Chapter 3

Porosity

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Porosity

Introduction

The introduction to this thematic chapter sets the stage for presenting the concept of 'Porosity', and its eventual applications in current urban research issues, and then provides an overview of the four articles that contribute to the theme within the research agenda of the sos Climate Waterfront project.

Cities today are faced with rapid, unprecedented urbanization and the effects of climate change. The dynamic processes developed historically to help cities adapt to change cannot face the present complex urban realities. As a result, there is an urgent need for new strategic design agendas and conceptual design frameworks for viewing and knowing the city within the present condition. Specifically, waterfront areas and their communities are considered more vulnerable to the effects of climate change and extreme weather events due to their geomorphology and close relationship to water.

'Porosity' is viewed in this chapter as a conceptual framework for developing adaptation and mitigation strategies to tackle climate change, meaning the devastating ecological impacts of storms, floods, rising water levels, heat waves and droughts, while increasing urban resilience.

Exploring the Porosity concept

"Pore" (from Greek πόρος) means "a minute opening". "Porosity is the noun derived from the adjective porous. Something that is porous has many small holes, so liquid or air can pass through, especially slowly, i.e. porous soil with good drainage or porous brick walls or a porous polymer membrane"[1].The term 'Porosity' is originally used in biology, medicine and organic chemistry[2]. Alongside the concept of 'Porosity', literature has often discussed the concept of 'Permeability' and sometimes uses the two concepts interchangeably even though defined differently[3]. 'Porosity' refers to the extent or degree of being porous, while 'Permeability' measures the ease of flow through a porous object and not the extent of being porous[4].

The concept of 'Porosity' has been widely applied in various domains and disciplines such as, but not exclusively, material science, civil engineering and construction, architectural and urban design[5] [6] [7], hydrology[8], and soil mechanics[9]. Also, the concept has been used across disciplines, such as planning and physical design in various scales with an approach of blending architecture, biology, organic forms and processes providing productive conceptual frameworks that can be reinterpreted, producing new meaning and applications within a new context[10]. As an example of this kind of metaphoric application, Coates[11] describes environmental history as an interdisciplinary scientific endeavour and a receptive porous discipline because of its willingness and capacity to absorb the insights of other disciplines, both proximate and more distant, and to adopt and adapt their methods in developing knowledge.

In the architectural and urban discourse, the concept of porosity and the relative term of porous city relates to the discussion of boundaries, flows, interface, exchange, connectivity, fluidity and absorption, both in material and immaterial, tangible and intangible conditions[12] [13] [14] [15]. Hence, 'Porosity' constitutes "a fertile instrument in nourishing ideas, interpretations, and projects for the city and the territory"[16] usefully included in a broad lexicon of terms for understanding the social and spatial world literally and figuratively[17].

'Porosity' has thus provided a resourceful theoretical foundation for novel approaches of the urban environment to mitigate the devastating effects of climate change[18]. The cross-disciplines applications of 'Porosity' for the study and design of the territory - across architecture, urban design, landscape design, urban planning, landscape urbanism, environmental planning, infrastructure design, water management[19], etc., is key for the development of holistic design strategies and governance policies in order to achieve a high degree of urban resilience. Such strategies seek to produce effective solutions that combine complex parameters from all scales of urban space, while at the same time activating numerous urban actors and agents and taking into consideration multiple temporalities — histories and records — for the creation, evaluation and adjustment of proposed urban models.

In fact, relevant literature on 'Porosity' within the urban agenda refers to various types of interchanges in the anthropogenic and natural realm. Physical, functional, social, and ecological porosity refer to different types of urban interactions and provide valuable tools to analyze and reorganize urban flows, dynamics and transformations with regards to sustainability and resilience issues[20] [21] [22]. 'Porosity' can also be conceptually applied to open governance and bottom-up, participatory policies as it characterizes the flows of communication between decision-makers, stakeholders, citizens and specialists involved in the strategic planning processes against the climatic crisis. Moreover, in the fast-growing digital realm the notion of ‘Porosity’ is associated with flows of information and data across disciplines and across regions that are required for tackling the challenges of climate change. Updated information flows are crucial for the management and efficiency of technologically advanced systems that operate in contemporary smart cities projects and for the accuracy and diffusion of meteorological models that provide the basis for all urban adjustment and reorganization in regard to climate change.

Overview of the Thematic Chapter

The following chapter brings together several veteran scholars from diverse disciplines — Geology and Climatology, Hydraulics and Environmental Engineering, Urban and Regional Planning, Urban and Architectural Design — mainly from academic and non-academic institutions. Their research papers explore a range of issues, focusing on understanding the climate change processes across spatial scales. Their contributions aim at developing inclusive, integrated adaptation strategies to climate change for vulnerable, urban waterfronts.

The paper by P. Tarani and S. Tsoumalakos introduces the concept of Porosity as a critical parameter in the environmental planning of cities in regard to climate change while providing a short literature review on this issue. Departing from this theoretical perspective, it argues that we should consider the emergence of a new “water geography” as a dynamic, hybrid, ecosystem paths’ network within the city, well-connected to its natural elements. This approach provides new key aspects for policymakers and planners, particularly as urban sustainability, resilience, and environmental crisis increasingly reshape metropolitan areas and pinpoint a need to consider these topics yet further. Water geography plays a crucial role in shaping the ecological functions of an urban area, and in this case that of the city of Thessaloniki. Elements such as the minimization of impervious surfaces, the enhancement of urban porosity, and the best management practices of rainwater, can contribute effectively to the preservation of the existing ecosystems and the formation of new ones.

The paper by M. Lazoglou, K. Serraos and G. Spiliopoulou stresses that adaptation strategies to climate change should be inclusive, integrated, and designed locally to the needs, requirements, and characteristics of each area. They emphasize the necessity of broad public participation for developing a new urban planning project. The paper refers to the case of ‘Mati’, in the Attica Region in Greece, an area that was developed outside the formal planning system and severely affected by a great fire that broke out in July 2018. It highlights the significant connection between the national and regional adaptation strategies to climate change and local spatial planning initiatives and examines the citizens' engagement during this process. The paper's objective is to bring attention to the connection between the already-established climate change adaptation strategies and local-level spatial planning initiatives in Greece. The research also explores whether communication of critical issues and information flow between decision makers and relevant stakeholders is adequate for ensuring an inclusive new urban plan, to mitigate and overcome the consequences of climate change.

The paper by S. Leontiadou focuses on urban porosity and criticizes the common soil sealing practices of waterfront sites in the Greek context, arguing for an environmental urban design approach that promotes porous and earthly surfaces. Leontiadou argues that this is particularly important for Greece, the country with the longest coastline in Europe, facing a high risk of urban flooding and sea level rise, while suffering considerable biodiversity loss. The article discusses various precedents of implementation of soft surfaces in projects in Sweden, UK, Netherlands, and Germany that can inspire initiatives in Greece towards urban transition for a more sustainable environmental planning approach in waterfront sites. Considering the general lack of urban greenways in the dense Greek cities' fabric, sustainable waterfront zones offer a valuable opportunity for the environmental upgrade of Greek cities, as well as the general well-being and living conditions of their inhabitants.

The paper by P. Zanis and K. Tolika argues for the need to reduce uncertainty and enhance the reliability of meteorological and climate data at regional/local level and understand the climate change processes. Improved reliability allows the assessment of the projected impacts of climate change risks on the environment and society. In doing so, the article aspires to develop modeling methods that combine climate change data and observations at the global level using Global Climate Models (GCMs) and Regional Climate Models (RCMs) to monitor the climate change processes and impacts at the regional and local levels. Even though the concept of porosity is not clearly spoken out, it is embedded in the processes of data exchange, dynamics and information/data flows between the global and regional/local scales to enhance our knowledge and understanding in designing plans and strategies for risk absorption.

Notes

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Water Geography: Defining New Ecosystem Patterns in the Thessaloniki Metropolitan Area

Introduction

Thessaloniki's urban body sprawls around an arc of coastline at the top of the Thermaic Gulf. A major spatial characteristic of the city's metropolitan area is the extent and multifunctional coastal line connecting the various urban activities, most of them of regional and national importance, such as the Axios River Delta (Natura area), the Thessaloniki Port, and the Macedonia Airport. With a more than 40 km length, Thessaloniki's shoreline is the city's major geographic and urban feature. We must also acknowledge the allusive structure of the many transverse streams that flowed into the sea and were absorbed by the corresponding urban grid that replaced them. Today, the city's extensive marine zone and the remaining streams are both natural ecosystems and hosts sheltering life, thus acting as a "bridge" between the technical and the natural "body" of the city.

In urban areas, streams are the main recipient of most of the pressures resulting from urban sprawl and its accompanying functions. Degradation of water quality, restriction of the riverbed, and often the transformation of the stream, into a closed underground conduit, are some of the pressures that streams can be subjected to, from the urban environment. In this context, it is very common for streams to be cut off from their natural environment, which leads to changes in the functioning of this natural ecosystem and the individual ecosystems that have developed within them. Human intervention is crucial both in reversing this situation and in encouraging a redefinition of the role of streams in urban areas. Urban streams can be seen as transitional areas where novel and hybrid ecosystems can be created.

The streams in the Conurbation of Thessaloniki have undergone significant changes and, over time, large parts of them have been transformed into closed underground conduits. Therefore, the picture that most streams present is one of partial preservation of the original bed at a specific point and the emergence of new, hybrid, local ecosystems. These ecosystems retain some of the original elements of the stream and they also try to adapt to the new situation and the constraints created by the built environment.

This paper argues that we should consider the emergence of a new "water geography" as a dynamic, hybrid, ecosystem paths' network within the city well-connected to its natural elements.

This approach provides new key aspects for policymakers and planners, particularly as urban sustainability, resilience, and environmental crisis increasingly reshape metropolitan cities and pinpoint a need to consider these topics yet further.

Water geography and the porous city concept
1. Water geography and the 'Porous' city concept – origins and concept evolution

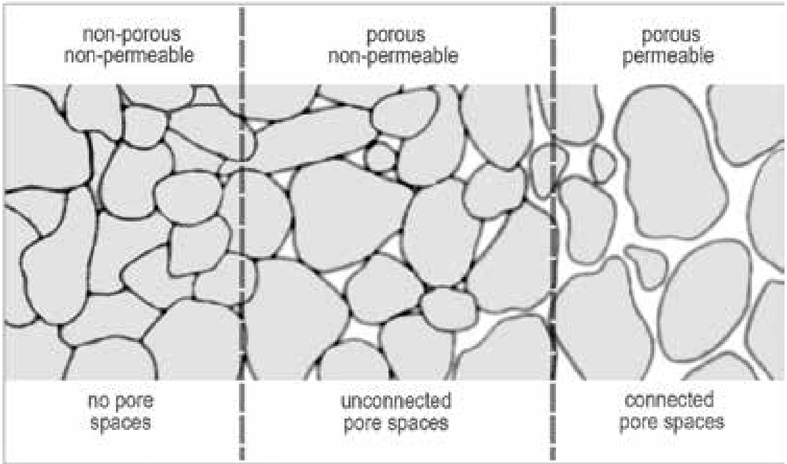
Creating urban spaces that allow the free flow and penetration of water and other natural elements is essential to the survival of contemporary cities in times of climate change. 'Porosity' can be understood in this context as a city's capacity to adapt to the natural flow of water, focusing on fluidity and flexibility as essential mechanisms of climate adaptability — elements often neglected in urban development. Breathable void and healthy pore structures, allowing for the flow and penetration of water and other natural values, are thus key necessities[3].

We owe the use of the term 'Porosity' for urban issues to Walter Benjamin and Asja Lacis. They used a term that originated in earth science and construction with reference to Naples' urban characteristics. They observed that the city of Naples had a unique quality of spatial and social interconnectedness, where various spaces merged into each other, and the boundaries between different areas were fluid. According to Benjamin and Lacis, this 'Porosity' gave rise to a sense of improvisation and unpredictability in the city's everyday life. The streets, squares, and other public spaces in Naples provided the backdrop for spontaneous encounters, chance encounters, and unforeseen events. This idea of 'Porosity' highlighted the dynamic nature of urban life and the potential for unexpected interactions and experiences[4].

In contemporary discourse, the term 'Porosity' is increasingly used conceptually to describe urban environments that exhibit similar characteristics. It refers to spaces that are open, permeable, and characterized by a fluidity of boundaries.

In this sense, 'Porosity' has become a theoretical framework for understanding and analyzing urban environments. It suggests a departure from rigid spatial divisions and encourages the exploration of more fluid and dynamic urban designs that foster social cohesion and spontaneous encounters.

Because of the term's "messy flexibility" that referred to various current issues as social interaction, inclusivity, sustainability and more, it is not surprising that it has been taken up more recently, now valued by architects and urban planners as an urban practice



dealing with the urban resilience to climate change[5]. In the early 00's, in Paris, during the discussion of the strategic plan of the Grant Paris, Bernard Secchi and Paolo Vigano (Studio 09) introduced the proposal to rethink Paris as an environmentally sustainable and porous metropolis[6].

More recently, the Bangkok based 'Porous City Network' works to make the city porous by transforming underused impervious surfaces into a system of productive public green spaces, and advocates maintaining threatened landscape infrastructure like agricultural land, canals, and ditch orchards, which help mitigate excess water[7].

Porosity is therefore an essential property of spatial boundaries, which is always present in nature and landscape, and ensures that separate landscape units are connected to each other and to the environment[8].

Various researchers, alongside the term of 'Porosity', referred also to the term of 'Permeability'. 'Porosity' and 'Permeability' are two interconnected, yet different terms used to describe soil properties related to water and air flows [Figure 102].

Porosity refers to the volume of pore spaces or voids in a soil or sediment. These pore spaces can be filled with air or water. Porosity is a measure of how much water a soil can hold and how well it can retain and transmit water. Soils with high porosity have more pore spaces and can hold more water.

Permeability refers to the ability of a soil to transmit water or other fluids through its pore spaces. It describes the rate at which water can move through a soil. Permeability depends on the size, shape, and connectivity of the soil pores. Soils with high

Figure 101: Relation between porosity and permeability, based on a microscopic view of sandstones ranging from very low permeability rock to high permeability rock. (credits: UC Denver)

permeability allow water to flow through quickly, while soils with low permeability have restricted water movement.

