A view from the Adriatic Sea. Innovation Ecosystems and applied research for climate transition

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The Upper Adriatic is a key setting for research 'by design and planning' on land-sea interactions and climate change adaptation. Addressing these topics from an interdisciplinary perspective is the goal of the project Interconnected Nord-Est Innovation Ecosystem (iNEST) project, coordinated by the Università di Trieste and co-funded by Italy's National Plan for Recovery and Resilience. iNEST offers an opportunity to explore two areas of focus. On one hand, its approaches and outcomes seek to reframe spatial planning tools and processes within the context of climate transition. On the other hand, Innovation Ecosystems challenge the role of universities in applied research, where technology transfer, knowledge cross-fertilisation, and the development of innovative entrepreneurial fields are integrated.
Parole chiave: Upper Adriatic; climate transition; spatial planning and design

Uno sguardo dal mare Adriatico. Ecosistemi dell'Innovazione e ricerca applicata per la transizione climatica

L'Alto Adriatico è un contesto chiave per una ricerca 'by design and planning' su interazioni terra-mare e adattamento climatico. Affrontare questi temi in una prospettiva interdisciplinare è l'obiettivo del progetto Interconnected Nord-Est Innovation Ecosystem (iNEST), coordinato dall'Università di Trieste e co-finanziato dal Piano Nazionale di Ripresa e Resilienza dell'Italia. iNEST offre l'opportunità di esplorare due campi di interesse. Da un lato, i suoi approcci e risultati re-inquadrano strumenti e processi di pianificazione territoriale nel contesto della transizione climatica. Dall'altro, gli Ecosistemi dell'Innovazione interrogano il ruolo delle università in pratiche di ricerca applicata in cui si integrano trasferimento tecnologico, contaminazione di conoscenze e sviluppo di nuovi settori d'impresa.
Keywords: Alto Adriatico; transizione climatica; pianificazione e progettazione territoriale

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Introduction: fostering territorial innovation

Following the 2019 global pandemic and the approval of the NextGenerationeu Recovery Plan for a just transition towards a greener, more digital and resilient Europe (European Commission, 2024a), in 2021 the Italian Government delivered the Piano Nazionale di Ripresa e Resilienza (National Recovery and Resilience Plan – nrrp). In the frame of the nrrp, the Ministry of University and Research committed 1.3 billion euros to the creation of 'Innovation Ecosystems' (ies), to promote territorialised leadership in research and development (r&d), and progress towards sustainable solutions «ensuring the full osmosis» with «industrial application» (Italian Council of Ministers, 2021: 123). ies provide contexts for collaboration among a variety of public and private actors, research institutions and enterprises, with the goal to deliver locally embedded innovation paths. Since 2022, eleven ies have been established all over Italy; their activities will develop until 2025 and are expected to become an ordinary practice after the end of nrrp. By covering different Italian territories (from dynamic metropolitan areas to inner and marginalised contexts), and with the purpose to foster more balanced social and economic wealth and growth, ies focus on Sustainable Development Goals-related issues, providing one of the Italian nrrp key operational support tools in the fields of: climate adaptation, green energy, and sustainable mobility; digital and technological innovation in the sectors of industry and manufacture, agriculture, building and urban regeneration, tourism and culture, health and food, robotics and Artificial Intelligence (ai) (Ministero dell'Università e della Ricerca, 2022). The article investigates this research device and organisational mode, whereas direct participation in the activities of one of the funded ies – *Interconnected Nord-Est Innovation Ecosystem* (inest), specifically, the thematic network Spoke 8 *Maritime, Marine and Inland Water Technologies: Towards the Digital Twin of the Upper Adriatic* – provides insights on the application of r&d to climate transition, land-sea maritime and spatial planning, and sea-inner waters-inland sustainable mobility in the North Adriatic Italian regions. Crossed by European-level land and maritime infrastructure corridors, these territories host important port systems and logistic nodes for national and international traffic (Trieste-Monfalcone-Porto Nogaro and Venezia, Koper, Rijeka), as well as outstanding environmental, cultural and tourist hotspots. In this cross-border area, complexity is rooted in a history of 'moving frontiers' (Biondi *et al.*, 1996; Selva, Umek, 2013), marked by alternating phases of frictions

and connections, in the past among states and empires, today among EU countries (Italy, Slovenia and Croatia).

These multifaceted conditions contribute to make the Upper Adriatic – namely the northern part of this sea and its coasts – a significant setting for the development of advanced research 'by design and planning' on land-sea interactions, their multiple dimensions and challenges. The main objective is to address the gaps that still hinder the governance of climate transition. These gaps include the lack of instruments that can help regional and local administrations build an overall picture of ongoing processes and their interactions, and define spatial visions for integrated maritime and coastal planning and management. Equally pressing, however, is the demand for interdisciplinary approaches within universities and between universities and private sector enterprises.

To tackle these issues, rethinking the relationship between the theoretical development of research and its operational application becomes crucial. Firstly, urban planning and design are called upon to closely integrate with technological innovation. In this perspective, one of the main expected outputs of the research conducted within INEST Spoke 8 is the delivery of technical tools to investigate and address the transition of territories that – due to the multiple overlapping effects of climate and weather changes (from sea level rise to river flooding) – are likely to become a patchwork of dry and wetlands. Furthermore, the complexity of ongoing transformations demands a thorough review of methodological approaches, with a pressing need to integrate competences and skills from a wide range of disciplines, from biology and informatics to spatial planning and design. In this sense, the expertise involved in INEST Spoke 8 provides a unique opportunity to bring together diverse viewpoints and scientific and technical tools. Finally, no less challenging is the objective of pairing research with activities of citizen engagement, lifelong learning, and 'cascade funds'. The latter are public funding programs issued by universities to finance networks of local enterprises settled in the north-eastern regions and provinces (the so called 'Triveneto', namely Veneto, Friuli Venezia Giulia, Trento and Bolzano) and in the South of Italy. The goal is not just to transfer knowledge from universities to the economic sectors, but to co-create knowledge and tools capable of addressing emerging environmental, social and economic needs and demands.

In the second paragraph of this article, a reflection on the role assigned to IEs and their overall organisation introduces the topics and methodologies that address INEST activities in the fields of spatial planning and design. The main question explored in the third paragraph is: how can we understand and manage the complex transitions of the Upper Adriatic marine and coastal territories? Here, critical review of scientific literature on the evolving relationships between land and water, as well as its disciplinary gaps, provides the background for the explanation of the research's spatial and governance contexts, its operational steps, and results. The paragraph ends with a reflection on the pivotal role that cross-fertilisation between universities and enterprises can play in addressing key operational issues. Finally, the conclusions highlight future research directions and demands, the challenges and potential of both the R&D approach of IEs and its application to spatial planning and governance.

Innovation Ecosystems and spatial planning perspectives

In the last decades, the debate about IEs – their functionalities and organisation within different policy, social and economic sectors – has grown (Ganstrand, Holgersson, 2020; Baldwin *et al.*, 2024), becoming a specific work programme within EU Horizon Europe (European Commission, 2024b). The emphasis is on building interdependencies and complementarities among a number of actors and activities, carrying diverse expertise, and covering the whole chain of innovation – from education, to research and the operational transfer of its outputs into new products and processes, management models and tools, material and immaterial values (Adner, 2017; Jacobides *et al.*, 2018).

