
Municipality of Venice	156,85 *	259.150*	1.652,22***
Mestre (Case Study)	224,98**	88.552**	393,60***

Table 2 - Distribution of the case study population.

** Source ISTAT 2019;*

*** Source Municipality of Venice.*

***Authors Elaboration;*

area and the metropolitan area, strengthening the opportunity of empirically test the method on this context.

The effects, induced by territorial artificialization processes and climate variability on the regime of surface water flows, highlight the existence of increasingly severe and recurrent hydraulic criticalities in urban areas [32][33]. The increase in the volume of surface water runoff due to soil sealing and CC (for example, increasing intensity and variation in the frequency of rainfall) subjects urban basins to a disruption of the natural hydrological cycle and an increase in the risk of flooding [34][35]. The increase in extreme weather events in terms of intensity and territorial extension tends to overload the urban drainage system [36], causing an uncontrolled increase in surface runoff [37][38]. This disturbs the territory and the urban ecosystem with increasingly persistent flooding.

In a process of containment of the urban runoff phenomenon, it is necessary to intervene effectively on its modelling and simulation[39][40][41]. Therefore, it is necessary to adopt innovative analysis technologies that, integrated with sustainable urban development solutions, make it possible to estimate hydraulic vulnerability, offering numerous advantages to the operational management of public space and the performance of the urban drainage system. On the other hand, Urban Heat Island impacts is a physical phenomenon generated by the coexistence of several factors - e.g., urban morphology, soil densification, exposed climatic-geographical zone, human activities - that contribute temperature accumulation in urban areas [29][42][43]. An urban fabric, mainly composed of buildings and paved surfaces, absorbs more heat and solar energy than natural surfaces.

Moreover, the heat accumulation causes overheating during the day, and in the night-time, transforming a city in a thermic cell with constant high temperatures. This predisposition and other factors - i.e., air pollution, industrial activities, and lack of water shortages - makes cities risk places for population health. UHI impoverishes the quality of life in cities, reduces the dispersion of air and water pollution, increases energy costs for cooling, lessens urban biodiversity and amplifies health risks for the population [44][45]. The study area is characterized by medium-sized settlements sprawled in a vast rural area fragmented by river courses, where urban heat island widespread within build zones.

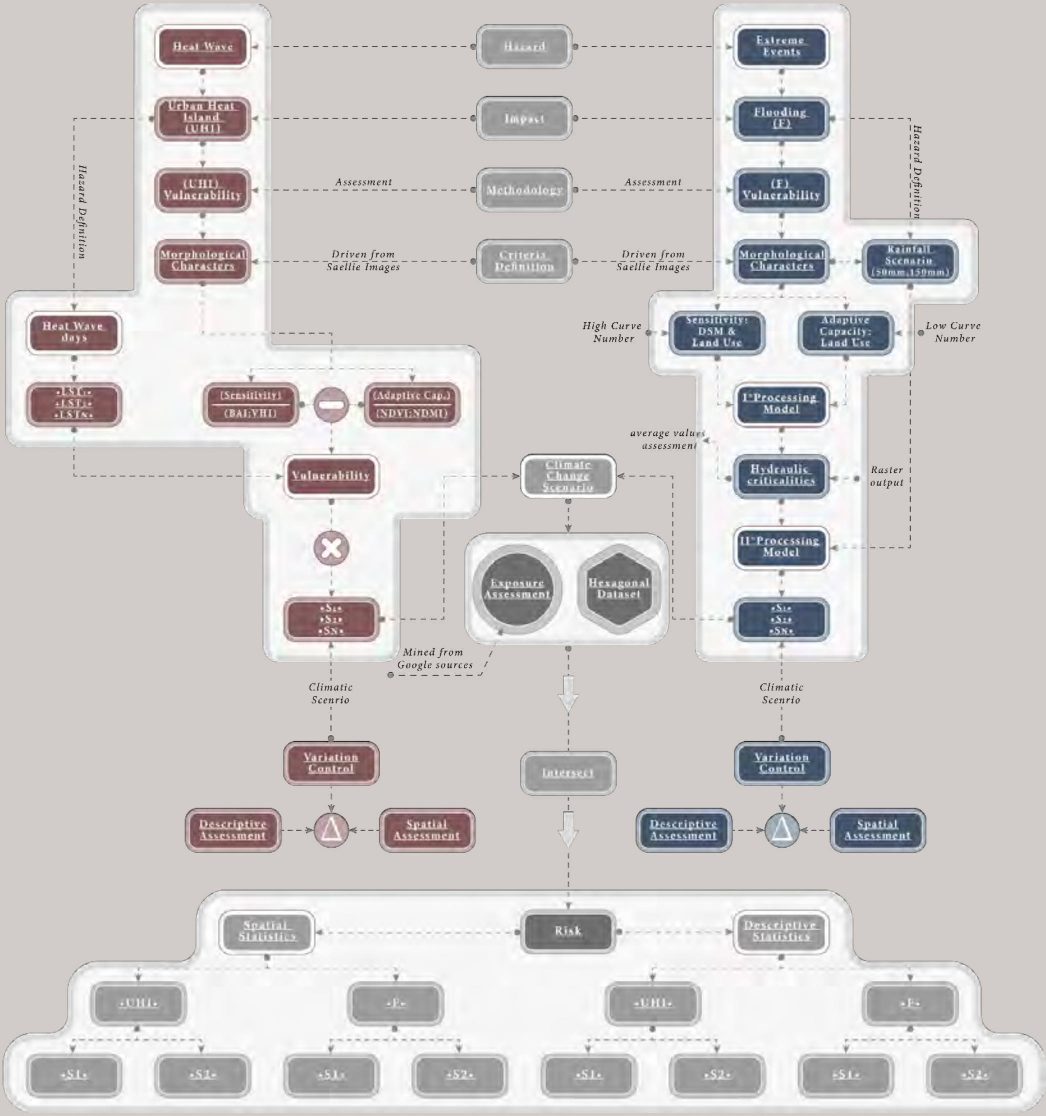
4.4. - Assessment Techniques

Chapter 4 develops a methodology for analysing UHI and Flooding impacts, aims to answer RQ 2 and 4 and acts as a link between Step 1 and Step 3 (Figure 1). The workflow (Figure 2) of the chapter combines different investigation techniques, technologies, and assessments - e.g., vulnerability, exposure, and risk. It bases on different binomials: urban morphology vulnerability, functional assets exposure and urban system multi-risk. The Assessment Techniques Chapter describes the different methodologies deployed to define these three indicators, including the identified climatic hazards.

4.4.1. - Workflow

The vulnerability assessment bases on morpho-typological indices organised into a geodatabase (GeoDB). The connection between geometry and tabular information is carried out in a GIS environment using a hexagonal grid with 150-meter side cells. From a methodological point of view, the preparation of the GeoDB separates into two distinct operational flows (Figure 2). The two flows aim at combining two different assessment methodologies – UHI and F - within a single multi-risk assessment approach. The GeoDB is the core of the SDSS and allows the risk atlas development. The workflow spatially associates assessments for both impacts by integrating exposure factors. These values are the socio-economic and commercial activities mined from Google's databases (Figure 2). The multi-risk analysis at F and UHI is the result of this process and considers progressive impact scenarios, according to Equation 3.

Figure 2 - Workflow.



4.4.2. - Data source

The research uses several sources (Table 3). Some data refer to spatial and alphanumeric information held by the municipalities (i.e., basic cartographic themes and general thematic cartography), others come from remote sensing elaborations.

Table 3 - Data Source.

Impact	Category	Description	Typology and resolution	Territorial extensions	Source	Elaborations
UHI	Remote sensing	Multispectral Satellite Image (09/08/2015): LC08_L1TP_192028_20150809_20170406_01_T1	*Raster-Geotif - 16 bits, 30m*	*provinces of Venice*	*Landsat 8 (United States Geological Survey - USGS)*	*Parameters supporting the study of the UHI: NDVI; Normalized Difference Moisture Index (NDMI); Vegetation Health Index (VHI); Built-up index (BUI); Built-up area (BAI); Land Surface Temperature (LST);*
		Multispectral Satellite Image (11/06/2017): LC08_L1TP_192028_20170611_20170627_01_T1	*Raster-Geotif - 16 bits, 30m*	*provinces of Venice*	*Landsat 8 (United States Geological Survey - USGS)*	*Parameters supporting the study of the UHI: NDVI; Normalized Difference Moisture Index (NDMI); Vegetation Health Index (VHI); Built-up index (BUI); Built-up area (BAI); Land Surface Temperature (LST);*

Flooding	Basic Map	DSM from 3D model	*Raster-Tif-1 m*	*provinces of Venice*	*Metropolitan City of Venice (MCV)*	*Supporting data for the simulation of stormwater surface runoffs*
		Primary watercourses	Vector	*provinces of Venice*	*Metropolitan City of Venice (MCV)*	*Supporting data for the simulation of stormwater surface runoffs*
	Thematic Map	Land Use 2012 - CCS 2012 plus	*Vector*	*provinces of Venice*	*Land cover database of Veneto region to 2012*	*Supporting data for the construction of the Atlas of Surfaces*
	Remote sensing	Multispectral Satellite Image: L1C_T32TQR_A012060_20190628T101033	*Raster-GeoTiff-10 m*	*provinces of Venice*	*Sentinel 2 (United States Geological Survey - USGS)*	*Normalized Difference Vegetation Index (NDVI): Supporting data for the construction of the Atlas of Surfaces*
		Multispectral Satellite Image: L1C_T33TUL_A020611_20190603T101642	*Raster-GeoTiff-10 m*	*provinces of Venice*	*Sentinel 2 (United States Geological Survey - USGS)*	*Normalized Difference Vegetation Index (NDVI): Supporting data for the construction of the Atlas of Surfaces*
	Flow index	SCS Curve Number (CN): hydrology parameter for predicting direct runoff or infiltration from rainfall excess. Curve Number depends on soil type, land use, land cover, and antecedent moisture conditions			*Soil Conservation Service (SCS 1972)*	*Supporting parameter for the simulation of surface runoff of rainwater*

4.4.3. - Vulnerability assessment

The evaluation model bases on the research experience synthesis developed by the Authors and capitalises on both theoretical and empirical evidence. ([6][23][39][46]). Vulnerability assessment is essential to identify areas that are less resilient to an impact, such as UHI and Flooding. The study of the UHI phenomenon uses satellite images, considering the incidence of vegetation and thermal parameters to describe the morphological quality of a territory and its different degrees of vulnerability [6]. On the other hand, the study of hydrological intense events effects on environments bases on spatial correlation analysis between land use patterns, orography, and land morphologies [47][48]. Specifically, it considers slopes, depressions, and land elevations. The vulnerability computation (V) for both impacts combines two environmental determinants, sensitivity (S) and adaptive capacity (AC) [49][7][5]. Equation 1 describes this correlation:

$$\text{Vulnerability} = \text{sensitivity} - \text{adaptive capacity}$$

where:
Vulnerability: territorial predisposition to accumulate the effects generated by an impact;
Sensitivity: the propensity of a system to suffer an impact;
Adaptive capacity: the intrinsic propensity of a system to be resilient to an impact.

The research updates the IPCC definition of the binomials hazard-sensitivity and sensitivity-adaptive capacity. The aim is to recognise the physical-environmental correlations between impacts and land morphology. The approach integrates hazards and its quantitative value into the vulnerability function. Therefore, it operatively considers for the assessment UHI and Flooding in their climatic dimension, not only at the level of reference scenarios. The result of equation (2) allows an integrated assessment, relating vulnerability and exposure levels to hazard variations.

$$Vx = (Sensitivity - Adaptive\ Capacity) \times Hy$$

where:
Vx: Vulnerability to Impact;
Hy: Hazard Scenario;
z: Baseline Scenario.

The analysis matrix enables the calculation and mapping of an urban fabric's propensity to react - negatively or positively - to climatic stress with different magnitudes. The relationship between climate impact and the city acquires three-dimensionality through the concept of exposure. This principle makes it possible to investigate the assets of a system, producing an operational analysis for decision-making. The main problem that exposure analysis presents links with data availability and result interpretation. To overcome this problem, the authors integrated the existing - public - knowledge frameworks with updated information. Thus, through a mining process, data from google maps and google places provided the knowledge base to articulate the assessment. The selection of the exposed assets is part of the planning decision-making process. Therefore, the sample of assets - described in the following chapters - aims at representing the database and the assessment model potentialities. The third step of the elaboration allows to map and summarise the urban risk basing on the spatial combination of vulnerability and exposure factors (Equation 3).

$$Urban\ Risk = Vulnerability \cap Exposure$$

4.4.3.1. - Urban Heat Island impact assessment

The left flow of Figure 2 presents the UHI vulnerability development phases. The UHI assessment uses four descriptors to map the impact, and through which analyses satellite data (Table 3). The selection of satellite images - described in chapter 4.2 – bases on climatic data provided by ARPA Veneto. The data analysis identifies two temporal moments that represent two of the conditions in which the urban system is vulnerable from a thermal point of view:

- The summer day of 9 August 2015 presents a heat wave condition. This day represent an emergency moment due to the duration of the phenomenon and temperature values 4° above the seasonal average;
- The summer day of 11 June 2017 has high temperatures in line with the seasonal trend. This condition is the threshold of thermal stress.

In this case, Sensitivity (S), and Adaptive Capacity (AC) acquires specific values. The first bases on the correlation between Build-up Area Index (BAI) and Vegetation Health Index (VHI), while the second bases on the correlation between Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI). The result (Equation 2) is related to the different Hazard (HUHI) scenarios resulting from different Land Surface Temperature (LST) conditions. This parameter identified through satellite image analysis (Landsat 8) allows to build different Hazard scenarios (S1; S2; ...; Sn) and thus to represent land vulnerability conditions (Equation 4).

$$V_{UHI} = (\text{Sensitivity} - \text{Adaptive Capacity}) \times H_{UHI}$$

where:
VUHI: Urban Heat Island Vulnerability;
HUHI =Land Surface Temperature Scenario .

Furthermore, the topological overlap between land uses (CCS_2012_plus), and the result of the vulnerability analysis allows

the classification of land uses enriching the knowledge framework. This correlation allows mapping land-use patterns and morphological features which favour UHI.
Each indicator which composes the UHI assessment requires a specific elaboration. The LST is processed with an algorithm for the extraction of land surface temperature based on thermal data [5]. The NDVI parameter is calculated by measuring the spectral pattern of vegetation, water, and bare soil by analysing the visible, near-infrared and red spectra [6]. NDMI - an indicator of the crop's water stress level - is the result of comparing reflected radiation in the near-infrared and the SWIR (Short Wave Infrared) [6]. The cross-reading between NDVI and LST shows that the presence of vegetation inversely determines a variation in temperature according to a linear trend. On the other hand, NDMI mapping allows evaluating the effects of the impact on vegetation in terms of water stress. Furthermore, land cover and land use can enrich this result.
Analysing the infrared field also allows determining the intensity of drought and its spatial extent (Bento et al. 2018; Cunha et al. 2019; Tripathi et al. 2013), whose reference index is VHI. Analysing the infrared field also allows determining the intensity of drought and its spatial extent [50–52], whose reference index is VHI. VHI estimation is indirect, as it bases on the response of vegetation - i.e., forest and agricultural - referred to thermal stresses or changes in soil moisture. In this research, the VHI is considered as a sensitivity variable, aiming to contextualise the presence of ecosystem imbalances triggered by urbanisation phenomena.

The VHI is obtained through the ratio of two satellite-derived indices: Temperature Condition Index (TCI), Equation 6, and Vegetation Condition Index (VCI), Equation 5. TCI calculation bases on LST, while VCI calculation bases on NDVI. VCI indicates standardised vegetation values reflecting - in % - soil moisture conditions [53].

$$VCI=\left[\frac{(NDVI_J - NDVI_{min})}{(NDVI_{max} - NDVI_{min})}\right]\times 100$$

Table 4 - Indicators and components of vulnerability according to the use of the equation (2).

TCI presents in percentage values (%) the vegetative stress related to thermal stress [53].

$$TCI=\left[\frac{(LST_{max}-LST_{j})}{(LST_{max}-LST_{min})}\right]\times 100$$

The VHI index is a proxy for the vegetation health status estimated according to the relationship between moisture values and stressful thermal conditions [53].

$$VHI=a\times VCI-b\times TCI$$

In Equation 7, a and b are coefficients that quantify VCI and TCI, i.e., vegetation response (with values ranging from 0 to 1). Low values of VHI identify areas that are more affected by stress conditions - e.g., drought phenomena, heavy rainfall - which may alter the vegetative well-being of the green infrastructure.

The NDBI index returns the incidence of urban areas by facilitating mapping built-up areas, with a degree of accuracy of about 93% (bibliography). The index is the result of a ratio between the difference and the sum of the short-wave and near-infrared bands (bibliography). Finally, BAI is derived from the difference between NDBI and NDVI.

The measurement of the UHI phenomenon makes use of the conceptual reworking of the Equation (2), declining the sensitivity, adaptive capacity and hazard components as follows (Table 4). The variables deployed to develop the UHI vulnerability analysis have 0 to 1 values.

Statistical unit	LST	BAI	VHI	NDVI	NDMI
Hexagonal cell (side 150 m)	*Hazard scenario*	*Sensitivity*	*Sensitivity*	*Adaptive capacity*	*Adaptive capacity*

Below is a graphic schematisation of the specific morphological-environmental factors that can favour and influence the UHI phenomenon in the planning unit (Figure 3).

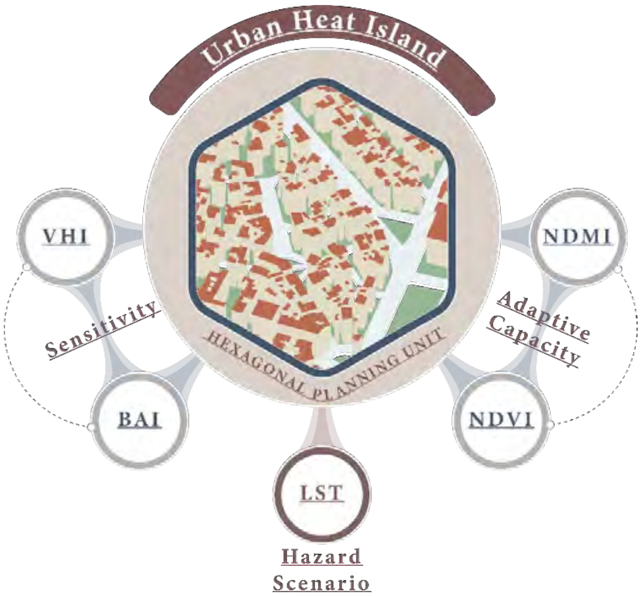


Figure 3 - Composition of certain morphological-environmental factors linked to the UHI phenomenon in the planning unit.