Understanding the porosity and permeability of soils is crucial in various applications, including agriculture, engineering, and environmental management. It helps determine water availability for plants, groundwater recharge rates, drainage capabilities, and potential for water pollution. Proper soil management practices, such as adding organic matter, improving soil structure, and preventing compaction, can enhance both porosity and permeability, promoting healthy soil conditions and sustainable land use.

2. Water geography and ecosystem functions

Water geography and ecosystem functions are interconnected concepts that relate to the role of water in shaping and influencing ecological processes and functions within the overall urban ecosystem. Water geography refers to the spatial distribution, movement, and interactions of water bodies, such as rivers, lakes, wetlands, and oceans, within a specific geographic area. Ecosystem functions, on the other hand, capture the role that water and vegetation within or nearby the built environment play in delivering ecosystem services[9] at different spatial scales (building, street, neighborhood, and region). It includes all "green-blue spaces" that may be found in urban and peri-urban areas[10].

Water geography plays a crucial role in shaping the ecological functions of an ecosystem. Here are some key points of their relationship:

Hydrological Cycle: Water geography influences the movement and availability of water resources within an ecosystem. Precipitation, surface runoff, groundwater flow, and evaporation are all part of the hydrological cycle, which affects water availability for plants, animals, and other organisms. The spatial arrangement of water bodies determines the pathways of water flow and its distribution across the landscape.

Nutrient Cycling: Water acts as a medium for nutrient transport within ecosystems. In aquatic systems, water bodies serve as conduits for the movement of nutrients like nitrogen and phosphorus, which are essential for plant growth. Water geography determines the connectivity between different water bodies, allowing for the exchange of nutrients and supporting ecosystem productivity.

Habitat and Biodiversity: Water geography plays a significant role in providing diverse habitats for various organisms. Different water bodies offer distinct ecological niches that support a wide range of plant and animal species. Wetlands, for example, are highly productive ecosystems that serve as nurseries for many species, provide habitat for migratory birds, and offer unique ecological functions such as water purification and flood mitigation.

Ecosystem Services: Water bodies and their geography provide numerous ecosystem services that are vital for human well-being. These services include water supply for drinking, irrigation, and industrial purposes, as well as recreational opportunities, tourism, and cultural values. Water geography influences the availability and quality of these services within a given region.

Climate Regulation: Water bodies, especially large water masses like oceans, influence climate patterns and help regulate temperature and weather systems. They act as heat sinks and can modify local climatic conditions, affecting precipitation patterns and wind regimes.

Understanding the relationship between water geography and ecosystem functions is crucial for effective water resource management, conservation efforts, and sustainable development. It allows for the identification of key areas for biodiversity conservation, the assessment of ecosystem vulnerability to climate change and human activities, and the development of strategies to maintain the integrity and functioning of aquatic ecosystems.

3. The role of streams for urban porosity and climate adaptation

Streams in urban areas today have acquired a particularly important role, which is composed of individual elements. Avoiding flooding, maintaining ecological balance and aesthetic improvement are some of these elements, which are inextricably linked to each other. However, streams are constantly becoming the recipients of the negative impact of urban expansion and human activities, which are often to the detriment of the streams[11]. Therefore, the urban or built environment can cause significant alterations or damage to the streams running through it. More specifically, alterations can occur in a stream's geomorphology, and in its hydrological and biochemical characteristics. Alterations or even permanent damage can also occur to the ecosystems maintained within it[12]. It is worth noting that another factor that is involved in the changes occurring in urban streams is climate change[13].

Within this context, a concept that has been used in recent years, in international literature, is the "urban stream syndrome". This term is often used to describe the consistent ecological degradation of streams that drain away from urban areas[14]. Several interrelated elements contribute to this degradation. The link which connects all the aforementioned is the change that is observed in the hydrological characteristics of a stream. In a fully urbanized catchment, where impervious surfaces — as opposed to natural soil

— predominate, the amount of water discharged into the stream can increase significantly[15]. This is often the case for the following three main reasons:

1. Due to the inability of the local drainage network to respond promptly and to remove rainwater from the road network, which eventually ends up in the streams.
2. Because of the predominance of grey infrastructure over green-blue infrastructure in urban areas, this does not allow for the retention and absorption of some of the rainwater.
3. And, finally, because of a combination of the two aforementioned reasons.

Therefore, in order for the stream to be able to meet the ever-increasing hydraulic needs arising from the urban environment, it is subject to significant modifications related to the geometric characteristics of the stream bed (width and depth)[16]. These modifications are the result of human activity, and in some cases, the modifications are so severe that the original natural stream eventually becomes an artificial drainage ditch, where the natural environment is often absent.

As a corollary to the aforementioned, another element contributing to the degradation of a stream is the replacement of the natural soil, both in the stream bed and on the slopes, and its lining with concrete[17]. Very often, in fact, the phenomenon of the complete sealing of the stream bed with the use of impermeable single concrete surfaces is very common. In this case, several aspects of the stream are affected, both at stream bed level and on the banks or slopes of the stream[18]. In particular, due to the waterproofing of the bed, the problems observed are: an increase in the flow and velocity of the stream water, an inability to absorb and filter some of the water, a degradation of water quality, an inability to retain sediment, and a destruction of the habitat of many native aquatic organisms (plants and animals). Similarly, on the banks and slopes of the stream with the application of impermeable materials, the problems that arise are: an inability to retain vegetation and animal organisms, an inability to retain and filter incoming water to the stream, a restriction of access to the stream bed. On this basis, the ecosystems that depend on streams in cities are significantly burdened and disturbed[19].

At this point it is useful to refer to another term, “hybrid ecosystems”. Hybrid ecosystems are related to the concept of the ‘urban stream syndrome’ and can be considered a subset of it. According to Hobbs et al[20], the distinction between the two is that in the case of the hybrid ecosystem, the stream, and therefore its ecosystem, experience changes that go beyond the expected — historically — range of variability, yet it still retains, to a significant extent, the elements of the original system. In other words, it can be described as a stage where there is a shift from the initial 'equilibrium state' of the ecosystem, but without alterations that are not yet reversible[21].

The situation is slightly different when the original natural stream is undergrounded in its entirety and becomes a closed drainage pipeline. In this case, most of the benefits that the presence of a stream provided in a city, as well as the ecosystems that had developed in it, are lost. This is because the stream loses its physical appearance and becomes a closed drainage conduit. The loss of the natural ecosystems that accompanied the original surface course of the stream is a major factor for the stream. In the past, no matter how many times an attempt had been made to uncover a stream and restore it to its original form, only partial recovery of its natural ecosystem had occurred. The reason is that the ecosystems that develop in a stream are usually quite vulnerable to change, and in some cases, they are particularly difficult to restore[22]. The degradation of the ecosystems has resulted in the degradation of the streams in cities.

To reverse the phenomenon of ongoing stream degradation, new and ecologically sustainable practices have been developed, described as "novel ecosystems" or "sustainable hydrological solutions"[23]. These practices aim to restore natural hydrological water circulation, absorb water and improve water quality. Novel ecosystems often include the use of green-blue infrastructure, aimed at sustainable hydrology. Indeed, a combination of green and blue infrastructure is often used, both in the wider area of the stream and within the main body of the stream (bed, banks, and slopes). These systems help to restore the natural hydrological balance and reduce the problems associated with urban rainwater runoff, such as flooding, water pollution, and soil degradation.

The case of Thessaloniki

1. An urban form based on the water geography

With a total length of more than 40 km, Thessaloniki's shoreline is the city's major geographic feature. It marks the end of Thermaikos Gulf, following its curve from the Axios River delta in the west to the coastal resort of Karabournou in the south. Its course has many, varied natural features, is full of history and is open to multitude of readings.

The extent multifunctional coastal line is one of the major spatial characteristics of the city's greater urban area, as it connects the various urban activities, most of them of regional and national importance (such as the City Port and the Airport).

The city sprawls around an arc of coastline of the Thermaikos Gulf. Thessaloniki's urban shape differs from other european cities that extend circularly around their historic center. Confined between its natural boundaries of Mount Chortiatis and the Thermaikos Gulf, the city has developed in a linear manner, having its activities arranged more or less in a line along its waterfront. A more careful observation of the urban hinterland will inevitably lead us to a butterfly pattern, whose skeleton consists of the public transport networks. The city does indeed seem to balance symmetrically along the sides of a central axis.

The streams that flowed from the mountain to the sea disappeared under the gradual expansion of the dense urban mass, and only a few sections are now visible [Figure 103].

Figure 102: The evolution of Thessaloniki's urban form across the coastline and the geographical background (terrain topography and streams). Maps based on A. Koussoulakou, et al., E-Perimetron, Vol.15, No. 1, 2020, pp. 46-47.

2. Thessaloniki Streams' current situation

From ancient times until today, streams have played an important role in the daily life of the city's inhabitants. However, very often human activities, combined with their accompanying constructions, have come into conflict with these natural elements. This conflict resulted in the obstruction and/or interruption of the smooth moving of water from upstream to the Thermaikos Gulf, especially after extreme rainfall.

In an effort to expand and improve the image of the city, the local authorities made significant changes in the second half of the 19th century. These changes influenced the structure of the urban area and hence the form and function of the streams that ran through it. The disorganized expansion of the city both to the east and to the west resulted in significant changes in the ground surface, which also affected the movement of water. As a consequence of the unruly and disorganized expansion of the city, the occurrence of flooding, as a phenomenon, was often catastrophic or even fatal. For this reason, the first large artificial drainage project was carried out in the same period [Figure 104], aiming to protect the western part of the city from flooding (the Dendropotamos stream)[24].

Thoughout the 20th century, Thessaloniki continued to expand in the undeveloped areas to the east and west of its original core, often at the expense of the streams. Thus, many of the city's streams were gradually covered and replaced by public utilities, roads, and buildings[25]. The covering of the streams was initially done for health and safety reasons, as open streams were perceived as a source of pollution and were considered responsible for floods within the city. Two other factors contributed negatively to this. The first factor was the limited tools and resources available to local authorities, at the time, so as to manage streams and deal with flooding. The second factor was the encroachment of parts of the stream, or all of the stream bed, by unauthorized constructions, which, combined with the absence of integrated planning, exacerbated the flooding phenomena in the town. In the 1950s, the city's second major drainage project, the Circumferential Trench was carried out[26]. This project relieved the streams of eastern Thessaloniki of large quantities of water from the adjacent mountainous area.

Up to the 1990s, many sections of the streams, that previously ran through the urban fabric, before winding up in Thermaikos Gulf, were undergrounded and turned into closed pipelines[27]. This resulted in the loss of a significant part of the natural environment surrounding the streams, the disruption of the natural corridors that served as a link between the peri–urban forest (the Seih Su

Forest) and the sea, and the degradation of the water quality of the streams. Today, the picture of the surviving sections of the streams is extremely degrading [Figure 105].

Defining New Ecosystem Patterns for the Thessaloniki Metropolitan Area

As the extent urban mass of the contemporary Thessaloniki ignores or has overridden the city's water geography, and facing the climate change mitigation and adaptation, there is a strong need for a nature-inclusive design that integrates natural features and habitats into the built environment.

There are many ways to rise new ecosystem patterns and paths in various scale of the metropolitan urban body, creating a delicate, touch-sensitive urban surface, aiming to emerge soil patterns, traces, and natural systems that have been evolved. The most efficacious of these patterns are the blue ones; they may consist of various forms that can host various public equipment elements together forming a nature absorbing porosity for the city. Reflecting pools, water walls, water channels in the traces of the pre-existing streams, rain gardens, gardening for wildlife, are some of them [Figure 106].

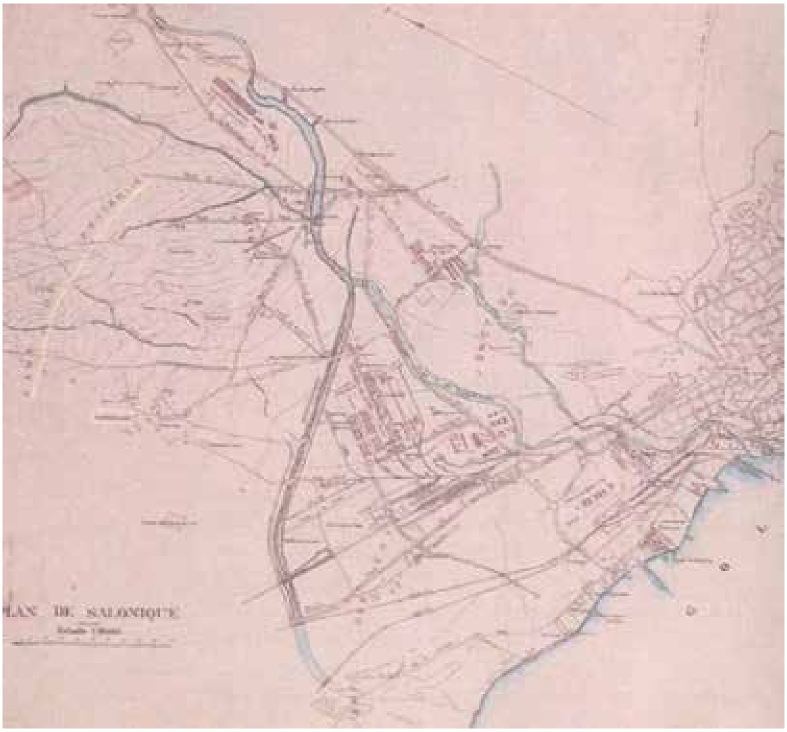


Figure 103: Dendropotamos stream after its diversion to the west in 1893. Cartographic illustration of 1909 - 1910. (Source: Thessalonikis Anadeixis - Charton Memories. General editor: P. Savvaidis, 2008, p. 303. Presented in *Blionis and Tremopoulos*, 2017, p. 123).