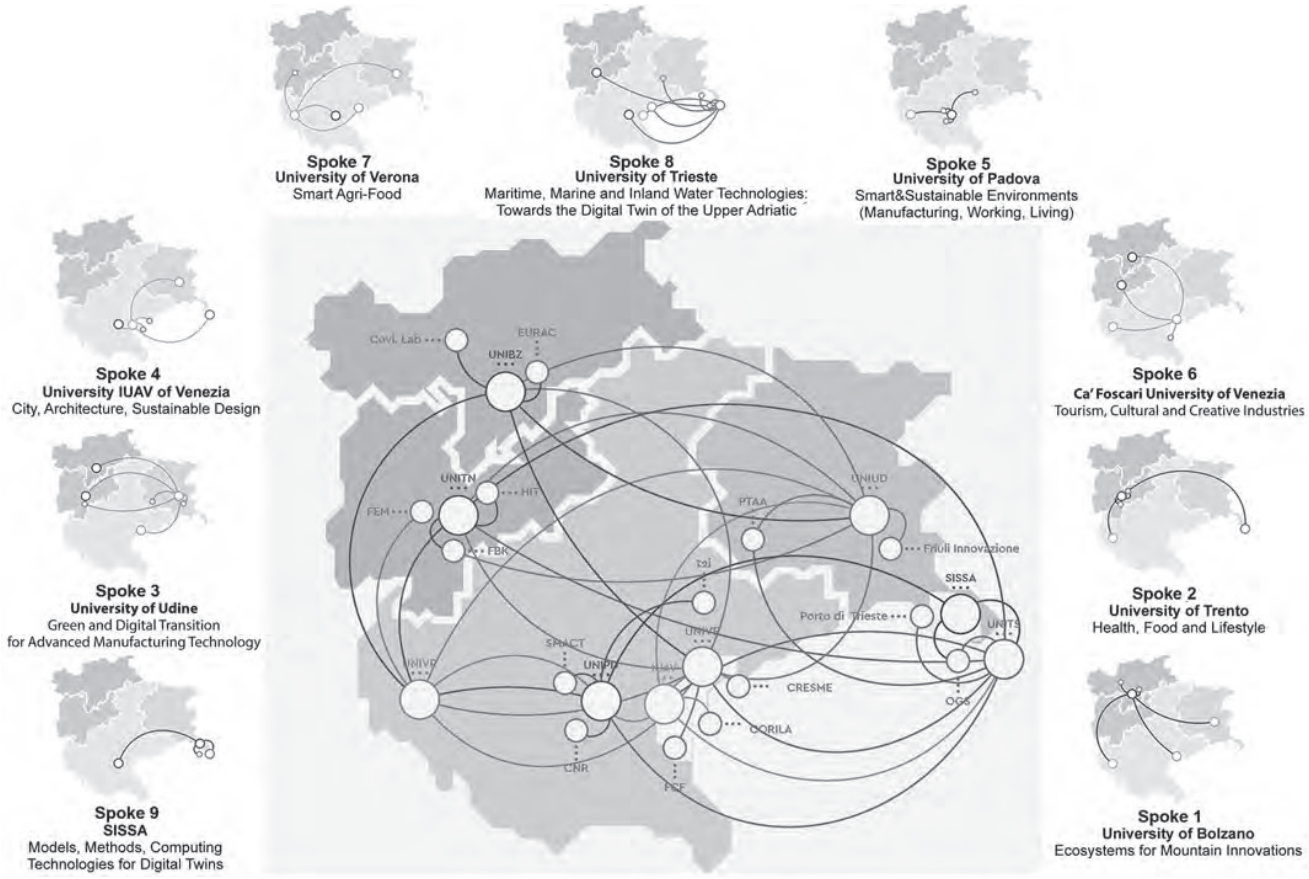
IEs as a complex device: multiple activities addressed to different targets

In the frame of the Italian NRRP, and with a focus on the guiding role of Higher Education Institutions (HEIs), IEs address technological specialisation to make scientific research concretely applicable to the productive vocations of the regional and supra-regional contexts HEIs are settled in. In particular, IEs are meant to create networks of universities, public research institutions, local administrations, and other highly qualified and internationally recognised private entities and enterprises. Each IE works as an 'Hub' with its own governance and management structure. It is divided into a number of 'Spokes': thematic nets, encompassing a large variety of technical and technological fields, their economic and environmental sustainability, and social impacts.

Under the guidance of the Hub, the Spokes and their permanent staff (mainly universities' administrative teams and researchers with different disciplinary backgrounds) play the role of scientific and organisational references to activities oriented to different targets: i) applied research and technological transfer from HEIs to economic assets, through cascade funds addressed to local large, small and medium enterprises; ii) support to start-ups and spin-offs, through the delivery of accelerator programs; iii) settlement of 'lab villages', understood as place-based laboratories where scholars, master's and PhD students, institutions and company employees work together; iv) citizen engagement initiatives, ranging from information and communication to the planning and realisation of products and actions (e.g., co-design, co-implementation, and co-evaluation); v) finally, at different levels of education and life-long learning, the cultivation of knowledge, skills, attitudes and values enabling people to contribute to an inclusive and sustainable future.

IEs essentially act as complex R&D devices, asking for significant innovation in processes, products, and interactions among territorial stakeholders and their actions. In this perspective, IEs provide the frame allowing to put into practice the EU objective to enhance HEIs' position of «key actors for the green transition and for a more sustainable world», and their «role in conducting research to find solutions, in cooperation with industry and society to environmental and climate challenges in view of achieving climate neutrality, reversing biodiversity loss and stopping pollution, and in developing climate and environmental literacy for all students across all levels and disciplines, as well as for the public at large through community engagement» (European Commission, 2022a: 16).

However, in the face of unprecedented financial resources, the preparedness of Italian universities to effectively take advantage of



1. iNEST. The partnership and the 9 Spokes. Source: Iuav.

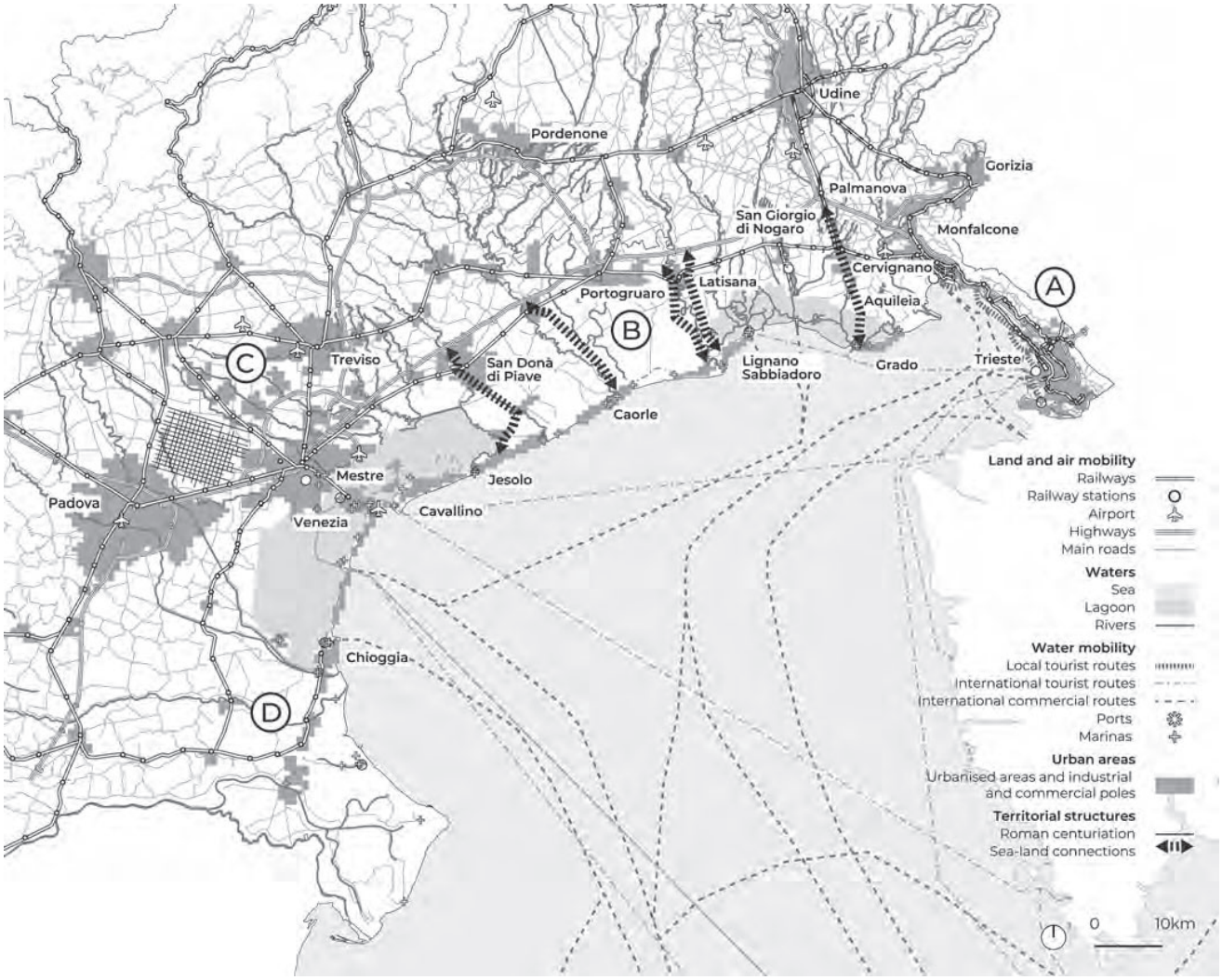
these opportunities, by supporting each other and their territories in the construction of novel projects and activities, should not be taken for granted. In fact, what the establishment of IES asks HEIS to perform is a deep reframing of the ways they conceive and implement research and education, interact with social and economic actors, co-build usable tools and knowledge, and more effectively disseminate them to the civil society, public administrations and local enterprises.

iNEST approach: an interdisciplinary, spatialised and reversed point of view

Among the IES established in Italy, iNEST focuses on the Triveneto area. It is divided into nine Spokes working on different territories and R&D fields: advanced industry and manufacture; smart agri-food; sea and water technologies; demographic changes in inner and mountain areas; sustainable cities design and architecture; tourism, culture and creative industries; health and food (fig. 1) (Consorzio iNEST, 2024a). This article focuses on the activities carried out within Spoke 8 *Maritime, Marine and Inland Water Technologies: Towards the Digital Twin of the Upper Adriatic*, led by the Università di Trieste (UNITS).[1]

Being inspired by the 2030 *EU Mission: Restore our Ocean and Waters*, and its purpose to bring together «research and innovation, citizen engagement and blue investments» (European Commission, 2024c), the goal of Spoke 8 is to develop and test technologies and spatial solutions for the management, monitoring, and climate change adaptation of marine and coastal environments. The main expected output is the creation of a Digital Twin (DT), a highly challenging field of both theoretical and applied research, yet one marked by relevant scientific gaps. Although many disciplines are already working on this topic, with substantial funding provided by the European Commission and the United Nations (Bahurel *et al.*, 2023), poor interaction between different areas of expertise remains a key issue. The risk is that the development of DTS could be trivialised, reducing them to the mere construction of technological decision-support and visualisation tools based on extensive datasets and AI predictive models, without sufficient critical reflection on their practical applicability to the complex, multiscale, and integrated environmental, social, and economic dimensions of spatial planning and governance processes (Grossmann *et al.*, 2022; Zhaoyuan *et al.*, 2024).