Vulnerability is measured in terms of the potential effects generated by thermal alterations (LST) on the morphological response levels of urban and territorial systems to the heat wave according to its intensity and duration (Equation 8).

$$V=\left\{\left[\frac{(\text{Built-up area}+\text{VHI})}{2}\right]-\left[\frac{(\text{NDVI}+\text{NDMI})}{2}\right]\right\}\times \text{LST}$$

The vulnerability value, result of the equation, is always included between -1 and 1, where -1 is the worst possible condition and 1 the least vulnerable condition.

4.4.3.2. - Flooding vulnerability assessment

The second flow (right axis of Figure 2) assesses the vulnerability from Flooding (F). The test shows the correlation between Curve Number (CN) coefficient and soil sealing. F vulnerability bases on Equation 2 and is developed in GIS environment through Hydrology function. This step allows the territorial hydraulic system representation, assessing qualitatively and quantitatively its performance. Using an ad hoc statistical model, it is possible to correlate the CN coefficients to geomorphological features by a variety of land use patterns. The model shows which are the land-use changes most influential on the overall efficiency of the hydraulic system and his regression to less efficient performance. Thanks to the implementation of surface runoff scenarios (S; S2; ...; Sn), linked at the CN and rainwater forecasts, it is possible to estimate different critical conditions.
The test supports two scenarios (according to Rainfall data provided by ARPA Veneto - Regional Agency for Environmental Protection):

- 150 mm/hour critical rainfall, with a Return Time (TR) of 200 years. This scenario links with a rainfall volume of 150/200mm per sqm and corresponds to 24-hour precipitations;
- 50 mm/hour rainfall, with an RT of 5 years. This scenario links with a rainfall volume of 50 mm per sqm and corresponds to 12-to-24-hour precipitations.

The daily rainfall volume concentrated in a single hour highlights the reactivity of land-use patterns according to the Soil Conservation Service model [54]. The SCS-CN method supports the implementation of Equation 2 integrating with rainfall scenarios the vulnerability analysis (Equation 9).

$$V_F = (\text{Sensitivity} - \text{Adaptive Capacity}) \times H_F$$

Where:
VF= Flooding Vulnerability;
HF = Rain Scenarios x CN.

Similarly, to the UHI Assessment, the topological overlap between CCS_2012_plus and the result of the vulnerability analysis highlights those territorial patterns which favour Flooding.

The recognition of spatial responses to different degrees of hydraulic criticality is developed through three phases of work operationally connected, but technically distinct in procedures.
Step 1: Integrated use of satellite imagery and spatial land cover data for the construction of a geographical database of surfaces.
Phase 2: simulation of soil hydrodynamic response based on the study of the spatial correlation between artificial (sensitivity, [7]) and natural (adaptive capacity, [7]) morphological factors.
Step 3: restitution of surface runoff scenarios measured linking to the use of rain (hazard) reactivity, weighted on soil specific saturation volume estimation.www
The first phase of the work foresees the construction of an Atlas of Surfaces through the integration between Sentinel 2 satellite information sources and the cartographic knowledge on the use and land cover themes of the Veneto Regional Database (CCS_2012_Plus). The work demonstrates the potential of radiometric information in the definition of a mapping of urban green areas, equipping the information content with an interesting statistical accuracy and an adequate spatial correspondence with the polygonal database. The thematic analysis based on Sentinel data increases the spatial detail of waterproof, permeable and mixed urban cover morphologies considering the fabric of cities. The coverage variations that can be obtained from the weaving of the satellite image make it possible to define a land-use configuration independent of matrix patterns (those required by law), with improved urban and peri-urban ecological detail (public and private greenery).
The second phase of work uses the new spatial input (Atlas of

Surfaces) to test a new process of correlation between outflows and morpho-typological relations. The use of remote sensing facilitates the assessment of hydraulic vulnerability in the phase of recognition of soil classes, depending on the type of surface and its permeability rate (see Table 5). The permeability levels are defined using the Curve Number (CN) method: a tabulated parameter on the infiltration capacity of the soil, defined based on descriptive characteristics of the vegetation cover and the hydrology of the soil. The estimate adopted can be traced back to the hydrological soil categories developed in the United States by the Soil Conservation Service.
Table 5 shows the values of the CN parameter under the different conditions of land use and crop:

Type of surface	CN*	Hydrological soil class**
Buildings	98	A
Waterproofed surfaces	81	A
Grass/tree	30	A
Agricultural land	62	A
Wooded land	25	A
Water/wet areas	100	A
Shaft cover	45	A

Table 5 - CN parameters linking to Atlas of Surfaces.

** CN values can vary from 0 (when the water is completely retained from the ground) to 100 (when the water drains completely from the draining surface.*

** Low outflow potential. Includes soils consisting of sand, gravel, silty sands, and sandy silt; these soils have a transmissivity greater than 0.76 cm/h.*

The third phase of outflow modelling exploits a statistical model based on a logic of spatial association between land uses and land morphologies (DSM). The use of a specific statistical model - developed in GIS environment - allows clustering surface runoff dynamics in the different land use categories (see Table 5) using surface water direction and accumulation functions calculated at the hydrogeological basin scale. Through the use of hydrological functions, the relationship (10) is defined [27][6], which allows estimating hydraulic impacts for land use variations by assigning to the CN value the accumulation of flow (Flooding vulnerability – Vf). This correlation is expressed as % of the rain that transforms into surface runoff (range from 0.25 to 0.98, see Table 5).

$$V_f = \left\{ \frac{[(CN \times F_{AS}) + CN° \times (F_{DSM} - F_{AS})]}{F_{DSM}} \right\}_i$$

where:
CN= curve number associated with waterproof areas;
CN°= curve number associated with permeable areas;
FDSM = flow accumulation calculated on DSM;
FAS= flow accumulation related to the surface atlas;
U= land use in i.

As for the UHI vulnerability assessment (see Equation 4), the UAF modelling also makes use of the sensitivity and adaptive capacity components, declining them in the following way (see Table 6, and Equations 9 and 10).

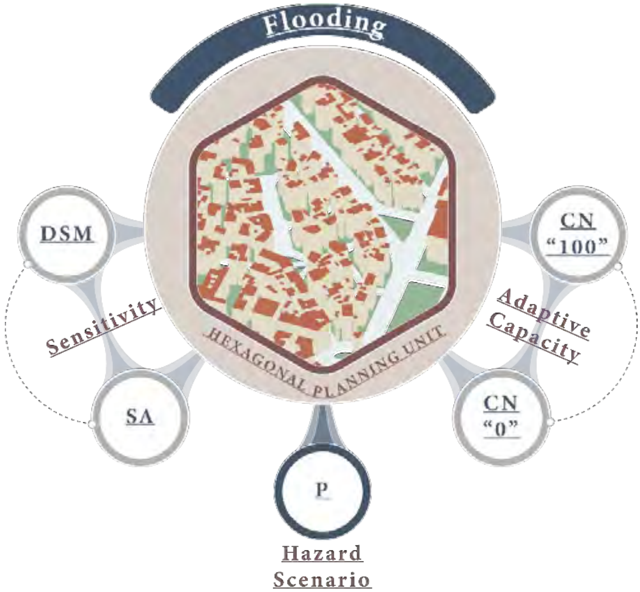
Statistical unit	**DSM**	**Atlas of Surfaces [Surface Atlas]**	**Curve Number**		**Rain level [Precipitation]**
			100 waterproof areas	0 permeable areas	
Pixel	Sensitivity	Sensitivity	Adaptive capacity	Adaptive capacity	Hazard scenario

Table 6 - Indicators and components of vulnerability according to the use of the equation (2).

Below is a graphic schematisation of the specific morphological-environmental factors that can favour and influence the Flooding phenomenon in the planning unit (Figure 4).

The modelling of surface runoff assesses the intensity of rainfall as a hazard component (see Table 6). The use of rain scenarios makes it possible to return a surface runoff condition, hypothetically synthesized as an indicator of reactivity to rainfall.

Figure 4 - Composition of certain morphological-environmental factors linked to the Flooding phenomenon in the planning unit.



Reactivity can be estimated through the use of the Equation (11) derived from the SCS method [54] for the identification of the height of the drained rain (Pn) in the network, that is:

$$Pn = \frac{(ha - 0.2VS)^2}{ha + 0.8VS}$$

where:
ha = cumulative net precipitation scenario in mm at time t (area of rain);
VS = specific saturation volume (maximum retention of the pelvis);
0.2 and 0.8 = coefficients of proportionality referred to the CN, determinable according to the type and land use of the basin.

The maximum retention volume VS [54] is related to the characteristics of the basin and is normally attributed through the use of an intermediate parameter, the Curve Number (CN), according to the relationship:

$$VS = S_0 \times \left(\frac{100}{CN} - 1\right)$$

where:
S0= scale factor of 254 mm
CN= 0< CN≤ 100

As with the UHI vulnerability assessment, it is also possible to recognise the spatiality of rainfall scenarios by drawing geometric contours from the rasterised base. This information can thus be related to the information layers contained in the GeoDB for the assessment of the UHI effect.

4.4.4. - Exposure assessment

The following analysis process represents an opportunity to update the assessment of territorial vulnerability to orient the assessment of territorial vulnerability towards a perspective of exposure elaboration based on the prefiguration of 'multi-risk', starting from the spatialization of possible different scenarios.
This study allows representing the qualitative and quantitative estimate of the probability of exposure of a given urban situation considered in its socio-economic complexity compared to the vulnerability assessments of the two impacts considered.
The methodology of the analysis foresees two work phases:

1. Collection by Python script of information levels (entities);

2. Migration of information related to UHI and Flooding territorial vulnerabilities on the exhibition fabric.

The variables that contribute to the definition of the exposure refer to a survey domain that exploits information directly linked to the geolocation of PoI (Point of Interest) [55][56], using the Application Programming Interface (API) of Google Maps [57] and Google Places [58]. Geolocation maps urban fabrics and sites with a high concentration of environmental, cultural, and economic-social activities. Besides the urban ecosystem phenomenon mapping, the survey assesses territorial socio-economic and cultural trends. The algorithm uses Google's APIs to mine from Google Maps and Google Places databases to transform the information obtained in table format into geo-referenced point elements [59][60]. This set of vector elements can be reworked in the GIS environment and related to the vulnerability analyses carried out and translated into the hexagonal grid.

The construction of the exhibition database is carried out through a semi-automatic survey carried out between August 2020 and September 2020. At the end of the survey, a single GeoDB of about 20,000 surveys (or PoI) was produced, organised into 15 macro-classes: 'Agencies and finance'; 'Receptive'; 'Art and culture'; 'Worship'; 'Free professionals and craft activities'; 'Commerce'; 'Entertainment, health and beauty'; 'Park'; 'Equipped sports area'; 'Institution'; 'Health and social assistance'; 'Hospital'; 'Community services'; 'Fire brigade'; 'Public transport'.

The study aims to carry out an in-depth study by developing the relationship between some macro-classes according to the spatialization of the impacts considered and therefore implicitly assessing also the physical-morphological characteristics of the urban fabrics under examination. This binomial is developed with the aim of characterising and spatialising exposure and risks linking to certain urban functions (Figure 5).

Figure 5 - Selection of Exposed Urban Activities in the planning unit.

4.4.4. - Exposure assessment

The risk characterisation (Figure 6) derives from the product of three weighted variables: vulnerability, hazard, and exposure (IPCC 2014). The main steps which lead to the risk assessment, and therefore to the risk atlas, namely are:

1. Knowledge: classification and management of urban activities exposure sensitive to UHI and Flooding territorial vulnerability domains.
2. Overlay: extraction of the risk vector through a procedure of spatial intersection between vulnerability values and exposure classes.
3. Spatial analysis: generation of new layers starting from the basic information layer 'urban activities exposure' through spatial analysis operations. The procedure returns a classification of activities exposed to UHI and Flooding impacts in a range of

maximum values identified in the shp files of spatial vulnerability maps from UHI and Flooding. (see Hexagonal GeoDB).

4. Mapping: defined risk mapping related to the potential adverse consequences on the elements exposed to the classes of the maximum territorial vulnerability domain levels.

Therefore, the risk study consists in integrating the process of choice of spatial elements generated by non-additive procedures (exposure from Google Maps) with the calculation of spatial additivity of the morphological-environmental components supporting the phase of territorial vulnerability estimation (see Equation 3 and Table 7).

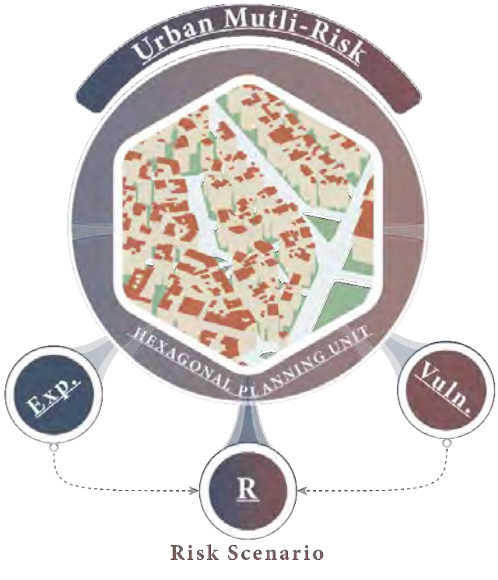


Figure 6 - Multi-Urban Risk Definition.

Table 7 - Exposure components and risk processing methodology.

Territory of investigation	Exposure	GeoDB	Risk	Unit statistics
CMV	Urban activities exposure	Territorial vulnerability assessment	Intersect between Exposure and GeoDB	Urban activity

4.5. - Results

Chapter 5 describes the empirical application of the methodologies developed in Chapter 4 and constitutes the second part of Step 2 (Figure 1). Survey tools application aims to highlight the methodology potentialities and limits in answering RQ2 and RQ4. The Results chapter divides the assessment tools empirical application into two territorial levels: the first one refers to the whole study area of the CMVE (Chapter 5.1) and the second one refers to the study area of Mestre, part of the CV (Chapter 5.2). Therefore, Results presents the different output of the assessment of the impacts at a different scale. The objective is to demonstrate the tool potentialities supporting the definition of metropolitan coordination strategies and local measures implementation. In these terms, the UHI and F assessment results allow reading at the metropolitan scale the distribution of vulnerability linking to land use classes and to the 44 municipal units that compose CMVE. These assessments define effective governance processes - at the metropolitan scale - orienting strategies in municipalities and areas characterized by vulnerable land uses.

At the municipality scale, the same assessments zoom in on the Mestre area, part of the CMVE, allowing to read the risk per 150 m planning unit. The combination of the two representations aims at presenting the atlas potentialities and its SDSS function both at the CMVE and CV governance level.

4.5.1. - Metropolitan area Results

The results obtained at metropolitan scale operations bases on descriptive and spatial statistical data. The survey controls the increase and the reduction of vulnerability that occur spatially in a certain period of time by calculating different possible scenarios and defining their variation within the time interval considered (Δ). Scenarios are defined through remote sensing and spatial modelling techniques and are elaborated by the logical-operational workflow of Figure 2. The comparison of data coming from the elaboration of different scenario variables (hazard), extreme or more contained (in terms of intensity and duration), shows how significant variations in LST and heavy rainfall levels can negatively (or positively) influence the vulnerability and exposure gradients of the territory (delta control analysis on CCS_2012_Plus uses). The different land use classes and their functions are characterised by urban morpho-typologies that directly affect the vulnerability performance of the whole urban system. As defined in chapter 4.3, the research employs an asset of quantitative indicators to make these different characteristics representable and calculable according to the assessment of vulnerability to excessive heat accumulation or performance in terms of absorption of heavy rainfall. Through the definition of the Δ between different scenarios and the risk assessment, it is possible to spatialize territorial behaviour linking to the stresses triggered by the climate change phenomenon. This knowledge of the different characteristics of the territory, both from the point of view of vulnerability and exposure (of environmental, social, economic, and cultural elements) is the main tool to be able to develop a wide area strategic frame, to be able to coordinate punctually the implementation of more effective measures and to make more efficient the subsidiarity of governance processes.

4.5.1.1. - UHI Vulnerability Results

The UHI vulnerability assessment investigates the relationship between the thermal behaviour of the Earth's surface (as a response to intense thermal stress lasting 5 days, recorded by the Landsat 8 satellite in the first decade of August 2015, with a higher maximum apparent temperature of 36.4°C) and land uses. The evaluation considers this relationship in its spatial dimension and therefore relates the location of the phenomenon to urban functions. With this objective, the assessment bases on land use values belonging to class 1 of Veneto

Region Soil Coverage Database (Artificially modelled territories - database CCS_212_Plus). To effectively map the assessment results, the evaluation uses a values graduation based on Natural Breaks (Jenks) statistical algorithm identifying 3 grouping classes (territorial vulnerability between -0.62 to + 0.80).

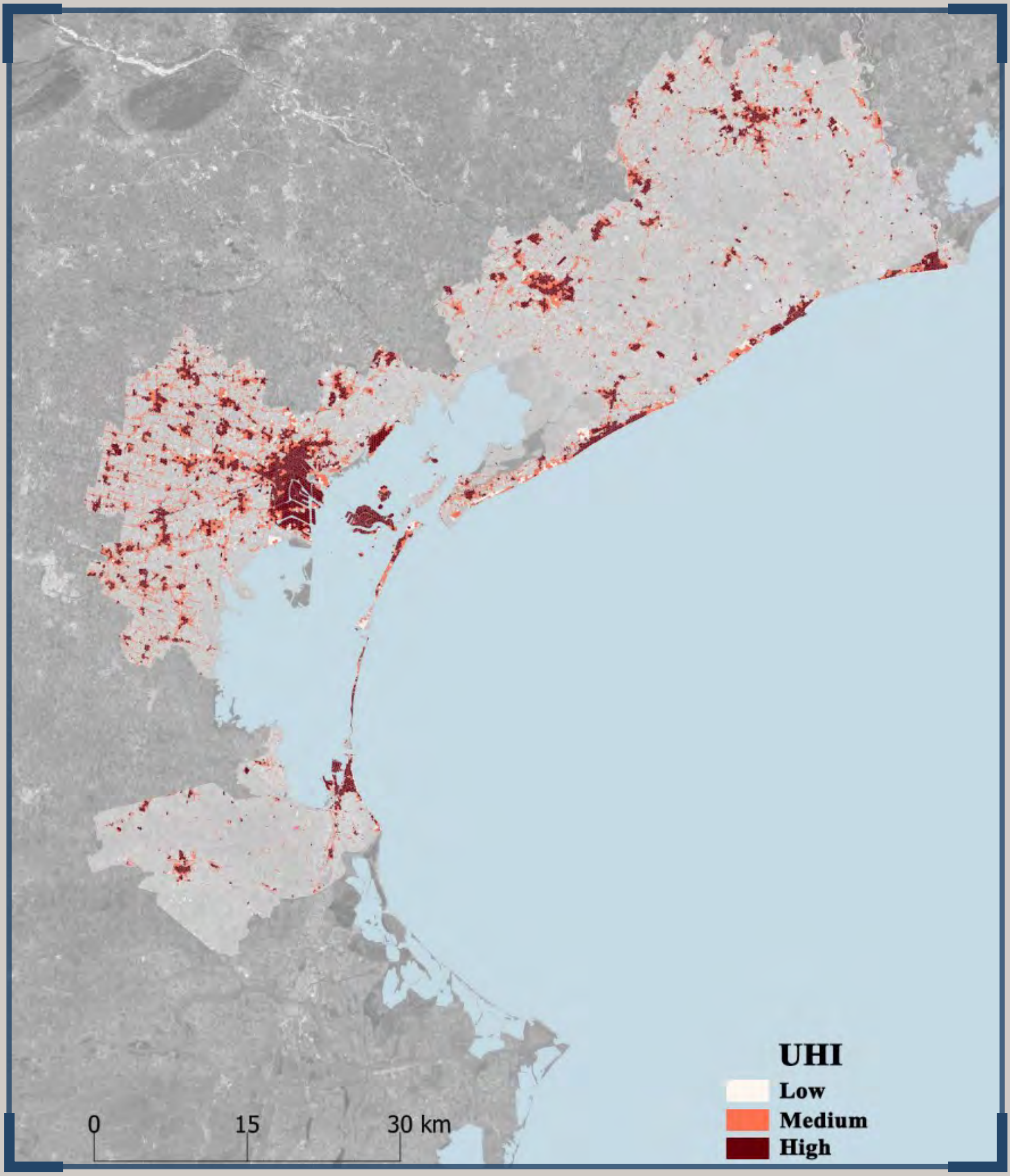
Figure 7 shows with a spatial dimension the UHI stress levels to which the CMVE's anthropized territories are subjected. Heat island effect is prominent in urban, industrial, commercial, and infrastructural areas, where the levels tend to reach an average (weighted) value of vulnerability ranging between + 0.11 and + 0.125 (Table 8). In these areas, the phenomenon is particularly virulent due to the morpho-typological conformation of urban fabrics and the historical implementation of planning approaches that have favoured the increase of artificial surfaces at the expense of natural ones. This condition affects the effectiveness of territorial systems in the management of phenomena linked to heat accumulation and makes the ecosystem services present in each type of fabric insufficient to cope with CC impacts.