To round off, the replacement of any impervious surface with a more porous one, in the urban area of Thessaloniki, can be considered particularly beneficial. For instance, even the replacement of the asphalt, in a parking lot, with a grid of herbaceous vegetation, and cement, could positively affect the microclimate of the area in which it is applied.

Conclusions

Water geography plays a crucial role in shaping the ecological functions of an urban area, such as that of the city of Thessaloniki. Elements such as the minimization of impervious surfaces, the enhancement of urban porosity, and the best management practices of rainwater, can contribute effectively to the preservation of the existing ecosystems and the formation of new ones.

Understanding the intricate connection between water geography and ecosystem functions of an urban area is essential for effective urban sustainable management. The approach of understanding the city's water geography, as a main urban feature, provides new key aspects for policy makers and planners for reaching city resilience and adapt and mitigate the impacts of climate change.

The city's streams or even the parts of the city through which streams used to flow, and which have left their 'traces' in the built environment, can be the main points of application/implementation. Streams can be reconstructed and can also act as linear pockets of new ecosystems in the densely built urban area of Thessaloniki. The main aims are:

- To restore, to the maximum possible extent, the degradation of the hydrological cycle in the urban area of Thessaloniki, the effects of which are becoming visible in the remaining streams of Thessaloniki.
- To integrate into the network of new ecosystems, the free surfaces left behind by the undergrounding of the streams over the past decades.
- To spatially reconfigure and ecologically enrich the city's green vertical axes, which form the link between the sea and the forest.

Figure 104: Uncovered sections of the streams in the urban area of Thessaloniki in 2023. (Source: personal archive of Stavros Tsoumalakos, 2023).

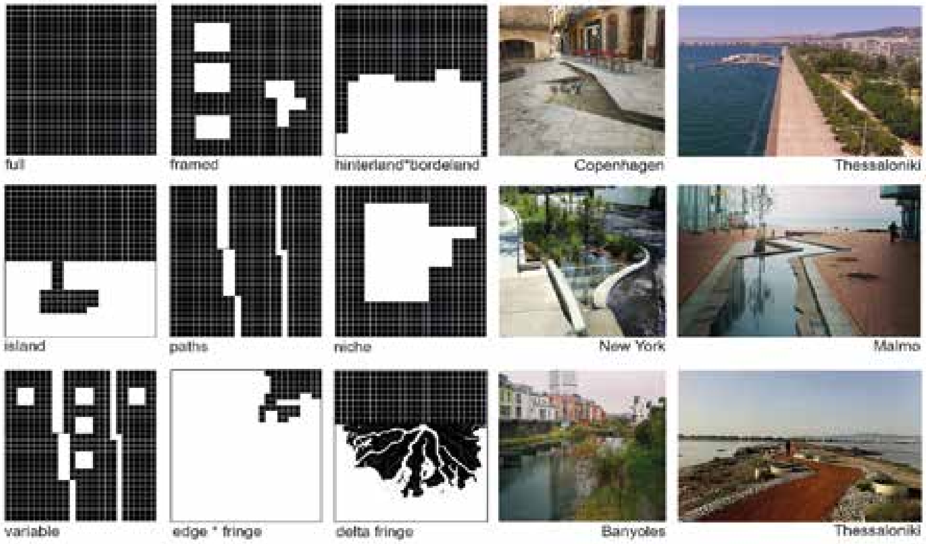


Figure 105: Porosity patterns and solutions for Thessaloniki metropolitan area.

Notes

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Spatial Planning, Climate Change, Adaptation and Public Participation:
Evidence from the Mati area in Attica

KEYWORDS:
Climate Change, Adaptation, Public participation, Spatial Planning, Coastal Areas

Abstract

Adaptation strategies to climate change should be inclusive, integrated, and shaped according to each area's particular needs, requirements, and characteristics, while also paying attention to the necessity of a broad public participation procedure. However, since the attempt to issue combined spatial plans for adaptation to climate change in Greece is entirely new, the experience of participatory processes in decision-making is relatively poor to date.

This research examines the first citizen engagement process for such an urban planning attempt combined with essential climate change adaptation policies, referring to the case of 'Mati', at the northeastern Attica Region. This case constitutes an example of the pathologies of the Greek spatial planning system. This area has been severely affected by a great fire that broke out in July 2018, a disaster that is undoubtedly linked to climate change.

The 'Mati' area suffered enormous damages and a large number of victims due to the devastating fire. In response to this disaster, the Greek Ministry of Environment and Energy decided to develop a Special Urban Plan in order to meet all the particular requirements of this second-home area. 'Mati' was developed in a pine wooded area through informal urban planning processes and arbitrariness, a fact that added significantly to the fire's negative results.

The present paper's objective is to bring attention to the connection between the already-established climate change adaptation strategies and local-level spatial planning initiatives in Greece. The research also explores whether the residents of a fire-stricken area are prepared and willing to realize the need of collaborating in order to overcome the consequences of natural disasters directly related to climate change parameters.

Introduction

Approximately 50% of the world's population lives within 200 km of a coastline, with projections suggesting this figure will rise to 70% by 2025. This trend is also prevalent in Greece, that is characterized by a high degree of insularity and a long coastline (more than 15.000 kilometers) that is home to more than 60% of the country's population and hosts a variety of activities, landscapes, and ecosystems. Because of the high value of natural and socio-economic assets threatened or lost in coastal cities, it is crucial to identify the types and magnitude of problems related to climate change[4] [5].

A series of scientific studies should be used to develop strategies for adapting to climate change[6]. Policymakers can predict the effects of climate change on coastal areas by assessing their vulnerability to effects such as rising sea levels, floods, erosion, and other dangers[7] [8]. In addition, the strategies for adaptation to climate change should be shaped according to each location's needs, requirements, and features. Greece's policies and plans for adapting to climate change have rarely emphasized on the significance of public engagement in decision-making to date[9]. However, climate change adaptation requires a new "porosity framework" that allows the flows of data and information to be shared between stakeholders, policymakers, and citizens when formulating policies that combine spatial planning and climate change.

Some of the long-standing pathologies of the Greek spatial planning system include unplanned urban sprawl combined with out-of-plan building, conflicting provisions, legal flaws that cause uncertainty, and an overconcentration of powers and responsibilities within the central administration and bureaucracy. The settlement of 'Mati' was selected as the study area for this article as an illustrative example of these pathologies, many of which are recorded during its urban development.

After the disastrous fire of 23rd July 2018 at the 'Mati' area, in Attica, the Ministry of the Environment and Energy announced a Special Urban Plan (SUP), as outlined in L. 4447/16. Until then, most of the area was out of plan, having been built using informal practices without rules, while a significant part of the area has been pine forest land. Four years after the fire, the presidential decree of the SUP was finally issued, defining the urban planning zones, the areas of protection, the land uses, the building conditions and restrictions, the main road network, and additional provisions and restrictions.

The proposed by the SUP town plan includes residential and second-home blocks, vehicular traffic, bike and pedestrian networks, public and green spaces, space for the development of public services and social infrastructure, free places of refuge in the event of a disaster, a footpath along the coastal zone, and open areas (public or private) that connect the coastal zone to the more extensive network of public spaces.

This research investigates the adoption of the town plan during the area's redevelopment through a comparative statistical analysis of the unique objections submitted for the SUP by the interested parties. This approach was used to examine the processes of citizen engagement in the policy-making process using a case study of an area in Greece significantly impacted by a natural catastrophe related to climate change, taking into consideration the new conditions set by the need to adapt to the expected impacts of climate change.

Climate Change Adaptation Policy in Greece

1. National Adaptation Strategy

The Greek National Adaptation Strategy (NAS) and the National Council on Climate Change Adaptation were established in 2016 (L. 4414/2016). The NAS has a 10-year timeframe and defines significant policy objectives and adaptation measures in vulnerable sectors. According to L. 4936/2022, the development of Regional Adaptation Action Plans (RAAPs) should always be followed by the development of the NAS.

The NAS's primary objectives are to[10]: (i) estimate the expected short-term and long-term impacts of climate change on the Greek territory based on a vulnerability assessment analysis; (ii) identify the priority areas in which climate change adaptation measures should be taken; and (iii) outline the legislative measures required to ensure effective adaptation to climate change. The RAAPs provide a comprehensive evaluation of these objectives.

The NAS focuses primarily on[11]: (i) scientific study and documentation to acquire the information essential for a greater comprehension of the problem of climate change and its specific impacts by type, sector, and activity; (ii) follow-up, as the implementation of the NAS should be supported by a monitoring mechanism and appropriate indicators and tools; (iii) public and stakeholder awareness about climate change and its impacts is the first step towards introducing a new philosophy and way of living and simultaneously designing the policies needed to deal with the new challenges climate change creates; (iv) discussion and conversation, given that the effects of climate change will affect all productive activities on both the local and national levels; thus, the government should build a framework for continuing deliberation and conversation with important economic and social stakeholders and local communities.

2. Regional Adaptation Action Plans

The NAS is Greece's strategic orientation document; as such, it does not evaluate the feasibility of particular adaptation measures and activities at the local or regional level or aim to rank the recommended measures. Such concerns are the responsibility of the RAAPs (L. 4936/2022, art. 6), which elaborate on the NAS's principles by establishing local adaptation priorities.

According to L. 4936/2022, (art. 6), RAAPs must direct regional authorities to: (i) conduct multi-sectoral climate impact and vulnerability assessments; (ii) identify climate risks and impacts by sector and geographical area; and (iii) support regional decision-making and adaptation action planning. In addition, each RAAP details the final selection, prioritization, and timing of the relevant actions and measures depending on the specifics of each region. Each RAAP has a 10-year horizon and evaluates the regional circumstances, requirements, and priorities.

The efficiency of acts is proportional to their potential for climate change adaptation, prevention, mitigation, and restoration. The RAAPs prioritize climate change adaptation measures per sector based on cost-effectiveness and cost-benefit studies. Through public consultations, stakeholders are also involved in selecting adaptation activities.

In addition, L. 4936/2022 requires that RAAPs should be linked with other regional-scaled plans. The Regional Spatial Planning Frameworks (RSPFs) are the most essential of these regional-scaled plans, as most climate change adaptation measures have considerable geographical implications, if not direct spatial reference. In particular, the RSPFs, following L. 4447/16, guide the spatial organization model each region should adopt and suggest steps regarding the structure of each region's residential network[12]. This strong relationship between RAAPs and RSPFs creates a new reality for the Greek spatial planning system.

The establishment of the thirteen Regional Adaptation Action Plans (RAAPs) is underway. Many RAAP studies have been completed, while the RAAPs of the Northern Aegean, Crete, Attica, Peloponnese, and Western Greece are already established (January

2023). By mid-2023, it is expected that the rest of the RAAPs will have been approved.

3. Local-scaled adaptation initiatives

The adoption of the Aarhus Convention into European Law (Directive 2003/35/EC) established the right of citizens to receive environmental information and participate in decision-making. These provisions allow citizens to voice their opinions, intervene in policy-making, and effectively participate in forming environmental protection policies, programs, projects, and activities.

The above institutional arrangements highlight the significance of appropriate, effective, and meaningful engagement in policy creation within a schedule that may contribute to the maturity of citizens' perspectives and their substantive participation based on the principles of transparency, justice, and equality. It is also evident that compliance with consultation processes beyond their form and substance provides value and credibility to the policies pursued[13].

Adapting spatial planning strategies to the new priorities that climate change introduces is a complicated and multi-factored task that requires the collaboration of all stakeholders (relevant authorities and the public). Although the issue of climate change has been generally incorporated into Local Urban Plans (LUPs) (L. 4759/20, art. 10) and Special Urban Plan (SUPs), as outlined in L. 4447/16 and L. 4759/20, and constitute the plans of the 1st level of the Greek urban planning system, the absence of a consistent culture of public awareness and participation in issues relating to local spatial planning initiatives hinders the objective of adapting to the anticipated effects of climate change and the resulting disasters. This becomes more evident in the consultation process of the urban implementation plan that follows (second level of urban planning system), as it is described in the case study of the present paper. The paradox is that, in Greece, the process of filing citizens' objections during the creation of an urban plan, has been applied to city plans since 1923, when the first urban planning law was implemented, although primitive and without provisions for climate change. However, it is argued that the depth of time of a process cannot ensure its actual implementation.

The Role of Local Spatial Planning in Promoting Climate Change Adaptation Policy in Greece

1. The outline of Spatial Planning Framework in Greece

The adoption of L. 4759/20 introduced a new reality for local-level climate change-related spatial planning. This conclusion could be confirmed by the fact that LUPs (L. 4759/20, art. 10) require the definition of climate change adaptation measures and emergency measures related to the management of the consequences of natural and technological disasters and other risks. There is also an apparent reference to the incorporation of the National Energy and Climate Plan (NAS), and the National Disaster Risk Reduction Policy during its inception.

The LUPs will establish provisions regarding land uses, building terms and regulations, areas that can be used for residential, environmental, or development purposes, areas that can host major urban planning interventions, and areas that can host specific incentive initiatives.

In addition to the LUPs, many SUPs, as outlined in L. 4759/20, will be developed during the following years, as planned[14]. The SUPs' objectives are urban revitalization, environmental conservation, and disaster recovery projects. Concerning climate change, their primary purpose is to enhance the resilience of urban centers concerning urban reconstruction, environmental protection, and natural disaster assistance programs (L. 4759/20, art. 12). In addition, they are utilized to address urgent spatial issues requiring immediate intervention or prevention (L. 4759/20, art. 12).

2. The case of spatial planning in Mati/Attica

After the disastrous fire of 23rd July 2018, a SUP was announced by the Ministry of the Environment and Energy. Until then, the greater part of the area was out of a plan, having been built anarchically, without rules, with a significant part of the area being forest land[15]. The scattered-forest character of the area was the main reason the State still needed to integrate the area into urban planning. However, due to the catastrophic fire that left dozens of people dead, the Greek State apparatus got activated in order to resolve the pending urban planning of the area, especially since many people were trapped in dead-end roads leading to the sea, which did not allow access to the coast, since paths were blocked by the coastal properties[16].