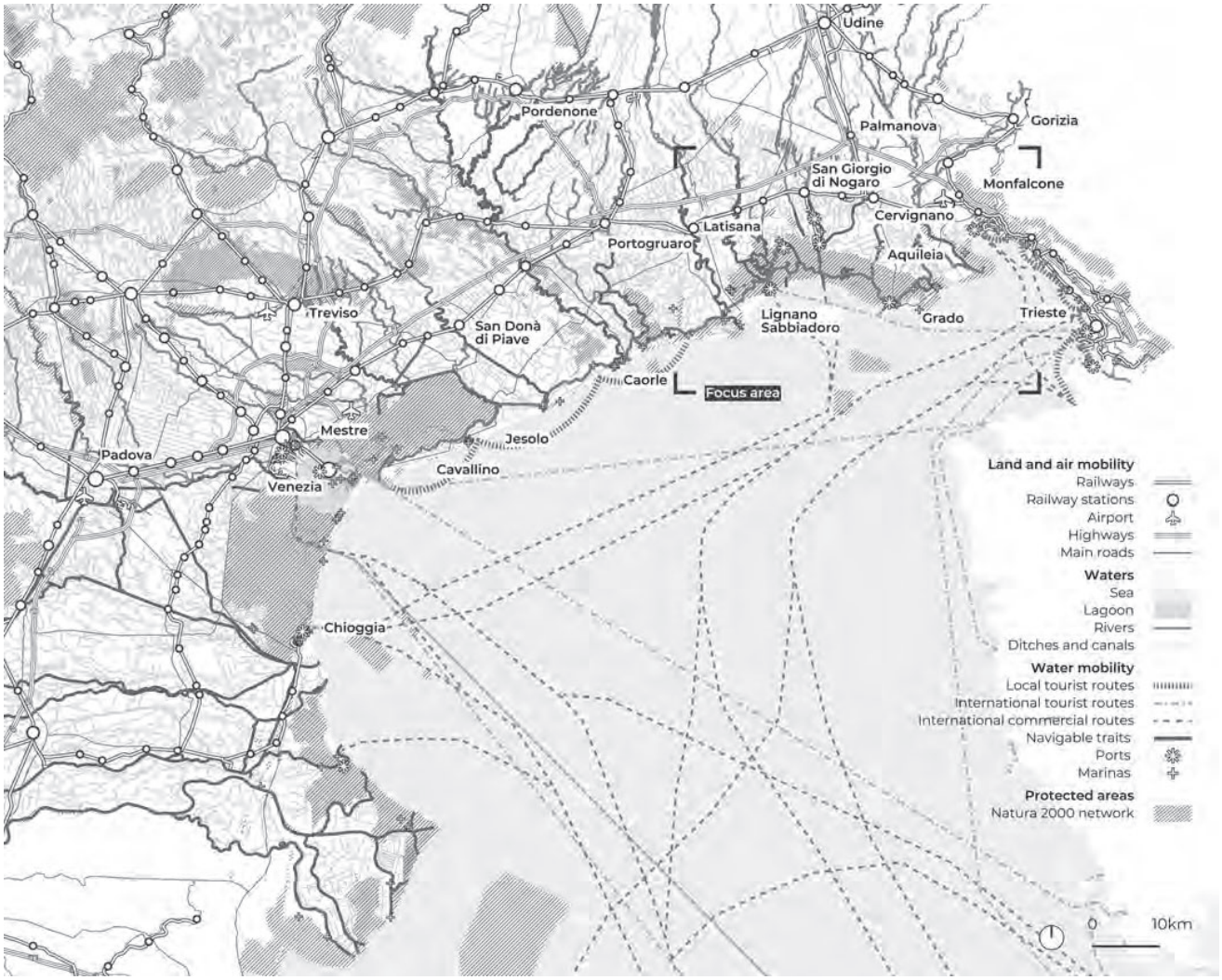
The establishment of a common research framework for a variety of technical perspectives is one of the main challenges that Spoke 8 is addressing, through interdisciplinary collaboration and the



2. North Adriatic, main sectors along the coastal strip. Maritime mobility is examined in both its commercial and tourist aspects. The source for commercial and maritime routes is the European Marine Observation and Data Network (EMODnet), which collects and compiles marine data, products, and metadata from over 160 local, national, regional, and international organisations.
Source: visual elaboration by UNITS (Ludovico Centis and Federico Vascotto) of datasets collected by Iuav.

assessment of both the difficulties and potential in delivering new tools for analysing and interpreting data, building future scenarios and solutions, and activating multi-stakeholder processes to support the climate transition of the Upper Adriatic marine and coastal territories. The Spoke is organised into five Research Topics (RTs), offering a broad set of R&D opportunities and outputs related to the Blue Economy sectors (European Commission, 2021a), and their spatial governance: tools for the preservation of freshwater and biodiversity (RT1); datasets and instruments to assess coastal vulnerability, sea level rise, flooding risk, and saltwater intrusion in the inland aquifers (RT2); prototypes of hybrid propulsive systems for electrification and decarbonisation of coastal transport (RT3); spatial visions and actions for integrated sea-inner waters-inland sustainable mobility infrastructures and services (RT4); a Digital Twin of the Upper Adriatic (RT5), understood as a AI-based machine improving the accuracy of the simulation of oceanographic scenarios and of weather models for short-term forecasts.

The applied research that UNITS and Università IUAV di Venezia are jointly carrying out specifically refers to RT4 *Land-sea Integrated Maritime and Spatial Planning*,[2] with a focus on the northern part of the Adriatic Sea and the coastal territories of the Friuli Venezia Giulia region. In these low reclaimed lands – extending below the actual sea level, and dramatically affected by its rise and flooding risks – both the survival of economic activities (from industry to agriculture and tourism) and the accessibility



3. North Adriatic, territorial framework and water infrastructure (the focus is on the case study area within sector B). A dense network of natural and artificial waterways flows towards either the Venezia and Grado and Marano lagoons, or the sea. Especially during the summer season, the sea is crossed by maritime routes related for both commercial and tourist purposes.
Source: visual elaboration by UNITS (Ludovico Centis and Federico Vascotto) of datasets collected by Iuav.

to welfare facilities are endangered. In the face of expected climate-driven major transformations, the need to explore new spatial and functional settings is therefore urgent and strong. The aim is to address existing deficiencies in spatial planning policies and tools related to the climate transition of coastal contests and the integrated management of their relationships with water (sea and rivers).

For decades, the European Commission has been guiding its member States towards the development of strategies and plans in which Maritime Spatial Planning (MSP), Integrated Coastal Zone Management (ICZM), and Climate Adaptation Planning (CAP) create stronger synergies (European Parliament and the Council, 2014; Commission of the European Communities, 2020; European Commission, 2021b, 2022b). However, in Italy, this crucial paradigm shift struggles to be concretely implemented, partly due to a persistent mismatch between scientific research and policy-making (Cantasano *et al.*, 2017; Maragno *et al.*, 2020). On one hand, after the enforcement of the directive on «Maritime Spatial Planning» (2014/89/EU) through Decree Law no. 201/2016, Italian national Maritime Space Management Plans were approved only in 2024, with one specifically dedicated to the Adriatic Sea (Ministero delle Infrastrutture e dei Trasporti, 2024). On the other hand, the proposal for a law to implement the *Protocol on Integrated Coastal Zone Management in the Mediterranean*, delivered by the United Nations Environment Programme (UNEP, 2008), is still under discussion in the