Referring to the comparative methodology application it emerged that areas with a lower weighted average vulnerability can be contextualised in green areas and mining areas, where the values vary between + 0.014 and + 0.006 (Table 8). The propensity demonstration bases on the comparison between two scenarios characterized by different LST conditions (Table 3).

The relationship between the two reference scenarios shows how the vulnerability and exposure gradients are particularly reactive to variations in LST, understood as an environmental determinant morphologically non-linear but representative of the UHI phenomenon.

The second step of analysis takes up the third grouping class (from +0.465 to +0.754) to spatially quantify the land use surfaces exposed to extreme temperatures (Table 9). What emerges from the first analysis is an analytical-spatial framework that confirms a dimension of high vulnerability mostly concentrated in the urban fabric and industrial, commercial, and infrastructural areas. As far as the urban matrix is

Figure 7 - CMVE - UHI Vulnerability in Emergency Scenario (values ≥ 0.465).


UHI
Low
Medium
High
0
15
30 km

Land uses	Emergency Scenario (09/08/2015) **	Stress Scenario (11/06/2017) **	Δ (%)
Industrial, commercial, and infrastructural areas	0,110*	0,099*	-10,45%
Green areas	0,014*	0,010*	-27,75%
Urban fabric	0,125*	0,110*	-12,23%
Mining areas, landfills, areas under construction	0,006*	0,004*	-30,31%

Table 8 - UHI Vulnerability: vulnerability distribution by land use (CCS_12_Plus) and vulnerability level.

** Weighted on average values.*

*** In terms of intensity and duration.*

concerned, about 34% of urbanized surfaces are exposed to extreme vulnerability, while for areas covered by industrial, commercial, and infrastructural areas the figure reaches values close to 61%. In these areas, settlement expansions tend to maximise the pressure of UHI impact, due to the degree of land exploitation (Figure 8).
The reading of the global profile confirms, finally, a percentage weight in first analysis more contained in the urban greenery system and the spaces destined to mining and construction areas.

Land uses	Total Surface (km²)	Extremely vulnerable Surfaces (km²) *	Vulnerable Surface (%)
Industrial, commercial, and infrastructural areas	116,4566	70,5714	+60,60%
Green areas	29,62231	7,1463	+24,12%
Urban fabric	197,1	66,5307	+33,75%
Mining areas, landfills, areas under construction	7,477049	3,8966	+52,11%

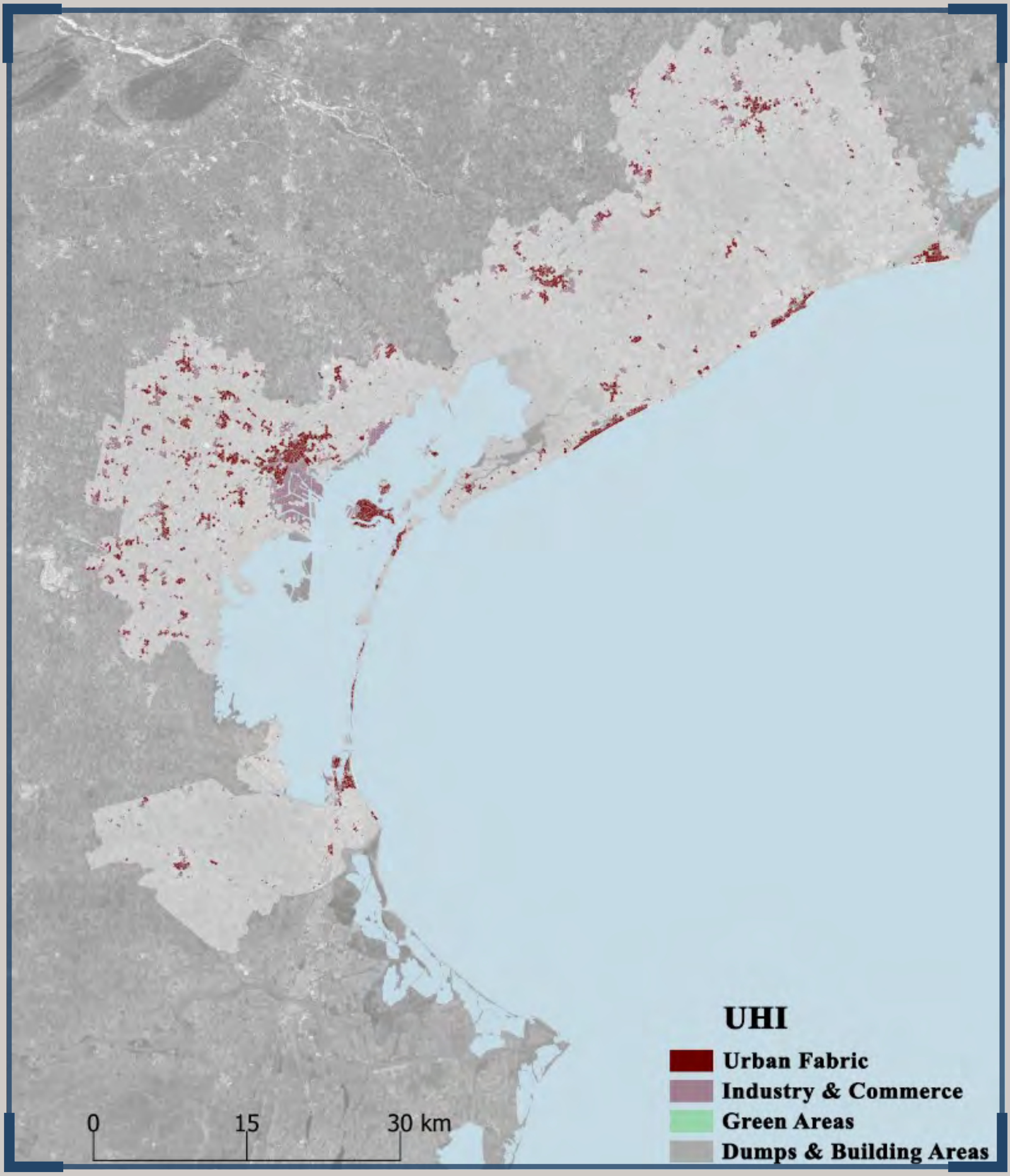
Table 9. - UHI Vulnerability: vulnerability distribution by land use (CCS_12_Plus) and worse vulnerability condition (values ≥ 0.465).

** Emergency Scenario (09/08/2015) with values ≥ 0.465*

Figure 8 - CMVE – UHI Vulnerability in Emergency Scenario (values ≥ 0.465) and Land Uses (CCS 2012).

4.5.1.2. - Flooding Vulnerability Results

The Flooding study returns a spatial index of hydraulic vulnerability. Vulnerability thresholds are calculated and weighted on soil morphology and hydraulic response of land uses in terms of stormwater absorption capacity. This modelling makes it possible to estimate the surface runoff coefficients of waters at basin scale using the CN method, but also to understand which surfaces contribute


UHI
Urban Fabric
Industry & Commerce
Green Areas
Dumps & Building Areas
0
15
30 km

to modifying the hydraulic performance of the land with effects on exposure and vulnerability assessment. The identification of surface runoff for two different scenarios (with hazard 50 mm of rain [h] and 150 mm of rain [h]) shows how the ratio between the water volumes generated by the hydrological modelling of the DSM undergo a significant increase in the runoff coefficient in industrial, commercial, and infrastructural areas, as well as in areas with intensive and complex urbanisation (Table 10). The variation between the values (Δ), which can also be identified spatially, is significant, increasing exponentially in correspondence with the reduction in the degree of permeability of the soil. It is appropriate to consider these areas only as geographical-urban partitions exposed to a certain danger of flooding, based on the estimate of the specific volume of saturation with 50 and 150 mm of rain. This varies with the intensity of the rainfall event and the spatial distribution of land use patterns. The spatial analysis compares the reactivity of the different surface types in the two rainfall scenarios. In residential and industrial settlements there is a high sensitivity to rain with a rainfall of 150 mm/hour. As regards the urban-residential context, about 58% of the waterproofed surfaces are exposed to high surface runoff (grouping class values from 106.98 to 132.21, Figure 9), while for industrial, commercial and infrastructural areas the figure reaches values close to 52% (Table 11).

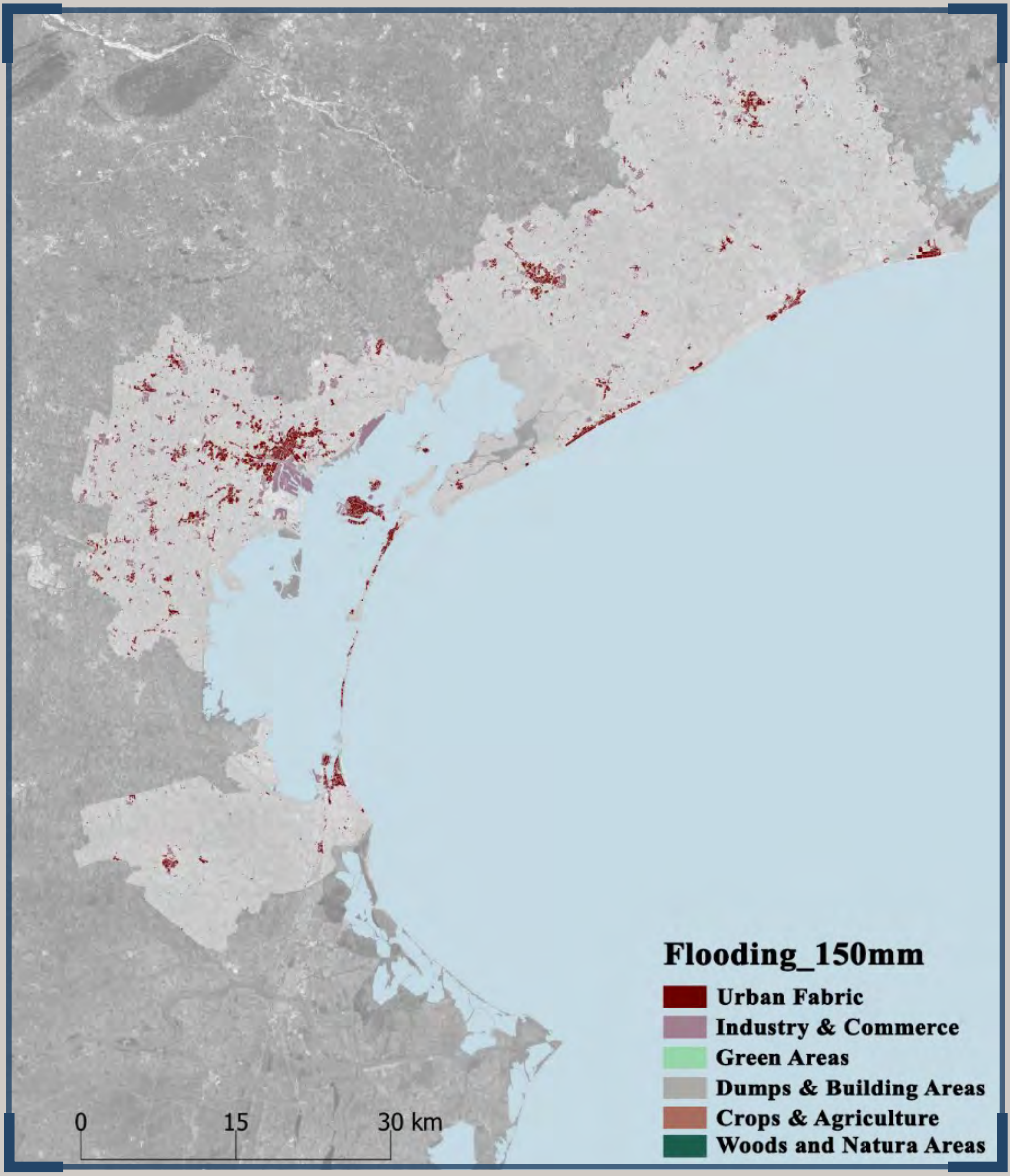
Figure 9 - CMVE: - Flooding Worse Vulnerability Condition (values ≥ 106.98) and Land Uses (CCS 2012).

Table 10 - Flooding Vulnerability: vulnerability distribution by land use (CCS_12_Plus) and worse vulnerability condition (values ≥ 106.98).

** Weighted average values.*

*** In terms of intensity and duration.*

Land uses	50 mm/hour scenario**	150 mm/hour scenario**	Δ (%)
	Rainfall Accumulation (mm/sqm)	Rainfall Accumulation (mm/sqm)	
Industrial, commercial, and infrastructural areas	15,16*	81,64*	+438,54%
Green areas	4,25*	43,76*	+930,32%
Agricultural territories	6,27*	70,38*	+1022,17%
Wooded territories and semi-natural areas	1,99*	22,90*	+1053,35%
Urban fabric	14,91*	78,01*	+423,33%
Mining areas, landfills areas under construction	5,30*	48,79*	+820,48%


Flooding_150mm
Urban Fabric
Industry & Commerce
Green Areas
Dumps & Building Areas
Crops & Agriculture
Woods and Natura Areas
0
15
30 km

Land uses	Total Surface (km²)	Extremely vulnerable Surfaces (km²) *	Vulnerable Surface (%)
Industrial, commercial, and infrastructural areas	124,47	52,02	+41,80%
Green areas	35,71	1,08	+3,02%
Agricultural territories	1477,42	2,65	+0,18%
Wooded territories and semi-natural areas	31,12	0,01	+0,02%
Urban fabric	219,28	57,84	+26,38%
Mining areas, landfills areas under construction	12,81	0,75	+5,86%

Table 11 - Flooding Vulnerability: vulnerability distribution by land use (CCS_12_Plus) and worse vulnerability condition (values ≥ 106.98).

4.5.2. - Local area Results

The risk analysis at the municipal scale bases on different degrees of vulnerability mapping linking to the assessment of the exposure of the following urban assets: i) commerce; ii) accommodation activities; iii) public transport; iv) education; v) health and social care.
The study, conducted on the urban area of Mestre, is spatially related to UHI and Flooding gradients (Urban Flooding on a municipal scale), considering the qualitative and quantitative distribution of urban activities exposure from Google in the highest urban vulnerability class (third grouping class obtained through Jenk's Natural breaks algorithm), in terms of extreme summer temperatures and heavy rainfall.
This type of analysis allows to contextualise and converge the concepts of vulnerability and exposure (urban activities) towards the definition of a local risk mapping. The elaborations, of a statistical-spatial nature, can capture and describe the different aspects and different forms of the investigated phenomenon linking to the distribution and spatial suitability of the needs expressed by the economic and social life of the city and its peripheral and central areas. The analysis considers two macro-assets of local risk exposure.
The first macro-asset considers the potential physical and economic

damage (direct or indirect) between maximum vulnerability from UHI and urban activities (i.e., commerce, accommodation facilities and public transport).
The second macro-asset, on the other hand, orients the mapping of places potentially predisposed to suffer economic and social damage due to a lack of usability (and/or usability) of the public-private service, specifically considering: services linked to local commerce, education, health, and public assistance.
The spatial association between urban activities and vulnerability values (Urban Risk) also makes it possible to evaluate the activities most affected by a significant convergence of effects deriving from the morphologies of the UHI and F (in a multi-risk analysis and evaluation perspective), giving back a critical behaviour of some physical-functional domains of the city in the face of particularly adverse climatic-environmental conditions.

4.5.2.1. - Urban Heat Island Risk Assessment Results

The UHI definition of local risk analyses three different types of urban activities spatially placed in the economic-social relationship between cities and heat waves: commerce, accommodation activities, public transport (Figure 10).
The first type of activity refers to the quantitative analysis of the urban fabric of commercial matrix with a UHI (extreme temperature scenario) vulnerability belonging to the third grouping class with a value ranging between +0.48 and +0.75. The survey considers a commercial sample of 2011 activities (or surveys), giving a percentage of exposure subject to maximum vulnerability (and therefore high risk) of about 50%. Observing the spatial distribution of the surveys, a commercial system particularly subject to high risk from UHI in its central locations is detected.
The second type of activity is anchored to the statistical-quantitative interpretation of the local accommodation fabric (hotels, restaurants, leisure, etc.). The survey is conducted on a sample of 2497 surveys, of

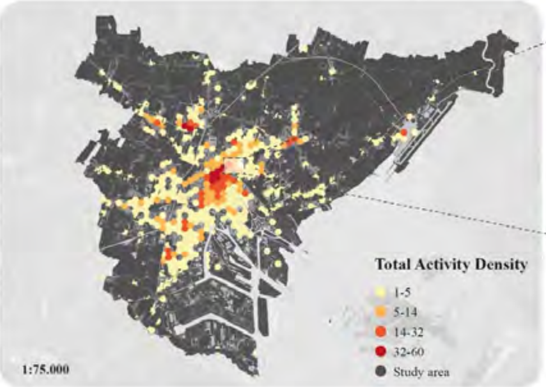
which more than 51% of the total sample is particularly vulnerable to intense and prolonged heat waves (data referring to the values of the third grouping class: +0.47 - +0.75). Most of the highly vulnerable accommodation facilities are concentrated in the city centre. This condition can negatively affect the localisation and usability processes of one of the main drivers of social and economic development in the city.
The third type considers urban activities related to local public transport. The activities are equally distributed throughout almost the entire urbanized fabric. The survey returns a spatial sample of 747 surveys, of which 38% of the total sample is highly at risk UHI (data referring to the values of the third grouping class: +0.42 - +0.69. Most of this can be placed in the urban spaces of the city centre, significantly conditioning the usability of LPT in conditions of thermal stress.