Four years later, having overcome several obstacles through *sur mesure* legislation, such as the declassification of areas incorrectly classified as forest areas since they derive from agricultural

distribution, the Presidential Decree of the SUP was finally issued and published in the Government Gazette (398 D'2022). The SUP defined the urban planning zones, the zones that remained outside urban planning for protection, the land uses, the building conditions and restrictions, the main road network, and additional provisions and restrictions. At the same time, the environmental approval of the SUP was granted, and the boundary lines of the streams were validated. Then followed, the town planning draft for the areas indicated by the SUP to be part of a new city plan (second level urban plans). These areas are part of five urban units, one of which is the 'Mati' area, which was the center of the disaster and where the majority of the deaths occurred; as a result, it has been chosen as the case study for this paper.

Figure 106: View of the blocked access to the coastal front of Mati. (Source: Urban Planning Research Lab, 2022).

Figure 107: A burnt building of Mati. (Source: Urban Planning Research Lab, 2022).

3. Mati's Implementation Plan: Experiences from public participation

The town plan of 'Mati' was posted just two months after the SUP came into force, informing the public and providing the opportunity to submit objections. The process lasted for a month following the current legislation and was completed by the 9th September 2022. Objections from the interested parties (that is, the owners of plots and houses) were submitted either to the Municipality, or to the Ministry of Environment and Energy, which is responsible for the entire project. Objections were collected, recorded, and compiled, and the Department of Planning and the Central Council of the Ministry examined their confrontation[17]. It should be clarified that the above process is entirely discrete, following the public participation procedure of the first level urban planning (the SUP) which concerns the general planning of the area and does not enter into the scale of each private property. On the contrary, the public participation procedure of the town plan (second level urban planning) is confronted with proposals that alter the surface and shape of the property as well as the legal rights upon it.

According to their declarations of ownership in the context of the cadastral survey, the area's permanent residents are 220 in total. That is, 8.4% of the total number of owners have their permanent residence in 'Mati', while 91.6% either use the area as a second-home place or own unbuilt land. There are 2.620 properties, while 71.87% of the plots (1.022 properties) are already built. Considering that 'Mati' has a total area of 1.371.000 sqm, each property is 523 sqm on average, including all existing roads and other spaces left for public use. This intense fragmentation of the land, combined with the huge build rate (72%), and the character of the area being a second-home town, leaves little room for apparent improvement. The proposed urban plan is shown in Figure 109. The town plan implements the SUP and creates residential blocks, roads, public and green spaces, blocks for public utilities, gathering places in case of emergency, a pedestrian road across the coastal zone, and accessible areas — either public or private — that connect to the network of roads and public spaces. In contrast, there is a provision for all existing buildings, although illegally built, to remain until their owners decide to turn them down and rebuild their property according to the new rules.

For the area of 'Mati', 710 unique objections were submitted, corresponding to 512 properties (almost half of those already built). Each unique objection contained several thematic fields, and as such, they were classified [Figure 110]. The widening

Figure 108: The proposed layout plan that was posted. (Source: https://ypen.gov.gr/chorikos-schediasmos/poleodomia/poleodomika-schedia/, September ,2022).

of existing streets was the most common reason for objection (346, or 68% of the objections). Then followed the opening of new pedestrian streets (299, or 58% of the objections), public green spaces (292, or 57%), the size of public green spaces (285, or 56%), and linear green public spaces (284, or 55%). Less than 50% of the owners objected for the reduction of their front yard width due to the widening of public space (206 or 40%), which of course depends on the private contribution to land, for which they objected 30% (156) as well as for the opening of new streets, for which they objected 28% (145). Eighty owners objected for the coastal pedestrian street (16% own coastal plots), followed by non-relevant objections such as cadastral data (76% or 15%) and streams (65% or 13%). Moreover, less than 10% objected for public parking spaces (48, or 9%), widening of existing pedestrian streets (35, or 7%), preference for converting land contribution into money (29, or 6%), construction rules (26, or 5%), and their disengagement from urban planning (3, or 1%) and that part of the property is still characterized as a forest (1 person).

In addition to the above, it is notable that eighty-one of the objections -that is, 15% of the total number- belong to five (5) 'types' with identical text where only personal information is differentiated. Type A (39 objections) is for the non-widening of an existing road (Nikitara); type B (14 objections) is for the non-opening or widening of other roads, as well as the project's short period of public consultation; type C (5 objections) is for the non-widening of Kianis Aktis street and the prohibition of linear green public spaces; type D (6 objections) is for a different street (Posidonos); and finally, type E (17 objections) complain again for the opening and widening of several streets.

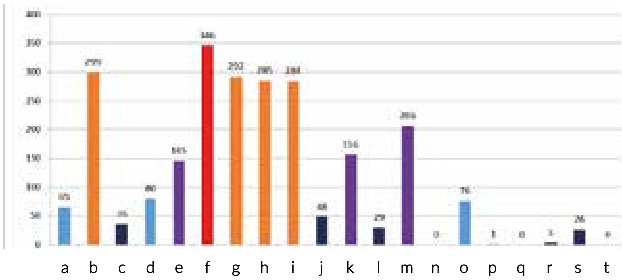

Figure 109: Objections filed against the proposed town plan by thematic area. (Credits: https://ypen.gov.gr/chorikos-schediasmos/poleodomia/poleodomika-schedia/ December, 2022).

More than half of the objections (64%) were rejected overall, 23% were partly rejected, and 13% were accepted in total. In most cases, the interested parties ask for their property to remain as such: not to modify its geometrical characteristics, not to reduce its surface area, not to reduce the front yard by widening the road, not to reduce the back yard by opening a new road, not to change the rules as they are. Respectively, the coastal properties object for the opening of the coastal pedestrian road, the decrease of their front yard's area, and their contribution to the public spaces.

In general, these objections are rejected because the inclusion in the city plan with the increased building ratio entails a reduction of the property by deducting a predefined contribution to land, according to the initial land surface. It falls under the responsibility of the State, however, to properly educate its citizens to accept their obligation to contribute, in exchange to their inclusion in a city plan, which must respond to climate change. The Implementing Act that follows will determine the plots' final geometric characteristics and the owners' compensation for any existing structures.

Discussion

Regarding the adaptation of local-scale spatial planning strategies to climate change, this is a complicated and multi-factored task in which all stakeholders (relevant legal entities, decision-makers, citizens, and academics) should collaborate. Adaptation needs to be improved by the need for a defined and structured culture of public understanding and involvement on issues related to strengthening the spatial resilience of an area. Therefore, it would be essential to construct local (municipal or municipal district) climate change adaptation plans to describe the criteria outlined in the respective RAAP. These plans could increase the effectiveness and relevance of informing citizens, while simultaneously expanding opportunities for engagement, as the issues addressed are much more pushing closer to people's daily lives and better understood. This approach will contribute to the gradual formation of a culture and tradition of consultation, which has been a significant issue for Greece over time.

There is a direct, but non-linear, connection between climate change adaptation policies and spatial planning, as spatial planning is the instrument through which many important climate change adaptation policies can be implemented. In Greece, consultation procedures in the formulation of spatial planning policies are now well-established. However, climate change adaptation policies implemented in Greece rarely consider public participation as a critical factor. In the case of 'Mati', a public consultation was conducted, with the Administration making every effort to accommodate the shaped reality.

The public participation in the new town plan of 'Mati' sums up to just one phrase: no one desires alteration of the established rules. Although very few constructions have been built with a building permit since most plots derive from an illegal division of the land, the given opportunity of legalizing illegal actions (constructions, division of the land, etc.) combined with the area's declassification as a 'forest' by a special law –a fact that allows for illegal buildings to get legalized– appears to be the reasoning of an unwanted new urban plan. This is reasonable when most citizens have built illegally their homes but later, have been given the opportunity to legalize them, not to mention the ability to rebuild them with government grants. The question then that reasonably arises is why would anyone agree to join a city plan that requires to lose part of one's property for the creation of new-common areas, when all pending issues, such as the risk of demolition due to lack of building permits, have been already resolved.

Either being within legal boundaries or not, citizens react to change, especially when change enters one's private property. More specifically, the waterfront properties that, before the urban plan, enjoyed total privacy, strongly protest against the opening of the coastal pedestrian road and the widening of the coastal space for the public. They, therefore, refuse to provide other people with the benefit of enjoying the seaside.

Beyond vested rights, the intense fragmentation of the land combined with the high built rate (72% of total plots), and the character of the area being a second-home town — that is, less needs for public infrastructure such as schools — does not leave much room for improvement. Although illegally built, the provision for all existing buildings to remain until their owners decide to demolish and rebuild their property according to the new rules, seems insufficient for owners to accept the new urban plan. In conclusion, even a tragic event of natural disaster does not seem capable to motivate citizens to accept a personal contribution for the public interest. However, it is up to the State to support the common benefit, according to the Constitution and the laws.

Adaptation policies to climate change should be based on a series of participatory, synthetic, and integrated negotiations. They should also follow a process that is adaptable to the needs, requirements, and characteristics of each area. The approach of public consultation in Greece as an essential process of policy formulation so that the effective incorporation of citizens' opinions is possible, emerges as a key condition for the successful management of disaster issues such as 'Mati', and remains a primary concern. In addition to creating a common framework of rules and procedures, while introducing climate change adaptation policies (ie. NAS, RAAPS), actions that have no impact on the State budget, such as establishing a minimum consultation period and perform the public consultation at an early stage and not when the study is completed, would significantly improve several of the aforementioned issues. Although climate change has been incorporated into spatial planning (LUPS and SUPS), there is an urgent need to reshape how citizens comprehend the benefits of accepting formal spatial planning approaches. It could also be argued that firm political will is required to implement effectively formal spatial planning initiatives (such as fines and demolitions). All the above, of course, presupposes a change in the building culture, which requires buildings to follow the area's inclusion to the urban plan in contrast to building off plan.

Notes

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Rethinking Hard Surfaces in the Greek Urban Waterfront:

Earth Revelations and the Phenomenology of Urban Living

Introduction

Cities are naturally formed through their linkage with the ground/soil[2], creating levels of the city according to morphological land features and relational identifications with the ground, revealing urban ground typologies that may become symbolic interpretations of original geographies and heritage. This paper argues the importance of porous and earthly surfaces as phenomenological opportunities for “active recreation, a green transportation alternative, a venue to celebrate our heritage as well as an opportunity to regenerate sensitive waterfront lands”[3]. It criticizes the tendency to soil seal, which is “one of the main causes of soil degradation in the EU”, and which “puts biodiversity at risk” and “contributes to global warming”[4]. Aiming to not only preserve natural soft edge transitions with the water but also take advantage of a site’s cultural and historic interest, the discussion also emphasizes the importance of natural arterial continuity (urban greenways) and morphological earth identification, offering alternative solutions to waterfront hardscapes. Although Greece is at the better end of european countries regarding the degree of soil sealing as a percentage of its total land area (1.35%)[5], it is a country which tends to soil-seal its urban waterfronts, despite the great opportunities to create ‘earthly’ connections not only along the seashore but also through the formation of soil arteries that could potentially reach the surrounding near mountains, from the sea.

The original contribution of this paper is the perspective of phenomenology in suggesting softer surfaces over soil sealing[6] within the context of Greek waterfront cities, helping enhance the scientific discussion on the field of environmental urban design and common landscape practices of permeable surfaces as new strategic initiation points towards urban renewal.

The physical attributes of the area in which a city is constructed may greatly influence how that city grows. Cengiz, who writes on improper land uses in cities and ecological landscape planning, mentions the importance of soil conservation and land use laws[7], which according to Milde, are not new concepts, correlating incorrect land and soil use in cities, which in turn can have detrimental effects on the wellbeing of urban ecosystems and human populations[8]. Furthermore, the relationship between a city and the soil on which it stands might result in the establishment of several layers of urban perceptual understanding[9], identified by relational identifications with the ground[10]; proximity to water, the existence of a certain type of soil, and physical land characteristics. In light of this, various sections within a city may reveal unique traits and purposes that speak of a place's identity, its morphological uniqueness, its heritage, and perhaps also cultural and indigenous features.

The belief that humans have a strong bond with the land and the natural environment that surrounds them has been referred to as living within the womb of Mother Earth — an analogy that views Earth as the loving and protecting 'mother'[11] who provides for her habitants a sense of security and protection. Elaborating on this, the phenomenology of 'being' in place[12] describes how people react to and perceive their local environments, and, consequently, attain a sense of connection that is crucial to their general well-being and feeling of identity and belonging. From this perspective, one sees that the relationship between humans and nature is one of interdependence rather than exploitation, where the natural environment is something necessary for human survival and prosperity rather than something that solely exists for use or domination.

Negative Impacts of Urban Hardscapes

In cities, walking on hard surfaces like concrete and asphalt can have a variety of detrimental ecological effects[13], resulting in a decline in biodiversity; more runoff and floods; a heat island effect; a reduction in carbon sequestration, since sealed soils are less efficient at absorbing and storing carbon dioxide than unprotected soils, and less green space available, impacting people's physical and mental health[14].

One of the significant negative psychological effects found in people is stress and anxiety, as walking on hard surfaces can exacerbate the overwhelming perception of a city's continual activity; noise, and visual stimuli[15], as a result of hardscapes' ability to reflect and magnify sound. Another consequence is taking away from "nature connectedness: […] an individual's psychological relationship or emotional bond with the natural world"[16]; a parameter also associated with physical discomfort, considering that walking on hard surfaces can become taxing on the body and cause pain, stiffness, and exhaustion. Consequently, walking or running is not enjoyed as much, causing more people to deter from partaking in physical activity[17].

Furthermore, because hard surfaces are less attractive than softer ones, they may hinder social engagement and community interactions[18], justified due to the physical design of hard surfaces that make a place appear cold and impersonal, and without softness, vegetation, and other natural aspects that typically promote social connection[19]. Furthermore, the amplified noise that is reflected upon the surfaces makes it more difficult for individuals to interact with one another, reducing social contact, while lighting also becomes a problem, especially at night, as hard surfaces reflect it, making visibility more challenging, and the place feel less welcoming and safe[20].