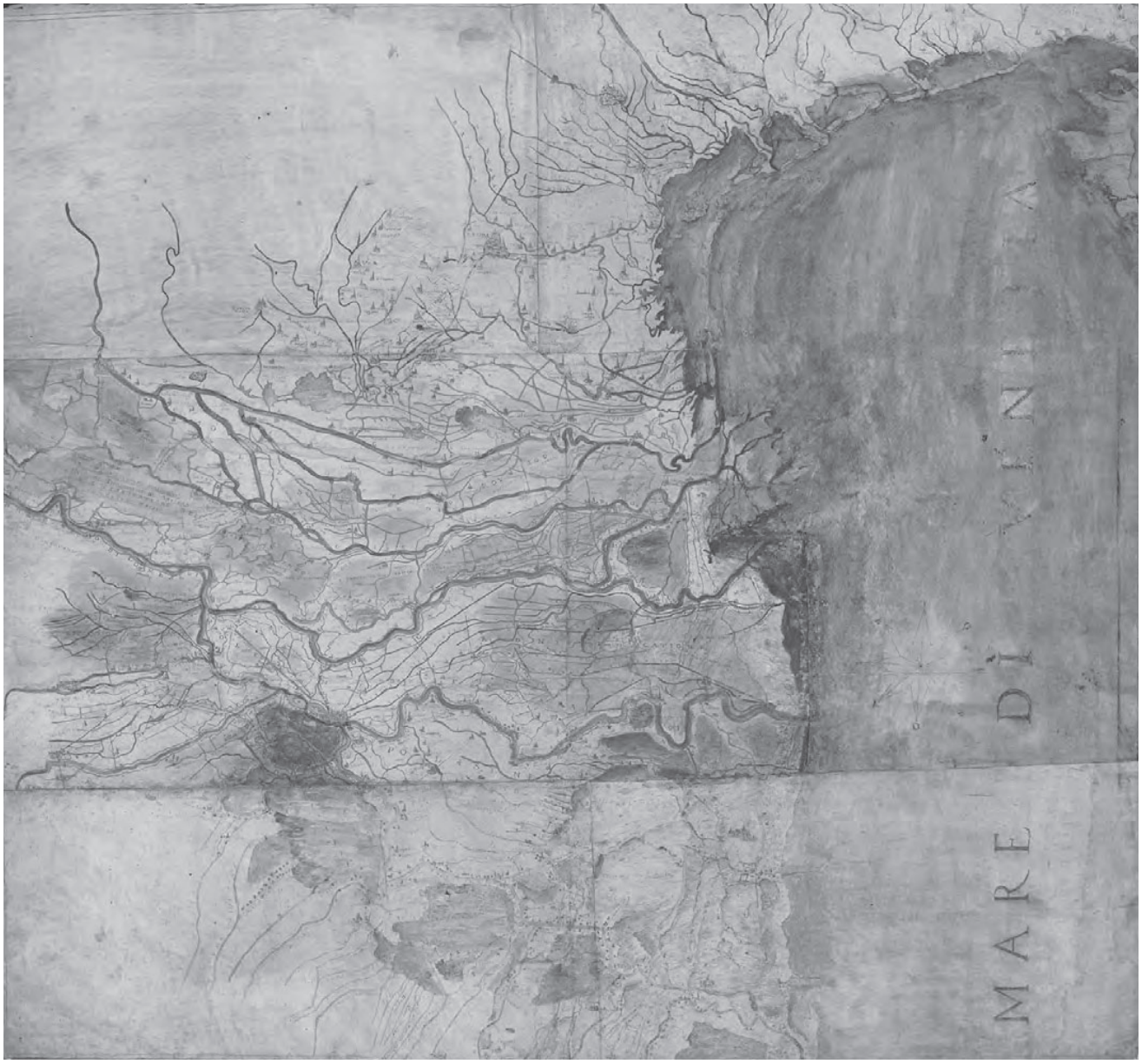
Italian Chamber of Deputies. The current situation is therefore one of fragmentation, with analyses and measures scattered across different, non-harmonised tools, where maritime and land planning remain separate, and no comprehensive governance of their interactions yet exists at the national level. As the third paragraph will discuss, the Upper Adriatic – in particular the coast of the Friuli Venezia Giulia region – is no exception.
With the aim of building and discussing future integrated visions with local administrations, communities, and economic stakeholder, RT4 provocatively proposes a reversed perspective to the one that still predominates in regional and local land use planning. By looking from the sea to the land, and focusing on the territories in-between, the research conceptualises the Upper Adriatic as a 'solid sea'. Together with inner waters (lagoons and rivers), these areas are considered as operational fields where rethinking water-land mobility can both support adaptation to new spatial, environmental, social, and economic conditions, and drive substantial change in current planning approaches and practices. In this context, climate transition and decarbonisation are addressed together, with a focus on developing sustainable transport infrastructures and mobility services – not only for commercial purposes but also for tourism, daily life, and commuting – along with protecting biodiversity and fragile ecosystems, reducing pollution, and advancing digital transition.
In collaboration with the other RTs within Spoke 8, and with the aim of providing a spatial perspective for the application of their outputs, the research explores a variety of topics:
– climate change impacts, local actions and tools (e.g., spatial mapping of vulnerabilities and risks; building of the state of the art of spatial strategies, plans and projects; interaction with public administrations and stakeholders);
– mobility assets and demands (e.g., analyses of the relationships between demand and offer of mobility and intramodality on a regional and inter-regional scale; implementation of observation and data systems referring to water-inland movements also relying on real-time flow detection, and understood as a component of 'on call' and targeted public transport services);
– spatial models and planning tools for integrated mobility and climate adaptation (e.g., identification of interchange transportation hubs; proposal of sea-inner waters routes and services, and their harmonisation with land-based soft mobility – cycling and walking; enhancement of economic and environmental, landscape and historical-cultural resources as a support for new land/water uses and settlement conditions in the Upper Adriatic);
– instruments and technologies to monitor climate change-related effects and environmental impacts of mobility and other human activities, to help address and (if necessary) revise planning strategies and actions.
RT4 activities will be completed by December 2025. As the following paragraphs will describe, the steps the research has taken so far have utilised mapping, analytical, and interpretative tools to assess the dynamics and effects of climate change, with the aim of laying the foundations for strategies and solutions for sustainable mobility across the sea, lagoons and rivers, coastal areas and inland regions. These activities were complemented by the development of a critical atlas of current planning studies and documents, along with an initial series of meetings with local stakeholders and public administrations at various levels. Additionally, more focused cartographic analyses, surveys, and listening processes provided inputs for detailed spatial investigations. Their purpose was to define interpretative frameworks and future perspectives for territorial planning and sustainable mobility in the Upper Adriatic (Centis *et al.*, 2025). By the end of INEST, these results will be synthesised and further implemented through: i) the delivery of planning guidelines, specifically a set of recommendations and site-specific design explorations for climate transition, and the integration of sea-land mobility and logistics into territorial plans and projects aimed at the conservation and enhancement of the environment, landscapes, settlements, and collective facilities in the Adriatic coastal and inland areas; ii) the development of pilot projects in synergy with RT3, understood as feasibility studies for water-land routes for public and sustainable transport; iii) the outputs of the projects financed by cascade funds.

Upper Adriatic: a complex transition

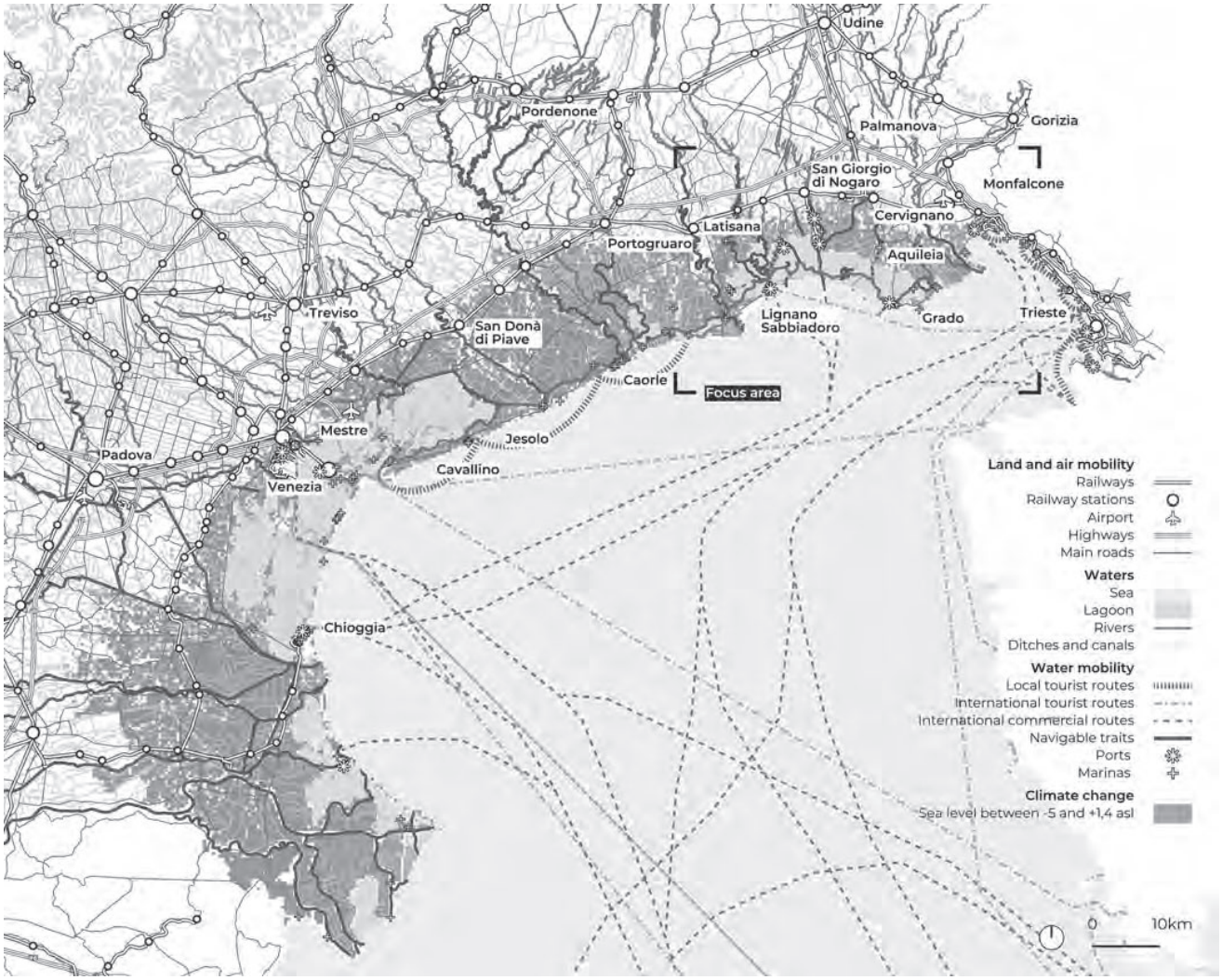
In the face of the dramatic climate and weather changes taking place, RT4 activities are driven by one main question: how can we think of a new way of functioning and a different habitability for the Upper Adriatic marine and coastal territories that, in the near future, are likely to become increasingly 'amphibious', similarly to many other contexts?
For some decades now, these issues have been at the centre of international debate, and many terms have been coined for their interpretation and application to spatial planning and design. From this plural set of reflections, some prompts come to the fore. The need to address the presence of water and its ever-changing relationship with land as a 'wet matter' that is unavoidable to deal with (Sigler, Whitman-Salkin, 2024); the urgency of describing and designing territories as consisting of different patterns of permeable and waterproof surfaces (Viganò *et al.*, 2016); the quest to explore new perspectives on 'water urbanisms' (Shannon, de Meulder, 2013), and to define spatial models and green and blue nature-based solutions enabling communities to 'inhabit' a radical ecological and climate crisis (e.g., the Chinese 'sponge cities' initiative; Yu, 2018; Turenscape, 2023).
These considerations provide a relevant background. However, no models can be directly transferred from one setting to another.