4.5.2.2. - Urban Heat Island Risk Assessment Results

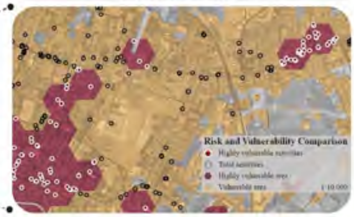
The local risk assessment of Flooding considers the potential effect on the following urban activities: Commerce; Education; Health and social assistance (Figure 11). The three exposures are spatially associated with the formulation of the relationship between climate stress and economic-social morphologies, conditioned by a high vulnerability from Urban Flooding with an extreme hazard of 150 mm of rain/hour.
The first type of urban activity takes up the quantitative analysis of commercial activities, isolating the highest vulnerability values. For this exposure class, flooding fluctuates between 108 and 132 mm of rain/h. The statistical survey is conducted on the entire commercial sample of 2011 surveys, returning a percentage of exposure subject to maximum vulnerability (and therefore high risk) of about 51%. Most of the commercial structures are highly vulnerable, and at risk of flooding, in the urban areas of the city centre. Here, flooding phenomena can significantly affect commercial functions and usability. Flooding can assume different spatial distributions and

Figure 10 - UHI risk for urban activities - Emergency Scenario: values ≥ 0.465.

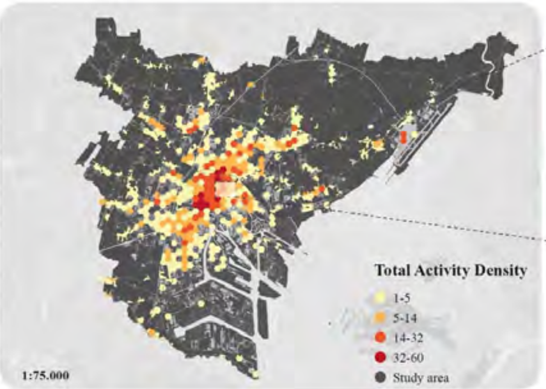
Urban Heat Island Exposure Assessment Results



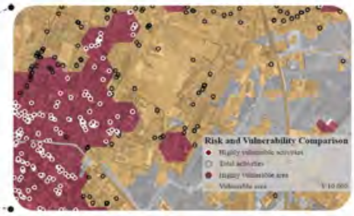
COMMERCE



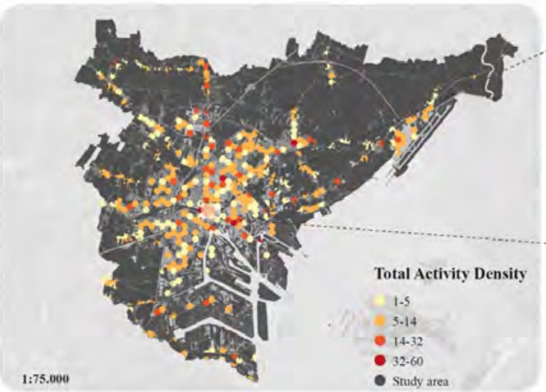
Total Activities	Vulnerable Activities	Vulnerability range
2011	1147 (57,04%)	0,465 - 0,7540



ACCOMODATION FACILITIES



Total Activities	Vulnerable Activities	Vulnerability range
2497	1304 (52,22%)	0,465-0,7540



PUBLIC TRANSPORT

Total Activities	Vulnerable Activities	Vulnerability range
747	228 (30,52%)	0,465-0,69

intensities (measured also in terms of time). In turn, this dynamic can greatly influence the response and adaptation rhythms of the commercial fabric. The association between exposure and urban morphological conditions can help urban planning in the reading and interpretation models of risk, in turn supporting new forms of adaptation provided by local planning tools.

The second type of urban activity considers the urban fabric related to places of education. The statistical survey is conducted on a sample of 339 surveys, of which 115 (i.e., 33% of the total sample) are particularly vulnerable to intense, concentrated, and prolonged rainfall. The places of education are condensed in the city centre. This condition is in common with a risk situation related to the commercial activities of the case study.

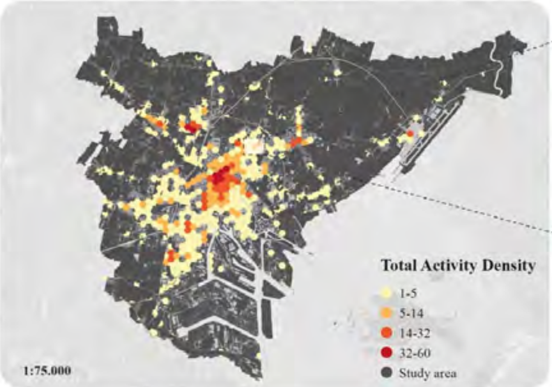
The third type of urban activity concerns social and health care functions. The statistical-spatial analysis analyses a sample of 1050 surveys. The activities are distributed by clusters of urban belonging (in terms of building and housing density), with a greater tendency towards aggregation in the city centre. 45% of the surveys (474 out of 1050) are predisposed to the risk of flooding. This percentage is more contextualized in the complex urban spaces in which numerous values and appurtenances destined to the performance of commercial, tertiary-directional and production of goods and services activities are intertwined. This mixture of morphological-functional interactions amplifies the dynamics of risk with cumulative effects that, over time, change linking to the type of exposure and intensity of impacts.

4.5.2.3. - Results Comparison

UHI and F multi-risk assessment - developed considering five exposure classes (Chapter 4.4) - allows mapping the more vulnerable physical-functional urban assets.
The approach integrates 5.2.1. and 5.2.2. Chapter contents presenting

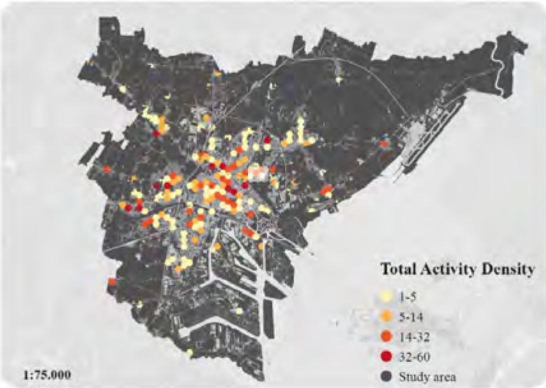
Figure 11 - Flooding risk for urban activities - Emergency Scenario: values ≥ 106.98.

Flooding Exposure Assessment Results

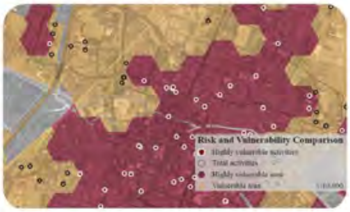


COMMERCE

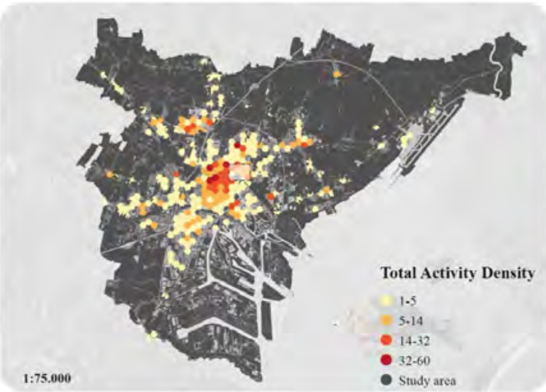
Total Activities	Vulnerable Activities	Vulnerability range
2011	1067 (53,06%)	106,98-132,21



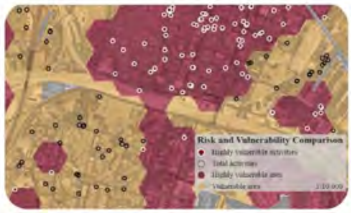
EDUCATION



Total Activities	Vulnerable Activities	Vulnerability range
339	105 (30,97%)	106,98-132,21



HEALTH &SOCIAL ASSISTANCE



Total Activities	Vulnerable Activities	Vulnerability range
1050	507 (48,29%)	106,98-132,21

urban complexity using worse vulnerability conditions. UHI and F thresholds are:

1. UHI with venerability level higher or equal to 0.4650 (using Jenks Natural Breaks).
2. Flooding with vulnerability level higher or equal to 106.98 (using Jenks Natural Breaks).

Table 12 returns the number of activities exposed to single and multiple impacts. Total values suggest that the more multi-impact exposed urban functions are the 49% of the Commercial asset, the 47.34% of the Accommodation Facilities asset, and the 42.29% of the Health & Social Assistance asset. Assessing multi-impact exposed assets highlights that the percentages of those elements that present both risks - UHI > 0465 and F < 106.98 - are 88.65%.
In multi-risk exposed areas, the mix of urban fabric patterns contributes to vulnerability levels, worsening the multi-dimensional conditions that trigger climate impacts.

Table 12 - Multi-Risk Assessment Results: vulnerability distribution by exposed assets and worse vulnerability condition (values ≥ 0.465 for the UHI and values ≥ 106.98 for the Flooding).

** The assets exposed calculation to both impacts is carried out concerning the total vulnerable assets, recognizing only those elements that present nominally and simultaneously a risk value higher than the threshold of 0.465 for the UHI and 106.98 for the F.*

Impact		**UHI**		**F**		**UHI & F***		
Class	Total Activities	Vulnerable Activities		Vulnerable Activities		Vulnerable Activities		% of total activities
Commerce	2.011	1.147	57,04%	1.067	53,06%	983	88,80%	48,88%
Accommodation Facilities	2.497	1304	52,22%	1.300	52,06%	1.182	90,78%	47,34%
Public Transport	747	228	30,52%	180	24,10%	155	75,98%	20,75%
Education	339	104	30,68%	105	30,97%	88	84,21%	25,96%
Health & Social Assistance	1.050	496	47,24%	507	48,29%	444	88,53%	42,29%
Total	6.644	3.279	50,65%	3.159	52,45%	2.852	88,60%	57,07%

Results show which urban assets have the highest priority in implementing adaptation measures and actions, enabling strategic coordination for multi-hazard management by public decision-makers. The statistics in Table 12 can provide a valuable tool for local governments wishing to implement climate-proof planning.

4.6. - Discussion

Chapter 6 is the first part of the research Step 3 (Figure 1) and presents the approach limits and potentialities answering the single RQs.

RQ1 - Is the metropolitan survey scale the more effective to support local and regional authorities in developing climate change adaptation strategies and measures implementation? RQ 1 answer considers the link between survey scale and adaptation strategies and refers to Chapter 3 and Chapter 5 findings. The assessment techniques are tested at the case study metropolitan scale and on the local dimension. The workflow (Figure 2) represents assessment techniques - for vulnerability, exposure, and risk assessment - combined use recognizing a vast area behaviour. Morphological and function descriptors allow developing a multi-sectoral and inter-scalar map. The approach can support integrated spatial planning and decision-making processes coordination. From this perspective, CMVE acts as a coordinator because basing on vulnerability and multi-risk assessment provides a strategic framework to 44 municipalities. Local administrations can share the same knowledge framework adopting strategically coordinated actions. Moreover, the atlas guarantees local decision-makers to undertake one conscious planning approach. They can choose - based on climatic exposure priority - on which sector to direct resources, i.e., building heritage redevelopment, neighbourhoods' regeneration, social inequalities reduction with an adaptation logic.

RQ2 - Which survey techniques and methodologies are suitable to support a knowledge framework construction to support adaptation governance and integrated territorial management? The answer considers new spatial information technologies use in supporting spatial governance process and refers to Chapters 4 and 5 dissertations. The results of Chapter 5 present new assessment techniques opportunities recognizing vulnerability and exposure geographical overlapping. This map can produce an innovative spatial knowledge which can retrofit urban and territorial planning approaches. The methodologies - described in Chapter 4 - aim at innovating planning and governance processes. Planning innovation can base as first on data representation and technological integration. Therefore, how new technologies extensive use in planning can modify planning approaches became a central topic. Vulnerability, exposure, and risk geodatabases development allows to map and to plan territories transformation according to international goals and local needs. Furthermore, these processes integrate different web sources and remote sensing data and spatial parameters.

RQ3 - Can local planning incorporate metropolitan-scale adaptation strategies? Can the same knowledge framework also support conscious local adaptation measures? The response refers to techniques and processes of investigation that can lead to innovative adaptation and mitigation solutions at local and inter-municipal scales and refers to Chapters 3 and 5 findings. The model - boosted by the case study assessment - supports strategies definition oriented to cope with local peculiarities and problems, maximising the collaboration between local administrations and effectively overcoming administrative boundaries. The theoretical and methodological base of this approach is the subsidiarity principle. The concept of subsidiarity can is the driving force of the governance process metamorphosis. This transformation can happen in terms of innovation of land governance policies through climate change impacts assessment, monitoring and adaptation. The constitutional principle of subsidiarity can operate vertically in the governance frame or among territories. This research considers two kinds of subsidiarity: 1) vertical subsidiarity; 2) trans-territorial planning. From an operational point of view, CMVE is representative of the technical-legal concept of vertical subsidiarity. The metropolitan authority coordinates 44 municipalities through its planning system. This governance model aims at managing the territory in a generically unitary way. The Interreg Ita-Slo SECAP project - in which CMVE is a partner and promoter - seeks a cross-border adaptation strategy - between Veneto Region, CMVE, Friuli Venezia-Giulia Region and Slovenia - definition. In strategies implementation and coordination municipal administrative units, CMVE necessarily bases on subsidiarity. The principle requires higher-ranking planning tools to impose on lower-ranking administrations. The Municipality of Venice is representative of the concept of trans-territorial subsidiarity. In a morphological and socio-economic perspective, the territory over which CV exercises its governance is among the more complex of Europe. Venice Municipal Adaptation Plan aims to implement operational actions in a heterogeneous environment. This transformation adopts the principle of subsidiarity to respond to territorial needs. The most representative example is the difference between the historic centre and modern Mestre. These urban contexts are inhomogeneous and not comparable, however - through mainstreaming and participation - the Adaptation Plan manages to be effective. In both cases, the planning performance bases on the awareness of the presented multi-risk atlas. The assessment results highlight the necessity of tailored adaptation strategies, context characteristics comprehension, governance model and socio-economic conditions awareness. The vulnerability atlas design aims at achieving these goals. The hexagonal mesh at the base of the atlas covers the entire CMVE, to make climate adaptation planning manageable, awarded, and tailored.

RQ 4 - Is it possible to effectively assess exposure and define risk? Which strategic role can this assessment play in the construction of efficient and effective climate change policies? RQ 4 response addresses spatial assessment processes strategic role in building new and effective climate change adaptation policies. It also considers the positive impact that the adaptation process could have in mitigating urban and social inequalities exacerbated by climate change and refers to Chapters 1, 3 and 5 findings. The research results confirm the analysis model usefulness and the redefining and innovating exposure and risk assessment capability. The exposure study opens to new integrations between different research, activating methodological solutions to study climate change impacts on urban areas. It gives new energy for planning processes, stimulating intersectoral planning with plans oriented towards increasing urban and environmental resilience. Climate adaptation process considers the interaction between climate risks and exposed urban assets. The vulnerability assessment allows reconstructing the spatial correlation between impact and territory - mapping local priorities from a morphological and functional point of view. Moreover, the exposure investigation allows decision-maker understanding and implementing governance models to address local risk management. This assessment dynamically reads urban behaviours and assets often not considered within policies. This new cognitive apparatus highlights local criticalities - i.e., integration, sensitive communities, urban critical conditions - mostly unconsidered in political agendas. Therefore, defining new representation and urban interpretation procedures aimed at climate-proofing results fundamental. The approach objective is to support the overcoming of sectorial and scalar approach, adopting an integrated and multiscale vision. The tests carried out on the CMVE case study seeks to optimise local decision-making capacities on urban and territorial global resilience enhancing. The tests performed with Venice Municipality partnership, allow enriching the ongoing planning activity and redefining urban and environmental resilience strategies.

4.7. - Conclusion

This chapter presents the second and last part of Step 3 - presented in Chapter 2 - and completes the research presentation.

The research aims at - responding to the RQs - developing a tool to support climate adaptation planning. This planning process, to be effective, requires three elements: awareness, strategic vision, tailored actions, and continuous monitoring.

Urban contexts and environments present several complexities linked to climate change impacts. Generally, the inertia that hinders climate adaptation planning are obsolete knowledge production tools; lack of medium-long term planning vision; integrated planning approaches; lack of financial resources and data.

The methodology, tested in the Results Chapter, combines different procedures to overcome - partially - these obstacles. The remote sensing tools and processes developed in a GIS environment and the ICT tools deployed to collect the information, allow to map the link between climate and urban patterns. The result is a multi-hazard atlas that can work as an SDSS for territorial governance. While the research produces a replicable methodology to analyse vulnerability, exposure, and risk, it also develops one territorial governance support. The paper directly bases on the case study planning experience. The climate adaptation planning needs of the Metropolitan City of Venice and the Municipality of Venice trained and refined the assessment approach. From this point of view, the case study offers the opportunity to implement an operational tool that is extendible and scalable to other contexts. Basing on this atlas, CMVE - within project SECAP - contributes to the cross-border adaptation strategy definition for the Veneto and Friuli Venezia Giulia Regions and Slovenia. Moreover, the Municipality of Venice implemented the tool in the Municipal Adaptation Plan, according to the New Covenant of Majors and C40 objectives.

The model can reorient territorial political priorities, mapping socio-economic changes and climate change impact risks. A quality

indicator of the tool is that the assessments base on open-source tools. This characteristic links to public authorities' economic resources lack to finance consistent and effective knowledge frameworks. Moreover, the atlas is designed to be integrated and updated with future studies.
From a planning perspective, the tool can be implemented as an SDSS. It supports two distinct and complementary planning approaches, namely:

- Parametric urbanism, to design mitigation and adaptation interventions;
- Urban governance, to update spatial government objectives and policy agendas.