The 'Hardness' of the Greek Waterfronts and Recommendations

Many (if not most) of Greece's picturesque and historic urban waterfronts are composed of hard surfaces, with a lack of vegetation and other natural elements. The challenge is found in many other countries besides Greece, however, the Greek case has been selected considering that it has a substantially longer coastline than any other country in Europe (excluding Norway's *fjords* and inlets), with a length of approximately 13,676km, while supporting recent efforts to look into theoretical frameworks that could aid in the redevelopments of Greek urban waterfronts[21]. Having in mind the nationwide common practice of implementing materials like concrete, asphalt, stone, and brick, which are typically chosen for stability and durability, drainage, aesthetics, and public use, this paper realizes the problem that a potential ongoing pattern of soil sealing Greece's urban waterfronts could have, and seeks alternatives.

Furthermore, urban flooding is a big problem in Greek coastal communities[22] as a result of a mix of variables including urbanization, climate change, and natural variability, according to a study published in the journal Water in 2020, which emphasizes the necessity for adaptation measures and enhanced stormwater management systems[23]. According to a 2018 assessment from the European Environment Agency, urban flooding should be Greece's main environmental concern to face, as increased precipitation, sea level rise, and storm surges can worsen urban floods and harm the country's economy, society, and land[24]. Adding on to the above, Thessaloniki, Greece, was the subject of a case study by the European Commission's Joint Research Centre in 2019, revealing that the city faces a substantial risk of flooding because of its proximity to the sea and its intricate drainage system[25]; a realization that was similarly made for Athens through the European Commission's Urban Adaptation Support Tool, suggesting a variety of adaptation strategies, like the creation of green infrastructure and the enhancement of stormwater drainage systems[26]. Moreover, Greece's natural coastal environments are home to several rare species, and their extinction might result from the encroachment of hard-surface waterfront development. While hardscapes have advantages as well, such as durability and accessibility, it is crucial to balance these against any possible drawbacks[27].

Hardscaping Greek waterfronts has been influenced by a number of environmental, social, and cultural elements: storm surges, sea level rise, and erosion, have been conditions taking place in Greece's extensive coastline, leading to the creation of seawalls and breakwaters, however, also causing unfavorable effects including the changing of natural coastal processes and diminishing habitat for marine life[28]. To restore these, environmentally friendly methods include adopting soft engineering techniques like beach replenishment and dune restoration[29].

Furthermore, many Greek waterfront regions have a high level of development and habitation with plenty of commercial and tourist activity, causing wide promenades and marinas to be in high demand to accommodate big crowds[30]. However, this causes unfavorable social effects[31], like restricting local citizens' access to the shoreline and fostering a homogenized, commercialized waterfront culture[32]. Creating parks and green areas to increase public access to the waterfront and supporting the growth of small, locally-owned businesses that reflect the culture of the neighborhood are two potential solutions[33].

Moreover, many of Greece's shoreline areas are home to significant historic and cultural landmarks, where hardscaping is used to aid in defending these sites against erosion and other environmental dangers. Ironically, this eventually tampers with the waterfront's historic character. Solutions may be utilizing local, traditional building methods and materials that are sympathetic to the local cultural and historic context while encouraging the preservation and adaptive reuse of historic sites.

The Phenomenological Perspective of Walking on Soil

Reaching the phenomenological level of this investigation contemplates how individuals experience and interpret the soil as they walk on it, their visual and aural perceptions, their sensing of the slope of the terrain[34], and other factors that come along with moving and the simultaneous perception of experiential aesthetics[35]. Phenomenology looks into the link between the walker and the environment[36], associated feelings and ideas, and recollections related to the experience[37].

According to research, walking on soil might enhance one's sensory perception and connectedness to nature and the uniqueness of a place[38], while it has been observed that soil contact promotes feelings of relaxation, confidence, happiness, and freedom[39], particularly if the ground is soft and loose[40]. Frampton, emphasizes the value of sensory experiences in establishing a feeling of location through the sounds of nature and the textures of the ground beneath the feet[41], also stressed by Corner, who writes: "Sensory experience is always registered in the body, in the manner in which the feet strike the ground, the aroma of a place, the sound of the wind or the crunching of leaves, the visual field and the play of light and shadow, and so on. Thus the phenomenology of the landscape always arises in a corporeal, situated and embodied encounter"[42].

Epistemological Benefits of Urban Waterfront Soil Paths

There are a number of benefits that can be found regarding the integration of soft and permeable surfaces alongside city waterfronts that reach levels of ecological, socio-geographical, heritage, and psychological considerations, adding on to the phenomenology of a place.

On an ecological level, waterfront softscapes may create habitats (e.g. dunes and marshes) for a broad range of animals, including fish, amphibians, and birds[43]. Furthermore, water quality may be improved by minimizing runoff and erosion, which may otherwise have a detrimental influence on aquatic ecosystems[44]. These surfaces can also act as natural barriers between cities and waterways and against storm surges and coastal erosion, trapping pollutants before they reach the water[45]. Moreover, waterfront soil surfaces may provide opportunities for the planting of trees and other vegetation, which can absorb and store carbon, and aid in the fight against the urban heat island effect and global warming[46].

Economic advantages associated with the argumentation deal with the attraction of tourists, a rise in property prices, a boost in local business growth, and employment. Furthermore, they could provide chances for ecotourism (e.g. kayaking, fishing, birding), consequently helping the local economy[47] and creating opportunities for urban rejuvenation and strategic initiatives for urban rehabilitation, reviving underused or abandoned areas and establishing new public spaces. They may also be utilized to enhance the city's livability through, i.e., community gardens and hosting gatherings like festivals and concerts.

On the socio-geographic, but also psychological levels, soft surfaces provide green network opportunities within metropolitan cities, which are otherwise a challenge; these may operate as focal points in the community, offering chances for social contact and civic involvement, consequently benefiting society[48]. These parameters also reach the level of cultural heritage preservation of specific terrain features and particularities of the waterfront morphology, drawing attention to the cultural importance and identity of a certain location.

Waterfront soft surfaces may also be utilized as educational tools[49], giving people the chance to learn about their surroundings, the history of the area, and their cultural heritage, but also increase awareness on environmental concerns like coastal erosion and the effects of climate change.

Good Waterfront Practices Utilizing Soil Porosity

Depending on the unique circumstances and intended results, there are several methods for introducing soil paths in urban waterfronts, promoting ecological sensitivity and all other benefits discussed above. Some of these possibilities include:

Natural soil surface/path:

To create this sort of surface, a way through an existing natural area should be cut, for example, by cleaning the trail of any rubbish and marking it with natural objects like stones or logs. The Malmö Western Harbor in Sweden [Figure 78], designed by the architectural firm Lundgaard & Tranberg based in Denmark, and realized and officially inaugurated in 2001, is an example that had preserved and incorporated its soil surfaces into the design of public spaces, to retain the memory of the once industrial harbor that transformed into an urban district[50]. Its gravel path that follows the edge of the water along the promenade in the Western Harbor provides insight for Greece in terms of its emphasis on pedestrian-friendly infrastructure and using local materials and sustainable design principles, and prioritizing local context and the community's social needs. Another example is found through the organic soil paths and green spaces found in the Harbour Circle of Copenhagen, Denmark [Figure 79], planned and developed by the Copenhagen Municipality from the late 20th until the early 21st century, highlighting Copenhagen's identity as a sustainable and livable city.

Mulch surface/path: To make a sturdy surface for walking, a layer of mulch, such as wood chips or straw, is spread on top of the soil. This kind of route can be readily built and maintained, and it may be used to make a trail that appears to have grown naturally through a forest. The River Lea Greenway (or Lea Valley Walk) in London, UK [Figure 80] is a 26km path along the river established in the 1970s and 1980s and continually developed

Figure 110: Natural soil path at Malmö Western Harbor in Sweden. (Credits: Stefan Anderberg, 2015).

Figure 111: The Harbor Circle's natural soil trail leading through a diverse range of landscapes. (Credits: Mark Werner, 2016).

and improved over the years by the Lea Valley Regional Park Authority, offering pedestrians a picturesque and environmentally friendly route across the city, primarily constructed up of natural surfaces, including mulch. In keeping with the locale's commitment to environmental sustainability and soil conservation, using mulch also encourages sustainable landscaping techniques, while distinguishing itself from other metropolitan areas thanks to the mulch's particular organic texture and color. This example of natural-surface paths may become a precedent for cities with a wider shoreline length.

Packed earth surface/path: This form of walkway entails compacted dirt, which can achieved manually or by using a machine to provide a path that appears more official. This technique is found in the Park Schinkeleilanden (or Schinkel Island Park) alongside the Vecht River [Figure 81], a seaside park in Utrecht of Netherlands, founded in 2005 and designed by Karres en Brands. The park's walks and cycling trails are made of packed earth (dirt, sand, or gravel), and offer a more comfortable, less expensive, simpler to maintain, and more environmentally friendly surface. Such precedent could potentially inspire the design of softscapes along the sea that seek to enhance their corresponding cities' historical and agricultural identities, similarly to the Schinkel Island Park case.

Stone dirt surface/path: Stones or gravel are placed on top of the soil in this sort of walkway, typically preferred for places with high foot traffic, creating a more formal-looking path. The Rheinauhafen waterfront in Cologne, Germany [Figure 82], designed by JSK International and constructed between 2002 and 2006, is one example of a city shoreline in Europe that has walkways made of stone dirt, within the context of a former industrial port area called

Figure 112: The mulch path at the River Lea Greenway in London, UK. (Credits: Paul Gillett, 2013).

the Rheinauhafen that has been turned into a mixed-use community with living, working, and entertainment areas. This example, utilizing a network of bike and pedestrian routes composed of natural stone and compacted earth running along the shoreline, may find relevance in shoreline cities with a relatable industrial past and a rich architectural history.

Permeable surface/pavers: This sort of walkway utilizes pavers that are specifically designed to enable water to pass through them and reach the soil beneath, helping reduce erosion and preserve the local area's natural drainage system. In Hamburg, Germany, the Hafen City urban waterfront development [Figure 83] designed by Kees Christiaanse Architects & Planners and realized in the early- to mid-2000s, is an example of an area using permeable pavers for its paths; a once abandoned port and industrial property that was turned into a mixed-use community of homes, businesses, and cultural venues. Permeable pavers allow rainwater to infiltrate the ground and recharge the aquifer instead of running off into the

Figure 113: Packed earth trail at the Park Schinkeleilanden alongside the Vecht River in Netherlands. (Credits: Guilhem Vellut, 2015).

Figure 114: Stone dirt surface at the Rheinauhafen waterfront in Cologne. (Credits: Neuwieser, 2010)

streets or storm drains, lessening the impact of urban heat islands, enhancing water quality, and mitigating urban flooding.

Finally, it is useful to also be aware of case studies that implement combinations of the above types of porous materials, like the S-E Coastal Park in Barcelona, realized in 2004 by FOA (Foreign Office Architects), which uses a variety of permeable paths like crushed stone, sand, and wood decking; the Rhône Riverbanks in Lyon built by In Situ Architectes Paysagistes in 2007, with its permeable concrete pavers, gravel paths, and planted areas with natural soil; the “stabilized gravel” and “porous concrete” of the Vestre Fjord Park by ADEPT in Aalborg, Denmark, constructed in 2019; The BUGA Heilbronn 2019 redevelopment of the riverscape by SINAI Gesellschaft von Landschaftsarchitekten, utilizing concrete pavers, gravel paths, and natural stone paving; and the Canal Corridor in King’s Cross built by Townshed Landscape Architects in 2017, with its resin-bound gravel, permeable block paving, and porous asphalt.

Greece could learn from the above examples not only from a sustainability point of view, but also from a phenomenological perspective: help people engage with their surrounding unique natural landscape and enjoy the environment’s sensory aspects, help organic features become part of the daily urban experience, and create opportunities for enticing and comfortable activities.

Figure 115: Permeable pavers at the Hafen City urban waterfront in Hamburg. (Credits: M. Prinke, 2008).

Conclusions

Overall, waterfront earth paths offer a variety of ecological advantages, make cities more livable, and allow access to nature, community building, education and awareness, economic growth, and urban redevelopment. Moreover, they also withhold the potential to preserve the cultural legacy of a place and the development of cultural tourism, with consequent economic advantages. Sustainable urban waterfronts' advantages may vary depending on their location, layout, and maintenance. Therefore, the community's and the surrounding ecology's unique demands should be taken into account, with the involvement of the community in their effective planning, development, management and administration. The development of hardscapes in Greek waterfront areas is influenced by a range of environmental, social, and cultural factors, and sustainable waterfront developments should balance the needs of people and the environment. Additionally, considering the context of climate change, urban flooding is a serious challenge for Greek seaside communities, calling for enhanced stormwater management and adaptation measures. Considering the general lack of urban greenways in the dense Greek cities' fabric, sustainable urban waterfronts offer a valuable opportunity for the environmental upgrade of Greek cities as well as the general well-being and living conditions of the inhabitants.

Using soil materials for shoreline urban surfaces can be initially challenging due to issues including cost, maintenance, and the requirement for suitable drainage and irrigation systems. In Greece, however, a variety of waterfront urban surfaces may be successfully constructed to build trails and urban greenways using local soil materials (e.g. topsoil, compost, mulch, gravel stone), while inspired by other european case studies with positive planning and design outcomes. Additionally, the soil may be utilized for urban agriculture and community gardens, for preventing erosion, and for creating natural trails along the coastline, allowing people to genuinely experience their natural surroundings. Ultimately, the phenomenology of 'being' within a picturesque and naturally rich Mediterranean landscape would add to the sense of identity, belonging, well-being, and cultural awareness and growth.