A 'becoming amphibious' setting

When working on a specific context – namely that of the Upper Adriatic – careful attention is required to understand its precise characteristics and transformation dynamics. Relevant planning and design issues for coastal zones at risk, as well as their specific challenges, need to be addressed: the identification of key water and land economies; strategies for intervening in mechanically drained agricultural areas, whose survival is increasingly linked to higher energy costs and significant environmental impacts; the definition of interventions to ensure accessibility to and between residential, tourist, and productive spaces, collective facilities, and services; and the maintenance and retrofitting of infrastructure networks (e.g., for mobility, fresh water supply, and energy).
According to this, reading the territory was the first step undertaken by RT4. From the perspective of settlement morphology, the coast stretching from the Gulf of Trieste to the Po River can be divided into four main sectors: the Trieste and Gorizia Karst and its high coasts, unfolding from the border with Slovenia to

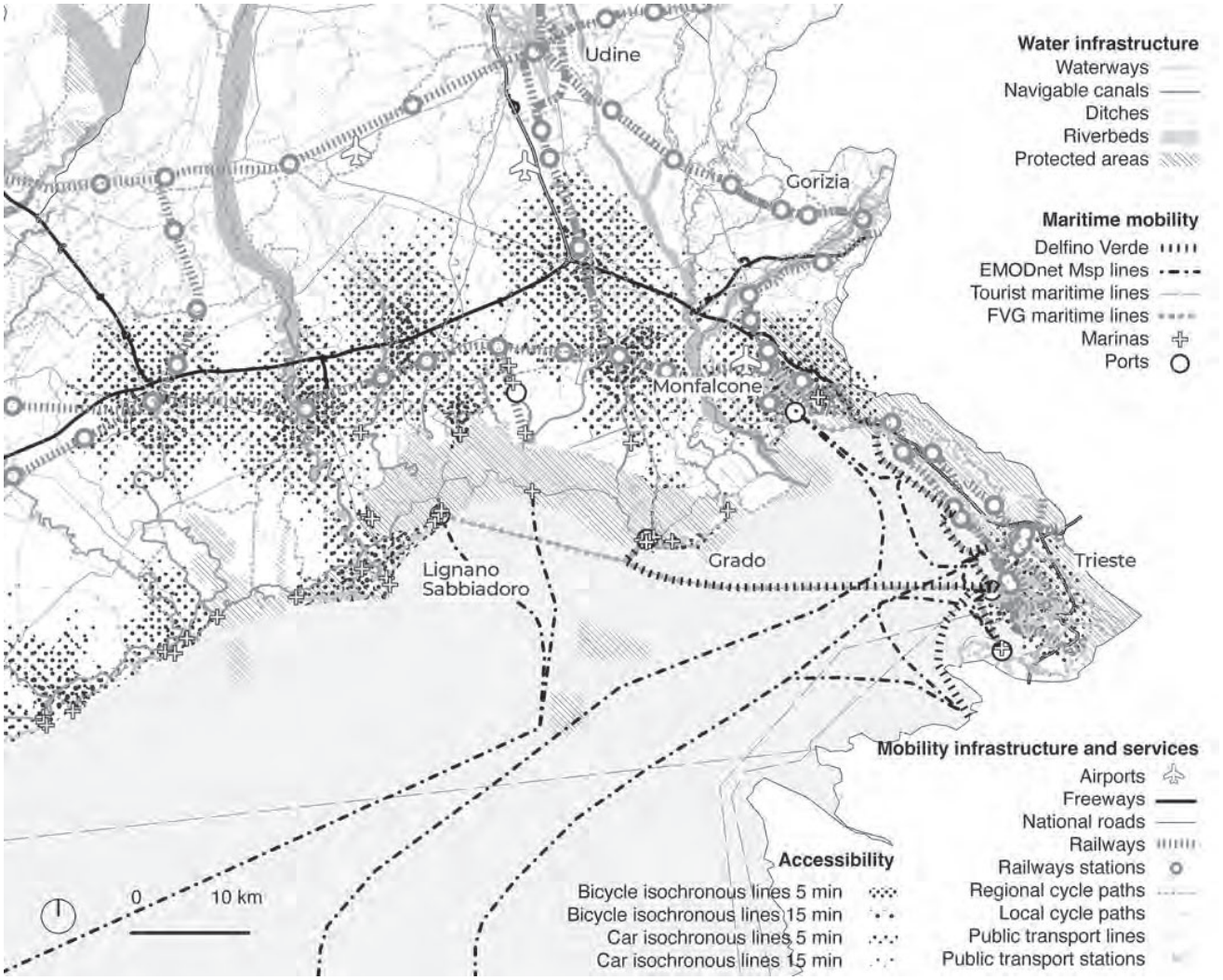


4. North Adriatic, lagoons and wetlands between Ravenna and Grado (Anonymous, 1434).
Source: Archivio di Stato di Venezia, Miscellanea Mappe.



5. North Adriatic, territorial framework and climate change (the focus is on the case study area within sector B). The grey surface represents areas located between -5 meters below and +1.4 meters above sea level. By 2100, these areas will be the most affected by sea level rise, according to the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports (particularly AR5) for the RCP-8.5 scenario (IPCC, 2013).
Source: visual elaboration by UNITS (Ludovico Centis and Federico Vascotto) of datasets collected by Iuav.

the Timavo River mouths (A); the low plains and the wetlands from Monfalcone to Jesolo and Cavallino (B); the coastal areas belonging to the polycentric urban network between Venezia, Treviso and Padova (C); the Po River delta (D) (fig. 2).
Within this framework, RT4 specifically refers to the territories overlooking the Upper Adriatic, largely belonging to the Friuli Venezia Giulia region. The focus is on the northern part of the sector (B), which is crossed by a sequence of rivers running perpendicular to the sea. These areas are understood as a 'deep' spatial strip, intersected by the Tagliamento and Timavo rivers, extending from the coast through the reclaimed lands facing the Marano and Grado lagoon, up to the Venezia-Trieste railway and the A4 motorway which run parallel to the sea at a distance of 20 to 40 km. Following the main river branches, secondary roads design a 'comb' system that connects inland and coastal areas.
All over the year, this constrained portion of territory is crowded with movements, activities, and economies converging on several key infrastructural nodes, as well as urban and industrial hubs located along the waterfront and in the nearby hinterland (fig. 3). The strongly 'urbanised' character (Couling, Hein, 2020) of the Upper Adriatic exacerbate incompatibilities with the presence of complex ecological habitats and dynamics. In the summer season, due to the presence of marine and cultural tourist destinations (e.g., Lignano Sabbiadoro, Grado and Aquileia), the road system is affected by traffic congestion. While river and sea mobilities are still limited to recreational boating, maritime