The integration between objectives is important to manage, understand and reduce past and ongoing urban conflicts. Furthermore, strategies and measures can be shared at different governance levels, overcoming the limitations imposed by administrative boundaries.
The approach supports climate adaptation planning process, opening to further contaminations and is versatile in achieving multiple objectives. Two consideration can describe the tool limits and strengths:

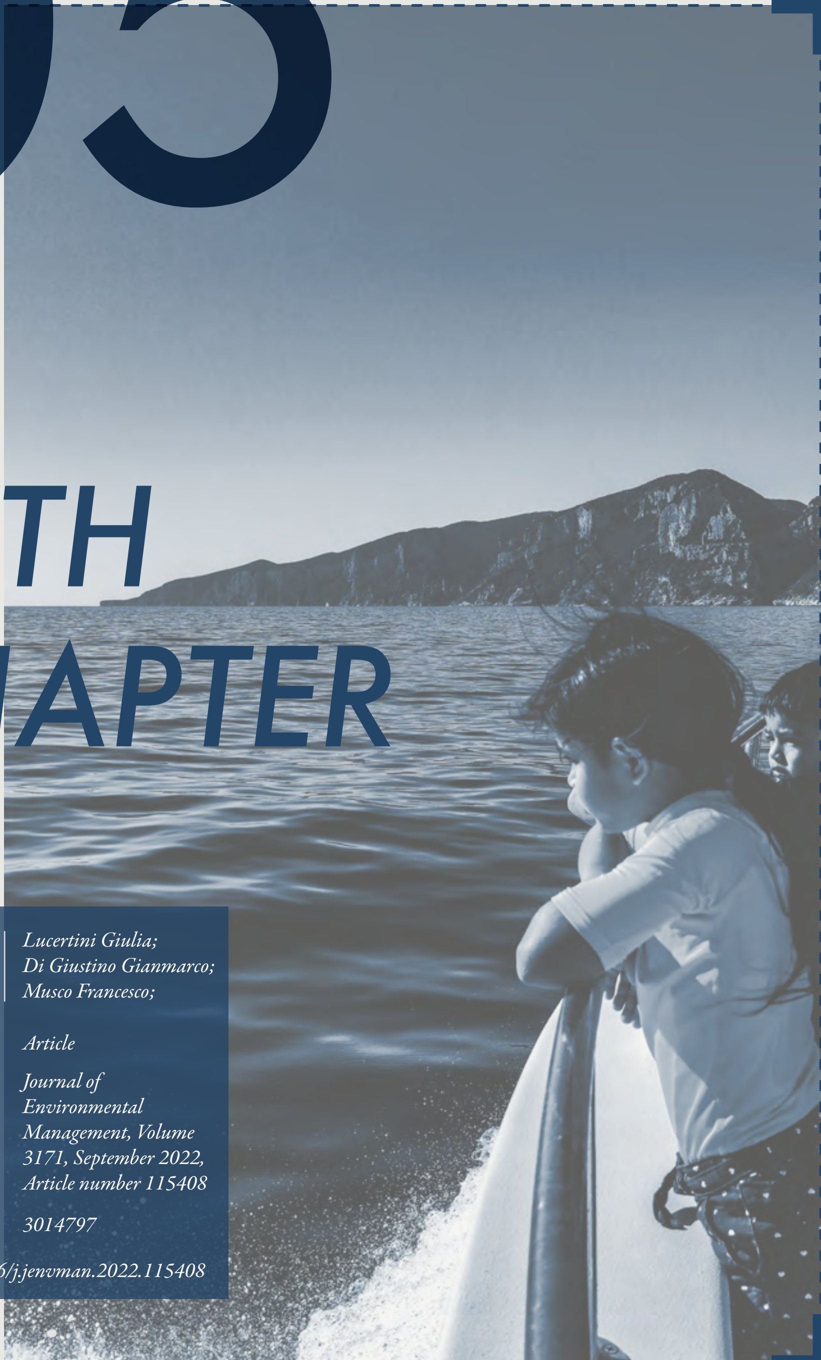
- First, this kind of tool requires new spatial information technologies -potentialities and limits - awareness. Technology alone cannot be considered a solution but could allow boosting urban planning innovation. To achieve innovation is necessary to educate and train public administrations about new technologies possible uses and their role in decision-making;

- The second consideration regards the subsidiarity principle implementation opportunity. This governance principle is fundamental to deploy effective strategies and adaptation measures. Local decision-makers play a central role in the territorial transformation and actions implementation. Therefore, subsidiarity is a driver to achieve inclusive and efficient forms of planning. To ensure this principle efficiency, administrations need to improve monitoring systems launching cyclical performance evaluations. These processes require a continuously updating of territorial systems information but can guarantee the adaptation processes efficiency.

Empirical research and learning by doing are the main opportunities to overcome these limits. Research, in general, grows thanks to theory and practice integration. Climate adaptation planning is one of our time unexplored frontiers. Therefore, it is essential to exploit every territorial experimentation opportunity, linking with spatial transformation dynamics, engaging stakeholders and decision-makers. Venice territorial system offers this opportunity since 2015, promoting the integration of academic research and territorial governance. If planning is a process, so is research. From this point of view, in Venice context, these two processes converge and contaminate: on the one hand, the empirical experience enriches scientific research; on the other hand, the mainstream of knowledge allows to inform and teach decision-makers innovative approaches. Sailing in this direction could allow avoiding past mistakes, instead of correcting negative planning outcomes, it makes possible to undertake aware choices.

05

FIFTH CHAPTER



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Document Type: *Article*

Journal: *Journal of Environmental Management, Volume 3171, September 2022, Article number 115408*

ISSN: *3014797*

DOI: *10.1016/j.jenvman.2022.115408*

Article Title:

An innovative climate adaptation planning process: iDEAL project

CHAPTER INDEX

Article Abstract

Climate change triggers increasing stresses on urban settlements and coastal areas. The intensification of climate-connected impacts requires municipalities and communities to undertake adaptation measures and plans. These interventions should be capable of reducing negative climatic effects on human habitat and regional bioregions. On the one hand, the international scientific community recognized the supported adaptation planning approach as the more suitable to cope with local needs and criticalities. On the other hand, there is a lack of practical guidelines and examples that can be used to implement the theory. From a perspective of growth of global awareness and sensitivity to the climatic emergency, it is necessary to develop a practical methodology able to link together impacts perception and public decision process at the local scale. The paper aims to fill the gap between the theoretical approach and the practice, through a replicable experience of integration among climate change adaptation concepts and decision-making processes. The proposed methodology is described in a 4-step process to support decision-makers in selecting tailored adaptation policies and measures. The article is based on the experience developed within the Interreg It-Hr project "iDEAL – Decision support for Adaptation pLan" project. The research combines a quantitative and qualitative methodology in local participation processes. The approach is tested on five Mediterranean coastal cities and allowed to support the development of tailored adaptation measures. Furthermore, the interaction with local actors during the process led to an acceptance of the implemented measures, designing each measure to stakeholders' ambitions and expectations.

5.1. - Introduction

In recent years, climate change (CC) adaptation and mitigation concepts gained worldwide attention [1]. However, only recently countries and cities are starting to adapt their territory and infrastructure to the climate change impacts [2]. Adaptation is a challenge that requires integrated long-term strategies and solutions and should be supported and coordinated by an integrated public service with a systemic frame of information and procedures. The synergic organization of data, pieces of information, and integrated production are necessary to achieve local and global goals. [3]. A non-adaptive city can be considered as a fragile system due to its obsolete or traditional urban structure, unable to cope with extreme climatic events, and to – eventually – benefit from them. By opposite, adaptive cities are based on an integrated public urban management system, which minimizes CC impacts on environment, economy, and society, adopting tailored approaches. The local effectiveness of measures and policies is made possible by context understanding and with the participation of the communities [4][5].

The EU Strategy on Adaptation to Climate Change [6] forecasts a complex evolution scenario for local climate conditions, generally[7][8]. Among the principal and most common threats that endanger and challenge Mediterranean areas there are temperature [9] and water abundance [10][11], and the CC impacts are Urban Heat Island (UHI) and Urban Flooding (UF). UHIs are areas where temperatures are higher than the ones recorded in peri-urban areas, and which could cause physical damages and death to sensitive people [12][13]. UF is mainly caused by continuous land-use changing processes that transformed natural permeable areas into anthropized ones. Impermeable surfaces modify the hydrological nature of local runoff, reducing water ground infiltration, and affecting the capacity of managing those peaks and volumes of water released during extreme events [14]. This resistance can cause damages to buildings and infrastructures and can endanger people's safety [15]. UF in the EU results to be the cause of more than 2500 fatalities and affected more than 5.5 million people over the period 1980-2011. Thus, taking no further adaptation measures could mean, according to official forecasts, an additional 26.000 deaths/year connected to heatwaves by the 2020s, rising to 89 000 deaths/year by 2050 [6]. UHI and UF have relevance in coastal urban areas where the risk is higher, due to the exposure of strategic infrastructures, government, and economic systems and where a high percentage of the European population lives [16].

5.2. - Theoretical Framework and Research Design

In this critical scenario, action and planning are left to regional, metropolitan, and municipal authorities. Despite the urgency and importance of adaptation, as identified by Hurlimann and March [17], there are only a few adaptation planning processes underway [18]. Most local governments have not understood the problem, and very few administrations are developing adaptation planning upgrading their urban plans [19]. Identifying and defining the right local-based measures and policies represents a hard and long-term effort, that requires a significant amount of information, and an inevitable trade-off among alternative solutions and resource allocations. Therefore, undertaking an adaptation process requires developing a defined decision procedure capable of supporting decision-makers through local-based evidence [20]; [21]. It emerges how central the role of local authorities is in the development of safer and climate-proof territories [22]. From a theoretical point of view, therefore, the main gap in this set of issues is the efficiency of public administrations and decision-making processes for the implementation of adaptation plans [23]. It is also useful to consider that the scenario of scientific production in this sector is based more on theoretical reflections linked to the principles of the planning discipline. This disciplinary sectorization is unprepared to deal with a new scale of issues and criticalities that affect the urban context for two main reasons: the first is that from an operational point of view the academy is not structurally involved in territorial management as, for example, happened after World War II [24]; the second is that there is little network experimentation in the implementation of adaptation plans and in particular there is little involvement of the academic world in these processes. It is possible to rely on the scientific literature that has recognized the limits of territorial government tools for the acknowledgement of these features of complexity, even if for different aspects and issues. Among these, the silo theory, i.e.

that of the recognition of the sectorialisation of the tasks of spatial government authorities as a limitation, is the one that can best describe the limits in the management of local climate impacts [25]; [26]. The reason is that the effects of climate change have a horizontal effect in both spatial and governance terms, affecting at the same time several sectors simultaneously [27]; [28]. This is demonstrated by the fact that in local administrations, climate change expertise is often concentrated in environmental departments, which tend to be somewhat marginalized within the organisational hierarchy of local government, plus have limited capacity to implement planning policy [25]; [26]. Hence, an understanding of these institutional barriers, particularly in a setting of cross-cutting wicked issues such as climate change, is of relevance to reach solutions [27].

At the same time, in planning the decision-making process is affected by a lack of legitimation, that is related to issues of participation and accountability [29]. Considering that, it is easier to understand that adaptation planning requires real shared governance that has to be supported by stakeholders participation based on collaborative exercise [30]. In fact, without a full legitimation and recognized utility an adaptation plan, which is moreover a voluntary plan, will be difficult to accept and implement. Hence, incorporate social knowledge, activate the participative process and public engagement in this field comparatively new, multisectoral and complex, become necessary. However, participation is an activity with high resource-consuming, especially money and time, two resources that usually are not available in public administration, especially the small [31].

This research aims to answer two questions: is it possible to overcome administrative limitations and sectoralisations? Is it possible to reach a full legitimation engaging stakeholders in useful time?

The paper aims to expose an innovative climate adaptation planning process, able to “break down silos” that limits administrative effectiveness, incorporating stakeholders needs and perceptions, and thus improve the decision-making quality [32]. The presented process is intended to link together stakeholders’ needs and analytical information through an operational methodology. The vision of the

model is oriented to enhance those synergies which already exist among governance sectors, planning tools, and procedures, leading to a synergic adaptation reconfiguration of territories. The present work is based and tested in the development of the INTERREG IT-HR "iDEAL project: DEcision support for Adaptation pLan." The project is part of the Italy-Croatia cross-border cooperation program. iDEAL is aimed to develop a shared climate adaptation action plan for each study area, through a shared and participated decision process. The project had five pilot areas: Municipality of Pesaro (IT), Municipality of Misano Adriatico (IT), Municipality of Dubrovnik (HR), Municipality of Vrsar (HR), Regional Natural Park "Coastal Dunes Torre Canne" (IT).
The paper was designed as follow. The section "Innovative adaptation planning process" it shows the operational methodology developed, highlighting the different steps to link together analytical data and stakeholders needs. The section "iDEAL application" contains the outputs obtained implementing the methodology in the five pilot areas of the iDEAL project. The section "Discussion" is devoted to collecting our observations and reflections about the implemented process, and finally, in "Conclusion" the summarized final remarks are reported.

5.3. - Innovative adaptation lanning process

The methodology, developed into the iDEAL project and presented in this paper, has the objective to support local administration to integrate adaptation measures in the planning and monitoring process, with an approach easy-to-use. It is tailored to those public administrations which are undertaking a Climate Adaptation Plan. It seeks to ensure cities to move toward a more adaptive and sustainable spatial evolution, focusing on planning tools, participatory processes, and vulnerability analysis. The methodological principles, that have been shared among the five pilot areas during the project development, are based on context conditions, which are capable of influencing adaptation effectiveness.. Economic, environmental, and climatic aspects, as well as social, cultural, and political ones, were fundamental to building a local knowledge framework on which to develop the adaptation plan [33] [34]. Moreover, the whole process is based on priorities and objectives that each city sets independently through its local perceptions of the environment, which represent "the strategic direction of the settlement" [35].

The process is organized in progressive and codependent steps (figure 1), alternating participative and technical ones. It starts from the governance identification and actors' perception, then impacts, risks, and climatic vulnerabilities assessment is developed, and finally, the evaluation and selection of the adaptation actions. This last part is dedicated to developing and testing the decision support and the Climate Adaptation Plans. The involvement of the decision-makers and stakeholders is developed to involve them since the very beginning of the process. This was a precondition to guarantee public participation in urban planning processes, hypothesizing a better performance for those solutions identified in accordance with citizens and local actors. The pursue was to demonstrate that shared decisions could lead to a more sustainable and feasible measure in which citizens are willing to implement actions directly [35]. Furthermore, this approach, from a strategic perspective, can gain knowledge, increasing users' ownership of the project, reducing conflict, encouraging innovation, and facilitating spin-off partnerships [36][37][38]. Scientific knowledge integrated with local knowledge can provide a more comprehensive understanding of complex socio-economic and environmental dynamics, and this can be used to evaluate the performances of the adaptation measures [39].

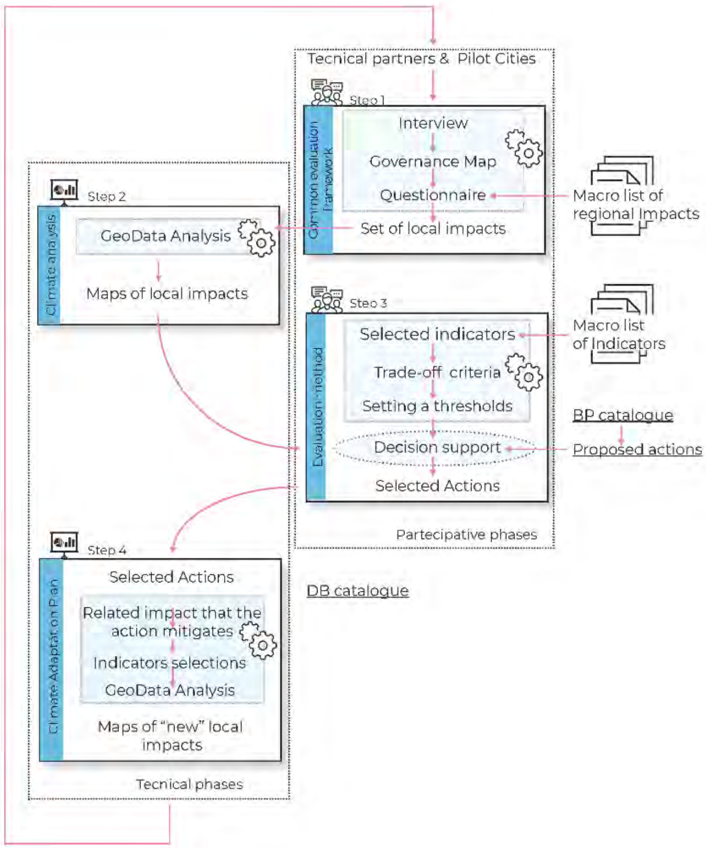


Figure 1 - The process to support the decision-making of adaptation measures through a climate adaptation plan.

Step 1:

The first step "the common evaluation framework" is devoted to producing three different outputs i) a map of the Governance system; ii) the frame of local consciousness about Climate Change; iii) the perception of the effect of impacts and the relative indicators. The purpose is to understand the stakeholder's perceptions about CC impacts on their spatial context, if and how they are involved in climate adaptation measures and policies, and if they are available to support or develop a new adaptation plan. To have a clear understanding of how each governance system is composed, all municipalities spread among their network a questionnaire to identify and distinguish local decisionmakers and stakeholders. Each actor got a specific section of the survey, to better identify opinions and collect data. The interviewees described their inner resources and the main climatic hazard and impact to which their activities are exposed. The primary process output is an actor map that represents the local governance system hierarchy and identifies specific decisionmakers and stakeholders, which can be involved in the planning process. The survey made it possible to select a set of impacts, organized by priority of action and linking their effects to identified actors. Taking as reference the outcomes of project TERRE [40] 25 indicators were selected to describe territories and necessities of each area. The evaluation was performed in a relationship with the impacts that emerged from the survey. This elaboration allows the city to use their customized system to analyze the strength - and the performances - of the adaptation measures that they would use to cope with local climate change effects.

Step 2:

Step 2 "Climate Analysis" is devoted to developing the climate vulnerability maps and the risk maps through a geodata analysis [41], these maps compose the necessary framework to raise awareness and improve knowledge about CC impacts among municipalities. A flexible working methodology was required to relate to the morphological differences among areas, experts and decision-

makers' ambitions, and the quality/quantity of available data. The backbone of the process was kept constant in each study area, using small changes in the step-by-step approach adapting it to specific context and challenges. In order to develop appropriate analysis, it was determined to limit the set of impacts and hazards, to the more relevant and general ones. The selection was made referring to the list drafted by the Environment Protection Agency 2018 [42]. The result is based on a two-phase process: i) the identification of a broader group of impacts; ii) selection of the most relevant and specific ones supported by experts. The project considers the following sectors of impact: agriculture, ecosystem & environment, energy, coastal areas, hydrology & water resources, socio-economic [43].
The European Strategy [4][44] through the use of a global forecast scenario determined a list of impacts effects for the Mediterranean Region focused on specific territorial sectors, namely:

1. Agriculture
    a. Variation in crop yield;
    b. Variation in livestock production;
    c. Increased irrigation demand.
2. Ecosystems and environment
    a. Loss of species;
    b. Loss of habitat;
    c. Increased forest fires;
    d. Increase of invasive species and parasites.
3. Energy
    a. Impacts on energy infrastructures;
    b. Increased energy demand for cooling.
4. Coastal areas
    a. Increased erosion;
    b. Coastal flooding;
    c. Damage to coastal human infrastructures;
    d. Damage to the coastal natural environment.
5. Hydrology and water resources
    a. Increase of drought;

   b. Increase of flooding;
   c. Increased competition for water;
   d. Increase of urban flooding.
6. Socioeconomic
   a. Increased Urban Heat Island effect;
   b. Impacts on the weakest group of people;
   c. Impacts on commercial activities;
   d. Impacts on public services;
   e. Impacts on industrial activities;
   f. Impacts on transportation network;
   g. Impacts on the tourism sector;
   h. Increased energy demand for cooling.