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The Essence of Climate Information from Observations and Climate Models for Studies of Climate Change at Regional/ Local Scale

KEYWORDS:
Climate change, Regional scale, Global climate models, Regional climate models, Dynamical downscaling, Statistical downscaling

Abstract

Human-caused climate change has driven detectable changes in essential climate variables in different regions around the world since the mid-20th century, and it is projected to cause substantial further changes at both global and regional scales under future warming. To reliably assess climate change at regional/local level, long-term high-quality station-based and satellite meteorological observations, as well as high-resolution climate information from climate models are a prerequisite both for the thorough understanding of key climate processes as well as climate change. The incorporation of the future effects of the evolving climate to climate data allows the assessment of the impacts on the environment and society. Without doubt the demand of reliable, long term time series for numerous climate variables is constantly growing for the assessment of climate risks as well as the implementation of efficient strategies and adaptation plans and measures. The observing systems which make up the Global Climate Observing System (GCOS) provide the long-term, high-quality climate data records and products that underpin regional climate change research, assessment and provide the reference basis for climate models. Commonly, Global Climate Models (GCMs) are the primary tools for attributing past climate change to human activities, and for projecting future climate change under different anthropogenic emission scenarios. However, the majority of GCMs still have a coarse horizontal resolution and so, methodologies such as statistical downscaling or dynamical downscaling with the use of Regional Climate Models (RCMs) are beneficial to enhance the regional/local information provided by Global Climate Models (GCMs).

Introduction

Human-caused climate change has driven detectable changes in essential climate variables in different regions around the world, especially since the mid-20th century, and it is projected to cause substantial further changes at both global and regional scales under future warming scenarios. Along with the fact that climate change has become nowadays more than ever a planetary issue, the availability of abundant and reliable climate data is essential for the in-depth comprehension of the Earth system as well as the sustainable societal growth within this system. Undoubtedly, observational data is one of our main and key source of climate change information, since climate change has both large-scale and long-period characteristics (Hua-Dong et al., 2015). Furthermore, the observing systems of station-based and satellite meteorological observations constitute the core for the development of high-quality climate data records and products that provide the reference basis for climate models.

While GCMs are the main tools for attributing past climate change to human activities, and for projecting future climate change under different anthropogenic emission scenarios, their course spatial resolution poses the need of using downscaling methodologies, such as statistical downscaling or dynamical downscaling with RCMs, to enhance the regional/local climate information provided by the GCMs. Overall, to reliably assess climate change at regional/local level, long-term high-quality station-based and satellite meteorological observations, as well as high-resolution climate information from climate models are a prerequisite both for the thorough understanding of key climate processes as well as climate change, since the larger the quantity of the Earth data is (along with the frequency and the thorough coverage), the more robust future estimations on the change of the climate characteristics are. The incorporation of the future effects of the evolving climate to climate data allow the assessment of the impacts on the environment and society.

Climate observations

Without doubt the demand of reliable, long term time series for numerous climate variables is constantly growing for the assessment of climate risks as well as the implementation of efficient strategies and adaptation plans and measures. The National Meteorological societies all around the world provide long term time series that reinforce our knowledge on the climate processes and factors that lead to climate change (WMO, 2021). These data, even though with gaps in some cases, are used with numerous techniques and approaches to give robust results for assessment studies of the changes of the mean and extreme climate characteristics all around the world. Vuckovic and Schmidt (2021) highlight that long — time meteorological time — series can provide important and essential information not only for the detection of the mean changes of the climate but also for the understanding and examination of the systematic monitoring of the potential changes of the characteristics of the extreme weather events which can lead to more efficient adaptation and mitigation measures and policies.

However, long term meteorological and climate data not only help us comprehend earth's climate system but also provide useful information on its variability, evolution and physical processes (Noone et al., 2020). Characteristically, Dolman et al. 2016 underline, the conservation and continuation of these data can contribute to monitoring the effectiveness of the Paris Agreement of Climate Change in 2015. Moreover, these time series in synergy with other observations can help for the creation of new and updated reanalysis data archives and estimate the skill of climate models in simulating the present climate conditions (Thorne et al., 2017).

The Global Observing System (GCOS) is an extremely complex undertaking, and perhaps one of the most ambitious and successful instances of international collaboration of the last 60 years, initiated in support of the world weather monitoring and forecasting, and then increasingly in support also of climate and climate change monitoring. It consists of a multitude of individual surface- and space-based observing systems [Figure 118]. The observing systems which make up the GCOS provide the long-term, high-quality climate data records and products that underpin regional climate change research, assessment and provide the reference basis for climate models. More specifically, GCOS help on the efficient characterization of the state of the planetary climate system as well as it's trends and variability. It also depicts both the natural and anthropogenic forcings on the global and regional climate helping also to understand the causes of the observed climate change. In synergy with the more recent addition of satellite data to the ground observations [Figure 119] a noteworthy improvement has been made in all the Essential Climate Variables (ECVs) — atmospheric, oceanic, terrestrial — on the analysis of extreme events and on the risk and vulnerability assessments (WMO, 2011).

Downscaling climate information at regional/ local scale from global climate models

Commonly, Global Climate Models (GCMs) are the primary tools for attributing past climate change to human activities, and for projecting future climate change under different anthropogenic emission scenarios. However, the majority of GCMs still have a coarse horizontal resolution to resolve the effects of local and regional scale forcings on regional climate. To reliably assess the impacts of climate change at regional/local level, higher-resolution climate information is necessary, and methodologies such as statistical or dynamical downscaling are beneficial to enhance the regional information provided by global climate models. Figure 119 illustrates a schematic with the typical model types and chains used in modelling and downscaling regional climate information, for climate impact assessment at regional/local level.

1. Global climate models

Global climate models include state-of-the-art Earth System Models (ESMs), coupled Atmosphere–Ocean General Circulation models (AOGCMs) or Atmosphere-Only General Circulation Models (AGCMs). The global climate models derive climate information

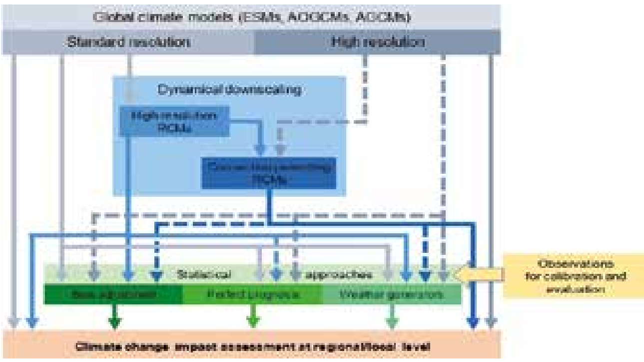
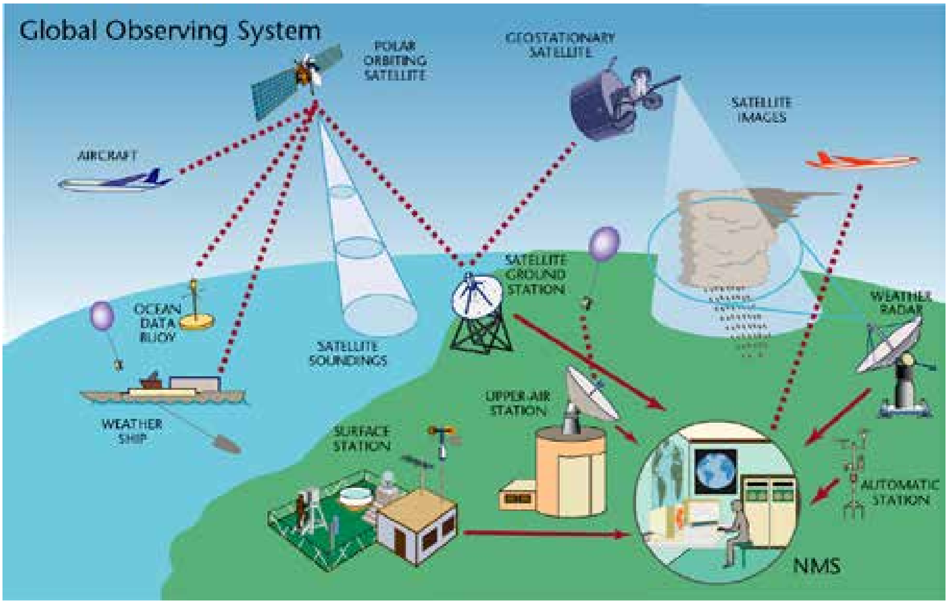
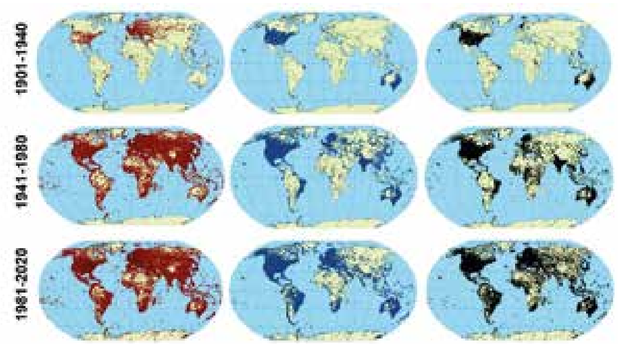


Figure 116: Schematic indicating the typical climate model types and chains used in modelling and downscaling regional climate information for climate change impact assessment at regional/local level (adopted with modifications from Figure 10.5 in Doblas-Reyes et al., 2021).





both for past and future climates with a nominal horizontal resolution typically in the range of 100–200 km and provide insights for the analysis of regional climate. Future projections with Global Climate Models are affected by three main sources of uncertainty, such as unknown future external forcings, deficient knowledge and realization of the response of the climate system to external forcings, and internal variability (Lehner et al., 2020). Although higher-resolution GCMs (at 50 km resolution or finer) are increasingly becoming available for climate change research (Held and Zhao, 2011) their typical resolution is rather coarse to resolve the effects of local and regional scale forcings on regional climate, such as topographic characteristics (complex mountain ranges, coastlines, peninsulas, small islands and lakes) as well as land-use characteristics and chemical composition of short-lived species (e.g. aerosols, tropospheric ozone). A rapidly developing field for Global Climate Models is the use of variable resolution global models, setting the finest resolution possible in the region of interest, while still resolving the climate processes at the global scale with lower resolution (McGregor, 2015). Nevertheless, increasing resolution by itself does not solve all performance limitations (Doblas-Reyes et al., 2021). Improving global model performance for regional scales is fundamental for increasing their usefulness as regional information sources. Methodologies such as statistical downscaling or dynamical downscaling with the use of Regional Climate Models (RCMs) are beneficial to enhance the regional/local information provided by Global Climate Models (GCMs). This underlines the importance for improving the performance of GCMs as they provide the boundary conditions in RCMs for dynamical downscaling and the input for statistical downscaling approaches, especially when regional climate change is strongly influenced by large-scale circulation changes.

2. Dynamical downscaling with regional climate models

Regional Climate Models (RCMs) have been developed for the application of dynamical downscaling methods to enhance the regional information provided by GCMs or by the large-scale reanalysis fields (Giorgi and Mearns, 1999). RCMs represent surface features (such as complex mountain topographies and coastlines as well as small islands and peninsulas) with a higher grid box resolution within a limited area of interest, thus resolving atmospheric process in a finer scale than GCMs. Dynamical downscaling using Regional Climate Models adds value in representing many regional weather and climate phenomena, especially over regions of complex orography or with heterogeneous surface characteristics (Doblas-Reyes et al., 2021). RCMs typically have a horizontal resolution between 10 and 50 km, but much finer spatial resolution at kilometer-scale is also employed to fully resolve deep convection and represent sub-daily precipitation extremes (Coppola et al., 2020). They are typically one-way nested, so that there is no feedback from the RCM into the driving global model. Nevertheless, two-way nested global model-RCM simulations are also carried out to investigate regional influence on large-scale climate (Junquas et al., 2016). RCMs can inherit biases from the driving global model in addition to producing biases themselves (Dosio et al., 2015), while spectral nudging techniques are also employed to increase consistency with the

Figure 117: World Meteorological Organization (WMO) global observing system in support of GCOS which assesses the status of global climate observations towards a world where climate observations are accurate and sustained for studying climate change (source: https://public.wmo.int/en/programmes/global-observing-system).

Figure 118: The evolution and increase of the number of land-based stations on a global scale during the past 120 years (sub-daily stations [red dots], center daily stations [blue dots] and monthly stations [black dots]), adopted with a small modification from Figure 3 in Noone et al., 2020.

driving model (Kanamaru and Kanamitsu, 2007). The Coordinated Regional Climate Downscaling Experiment (CORDEX) initiative provides ensembles of high-resolution historical and future climate projections for various regions, with a large body of literature emerging (Jacob et al., 2014; Giorgi and Gutowski, 2015; Ruti et al., 2016; Vautard et al., 2021; Coppola et al., 2021). RCMs typically do not include all possible Earth system processes, such as air-sea coupling or chemistry-climate interactions, which may influence regional climate. However, over the last two decades, several RCMs have been extended by coupling to additional components like interactive oceans (Ruti et al., 2016), rivers (Di Sante et al., 2019), glaciers (Kotlarski et al., 2010), and aerosols (Zakey et al., 2006; Zanis et al., 2012; Nabat et al., 2015).

3. Statistical downscaling, bias adjustment, and weather generators

Statistical downscaling, bias adjustment and weather generators are post-processing methods used to derive regional climate information, and they are considered useful approaches for improving the representation of regional climate from global and regional climate models. These methods require observational data for calibration and evaluation. Commonly, most methods are applied on temperature and precipitation, although some also represent wind, radiation and other variables with typical restrictions arising from the limited availability of high-quality and long observational records for such applications (Pryor and Hahmann, 2019). Statistical downscaling techniques are subdivided depending on whether the statistical model is fitted using observational data (known as Perfect Prognosis) or using data from a climate model itself (often referred to as Model Output Statistics). In perfect-prognosis statistical downscaling, a statistical model, linking large scale predictors to local-scale predictands, is calibrated to observed data and then applied to predictors simulated by climate models (Maraun and Widmann, 2018). Commonly, the statistical models use regression-like approaches (linear and stochastic), analogue methods and machine learning techniques. Recent developments include stochastic regression models to explicitly simulate local variability, while the use of machine learning techniques has been reinvigorated, including deep and convolutional neural networks (Doblas-Reyes et al., 2021).

Weather generators are statistical models that simulate weather time series of arbitrary length. Typically, they require only observed predictands, (although some are conditioned on observed predictors as well) and are calibrated to represent observed weather statistics, in particular daily or even sub-daily variability. Recent research has mainly focused on multi-site Richardson type (Markov-chain) weather generators, some explicitly modelling extremes and their spatial dependence (Doblas-Reyes et al., 2021).