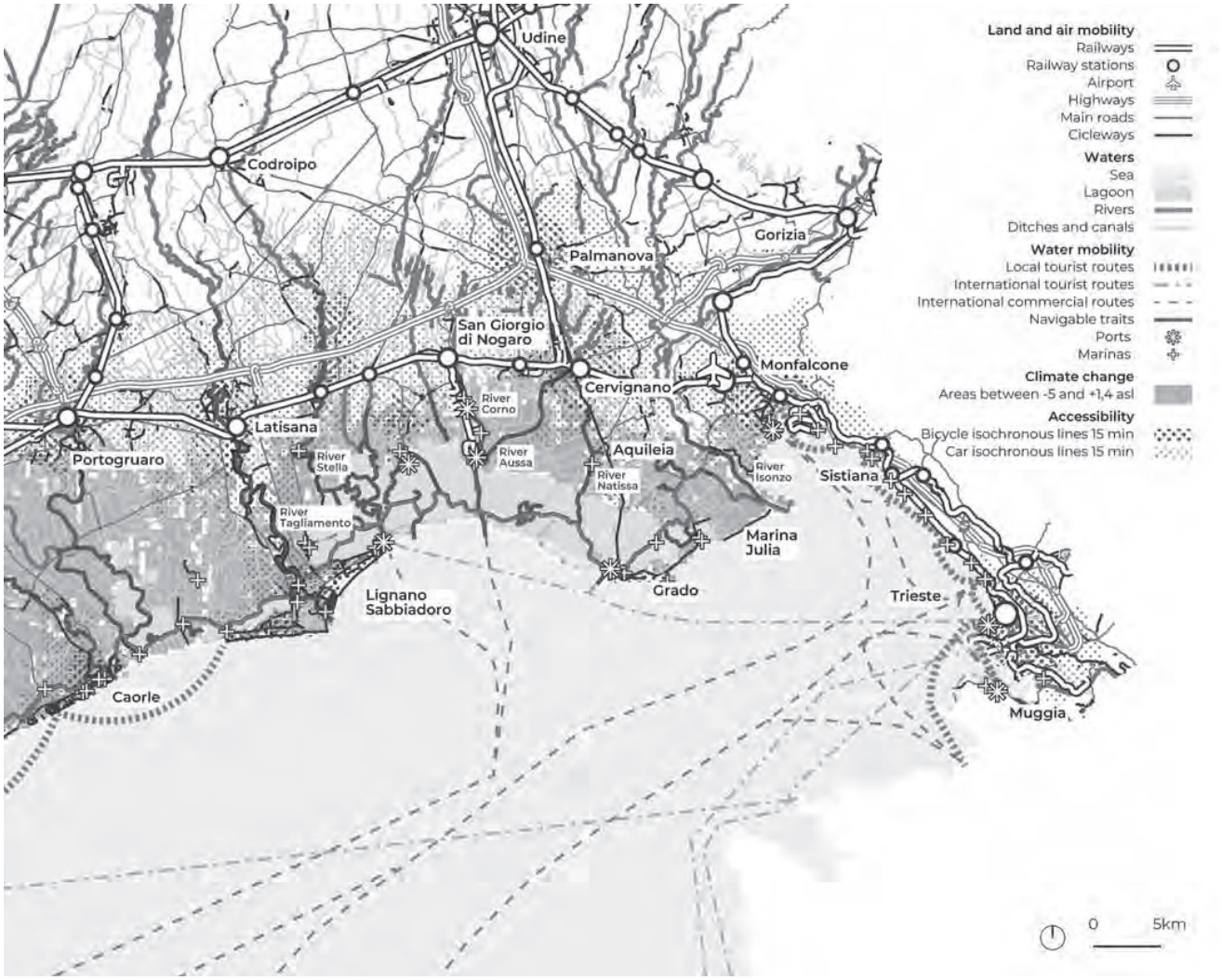
6. Upper Adriatic, water infrastructure and potential for land sea-interaction. The map illustrates various degrees of accessibility to water infrastructure, river, and maritime networks in relation to bicycle and car transportation. Source: visual elaboration by UNITS (Ludovico Centis and Federico Vascotto) of datasets collected by Iuav.

public transport services are largely insufficient to provide a viable alternative to the use of private cars.

Moreover, the coastal strip is acquiring 'viscosity'. As in the entire North Adriatic region, here land and water have historically interpenetrated (fig. 4). However, the survival of significant landscape and environmental resources along with their networks, as well as of socially and economically relevant settlement systems, are endangered by changing hydrogeological balances, significant risks, and pressures stemming from the impacts of climate change and human activities. At the same time, accessibility to the seafront is dramatically threatened. In the coming decades, the North Adriatic is expected to be one of the regions in Europe most affected by sea level rise (Antonioli *et al.*, 2017) (fig. 5). Coastal areas are therefore likely to become increasingly unstable, characterised by shifting spatial patterns across water, mud, and land, and by growing vulnerabilities and conflicts among different uses and functions.

The lack of integrated sea-land and climate adaptation visions and plans

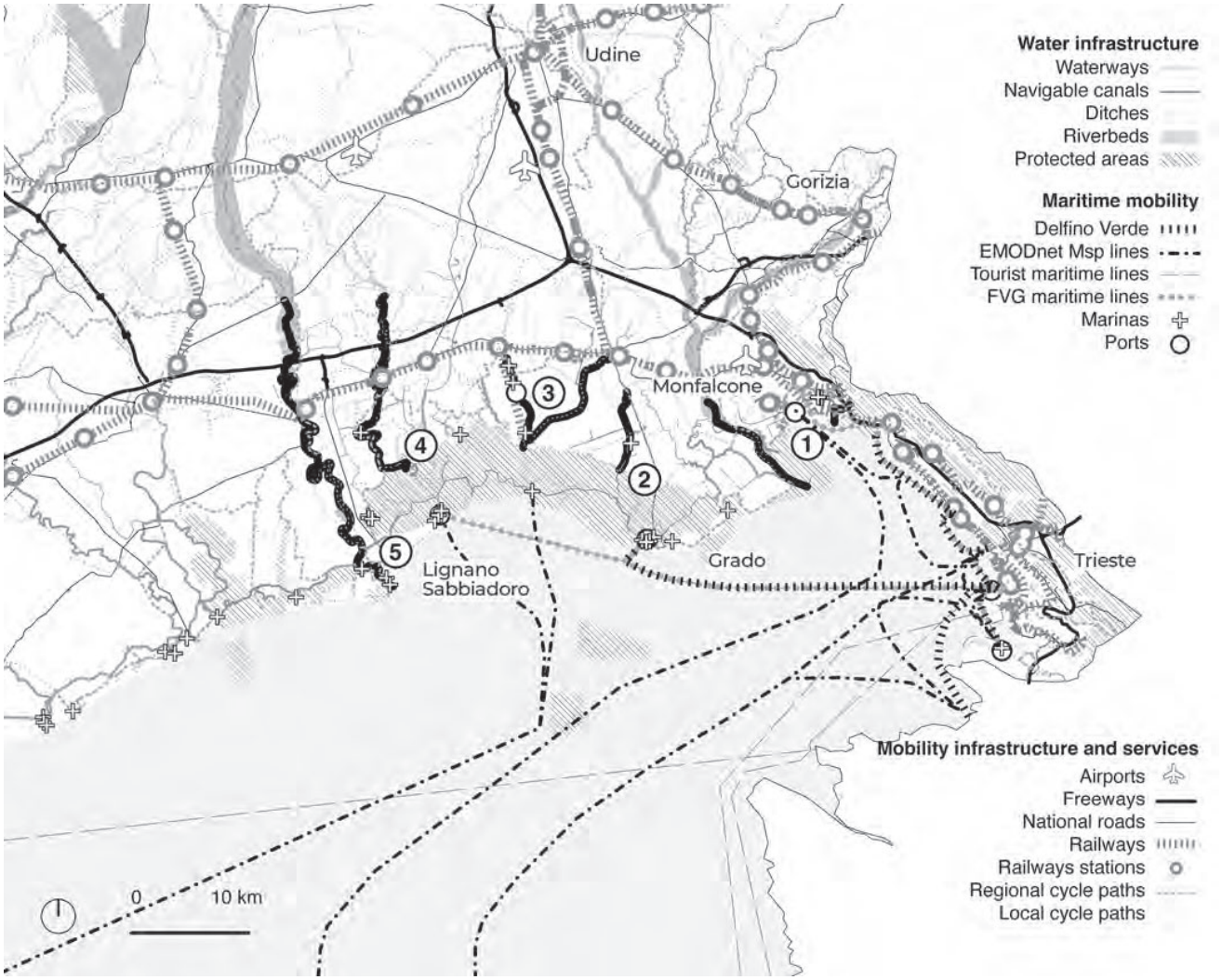
The impacts of climate change will, in fact, lead to drastic transformations in the way sea-inner waters-land interfaces operate. The reference is not only to sea level rise, variability of river flow, and the risk of floods, but also to the availability of fresh water during periods of drought and to the intrusion of the salt wedge. In particular, ongoing variations in rainfall



7. Upper Adriatic, potential for land sea-interaction and the impacts of climate change. The map shows the areas with the highest potential for land sea-interaction, which will be the most affected by sea level rise (based on IPCC AR5 for the RCP-8.5 scenario) (IPCC, 2013).
Source: visual elaboration by UNITS (Ludovico Centis and Federico Vascotto) of datasets collected by Iuav.

patterns will increasingly affect the availability of water resources for industry and agriculture, exacerbating already critical conditions due to the lack of rationalised groundwater extraction and the continued progression of subsidence. Transition is underway, and needs to be planned for.