The survey involved the decision-makers and the stakeholders to select and prioritize these indicators; in that way, each analysis is tailored to specific context and perception. In some cases, for example, Croatia's territory structural part of the datasheets and the morphological maps were unavailable. In this case, the selection of specific impacts and the related data was discussed with local actors and experts. The results produced are different for each focus area; this is both connected to the availability of data and partner choices, although the structural methodology is maintained constant to preserve its replicability. The method used in this project is based mainly on the IPCC principles and approaches that can be found in the 5th Assessment Report from the IPCC [45], where vulnerability is considered as the subtraction of the adaptive capacity to the sensitivity. The two used indicators are the "land surface temperature" and "vegetated surfaces" and are developed to describe the urban fabric morphological behaving under the pressure of a specific CC impact. For example, they are used to define and spatialize the "energy demand for cooling", "UHI", and "impacts on the touristic sector" [46] [47].

Step 3:

This third step "Evaluation Method" is based on the results achieved within the TERRE project [40]. TERRE developed a decision

support process to assess and classify by performances, local alternative actions. This decision support is based on a multi-criteria decision analysis (MCDA) [48] [49] [50]. An identified set of definite alternative actions (adaptation measures) were evaluated and classified through common and weighted indicators. A group of possible indicators was shared among local decision-makers, which make explicit their preference and trade-off about them.
To capitalize the process developed in TERRE, it was necessary to update scenarios, objectives and a set of criteria tailored to a different group of decision-makers with specific priorities and ambitions, but the logic structure was maintained to support actors during the decision-making process, from alternatives creation and evaluation to their ranking and selection. Consequently, the developed decision support integrates environmental-climate criteria with socio-economic and legal-institutional ones. With this method, it is possible to select climate adaptation strategies accord to quantitative and qualitative assessment, taking into account both the morphological and the governance aspects. Considering the decision not just as an act of choosing, but as something more complex, the "decision support" can be defined as a practical approach to assist decision-makers [51]. The goal is to introduce elements of rationality into the decision process, to enhance transparency, and to make phases replicable and legitimate.

Step 4:

Step four is the "Climate Adaptation Plan," namely, the selected adaptation measures are linked together considering the normative framework, the time frame, and the economic resources. Moreover, in this step, a contextual and coherent monitoring system was elaborated. The monitoring system was based on a set of indicators related to the previously selected impacts. Thus, the effectiveness of each action is evaluated to facilitate the interpretation of the obtained outcomes. The set of the proposed indicators to assess the performances of the adaptation action is developed as follow:

1. The surface of green areas provided by the action;
2. The surface of built-up areas made by the action;
3. LST, Land surface temperature mean value;
4. NDVI: Normalized Difference Vegetation Index;
5. NDBI: Normal Difference Built-up Index;
6. The surface of areas no longer vulnerable to "sea-level rise" by scenario involving 1 m;
7. Impermeable surface made by the action;
8. Floristic areas;
9. Public beaches surface;
10. Dunes surface;
11. Coastal protection infrastructures: (the amount of GI provide by the action);
12. Water consumption.

The update of the available information is fundamental to control and monitor climate adaptation plan efficiency over time, as well as to support local public administrations in making appropriate corrective measures. The developed methodology uses an algorithm to calculate impacts and risks to compare the actual situation with the project at time +1. The goal is to produce a proactive instrument able to adapt to site-specific urban environments and landscapes. A simplified graphical interface was provided to ensure the comfortable use of the tool.

5.4.-iDEAL project-based application

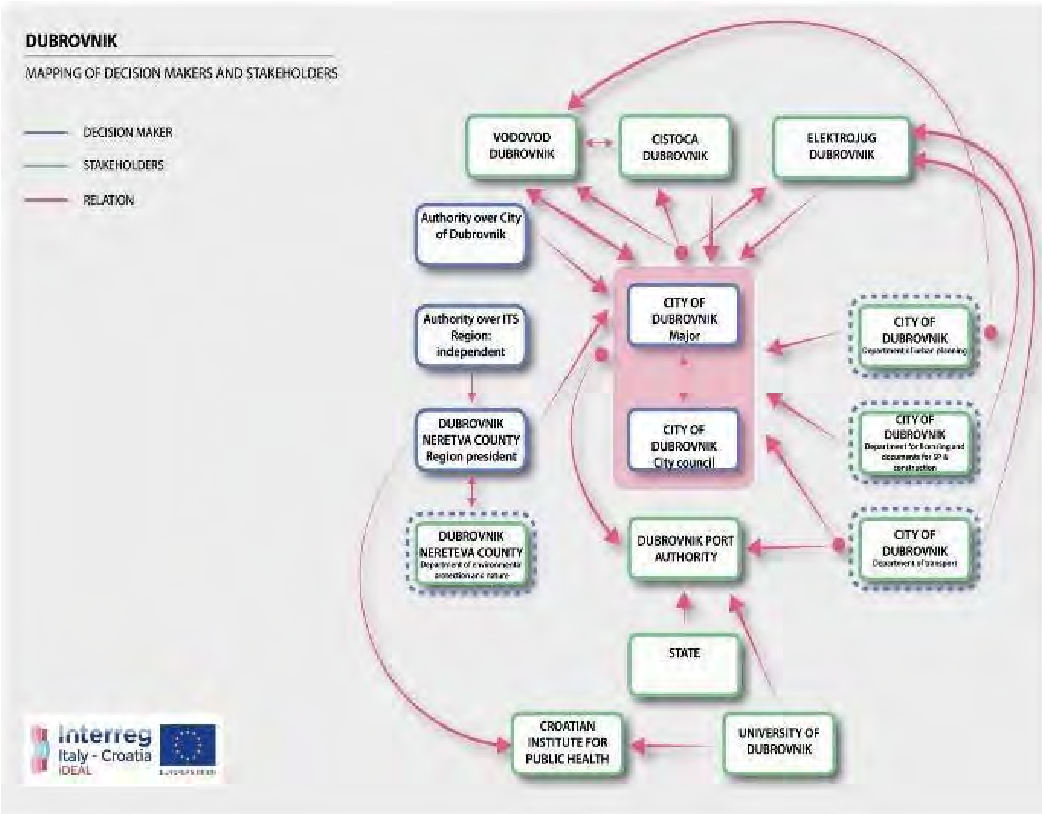
Following the above methodology, each study area started to undertake a process to reduce climate risk exposure and enhancing urban adaptivity. The proposed process deploys quantitative and qualitative analysis to estimate local criticalities and synthesizing the results into numerical indexes. This output is accessible information, which develops statistics and data elaborations to define efficient action design solutions [33]. In the following paragraphs, the main results are presented separately for each step of the methodology.

Step 1:

The Construction of a common and shared evaluation framework starts with the interviews and questionnaires, it was possible to identify some types of recurrent actors and create a governance map for each pilot city. It is noticeable the fragmentation of local governance system into separated departments and divisions (fig. 2).

Figure 2 - Example of governance map.

Table 1 - Decision-makers & Stakeholders emerged in governance map 56.



Partners	Decision maker		Stakeholder	
	Regional department	Port Authority	Environmental associations	Research institutions
Municipality of Vrsar	X	X	X	X
Dune costiere Park	X	-	X	-
Municipality of Dubrovnik	X	X	-	X
Municipality of Pesaro	X	-	X	X
Municipality of Misano	X	X	X	X

Except for the city of Dubrovnik, in every study area, it is possible to find at least one actor with environmental interests. The Croatian territory, unlike the Italian one, has at least one university research body within the stakeholders, which can be read as a knowledge transfer opportunity. Despite the similar coastal position of the pilot cities, not all of them have a Port Authority in their organization. The only two that do not have this kind of subject are Dune Costiere Natural Park and the Municipality of Pesaro (Table 1).

Partners	Set of selected impacts											
	Urban Heat island	Urban flooding	Sea level rise	Increased coastal	Impact on tourism	Variation in crop	Increased of drought	Increased competition for water	Increased energy demand for cooling	Impact on transportation	Loss of habitat	total
Municipality of Vrsar	X	X	X	-	-	-	-	-	-	-	-	3
Dune costiere Park	-	-	-	x	-	x	x	-	-	-	X	4
Municipality of Dubrovnik	X	X	x	-	-	-	-	-	-	-	-	3
Municipality of Pesaro	-	-	-	x	x	-	-	X	x	-	-	4
Municipality of Misano	-	-	-	X	x	-	-	-	x	x	-	4
total	2	2	2	3	2	1	1	1	2	1	1	

Table 2 - Selected impacts among the case studied. Selected indicators are signed by (X).

In table (2) are reported the CC impacts selected by the pilot cities. In the matrix, it is possible to recognize which specific impacts each partner decided to investigate. Trough ICT and GIS science, it was possible to assess UHI, flooding, and sea-level rise, using satellite images and open-access resources [41] [52].

From the analysis of questionnaires' results emerged that some impacts occur more than others. In the Croatian area, the "Increased coastal erosion" is the most frequent impact (60%). That was partly expected considering the geographical position of Croatia and Italy and the behaving of marine currents [53]. It is given modest attention to the "Impact on tourism sector", "Increased energy demand for cooling",

"Urban heat island", "Urban flooding" and "Sea level rise". The 40% of the answers referring to these impacts attests to growing attention on issues connected to urban heat waves, energy, tourism, and hydrology. Among those impacts which received a lower amount of preferences (20%), it is possible to recognize "Variation in crop yield", "Increased Drought" and "Loss of habitat". The last one was chosen only by Dune Costiere Park, which perceived this impact as relevant to its activities.
The main output of this phase was a practical test of the theory that economic activities and environmental services are linked to local climatic conditions. The importance of this result is that the methodology is participated and knowledge sharing among local stakeholders.

Step 2:

Through the study of the CC impacts study was possible to identify a multiplicity of areas effected by climatic risks and, at the same time, estimate their intensity (figure 3). These areas are characterized by physical, economic, and morphological peculiarities that often develop a pattern that replicates in the project areas. The impacts assessed are mainly connected to urban fabrics due to the type of partners involved in the project, except for the Coastal Dune Park.
The analyses of UHI and "Increased energy demand for cooling" confirmed this strong relation as reported in international studies [54]. On both sides of the Adriatic Sea, it emerged the same trend of exposure of built and dense urban environments to UHI. In particular, the impact affects mostly touristic residential areas and those historic centers located along the coastline. A reduced cooling capacity characterizes these areas. This fragility is caused by the urban morphology, which slows the air circulation and by the limited presence of green surfaces. A reduced "Sky View Factor" connotes those areas which are characterized by a higher UHI exposure, which is related to small road dimensions that may cause weak night-time cooling capacity.
Regarding the study of the urban flooding's impact, the more exposed areas are those with limited green spaces. This typology of the urban

fabric is mainly distributed along the mainlines connecting peripherical infrastructures with city centers. It is marked by the strong presence of impermeable surfaces that reduce the natural absorption capacity of soils, causing the need for an integrated rainwater management system. For what concerns the areas exposed to the "Sea Level Rise," it emerged that are characterized by a high density of infrastructures, residences, and economic activities. In this case, the nature and the morphology of the coastline determine the level of risk that rising sea can address. The areas that appeared to be significantly endangered are the more recent ones, mainly constituted by tourism facilities. It is possible to recognize the cause of this vulnerability in the last decades' urban development processes, which occupied sea-exposed areas. These activities altered and erased a large portion of the natural coastal dune system impoverishing the Mediterranean and Adriatic natural adaptive capacity [55]. Furthermore, also the historic centers appear to be threatened by this risk due to their location. Traditional human settlements along European coastlines used to have a dual relation with water (sea and rivers) both for a trading and defense reason. These urban principles are now become a source of exposure due to the strong relation of Adriatic coastal cities with water, i.e., Pola, Ostuni, and Dubrovnik.

The Coastal Erosion vulnerability assessment is focused on the exposure of dunes and natural ecosystems to the impacts of extreme storm surges and extreme events. The driving consideration regarding these territorial elements is based on the interpretation of dunes and coastal habitats as natural defenses. Due to the low information availability, the study of the areas exposed to the erosion risk is limited in identifying the phenomena distribution over time. The result presented moderate evidence, however, the project provides a tool to monitor coastal behaving after infrastructural modifications and sea currents changes. The Italian focus areas showed how this impact is connected to the ports and piers construction and other anthropic intervention which modify natural dynamics. It is interesting to note that in all the pilot cases, the most impacted areas are those on which coast-engineering responses were placed to defend touristic beaches.

Concerning the Impact on about "transport network" and the "impact on the tourism sector", the most affected areas were found to be distributed mainly along the coastline. These impacts are attributable to the high concentration of hotels, tourist assets, and transport infrastructures along the waterfront, in line with the economic vocation of the Adriatic regions.

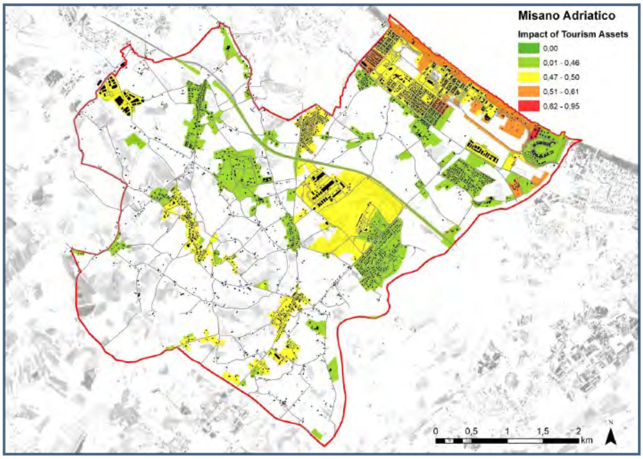
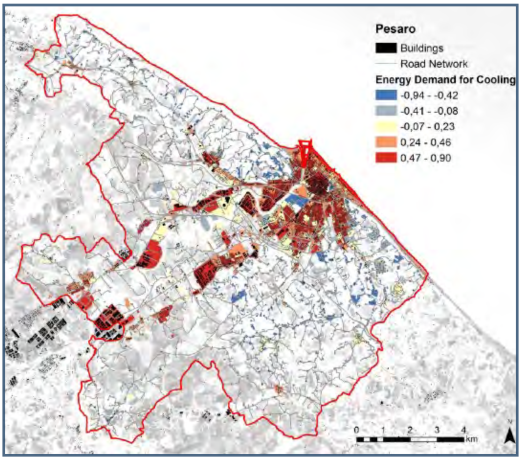


Figure 3 - Risk map of:
a) Impact on tourism assets;
b) Energy demand for cooling



Step 3:

The construction of an evaluation method allowed the estimation local-based of the goodness of the proposed actions. The process is easily measurable and comparable due to the selection of a set of indicators which are equally distributed between quantitative and qualitative ones (Table 3).

Table 3 - Indicators selection. Selected indicators are signed by (X).

Aspect	Indicator		Quantitative	Qualitative	Unit of measures	Municipality of Vrsar, Rovinj	Dune Costiere natural park	Municipality of Dubrovnik	Municipality of Pesaro	Municipality of Misano	N° of Preferences	Total preference	Total preference
A. Environmental	A.1	*Soil coastal erosion*	X		*m2*		X		X		*2*	*18*	*42%*
	A.2	*Soil drought*	X		*m2*		X				*1*		
	A.3	*Impermeability ratio*	X		*m2*					X	*1*		
	A.4	*Flooding area*	X		*m2*	X		X			*2*		
	.5	*Collected rain water*	X		*m3/year*					X	*1*		
	A.6	*Reused water*	X		*m3/year*				X		*1*		
	A.7	*Water consumption*	X		*m3/year*				X	X	*2*		
	A.8	*Habitat maintenance*	X		*m2*		X		X	X	*3*		
	A.9	*UHI reduction*	X		*C°*			X	X	X	*3*		
	A.10	*Energy use reduction*	X		*%*			X	X		*2*		
B. Social	B.1	*People who will benefits from the action*	X		*n°*	X		X	X	X	*4*	*7*	*17%*
	B.2	*New job created by the actions*	X		*n°*		X				*1*		
	B.3	*Km of upgraded infrastructures*	X		*Km*					X	*1*		
	B.4	*New infrastructures*	X		*Km*	X	X				*2*		
C. Economic	C.1	*Implementation cost*	X		*€*		X		X	X	*3*	*7*	*17%*
	C.2	*Management cost*	X		*€*				X		*1*		
	C.3	*Enterprises supported*	X		*n°*		X				*1*		
	C.4	*Traditional crops*	X		*Ton/year*		X				*1*		
D. Legal	D.1	*Legal feasibility*		X	*Low-medium-high*					X	*1*	*10*	*24%*
	D.2	*Procedural time*	*x*		*days*					X	*1*		
	D.3	*People acceptability*		X	*Low-medium-high*	X	X	X	X		*4*		
	D.4	*Political acceptability*		*x*	*Low-medium-high*	X	X	X	X		*4*		

Table 4 - Number of selected Indicators.

The selection of indicators revealed an inhomogeneous distribution of the preferences expressed by the involved partners. The indicators that received more preferences (4/5) were: "people acceptability", "political acceptability" and "People who will benefit from the action". That could be partially motivated by the role played by qualitative indicators in governance processes compared to quantitative ones. The relevance of this typology of indicators in decision-making processes can be demonstrated by the fact that 3/3 preferences were given to these markers. Some indicators, which usually are represented by quantitative unity of measure, were transformed into quantitative ones to reduce the difficulties in data retrieval and forecasts. In table 4, it is interesting to note that the environmental criteria are the ones with the highest number of total preferences (42%), as second comes "legal, institutional and perceptional" aspects (24%) and as third "social" and "economic" aspect (17%). That highlights the different priorities and perceptions that the pilot cities have.
Considering the total number of indicators chosen, the environmental aspect results in the most selected (10), especially from the Italian cities. It received more than the double of preferences than of the other identified indicators showing how adaptation is strictly perceived as an environmental issue.