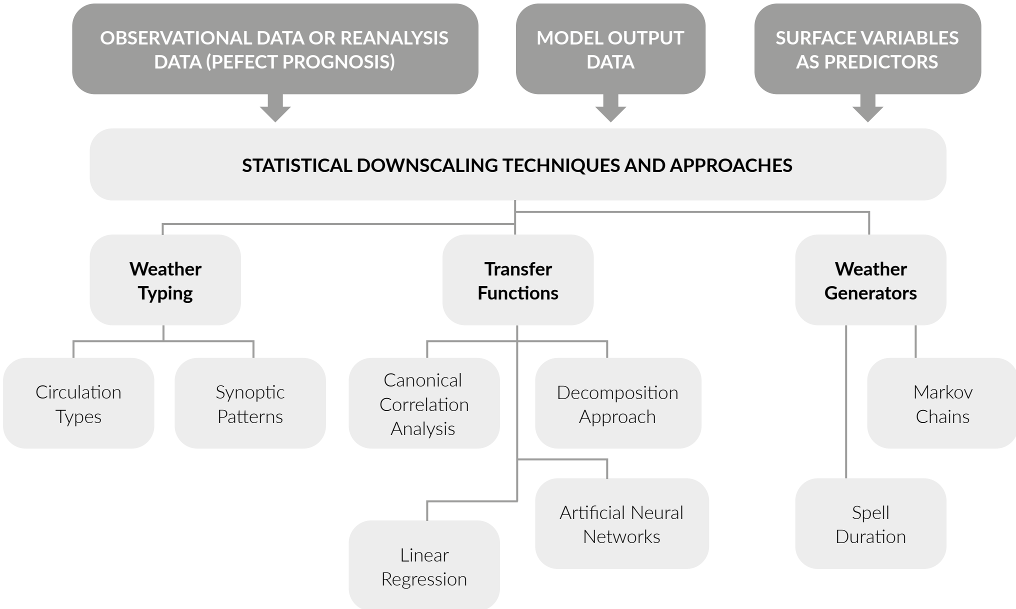


Figure 119: The main approaches and techniques used for Statistical Downscaling.

Bias adjustment is a statistical post-processing technique used to reduce the difference between the statistics of climate model output and observations. An important issue for bias adjustment is the correct representation of the required spatial scale. Ideally, bias adjustment is calibrated against area-averaged data of the same spatial scale as the climate model output. Hence, high-quality observed gridded datasets with an effective resolution close to the nominal model resolution are required. Driven by the need to also generate regional-scale information in station-sparse regions, researchers have considered derived datasets that blend *in situ* and remote-sensing data to produce high-resolution observations to be used as predictands (Doblas-Reyes et al., 2021). However, bias adjustment methods are often used as a simple statistical downscaling method by calibrating them between coarse resolution (e.g., global) model output and finer observations (Maraun and Widmann, 2018). Bias corrections in a climate model output is recommended before using it as input in hydrological model, as climate models have inherent systematic errors due to imperfect conceptualization (Chokkavarapu and Mandla, 2019). Nevertheless, bias adjustment cannot overcome all consequences of unresolved or strongly misrepresented physical processes such as large-scale circulation biases or local feedbacks.

4. Conclusive remarks

Long-term high-quality station-based and satellite meteorological observations, as well as high-resolution climate information from climate models and statistical downscaling methodologies are of key importance for advancing our understanding of climate processes and reliably assessing climate change at regional/local level. The global observing systems constitute the core for the development of high-quality climate data records and products that provide the reference basis for climate models. Dynamical downscaling through RCMs and statistical downscaling methodologies enhances the regional information provided by global climate models, which are the primary tools for attributing past climate change to human activities, and for projecting future climate change under different anthropogenic emission scenarios. RCMs can inherit biases from the driving global model in addition to producing biases themselves. The setup of global initiatives for RCM simulations as well as the related climate research, their model developments and techniques have been considerably expanded over the last two decades, while several RCMs have been extended by coupling to additional components of the earth's system. Methodologies such as statistical downscaling, bias adjustment and weather generators are beneficial as an interface between climate model projections and impact modelling and for realistically deriving many statistical aspects of present-day daily temperature and precipitation, but the performance of these techniques depends on that of the driving climate model.

Notes

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Team Project IV

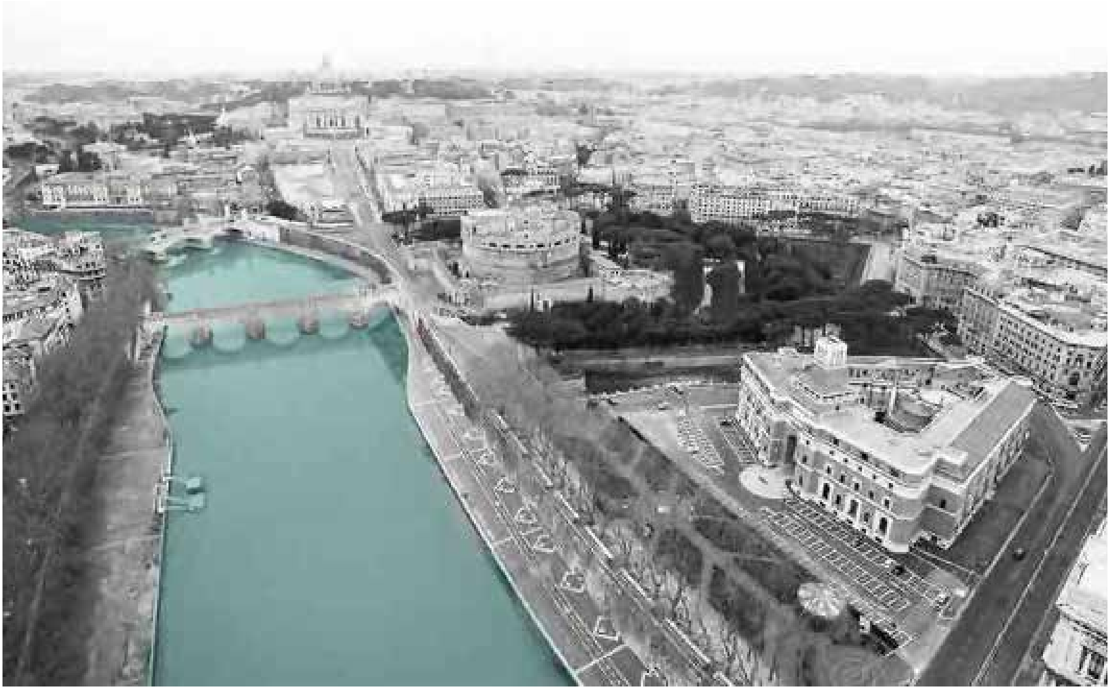
Let it Ti(be)r, Rome

The project in Rome focuses on the revitalization of the Piazza Mancini area in the Flaminio neighborhood, close to the Tiber river. Its main objective is to establish a stronger connection between urban spaces and nature, considering the risks of flooding caused by heavy rains, while improving public access to the river. The complexity lies in redesigning a solution that integrates the traffic node and parking area, the restoration of historic green corridors, which requires involving public authorities, private organizations and citizen's groups. The proposal design a greener, more adaptable and attractive place for the local community, tourists, museum visitors, citizens, residents and employees living and working nearby, as well as non-human species. The key is to establish connections at all levels, between nature, urban infrastructure and users. The project proposes a multi-level solution, transforming Piazza Mancini into a vibrant free space with pedestrian and cycle paths accessible to the River Tiber, while all car traffic and parking are located urderground.

Figure 120: Conceptual sketch.

Figure 121: Photomontage of Rome.

Figure 122: Photographs of study area.



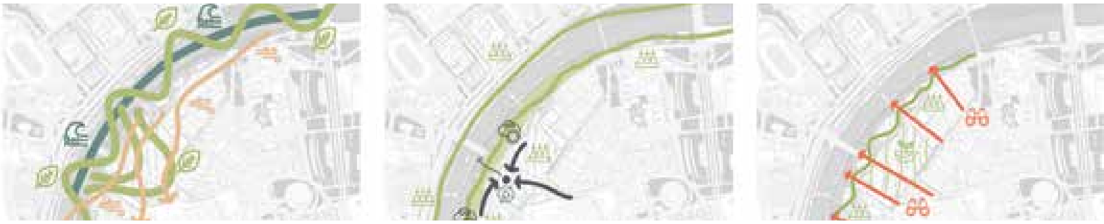
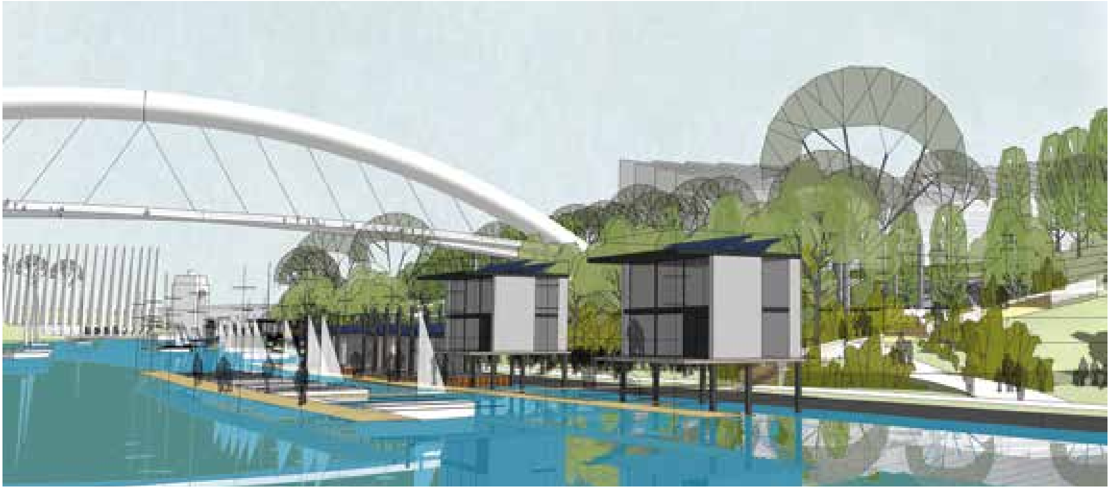


Figure 123: Render.

Figure 124: Diagrams.

Figure 125: Section.

Figure 126: Site Plan.



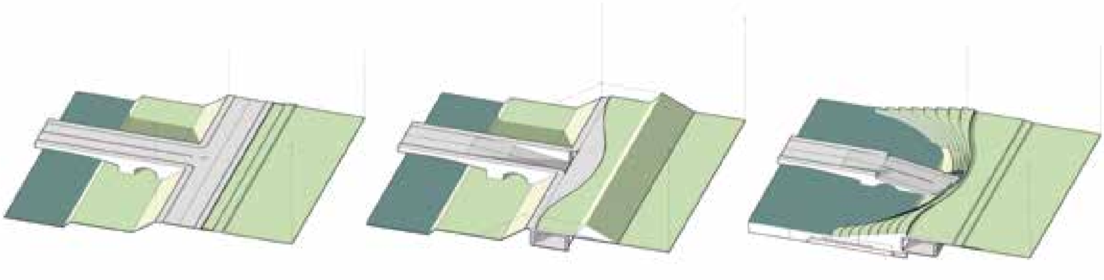
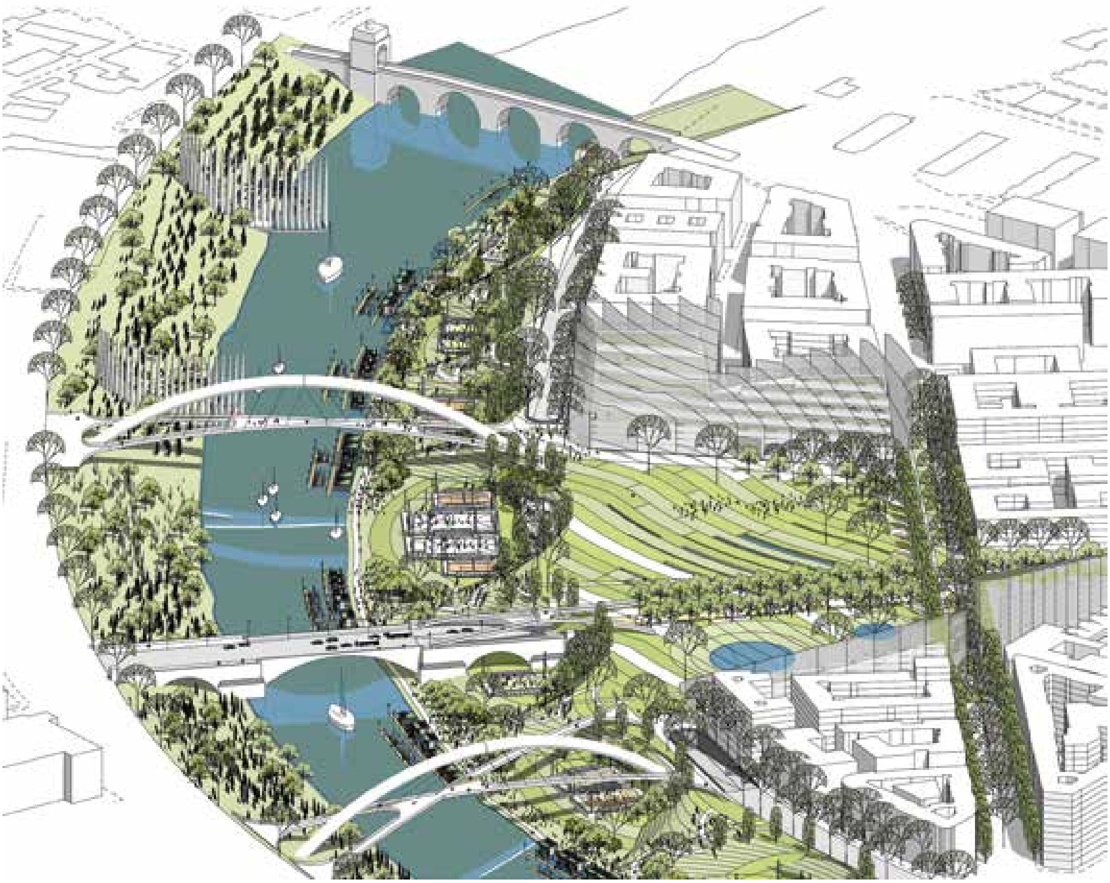


Figure 127: Render.