A second group of RT4 activities focused on investigating the spatial planning tools and management strategies conceptualised or implemented for the Upper Adriatic Italian regions. The picture is one of a heterogeneous collection of instruments and strategies, studies and projects, pertaining to a similarly varied range of government levels and actors (national, regional, local), themes, and spatial and operational fields. Strong is the persistence of sectoral approaches, as well as the lack of an overarching vision capable of addressing the complex interactions between multiple factors and dynamics. For several years now, also thanks to the participation in European cross-border cooperation projects such as *AdriaClim* (Interreg Italy-Croatia, 2021-23; ARPA FVG, 2023), the Autonomous Region Friuli Venezia Giulia (specifically, the Regional Agency for Environmental Protection – ARPA FVG) has been working on developing analytical frameworks based on the scenarios created by the Intergovernmental Panel on Climate Change (IPCC). These studies highlight the risks and the various effects associated with climate transition (ARPA FVG, 2018, 2023). However, their integration into territorial policies is slow; their role remains limited to providing general guidelines



8. Upper Adriatic, river courses with the greatest potential for the integration of mobility, sustainable land-sea logistics, and climate change adaptation. 1) Isonzo; 2) Natissa; 3) Corno and Aussa; 4) Stella; 5) Tagliamento. Source: visual elaboration by UNITS (Ludovico Centis and Federico Vascotto) of datasets collected by Iuav.

and objectives within the Regional Strategy for Sustainable Development, delivered in 2023 (Regione Autonoma Friuli Venezia Giulia, 2023), while no specific regional strategy on climate adaptation has yet been approved.

With regard to soft and sustainable movements, significant deficiencies in the infrastructural network are highlighted by the recently approved Regional Cycling Mobility Plan (PREMOCI), which also emphasises water-inland transport (Regione Autonoma Friuli Venezia Giulia, 2022). Over the past few years, attention to this issue has been increasing, particularly in light of the impacts of the fires that devastated large areas of woodland in the Gorizia Karst during the summer 2022. In that context, the prolonged closure of the A4 motorway severely disrupted daily mobility to and from the coast, and the attempt to shift transport from road to sea highlighted the limitations of a service that was primarily designed for summer tourism. In this scattered array of regional studies and tools, the recently approved Maritime Space Management Plan for the 'Adriatico' Area (MSMPA; Ministero delle Infrastrutture e dei Trasporti, 2024) and its policy measures overlap with another level of recommendations. The main objective of MSMPA is to govern the often-conflicting and multi-scalar interactions between the sea uses, their impacts on inland environmental assets, and various decision-making levels (Ramieri *et al.*, 2024). However, despite its sound theoretical aims, the approach remains largely functional in nature, leading to the definition

of large-scale zoning. In Friuli Venezia Giulia, the task that a new Regional Territorial Plan (the current one dates back to 1978) and the Regional Landscape Plan approved in 2018 (Regione Autonoma Friuli Venezia Giulia, 2024) will soon have to fulfil is, therefore, to spatialise MSMPA's general guidelines according to the different marine and coastal situations and their specific vulnerabilities.

The difficulties in building synergies between individual programs and actions, and in upscaling them up to regular planning practices, are the reasons why integrated sea-land spatial planning in Friuli Venezia Giulia still remains confined to the realm of exceptional practices developed voluntarily by groups of municipal administrations and local public bodies. This is the case with two initiatives. The first is the Cormor River Contract, whose Statement of Intent was signed in 2019 between the Region and 25 municipalities (Marchigiani, Cigalotto, 2019), with official approval granted only in 2024. The second is the Wetland Contract for the Marano and Grado Lagoon System, developed through the *CREW* project, funded by the Interreg Italy-Croatia program 2014-2020. The Statement of Intent for this contract was signed in 2021 (Comunità Riviera Friulana, 2021), and it is still awaiting formal implementation. Despite the fragmentation and continuous stop-and-go nature characterising these processes, an initial round of consultations with the actors reached out by INEST (e.g., municipalities, reclamation consortia, third-sector associations) provided valuable insights. What the meetings and interviews organised by the RT4 team highlighted is the ability of these initiatives not only to build networks of local actors but also to actively engage them in securing EU funding and in integrating various fields of intervention: environmental protection, coastal area defence and erosion mitigation, and the creation of services and infrastructures aimed at promoting new forms of multimodal and sustainable water-land mobility.

Transect planning: towards integrated mobility and beyond

In order to investigate current and future trends and explore ways to address them through planning, RT4 carried out extensive mapping activities based on the spatialisation and integration of a wide range of institutional and open-source data concerning the location and distribution of: i) main polarities and routes of inland private and public transport systems, focusing on different mobility modes, their seasonal use, and accessibility (e.g., through the design of isochrones); ii) nodes of commercial maritime mobility and sea public transport systems; iii) nodes and services for tourist shipping (marinas) along the coast and the rivers (fig. 6).

By pairing these analyses with a spatialised and quantitative appraisal of sea level rise and other impacts of climate change in the coastal areas of the Upper Adriatic and the Friuli Venezia Giulia region (fig. 7), factors such as navigability of sea and inner waters, proximity to regional and national transport infrastructure (railways, motorways, cycle paths, ports and marinas), and location of areas of environmental interest and key tourist attractions were jointly assessed. This approach helped identify some river courses with significant potential to support land-sea interaction and serve as large-scale structural and mobility connections. Apart from the Gulf of Trieste, where the Karst geographical features and the limited presence of watercourses restrict intra-modal connections to a narrow sea-coast interface, five inland waterways and their corresponding territorial 'transects' were specifically identified, providing insights into different topics, spatial and socio-economic conditions, and related planning issues (fig. 8). The assumption is that, by focusing on these areas, climate transition plans and projects integrating various transport modes can be strategically implemented in the next future.

Transect planning is another long-standing concept. Originally used to investigate complex sequences of landscapes, human settlements, and natural ecosystems, it has more recently been applied to the re-design of sea-land interactions from a climate resilient perspective (Han, 2021; Innocenti, Musco, 2023). In the context of RT4 activities, transect planning has proven to be particularly useful in bridging the gap between different and still sectoral tools and approaches: on one hand, as already mentioned, those of Maritime Spatial Planning, Integrated Coastal Zone Management, and Climate Adaptation; on the other hand, those related to Flood Risk Management and the river basin-scale planning required by the EU directives on 'water policy' and 'flood risks' (European Parliament and the Council, 2007, 2020).

Specifically, the first identified transect refers to the Isonzo river and the canals built from the early twentieth century as part of the reclamation works implemented during the Fascist regime. Here the conurbation of Monfalcone is characterised by the co-presence of agricultural crops, leisure facilities, and large port and logistics areas, which are in close contact (and conflict) with wetlands and fragile environmental reserves and hotspots. Proceeding westward, the Natissa river is a relatively short watercourse, stretching for 15 km from the lowlands to the eastern side of the Marano and Grado lagoon. It connects important historical and tourist attractions: Aquileia, located on the mainland and listed as a UNESCO World Heritage site; the lagoon; and the island of Grado, an ancient maritime port and now a popular seaside destination. The third transect is structured around the Corno and Aussa rivers, both of which flow into the lagoon. The first river provides a connection to the logistic and industrial zone of Porto Nogaro. The second splits into two branches: one passes through Torviscosa (a city founded during the Fascist era), while the other reaches the inland intramodal hub of Cervignano. The area of land between the Corno and Aussa rivers is particularly vulnerable to severe flooding and suffers from high levels of pollution due to intensive industrial activity over the past century. Approaching the western borders of the lagoon, the 45 km-long resurgence Stella river, since Roman times, has been an important communication route for intra-lagoon transport towards the plains. Today, its shores are recognised for their significant ecological value, and are only occasionally punctuated by economic activities, ranging from aquaculture to small marinas. Finally, the Tagliamento river stretches nearly 180 km from the mountains to the Adriatic Sea. For most of its length, its course remains largely unaltered by human intervention, except for embankments that protect the reclaimed rural areas along its lower stretch. On both sides of the Tagliamento's mouth there are popular seaside destinations, such as Lignano Sabbiadoro and Bibione; they boomed during the twentieth century and now experience intense activity during the summer months.

Building on this framework, ongoing research activities use the five rivers and their spatial transects as pilot contexts, with the aim of developing scenarios and planning visions for the conservation and enhancement of economies, environments, landscapes, settlements, and cultural heritage in the Upper Adriatic coastal areas. Adopting the recent EU regulation on «Nature Restoration» as a key reference, along with its holistic perspective and integrated measures for «terrestrial, coastal and freshwater ecosystems» (European Parliament and the Council, 2024), RT4 methods and tools follow a 'research by design' approach. Specifically, an urban planning laboratory held at UNITS during the 2023-24 academic year and a master-class involving INEST researchers and PhD students, organised in September 2024, facilitated both discussions with local administrations and the study of specific short-, medium- and long-term actions for the territorial regeneration and climate transition of each transect.