Aspect	Number of chosen indicators					
	Municipality of Vrsar	**Dune costiere park**	**Municipality of Dubrovnik**	**Municipality of Pesaro**	**Municipality of Misano**	**Mean value**
A. Environmental	1	3	3	6	5	3,6
B. Social	2	2	1	1	1	1,4
C. Economic	1	3	0	2	2	1,6
D. Legal, institutional and perceptional	2	2	2	2	2	2
Total	6	10	6	11	10	

Aspect	Trade off aspects					
	Dune costiere park	**Municipality of Vrsar**	**Municipality of Dubrovnik**	**Municipality of Pesaro**	**Municipality of Misano**	**Mean value**
A. Environmental	0,20	0,25	0,20	0,4	0,4	0,29
B. Social	0,20	0,25	0,30	0,15	0,3	0,24
C. Economic	0,20	0,25	-	0,15	0,1	0,14
D. Legal, institutional and perceptional	0,40	0,25	0,5	0,3	0,2	0,33
Total	1,00	1,00	1,00	1,00	1,00	1,00

Aspect	Summary of proposed action			
	Grey infrastructures	Green infrastructures	Regulation measures	Total
Dune Costiere park	-	5	2	7
Municipality of Vrsar	7	2	-	9
Municipality of Dubrovnik	5	7	-	12
Municipality of Pesaro	2	4	-	6
Municipality of Misano	2	6	2	10
Total	16	24	4	44
Total in %	36%	55%	9%	100%

Table 5 - Trade-off aspects.

Table 6 - Summary table of the types of proposed actions.

What is interesting in this distribution is the resulting outcome for the "legal, institution and perception" which is considered with the public-opinion as a fundamental criterion.

The trade-off phase (table 5) among the different aspects shows how the "legal, institutional and perceptional" (0,33) and "environmental" (0,29) are perceived as the more important, followed by the "social" (0,24), and the "economic" ones (0,14). These results bring to the attention the implicit reasons which can move a decision-maker

to consider one aspect more relevant than another from a Climate Adaptation Plan perspective. Probably the attention is first directed to the "legal, institutional and perceptional" aspect because of the significant public impact that the proposed measures may have. Furthermore, the number of authorizations, permits, and bureaucratic processes can be viewed as a real implementation limits able to generate extra costs, and thus, something that must be avoided. The economic criteria appear to be perceived as the less decisive in the evaluation, probably due to the low capacity to estimate the overall costs of local interventions. Moreover, it is interesting to note that the municipality of Dubrovnik was the only one that did not consider the "economic" aspects for the evaluation. That could suggest, on the one hand, good availability of economic funds for that local administration, on the other, a strong desire to defend local economies.
The evaluation method was used to assess the proposed alternatives (adaptation actions) and divide them into three groups unacceptable, acceptable, and good. Approximately 10% of the actions were assessed as unacceptable and discarded, in favor of the acceptable or good.

Step 4:

The construction of the Climate Adaptation Plan takes place as the final phase of the process and is split into consecutive phases as follow: i) Introduction; ii) Analysis; iii) Recognition of planning; iv) Selection of impacts; v) Methodology; vi) Actions and measures; vii) Monitoring system. This kind of planning allows municipalities to undertake local strategies, capable of adapting the territory. The comparison of the various climate adaptation plans presented shows that each of them contains from a minimum of (6) - actions in the case of the Municipality of Misano - to a maximum (12) - in the case of the Municipality of Dubrovnik. The results are summarized in table 6. At a quick reading, the proposed measures can be divided into physical and non-physical ones. The first represents most of the cases (91%), leaving marginal importance (9%) to soft (regulative) actions. By studying the functioning, it was possible to subdivide the physical actions, in natural (Green) or Engineering-technological

(Gray). Following the European trends, it is possible to note as the green infrastructures represent the preferred solution (55%), leaving a secondary role to the use of gray infrastructures (36%). These results show how the involved public institutions and municipalities, have acquired a good environment sensitivity, choosing sustainable and multifunctional adaptation measures. Green solutions are present in all contexts, in line with similar processes.

The strong presence of these can be attributed to the numerous benefits that these can provide and the strong education provided by the EU on it (Nature-based Solutions). Regulation measures (9%) instead have been implemented only by two partners: Dune Costiere Natural Park and Municipality of Misano. In both cases, regulations are related to water issues, where attention is given at preserving the water from climate hazards and risks, through sustainable use principles. Observing table 7 is interesting to note that most of the proposed measures are related to the impacts of UHI (8) and Energy demand for cooling (7). This result is connected to the strong diffusion of the hazard and its risk perception compared to other less known. Furthermore, based on local priorities, the strategies developed from the proposed actions were further characterized by simple time priorities, listed to plan their effects in the short, medium, and long term.

Instead, for some Italian cases, the monitoring system is referred to as higher-level agencies, which periodically produce the necessary data to control the modifications of the territory. As shown in table 8, the implementation of the monitoring system was possible for just (5/12) of the impacts initially investigated. Among these, it is easy to note how the typology of the "areal" variables are the most used (4/5) due to their open-access nature. Except for Urban Flooding, which is based on a standardized remote sensing index, the other impacts have at least one such variable within them (Table 9).

The reason for this can be found in the increasing availability of satellite

Table 7 - Summary table of proposed actions. In the table, the values represent the number of actions referable to the type of measure.

Action typology		Measurers and actions		Related impact	Municipality of Vrsar, Rovinj	Dune Costiere natural park	Municipality of Dubrovnik	Municipality of Pesaro	Municipality of Misano	Total.
Physical measures - 91%	Grey infrastructures - 36%	1	*Water heat pumps*	Urban Heat island	1					1
		2	*Wave to energy*	Urban Heat island	1					1
		3	*Overtopping breakwater*	Sea Level Rise	1					1
		4	*Sea kite*	Urban Heat island	1					1
		5	*Protection of coastal infrastructures*	Sea Level Rise	3					3
		6	*Sea Wall*	Sea Level Rise			1			1
		7	*White roof*	Urban Heat island			3			3
		8	*Building a real estate complex*	Energy demand for cooling				1		1
		9	*Improve outdoor microclimate*	Energy demand for cooling					1	1
		10	*Innovative practices to tackling coastal erosion*	Coastal erosion					1	1
	Green infrastructures - 55%	1	*Deep green*	Urban Heat island	1					1
		2	*Natural shading and planting*	Urban Heat island	1					1
		3	*Green parking lots*	Urban Flooding			3			3
		4	*Green roof*	Urban Heat island			3			3
		5	*Natural shading*	Urban Heat island			1			1
		6	*Green parking space with filter strip*	Urban Flooding			1			1
		7	*Greening brownfield area by NbS*	Energy demand for cooling				1		1
		8	*Recovery dune coastal environment*	Coastal erosion		1		1		2

		9	*Implementing of a new school with NbS*	Energy demand for cooling				1		1
		10	*Restoring cliffs ecosystem services*	Coastal erosion				1		1
		11	*Greening*	Energy demand for cooling				1		1
		12	*Enhancing permeability of parking lots*	Impact on transport network					1	1
		13	*NbS as traffic calming solutions*	Impact on transport network					1	1
		14	*Cycle path adapting to climate change*	Impact on transportation network					1	1
		15	*Greening the waterfront*	Coastal erosion					1	1
		16	*Urban forestation*	Energy demand for cooling					1	1
		17	*Sustainable urban drainage system*	Urban Flooding					1	1
		18	*Dry agriculture*	Variation in crop yield		1				1
		19	*Restoration and management of biodiversity*	Coastal erosion		1				1
		20	*Conservation of (Tetrax tetrax) forest*	Loss of habitat		1				1
		21	*Green connections*	Loss of habitat		1				1
Soft measures - 9%	Regulations and policies - 9%	1	*Reduction of cooling needs in tourist accommodations*	Energy demand for cooling					1	1
		2	*Water savings in camping sites and beach resorts*	Impact on tourism sector					1	1
		3	*River contract*	Increase of drought		1				1
		5	*Coastal monitoring*	Coastal erosion		1				1
					9	7	12	6	10	54

Impacts	Monitoring system implementing
Increased energy demand for cooling,	yes
Impacts on transportation network	no, depend by higher-order agency
Impacts on tourism sector	no, depend by higher-order agency
Increased competition for water	no, depend by higher-order agency
Increased coastal erosion	yes
Increased energy demand for cooling	no, depend by higher-order agency
Variation in crop yield	no, depend by higher-order agency
Increase of drought	no, depend by higher-order agency
Loss of habitat	no, depend by higher-order agency
Urban heat Island	yes
Urban flooding	yes
Sea level rise	yes

Impacts	Total variables	Variables considered	Unit of measures
Urban heat island	3	*Green areas*	*m2*
		Built-up areas	*m2*
		Land surface temperature	*m2*
Urban flooding	2	*Normalized Difference Vegetation Index*	-
		Normal Difference Built-up Index	-
Sea level rise	1	*Areas no longer vulnerable by scenario +1 m above s.l.*	*m2*
Coastal erosion	2	*Green areas*	*m2*
		Built-up areas	*m2*
Increased energy demand for cooling	3	*Green areas*	*m2*
		Built-up areas	*m2*
		Land surface temperature	C°

Table 8 - Summary of monitored impacts by data availability.

Table 9 - Monitored impacts by variables availability.

data, which provides extensive coverage of geographic information. Moreover, another limitation that emerged from the monitoring system implementation is represented by specific actions that overlap in the same area. The actions evaluated are based on indirect data that are not able to consider the individual contribution but to evaluate the aggregate effect. For these reasons, it appears challenging to evaluate the effectiveness of the single action.

5.5. - Discussion

From iDEAL experience, it emerged that local climate adaptation planning requires two fundamental elements: (i) technical data and social-perceptional information, (ii) developing a decision process with stakeholders and decision-makers, which became central in creating a mainstream understanding of local issues and implementing adaptation measures effectively. The methodology developed and tested within the five pilot cities demonstrates how the steps of the process are useful to support public choice decisions and Climate Adaptation Plan development. Considering the stakeholders' experience and local administration knowledge, it was possible to characterize each pilot case.

What emerged from the five Climate Adaptation Plans is that among the proposed issues, the one which more engages local administration is the environmental aspect. Moreover, particular attention was addressed to specific measures aimed to adapt, preserve, and develop the urban context. Outputs are coherent with international trends and dynamics, confirming the reasonable increase in attention to environmental challenges [56]. Focusing on the proposed actions typology, most of them can be considered as green infrastructures (GI) (55%). In the last decade, international and national studies demonstrated that this category of measures has a consistent capacity to lead to the adaptation of urban fabrics [50][51][57]. Furthermore, GIs were the most chosen option because of their multifunctional and natural characteristics. In this sense, classical engineering intervention achieved a lower score of preferences in favor of a greener approach (35%). Architectural interventions played a central role in supporting the mainstreaming of GI's principles. The majority of the proposed measures are aimed to cope with UHI impact, energy demand for cooling, and coastal erosion impacts. These are the impacts perceived as local priorities. The more probable reason for this selection can be the morpho-typology of the Adriatic coastal urban areas and the traditional local relationship with adverse weather conditions. The five pilot cities, belonging to different geographical, physical, normative, and cultural contexts, achieved different results during the process steps. The cause of these differences can be tracked into the different climate problem sensitivity and/or the effort put in place by the administrations for their involvement.

Another decision aspect that is necessary to highlight is the importance given to the "Legal, institutional and perceptual" aspect. It emerged that these practical issues - like timing and administrative feasibility - are important to public institutions, notwithstanding this criterion is not considered into similar processes. Climate adaptation plans are voluntary tools for local administrations, and this means that decision-makers have to justify its implementation and relative costs even better than any other public decision. Nevertheless, they are also instruments capable of involving many local actors and activating synergies. These are the primary factor for legitimation, and Climate Adaptation Plans can be recognized as an opportunity to capitalize [56].

In addition, the strategic stakeholders' involvement is crucial to create a constructive discussion between local actors and support climate adaptation mainstreaming at an operational level. The iDEAL process allows communities to understand the framework in which they act, considering both each different aspect singularly and their simultaneous comparison.

Possible obstacles to the methodology implementation can be the lack of available technical data on climate impacts (as experienced by the Croatian partners), lack of expertise in applying specific steps of the methodology (as evaluation method or monitoring for which a particular training has been developed) and difficulties in identifying, reaching, and involving relevant stakeholders.

5.6. - Conclusions

In the last years, climate change and adaptation issues obtained increasing attention, both from scientists and practitioners. However, despite the increasing number of studies, papers, and projects on climate adaptation, there is a lack of practical application and operationalization in policy and decision-making processes. Decision making is a central issue in public policy-making processes. It is an essential task in climate adaptation and urban planning because it can legitimate decision-makers choices, mixing different typologies of information. Local administrations still need comprehensive guidelines and methodology useful to support them to set up a proper decision-making process that incorporates different typology of data and information in planning. This article contributes to filling this gap proposing a methodology that can support step-by-step decision-makers in selecting climate adaptation measures and policies. The process is composed of four steps that combine different tools and methods, namely:

- Vulnerability analysis;
- Policy analysis;
- Survey;
- MCDA;
- Urban planning
- Monitoring indicators.

A relevant element that should be highlighted is the fact that the methodology developed and presented aims at overcoming the structural obstacle of homogeneous data availability in Europe. From this perspective, the difference between regulation, open data, quality of the information is radically different between Italy and Croatia. The future researchFuture researches, should keep liking to transboundary policy making which is at the same time one of the prioritiespriority for the EU Community and one of the more efficient waysway to achieve a structural territorial adaptation to climate change. Furthermore, in recent years, the World Bank Organization, the European Union, the IPCC, and similar international organizations, produced numerous scientific reports, articles, guidelines to support territorial transformation in light of exposure of economic activities, infrastructures, ecosystem services, and urban settlements. Therefore the process presented in this article is suitable to be replicated in other similar contexts methodology can be recognized as innovative because it combines simultaneously different typologies of data, qualitative and quantitative information, and scientific and informal sources into the decision-making process.

06

SIXTH CHAPTER

Conclusion and Implications

CHAPTER INDEX

Abstract

Pursuing a logical-formal approach consistent with the rest of the dissertation, the Conclusion and Implications chapter dialogues systematically with the previous chapters. The Dissertation conclusions aim at presenting some reflections that emerge from the earlier chapters by identifying the common thread that connects the different RPs. Three sections divide the chapter, and each links to other previews chapters, paragraphs, and sections presented in the dissertation, specifically:

- 6.1. Research Overview and Implications responds to the research questions (Chapter 1.1.1. Hypothesis and Research Questions), highlighting the contribution of each RP in identifying evidence that supports the thesis argued. The section also identifies three invariant pillars, which link the CAP approach to other forms of complex planning and may allow gateways for further interaction (Chapter 1.2.2. - Climate Adaptation Planning, examples of an open approach);
- 6.2. Individual Contributions of Each Paper presents the author's contribution to each of the RPs (Chapter 2, 3, 4, and 5) and the personal approach introduced within the investigations;
- 6.3. Observations Across Studies and Limitations presents a summary of the limitations recognized within the RPs and outlines the horizon for future research.

In general, the chapter development is based on the consideration that could not provide definitive and definite facts. This reflection links to the Dissertation hypothesis: "CAP can be an open planning approach capable of integrating other forms of sectoral planning." Therefore recognizing a limitation to the possible interaction of the CAP model would contradict the research design.

6.1. - Research Overview and Implications

6.1.1. Answering the Research Questions

The chapter presents the answers to the 4 research questions (RQs) of this dissertation (1.1.1. - Hypothesis and Research Questions). The RQs summarize the issues raised within the RPs and aim to contextualize the research hypothesis.Previous chapters proposed different integration testing between CAPs and other forms of complex planning.

Can Climate Adaptation Planning integrate, and support a reorganization of planning approaches?Through which tools can this integration take place?

RP 1.

Each combination of CAPs and other planning approaches is experimentally possible, replicable, and, most importantly, provides knowledge elements that enable triggering a complete planning process.

In general, each RPs provides factors to answer the first part of the question positively. Each RPs responds to the second part of the question, suggesting that a more profound territorial knowledge is the critical tool for achieving integration (Chapter 1. Introduction).

This integration can enable overlapping governance processes and interests. At the same time, a common limitation emerges in the availability of economic resources and vision.Nevertheless, overcoming these obstacles is possible, according to RPs, through cooperation between decision-makers and the research and innovation community.

RP 2.

On the city-region scale, is it possible to recognize those obstacles that inhibit the achievement of sustainable growth and climate change adaptation goals?

All RPs agree that CAP is not limited by the capabilities and functions of the available planning tools. Instead, they assert that CAP is a complex process with different layers of spatial and implementation complexity whose boundaries remain to be recognized. All RPs agree that CAP is not limited by the capabilities and functions of the available planning tools. Instead, they assert that CAP is a complex process with different spatial and implementation complexity levels whose boundaries have yet to be recognized. Some of the effects of climate change are still unknown, and the forecasting tools do not currently allow us to picture the impacts they will have on territorial systems accurately. Therefore, recognizing its effects and thus the lack of performance of planning tools and tools is an ongoing process. In general, RPs agree that, at present, it is possible to recognize only a part of the obstacles that prevent the achievement of CAP goals. Nevertheless, RPs 1, 3, and 4, identify specific barriers in implementation that can be summarized as the lack of coordination between governance, funding, and research processes.

Can the Climate Adaptation Planning approach, provide a horizontal and coordinating response between sectoral planning approaches?

RP 3.

RPs 1, 3, and 4, focus on the possible benefits of integrating CAP and other forms of sectoral planning. These include a substantial improvement in using limited resources and a more effective implementation of strategies and actions. The fundamental principle is that CAP can achieve multiple objectives simultaneously, comprehensively improving the quality of investments and initiatives and anticipating future and imminent critical situations. It emerges that coordination among governance processes and convergence between research and spatial planning processes can support the implementation of positive principles such as subsidiarity (RP3), knowledge redundancy (RP1), and complementarity among initiatives (RP 4).

What are the limitations of nowadays Climate Adaptation Planning tools from the perspective of implementing strategies and measures? How can they be overcome?

RP 4.

All RPs recognize the same obstacles: lack of cooperation and dialogue between institutions and shortage of economic resources. The obstacles affect each stage if an effective planning process is based on three main elements: knowledge, strategy, and action. The RPs present a possible solution to overcome these obstacles because they focus on an experimentality of integration between CAP and other forms of specific planning. However, it emerges that common elements to overcome these obstacles lie in cooperation between governance processes, improving access to funding, and coordination with the R&I world.

6.1.2. Three Common Pillars

The four RPs, the disciplinary considerations presented in the previous chapters, and what has emerged from the research allow determinating of three fundamental pillars for the effective implementation of CAP processes (Figure 1). These pillars are indispensable elements to formulating an effective convergence between complex planning processes, with territorial climate management overcoming one of the main obstacles: the exceptional nature of planning actions and the lack of sedimentation of these experiments within territorial management regulations and practices.
These obstacles feed a negative process: the unnecessary investment of resources, the objectives failing, and the worsening territorial conditions. The case of the North Adriatic studied through the four RPs, allows recognizing the following pillars as the gateways which can trigger further, more widespread, and effective planning processes. The identified pillars and their characteristics are:

P1: Governance

Governance refers to all those processes of cooperation between decision-makers and stakeholders that lead to the implementation of spatial management and transformation strategies. Positive, fertile, and versatile processes must be devoted to the principles of subsidiarity between territorial scales, redundancy - understood as the overlapping of objectives and sharing of strategies - and administrative complementarity.