Figure 128: Diagrams.

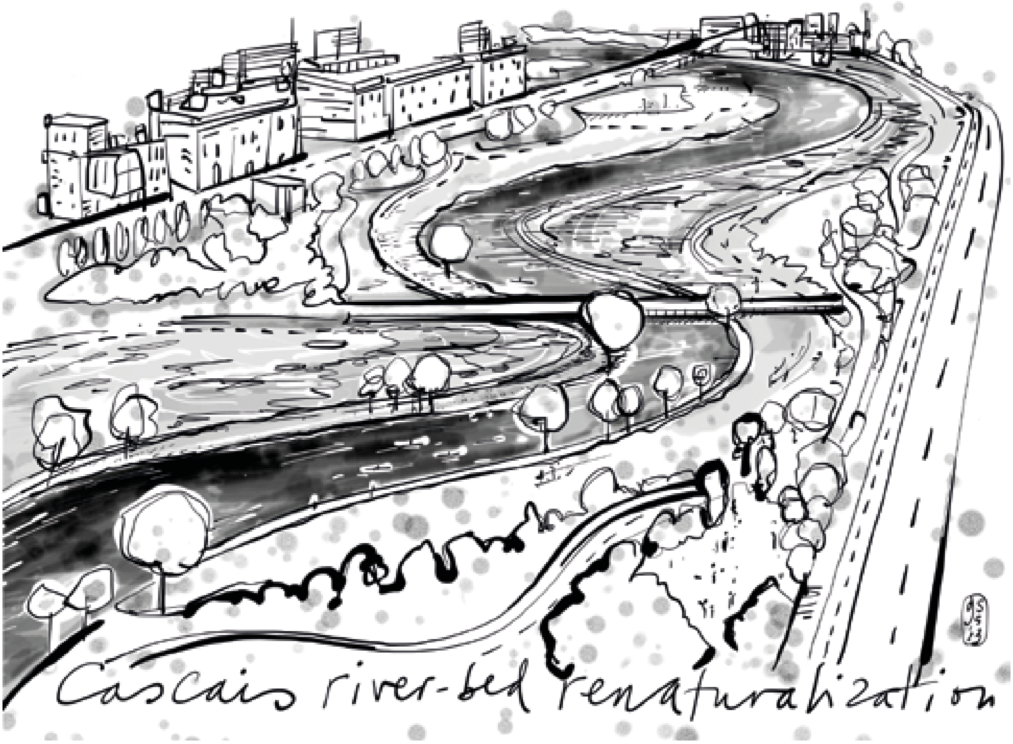
Figure 129: Section.

Figure 130: Axonometric.



Team Project V

Vinha as a Pine, Lisboa



In the Lisbon Metropolitan Area several prominent sites were identified the solution presented here is located in a south-facing coastal area, directly related to the ocean, establishing a continuous but fragmented system of public spaces ending with a promenade and a seak wall. The main problem identified in the Ribeira das Vinhas, Cascais, facing floods, sea level rise and other climate hazards, jeopardises community protection and ecological balance in the region. The proposal is in harmony with the morphology of the land that has been ignored by urbanisation in the 20th century. The canalised water stream if uncovered and transformed into urban hydrological infrastructures that prevents flooding and accommodates rising sea levels in the Atlantic Ocean. The exposure of an open river would result in an opportunity to expand and improve public space for the local community and create a continuous public space from the seal wall to the hinterland.

Figure 131: Conceptual sketch.

Figure 132: Photomontage of Lisbon.

Figure 133: Photographs of study area.

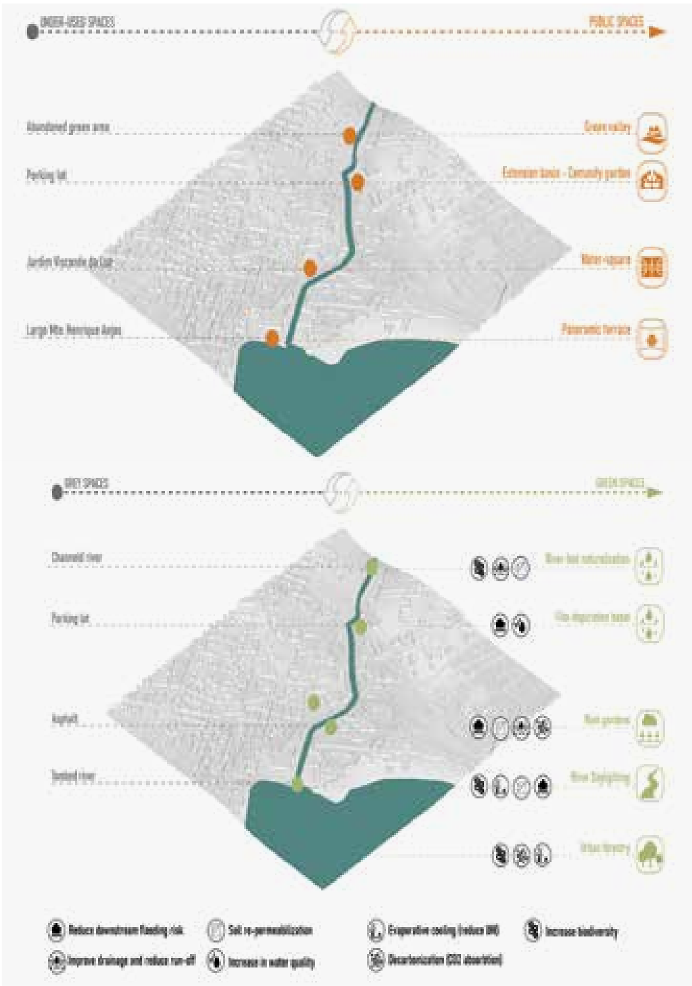
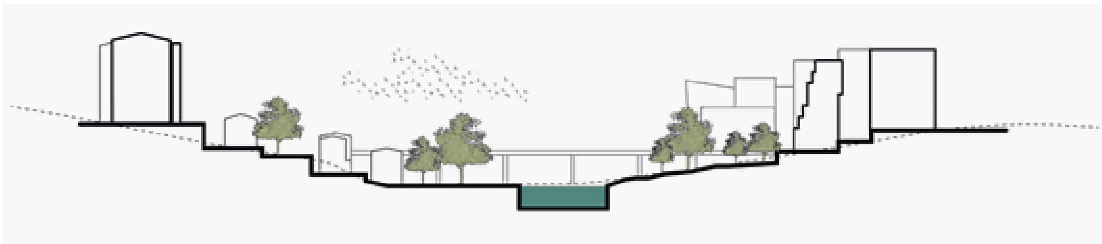


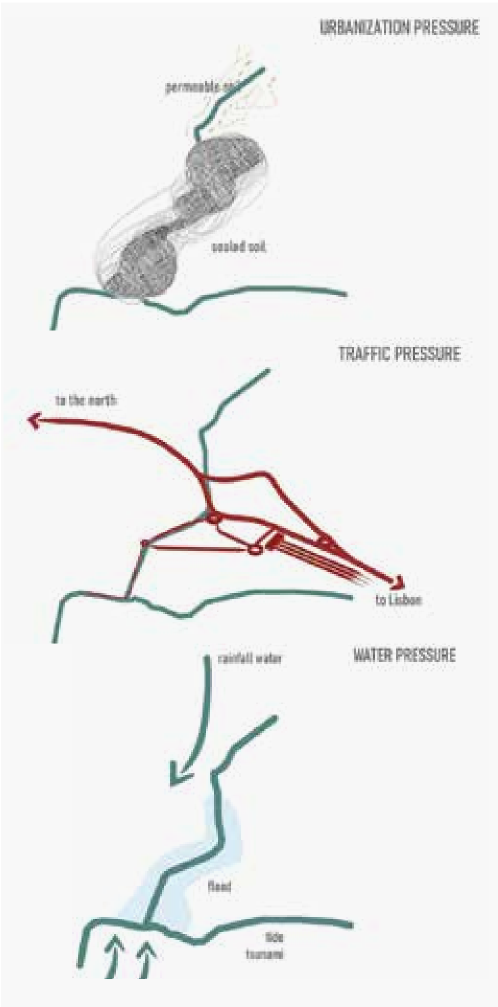
Figure 134: Render.

Figure 135: Diagrams.

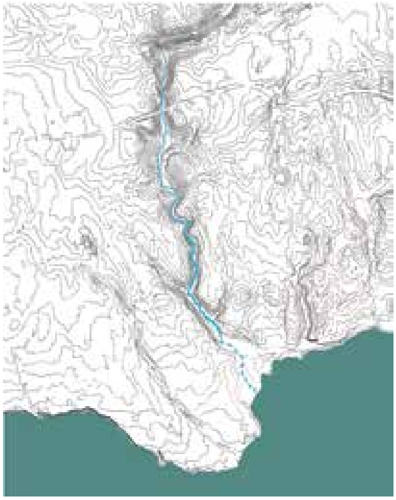
Figure 136: Site plan.

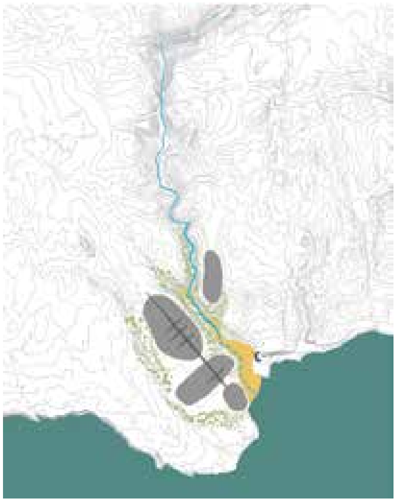
Figure 137: Section.





URBANIZATION PRESSURE
permeable so
sealed soil
TRAFFIC PRESSURE
to the north
to Lisbon
WATER PRESSURE
rainfall water
flood
tide
tsunami





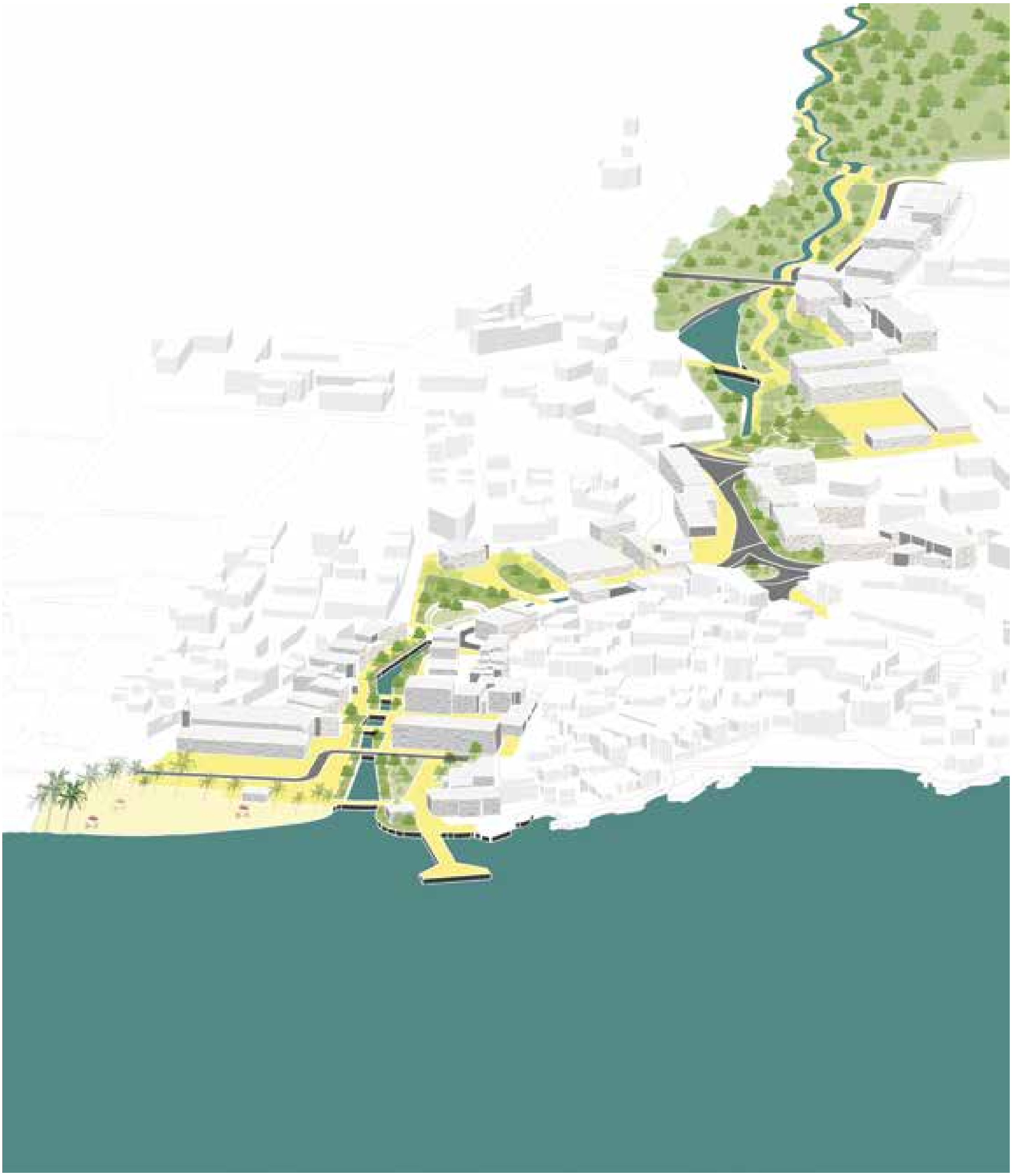


Figure 138: Render.

Figure 139: Diagrams.

Figure 140: Diagrams.

Figure 141: Axonometric.