Although the investigations carried out so far focus on the Italian side, the intent is to use this work as a prototype that can also be applied to other territories, extending beyond regional and national borders. In fact, one of the main expected outputs of RT4 is the development of planning guidelines, understood as a set of recommendations, technical tools, good practices, and examples derived from place-based design and planning exploration. These guidelines aim to support local administrations in the following areas:

– reading and interpreting the conditions and potential for rethinking land and water mobility and accessibility in the context of climate transition (e.g., through integrated spatialised datasets and maps; methodologies for conducting site-specific analyses and assessing vulnerabilities and exposure to climate change impacts on environmental, cultural, and real estate values; approaches to organising participatory processes with stakeholders);

– defining priorities and strategic interventions, as well as integrating them into existing and new territorial plans and projects (e.g., through regulative tools; mapping funding opportunities; recommendations for building networks of public and private actors and resources);

– monitoring, assessing, and adapting strategies and solutions (e.g., through methodologies to evaluate the impacts of new transportation services on road traffic reduction, enhancement of touristic attractiveness, water and air pollution diminution, and adaptability to climate change).

The planning guidelines will technically translate a transitional and adaptive planning approach, based on continuous management and evaluation of results, and allowing for the re-focusing of actions to achieve specific goals and benchmarks. This work will also involve the organisation of further meetings with public administrations and local associations.

The added value of research and enterprises cross-fertilisation

Among the main issues highlighted by the activities developed so far by RT4 there are significant gaps in the current availability and integration of existing datasets. Many of these datasets are produced by different institutional sectors and bodies, with varying aims and spatial coverage. Moreover, their reliance on specific, time- and cost-demanding data collection campaigns often makes information outdated, thus preventing a real-time representation of the ongoing changes and effects of human activities and climate-related pressures and risks.

Supporting the production of new and dynamic knowledge and tools for the development of digital models (Digital Twins) for marine and coastal areas is precisely the aim of two rounds of cascade funding, promoted by Spoke 8 RT4 and addressed to enterprises based in the Triveneto and Southern Italy regions – the first round delivered in August 2023, and the second in May 2024 (the selection process for the latter will be closed by November 2024) (Consorzio INEST, 2024b).

In the framework of RT4 topics and activities, these calls for projects specifically focus on the development of tools using ICT and AI technologies, including: i) infrastructures and services for integrated public water-inland transport in the context of climate change (e.g., tools for registering seasonal changes in water flow and navigability of lagoons and rivers, organising intermodal hubs in emergency situations and/or in response to seasonal variability in accessibility to facilities, and managing on-demand services); instruments for forecasting climate and weather conditions, evaluating environmental changes, and monitoring the implementation of proposed infrastructures and services (e.g., focusing on the reduction of greenhouse gas emissions, hydraulic risks, pollution, and water and energy consumption, as well as on promoting biodiversity, green networks, economic transition, and the reorganisation of accessibility to facilities and services).

The two projects funded by the first call are particularly promising.[3] They open up new perspectives for developing tools that can effectively support innovation in transitional and adaptive spatial and mobility planning and design, as well as in the delivery of technical prototypes and pilot solutions. On one hand, the project proposed by a network of enterprises from Triveneto focuses on the Grado and Marano lagoon and its inland drainage basin.[4] Its goal is to deliver a technological platform for the systematic analysis of different environmental variables by integrating data collected from existing monitoring systems with satellite data and advanced AI-based processing models. On the other hand, the project funded by the South Italy call will develop a Collaborative Spatial Decision Support System (C-SDSS) as part of a Digital Twin prototype.[5] From a citizen science perspective, the aim of this project is to foster interactive and continuous co-production of knowledge and interpretation of spatial land-sea interactions, mobility perceptions and demands, and to integrate these processes into spatial planning and policy-making.

To conclude: some open issues

In recent years, there has been an increasing call for universities to take on strong responsibility in translating the goals of sustainable development into action – particularly those related to just, climate and green, digital and economic transitions (Marchigiani, Garofolo, 2023). In this context, the main challenge for Higher Education Institutions (HEIs) is to pair education and research with their so-called 'third mission'. With the overarching objective of contributing to societal welfare through dialogue and collaboration with social actors, public agencies, businesses, and other entities within a given

territory, the aim is to integrate the production of public goods with continuous technological transfer, knowledge valorisation, and exchange with economic enterprises. In this perspective, there has been growing demand for more active support in organising and developing participatory, co-planning, and co-implementation processes for open education and life-long learning, engaging local institutions and raising awareness within civil society. However, translating universities' role as powerful drivers of change into practice is a highly complex task, requiring a substantial reset in the ways they perform educational, research, and third mission activities both inside their institutional settings and in relation to external contexts and stakeholders. Spatial planning and design are inherently connected to social and policy-making dimensions; therefore, the challenges faced in these theoretical and operational fields are equally significant.

iNEST activities are still ongoing; nonetheless, they provide the opportunity to reflect on some of the issues raised by research practices within Innovation Ecosystems (IES).

First of all, strong investment in the internal organisation and training of HEIS' administrative and research staff is essential. In fact, assuming the role of expenditure centres, managing the delivery of cascade funding to economic enterprises, and assessing their outputs represents a new challenge for most of universities and research bodies. The difficulties encountered in the initial phases of iNEST clearly demonstrated that this role requires not only specific administrative expertise and dedicated governance structures but also innovative approaches to conducting technical and technological research. In this context, research must begin with a deeper understanding of the needs and potentials of economic, social, and institutional actors, as well as their operating rules and routines. If universities are to be prepared for new fields of study and action, rethinking their various levels of education and training is, therefore, a key issue to address.

As far as the topics of spatial planning central to RT4 activities are concerned (particularly those related to climate and territorial transitions), there is a need for the integration and synthesis of various approaches and tools: from the innovative and advanced use of GIS, ICT and AI in developing analysis and assessment methods and instruments, to the 'radicalisation' of design and planning hypotheses and solutions aimed at paving the way for a deep and comprehensive rethinking of ecological, economic, and social assets and lifestyles (Viganò, 2023). This is linked to the effort to cross-fertilise knowledge across different disciplines, whereas fostering effective collaboration between the various expertise and operational fields involved in Spoke 8 (particularly between those of SSH and STEM) remains a significant challenge that hampers the development of the Digital Twin. The gap between the demand for territorial planning and the available knowledge on spatial assets, climate trends and scenarios, biological and environmental dynamics, and the organisation of transportation and logistics facilities is considerable. However, building at least a catalogue of existing datasets, and identifying their potential for harmonisation and further elaboration is a necessary and strategic step. More structured synergies between the activities carried out by the different HEIS involved in iNEST and Spoke 8 should therefore be pursued.

Finally, the previous considerations highlight another equally important issue. In order to stabilise the interaction between HEIS, their territories, and stakeholders, and to foster innovative processes and products, continuity in commitment and the creation of long-lasting organisations are essential. Difficult and complex operations, such as those leading to the creation of IES, must extend beyond the duration of a single project. One major expected outcome is, in fact, the establishment of stable and place-based 'living-labs' understood as 'open innovation systems' (European Commission, 2016) and 'trading zones' (Sandberg *et al.*, 2015); that is, concrete spaces for interaction between the different cultures, know-hows, and purposes of public institutions, private actors, and citizens, as well as opportunities to share and co-create common values, goals, and technical/technological solutions. This is exactly the perspective iNEST is trying to put into practice, by transforming its consortium into an economically viable intermediary body, operating in-between HEIS and economic and social stakeholders – an entity with its own management, administrative, and research structure, specialised in knowledge creation and transfer to the local production *milieu*.

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Notes

1. Spoke 8 involves seven partners: four universities (Università di Trento, Università Iuav di Venezia, Università Ca' Foscari di Venezia, Università di Padova), a public research body (National Institute of Oceanography and Experimental Geophysics – OGS), a technology transfer body (Andrea Galvani North Adriatic Technological Pole), and a territorial partner (Port System Authority of the East Adriatic Sea).
2. RT4 is coordinated by Elena Marchigiani and sees the participation of a number of professors and researchers: Ludovico Centis, Stefano Graziani, Alvise Pagnacco, Federico Vascotto (UNITS); Francesco Musco, Maria Chiara Tosi, Daniele Brigolin, Sebastiano Fabbrini, Barbara Gasparini di Gaetano, Emanuel Giannotti, Davide Longato, Giulia Lucertini, Maria Manfroni, Denis Maragno, Vittore Negretto, Michela Pace, Nicola Romanato, Elisa Scattolin, Stefania Tonin, Luca Velo (Iuav).
3. Projects submitted to the second call have just passed the final evaluation process, and no meetings with RT4 team have been organised yet.
4. The project M.A.R.A.N.O. – *Monitoraggio Ambiente, Risorse Acquatiche e Nautica On-line Imprese* is coordinated by the enterprise T.E.R.R.A.
5. The project MERCIE – *Modelli Eco-sostenibili per Rigenerazioni urbane Collaborative Integrate e inclusive del sistema terra-mar*e is coordinated by the Università di Napoli Federico II (the PI is Michelangelo Russo) and sees the participation of the enterprise Digimat.

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