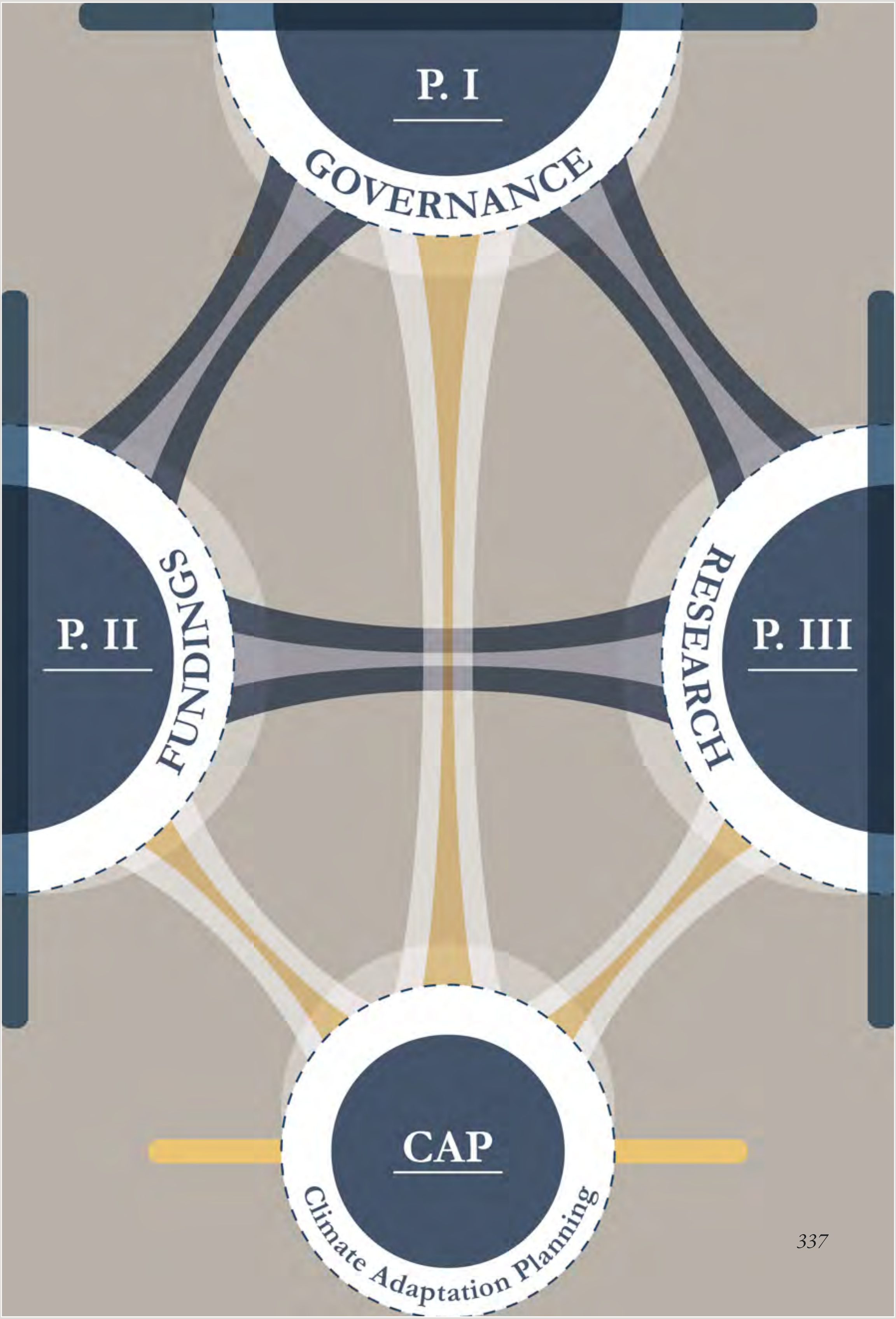
P2: Funding

Funding refers to positive investment processes promoted at the level of the European Community and funding lines that enhance cooperation and capitalization of results. In addition to European forms of funding, it is possible to recognize how Western government systems are increasingly putting resources into climate management and disaster reduction (i.e., National Scientific Foundation, NATO Public Diplomacy Division). It also emerges how preparedness in managing these resource flows defines a better capacity of public resources ordering. In addition, it is possible to recognize that there are multiple objectives in funding processes and that convergence among them can lead to more stable and lasting results.

P3: Research

Research can meet three prerequisites: interdisciplinarity, equity, neutrality among interests, scalability, and internationality. The research is a comprehensive process involving public and private research institutions, foundations, and universities. These processes can engage stakeholders and decision makers within cross-border cooperation processes, bringing to cooperation contexts that would otherwise encounter cultural and vision inertia in sharing common goals. At the same time, collaboration, for example, with SMEs or local authorities, can lead to the definition of technologies, protocols of actions, and monitoring systems that are exportable even in disadvantaged contexts.

Figure 1 - Linking the three Pillars with CAP.


P. I
GOVERNANCE
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6.2. Individual Contributions of Each Paper

The author's main contribution to the RPs is the definition of Research Design for Climate Adaptation Planning, that is, each paper's logical and formal structure.
For Research Design, it is possible to adopt the definition:

Aboelela et al., 2007

Any study or group of studies undertaken by scholars from two or more distinct scientific disciplines. The research is based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process.

The central ideation of the author of this dissertation resides in the structure of the papers themselves. Nevertheless, this approach did not always encounter the approval of some editors and reviewers. The dissertation presents the combination of CAP and different forms of complex planning, so the search for a Research Design that would allow these experimentations comparison has been a core objective from the very beginning of this doctoral career. Thus, each RPs has a similar structure: Introduction, Research Questions, Hypothesis, Case Study, Technical Methodology, Empirical Results, Discussion of Hypothesis compared to Research Questions, and Conclusion introducing the subsequent experimentation (Tobi & Kampen, 2018).
The RPs' production time spans a four-year period, during which many other research products and operative projects allowed to refine the research technique and the thinking approach. This experience made it possible to produce this dissertation, comparing theses and experiments organized homogeneously and tying them together in an open research path. From this perspective, the dissertation is the fifth product and introduces a new process of chained research, some of which are already in publication.
Therefore, it is, with a concession from the other authors, to assert that one of the main contributions made by the dissertation author is the thinking structure behind the technical experiments themselves.

The RPs are a collaboratively written process result developed with other authors, fellow researchers, and dear colleagues. In each RPs, the author contributed differently but uniformly to the definition of the four scientific products that constitute this dissertation's backbone. The specific contribution to each of the RPs is reported hereafter.

RP 1.

Conceptualization; Methodology; Investigation; Resources; Data Curation; Writing-original draft preparation; visualization.

RP 2.

Conceptualization; Methodology; Validation; Investigation; Resources; Writing-original draft preparation; Writing-Review and Editing; Visualization.

RP 3.

Conceptualization; Methodology; Investigation; Resources; Data curation; Writing-original draft preparation; Visualization.

RP 4.

Definition and testing of the methodology developed in the iDEAL; Writing the paragraphs "Methodology and Materials" and "Results" and review of the whole paper.

6.3. Observations Across Studies and Limitations

T

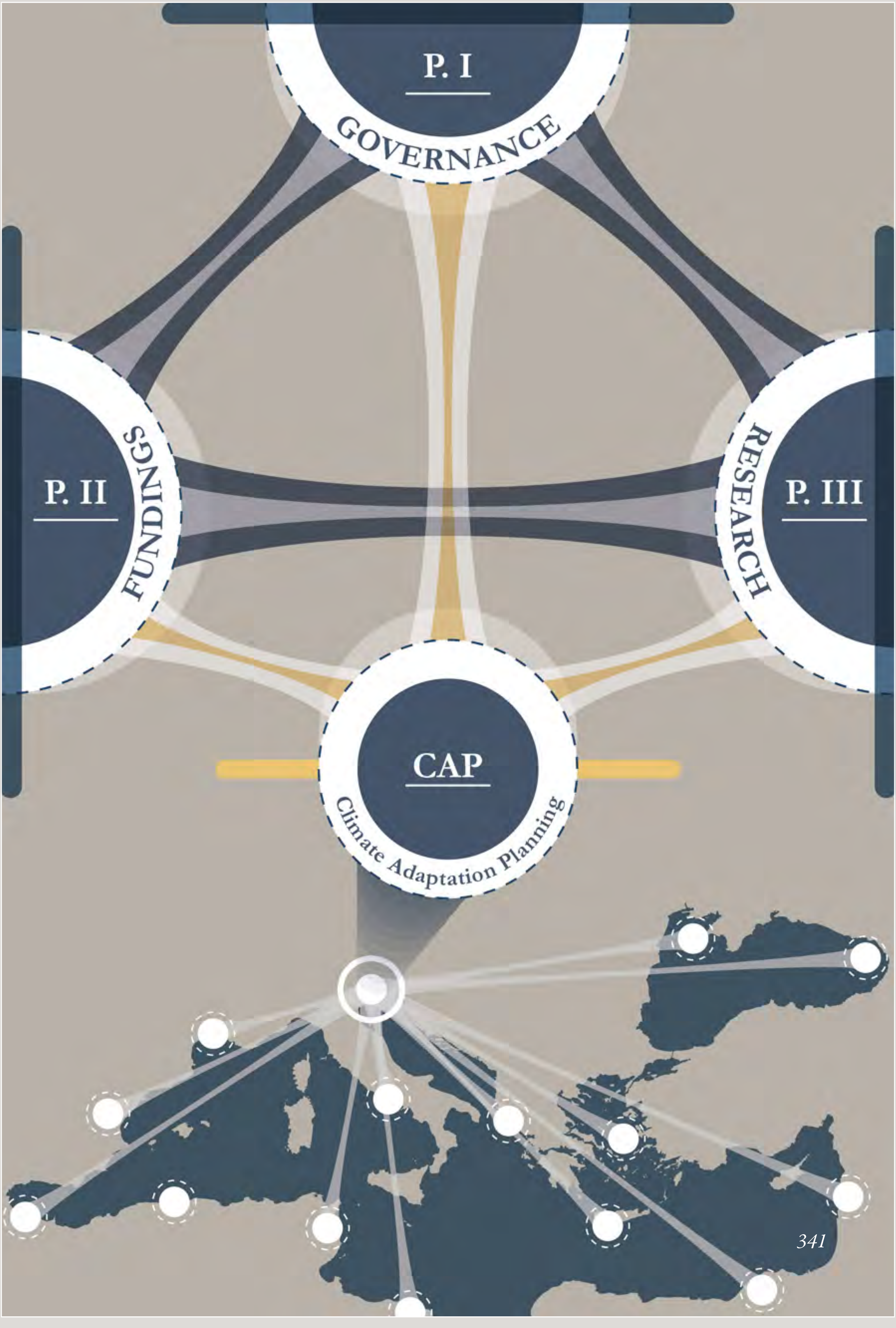
The pillars (Figure 2) have both the role of supporting CAP implementation and, at the same time fostering symbiosis with other complex spatial planning processes. The lessons that can be learned from the experiments described within the four RPs on the North Adriatic allow one consideration to be advanced. Historically, the Adriatic has been part of the Mediterranean system, not only for obvious geographic reasons, but it is a representative territory due to historical, economic, and geopolitical complexities.

At the same time, this dissertation recognizes the Adriatic as a threshold, a kind of phase zero, where we can experiment and test this approach for climate management. The Mediterranean thus constitutes the frontier of ambitions, technical capabilities, and vision for investments, governance processes, and research. The Mediterranean geographic scale is, at the same time, an opportunity to test simplified or theoretical models in a territory large enough to validate actions and strategies that link the urban to the regional and cross-border scales.

Today's paradigm of actions used in land management, cities, neighborhoods, and sometimes individual buildings is based on a dimension of exceptionality. This scenario has a favorable implication because it allows one to strive for the best result in the individual project, but at the same time, it is a negative factor because it does not allow the paradigm of the design culture itself to evolve toward new normality.

The between pillars are, therefore, the critical nodes, strengths, and success factors for the exportation of the integration model between CAP and other planning approaches.

Figure 2 - Linking the three Pillars and CAP with the Mediterranean Context.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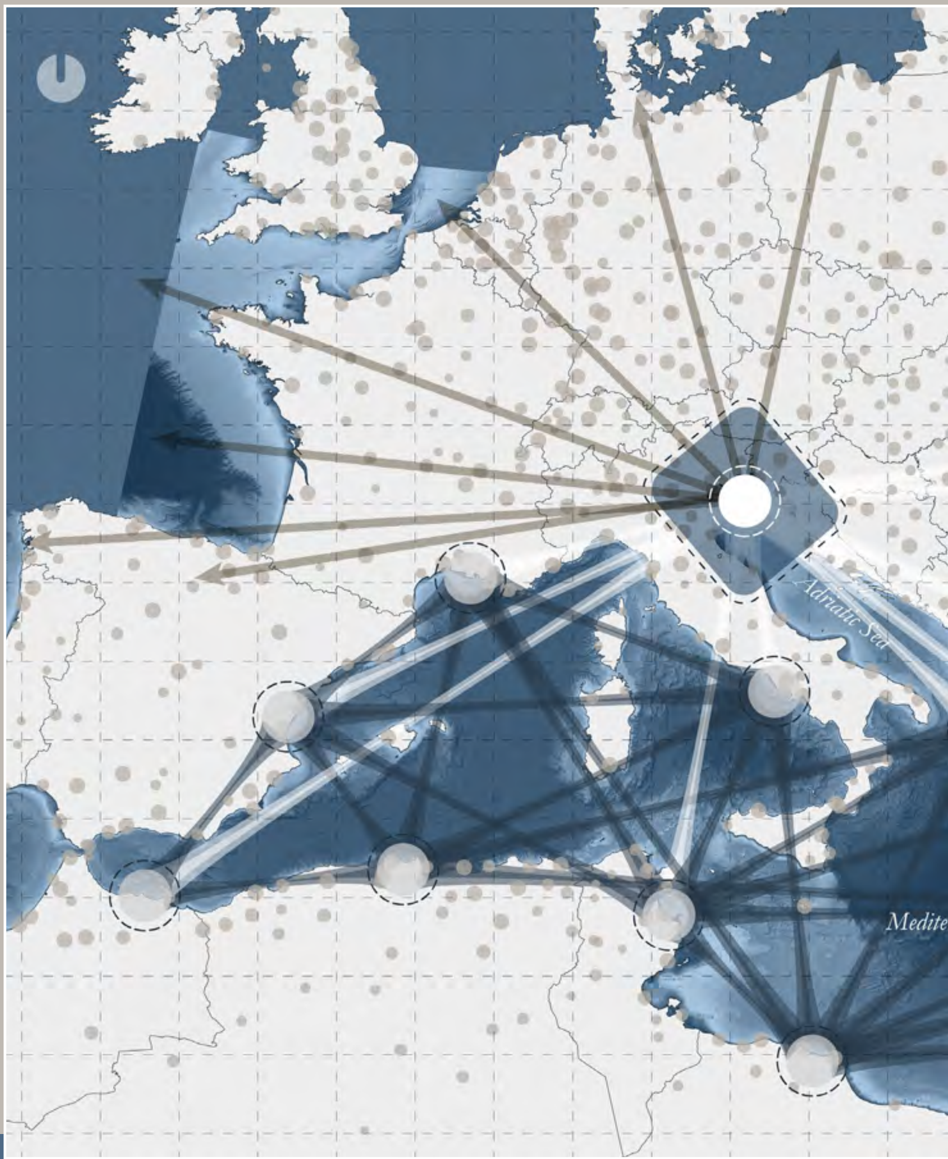
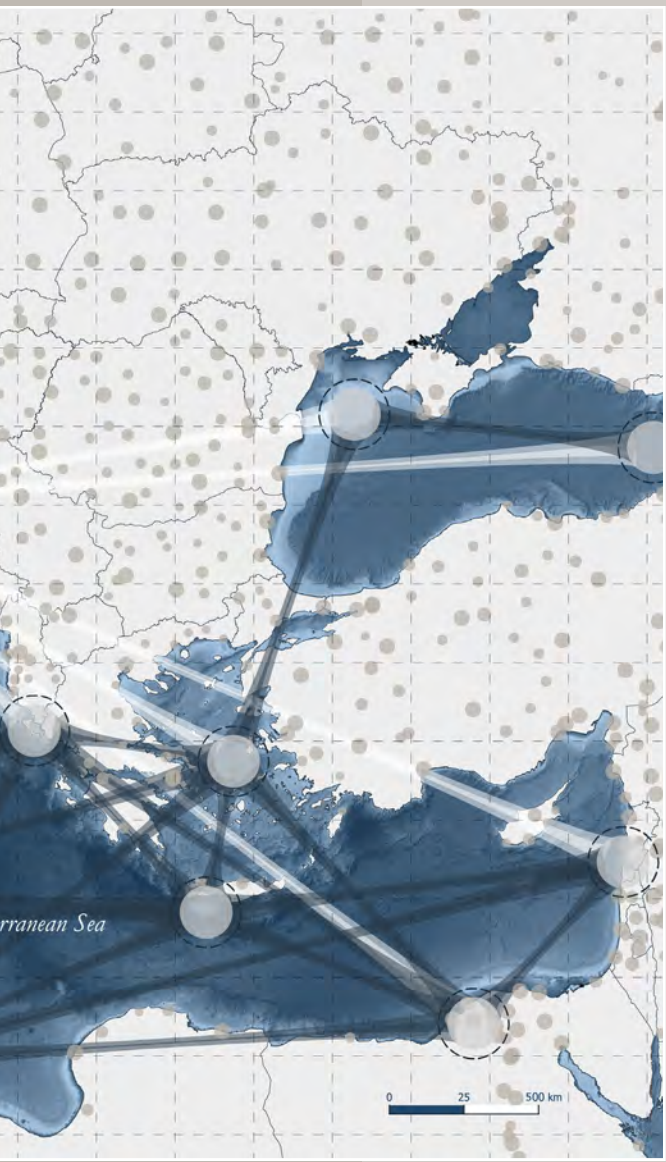


Figure 3 - Towards the Mediterranean experimentation.

6.3.1. Future Research and Towards the Mediterranean Area



The previous chapters refer to the fact that this dissertation is, in effect, the closing product of the first research phase and, simultaneously, the basis for a new form of experimentation. This experimentation is already oriented toward new frontiers of cooperation:

- CAP and Public Health;
- CAP and Military Strategic Planning;
- CAP and Real Estate Management;
- CAP and Transportation and Logistics Management;
- CAP and Post-Disaster Migration.

Future phases of the research aim to investigate these combinations in the Mediterranean context and consolidate the practices produced in the North Adriatic context through: interdisciplinary research, contamination of governance processes, and search for funding based on cross-border cooperation.

07

SEVENTH CHAPTER

References

CHAPTER INDEX

Abstract

Chapter 7 aims to present, catalog, and make accessible the apparatus of references, images, and graphic tools that support this dissertation. The organization of this material follows the chapter structure. Within Chapter 7, the references are divided following the architecture of the dissertation.
The citation style employed refers to the scientific writing practice of the American Psychological Association (7th edition).

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Chapter 1.

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